PROCEEDINGS

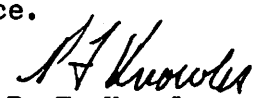
FIRST INTERNATIONAL SAFFLOWER CONFERENCE

UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA
JULY 12-16
1981

FOREWORD

Participation in the First International Safflower Conference was a source of great satisfaction and joy to me. It brought to the University of California at Davis many of the leading safflower researchers and developers from many parts of the world. Old friendships were renewed and new ones developed. All of us were brought up to date on the status of safflower in terms of both research and commercial developments. Further, the Conference looked into the future with respect to needs in research, in germplasm, and in both international communication and future international conferences. I am grateful to the Conference for honoring me with one of its two awards.

Work on the Proceedings has brought mixed feelings. There was a great deal of time involved in both typing parts of the Proceedings and in editing some of the papers. On the other hand, I benefited greatly from closely reading the papers and summarizing discussions. I am sincerely sorry that their completion took so long. In part it was a result of retirement, a move from Davis to Washington State, international involvements, some consulting, and carry-over commitments to graduate students. Ironically it was major surgery this year that limited travel and physical activity that encouraged me finally to complete the Proceedings. I can report that I am essentially fully recovered, so much so that I am looking forward to the next international safflower conference.



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The First International Safflower Conference had its beginning in a breakfast conversation which Dr. Donald L. Smith of Cal/West Seeds, Dr. P. Poetiray of FAO and I had at the 8th International Sunflower Conference in Minneapolis, Minnesota, in 1978. We discussed the possibility of an international safflower conference at that time and later with others who worked with safflower, and found enthusiasm for the idea. About six months later the project was launched.

National safflower conferences had been held in the United States at: Utah State University, Logan,Utah, in 1961; University of Arizona, Tucson, AZ, in 1963; USDA Western Regional Research Laboratory, Albany, CA, in 1967; University of California, Davis, CA, in 1969; and at Fresno, CA, in 1974. Such conferences had focused on research and development of safflower in the United States. A need was felt to get a world perspective, hence an interest in the present conference.

The First International Safflower Conference was held at the University of California at Davis from July 12 to 16, 1981. It was followed by a Safflower Workshop on July 17, also held at UC Davis. The Conference was sponsored by:

The University of California at Davis
The Food and Agriculture Organization of the United Nations
The Western Crop Development Council

A great many people with the University, the US Department of Agriculture, and companies interested in oilseeds served on local committees and provided assistance in other ways.

The purpose of the Conference and Workshop was to provide a forum for presentation of advances in research and development of safflower in several countries. Further, it provided an opportunity for scientists and industry leaders interested in safflower to share on an informal basis experiences and solutions to problems. Finally, it identified research priorities for the future.

In summary the schedule of events was as follows:

July 12: Registration and reception.

July 13: Welcome; country reports; and a session on breeding and genetics.

July 14: Tour of oilseed research at Davis; country reports; session on physiology and production; and banquet.

July 15: Sessions on: diseases and their control; quality and utilization; breeding and genetics; and topics of international interest.

July 16: All-day tour of safflower fields and breeding nurseries of commercial companies.

July 17: FAO Safflower Workshop.

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SOWING TIME EFFECTS ON YIELD, COMPONENTS OF YIELD AND DEVELOPMENT OF IRRIGATED SAFFLOWER IN THE CENTRAL WEST OF NEW SOUTH WALES

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ABSTRACT

Sowing time studies with Gila safflower at the Agricultural Research Station, Trangie (31°S, 148°E) from 1975 to 1979 have shown that highest yields (2.4 - 3.1 t/ha) result from mid May to late June sowings. Earlier sowings were often damaged by frost during stem elongation. Later sowings were shorter and produced less dry matter because of a large reduction in the length of the vegetative stage - a 5 month delay in sowing (May to October) resulted in only a 5 weeks delay in flowering. At this latitude, flowering is not initiated until daylengths reach approximately 12½ hours (early October).

Seeding rate studies have indicated populations between 20 - 30 plants per square metre are sufficient for irrigated production. However, with delayed sowings plants become smaller and produce less capsules and populations should be increased up to 60 plants per square metre. On dryland, there was no response from increasing populations beyond 15 plants per square metre because of limited moisture.

Irrigated safflower yields were 93% above dryland yields, when 3 irrigations were applied in addition to the 73 mm of rainfall received during the growing season (July to November).

Safflower in New South Wales has had a chequered history since significant commercial production began some fifteen years ago. The area planted has fluctuated from almost nothing up to 40,000 hectares, largely due to poor seasons, price fluctuations and disease (predominantly Alternaria and Phytophthora). The most consistent areas of production are found in the north and north west of the state because of the predominance of deep, high water holding capacity soils (self-mulching black and grey brown earths) and the mild winter temperatures found there. Safflowers' deep taproot and its greater ability to withstand higher temperatures compared to other winter crops has also enabled it to be grown as an opportunity crop on dried up lake beds and after floods along the river systems of the hot, dry interior. It is also being grown with increasing popularity as a dryland crop in rotation with irrigated cotton on soils which have compacted and developed poor infiltration rates due to continual cultivation with heavy machinery. Its vigorous taproot has the effect of drying the subsoil, enabling the compacted layer to be shattered through deep ripping.

Trangie is situated in the Central West of New South Wales (31°51'S, 147°57'E) on the floodplain of the Macquarie River and lies in the centre of an irrigation district. The average annual rainfall is 479.8mm (1885-1980) and is non-seasonal. However, rainfall is unreliable and highly variable, especially in summer (124% variability). Protracted rainless periods are also common and are longest in autumn. Temperatures are cool to mild in winter, (average maximum 16°C, average minimum 4°C) but rise rapidly from early spring onwards. An average of 36 frosts occur from late April to early October.

Safflower sowing time studies commenced at the Agricultural Research Station, Trangie in 1976 and continued until 1979. Studies were irrigated and confined to alkaline self-mulching medium grey clay soils which were considered most suitable for safflower, and the variety Gila was used. The objectives were to measure the effect of sowing date on yield and yield components and to study the developmental pattern of safflower in this environment.

GRAIN YIELDS

Highest yields (2.4 to 3.1 t/ha) were achieved by sowing from mid-May to mid-June (Figure 1). Sowings earlier than mid-May were lower because of frost damage. The early May sowing in 1976 and the late April sowing in 1977 were both damaged by frosts during winter. Plants had elongated 40 to 60 cms when damage occurred and symptoms were split and distorted stems and wilted leaves. Secondary infection often followed this injury, and only about 50% of plants survived to maturity. Yields steadily declined when sowings were made after mid-June.

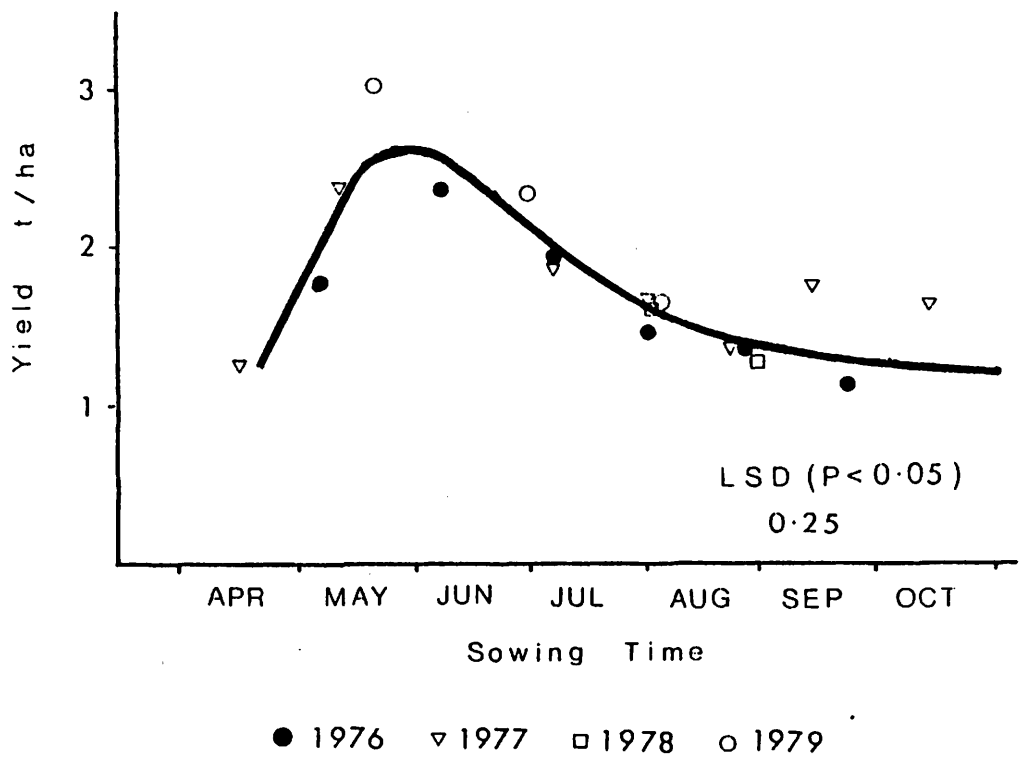

Fig. 1. The effect of sowing time on safflower yields (tonnes/ha) at the Agricultural Research Station, Trangie, 1976 to 1979.

Associated with this decline in grain yield were significant declines in plant height and dry weight of the tops (Table 1). Oil content of the seed was not influenced by sowing date except at the very late sowings which were higher, possibly due to the larger seed sizes (Table 1).

YIELD COMPONENTS

Only yield components for 1977 are presented because of the similarity between years. The number of seeds produced per hectare was the most closely related component to yield (Table 1). At the earliest sowing, fewer seeds were produced because of the low plant densities resulting from frost damage. The surviving plants produced a greater number of heads, but this was insufficient to fully compensate. The greater number of seeds were produced at the next two sowings (11 May, 6 July). This resulted from both a higher number of seeds per head and heads per plant. With later sowings, the number of seeds per hectare declined, primarily because of a reduction in the number of heads produced per plant. Seeds per head also declined with later sowings, but this was partly offset by an increase in seed size.

Table 1: Sowing time effects on a range of attributes with irrigated Gila safflower in 1977 at Trangie.

Sowing Date	Height (cms)	Dry Matter (t/ha)	Oil (%)	100 seed St (g)	Seeds/ Head	Heads/ Plant	Seeds/ ha (M)
16 Apr	88	8.28	34.9	3.41	27.6	20.3	54.3
11 May	110	10.68	34.9	3.51	35.2	13.5	77.1
6 July	98	9.65	33.6	3.40	34.8	8.4	75.8
3 Aug	87	6.98	34.5	3.42	28.7	8.8	53.5
24 Aug	76	6.25	32.9	3.53	28.6	7.6	48.8
14 Sept	62	5.55	36.7	3.89	30.6	6.8	52.1
13 Oct	49	4.56	37.6	3.92	27.6	6.3	45.7
LSD (P<0.05)	4.1	1.96	1.4	0.24	4.8	3.0	13.7
Corr. Coef.		.757**		-.198	.721**	.155	.967**

** Correlation coefficients with yield significant at 1%

PLANT DEVELOPMENT

The length of the growing period decreased linearly from 250 to 110 days when sowing was delayed from 16 April to 13 October respectively and was due mainly to reductions in the length of the vegetative periods (Table 2). This six month gap in sowing date was reduced to only six and a half weeks by the time flowering had commenced - 27 October and 12 December respectively, suggesting some mechanism was operating to prevent the earlier sowings from entering the reproductive phase at an earlier date.

Table 2: Sowing time effects on the stages of development (days) of Gila safflower in 1977.

Sowing Date	Sowing to Flowering	Beginning to End Flowering	End Flowering to Maturity	Sowing to Maturity
16 Apr	194	28	28	250
11 May	174	23	30	227
6 July	216	22	26	174
3 Aug	105	19	28	152
24 Aug	90	19	29	138
14 Sept	76	21	25	122
13 Oct	60	26	24	110

In my experiments, the significant reduction in the length of the vegetative period with delayed sowings suggests safflower responds strongly to increasing photoperiods. Work by Horowitz and Beech (1974) provides support for this theory as they found stages of development in safflower were strongly influenced by photoperiod and eliminating this response advanced flowering significantly. However, a similar reduction in the vegetative

DISCUSSION

Beech and Norman (1963) and Abel (1975) also found safflower yields declined with delays in sowing from late autumn to late winter, and this was similarly associated with reductions in height, dry weight of the tops and length of the growing period. However, the yield reduction in Beech and Normans' studies occurred as a result of declining seed numbers per head and seed size, and the reduction in the length of the growing period occurred mainly at the flowering and seed filling stages and was caused by rapidly rising early spring temperatures.

period in Beech and Normans' (1963) studies did not occur (Table 3) and they suggested temperature had more influence on the crops duration and photoperiod had secondary, if any, effect. However, Beech and Normans' experiments were conducted at the Kimberley Research Station in Western Australia (15°S), where winter daylengths are at least one hour longer than at Trangie (32°S). Therefore, their longer photoperiod in winter could have been sufficient to initiate flowering much earlier and hasten maturity, and the result was early May sowings at Kimberley took 89 days to flower and 142 days to mature compared to 174 days and 227 days respectively at Trangie (Table 3). Winter temperatures at Kimberley are on average 8°C warmer than Trangie, and this could also have contributed to earlier flowering.

Table 3: The effect of sowing date on time to flower (days) in safflower at three locations.

Sowing Date	Arizona* (33°N)	Trangie (32°S)	Kimberley** (15°S)
May	168	174	89
July	137	126	88
August	104	105	72

* Abel (1975)
** Beech and Norman (1963)

Sowing time experiments conducted in Arizona (33°N), (Abel 1975) also provides support for safflower's sensitivity to photoperiod. Days to flowering were similar in magnitude to Trangie and decreased by similar amounts with delays in sowing (Table 3) which could be expected if photoperiod had a dominant role in flowering initiation.

CONCLUSION

Delays in sowing safflower from late autumn to early spring resulted in a large reduction in the number of days required to reach flowering. As a result, growth periods became compressed, and heights, dry weights, head production and yield were reduced.

Photoperiod appeared to play a dominant role in plant development and temperature had a secondary effect, however, I was unable to define a more precise role for each. Future work in controlled environments is required to achieve this. Varieties such as Gila which are sensitive to photoperiod seriously jeopardise safflower's potential as a dryland crop in higher latitude environments such as Trangie because its flowering period occurs in late spring - early summer and this coincides with unreliable rainfall and very hot temperatures. A daylength insensitive line is required so as flowering can be re-scheduled into the more favourable spring period. This will make safflower more competative with wheat, which in most cases is the alternative crop option.

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WATER USE BY SAFFLOWER, WHEAT AND CHICKPEAS IN A SEMI-ARID ENVIRONMENT IN SOUTHEAST QUEENSLAND, AUSTRALIA

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ABSTRACT

Three crops, safflower, wheat and chickpeas were sown in a black self mulching clay soil previously maintained under clean fallow to store water. The crops were sampled regularly for dry matter, leaf area and soil water.

Wheat produced the highest dry matter and grain yields, followed by safflower and then chick peas. The maximum leaf area indices obtained in the experiment were 1.39, 1.32 and 1.86 for safflower, wheat and chickpeas respectively.

At the time of sowing the soil profile contained 77.3 mm held at available water potentials above -15 bars, all of it in the first 100 cm. Rainfall contributed a further 43-78 mm during the course of the experiment. Soil water usage was almost identical for all three crops until the maturity of the wheat which coincided with the early stages of flowering for the safflower. The soil for both safflower and wheat reduced soil water below -15 bars throughout the sampled profile by the time of flowering while it occurred during the flowering and pod filling phase for the chick peas.

The deep rooting safflower showed no advantage in water extraction over the more shallow-rooted wheat in this situation where the profile was not wet beyond the root zone for wheat.

Water use efficiencies were low for all crops; wheat ranked highest on a grain yield basis and safflower on a gross return basis.

The growth and yield of winter crops in a predominately summer rainfall environment such as central and south-east Queensland, depend largely upon their ability to exploit the soil water stored during a period of summer fallow. Two winter crops grown extensively in these regions are wheat and safflower, although the area sown to the latter has declined in recent years due to the disease Alternaria carthami (K. Jackson pers. comm.). Recently chickpeas (Cicer arietinum), a grain legume has been released as a winter crop for these regions (Beech and Brinsmead 1980).

In these environments, water supply and its utilization limit yield. Therefore it is important to grow species which are most efficient at obtaining the stored water and converting it to dry matter and grain.

Past research has shown that wheat can extract soil water to depths greater than 100 cm (Angus et al. 1980) and safflower to at least 150 mm on clay soils (Pugsley and Winter 1947).

An experiment was initiated to make a comparative water use study during 1980 winter at at a site on the black soil plains of the Western Darling Downs near Dalby (27°11'S, 151°16'E). The soil type was a Vertisol belonging to the Waco Association which are fine-textured, dark-coloured self-mulching and alkaline clays (pH 8.2).

The experiment discussed in this paper was sown on June 1, 1980 into moist soil using a cone-seeder and safflower, cv. Gila, wheat, cv. Kite and chickpea, cv. Tyson. Plant densities of 14, 28, 42 and 56 plants per m^2 were used to vary the rate of soil water extraction. The row spacing for all treatments was 35.6 cm and the plot size was 20 m by 3 m. Soil water characteristics were determined by a pressure plate as follows:-

Depth (cm)	0-15	15-30	30-45	45-60	60-100	100-140	140-200
% water at -.1 bars	77.3	78.7	84.7	85.0	86.4	79.7	71.1
% water at -15 bars (wilting point)	35.0	37.0	38.6	38.0	37.2	37.4	37.3

Soil water was determined gravimetrically from soil cores taken with steel tubes (diameter 32 mm). At time of sowing the soil profile contained a total of 77.3 mm of available water (i.e. above -1.5 MPa [-15 bars]) all of which was located in the first 100 cm. Little rainfall during the course of the experiment; the wheat received a total of 43 mm, chickpeas and the safflower received 78 mm..

Regular samplings (Table 1) were taken to measure soil water content, LAI, and dry matter production of tops, and grain harvested at maturity.

RESULTS

The results for the four populations were similar so only the data for the highest population will be presented.

DRY MATTER AND GRAIN YIELD

The highest dry matter yield at each sampling was obtained from wheat, followed by safflower and then chickpeas. The last sampling of safflower showed a slight decline in dry matter, associated with some plant mortality and leaf fall (Fig. 1a).

Changes in the dry matter yields expressed on a per-plant basis are shown in Table 1. After 37 days above ground dry matter production was the same for safflower and wheat while chickpea had almost three times the yield. However this difference changed with

subsequent samplings and at 135 days the highest yield was from wheat followed by safflower and chickpeas. At maturity the yield of chickpeas was about 58% of that of wheat. Sheldrake and Saxena (1979) report a similar pattern of growth for chickpeas grown under conditions of increasing water stress in India.

The pattern of the leaf area index was similar to that of top dry matter until 114 days after sowing when chickpeas exceeded that of the other two crops and obtained a maximum of 1.8 (Fig. 1b). This result is again comparable to that obtained by Sheldrake and Saxena (1979) a similar cultivar grown under a regime of progressive moisture stress.

SOIL WATER

The rate of soil water depletion was similar for all three crops until the maturity of wheat at about day 135, by which time chickpea had removed an additional 21 mm of water and safflower an additional 38 mm. However safflower was much later maturing than wheat and chickpea and used more water overall (Table 2). With both safflower and wheat the water content was reduced below -15 bars throughout the sampled profile by the time of flowering while chickpeas were in the pod development phase and still flowering. The changes in the soil water for safflower are shown in Fig. 2.

Details of the efficiency of water use in terms of dry matter and grain yield are given in Table 2. The efficiencies for safflower are lower than those recorded in the literature. In India, Bajpai et al. (1978) obtained an efficiency of 0.38 g m^{-2} mm^{-1} for safflower seed, while Eric and French (1969) recovered 0.29 to 0.37 g m^{-2} mm^{-1} in Arizona. These are approximately three times greater than the values obtained in this experiment. This difference would be largely contributed to the very low soil water supply during seed development. This produces a large percentage of unfilled seed or partially filled seed as occurred in this experiment (2.94 g/100 seeds).

The efficiencies for wheat have been determined by several workers and range from 0.40 g m^{-2} mm^{-1} grain (Schultz 1971) to 1.94 g m^{-2} mm^{-1} grain (Passioura 1976). The latter figure was obtained from a controlled glasshouse study and therefore may be expected to be an extreme figure. The lower figure comes from a field experiment which used 236 mm water and therefore is more comparable to my experiment which used 227 mm of water. My result of 0.337 g m^{-2} mm^{-1} is therefore very similar.

The water use efficiency for chickpeas was slightly better than safflower and were approximately 60% found in previous experiments under a more favourable water regime (G. Leach, pers. comm.). However, recent work in India indicates that the .201 g m^{-2} mm^{-1} for chickpeas was comparable where irrigation was not applied. Singh et al. (1980) obtained .186 g m^{-2} mm^{-1} with 117 mm water used and Nagarajrao et al. (1980) .165 g m^{-2} mm^{-1} with 107 mm water used.

The experiment indicates that when there is a low level of available soil water wheat isthe most efficient crop on a grain yield basis, followed by safflower and chickpeas. However, on a gross returns basis (on current Australian prices), the ranking was safflower, chickpea and wheat.

The study shows that when the soil profile is wet only to the depth exploitable by wheat, safflower has no advantage and is handicapped by later maturity. Chickpea has a distinct advantage over the two other crops in that its indeterminant habit and earlier flowering is more adaptable to these adverse soil water regimes.

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Table 1. Progressive dry matter yields expressed on a per-plant basis (g).

Days from sowing	Safflower	Wheat	Chickpea
37	0.04	0.04	0.11
71	0.53	0.66	0.63
94	2.84	3.21	1.42
114	7.53	7.76	4.32
135	11.50	12.99	7.49

Table 2. Comparison of water use efficiences for safflower, wheat and chickpeas.

Crop	Water used	D.M.	Seed
	mm.	$g\ m^{-2}\ mm^{-1}$	$g\ m^{-2}\ mm^{-1}$
Safflower	264.5	1.35	.187
Wheat	226.7	2.17	.337
Chickpea	247.8	1.24	.201

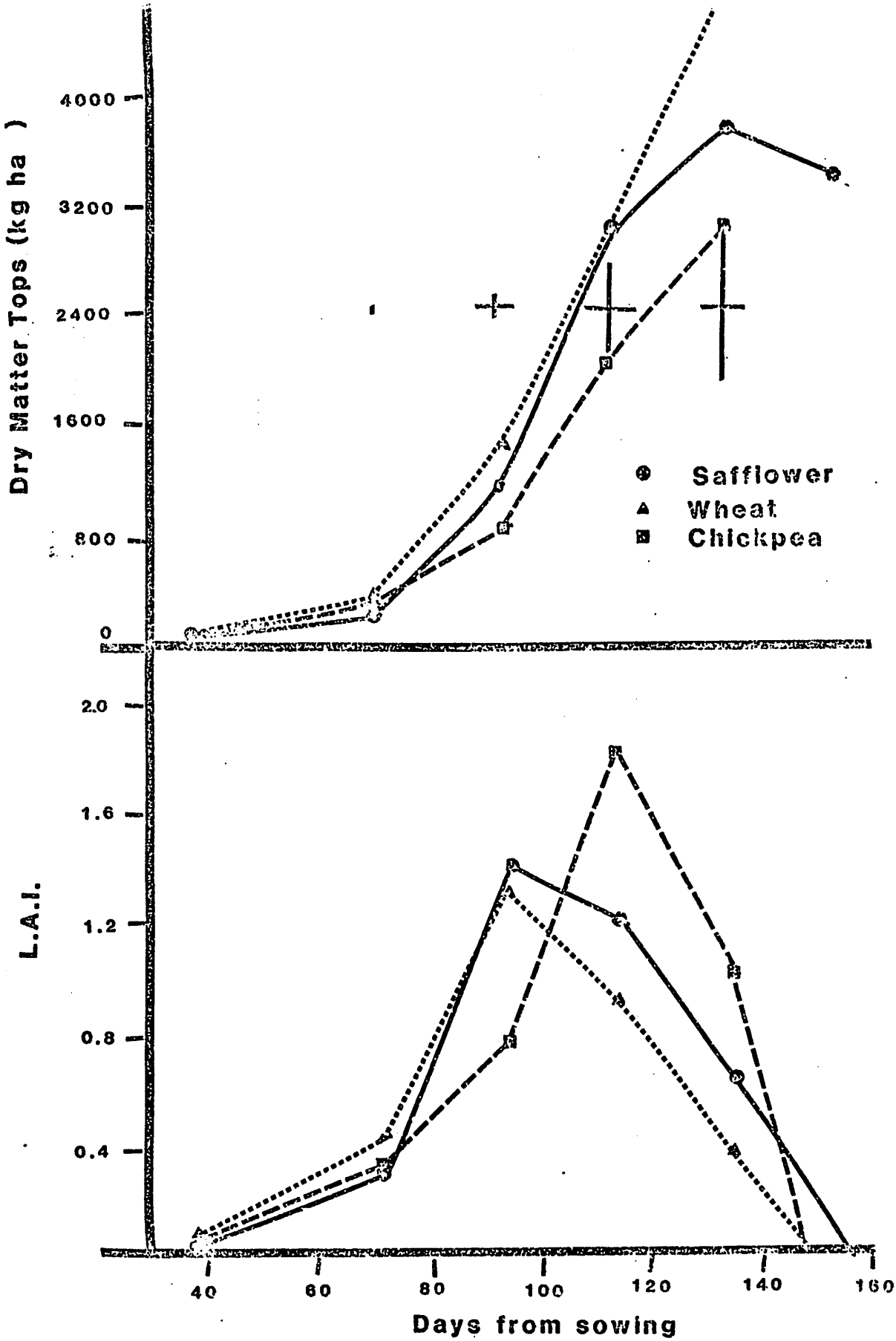

Fig.1 Dry matter of tops and leaf area index for three crops.

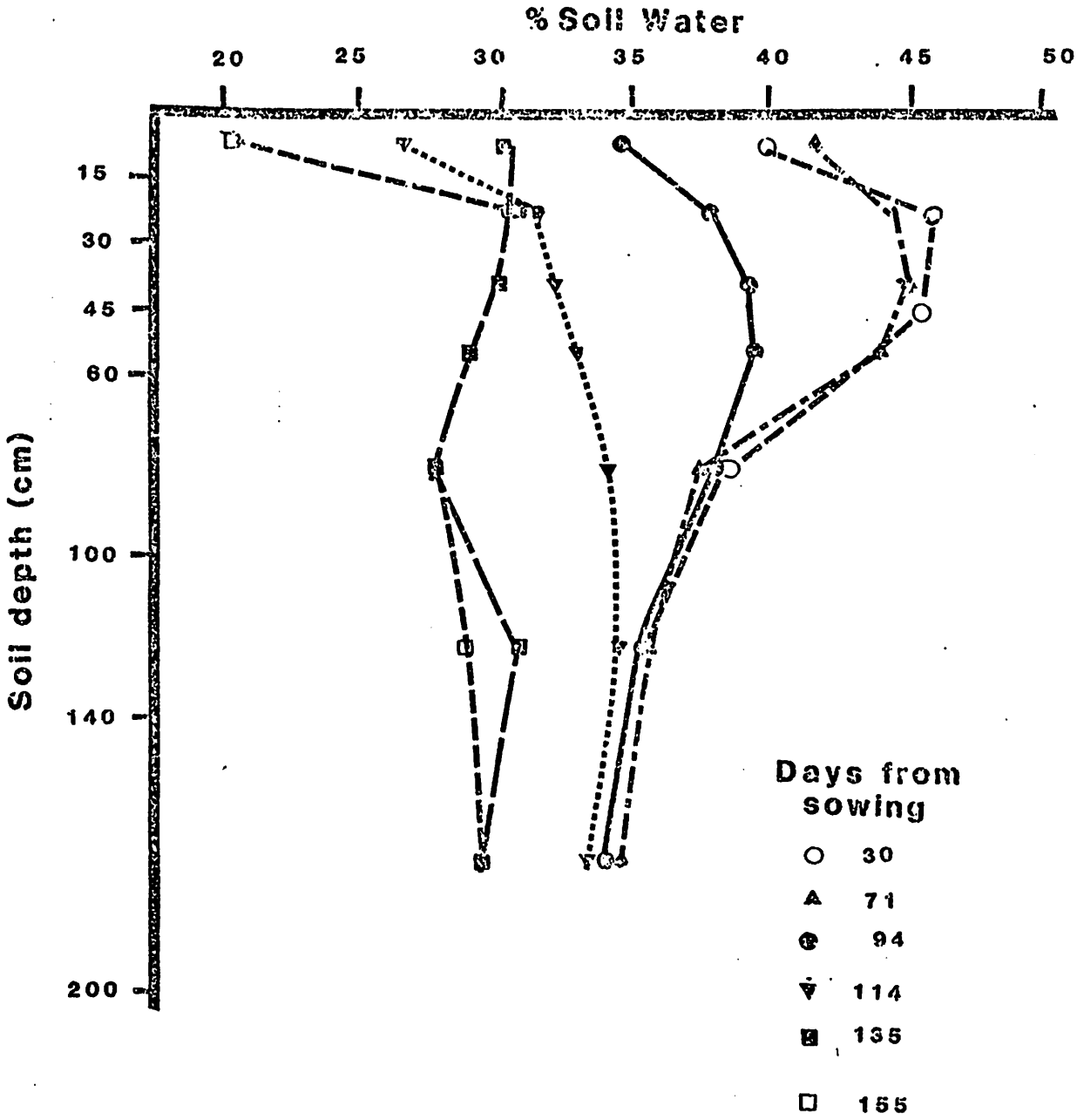

Fig.2 Changes in soil water content under safflower

SAFFLOWER CULTURE IN TULARE LAKE

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ABSTRACT

Growing of safflower as a commercial crop was started in the early fifties in California. By trial and error farmers have eventually settled on production of safflower on the heavy soils adjacent to rivers and on the low lying sedimentary soils in historic sloughs and lake bottoms.

Safflower is used generally as a rotation crop where more highly economic crops such as cotton, rice and tomatoes are grown. The key to good safflower production lies in selecting highly fertile, heavy soils with good water holding capacity.

Insects have not been a problem in safflower production. However, migration of lygus bugs and stink bugs from drying safflower fields can cause serious problems in adjacent crops if not controlled in the safflower field.

Good safflower production is directly related to water availability in the soil. This deep rooted crop uses about 25 inches of available water to develop the seed and oil content consistent with inherited characteristics.

Although safflower cannot compete economically with most crops on a revenue producing basis, we will continue to produce this colorful crop because of its important place in our overall crop rotation system.

SOIL REQUIREMENTS

Growing of safflower as a commercial crop was started in the early fifties in California. This crop has had failure as well as success on the way to becoming a viable crop in the San Joaquin Valley. Farmers have tried to grow the crop on light soils where frequent irrigations are necessary and the result has usually been frustration and economic loss.

By trial and error research workers and farmers have found safflower to be adapted almost exclusively to the heavy clay soils with a high water holding and availability capacity. In general, low lying soils adjacent to rivers and the sedimentary soils of historic sloughs and inland lake bottoms have been the most economically productive. In these heavy, low lying soils water tables are perched above impervious clay layers which act as reservoirs from which safflower plants draw moisture during the critical seed maturation period.

CROP ROTATION

In Tulare Lake, our area of production, the soils are heavy and are underlain with high water tables throughout the area. This would be a detrimental condition if we were to confine our crop production to the shallow rooted crops grown in many areas of California. However, by growing cotton as our major crop along with wheat, seed alfalfa and safflower, we have been able to use water tables as a manageable asset. Since cotton is our major crop, we manage the other crops to complement soil structure, salt leaching and organic matter in a rotation system designed for improvement in water penetration, weed control and soil salinity.

Generally we plant safflower following cotton in the rotation. This enables us to grow safflower behind a crop where weed control has been thorough and on soil which will have residual deep soil moisture following two years of cotton. In the remainder of my presentation I will discuss the cultural practices we are using to produce safflower following cotton.

LAND PREPARATION

Our cotton is harvested in October through December. Immediately following the second picking the stalks are cut, phosphate is broadcast and incorporated into the soil surface using a heavy disc harrow. Since timing is critical for all operations, we use large equipment capable of covering large areas in a short period of time.

FERTILIZATION

Following discing, about 150-200 lb/A (170-230 kg/ha) of nitrogen in the anhydrous ammonia form is applied with large chisels. Using two of these implements per field, we cover about 600 acres (240 ha) in four shifts per day. Heavy rates of nitrogen produce a dark green plant capable of producing a higher portion of 41% protein meal. In addition, by using a high soil nitrogen level, a very vegetative plant is produced which promotes deep root development and ultimate deep moisture extraction.

PLANTING SYSTEMS

Three systems of seeding are used to plant safflower over a three-month period. Some soils which require planting in January are irrigated up and receive a supplemental irrigation in March when the plants are about 8 inches (20 cm) tall and soil temperatures are still cool. Other fields are flooded, drained and seed is applied by air into a mud slurry. On our best soils fields are flooded by applying 18 inches (45 cm) of water and are allowed to dry until March when soil moisture is just right for direct seeding in a prepared moist seedbed. In the latter system three operations are performed simultaneously starting with discing around the field followed closely behind with drilling and harrowing to seal the seedbed moisture. It usually takes about three shifts to complete an entire section (256 ha) of land.

DISEASES

Irrigation and disease control are inseparable in the production of safflower. Our safflower is seldom irrigated after planting except on lighter land where the crop is irrigated up in late January. We know that Phytophthora root rot is a devastating disease, and we do everything in our power to prevent this disease from developing. Cool soil temperatures, precise irrigation and surface drainage are crucial factors in holding Phytophthora root rot to a low level.

Rust has always been a problem in safflower culture. This disease is ever present in the soils where safflower is grown and spores are carried on all seeds. Through the use of a good fungicide seed treatment, crop rotation, and a heavy pre-irrigation by flooding, we have reduced this problem to a very low level.

INSECTS

Although we do have some limited problems with cutworms in the seedling stage, insects are not a real problem in safflower production. Our real insect problem related to safflower production comes when lygus bugs are allowed to develop and migrate into adjacent cotton and seed alfalfa fields. We have had a standard program for many years of treating our safflower a few days prior to bloom and again immediately following bloom. Using this program we prevent migration of harmful insects and allow honey bees to collect pollen and nectar without pesticide applications during the bloom period which lasts about three weeks.

POLLEN AND NECTAR

In addition to crop rotation safflower is used extensively in our area to feed honey bees which are used in great numbers to pollinate our seed alfalfa crops. In fact safflower is planted within bee flight distance of all our seed alfalfa fields over the entire ranch.

PLANT MATURATION

As mentioned earlier safflower is used to extract deep moisture to facilitate subsequent leaching of salt. The deep penetration of safflower roots in heavy moist soil promotes bloom over a long period of time. This slow bloom and maturation period allows for the greatest number of heads per unit area and maximizes seed size and resultant oil development per acre.

SEED YIELD

If we have done a good job of growing the safflower crop, our yields lie between 1 1/4 and 1 3/4 tons per acre (2850 and 4000 kg/ha). Observations over the years have shown high yields to be directly correlated with high oil percentage. Therefore, any practice which promotes high seed yield automatically gives us the highest possible pounds of oil per acre.

Under the best growing conditions about 35 days are required to mature safflower seeds after the flowers have dried -- the longer the "dry-down" time, the better the yield.

HARVESTING

We start harvest as soon as the safflower plant is dry and the seed moisture content is below seven percent. Harvest can usually be started on our early fields about July 20, and we continue on fields with heavier growth until September. The same harvesters used for wheat are used for safflower.

Due to the development of high-oil, thin-hull varieties, particular emphasis is put into the harvesting operation to insure a minimum amount of cracked seed. Each harvester is checked daily for seed crackage and seed losses to insure minimum damage.

MOISTURE EXTRACTION

Moisture extraction to depths of 10 feet (390 cm) is common and results in lowering of water tables as much as 4 feet (120 cm) in four months. We seldom apply more than 18 inches (45 cm) of water for safflower due to the soil moisture being relatively high following cotton. However, when we apply water following safflower harvest, we find that 25 inches (62 cm) are required to replenish the soil moisture depleted by the safflower crop.

AN UPDATE ON MONTANA SAFFLOWER RESEARCH

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ABSTRACT

The principal diseases of safflower in Montana are Pseudomonas bacterial blight, Sclerotinia head rot, Alternaria leaf spot, and rust. The symptoms, prevalence, and control of each disease in Montana will be discussed. Varieties developed in Montana with improved disease resistance to bacterial blight and Alternaria leaf spot are Sidwill, Hartman, and Rehbein. The cropping systems, fertilizer needs, and weed control practices recommended for safflower grown in Montana will be discussed.

Safflower is grown as an alternate crop with small grains in dryland areas of north central, south central and eastern Montana, northwest South Dakota and western North Dakota. Growing safflower in conjunction with chemical weed control is an effective way to clean up land infested with annual weeds that build up in a strict small grain rotation. Safflower production also disrupts the cycle of small grain insects and diseases that commonly occur in the northern Great Plains.

Safflower production is particularly helpful in dryland areas where a deep-rooted, long-season, annual crop is needed to extract surplus soil water from recharge areas that contribute to saline seep.

Dryland growers utilize the same farm equipment used in small grain production to plant and harvest safflower.

DISEASES AND CONTROL

Bacterial blight incited by the bacterium Pseudomonas syringae is a serious disease of safflower in Montana and the Dakotas. Bacterial blight occurs in spring months when cool, wet weather prevails. Wind-driven rain enhances infection. Symptoms are dark, water soaked lesions on stems and leaf petioles and reddish-brown spots with pale margins on leaves and severe necrosis of the terminal buds. Older lesions are whitish in appearance. As the weather becomes drier and warmer, the plants recover and resume normal growth.

Alternaria leaf spot caused by the fungus Alternaria carthami is another serious disease of safflower in the northern Great Plains. Alternaria leaf spot occurs when heavy dews or rainy periods prevail during the safflower flowering periods (mid-July-August). Characteristic large, brown spots, resembling fingerprints, develop on leaves. Seeds may be discolored if infection is severe. Alternaria leaf spot may also cause seed rot and damping off of untreated seed.

Other diseases of safflower noted in this production area are rust, Sclerotinia head rot, and root rots. These diseases are usually avoided by planting treated and disease-free seed and following proper crop rotations. At least two crops should intervene between safflower crops to avoid losses from these diseases. Likewise, the risk of disease or insect losses is minimized by not seeding safflower on sunflower, field bean, mustard or rapeseed stubble. Sclerotinia head rot is commonly found in irrigated fields of the lower Yellowstone River Valley but has not been a serious disease in the dryland areas.

VARIETIES

S-208, Sidwill, Hartman, and Rehbein are the recommended varieties for 1981 production in Montana and North Dakota.

S-208 has yielded well in comparison to other varieties when grown under dryland conditions in Station trials. S-208 has some tolerance to Alternaria leaf spot but is susceptible to Pseudomonas bacterial blight. When the incidence of disease is light-moderate, S-208 will yield equal to, or better than, other varieties. This level of disease incidence is usually not exceeded when safflower is grown under dryland recrop conditions. Thus, S-208 is best suited for production on recrop land.

Sidwill with the pedigree of Sidney Selection 87-42-3/AC-1 was released as a stop gap variety by the Montana and North Dakota Experiment Stations in 1977. Sidwill has a higher level of resistance to Alternaria leaf spot than S-208 and other commercial varieties. It also has a moderate level of resistance to Pseudomonas bacterial blight. When the incidence of Alternaria leaf spot and bacterial blight is moderate to severe, Sidwill is superior to S-208 in both yield and test weight. Under disease free environments, Sidwill is similar in yield and test weight to S-208 but will average 2-5% lower in seed oil content.

Hartman, a Montana developed variety with the pedigree 87-42-3/AC-1, was released for production in 1981. Hartman has improved oil content, improved meal protein content and improved resistance to Pseudomonas bacterial blight when compared to Sidwill. Hartman is 1-2 days later in maturity than Sidwill or S-208. Hartman is recommended for production on fallow, irrigation, and in early plantings where the risk of bacterial blight and Alternaria leaf spot is greatest. The seed oil content of Hartman under disease free environments will average about 0.5 to 1% lower than S-208. Conversely, Hartman will normally have an oil content 0.5 to 1% higher than S-208 when the disease incidence is moderate-severe.

Rehbein is a Montana developed variety with the pedigree of 87-42-3/AC-1 released in 1981. Rehbein is 1-2 days earlier in maturity than Sidwill. Rehbein has a seed oil content intermediate between S-208 and Sidwill. This variety is expected to yield well in all safflower production areas in Montana and the Dakotas. Both Hartman and Rehbein are expected to gain in acreage in Montana and the Dakotas in 1982.

CROPPING SYSTEMS AND FERTILIZATION

The recommended cropping sequences for safflower are spring (winter) grain-safflower-barley-fallow or spring (winter) grain-safflower-fallow. The first sequence is used only if spring soil moisture is sufficient to assure a crop of recrop barley. Likewise, adequate spring soil moisture is needed to assure a stand of recrop safflower in its production year, e.g., minimum moist soil depth of 20-24 inches.

Safflower's response to N and P fertilization on recrop land is as good as, or better than, spring wheat or barley. Results obtained by USDA staff on the Soil Conservation District Research Farm near Culbertson, MT showed that safflower recrop yields are nearly doubled with an application of 30 lbs. of N per acre. Adequate N and P fertilization also tends to improve seed test weight, oil content, meal protein, and promote early maturity. For soils testing very low or low, in available P, 20-30 lbs. of P_2O_5 is recommended to be applied with the seed. P-responses on recrop occur only after N-fertilizer needs of the safflower crop have been supplied.

As a fallow substitute crop to control grassy weeds, safflower will return the producer $30-70 per acre above production costs under proper management compared to a $25-30 cost per acre to fallow. Necessary management practices for optimum yields include proper herbicide use and incorporation, early seeding, shallow seeding of 1-1½ inches deep, and adequate N and P fertilization.

Safflower may be produced on summer fallow but fallow yields have been very similar to recrop yields, principally due to disease problems. This practice will become more common with commercial production of resistant varieties. No additional N-fertilizer is usually needed for safflower grown on fallow except during relatively wet seasons. Nitrogen applied in excess of the amount needed for safflower will delay its maturity and increase the potential for plant disease losses and fall frost damage. Therefore, little or no N-fertilizer on fallow safflower is needed for relatively dry growing seasons, and no more than 20 lbs. of actual N per acre would be needed on fallow safflower for relatively wet growing seasons.

The level of soil P availability is very critical on fallow to promote early maturity. For summer fallow soils testing very low, low, or medium in available P, 45-60, 30-45, and 0-30 lbs. of P_2O_5 per acre should be applied with the seed.

Incorporating safflower in the small grain rotation in our production area reduces the disease, insect and weed problems that are associated with strict small grain production and permits more intensive cropping. Although the threat of serious outbreaks of Alternaria leaf spot and Pseudomonas bacterial blight in the northern Great Plains area is always present, the availability and production of safflower varieties with moderate resistance to these diseases should encourage an ever increasing acreage of safflower in Montana and the Dakotas and promote the growth of the safflower industry.

THE PRESENT STATUS OF RESEARCH AND DEVELOPMENT OF SAFFLOWER

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ABSTRACT

The increasing deficit of edible vegetable oils in Pakistan, which is over 400,000 tons, has necessitated development efforts on new oil crops like sunflower, safflower and soybeans. Despite its long history of limited cultivation in some areas of Pakistan for fodder, safflower has received importance as an oil crop only recently with provision of a guaranteed market for the produce. The available research information indicates that safflower has promise as a rotation crop with rice, especially in southwestern Pakistan. Spiny varieties did not prove popular. A spineless variety 'Thori/78' has been grown this year on 4,050 hectares in rice areas on residual soil moisture. Safflower has responded well to fertilizer applications both in irrigated as well as well as unirrigated conditions. The potential acreage that can be available for its cultivation in rice lands alone is expected to be over 400,000 hectares. However, more research information for identifying its position in cropping patterns of other areas is needed. The potential problems are damages by black aphid, safflower fly (Acanthiophilus helianthi) and leaf spot (Ramularia sp.) disease. Research needs of immediate importance are determining comparative values of spiny and spineless types, screening for earliness, disease and insect pest resistance and standardization of a package of improved production technology for different conditions together with proper utilization of the meal.

The edible oil requirements of Pakistan have been increasing rapidly, but the local production is stagnant resulting in a steady increase in imports as shown below:

Year	Local production (000s metric tons)	Imports (000s metric tons)	Total (000s metric tons)
1972-73	248	72	320
1973-74	206	169	375
1974-75	224	198	422
1975-76	179	270	449
1976-77	175	285	460
1977-78	200	298	498
1978-79	192	361	553
1979-80	239	366	605

Cottonseed and rapeseed and mustard are the main contributors to the local production of edible oil. Although groundnut and sesame are also important crops, their production is only enough for consumption as seeds and no oil is extracted. In view of the widening gap between consumption and production and also due to the fact that the established crops alone cannot reduce this gap, development programs of new crops,

primarily sunflower, safflower, and soybean, have been initiated in different areas with provision of a guaranteed market. Ghee Corporation of Pakistan (GCP), which controls the production and distribution of 'vanaspati' (hydrogenated oil), has been entrusted with the following responsibilities with respect to the new oilseeds:

a) Provision of pure seed to the farmers.

b) Procurement of the produce at floor prices fixed from time to time.

c) Promotional activities in collaboration with provincial agriculture departments.

Research on traditional as well as new oilseeds has also been accelerated by the Pakistan Agriculture Research Council (PARC) and the provincial Agriculture Research Institutes in cooperative programs. For new oilseeds identification of suitable production areas and standardization of improved production technology for different conditions is receiving the highest priority in the cooperative programs.

Although safflower is known to have been cultivated for fodder, for medicinal uses of the seed and for flowers as a coloring agent in some parts of Pakistan for many years, regular testing as an oil crop has only started recently. Its wild relative called 'pohli' (Carthamus oxyacantha) was established long ago as a weed, especially in the unirrigated northern areas of Pakistan, which suggests that cultivated safflower would also establish well. It is, however, evident from the research information so far available that safflower would be more successful as a 'dobari' crop (raised on residual soil moisture after rice) in drier areas of southwest Pakistan, and mostly in the province of Sind. In the central and northern areas (Punjab and Northwest Frontier provinces respectively), there is a higher incidence of leaf spot diseases (Ramularia and Alternaria species) due to high humidity in the winter which reduce yields.

In the early performance tests the local varieties proved lower yielding than the introductions. The variety 'Gila' was released for general cultivation in 1974 for Sind Province. In 1975-76 about 70 hectares were grown for seed increase and demonstration in irrigated areas. But difficulties in manual harvesting and threshing of this spiny variety proved a limiting factor for further increase in acreage. Inadequate water management also proved damaging because of increased incidence of root rot disease.

In 1978, a spineless variety, 'Thori/78', selected from the U.S. world collection, was released. Extensive performance tests of Gila and Thori/78 in irrigated as well as dobari areas in Sind Province have shown the latter variety to yield 20% lower than the former and also to have lower oil content (32% compared to 36% for Gila). It is also later maturing than Gila by about a week. However, due to absence of spines this variety presents no problem in manual harvesting and threshing. During 1980-81 it was sown on 4,000 hectares, mostly in dobari areas of Sind and Punjab provinces.

In the Punjab and Sind there are over 1.7 million hectares planted to rice annually. The predominant winter crops grown on dobari are gram (Cicer arietinum) and a winter pea (Lathyrus sativus) in Sind and wheat in the Punjab. With the replacement of local varieties of rice by IRRI types in Sind, the maturity period of the crop has been increased by three or four weeks which has reduced the acreage under gram due to late vacation of the land. Winter peas, generally with a mixture of brown mustard (Brassica juncea), are broadcast in the standing crop of rice before harvest when there is still enough moisture on the surface of the soil for germination. No tillage is provided. Gram, however, cannot be sown without opening up the soil. It is estimated that only about 50% of the rice area is covered with winter crops; the rest is left fallow due either to high salinity or failure of the land to come into condition in time for planting of winter crops. Assuming that about 0.4 million hectares are unfit for safflower due to high salinity, at least 0.4 million hectares can be available for this crop. A partial replacement of field peas and wheat would also be expected in these areas because safflower gives higher yields in November than in later sowings (Fig. 1).

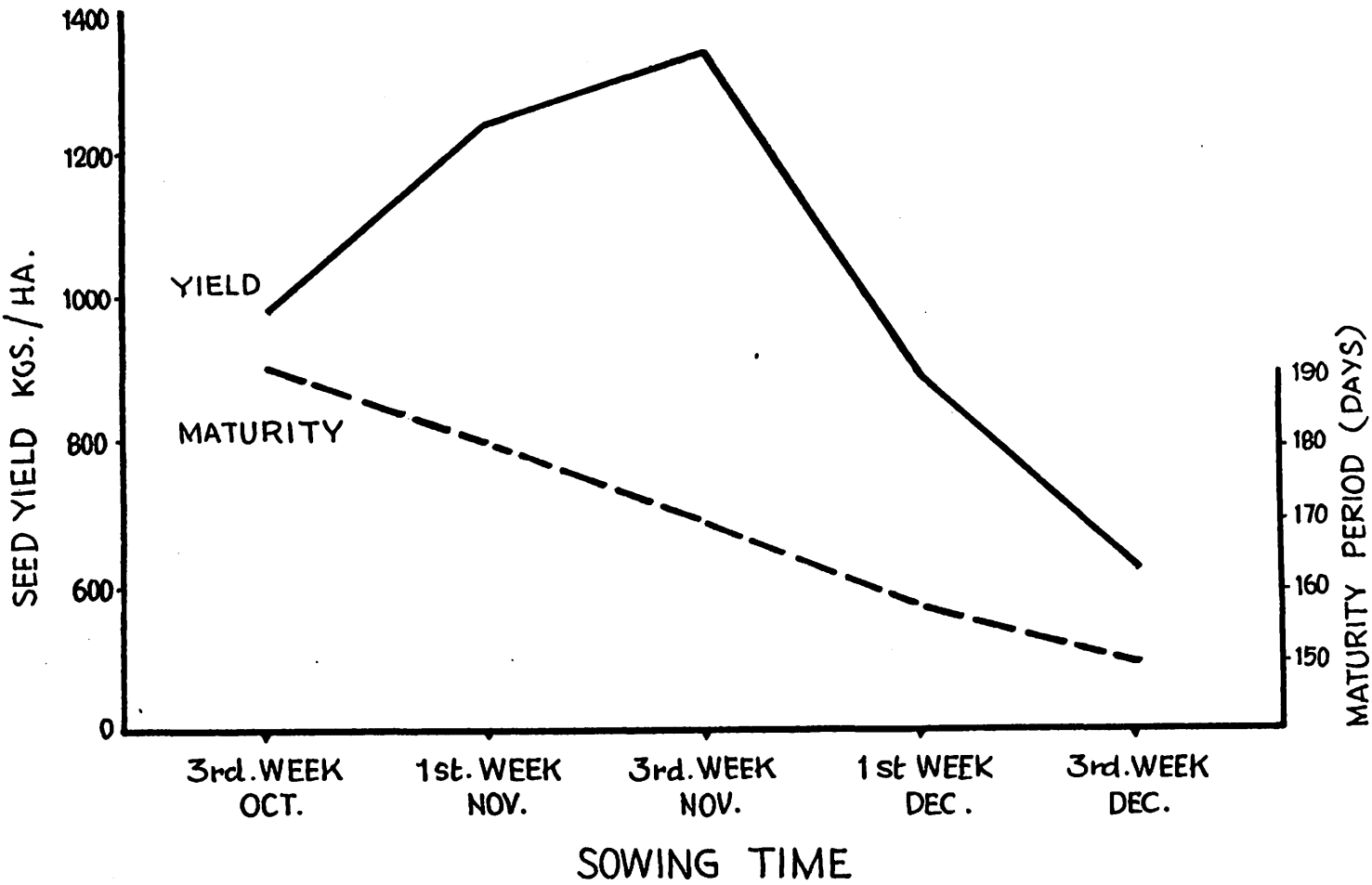

Fig. 1. Effect of planting time on yield and maturity of safflower variety Thori/78. Mean of two years, 1978-79 and 1979-80.

Response of safflower to fertilizer applications has been very good both under irrigated as well as dobari conditions. An application of 134 kgs N + 67 kgs P_2O_5/ha increased the yield by 100 to 200% over no fertilizer under irrigated conditions. A similar response to fertilizer was obtained in dobari on residual moisture (Fig. 2). In that experiment the contribution of P_2O_5 appeared to be quite high. In a more recent test an application of 84 kg N + 56 kg P_2O_5 + 28 kg K_2O/ha gave higher yields than 56 kg N + 56 kg P_2O_5 /ha. A survey of the commercial fields in dobari areas of Sind in February, 1981 showed that where no fertilizer was added the crop suffered from nitrogen deficiency particularly.

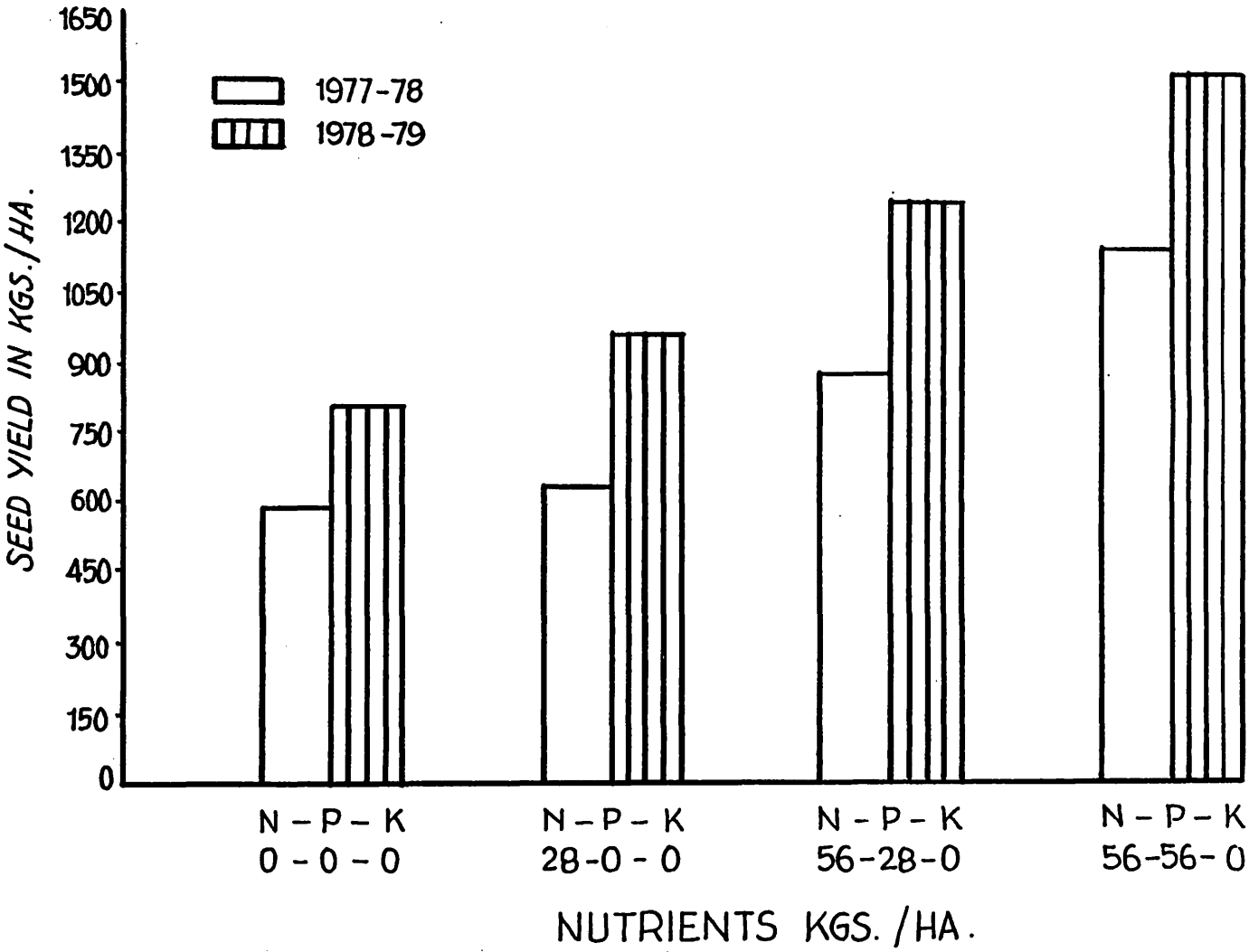

Fig. 2. Effect of fertilizer rates on performance of safflower in dobari.

The most important insect pest is black aphid (sp. ?) which in some years proves to be a limiting factor in production. It apparently follows the same infestation pattern as mustard aphid (Brevicoryne indobrassicae), the severity being lower in the northern areas compared with the southern coastal region. Safflower fly (Acanthiophilus helianthi) is another important pest which damages the growing buds. Occasionally cutworm (Heliothis sp.) attacks the crop in early stages. White flies (Bemesia tabaci) also infest the crop in early stages.

Among the diseases, leaf spot (Ramularia sp. and Alternaria sp.) and root rot (Phytophthora sp., Sclerotinia sp., and Fusarium sp.) are important. Leaf spot is the most damaging, especially in the Punjab where late winter rains occur frequently. So far no variety has shown resistance to this disease. A root rot complex is a problem mostly under irrigation where poor water management prevails on heavy soils. The problem is more severe in later stages of growth in March and April.

FUTURE SCOPE AND RESEARCH NEEDS

As with any new crop the scope of safflower will depend primarily on its economic competitiveness with existing crops. Although in irrigated areas the potential of safflower is quite high (up to 3 tons/ha), wheat is a strong competitor. It has an immediate scope in rice areas where yields of 1.5 tons/ha under good management conditions would not be uncommon, and thus would appear to be a better choice than low yielding (about 0.5 tons/ha) winter peas. Safflower will be useful in the rotation due to its deep root system, thus providing soil opening and lowering of the water table. Substantial acreages would be available in those areas which are left uncultivated due to failure of land to come into condition early for planting some winter crops. A similar situation would be met in the irrigated areas where, after the harvest of cotton, wheat sowing is not possible.

A safflower development project aiming to bring 40,000 ha by 1983-84 under this crop in dobari areas of Sind is being initiated by the Pakistan Government. Adaptive research and demonstration plots in selected areas would form the major component of the project.

Other areas which hold promise for safflower, but where sufficient research information is not yet available, are the 'Kacha' (riverine) areas and 'barani' (rainfed) areas of northern Pakistan.

Safflower takes about one month longer than wheat to mature and would complete development by the end of April to mid-May. To get enough time for preparation of land for summer crops early maturing varieties are badly needed.

The other research problems which need to be tackled in order to make this crop successful in Pakistan are:

- Evaluation of spiny vs. spineless types
- Improving yield and oil content of spineless varieties
- Screening for leaf spot and black aphid resistance
- Screening for tolerance to salinity
- Developing improved production technology for different areas
- Better utilization of byproducts, viz. meal, hulls etc.

DEVELOPMENT OF SAFFLOWER AS A COMMERCIAL CROP IN THE UNITED STATES

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ABSTRACT

The first serious effort to establish safflower as a crop in the United States was in the state of Nebraska in the late 1940's. Beginning in 1950, efforts to develop safflower as a crop were concentrated in California. By 1954, hectarage was up to about 20,000 in California. During the past 20 years, the total area planted to safflower in the United States has varied from 70,000 to 175,000 hectares. Considerable improvement in safflower varieties has been accomplished during the past 30 years and additional improvements are still to be made. Both linoleic and oleic varieties of safflower are being produced in California. Both oils need to be marketed as premium oils in order for processing mills to pay enough for safflower to make it competitive with other crops grown. Safflower must compete for hectarage mainly with wheat and feed grains. The main producing states in the U.S. are California, Montana, North Dakota and Arizona.

EARLY HISTORY

Safflower was first brought into the United States by immigrants, mostly of European origin. My mother's family, in approximately 1879, was one of these immigrants from the Russian Ukraine who brought some safflower seeds with them and grew them in central Kansas. They grew them in their gardens as did other immigrants primarily for the florets that were used to add yellow color to some of their foods. One can occasionally still find safflower plants growing in California gardens for the same purpose. Many of the latter families had their origins in Spain and Portugal. I have collected seed samples from those sources and found that they grew quite well in California, but the seed had oil contents of only 20-24% and a hull perentage of plus or minus 60%. Because of the low oil percentages they had no value as oilseed varieties.

EARLY TESTING

The earliest test by Agricultural Experimental Stations as far as I can find was in 1899 by the State of California Foothill Substation. Only a small footnote about that test could be found indicating that safflower showed drought resistance, but was inferior to sunflower in yield of seed for oil or poultry feed.

Between 1925 and 1935 the U.S. Department of Agriculture made a few introductions from India and Russia. These were tested and maintained at the Experimental Station, Huntley, Montana. No attempt was made at that time by the U.S. Department of Agriculture to maintain the purity of the introductions or to do any breeding work. By the time I obtained seed of those materials in 1942, they were very mixed.

My first exposure to safflower was when I was a graduate student at Washington State University at Pullman, Washington, from 1939 to 1941.

During Dr. E. F. Gaines' (one of the early wheat breeders in the U.S.) visit to Russia in the mid-1930's, he brought back a sample of safflower from Russia and grew it at the Experimental Station at Pullman. That introduction was very different from the Indian types that had been maintained at Huntley, Montana. It had an oil content of approximately 22-24%, whereas the varieties from India had about the same oil content or slightly higher, namely 22-29%. Under a few conditions some of the Indian varieties would attain 30% oil on a moisture-free basis. The sample brought from Russia by Dr. Gaines was similar in type to the introductions made by U.S. immigrants from Europe in the 1800's.

BREEDING PROGRAMS

In December of 1941 I was hired as a Research Agronomist at the Nebraska Agricultural Experiment Station at Lincoln to do research on possible new crops. After one year's testing of many new crops in all the major agricultural areas of Nebraska, safflower was chosen as one crop on which to start a breeding program. I began this program in 1942, and continued at Nebraska through 1949.

In 1950, a friend of mine, Richard Hoagland, and I decided to start our own company in California. This was a partnership which we called Western Oilseeds Company. Permission was obtained from the Director of Agriculture, Nebraska Agricultural Experiment Station, to take a portion of all breeding materials with me to Western Oilseeds Company. That research program still continues although the company has gone through several name changes: 1950 to 1954, Western Oilseeds Company; 1954 to October, 1980, Pacific Oilseeds Incorporated; and since 1980, SeedTec International Incorporated.

Early tests in Nebraska showed that safflower had reasonably good adaptation at Scottsbluff, Nebraska under irrigation, and at Alliance, Nebraska under nonirrigated conditions. Both of these locations are in the Nebraska panhandle, in the extreme western part of the state, where yearly rainfall varies from 250 to 700 mm with an average of 425 mm.

During our first years' observation trials in Nebraska in 1942 we did not have more than ten different varieties to test. After the 1942 harvest an effort was made by correspondence to obtain as many different introductions as possible. Introductions during the next several years were obtained from India, Iran, Turkey, Egypt, Sudan, Ethiopia, Somaliland, Morocco and Rumania. The total number was probably not more than 100. For several years the more promising of those lines were placed in replicated yield tests, and an intensive selection program for yield and oil content was made. Most of the introductions made during this time were not pure in plant type.

GERMPLASM COLLECTIONS

During 1958 and 1964-65 Dr. Paul Knowles, University of California at Davis, made extensive safflower seed collection trips throughout the Mediterranean, Middle East and south Asian areas collecting well over 1,000 samples and also a sizeable collection of other species of Carthamus. This is no doubt the most extensive and complete collection of safflower species in the world today which is being maintained by the USDA at Pullman, Washington.

Some reference should be made to the world collection of safflower made during the 1930's by Vavilov in Russia. In addition to his collection he published a detailed taxonomic key to the identification of sub-types collected from various parts of the world. At one time I had an English translation of that paper obtained from Dr. L. M. Pultz (now deceased) of the USDA Beltsville office. Safflower researchers would find that publication by Vavilov useful (the approximate date of the publication was 1935).

Concerning my own efforts, most of the material obtained from Turkey and Iran was more or less spineless and late in maturity. The Indian material and that from the Sudan was some of the earliest in flowering although very different in type. Ethiopian material was very late and included crosses to wild species. Selections with highest oil content were obtained from the Sudanese introductions. Most of the material from that country had at least 33% oil, and some was as high as 35%. There were also some fairly high oil types out of Egypt, some single plant selections going as high as 36-37%. Some of the material from Iran had oil contents of 32-33%.

VARIETIES

While I was in Nebraska only two varieties were increased and released. The most important was Nebraska-852. This was a mass selection from an introduction from the Sudan. However, by selection and reselection from 1943 to 1949, ten distinct selections were purified and were at least in the beginning stages of increase. These were numbered Nebraska-1 through -10 (often abbreviated N-1, N-2, etc.). The first four varieties were spineless. None of these spineless varieties became established commercially although some fields were grown. N-1, a selection from an introduction from Turkey, had complete resistance to rust infection on the roots.

Varieties selected in Nebraska that became important commercially in California were N-852, N-10 and N-6. N-10 was a further selection from N-852 with 1.5 to 2% higher oil content, and N-6, selected from a very mixed introduction from Egypt, had very large seed heads and 35-36% oil.

During the time I was in Nebraska an extensive crossing program was started between safflower selections. This was later made a cooperative program between Dr. Charles Thomas, USDA plant pathologist at Beltsville, Maryland, and our company. This program was started in 1951 and continued for approximately 15 years.

The crosses from this material were shared with the USDA breeding program on safflower in Arizona then headed by Dr. David Rubis. In 1958 one release from this program was Gila, a selection made by Dr. Rubis from a cross of N-10 x Western Oilseeds-14. This variety became of some importance in Arizona and California. In the mid-1960's the Sacramento Valley had temperatures during flowering in the rice producing area of 110-115 F (43-46 C) with high humidity. This combination sterilized most of the florets of Gila and Pacific-3 (P-3). From then on Gila was never again grown extensively in the Sacramento Valley.

After leaving Nebraska all additional releases of safflower by our company were the result of single or multiple crosses. During the period 1958 through 1973 Dr. Donald L. Smith was Director of Research. For the past three years our research has been under the direction of Dr. Thomas Heaton.

Pacific No. 1 (P-1), released during 1954-56, was a cross of N-10 x a European type. It had about 37% oil, was a very high yielder, and seed set was less affected by high temperatures combined with high humidity than any other variety that we ever developed. When first released it was immune to leaf rust. Within 3-4 years after its release it became one of the more susceptible varieties to a new race of rust. It was also very susceptible to Phytophthora and Fusarium root rots. This variety has been out of production for 12 years.

Several other lines released soon after P-1 were P-3 and P-9, both with 42-43% oil. P-3 had a striped hull and P-9 normal but very thin hull (this may be the same hull type referred by Lee Urie as reduced hull). This variety was very spiny and had many small heads, but had good yielding ability. Other varieties that became of some importance were S-414, S-515 and S-999. These were released during the early 1960's.

About 1965 Fusarium root rot started to show up in a few isolated areas. Resistance was found in some introductions. By 1967 we were beginning to increase our first Fusarium resistant variety S-296 which we used in areas that had Fusarium problems.

Since Fusarium root rot was first isolated, Dr. John Klisiewicz has isolated four different races. Race 4 is not widely scattered and even the other three races are prevalent in only certain areas of California. The most heavily infected areas are by-pass areas along the Sacramento River and some of the Delta area.

The commercial varieties developed by SeedTec that are still grown extensively in California are: S-208 released in the late 1960's which is susceptible to all races of Fusarium; S-400 released in mid-1975 which has high resistance to the three most prevalent Fusarium races 1, 2, and 3; and S-541 released in 1978 which is resistant to races 1 and 3. S-317 released about 1976 is a high oleic variety that is resistant to races 1, 2 and 3 of Fusarium and has high tolerance to Phytophthora root rot. S-317 has extended branching. If there is adequate soil moisture and fertility this character will express itself by forming more branches and seed heads. These varieties are the only ones developed by SeedTec that are still sold at this time.

No mention has been made of high oleic varieties. The first high oleic variety used in California, UC-1, was developed by Dr. Paul F. Knowles and released in 1966. From crosses with this variety SeedTec has released several new varieties, S-304 in about 1970, and S-317 in 1976. The early releases of high oleic varieties did not yield as well as linoleic varieties then grown by farmers and they demanded a premium to get them grown. S-317 is a top yielding high oleic variety with about 42-43% oil. Because of its high yielding ability this variety is bought in California at the same price as linoleic varieties.

ESTABLISHING SAFFLOWER AS A CROP IN THE UNITED STATES

To the best of my knowledge Alfred Rehbein Sr. of northwestern Montana was the first farmer to grow small fields of safflower in the United States. I had the privilege of visiting him on his farm in Montana on several occasions, the first time in about 1945, and several times in the 1950's. I do not remember the exact year he first grew safflower but I am quite sure it was in the 1930's. The type of safflower he was growing was of Indian origin. A small amount of his seed was sold for planting. However, most of it was fed to poultry and cattle. His pioneer efforts did not result in the establishment of safflower in the United States.

In mid-1947 a small company was incorporated at Scottsbluff, Nebraska to act as a buying agency for safflower that I had encouraged farmers to grow in western Nebraska, northeastern Colorado and eastern Wyoming. In 1949 an oilseed processing company was established at Longmont, Colorado. The attempt at commercialization of safflower in eastern Colorado was based on N-5, an Indian selection, N-852 and N-8. Within a few years after incorporation this company went into bankruptcy.

Hectarage of safflower in the above area was not large during the late 1940's and early 1950's, and the maximum may have reached 10,000 hectares. Disposal of the seed harvest was difficult.

ESTABLISHMENT IN CALIFORNIA

In the late 1940's I was sending seed samples of some of my selections to a number of cooperators at various agricultural experiment stations where I thought safflower should be adapted. One of these cooperators in 1947 and 1948 was Dr. Paul Knowles at the University of California at Davis. His results were quite promising.

During those same years I was using the Imperial Valley of California for winter increase of some of the new selections for use in Nebraska. My cooperator in the Imperial Valley, Mr. Richard Hoagland, thought so highly of the safflower potential in California that he made several trips back to Nebraska to see me and what I was doing on safflower.

In the summer of 1949 he convinced me that I should make a trip to California to visit the oil mills in that state and to consider seriously resigning from the University of Nebraska and starting a company with him in California. I did spend 7-10 days in the fall of 1949 visiting all the major California oil mills, some farmers, and Dr. Paul Knowles.

After that trip I was convinced that safflower could be established as a successful crop easier in California than in the Midwest. In Nebraska or Colorado there was no experienced local oil mill in the potential areas of production. There were several experienced oil mills in California. A decision was made in the fall of 1949 to resign from the University of Nebraska and with Richard Hoagland to start our own company in California. The main purpose of this company was to get safflower started as a commercial crop in California,

The first real effort to develop commercial safflower acreage in California was made during the 1950 growing season. Four different processing companies had a part in trying to develop safflower acreage that year. The first year there was approximately 7,500 hectares of safflower planted in California. Most of this was in the San Joaquin Valley, some in Imperial Valley, and very little in the Sacramento Valley. Practically all of the safflower in the San Joaquin Valley and Imperial Valley was grown under irrigation. The bulk of the planting was N-852.

N-852 was highly susceptible to Phytophthora root rot. Under dryland conditions this disease normally does not express itself, but under irrigation the disease can be very serious, particularly if the soils are heavy. If the land is irrigated when the temperatures are above 100 F (38 C), severe infections can occur, and did occur during the 1950 growing season. At least 10% of the crop in 1950 was not harvested because of total destruction by Phytophthora root rot.

There were, however, a few fields on the west side of the San Joaquin Valley that produced over 4,500 kg/ha. In those fields safflower was usually planted on vegetable beds and the soils were usually a sandy loam and not a heavy clay, and very little Phytophthora occurred. Also, the fields grown in the Sacramento Valley, although few in number, produced good yields. There were several fields grown on normally high water table land near Meridian, California that produced over 3,700 kg/ha with no irrigation and no fertilization. After the 1950 harvest most farmers and processors considered safflower to be a failure and were ready to give up.

I made a point during the fall of 1950 to revisit all the oilseed processors. I was convinced that we had to have Phytophthora root rot resistance if we were going to try to grow safflower under irrigation, but in the Sacramento Valley and Delta areas of California there appeared to be a good place for safflower on heavy soils that hold water well as a rotation crop with rice, beans, barley and wheat. I was able to convince Pacific Vegetable Oil International that if they would finance our company and give us a few years time, we could work with the growers where the crop was adapted and get this crop established in California.

In 1951 we were able to develop only about 6,000 hectares under contract to PVO International, most of it grown without irrigation and producing sufficient yields to be somewhat encouraging. By the end of 1953, we had safflower growing on approximately 20,000 hectares, which produced a total of about 40,000 tons. At that time it became evident to PVO International that we were going to be successful in establishing safflower as a crop in California.

It also became obvious to them that they did not want a year-to-year contract with Western Oilseeds Company, but wanted to buy control of this small company. At this Juncture my original partner, Richard Hoagland, decided to go his own way with hybrid castorbean seed production and sales. We had, in 1953, hired Al Hoffman from the University of Nebraska as our first employee. Mr. Hoffman had been working as my assistant at the University of Nebraska at the time I left Nebraska. In 1954 Mr. Hoffman and I incorporated Pacific Oilseeds Inc., and later that year sold 50% of the shares to PVO International.

During the 1950's and 1960's safflower continued to grow in importance as a crop in California. By 1956 it was considered an established crop. For much of its success I would like to give credit to the assistance of the University of California, through the leadership of Dr. Knowles and the Agricultural Extension Service. Farm advisors who were particularly helpful in getting safflower started were: Hilton Miller, Karl Ingebretzen, Ted Torngren and Ron Baskett.

During the 1970's the area of production was usually between 70,000 and 90,000 hectares. Production during the last 10 years has been about equally divided between the Sacramento Valley and San Joaquin Valley. The Tulare Lake basin of San Joaquin Valley has grown 10,000 to 25,000 hectares per year for the past 15 years. In that area is the largest grower in California, the J. G. Boswell Company. Safflower in that area is grown on very heavy soils that are pre-irrigated. In the summer the heavy clay soils are able to hold enough water to produce high yielding safflower without additional irrigation

OTHER STATES

In the late 1950's and early 1960's safflower processing plants were established by FVO International at Sidney, Nebraska, and at Culbertson, Montana. After the establishment of those plants safflower acreage surrounding both of them in some years was as high as 45,000 hectares.

In both areas in good years with adequate rainfall (350 to 700 mm) average yields of approximately 800 kg/ha were obtained, with maximum yields about 2,000 kg/ha. However, in the western part of the Great Plains there are years when rainfall is only 150 to 300 mm per year. During those years there were many failures and/or very inadequate yields.

Only the mill at Culbertson, Montana is still in operation, and it is now owned by Continental Grain Company. Total areas seeded to safflower in eastern Montana and western North Dakota vary greatly from year to year depending upon rainfall and comparative prices of safflower and wheat. There is virtually no safflower grown in Nebraska and Colorado at this time.

When wheat acreage was controlled under an allotment system, safflower fitted in as a very good substitute crop. When the USDA does not control wheat acreage the local farmer makes his choice of crop on the basis of profitability. Even so, under normal rainfall, many farmers in northeastern Montana and western North Dakota will grow sizeable amounts of safflower. Production is variable from year to year, primarily because of soil moisture conditions.

Other states that have grown some safflower during the past 30 years include Washington, Idaho, Utah and Oregon. However, it cannot be considered an established crop in any of those states, although production in some years has been as much as 7,000 hectares.

Total U.S. hectarage in 1981 is lower than it has been for years, possibly between 40,000 and 50,000 hectares.

FUTURE PROJECTIONS

Why is the current production of safflower in the United States less than it has been for the last 15 years? The greatest reason is that U.S. farmers choose that crop that will return to them the most money. In rice and cotton areas, these crops have been difficult for safflower to compete with on net returns per acre at any time.

In 1981 the prices of wheat and barley have been very competitive with safflower. In order for oilseed mills to get some farmers to grow safflower they have had to pay prices for seed which makes safflower oil cost 45-50 cents per pound and in some cases more, where soybean oil is selling for 21-25 cents per pound. When selling at such premiums the market for safflower oil, whether it be oleic or linoleic, has to be for very special uses. These markets are limited. If safflower price is not at least 2.5 times the price of wheat, U.S. farmers are likely to grow wheat. If safflower is three or more times the price of wheat, areas planted to safflower will increase at the expense of wheat.

Other factors influence the farmers' choice of crops. For example, weed problems encountered in growing safflower may be greater than those for other crops. A deep rooted crop like safflower often improves yields of crops that follow.

Putting everything into a crystal ball, my best estimate is that the safflower area planted this year is one of the lowest that we shall have for some time. However, I do not expect to see 200,000 hectares of safflower in the U.S. in the next year or two unless we see a big economic change in comparative prices of crops that are now being grown by U.S. farmers.

I cannot at this time foresee the proportion of oleic to linoleic varieties that will be grown in the future. I have been surprised that the oleic market has not grown faster than it has. In the U.S. this oil has been available commercially for over 10 years.

It should be clear to all of us from the United States that the sales of safflower that mills buy at $375 per ton are limited to the special markets that are available. At 180-200 dollars per ton the mills might be interested in a very large quantity of safflower that would allow them to sell safflower oil competitively with soybean oil. A somewhat similar relationship probably exists in all the developed countries of the world. However, in the developing countries safflower oil will likely have to compete with whatever other vegetable oils are available. A premium market may not exist for safflower oil of either the linoleic or oleic types.

ADAPTATION AND PRODUCTION OF SAFFLOWER IN SOUTH ITALY

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ABSTRACT

This paper summarizes data collected from several research projects conducted in different environments of South Italy regarding the production and adaptation of safflower varieties. Safflower seems to be adaptable to different environments of South Italy provided that the soil is deep and seeding is done in the fall. Seed yields of about 2.5-3.0 tons/ha and 30% oil in the seed have been obtained. No appreciable increase in seed production has been obtained when safflower was cultivated under irrigated conditions and with spring seeding. In some environments it has been observed that a heavy attack by insects (Diptera, Trypetidae) significantly reduced seed production. Among the diseases, Puccinia carthami Cda and Macrophomina phaseolina (Tass) Goid have been found in different localities but did not significantly affect seed production.

Safflower is relatively new to Italian agriculture. In past years it was cultivated in small areas as a source of dye for clothing and food. The increasing requirement of oil for food, at present satisfied by importing seeds and fruits from other countries, has encouraged research on several annual oil crops (sunflower, soybeans, safflower, castors and rapeseed). Among these, safflower has not received much consideration.

However, a research program sponsored by the Agriculture Ministry was started in 1979 involving several regions of Italy, but the results are not yet available. Before that project the Agronomy Institute of Bari conducted for five years (1974-1978) several trials in different localities of Apulia, Brasilicata and Calabria with the goal to study adaptation and production of safflower under different environmental conditions. The results have been published already (L'Informatore Agrario, 36, 1980); therefore in this paper a brief summary of the results will be given.

INFLUENCE OF IRRIGATION AND SPRING SEEDING ON SEED PRODUCTION

This trial was conducted during 1974 at Policoro field, which has a deep, loam soil with the water table at a depth of about 3 meters. Five varieties (Gila, US-10, UC-83, Oleic Leed and U-5) were employed under dry and irrigated conditions with two seeding dates (March and April).

Results (Table 1) show a sensible negative influence on seed production from an April seeding (5.7 q/ha) compared to that of March (17.1 q/ha). No differences were found between dry and irrigated crops (respectively 10.9 and 11.8 q/ha) and among varieties except U-5 was significantly lower in yield (8.5 q/ha).

Table 1. Seed production (q/ha) of safflower varieties under different environmental conditions at Policoro field, 1974.

Varieties	Dry crop	Irrigated crop	Seeding time March	Seeding time April	Variety mean
Gila	12.7	13.2	18.8	7.2	12.9
US-10	11.9	12.7	18.1	6.5	12.3
UC-83	11.0	12.9	17.8	6.2	12.0
Oleic Leed	10.4	11.5	17.2	4.8	11.0
U-5	8.3	8.8	13.5	3.6	8.5
Mean	10.9	11.8	17.1	5.7	11.4
LSD (P=0.05)	--		7.0		2.4

INFLUENCE OF FALL AND SPRING SOWING UNDER DRY FARMING ON SEED PRODUCTION

A trial was established in 1974 at the Bari field on "terra rossa" soil to study the influence of different seeding times on seed production of four safflower varieties.

The November seeding (Table 2) gave on the average the best results for seed production (24.0 q/ha) whereas February and March sowings produced significantly less (7.5 and 2.7 q/ha respectively). No differences were found among the varieties tested.

Table 2. Seed production (q/ha) of safflower varieties with fall and spring sowing at the Bari field (1975).

Varieties	Seeding time November	Seeding time February	Seeding time March	Mean
Gila	28.7	6.9	3.1	12.9
Oleic Leed	25.2	8.8	2.9	12.3
VFSTP-1	23.2	5.4	2.1	10.2
Ute	18.8	8.9	2.6	10.1
Mean	24.0	7.5	2.7	11.4
LSD (P=0.05) seeding time		5.6		

The highest seed production with fall sowing is mainly due to the high number (23.0) of heads per plant (Table 3) in contrast to spring seeding (10.0 and 4.2 heads/plant with February and March sowings, respectively). These results can be explained as the positive influence of low temperature during the rosette stage of the plant.

SEED PRODUCTION ON SHALLOW AND DEEP SOIL

Soil depth plays an important role in determining seed production. In

our experience (Table 4) low yields have always been observed on shallow and stony soil (5-10 cm in depth), while with deep and fertile soil seed production was sensibly higher.

Table 3. Number of heads per plant of safflower varieties with fall and spring sowing at the Bari field, 1975.

Varieties	Seeding time			Mean
	November	February	March	
Gila	15.8	7.0	3.4	8.7
Oleic Leed	17.7	8.5	3.5	9.9
VFSTP-1	35.3	12.1	4.6	17.3
Ute	23.4	12.4	5.3	13.7
Mean	23.0	10.0	4.2	12.4
LSD (P=0.05)				
Seeding time	5.9			
Variety	6.8			
Interaction	11.9			

Table 4. Seed production (q/ha) of safflower varieties on shallow and deep soil with fall and spring sowing.

Varieties	Fall seeding		Spring seeding	
	Shallow soil (1)	Deep soil (2)	Shallow soil (3)	Deep soil (4)
Gila	7.3	--	4.2	18.3
Ute	6.8	26.5	5.1	21.7
VFSTP-1	6.4	--	4.2	22.1
Oleic Leed	8.1	30.0	6.2	19.2

(1) Mean of 2 localities (1976 and 1977)
(2) " " 2 " (1976, 1977, and 1978)
(3) " " 6 " (1975 and 1976)
(4) " " 1 locality (1976)

COMPOSITION OF SAFFLOWER OIL

Table 5 gives the oil content and fatty acid composition of four safflower varieties grown in South Italy. On average the oil content was about 30%, with Oleic Leed the highest (34.8%). That variety had an oleic acid content of 67%, close to that of olive oil. Sterol analyses should identify differences between the two oils.

DISEASES AND INSECTS

Puccinia carthami Cda and Macrophomina phaseolina (Tass) Goid have been the most frequent diseases, but their effects on yield have not been measured. An insect belonging to Diptera, Tripetidae has caused serious damage.

Table 5. Mean values of fatty acids (expressed as percent of total fatty acids) and other characteristics of safflower oil.

Varieties	Acidity of extracted oil	Oil percentage	Iodine value	Oleic acid	Linoleic acid	Linolenic acid	Stearic acid	Palmitic acid	Palmitoleic acid
Gila	1.70	30.82	138	14.6	75.3	0.2	2.6	7.3	--
Oleic Leed	1.15	34.76	96	67.0	25.7	0.1	1.8	5.4	trace
VFSTP-1	1.31	28.81	143	14.7	75.3	0.2	2.6	7.2	--
Ute	1.46	30.14	139	14.2	73.4	0.3	2.8	8.6	trace

The analyses were conducted on samples harvested in 1975 from spring (March) sowings.

Each sample is a mixture of the same variety grown in five different localities on shallow soil.

CARBON ASSIMILATION IN SAFFLOWER (*Carthamus tinctorius* L.) UNDER NaCl SALINITY

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) (var. APRR 1) plants subjected to low (35 mM) and high (70 mM) levels of sodium chloride salinity revealed interesting changes in the amino acid pattern. Salt sensitive crop plants generally respond by showing a reduction in proteins and increase in alcohol soluble amino acid fraction. Safflower, which is considered as a tolerant species, responded to sodium chloride treatment in a favorable manner. Salt treatment induced an increase in vegetative growth and dry matter production associated with higher rates of $^{14}CO_2$ incorporation.

The observed amino acid changes can be divided into three categories. The accumulation of proline which is a common response to stress was not observed. There was only a negligible increase of proline in salinized plants. On the other hand, simple amino acids like alanine, glycine, leucine, valine and the heterocyclic amino acid histidine, were found to be increased by 100%. The basic and acidic amino acids like aspartate, glutamate, lysine and arginine showed a 75% increase, while the sulfur containing amino acids like methionine were present in trace amounts. The pattern of $^{14}CO_2$ incorporation into amino acids also indicated essentially a similar trend. This response indicates an alteration in the pathway of carbon in growing the crop in saline soils.

The cultivation of safflower (*Carthamus tinctorius* L.) in India in ancient times was mostly for its dye; but subsequently the crop was and is grown for its oil. It is cultivated in the semiarid and arid zones of India (Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, Bihar and Uttar Pradesh) because of its low water requirement and salt tolerance at later stages of growth (1). Soil salinity at an exchangeable sodium percentage level of up to 28.5 was reported to stimulate growth (2). It was suggested that Na^+ may substitute for K^+ when K^+ supply is low and that application of Na^+ to safflower may give better growth (3). It was also confirmed that safflower responds to sodium fertilization in the presence of ample potash. Studies on the effects of salinity on safflower growth (4), yield (5), mineral content (6), oil content (7) and on stomatal behavior (8) are available, but metabolic studies in relation to salinity are scanty. Therefore, an attempt was made to understand the carbon assimilation in safflower var. APRR 1 under two levels of sodium chloride salinity.

MATERIALS AND METHODS

Safflower seeds of the variety APRR 1 were obtained from the Oilseed Specialist of Andhra Pradesh Agricultural University, Hyderabad. They were surface-sterilized with 0.1% $HgCl_2$, washed thoroughly, and soaked in tap water for 24 hr at room temperature. The seeds were sown in earthenware pots (30 cm diam) which were filled with red soil and manure (3:1 ratio).

When the seedlings were 7 days old salinity was induced by adding 2% sodium chloride solution at 35 mM and 70 mM levels, i.e. 0.2% and 0.4% salt on dry weight basis of the soil. Control plants received deionized water. Pots were kept in a glasshouse and watered daily, and the moisture content was maintained between 40 and 50% of field capacity of the soil to avoid leaching. The plants were thinned to three of uniform size in each pot. The pH and Ece of the soil were measured from the soil water extract (1:3) with an Elico pH meter and Phillips's conductivity bridge respectively (Table 1).

Table 1. Electrical conductivity and pH of the soil extract

	Concentration	Molarity	M.eq./l	pH	Ece mmhos^{-cm}
Control	deionized H_2O	--	--	7.3	0.98
1st treatment	0.2% NaCl	35 mM	34.18	7.4	1.98
2nd treatment	0.4% NaCl	70 mM	68.37	7.6	2.20

Growth rate was determined at four stages: 15 days, 20 days, 25 days, and 30 days after sowing, taking random samples from different pots. The height, leaf area, dry wt/g fresh wt were determined.

As the growth rate was found to be at its maximum in all samples at the 25-day stage, this stage was selected for the studies on $^{14}CO_2$ incorporation, amino acid analysis and determination of protein and nitrogen content. Protein content was determined by the Lowry (9) method, and total nitrogen was estimated according to the method of Markham (10). Protein nitrogen was estimated by the method of Thimann and Loos (11) and the soluble nitrogen was calculated from it.

$^{14}CO_2$ incorporation studies were made following the technique of Beery et al. (12) with slight modification. The time of exposure was 10 minutes. Light intensity, measured with a Lux meter, was 40,000 lux. The radioactivity was measured using a Beckman liquid scintillation counter. The results given are averages of three sets of experiments for all the metabolic studies. The samples for the amino acid analysis were prepared after acid hydrolysis. The acid was evaporated and samples collected with 5 ml 2.2 pH citrate buffer, centrifuged and loaded on an automatic amino acid analyser (Beckman Unichrom model). The amino acid content was expressed as μmoles/g dry wt.

RESULTS AND DISCUSSION

In salinized plants the growth rate slowed down for a short period from the 8th to 15th day after treatment. This is presumed to be the period of acclimatisation and adjustment to the treatment given. From the 15th to 30th day the growth rate was restored and even stimulated as indicated by growth parameters like height of plant, fresh weight, leaf area and dry weight per g fresh wt (Table 2). This is in contrast to the general response of most plant species to salinity which exhibit stunted growth, reduction in leaf area and decrease in dry weight per g fresh wt (13, 14). Safflower responds to NaCl treatment in a different manner in that it is

Table 2. Influence of NaCl salinity on growth of safflower plants. (Values are means of 3 replications).

Days after sowing	Treatment	Height in cm	Leaf area in sq cm per plant	Fresh weight in gm per plant	Dry weight in mg per plant	Dry weight in mg per gm fresh wt
	Control	3.00	24.26	1.54	77.25	50.30
	± SE	0.00	0.17	0.05	0.82	
15	35 mM	3.50	27.13	1.46	72.57	49.70
	± SE	0.00	0.23	0.04	0.77	
	70 mM	3.00	18.30	0.93	51.02	54.80
	± SE	0.02	0.33	0.05	0.44	
	Control	7.50	51.20	2.10	118.60	56.30
	± SE	0.03	0.41	0.04	1.30	
20	35 mM	8.00	46.73	2.49	149.22	60.00
	± SE	0.05	0.36	0.05	1.04	
	70 mM	7.00	34.70	2.03	118.06	58.16
	± SE	0.06	0.26	0.06	1.23	
	Control	14.30	63.96	3.29	169.04	51.30
	± SE	0.13	0.34	0.09	1.03	
25	35 mM	15.90	85.22	4.08	253.27	63.00
	± SE	0.13	0.45	0.10	1.54	
	70 mM	14.40	84.77	4.20	261.44	62.24
	± SE	0.08	0.46	0.11	1.43	
	Control	19.00	87.97	4.20	218.00	51.90
	± SE	0.15	0.55	0.09	1.72	
30	35 mM	20.00	103.30	5.48	317.61	57.90
	± SE	1.17	0.70	0.13	1.63	
	70 mM	21.00	119.08	6.50	377.00	58.00
	± SE	0.19	0.89	0.13	1.83	

not only salt tolerant but also shows stimulated growth rate. This concurs with the earlier observations that Na^+ stimulates growth in safflower in early stages (2, 3, 4). It was reported that certain glycophytes show favorable growth response to Na^+ under conditions where K^+ is not limiting (15). Though sodium was not listed as an essential element except in certain salt tolerant species with C_4 syndrome, it might have some role in the Crassulacean acid metabolism (CAM). Induction of CAM by NaCl is considered as part of the response to water stress. Existing literature seems to be scanty in the elucidation of the role of Na^+ in either direct or indirect activation of some enzymes related to C_4 or CAM (16).

The protein content of the treated plants was also found to be higher, when compared to the controls, on the 25th day after sowing. It was almost the same in both the treatments, i.e. 35 mM and 70 mM salt levels. The total soluble and insoluble nitrogen contents agreed with the measurements of protein (Table 3). A decline in protein content and insoluble nitrogen fraction is the normal salinity effect on crop plants (17). The findings in the present studies are in contrast to the above but in accordance with the observed stimulated growth.

Table 3. Effect of NaCl salinity on protein and nitrogen content in 25-day old safflower plants. (Values are means of three replications.

Treatment	Protein mg/g dry wt	Total nitrogen mg/g dry wt	Insoluble nitrogen mg/g dry wt	Soluble nitrogen mg/g dry wt
Control	56	11.5	10.0	1.5
35 mM	90	16.0	14.0	2.0
70 mM	90	16.0	14.0	2.0

The $^{14}CO_2$ incorporation was found to be more in the treated plants at both the levels of salinity when compared to controls at the 25th day of growth. Maximum incorporation was noticed in plants treated with 70 mM NaCl. However, the incorporation into the insoluble fraction in the plants treated with 70 mM NaCl was less than that of 35 mM treated plants (Fig. 1).

The photosynthetic rates were also reported to be lower in the plants under NaCl salinity (18). But in safflower NaCl treatment not only caused greater $^{14}CO_2$ uptake but also increased the protein content. Apparently, this may be the reason for the observed stimulated growth rate of plants under NaCl salinity.

The total amino acid content as measured by the automatic amino acid analyzer was observed to be higher in the salinized plants (Fig. 2, Table 4). Amides could not be detected in the sample because acid hydrolysate was used for analysis. Though there was about 34% increase in the amount of proline, this quantity is negligible when compared to the plants where proline accumulation up to 200 fold was reported under stress conditions (19). The heterocyclic amino acid histidine was found to increase by more than 100% in the plants at the lower salinity level (35 mM) and only by 82% at the higher level (75 mM) of salinity. The other heterocyclic amino acid, tryptophane, could not be detected.

The simple amino acids, alanine, glycine and isoleucine, were found to increase by about 90% to 70% in both the treatments. Leucine was found in higher quantities in the plants with the higher level of salinity, with about 82% increase over the controls whilein plants with lower salinity level it was only 58%. In both the treatments only 50% increase was detected in valine. The acidic and basic amino acids also increased by 60%

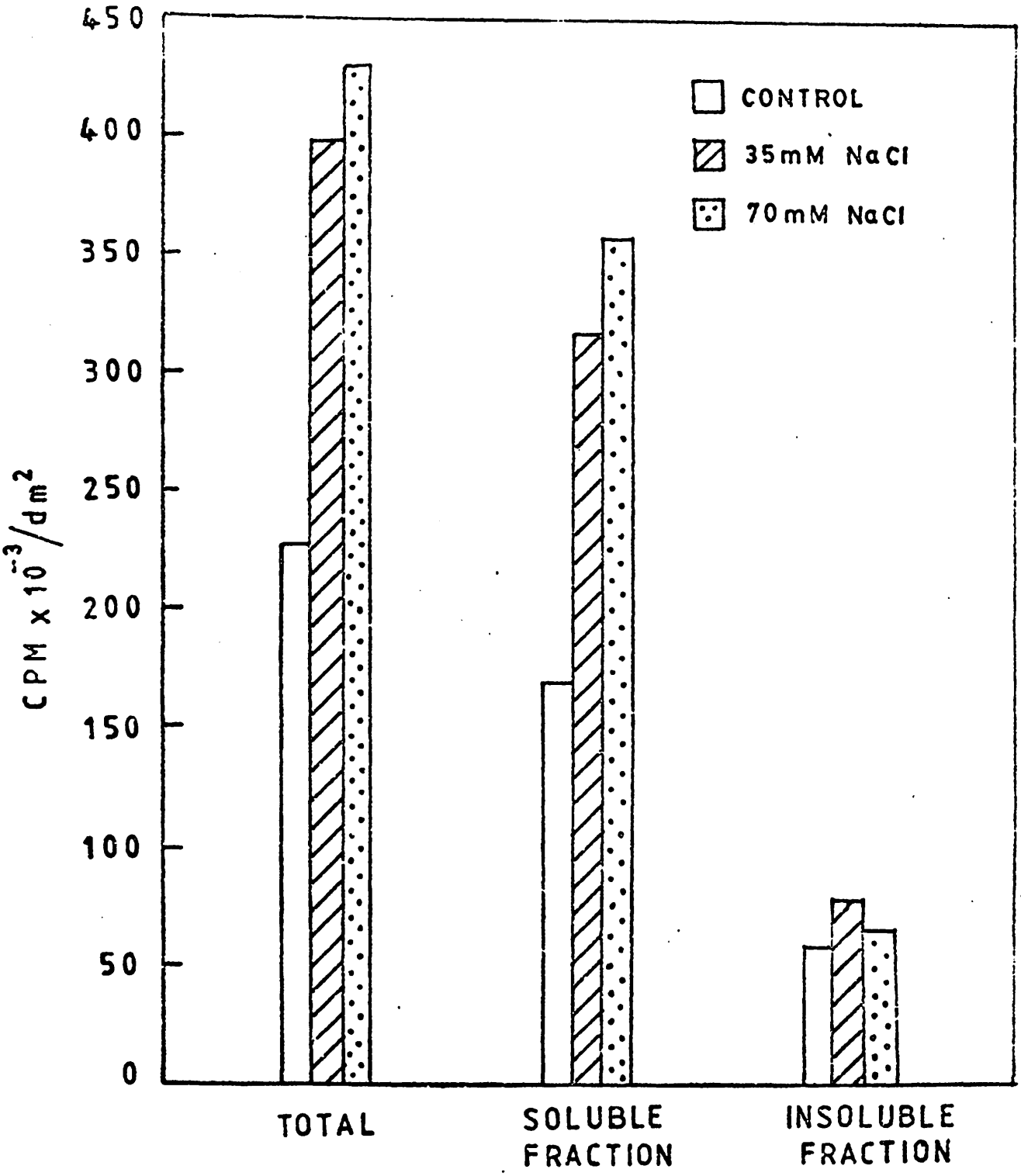

FIG.1. INFLUENCE OF NaCl SALINITY ON $^{14}CO_2$ INCORPORATION IN 25 DAY OLD SAFFLOWER PLANT

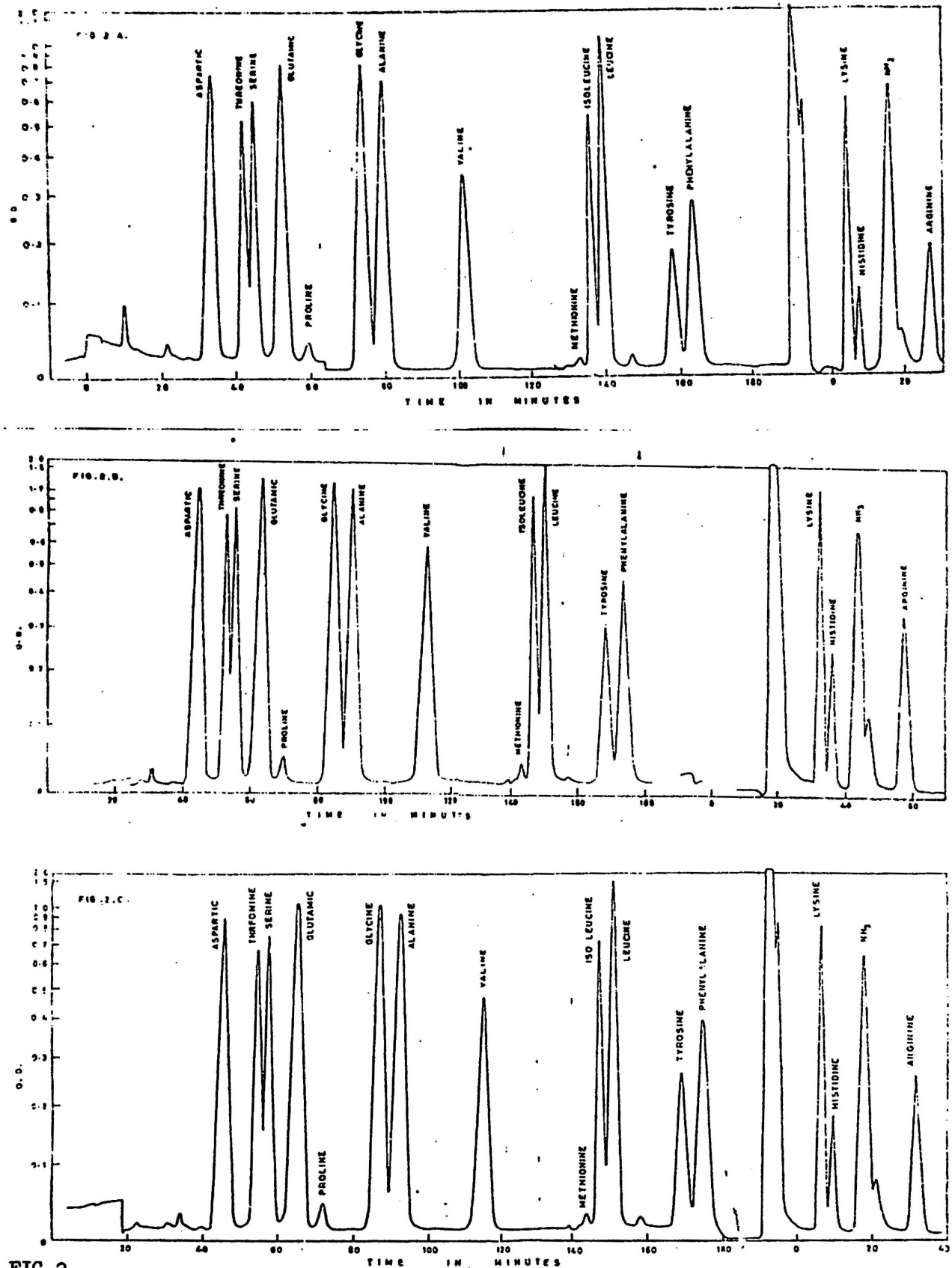

FIG 2

Total Amino Acid Content of 25 Day Old Safflower (A) Control Plants
(B) Plants salinised with 35 mM NaCl (C) Plants salinised with 70 mM NaCl

Table 4. Total amino acid content in 25 day old safflower plants under the influence of salinity. μmoles/gm dry weight.

Amino acid	Control	35 mM	70 mM
Proline	8.33	11.20	11.52
Histidine	2.28	4.63	4.17
Alanine	13.13	25.28	24.10
Glycine	13.91	25.60	25.59
Valine	9.18	14.12	13.69
Leucine	14.23	22.56	25.95
Isoleucine	5.52	9.80	9.43
Aspartic	13.95	22.98	21.99
Glutamic	13.88	19.38	21.99
Lysine	10.20	17.03	14.61
Arginine	7.05	12.13	11.81
Serine	6.78	10.52	11.59
Threonine	7.05	11.11	11.79
Tyrosine	4.68	7.28	7.5
Phenylalanine	7.90	12.23	11.91
Methionine	in traces only		

to 70% in both the treatments except that glutamic acid was more in plants treated with 70 mM NaCl while lysine was more in plants treated with 35 mM NaCl. The hydroxy amino acids serine and threonine increased by 55-60% with the lower level of treatment and nearly to 70% with the higher level of salt. The increase in the amount of aromatic acids was almost the same in both the treatments (50-60%). Out of the three S-containing amino acids, methionine only could be detected in traces in both the controls and treatments. The other two might have oxidized during hydrolysis.

The values of protein and total amino acid content were found to be almost the same in both the treatments though there is a slight change in the amino acid pattern. The higher rates of $^{14}CO_2$ incorporation in plants with higher salinity level do not agree with the above measurements. No proportionate increase in either the rate of growth or the amino acid

is observed with increasing salinity level. Na^+ might have increased the metabolic activity in terms of increased photosynthetic carbon fixation; but the salt treatment at higher levels might have caused inhibition of further transformation of assimilated carbon at some stage or other. This perhaps might not have been the case with 35 mM salt treatment which may be considered as the optimum level for the vegetative growth of the plant.

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OCCURRENCE OF SAFFLOWER (Carthamus tinctorius L.) DISEASES IN EGYPT

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ABSTRACT

Safflower (Carthamus tinctorius L.) is grown in Egypt as a winter crop and has been cultivated for over 3,500 years for the extracted dye from flowers and the oil in the seed. It is grown on a small scale in scattered areas in Upper Egypt and in the New Lands area at Nubaria. Field surveys were undertaken during the last three growing seasons from seedling stage to maturity. From field surveys in Egypt several diseases which prefer to make safflower their home were recorded. Disease of safflower, like those of other crops, vary in severity from year to year and from one locality or field to another, depending on environment, causal organism(s) and host resistance. Egypt has no records yet of root and stem rot incited by Phytophthora drechsleri Tucker, but does have problems from rust (Puccinia carthami Cda.). Foliar spotting attributed to Alternaria spp., root rot caused by Sclerotium rolfsii Sacc., powdery mildew caused by Erysiphe cichoracearum D.C., wilt incited by Fusarium spp. and Rhizoctonia blight caused by Rhizoctonia solani Kuhn are also present. Rust in all principal areas of safflower production was most severe in all years and showed two pathological phases, a seedling phase and foliar phase. Leaf spotting was considered severe, and the other recorded diseases were of minor importance during the surveyed years. In addition to these diseases, safflower was subject to infection with Orobanche spp. (broomrape), which caused serious damage to individual plants particularly in New Lands near Nubaria.

Egypt's rapidly expanding population and increasing consumer demand are expected to strengthen both production and imports of oilseeds and vegetable oils. Oilseeds, such as cottonseed, soybean, sunflower, peanut, sesame and safflower seem to offer the cheapest and most promising readily available new sources of protein for human foods. Essentially all the vegetable oil produced in Egypt comes from cottonseed. Safflower (Carthamus tinctorius L.) has been grown as a winter crop in A. R. Egypt for over 3,500 years for the extracted dye from flowers and the oil in the seed. An estimated 1,700 ha are grown in the New Lands near Nubaria and a total of about 380 ha are grown in the Nile Valley. According to the ecological conditions, Egypt is divided into four climatic zones as follows: Upper Egypt; Middle Egypt; Lower Egypt (Delta region); and New Lands area (coastal regions).

Safflower was reported to be attacked by various plant pathogens during its growth. There are 20 or more known diseases of safflower, but only 10 are commonly observed (2, 3, 11, 13). A number of pathogenic diseases were reported on cultivated safflower in Egypt by Bekhit in 1963 (1). Among the diseases recorded were: rust (Puccinia carthami), powdery mildew (Erysiphe cichoracearum), root rot (Sclerotium rolfsii) and wilt (Fusarium sp.). However, Thoma in 1979 (6) studied extensively the rust disease attacking safflower in Egypt. From field surveys undertaken

during the growing seasons 1978, 1979 and 1980 a number of diseases were reported and the causal organisms were identified. Commercial fields, breeding field trials, regional test fields and introduced safflower germplasm were included in the survey.

Rust incited by Puccinia carthami Cda. was the most common and widespread disease in the growing fields during the period of the survey. An autoecious species with uredinoid aecia, it causes a destructive foot and root disease, as well as yield loss due to foliage infection. The disease was most severe all years, and probably was favored by particularly humid conditions that occurred during the growing season and on late sown fields. Leaf spotting disease caused by Alternaria carthami has been reported as the most common leaf spot in safflower plantings in Egypt. The disease showed a high incidence of infection under moist conditions. The infection rate depends on the relative humidity of the air and the soil moisture, and was correlated with irrigation intervals. The infection rate ranged from 5-100% and was more abundant on the lower leaves. A leaf spot infection attributed to a species of Cladosporium has been seen a number of times and showed a moderate infection on Giza I variety. Powdery mildew caused by Erysiphe cichoracearum D.C. was recorded in a field of Giza I at Giza Governorate in 1979. The plants were heavily infected and both upper and lower leaves showed disease symptoms. Zimmer (11) reported powdery mildew on safflower caused by a species of Erysiphe in the United States in 1961.

A root rot complex of diseases attributed to soil-borne fungi is of major importance on safflower in Egypt and continues to occupy the attention of safflower growers. Isolations were made from diseased plants showing rotted and discolored roots and stunting, and five species of fungi were recovered: Fusarium oxysporum, F. solani, Pythium, Alternaria and Rhizoctonia solani. Root rot diseases have subsequently occurred in production areas along the Nile Valley and resulted in heavy losses of up to 20% in some fields. So far, Egypt has no records of root and stem rot incited by Phytophthora drechsleri Tucker which is reported to be one of the more serious diseases of safflower, especially on surface irrigated land (3, 7, 8, 9, 10, 14).

Late in the growing season of 1980, charcoal rot incited by Macrophomina phaseolina (Tassi) Goid (= M. phaseoli (Mauble) Ashby) was observed in several safflower fields in a number of governorates located in Upper Egypt. The disease caused damage of 10-20% in some years and appeared mostly at the time the plants approach maturity, especially in wet regions. Sclerotium rot (southern blight) due to Sclerotium rolfsii Sacc. was detected in a few safflower fields late in the growing season causing leaf wilt and root rot, and many plants were damaged as a result of this disease in the fields surveyed during the three growing seasons.

Survey work conducted during the 1980 growing season revealed the presence of several genera of nematodes from soil samples collected from the safflower rhizosphere and were identified as follows: Meloidogyne, Longidorus, Helicotylenchus, Tylenchorhynchus, Criconemoides, Pratylenchus, Hoplolaims and Heterodera. The root knot nematodes were more prevalent and destructive in sandy soils. Reynolds and O'Bannon (5) found that the safflower variety Gila was very susceptible to both Meloidogyne javanica and M. incognita. Lear et al. (4) studied the relative susceptibility

of some varieties and breeding lines to four species of root knot nematodes and to the sugarbeet nematode. The four species were: Meloidogyne hapla, M. incognita, M. javanica and Heterodera schachtii.

In addition to diseases safflower was subject to infection with broomrape identified as Orobanche crenata. Damage was most noticeable and serious in New Lands near Nubaria and Giza Governorate.

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THE USE OF THE SINGLE SEED DESCENT METHOD IN BREEDING SAFFLOWER VARIETIES

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ABSTRACT

The initial population of this study was a BC_2F_1 from a cross of a local Spanish cultivar, 'SH202', and a high oleic cultivar, 'Oleic Leed', the former being the recurrent parent. Six hundred plants were grown in a growth chamber in a 3 m^2 area.In each generation one plant was grown from a single plant of the previous generation. Because of a failure of about 5% of the plants in each generation to produce seed, there were 527 BC_2F_3 plants. Of these 379 produced enough seed to plant BC_2F_4 lines in the field, each in a 5 m row. The range of performance was as follows: yield, 858 to 2,860 kg/ha; and oil content, 36 to 49%. Yields and oil contents of SH 202 and Oleic Leed were 1,918 kg/ha and 43%, and 1,614 kg/ha and 44%, respectively. The advantages of this method of breeding in safflower are discussed.

Safflower has been traditionally cultivated in Spain in localized areas of the South. The area peaked at about 100,000 ha in 1970. In the following years the area declined drastically down to 5,000 ha due to a severe attack of a disease caused by Pseudomonas which destroyed many fields. Presently, the cultivated area has become stabilized between 30,000 and 40,000 ha.

The pedigree method of breeding self-fertilized crops requires much time and effort in obtaining homozygous types because selection should be started as early as possible for maximum efficiency and done under normal growing conditions. For safflower this means at least four years to get F_4 lines. Selection based on individual F_2 plants has been generally found to be ineffective for yield (3) and on the other hand early generation testing has shown that correlations from generation to generation are not always consistent (4). Furthermore, even when those are significant it is questionable whether the results justify the large amount of work involved.

An alternative procedure consists of carrying a considerable number of lines without selection to a later, more homozygous generation (F_4 or F_5) and then selecting on the basis of yield tests. Such an alternative was first proposed by Goulden (2) and it is now known as the single seed descent (SSD) method. A similar modified pedigree method was described by Brim (1) for soybeans (Glycine max). This method when applied to safflower would result, theoretically, in a large number of lines in a short period of time and in reduced space under artificial environmental conditions.

The Department of Oil Crops of the National Institute of Agricultural Research at Cordoba, Spain started a program in 1978 to determine whether or not the SSD method could be applied to safflower and to compare it with other breeding methods. Preliminary results of the use of this method in safflower are presented here.

MATERIALS AND METHODS

One local Spanish cultivar, 'SH202', and the high oleic cultivar released by the USDA, 'Oleic Leed', were used as parents. They are similar in blooming time and height, although SH202 outyielded Oleic Leed, and the latter was higher in seed oil content under Spanish conditions.

SH202 and Oleic Leed were crossed and the former was used as the recurrent parent in two backcrosses. BC_2F_1 seeds were planted in square containers 0.6 x 0.6 x 0.3 m. Plants were 6 cm apart. Containers were placed in a 3 square meter growth chamber which allowed the growing of 600 plants in each generation. During one generation other spacings between plants, 3 and 10 cm, were tested.

Temperature was controlled to a minimum of 18 C during the night and 20 C during the day. Photoperiod was 14 hours. After maturation, plants were harvested individually and several seeds from each plant were germinated prior to planting. After seedling emergence, the hills were thinned to leave one plant per hill. In this way in every generation one plant was obtained from each plant of the previous one. BC_2F_3 plants were allowed to grow with more space, namely 10 cm apart, in order to obtain enough seeds per plant to be able to grow a 5 m row of each BC_2F_4 line under field conditions. Planting in the field was done by hand in February, and thinning was carefully done to leave the same number of plants per row. Rows were 1 m apart, and three irrigations were applied during the growing season.

The nursery was placed in an area of very uniform soil at the farm of the Agricultural Research Institute at Cordoba. Harvest was done by combine and each entry was evaluated for yield and oil content. Non-uniform rows, which lacked plants, were not considered for yield. Oil content was measured by nuclear magnetic resonance (NMR).

RESULTS AND DISCUSSION

Starting with 600 BC_2F_1 plants in the growth chamber under the conditions mentioned above, and growing a plant from each one of the previous generation, seed from 527 BC_2F_3 plants was obtained. Under those conditions, with plants spaced 6 cm apart, 20-30 plants were lost every generation (around 5% of the total). As germination of at least one seed was ensured by germinating several seeds from each plant, losses were due in most cases to weak plants with small heads that failed to produce seeds. When plants were separated by 10 cm the percentage of lost plants was less than 1%, and when separated by 3 cm the loss was between 20 and 30% and the number of seed per plant was very small which increased the probability of not obtaining progeny plants. This number varied between 0 and 30 when plants were separated 6 cm, the average being 12. The average period from planting to blooming was 50 to 55 days as compared with 90 to 95 days under normal growing conditions in the field, which permitted four generations per year.

Yield and oil content of BC_2F_4 lines grown in the field are given in Fig. 1. Yield data were obtained only from uniform rows while oil content was measured in all lines. Means and range of yield and oil content are given in Table 1, where the data are expressed in absolute values and as a percentage of the higher parent.

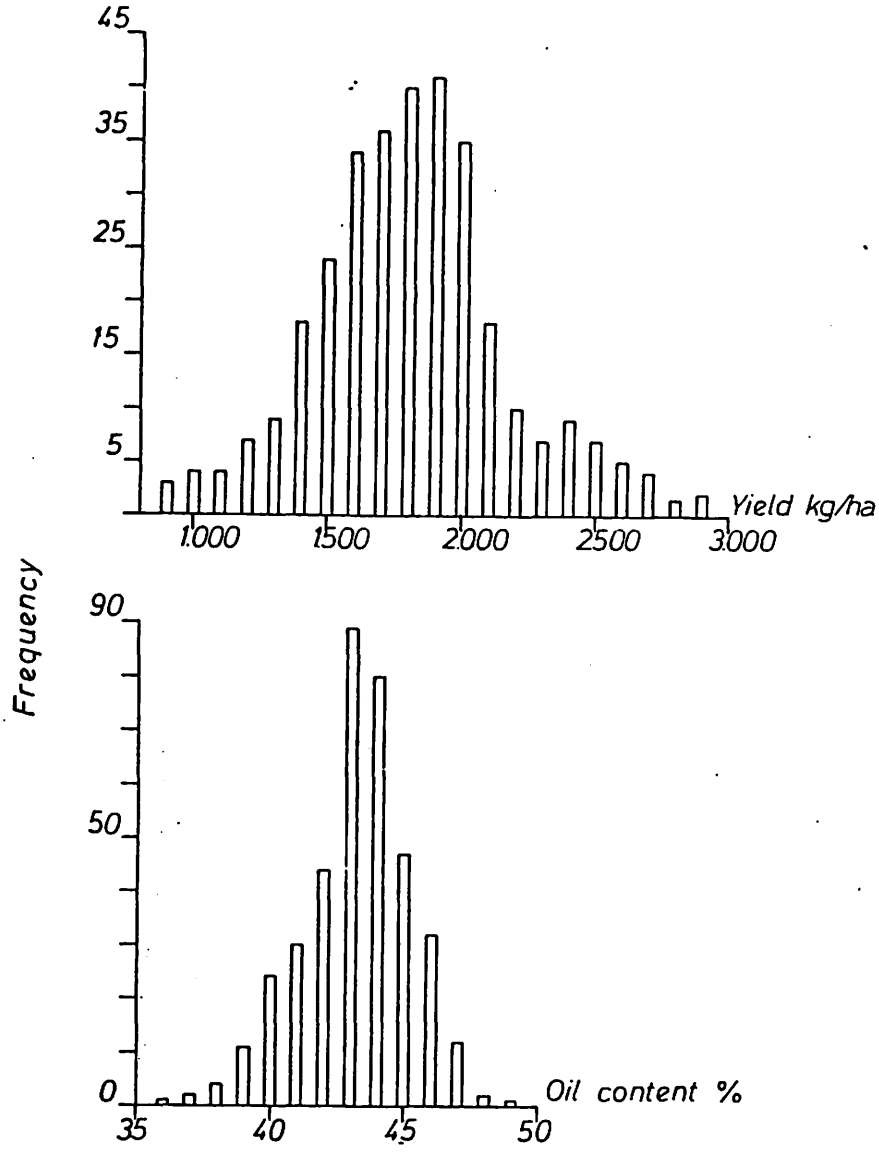

Fig 1: Distribution of yield and oil content of BC_2F_4 lines

Table 1. Yield and oil content of BC_2F_4 lines.

Entry	Yield			Oil Content		
	No. of lines	Mean	Range	No. of lines	Mean	Range
	absolute values (kg/ha)					
BC_2F_4	319	1810	858-2860	379	43.4	36-49
	% of higher parent					
	319	91.3	43-143	379	98	82-111
Oleic Leed	-	1614	-	-	44	-
SH202	-	1988	-	-	43	-

Although SH202 was backcrossed twice and selfing was carried out in the following four generations, transgressive segregation resulted in a wide range for both yield and oil content. The means, as expected, were closer to SH202. Sixty four lines outyielded SH202, the highest yielding parent, and 95 were higher than Oleic Leed for oil content. Sixty two lines exceeded the product, yield x oil content, of the superior parent. There were also lines which yielded about 50% of the poorest yielding parent.

Rows were evaluated visually at several stages of growth and some relationship between this evaluation and yield was found, especially for the low yielding lines. Some of these lines were homozygous for the recessive "partial hull" gene reported by Urie (6) which was present in a very low frequency in Oleic Leed.

Fatty acid analyses were performed on all BC_2F_4 lines, and 27 were homozygous for the ol gene responsible for high levels of oleic acid (5) which is carried by Oleic Leed.

Small differences were observed in blooming time and height due to the fact that both parents are similar for these characters.

From the results presented above it seems that the SSD method presented by Brim (1) is a useful breeding method in safflower. Using reduced space, four generations per year of a reasonable number of lines can be obtained. Although data to compare with the pedigree method are not yet available, the preliminary results seem to indicate that considerable progress can be made by handling segregating populations using the SSD method which results in great saving of time and effort.

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INHERITANCE OF VERY HIGH LEVELS OF LINOLEIC ACID IN AN INTRODUCTION OF SAFFLOWER (Carthamus tinctorius L.) FROM PORTUGAL

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ABSTRACT

The seed oil of a selection of a safflower introduction (P.I. 253,568) from Portugal was found to have iodine values of 146 to 154 and levels of linoleic acid between 85 and 90%, some 10% higher than in the normal high linoleic safflower. One major recessive allele, li, appeared to be involved. It was at a different locus than both the ol alleles and st alleles that govern levels of oleic acid and stearic acid respectively.

In safflower (Carthamus tinctorius L.) three alleles have been found (3, 4, 5, 6) that govern levels of oleic and linoleic acids in the seed oil: The genotype OlOl is the low oleic acid type with levels of linoleic acid between 75 and 78%; olol is the high oleic acid type with levels of oleic acid between 75 and 78%; and $ol^{1}ol^{1}$ is the intermediate oleic acid type with about equal amounts of oleic and linoleic acids. An allele st at another locus governs levels of stearic acid, the genotype OlOlstst having 5 to 12% stearic acid instead of 1.0 to 2.5% in the genotype OlOlStSt (7).

The seed oil of a selection of an introduction (P.I. 253,568) from Portugal was found to have iodine values of 146 to 154 and levels of linoleic acid between 85 and 90%, some 10% higher than in the normal high linoleic safflower. Original plants werecollected in 1958 by Mr. B. V. Reinha (Collection No. 3667) at the suggestion of Eng. A. R. Pinto da Silva, Estacao Agronomica Nacional, in the Province of Algarve near Conceicao, Tavira, and passed to the junior author on September 22, 1958. This study is not yet complete, so conclusions must be somewhat tentative.

MATERIALS AND METHODS

The introduction with very high levels of linoleic acid, termed 'Portugal', was crossed to the following cultivars, and/or genotypes: 'Gila', with high levels of linoleic acid (genotype OlOl); 'UC-1', with high levels of oleic acid (genotype olol); and 'High Stearic', with high levels of stearic acid (genotype OlOlstst). Some F_1 plants were grown in a field nursery in 1979, and other F_1's in 1980. F_2 plants of some crosses were grown in 1980.

Iodine values of the oil were obtained from open-pollinated seed of parents and F_1 and F_2 plants using a Bausch and Lomb grain grading refractometer. The fatty acid composition of the oil of single F_2 seeds (on F_1 plants) was obtained using the following procedure, a modification of that described by Bartholomew (1).

The oil of the seed was extracted by crushing it in a glass mortar with petroleum ether, and removing the residue by filtering. The filtrate was then dried using a rotary evaporator over a water bath at 80-90 C. The

dried sample was refluxed with 10 ml 1.25% thionyl chloride-methanol solution (using air condensors) for half an hour, to obtain methyl esters of the fatty acids. The thionyl chloride solution was also dried as described above. The esters were dissolved in 0.5 ml hexane, and about 300 mg $NaHCO_3$ added to neutralize any residual chloride. Approximately 1.5 µl of the solution was injected into a Varian Aerograph gas chromatograph Model 3700 (with a flame ionisation detector). The glass column was 2 mm in diameter (inside) and 100-cm long, and was packed with Supelco 10% SP-2340 on 100/120 Chromosorb W Acid Washed. The column temperature was 160 C, and that of the injector and detector was 250 C. Nitrogen, the carrier gas, was set at approximately 22 psi. Elution time was 4-4.5 min. A Varian Aerograph digital integrator, Model CDS 111, recorded the amounts of fatty acids in percentages.

RESULTS AND DISCUSSION

Portugal x Gila. Fig. 1 gives the iodine values of the seed oil of the parents, the F_1 (F_2 seed) and the F_2 (F_3 seed). Although the F_2 population was small, it clearly showed a 3:1 segregation (Chi-square = 0.33, and P = 0.5 to 0.7). Similarly, when the fatty acid values of the oil of single F_2 seeds were obtained (Fig. 2), they showed a 3:1 distribution (Chi-square = 0.287, and P = 0.5 to 0.7).

It is apparent that a single gene governs the differences in the fatty acid composition of the oil of Portugal and Gila. It was not known at this point whether it is at the locus of the ol alleles or at some other locus. The allele for very high linoleic acid content is recessive to that for high levels. The increase in linoleic acid occurred at the expense of oleic acid, which was at levels of 5 to 8% in genotypes with very high linoleic acid content.

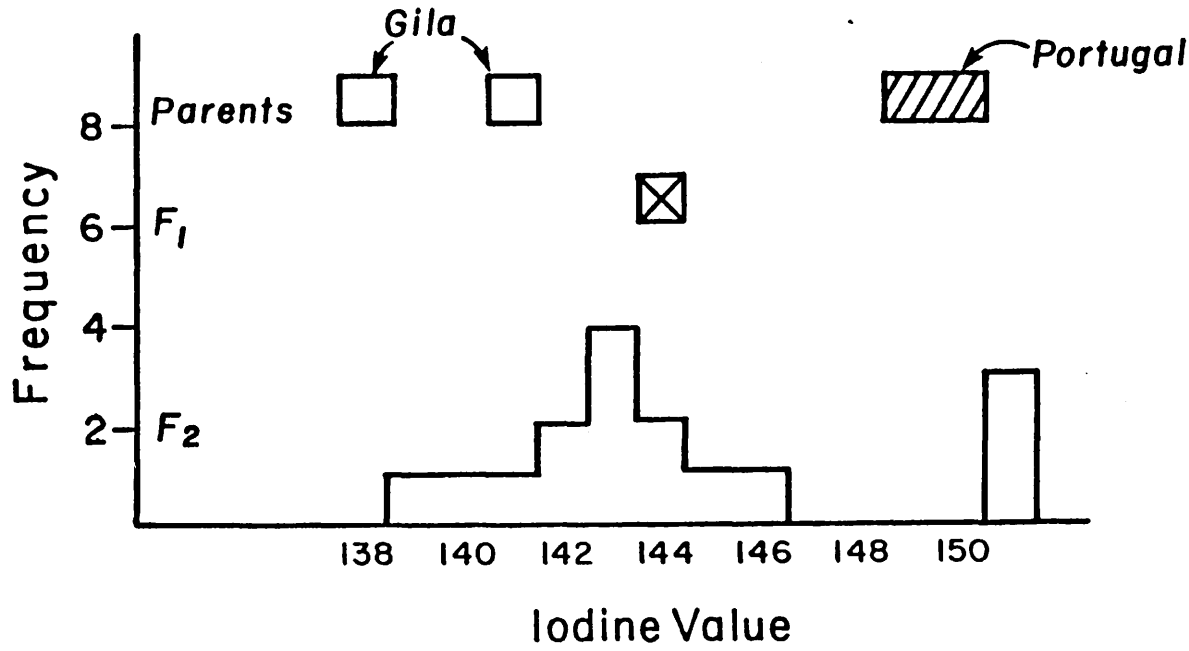

Fig. 1. Iodine values of seed oil of parents and F_1 and F_2 plants of the cross, Portugal x Gila.

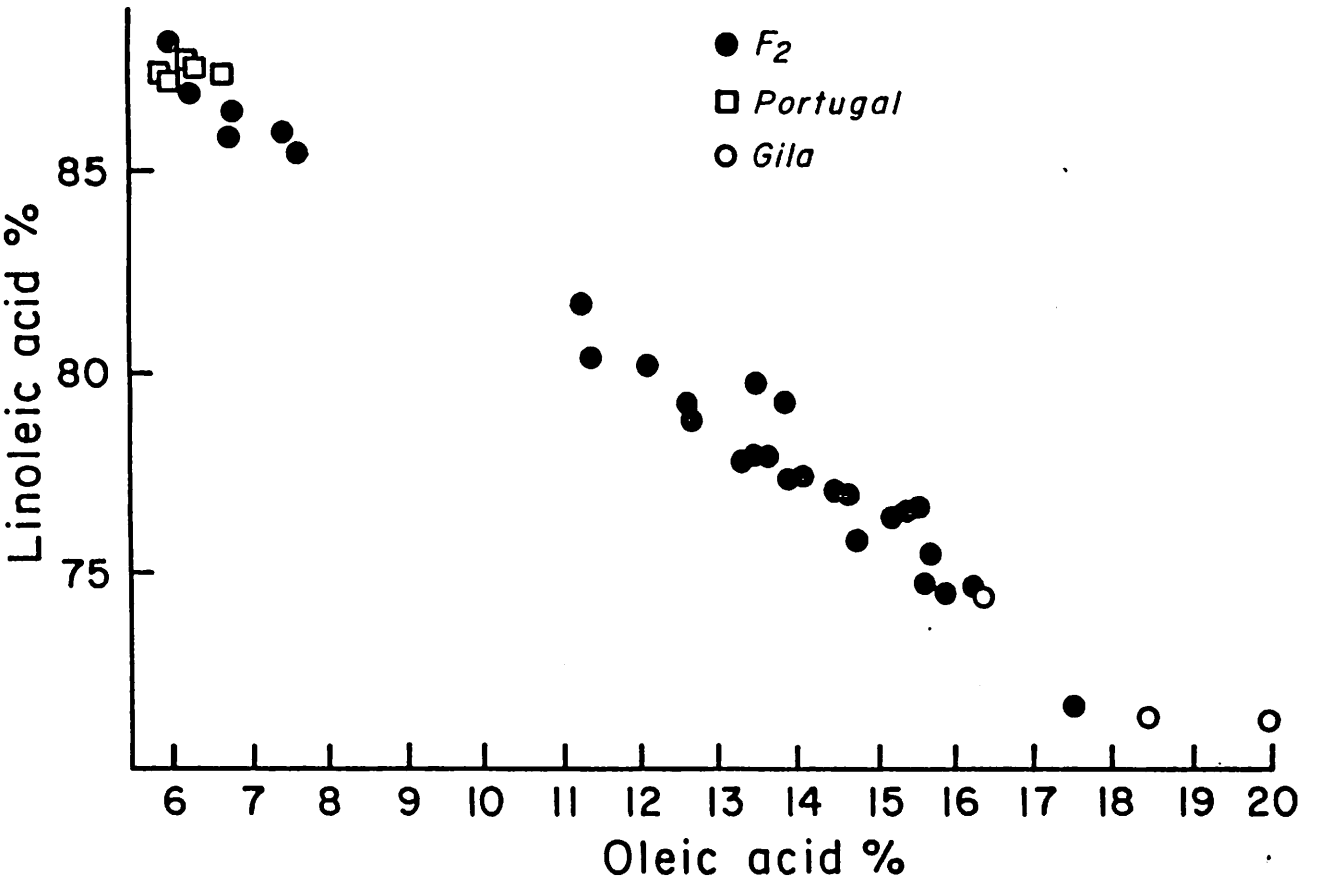

Fig. 2. Linoleic and oleic acid contents of the oil of single seeds of parents and F_2 seeds of the cross, Portugal x Gila.

Portugal x UC-1. Fig. 3 gives the iodine values of the seed oil of the parents, the F_1 (F_2 seed) and the F_2 (F_3 seed). If Portugal and UC-1 differed by a single allele at the ol locus, three genotypes would have been expected in F_2, one like Portugal, one intermediate, and one like UC-1, in the ratio 1:2:1. The distribution of iodine values, which was not trimodal, suggests that the gene differentiating the iodine values of Portugal and Gila is at a different locus than ol. The second locus is termed li, for linoleic acid. Assuming that Portugal has the genotype OlOllili and UC-1 ololLiLi, the genotypes of plants in Fig. 3 would be as shown in Table 1. In that table the observed and expected numbers are in good agreement.

Fig. 4 gives the linoleic and oleic acid composition of the oil of single F_2 seeds on an F_1 plant. In Fig. 4 genotypes were assigned to the different arrays of data. The actual and expected frequencies of the genotypes are in good agreement (Table 2).

Portugal x High Stearic. Results are not given here. Futehally (2) showed that the li gene is at a locus different from st for higher levels of stearic acid.

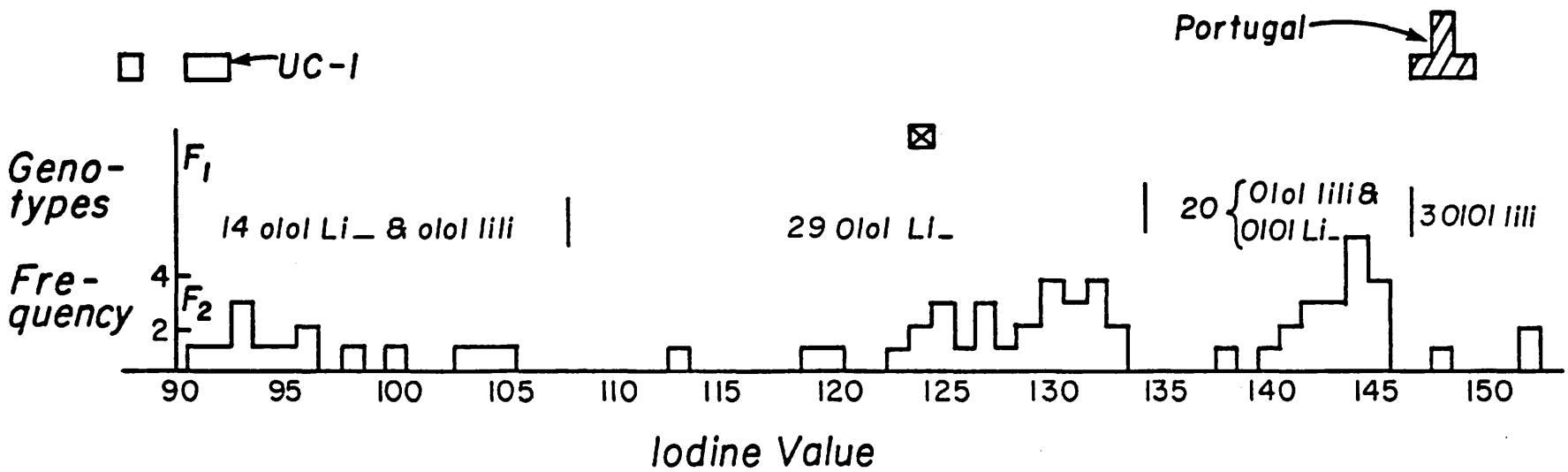

Fig. 3. Iodine values of seed oil of parents and F_1 and F_2 plants of the cross, Portugal x UC-1.

Table 1. Frequency of genotypes of F_2 plants from the cross Portugal x UC-1 (see Fig. 3).

Iodine value	Genotypes	Number Observed	Number Expected
90-105	3 <u>ololLi-</u> 1 <u>olollili</u>	14	16.5
113-133	6 <u>OlolLi-</u>	29	24.8
138-146	2 <u>Olollili</u> 3 <u>OlOlLi-</u>	20	20.6
148-154	1 <u>OlOllili</u>	3	4.1

Fit to 4:6:5:1 ratio: Chi-square = 1.402, and P = 0.5 to 0.7.

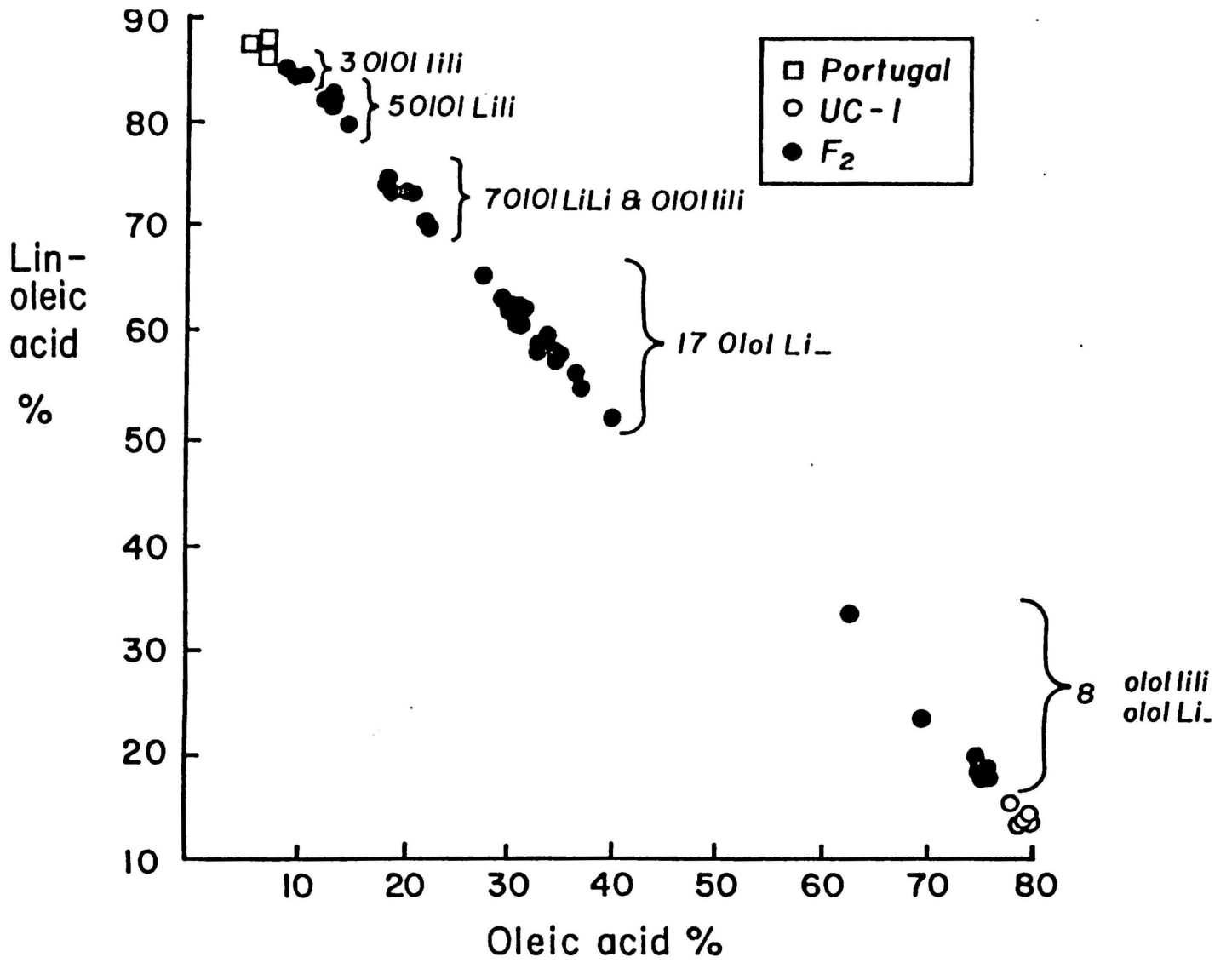

Fig. 4. Linoleic and oleic acid contents of the oil of single seeds of parents and F2 of the cross, Portugal x UC-1. Supposed genotypes of F2 are given.

Table 2. Frequency of genotypes of F_2 seeds from the cross Portugal x UC-1 (see Fig. 4).

Ratio	Genotype	Frequency	
		Actual	Expected
1	O1O1lili	3	2.5
2	O1O1Lili	5	5.0
3	O1O1LiLi O1ollili	7	7.5
6	O1olLi-	17	15.0
4	olollili ololLi-	8	10.0

Fit to a 1:2:3:6:4 ratio: Chi-square = 0.8, and P = 0.90 to 0.95

CONCLUSIONS

The data of this study indicate that it will be possible to develop cultivars of safflower with oil having linoleic acid levels between 85 and 90%. In such types (genotype O1O1StStlili) the levels of other fatty acids will be as follows: oleic, 5-8%; stearic, 1-3%; and palmitic, 4-6%. The market acceptance of such a type has not been determined.

This and previous studies of the inheritance of fatty acid composition of safflower oil encourage us to believe that future studies will uncover even more variation in levels of the fatty acids.

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COMMERCIAL PRODUCTION OF SAFFLOWER IN MONTANA -- PAST, PRESENT AND FUTURE

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ABSTRACT

The first large scale production of safflower in Montana was in 1959, following the completion of a crushing facility in Culbertson. That year there were 50,000 acres of dryland production. By 1962 the acreage had grown to 100,000 acres, but in 1963 there were 1,700 acres. Weeds, disease, and poor cultural practices nearly stopped production until after the introduction of trifluralin for weed control in the mid-1960's. Since that time the growth of safflower acreage has been sporadic due to pricing, moisture, farm programs, disease and weed control. A significant contribution has been the introduction of S-208 to Montana in 1969. Safflower's best year for total acreage, production and quality was 1979 with 175,000 acres. With California and Arizona decreasing safflower production, Montana will be looked to for increased production. This can be accomplished with prices that are competitive to small grain production, with the promotion of irrigated production, and with advancements coming from ongoing public and private research. The specific advancements needed from research are better weed control methods and safflower varieties that are higher yielding, higher in oil content, disease resistant, and having a shorter maturing season. Needed for weed control are effective preplant herbicides that do not need to be incorporated twice and effective postemergence herbicides. Our company has hired a specialist to pursue this goal. The ultimate production ability of Montana could be 500,000 to 1,000,000 acres.

Alfred Rehbein first grew safflower at Lambert, Montana in 1928. He obtained the seed from India through Dr. Frank Rabak of the Bureau of Plant Industry, U.S. Department of Agriculture. Dr. Rabak was compaigning to develop new crops at that time.

Rehbein continued to grow safflower every year from 1929 to 1963. He was very instrumental in the development of safflower as a crop in this country. During those early years of production, acreage fluctuated below 10,000 acres in Montana. The oil content of safflower grown in Montana in 1949 was reported to be 25 to 30%. At that time the seed from Montana was being shipped to a Cargill plant in Savage Minnesota for processing. The seed was decorticated before removing the oil.

The first large scale commercial production of safflower in Montana was in 1959, following the completion of a crushing facility built by Pacific Vegetable Oil, Inc. in Culbertson, Montana. In that year there were 50,000 acres of dryland production. By 1962, there were 100,000 acres. In 1963 acreage fell to 1,700 acres, due to weeds, disease and poor cultural practices. Production nearly stopped until after the introduction of trifluralin for weed control. The best combination of these factors was in 1979 when 175,000 acres were harvested and yield ranged from 600 to 1,400 pounds per acre.

S-208, the most widely grown safflower variety in Montana, was brought from California in 1969. The Montana grown S-208 has an oil content of 32 to 40%. S-208 is susceptible to Pseudomonas and Alternaria leaf spot diseases which caused serious damage in some years. Dr. J. W. Bergman at the Eastern Montana Agricultural Research Station, Sidney, Montana has been successful in breeding safflower varieties that have better resistance to these diseases than S-208. These varieties are Sidwill, Hartman and Rehbein. S-541, developed by SeedTec International, Inc., is being grown for commercial production for the first time this year.

Three processors are currently contracting safflower in Montana: Continental Grain Co., Culbertson, Montana; Agricom, Inc., Grimes, California; and Pacific Vegetable Oil, Inc., Richmond, California. Safflower for bird seed is occasionally contracted on a limited basis.

The major obstacle to acceptance of safflower in Montana is weeds. The double soil incorporation required with trifluralin, the preplant incorporated herbicide now used on safflower, tends to dry the surface soil prior to planting. The dry surface soil then delays the germination and emergence of safflower unless a timely rain occurs. Initiating plant growth by approximately May 10th is essential to the development of a fully mature crop by the time of the average first killing frost in the fall.

Continental Grain Co. initiated a safflower weed control research program in the fall of 1980. A large number of preplant incorporated, preplant non-incorporated, postplant preemergence, and postemergence herbicides are being tested. Success of this program is critical to the growth of safflower as a crop in Montana. Ideally, herbicides that are effective in minimum and/or no-tillfarming systems would be most desirable.

Variety development for our area is being pursued by Dr. Bergman, Dr. D.D. Rubis, Tucson, Arizona, Dr. D. C. Sands, Bozeman, Montana, Dr. T. C. Heaton, Woodland, California, and Dr. H. H. Mundel, Lethbridge, Alberta, Canada. Needed are varieties that are higher yielding, higher in oil content, disease resistant and having a shorter growing season.

The future of safflower in Montana hinges on safflower prices that are competitive with returns from small grain production, the promotion of irrigated safflower production, and advancements coming from ongoing public and private research. With success in these areas, a stable production of 500,000 to 1,000,000 acres of safflower in Montana is a reasonable goal.

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SOME AUSTRALIAN DEVELOPMENTS TOWARD DISEASE RESISTANT SAFFLOWER

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ABSTRACT

Safflower (Carthamus tinctorius L.) is a potentially important crop for Australia as an edible oil and as a dewatering component in crop rotations under irrigation. Acreages are presently limited to 5-10% of total oilseeds due principally to susceptibility of commercial varieties to two fungal diseases, viz. root rot (Phytophthora cryptogea) and leaf blight (Alternaria carthami). In an attempt to obviate this disease problem and develop new cultivars for both irrigated and dryland agriculture, part of a world collection was assembled to provide a germplasm base for breeding and selection. Screening methods are as follows:

P. cryptogea is routinely re-isolated from field infections and maintained as pure cultures in liquid media. Zoosporangia formation is achieved in liquid culture on cotton mesh. Zoospore release is initiated under a temperature regime involving reduction from 25 to 15 C. An inoculum density of 5 x 10^6 zoospores per ml of culture medium is applied to 10-day-old seedlings following mild water stress in coarse sand at 25 C in darkness for 24 hours. Seedlings are then held in controlled environment conditions under a 16/8 hour light/dark cycle for 7 days.

A. carthami has been established in pure culture (on agar plates) and is regularly re-isolated from infected seedlings to ensure pathogenicity. Sporulation is induced by a combination of mycelial wounding and light/dark cycling (12/12 hours) for two days. Aqueous suspensions of spores and/or mycelial fragments offer suitable inoculum for a resistance assessment after seven days under humid greenhouse conditions.

To date, 1065 accessions have been field screened and a number of disease resistant lines with acceptable agronomic traits have emerged. One elite line resists both pathogenic fungi.

Safflower (Carthamus tinctorius L.) is a potentially important crop for Australia both as an edible oil and as a dewatering component in crop rotations under irrigation. Acreages in Australia are presently limited to 5-10% of total oilseeds due principally to the susceptibility of commercial varieties to two fungal diseases, viz. root rot caused by Phytophthora cryptogea and leaf blight caused by Alternaria carthami. In an attempt to obviate the disease problem and develop new cultivars for both irrigated and dryland agriculture, part of a world collection of safflower cultivars has been assembled to provide a germplasm base for breeding and selection.

DISEASE RESISTANCE SCREENING

Phytophthora root rot

Cultures of the fungus Phytophthora cryptogea (including P. drechsleri)

have been isolated from diseased safflower in the field and maintained as pure cultures for inoculation purposes. Cultures are regularly re-isolated from diseased safflower seedlings to maintain the pathogenicity of the isolates. Safflower plants are inoculated using suspensions of mobile zoospores which is the stage in the life cycle of the fungus considered the major source of field infection.

Laboratory techniques have been examined to ensure a regular and plentiful supply of infective zoospores.

a) Mycelium is grown in a liquid medium consisting of 200 ml of V-8 juice per liter (Campbell's Soups, Australia, Pty, Ltd.). After 48 hours growth at 25 C mycelial pads are transferred to dilute V-8 medium (30 mls V-8 juice per liter) before being homogenized in a Sorvall Omnimix chamber.

b) Zoosporangia, from which zoospores are eventually released for disease screening, are formed from the mycelial homogenate by the method of Chen and Zentmyer (1) with the following modifications. The diluted homogenate is aseptically distributed over an 80-mm disc of cotton mesh in a 90-mm diameter petri dish. This mycelium is cultured in the dark for 48 hours at 25 C. Zoosporangial formation is initiated by replacing the V-8 growth medium in the dishes with three changes of sterile mineral salts solution (4) and illuminating with daylight fluorescent lamps for 42 hours. Optimal light intensity for zoosporangial formation, 6-10 Wm^{-2}, was achieved at a distance of 250 mm from the lamps. Improved zoosporangial numbers were achieved by draining the excess mineral salts solution from the mycelium clinging to the cotton mesh during the last 16 hours of illumination. Improved aeration is a likely explanation for this phenomenon as was observed for zoosporangial formation in soil (2). Use of coarse cotton meshes also improved zoosporangial numbers compared with fine meshes.

c) Zoospores are released from zoosporangia by replacing the mineral salts solution and reducing the temperature from the 25 C growing temperature. Optimal temperatures for zoospore release were 12-15 C and occurred within 1 hour. Zoospore numbers were reduced below 10 C while at 25 C those spores that were released shed their twin flagella and commenced encystment rapidly. The most favorable temperature for the maintenance of active spore motility was 15 C with some spores remaining motile for up to 96 hours. Zoospore suspensions were counted in a haemocytometer microscope chamber and diluted to standardized concentrations for safflower inoculations.

Ten-day-old safflower seedlings were inoculated under controlled environment conditions and rated for disease symptoms after 4 days. Inoculations using serial dilutions of zoospore suspensions showed that 2×10^6 spores in 200 ml of mineral salts applied to the roots of 110 seedlings growing in a seedling tray of sand was the minimum number of spores required to rot at least 95% of a susceptible cultivar. A period of mild water stress prior to inoculation improved the uniformity of infection of susceptible control plants. This was achieved by allowing the sand growth medium to dry from a water-saturated condition over 48 hr in controlled environment chambers having a temperature range of 28/18 C and 12 hr light and 12 hr dark regime. This confirms an early report by Duniway (3) of increased susceptibility of mature safflower plants to root infection following a period of water stress. Seedlings growing in a coarse sand

medium (500-1500 μm) were more uniformly infected with zoospores than those growing in fine sand (250-710 m) and is likely a result of facilitated movement of the spores towards the roots through the coarser sand matrix (5).

Successful candidates from root rot screenings enter the breeding program of which the progeny will continue to be challenged by the pathogen to establish the heritability of resistance.

Alternaria leaf blight

Alternaria carthami has been isolated from leaf, bract and seed infections in the field. The fungus has been established in pure culture and, like P. cryptogea, is regularly reisolated from infected seedlings to ensure infectivity. A. carthami, unlike many species of Alternaria, sporulates poorly on culture media. Improved sporulation has been achieved by the combination of two stimuli: mycelial wounding; and alternating light and dark conditions of long wavelength U.V. light. Mycelial wounding initiates sporulation; however, sporulation only occurs if the fungus is subsequently subjected to the light and dark cycle. Exposure to U.V. light induces conidiophore formation, while spore (conidial) release requires a period of darkness. The relationship between light intensity and spore release has been examined. An intensity of between 6.5-9 Wm^{-2} induces greatest spore production and this intensity was achieved at a distance of 325-425 mm from a single long wavelength U.V. and two white fluorescent lamps (as recommended in the CMI, Handbook of Plant Diseases). Prior to exposure to lamps on a 12/12 hr light/dark cycle, cultures which had been grown on potato carrot agar in 90 mm diameter petri dishes were macerated into cubes 2-5 mm long. Abundant spores were formed after 2 days.

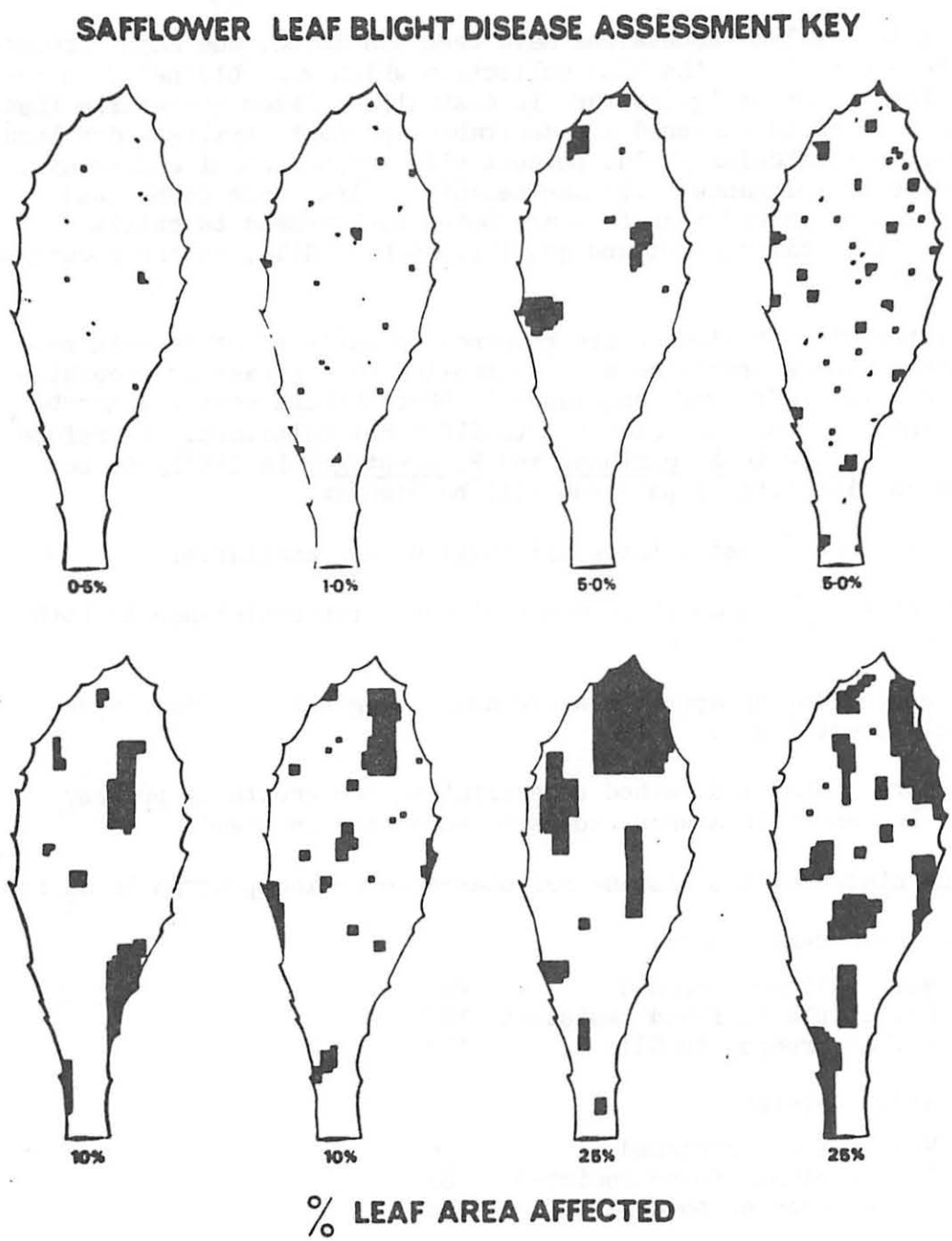
Infective material used in the screening program consists of both spores and mycelial fragments. This choice was made because field infection results from either spores or resting mycelial fragments. A disease assessment key (Fig. 1) based on percent of leaf area affected was devised to ensure reproducible and quantitative rating of disease. Many factors influence the extent of disease at the time of assessment; e.g., inoculum concentration, leaf surface area inoculated, plant age, and infection time. Standardization of these factors is an essential requirement of reliable disease assessment. Relationship between inoculum concentration and disease expression have been examined for a susceptible variety. The inoculum concentration of mycelial fragments or spores was estimated from a haemocytometer microscope count and standardized suspensions of inoculum were obtained by dilution using distilled water. Routinely an inoculum concentration of 10^5 spores or 2×10^5 mycelial fragments/ml was used for inoculation purposes.

Disease rating after 4 to 7 days demonstrates the effect of infection time on disease expression.. Only after 7 days is disease expression fully developed at this inoculum concentration.

Glasshouse temperature (28 C max; 18 C min) and humidity (90-100% RH) conditions were established during the initial 16 hr of infection period to favor fungal growth and penetration.

As in the Phytophthora root rot resistance screening, successful candidates from glasshouse disease screening are taken into the breeding

Fig. 1 An evaluation key used to assess Alternaria leaf blight on safflower.



program and the progeny from subsequent cross-pollination is screened again to establish the heritable nature of disease resistance.

BREEDING STRATEGIES

Variable safflower yields of Australian commercial sowings and the widespread incidence of root rot and leaf blight disease necessitated the acquisition of a wider range of germplasm as a basis for improving the adaptation and disease resistance of commercially available cultivars. This program was initiated in 1974 at the CSIRO, Division of Irrigation Research by Mr. Alistair Low where he was joined by Mr. Ken Harrigan and two plant pathologists, Dr. Alan Heritage and Miss Cheryl McRae.

To date a total of 1424 accessions have been assembled, the major proportion of these comprising the USDA collection which was obtained from the Victorian Department of Agriculture in Australia. After quarantine these accessions were field screened for desirable agronomic traits under local conditions; in particular yield, percent oil, morphological characters, host and disease tolerance. Disease-resistant lines have been found to have low oil content and therefore are being backcrossed to cultivars having acceptable oil content and quality, such as Gila, as the recurring female parent.

Subsequent breeding strategies are governed by patterns of inheritance, i.e., whether disease resistance is controlled by dominant or recessive genes. Genes for safflower resistance to Phytophthora root rot may be either dominant (6) or recessive (7) in different cultivars. Therefore combined resistance to A. carthami and P. cryptogea is likely to be multigenic and inheritance patterns will be complex.

Depending on progeny tests, three alternatives are available:

1) An express program where dominant genes for resistance to both fungi occur in a single line.

2) A consolidating approach where dominant genes for resistance occur in different lines.

3) A more protracted method necessitating the growth of progeny through to F_2 generations when recessive genes are involved.

The present status of the disease resistance screening program is as follows:

Phytophthora resistance

No. of lines screened	218
No. of plants found resistant	118
No. of crosses to Gila	147

Alternaria resistance

No. of lines screened	144
No. of plants found resistant	89
No. of crosses to Gila	158

At present only seven lines with consistently high levels of resistance to each pathogen have been found of which only two lines have resistance to both pathogens. If the doubly resistant lines prove to be dominant then a rapid backcrossing program will lead to the early release of a commercially acceptable disease-resistant safflower.

However, in the longer term, using a more extensive crossing and field selection program, it will be necessary to find a replacement for Gila as the recurring female parent due to its yield limitations.

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POSSIBILITIES FOR THE USE OF CARTHAMUS LANATUS L. IN THE IMPROVEMENT OF SAFFLOWER, C. TINCTORIUS L.

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ABSTRACT

The wild species of safflower, Carthamus lanatus L., is found throughout the entire range of the genus. It has also become an established weed in parts of Australia, Chile, and the United States (California). As such, it has demonstrated broad adaptation in diverse environments. Attempts to artificially synthesize C. lanatus, n=22, from other safflower species having chromosome numbers of n=10 and n=12, have been unsuccessful, thereby suggesting that C. lanatus is an ancient species whose component species are undiscovered or perhaps even extinct. Previous research together with recent findings indicates that C. lanatus is a unique germplasm resource that possesses multiple disease resistance and tolerance to environmental stress, characteristics that could broaden the adaptation of cultivated safflower, C. tinctorius L. An alloploid derived from colchicine treatment of hybrids of C. tinctorius x C. lanatus, n=34, shows promise as a source of useful genes for the improvement of C. tinctorius.

The discoverey of new characters that enhance the use of safflower or broaden its range of adaptation is the main goal of plant improvement programs. Researchers are fortunate to have a great amount of variability in wild species of safflower. For example, rust resistance from Carthamus oxyacantha Bieb. was identified and incorporated into cultivated safflower (9). Perhaps the species that is potentially most useful is C. lanatus L. C. lanatus is found throughout the entire range of the genus in the Old World and has shown remarkable persistence as a weed where it has become established in parts of Australia, Chile, and the United States in California (8). In California, C. lanatus has a winter growth habit with a long rosette period. Stalk elongation occurs in the late summer followed by flowering in September about the same time that C. tinctorius is being harvested.

C. lanatus has been the subject of many cytogenetic studies itself and has been included in most other studies involving species relationships. Table 1 presents a summary of the research that has most clearly defined the species relationships of C. lanatus. C. lanatus is a unique species in the genus with 22 pairs of chromosomes. Other species of Carthamus have chromosome numbers of n=10, n=11, n=12 and n=32 (1, 2). It has been suggested with some cytogenetic evidence that the polyploid species C. baeticus and C. turkestanicus which have 32 pairs of chromosomes are the result of hybridization between C. lanatus and species having 10 pairs of chromosomes, most likely C. leucocaulos and C. glaucus respectively. Morphological data from interspecific hybrids tend to support that hypothesis (7).

Attempts to synthesize C. lanatus from other species have been largely unsuccessful. Interspecific hybrids of C. lanatus with species having 10 or 12 pairs of chromosomes have had less than 8 bivalents in meiosis and have been sterile. Even in those circumstances it was impossible to

Table 1. Chromosomal associations of Carthamus species and C. lanatus.

Interspecific cross	n x n	Bivalents	Source
C. baeticus x C. lanatus	32x22	22	1, 7
C. turkestanicus x C. lanatus	32x22	22	7
C. leucocaulos x C. lanatus	10x22	7	1[1], 7
C. glaucus x C. lanatus	10x22	8	7
C. baeticus x C. turkestanicus	32x32	24	6
C. tinctorius x C. lanatus	12x22	5	1, 5

[1] C. leucocaulos was called C. alexandrinus

know to what degree pairing in the interspecific hybrid was autosyndetic. That is, some of the bivalents could have resulted from remnant homology between the 10 and 12 chromosome genomes that most likely combined to form C. lanatus.

Failure to synthesize C. lanatus might be attributed to failure of discovery or extinction of component species since hybridization first occurred thousands of generations ago. It is possible, however, that failure to identify component species of C. lanatus is due to the presence of genes in C. lanatus that prohibit pairing of chromosomes that are not exactly homologous. Such a mechanism could have evolved within C. lanatus to prevent multivalent formation between component genomes of 10 and 12 chromosomes.

When C. lanatus is crossed to C. tinctorius the interspecific hybrid at meiosis forms about 5 bivalents and is sterile. A first conclusion is that there is very little opportunity for genetic exchange between the two species. However, the chromosome number of the hybrid can be doubled and the alloploid is fertile (5). It is known that C. tinctorius will tolerate extra genomic material (3). A conventional backcross program of the alloploid to C. tinctorius should result in the creation of alien addition lines thereby isolating individual chromosomes of C. lanatus. If there are genes in C. lanatus that hinder pairing of non-homologous chromosomes, those genes may be on chromosomes other than the chromosomes on which genes for useful characters are found. If this is the case, isolated single chromosomes of C. lanatus may pair nicely with chromosomes of C. tinctorius in the absence of genes that regulate pairing in C. lanatus. Should it be found that genetic exchange via recombination in addition lines is not possible, then artificial methods that cause chromosome breakage can be employed.

Many useful characteristics in C. lanatus have been identified and are summarized in Table 2. In addition to the characters already known, C. lanatus probably is a good source of drought tolerance. Moreover, it probably possesses some insect resistance due to its general pubescence.

Table 2. Useful characteristics identified in Carthamus lanatus

Characteristic	Source
Resistance to Alternaria carthami Chowd.	5, 8
Resistance to Fusarium oxysporum Schlecht race 4	5
Resistance to Pseudomonas syringae van Hall	5
Resistance to Puccinia carthami Cda	9
Resistance to Verticillium dahliae Kleb.	5, 9
Seedling cold tolerance (-13 C)	11
Winter growth habit	4, 11

A preliminary study of disease resistance in the alloploid of C. tinctorius x C. lanatus indicates that some of the useful disease resistances found in C. lanatus are also found in the alloploid. The results suggest that there are dominant genes for disease resistance in C. lanatus (5). Clearly, the incorporation of the characteristics of C. lanatus shown in Table 2 into C. tinctorius would strengthen the position of safflower as a crop worldwide.

In conclusion, germplasm conservation programs should be supported. Colleagues who live and work in the center of diversity of the genus Carthamus should be encouraged to continue their efforts in germplasm collection so that researchers will be assured of a continual supply of new and useful characters from wild relatives of safflower.

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DEVELOPING WATER MANAGEMENT RECOMMENDATIONS FOR IRRIGATED SAFFLOWER ON ITS INTRODUCTION INTO CALIFORNIA

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ABSTRACT

In the late 1950's safflower's reputation for high susceptibity to root rot led to a common belief that it could not be grown under irrigation in California. Experiments and observations determined the soil water conditions conducive to severe root rot and developed the pattern of soil conditions, irrigation water management, and cultural practices necessary to minimize yield loss from the disease. This information was translated into a short list of recommendations which are the guidelines for successful production under irrigation.

By the time appreciable interest developed in growing safflower in California it was apparent that a major question was whether or not the crop could be grown under surface irrigation, the most prevalent form of water application. Its known susceptibility to root rot and several observations of severe injury associated with a single irrigation caused concern that production of irrigated safflower was not feasible.

It was well known that root rot caused by species of Phytophthora was associated with wet soil conditions, but no quantitative data existed on levels of soil water required for severe injury, nor on how long such conditions could be endured. Therefore cooperative studies were started to provide the data needed to determine the potential for growing safflower under surface irrigation and to provide guidelines for selecting soils, water management systems, and cultural practices for producing irrigated safflower.

1959 TEST

On the University Farm at Davis, K. E. Mueller and R. T. Edwards conducted a test of effects of number of irrigations and irrigation methods on root rot on several varieties. I assisted in evaluation of soil moisture conditions. Fortunately, although the plot area was not uniformly bad, soil compaction was severe from a depth of 20-25 cm to 45-50 cm. Water penetration was slow, and there was a marked tendency for the surface soil to waterlog and to drain slowly. Root penetration was slow, and effects of drought occurred by early June in treatments not irrigated by that time.

Four irrigation treatments, consisting of 0, 2, 4, and 8 crop irrigations were applied to plots flat-planted and flood-irrigated and to bed-planted, furrow-irrigated plots. Moisture conditions were evaluated with tensiometers in the row at 15, 30 and 90 cm depths in N-10 variety plots receiving 2 to 8 irrigations. The experiment led to several interesting conclusions:

1. Where rootrot occurred, it was much more severe under flood irrigation than on bed-planted, furrow-irrigated plots. Although furrow- irrigation was of much longer duration to try to get equivalent depth of applied

water, near saturated conditions in the top 30 cm of soil occurred for much shorter periods except for early irrigations when beds were loose. Data for the single most injurious irrigation (8 irrigations) are given in Table 1. They indicated that where soil moisture tensions less than 1/10 bar persisted less than about 48 hours in the top 30 cm of soil there was little injury to any variety.

Table 1. Comparison of moisture conditions and disease incidence under furrow and flood irrigation, June 1959, at Davis.

	Date[1]	Duration[2]	Wetness[3] 15 cm	Wetness[3] 30 cm	% Disease[4] Before	% Disease[4] After
			N-10 variety			
Furrow	6/22	52	12	12	1	4
Flood	6/22	12	72-96	24-48	10	75
			Pacific-1 variety			
Furrow	6/22	52	12	12	0	0
Flood	6/22	12	72-96	24-48	5	75
			Gila variety			
Furrow	6/30	52	12-24	12-24	0	1
Flood	6/30	11	72-96	48-72	18	75
			US-10 variety			
Furrow	6/30	52	12-24	12-24	0	0
Flood	6/30	11	72-96	48-72	3	18

1/ Date of single irrigation causing greatest injury.

2/ Hours water was kept on the ground surface. Flooded plots surface drained after this period.

3/ Hours that soil moisture tension was less than 1/10 bar under the row. Tensions measured in N-10 plots only.

4/ Expressed as percent plants killed or severely wilted; root systems not evaluated.

2. Under these soil conditions, 8 flood irrigations caused serious injury. In contrast, 4 irrigations produced vertually none. Soil moisture conditions in the 4-irrigation treatments were not evaluated, but evidently minimizing the number of irrigations while preventing drought reduced the chance of serious root rot.

3. The treatment receiving 2 irrigations caused serious root rot on flood-irrigated plots in the first irrigation applied June 4. Comparison of 2- and 4-irrigation treatments indicates that drought prior to irrigation increased severity of the disease. This confirmed field observations. Except for the treatment receiving no crop season irrigations, yields were closely related to disease incidence. Table 2 illustrates this for two varieties.

Table 2. Yields (kg/ha) and disease incidence for treatments at Davis, 1959, for two varieties. Figures in parentheses are percentages of plants severely affected by July 29.

	Crop irrigations			
	8	4	2	0
		US-10 variety		
Furrow	4160 (4)	4430 (1)	3370 (14)	2910
Flood	2990 (26)	3542 (1)	600 (100)	2130
		N-10 variety		
Furrow	3670 (25)	4280 (3)	3100 (24)	2770
Flood	1023 (100)	3280 (12)	420 (100)	2400

1960 STUDIES

Investigations dealing with soil moisture conditions and root rot consisted of four phases, all in cooperation with K. E. Mueller and R. T. Edwards. Some aspects were in cooperation with county farm advisors.

Irrigation Plot Test, Davis

A randomized experiment was conducted on Yolo loam with four irrigation treatments, each applied to bed-planted (furrow-irrigated) and to flat-planted (flood-irrigated) plots of the US-10 variety. Soil conditions were much better, with only slight compaction from 15 to 30 cm. The soil was moist to a great depth at planting time. Moisture conditions during and immediately following irrigation were studied in detail with tensiometers, and all data showed little waterlogging during irrigation and rapid internal drainage. There was virtually no root rot except in the treatment receiving only one irrigation, applied after nearly all the available moisture was depleted from the top 1.8 to 2.4 m of soil. This was additional confirmation that drought increases severity of the disease. Injury occurred late enough that there was no decrease in yield from the irrigation, but there was likewise no advantage (Table 3). Yields from bed-planted, furrow-irrigated treatments were lower than those of comparable flat-planted, flood-irrigated treatments. Thus with little root rot, bed-planting was not superior to flat-planting. The reduced yields were attributed to deeper planting on beds, ragged emergence, and poorer stand.

The experiment demonstrated that on soil with rapid internal drainage safflower can be surface irrigated even by excess flooding (6 irrigations on the wettest treatment) without serious root rot injury.

Data from this experiment also showed that safflower has a tremendous potential for rapid root development, extending to effective depths of 3.0 to 3.6 m or more by maturity under favorable soil conditions, indicating the possibility of minimizing injurious crop irrigations by thorough preirrigation. Fig. 1 shows residual available water at various depths in the soil at maturity for the soil of the plot area (Yolo loam). These data indicate that the crop was able to obtain about 40 cm of water from that stored in the soil at planting time. This and many subsequent tests

Table 3. Seed yields (kg/ha) for different irrigation frequencies and irrigation methods, Davis, 1960.

Culture	Irrigation method	Number of irrigations 0	1	4	8
Flat	Flood	2860	2950	3320	3170
Bed	Furrow	2762	2670	2930	2920
LSD (0.05) for irrigation treatments = 236					
LSD (0.05) for irrigation method = 241					

demonstrate little or no yield increase from irrigating on this soil. However, subsoil water uptake was highly restricted on Capay clay (see also Fig. 1) by a dense claypan, showing that in soils with slow internal drainage where it was important to minimize crop-season watering, relying on preirrigation was not feasible. Yield on Capay soil was less than half that on Yolo soil although the fields were less than 16 km apart.

Data similar to that in Fig. 1 on Yolo soil were obtained for several varieties. No detectable difference was noted among US-10, Gila, Pacific-1, and Pacific-7.

Tank Experiment

To simulate a wider range of soil moisture conditions than is usually obtainable with a given soil, 60-cm diameter tanks containing 1.2 m depth of Yolo loamy sand were equipped with a drainage outlet which could be closed when desired. This system permitted both complete saturation of the soil and rapid drainage of the surface soil (80 to 90 mb tension in less than 24 hours) when desired.

The tanks were planted to the US-10 variety. Three irrigation treatments were used. Half the tanks in each treatment were saturated and drainage started within two or three hours. The remaining half was kept saturated for 48 hours before draining at each irrigation.

No root rot symptoms appeared, suggesting that the 48-hour period of waterlogging was too short to cause much injury.

Solano County Field Tests

Soil moisture conditions during and immediately following irrigation were evaluated rather intensively with tensiometers in two tests with cooperating farmers. They involved differential treatments in cultural operations and/or fertility but not differential irrigation treatments. However, they afforded an excellent opportunity to relate moisture conditions to root rot incidence on soils different from that at Davis.

The first soil was mapped as Capay clay loam (a claypan). The subsoil was less permeable than the top soil, comparatively dense, and extremely hard when dry. Only about 60 cm of soil was moist at planting time. There were deep furrows in both flat and bed plantings.

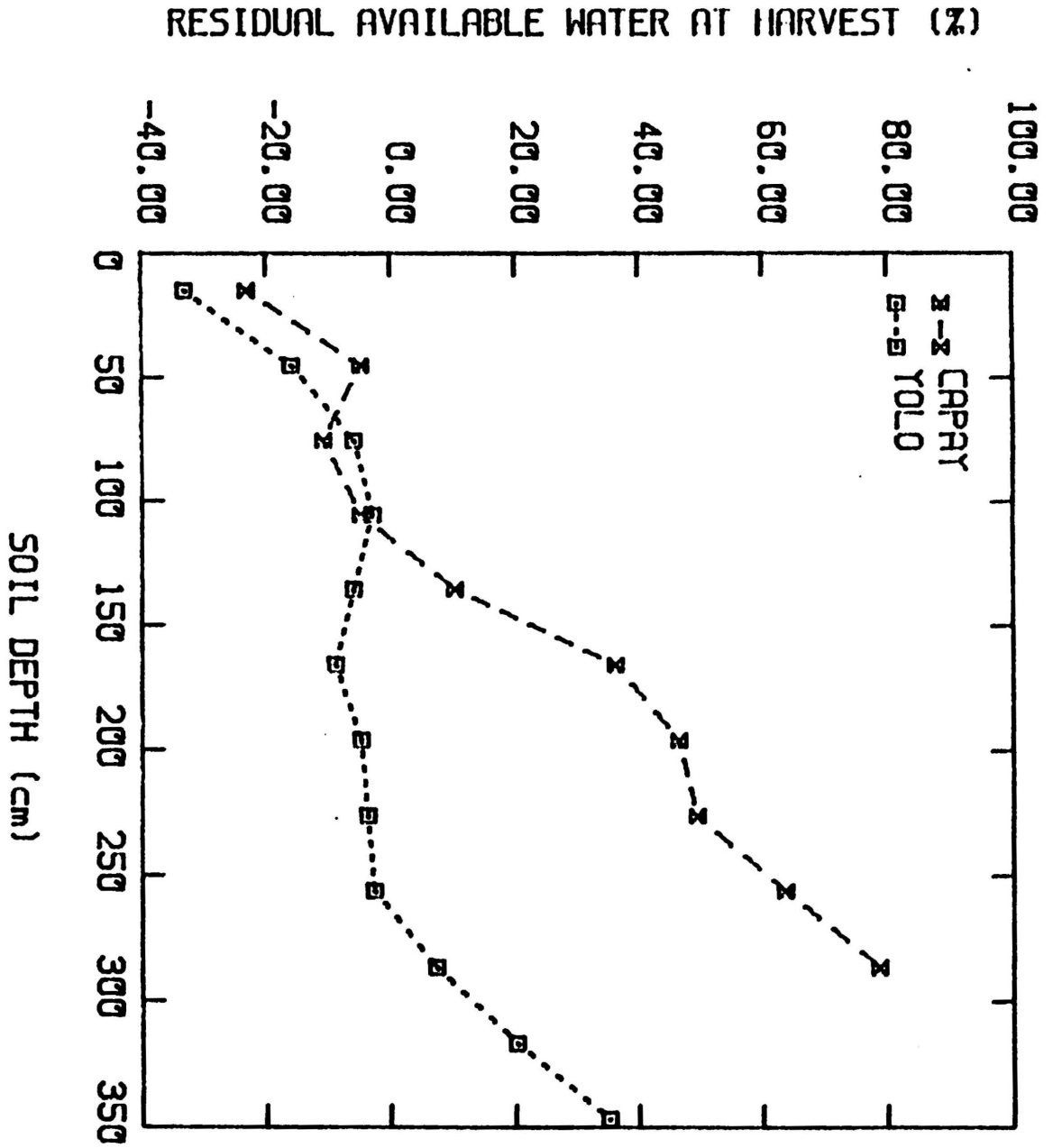

Figure 1. Residual soil water at maturity. Both soil profiles were near 100% available water early in the growing season.

Tensiometers showed complete and rapid waterlogging of the surface soil during irrigation, even in the beds, and drainage was slow. Root rot was serious in an area kept wet for several days by seepage from an irrigation ditch during the first irrigation. Subsequent irrigations caused additional widespread injury, and final yields were unsatisfactory for irrigated safflower. In general the plants suffered alternate periods of drought and excessive moisture.

Tests proved very interesting on the second farm because the upper end of the field was Yolo soil, while the lower end was Caypay clay loam. Tensiometers showed somewhat more rapid drainage in the Yolo soil. In the early crop, which was planted flat and flood irrigated, the first irrigation killed virtually all the plants on Capay soil, but there was no injury apparent on Yolo soil. A later planting was furrow-irrigated. There was moderate to serious injury on Capay soil, but none on Yolo soil.

Field Survey

California soils have been classified according to Profile Groups, providing insight into probable internal drainage characteristics. Profile Groups I and II have little to slight clay accumulation in the subsoil, Group III appreciable subsoil clay, and Group IV sufficient to be called claypan soils. Group V is characterized by a cemented hardpan in the subsoil. Yolo soil is Profile Group I, Capay, Profile Group IV.

A field survey of surface irrigated safflower fields in the Sacramento Valley was conducted in cooperation with Carl Claassen. The objective was to get a broader view of the influence of internal drainage characteristics of soils on rootrot. Some 23 fields were visited with most of the county farm advisors concerned. Data were collected on soil type and disease ratings. While some soil categories were not well represented, the only fields visited which were substantially free of disease were on recent and young soils of Profile Groups I and II. Many fields of Profile Group IV suffered serious damage or complete loss. One field on Columbia series (Profile Group I) was injured in spots. In this soil type high water tables are common. Several good fields had killed areas, minor in extent, where surface drainage of tailwater was poor.

One common feature of the fields visited was that maturity was too early and rapid, apparently caused by drought. Evidently there was lack of reserve subsoil moisture at planting and/or irrigation was stopped too soon to supply the crop with available moisture to normal maturity.

1961 TESTS

Experiments consisted primarily of short-term tests on effects of soil moisture conditions on disease incidence. These were carried out in the tanks described previously, using US-10 exclusively.

The general procedure was to grow plants to about the bud stage under favorable moisture conditions, apply differential moisture treatments, and evaluate the treatments one to two weeks later. When treatments were started, the soil in all tanks was saturated. Treatments included maintaining the water table at the soil surface for varying periods of time, dropping it a few inches immediately then maintaining it at the lower level for

varying periods of time, or draining the soil of the tank completely as quickly as possible (usually starting one to three hours after saturation) for a control treatment. The soil was not sterilized, so we were dealing with the native population of soil microorganisms. No attempt was made to differentiate between injury due to poor aeration and pathogenic fungi.

The first experiment compared effects of treatments involving periods of complete saturation, ranging from a few hours to six days. Disease incidence was evaluated in terms of percent of plants showing severe top symptoms (death or severe wilt) and roots showing complete rotting or local lesions on the tap root. The data for the first experiment are given in Table 4. There was essentially complete kill with five- and six-day flooding periods, with progressively less injury with shorter periods.

Table 4. Irrigation treatment and root rot tank experiment, May, 1961.

Treatment	Percent injury	
	Tops	Roots
Saturated 2-3 hours	0	15
Saturated 2 days	25	45
Saturated 3 days	50	75
Saturated 4 days	65	90
Saturated 5 days	100	100
Saturated 6 days	100	100

The second experiment was essentially the same as the first except that additional treatments involving maintenance of water at 30 cm below the soil surface were included. In these treatments soil moisture tension at the 15 cm depth should theoretically be only 15 mb, or 0.015 atmosphere. Mercury manometer tensiometers showed zero tension at this depth for all practical purposes. However, this nearly undetectable change in soil moisture tension as compared to saturated treatments markedly reduced severity of the disease (Table 5). One partial explanation is that the safflower plant seemed remarkably healthy even though the tap root was rotted off 15 to 20 cm below the ground surface and/or many small lateral roots were injured. Such plants appeared to have considerable potential for growth and seed production.

RECOMMENDATIONS

These studies led to the formulation of the following recommendations:

1. Safflower which is to be surface irrigated in the summer months should not be planted on soils with slow internal drainage. This generally includes clay soils, stratified soils, soils with high water tables, and soils of Profile Groups III, IV, and V (primarily claypan and hardpan soils).

Table 5. Irrigation treatment and root rot tank experiment, July, 1961.

Treatment	Percent injury	
	Tops	Roots
Saturated 2-3 days	5	25
Saturated 2 days	10	25
30 cm water table, 2 days	0	25
Saturated 3 days	20	65
30 cm water table, 3 days	5	30
Saturated 4 days	35	55
15 cm water table, 4 days	10	35
30 cm water table, 4 days	5	10
Saturated 5 days	70	85
30 cm water table, 5 days	5	10
Saturated 6 days	80	100

2. Provide complete surface drainage, particularly on soils whose internal drainage is moderately slow.

3. Avoid prolonged irrigation, especially in warm or hot weather.

4. Irrigate before appearance of severe drought symptoms. Drought increases susceptibility to root rot injury.

5. Minimize the number of irrigations after planting by storing as much usable water as possible in the soil at planting time. Spring planted safflower uses 45 to 60 cm of water in producing good yields. The percentage of this amount that can be stored depends on the water storage capacity of the soil, the effective depth of root penetration, and the rate at which the root system increases in depth. In the best soils, safflower will root at least 3.6 m deep, but root development is retarded in many soils.

6. If there is any doubt about rapidity of internal drainage, plant on beds and furrow irrigate. Furrows also facilitate surface drainage.

7. Plant one of the varieties more resistant to root rot.

NITROUS OXIDE DOUBLING OF CHROMOSOMES IN CARTHAMUS SPECIES

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ABSTRACT

In order to obtain progenies of crosses of Carthamus lanatus (n=22) by C. tinctorius (n=12) and C. lanatus by C. palaestinus (n=12), I doubled the F_1 chromosome number using nitrous oxide (N_2O). Treatments of 4 hours at 50 pounds per square inch of N_2O after 2 hours of light produced fertile hybrids. Successful doubling was measured by pollen size and stainability, and stomatal leaf prints.

Schank and Knowles (1) were able to induce autotetraploids in Carthamus tinctorius L. by treating seedlings with colchicine. I have tried using colchicine to double chromosome numbers but achieved low levels of success.

When I heard about the carcinogenic properties of colchicine I decided to look for some other way to double chromosomes. In my reading I found references to the use of nitrous oxide (laughing gas) under pressure to relax chromosomes. The gas prevented the coiling of chromosomes and, when used on dividing tissue, led to the accumulation of DNA. In order to try nitrous oxide (N_2O) doubling on safflower I began looking for a pressure chamber. When I priced pressure chambers for the project they were much too small and too expensive. I found, however, in one of my supply catalogs a painter's supply pot for spraying that would hold 7 1/2 gallons of paint and would work at up to 60 pounds per square inch (psi). Having solved the pressure chamber problem, I went to an industrial gas supplier and tried to buy a small cylinder of N_2O, but found I needed a medical degree and a lawyer to get one. I discovered, however, that I could buy a large cylinder with only a simple disclosure form.

In June, 1979, Katherine Hill did a study (unpublished) in which she treated safflower seedlings at 40 psi of N_2O with exposure times of 1/2, 2, 4, and 8 hours. Root tip smears showed that by 4 hours all cells had doubled chromosomes.

In December I used this same treatment on some seedlings of C. leucocaulos x C. tinctorius crosses. I grew the plants in pots until the first true leaves began to show, then placed the pots in the pressure chamber for 4 hours at 40 psi. When these plants began to flower they were totally sterile and undoubled. Clearly, something had to be different between Katherine's conditions and mine. I considered the differences and similarities. The pressure and time were the same. The species and time of year were different. I decided not to worry about species differences at this point, but I did consider the June versus December conditions. June here is hot and bright whereas December is cold and often foggy or cloudy. I also know that cell division occurs in the dark after periods of light. Therefore, I would make sure the plants had at least two hours of saturated light before treatment.

With all of this in mind, I chose a sample of approximately 200 seeds of assumed crosses made between C. lanatus and both C. palaestinus and C. tinctorius, with the latter as pollen parents. I grew these seeds in 7-inch pots until the first true leaves appeared. After exposure to a minimum of two hours of saturated light the plants were treated, six at a time, in the pressure chamber, at 50 psi for four hours. During pressurization the chamber became very cold to touch so I turned up the heat in the room to 80 F. The plants were allowed to grow in the greenhouse until 15 to 18 inches tall.

I took leaf prints from the 18-inch treated plants by placing a thumbnail-sized blob of silicon sealant on the underside of a leaf. One hour later I peeled the sealant off and painted the surface of the sealant with clear nail polish. When the polish had dried it was peeled from the surface of the sealant and placed on a slide under a cover slip. Every treated plant had approximately twice as many stomata per unit area as the untreated plants. When these treated plants began to flower their pollen was stained with tetrazolium bromide. Every treated plant had nearly 100% viable pollen and the pollen was larger than pollen from untreated plants. From previous experience with such hybrids that were not treated with N_2O there was never more than 2% viable pollen.

REFERENCE

1. Schank, S. C., and P. F. Knowles. 1961. Colchicine induced polyploids of Carthamus tinctorius L. Crop Sci. 1:342-344.

PRODUCTION OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) IN QUEENSLAND

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ABSTRACT

Safflower was first grown commercially in Queensland in 1955. Adaptation problems encountered during the early years of safflower growing, as well as government and private research conducted during this period, are outlined. The current government research programme, commenced in 1972, is discussed in relation to safflower production in a tropical to subtropical, subhumid to semi-arid climate where availability of water is the main constraint on production. Manipulation of planting date is necessary to prevent flowering during severe frosts in July and August, and to minimize the effects of rapidly rising temperatures in spring on yield potential. Presence of the disease caused by *Alternaria carthami* (Chowd.) in commercial crops has been identified as a major cause of yield loss in seasons when extended wet periods are associated with rising spring temperatures, and flowering. Only 38,600 hectares have been successfully cropped, but much larger areas (2.7 million hectares) could be utilized provided better adapted varieties become available. These new varieties will have disease resistance, higher oil content and greater yield potentials. Photo-insensitivity and cold tolerance in these varieties will increase flexibility in cropping management.

In the arable regions of sub-coastal Queensland where 70-75% of the annual rainfall occurs between October and March, safflower can play an integral role in the rainfed cropping system because of its ability to utilize stored moisture in the relatively dry winter season. However, we do not have a variety that is well adapted to the rigorous demands of this environment. This is reflected in the past performance of the industry which has had widely fluctuating levels of success with only brief periods of promising stability. Agronomic research and cropping experience have determined many of the desirable traits needed to be combined in a suitable variety. We feel confident that the genetic material exists for the development of suitable varieties, but this will require a more extensive Australian breeding effort than has been conducted in the past. This paper traces the development of the Queensland safflower industry from its commencement in 1945 to the present in relation to the research undertaken to establish and maintain a viable industry.

EARLY RESEARCH

The first serious studies with safflower in Australia were conducted by the Commonwealth Scientific and Industrial Organization in 1944-45 near Rockhampton in central Queensland (11). The assessment of introduced lines in these initial studies was followed by the establishment of a plant breeding programme by CSIRO in South Australia. The two varieties, Horowitz and Kimberley 4-1, were developed in this programme and released in the early 1950's.

Agronomic studies were conducted throughout Australia by CSIRO in conjunc-

junction with the State Departments of Agriculture from 1949-55. Sites on the Darling Downs in southern Queensland and at Biloela in central Queensland gave promising results with yields ranging between 1400 - 2200 kg ha^{-1} (5). Varietal selection and time of planting trials were also conducted at Lawes in southeastern Queensland during the period 1946-51. These studies indicated that yields of 2200 kg ha^{-1} could be obtained in good seasons and that yields declined as planting date was delayed from early May to late July (4).

EARLY COMMERCIAL DEVELOPMENTS

The first commercial crop of safflower was grown in 1955. Horowitz was the variety chosen. However, because of its low oil content (30%) it was used mainly for grazing rather than oilseed production. Most of the early production was restricted to the eastern portion of the Darling Downs (Fig. 1). Problems associated with water logging, frost and seed germination in the maturing heads were soon apparent in these early commercial plantings. Meanwhile, the major research undertaken after 1955 was that by the Queensland Department at Biloela in central Queensland. Plant population and row spacing studies at this site revealed that yields were virtually unaffected although planting rates varied from 11-60 kg ha^{-1} in row spacings from 18-25 cm (1). Subsequently, the majority of commercial crops were planted in 36 cm rows at a rate of 11-22 kg ha^{-1}. Studies during this period to investigate the potential of safflower as a grazing crop determined that it was a useful alternative to oats as a winter fodder crop (3).

In the late 1950's the variety Gila was introduced from the United States and trials conducted at Biloela soon proved that it was superior to Horowitz in yield and oil percentage (2). With the release of Gila seed for commercial plantings in 1963, the area planted to safflower in Queensland increased rapidly (Fig. 2). At this time, the centre of safflower production moved from the Darling Downs (shaded area Fig. 1) to the Belyando, Peak Downs, Emerald and Bauhinia shires and to a lesser extent the Banana and Duaringa shires (Fig. 1). A major reason for the increase in safflower production in the central Queensland shires was that economically, there was little difference between the two crops here compared with the substantial advantage of wheat over safflower in southern Queensland. The central Queensland region also proved to be more suitable climatically for safflower production as there was less chance of rain damage at flowering and seed maturation.

CONTINUED RESEARCH

Pacific Seeds Australia Pty. Ltd. (now a division of Continental Grains Australia Pty. Ltd.) conducted most of the safflower investigations in Queensland in the period 1963-72. This research was again centred at Biloela where the major emphasis was placed on the development of earlier maturing, higher oil yielding varieties. Two selections from this programme, namely, Saffola G-27, a selection made within Gila, and Saffola 2-47, a selection made from Saffola 208, had improved oil contents. State Government research during this period was mainly limited to varietal assessment in which introduced lines and lines developed by Pacific Seeds were evaluated. Part of this evaluation was conducted at Emerald to determine varieties suitable for irrigated production as an irrigation

Figure 1 Shires in Queensland Safflower Belt showing potential area of land available for safflower production ('000 ha) and the percentage of this potential area planted in the 1978 season.
(Location of climatic stations used in Figure 3 shown as well as eastern Darling Downs)

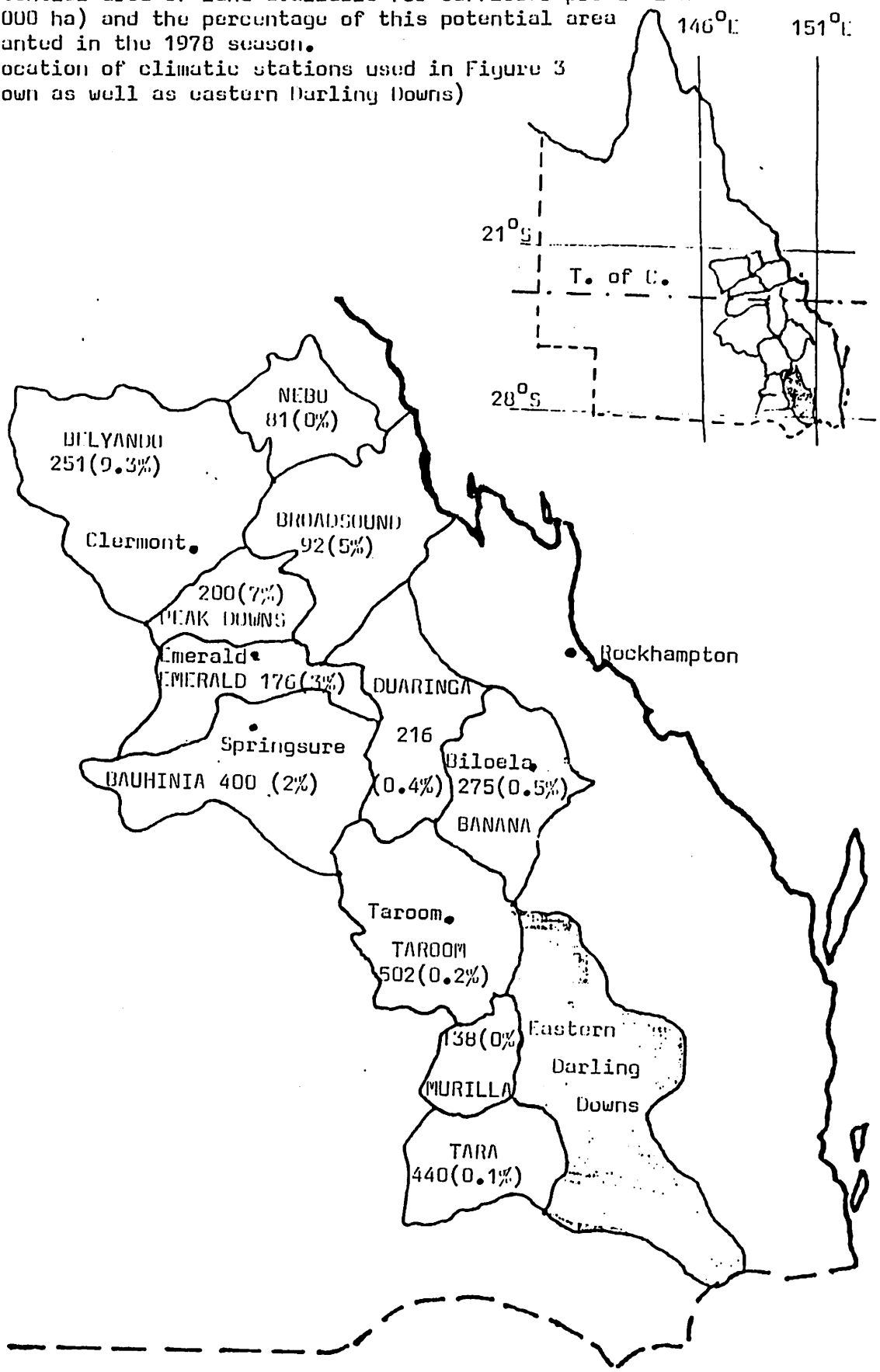
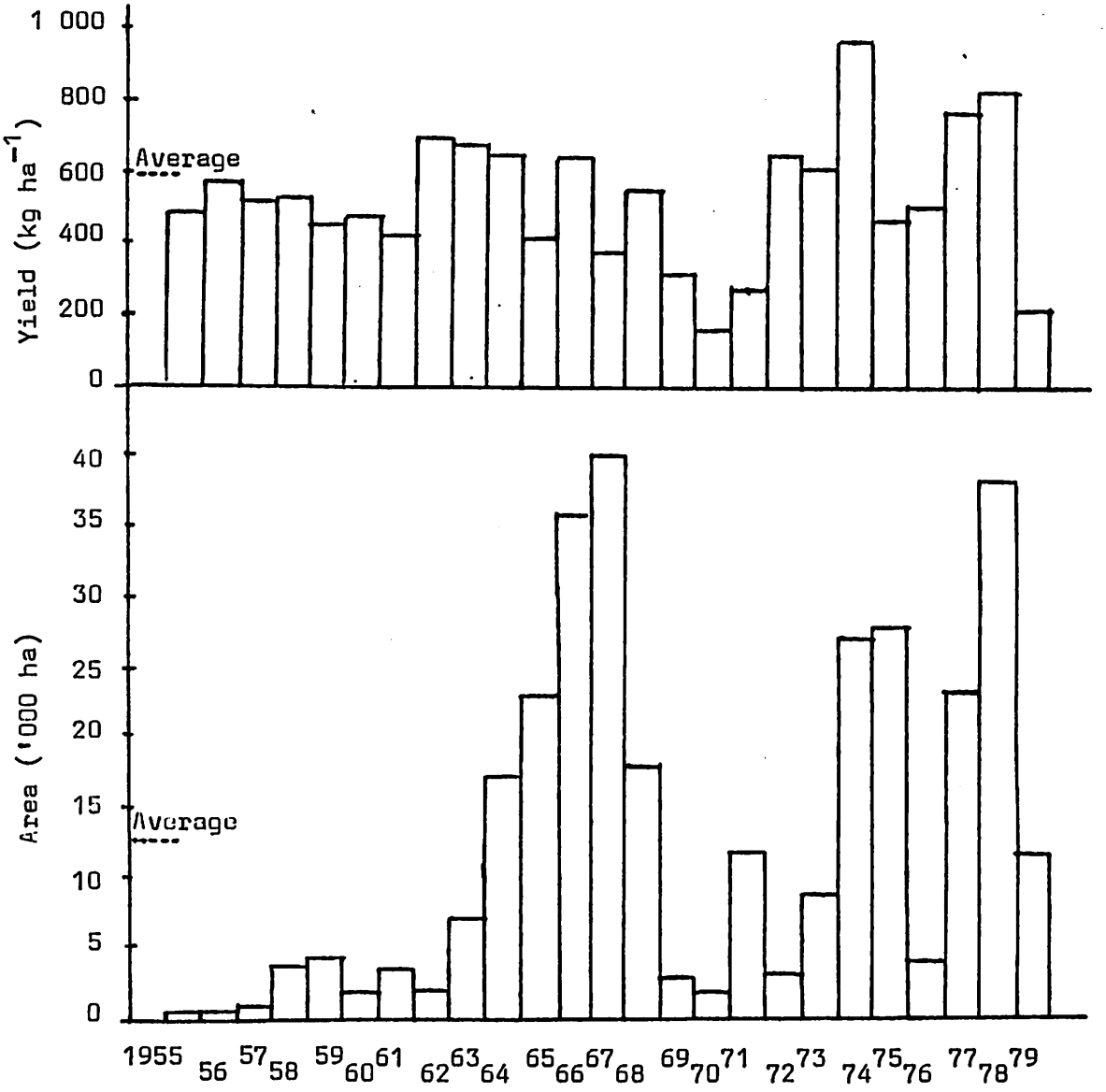


Figure 2. Development of Queensland safflower industry showing average yield (kg ha^{-1}) and hectares sowm for each year 1955-79.



scheme for the Emerald area was under development. Saffola G-27 was released by Pacific Seeds as an alternative rainfed variety to Gila on the basis of its relatively higher oil content (up to 2%) and earlier maturity (1-2 weeks). Saffola 2-47 demonstrated potential as an irrigated variety but was not released.

After two years of severe drought in the late 1960's, associated low safflower yields and general farmer disinterest in the crop, the future of the Queensland safflower industry was in jeopardy. As a result, in 1972, the Queensland Government decided to thoroughly investigate the agronomy of safflower in central Queensland to determine the potential of the industry.

This work commenced with a survey in the form of a questionnaire which was distributed to all farmers who had grown safflower in the central Queensland region. The survey indicated that May to June plantings had produced the highest yields, but that the majority of plantings had been made in July and August. Moreover, only small areas were planted early in the season with largest sowings being made in July, August and September. The survey also indicated that the crop was often planted on shallow soils and in areas where seedbed preparation was inadequate for wheat. It was evident that the majority of growers would plant wheat after the first winter planting rains on the best prepared land. Safflower was regarded as a versatile crop that could be planted as late as September on shallow, poorly prepared soils because of its drought tolerance.

Following the survey, detailed studies on time of planting, moisture usage and plant populations were commenced at Biloela. Three years of trials established that mid-May to mid-June was the optimum planting time and that populations of 12 and 25 plants m^{-2} had no effect on yield over monthly plantings from May to September inclusive (K. Jackson, unpublished data). Soil moisture studies indicated that 20-25 cm of stored moisture were required to produce 1000 kg ha^{-1} (K. Jackson, unpublished data). Because of the predominant summer rainfall (Fig. 3) successful crops depend heavily on stored subsoil moisture. Soils in the shires suitable for safflower production (Fig. 1) vary in depth from 30-180 cm and are capable of holding 5-6 cm of available moisture per 30 cm of depth. As winter rainfall is both low and unreliable (Fig. 3) it is imperative that safflower is planted on soils at least 1 m deep and well supplied with stored moisture. When these soils have been selected, commercial yields of 800-1000 kg ha^{-1} have been achieved in seasons without rain from planting to harvest.

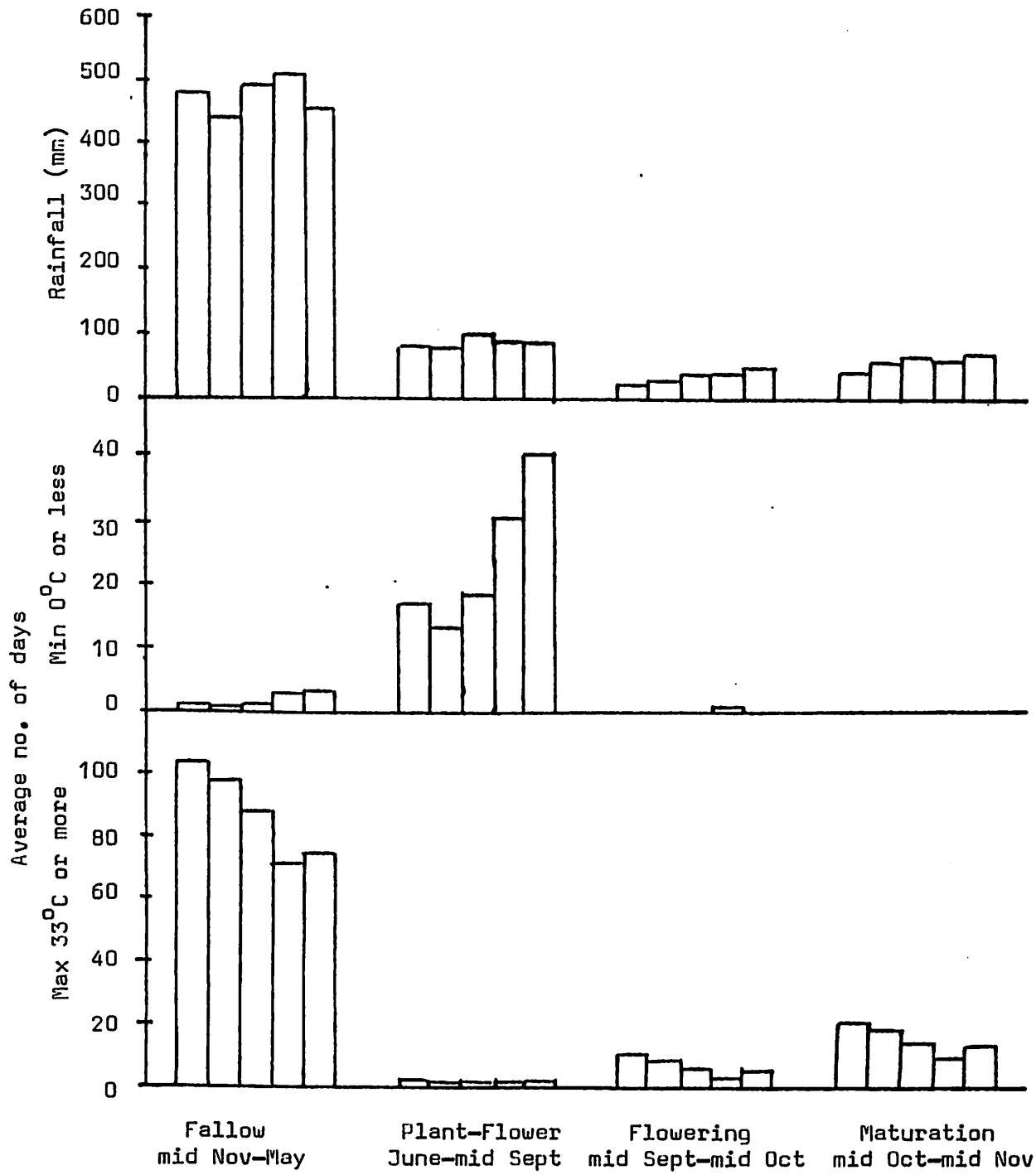
Frost was the other major climatic factor affecting safflower production in Queensland. It occurs in all the safflower production areas and is most prevalent in July. Frequency and severity increase southwards from the Tropic of Capricorn (Fig. 3). The occurrence of frost has an important effect on selection of planting date because of the devastating damage it causes at flowering (10). Mid-May is the earliest date that planting can be contemplated to avoid frost damage at flowering as earlier plantings with current varieties will flower in July-August, a period when the likelihood of frost is greatest (Fig. 3). If plantings are made later than June, yields decline because of the complex interactive effect of changing photoperiod and rising temperatures on reducing yield potentials including heads per plant, seeds per head and seed weight (K. Jackson, unpublished data). Yields are further reduced by declining moisture availability due to increasing evaporative demand in late spring. Late plantings mature in early summer and harvesting coincides with periods of increased rainfall and consequent maturation problems reduce seed quality.

CONTINUED COMMERCIAL DEVELOPMENT

The findings of the 1972-74 research programmme were commercially implemented in 1974 and probably contributed to the record yields in that year (Fig. 2). Varietal evaluation during this period was aimed at replacing Gila and Saffola G-27 with improved oil yielding varieties. Many introductions were made from safflower production areas outside Australia, but none of the new cultivars were superior in oil yield to Gila (8) although many of them had proven superior in overseas research.

Figure 3 Rainfall, frost, and maximum temperature data throughout the optimum growth cycle for safflower at representative sites in Queensland.

(Sites - Clermont, Emerald, Springsure, Biloela and Taroom respectively)



By the end of 1974, a high degree of confidence in growing safflower had been established among farmers. This resulted in a similar area being planted in 1975 to that planted in 1974 and similar yields were expected. However, a severe outbreak of the disease Alternaria carthami which causes leaf, stem and head blight occurred in September following a week of intermittent rain. An estimated 50% reduction in yield was attributed to the disease. This was the first occurrenceof the disease in commercial plantings although it had been first recorded in Australia on trial plantings in 1973 (6). Much of the Queensland Government research conducted since 1975 has been aimed at further determining the severity of the disease and methods of control (7). The disease is capable of causing early seedling death and plant death at flowering when heavy infestation occurs. Lighter infestations have detrimental effects on all quality factors of the seed and oil (K. Jackson, unpublished data). Development and spread of Alternaria are particularly rapid in seasons when extended wet periods coincide with increasing spring temperatures. As flowering also occurs in early spring, damage in these seasons can be substantial. It is estimated from rainfall records that conditions favorable for Alternaria epiphytotics could be expected every 3-4 years in central Queensland. Research has shown that the disease is capable of persisting in the soil for at least two years on diseased stubble (9). The susceptibility of all the varietal material material available for commercial production has provided renewed interest in the crop for private seed companies to develop resistant varieties. The CSIRO which commenced a plant breeding programme in the mid-1970's in southern Australia is also working towards resistance to this disease (K. Harrigan, personal communication).

The continuing threat of Alternaria in the Queensland safflower industry has once again left this industry in disarray. A recent assessment of the agricultural potential in Queensland has projected a figure of 2.7 million hectares of land thatare suitable for safflower production. Of this area, 37% would require a pasture phase to maintain fertility and minimum erosion (J. Harbison, personal communication). The percentage of this potenial area that exists in each of the safflower producing shires together with the percentage of the potential area achieved in the 1978-79 season are shown in Fig. 1. A large percentage of the arable land in the safflower area is undeveloped at present. However, with the infrastructure development associated with coal mining in the area, cultivation of virgin country is rapidly increasing.

Because of the climatic extremes experienced in the arable , sub-coastal area of Queensland, increased cropping options are essential to allow for greater stability in dryland farming enterprises. Additionally, the availability of a range of crops enables crop rotation to prevent or limit development of specific crop diseases, insects and weed pests. The main crops grown in the region are sorghum and sunflower in summer, and wheat and safflower in winter. Safflower has an important role in winter cropping as it allows the farmer to spread his risk. In many seasons, rain after planting may not occur for several weeks. This is disadvantageous for wheat as secondary roots may not develop without further rain. In seasons with no rain from planting to harvest wheat crops may fail, but safflower can be very successful. Although mid-May to mid-June is the optimum planting date for safflower, in seasons when winter planting rains first occur in late June safflower can provide a better return compared to wheat.

Future success of the safflower industry will rely primarily on the development of varieties resistant to Alternaria. Seed oil concentration of at least 44% on a moisture free basis is also required if safflower is to provide an economical option in the cropping system. Photoinsensitivity and cold tolerance would be useful characters to include in new varieties as they would reduce the growing season and hence moisture usage which is the major climatic factor reducing yield. The development of safflower hybrids with these characters and associated yield improvement should ensure future success for this industry in Queensland.

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STUDIES OF F_1 HYBRIDS OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

Prevention of anther dehiscence by enclosing capitula in low density polythene bags and subsequent hand pollination made it possible to produce seed in large quantities. At wide spacing (90 x 50 cm) hybrids yielded up to 4 times as much seed as the better parent. At closer spacing (50 x 15 cm) and under good agronomic conditions the yield of hybrids was on a par with elite varieties, but under poor agronomic conditions hybrids yielded more than the latter. Correlations between yield and yield contributing factors showed seed weight per capitulum to be the most important factor (r=0.56), followed by number of capitula per plant (r=0.48). Multiple regression of quantitative characters upon characters of both parents showed greater influence of the better parent on earliness of flowering, number of primary branches and capitula per plant, seed weight per capitulum and 100-seed weight. The parent with lower values had greater influence on height, capitulum diameter and seeds per capitulum. Resistance to Alternaria leaf blight was found to be dominant. Crosses between resistant and susceptible parents showed greater polyphenoloxydase activity than both parents.

EMASCULATION WITH POLYTHENE BAGS

Anther dehiscence fails to occur if safflower capitula are enclosed in a low density polythene bag. We regularly use this method as a substitute for hand emasculation when making experimental crosses. Concrete recommendations for breeders who wish to use this method are as follows:

Capitula which are about to flower should be enclosed in polythene bags after cutting off free laminae of the involucral bracts. At anthesis, when stigmas protrude out from the corolla tubes, pollinate them with pollen from the desired pollinator parent. The polythene bag should be replaced immediately after pollination. Repeat this process every day until the end of anthesis. Use only 5 to 6 capitula per plant for crossing and prune off all the unused ones. This ensures that the crossed capitula get sufficient food for good seed set. Remove the polythene bag after the florets begin to wilt. It should be noted that this method is useful only in a cool climate. In hot weather, the polythene bag acts as a heat trap and capitula covered by such bags suffer heat injury.

Use of this method enabled us to produce enough hybrid seed to conduct regular field tests of hybrid safflower.

YIELDING ABILITY OF HYBRID SAFFLOWER

Hybrid plants generally tend to grow much larger than the parents. If parents and hybrids are both tested under wide spacing, which allows the hybrids to develop their full potential, hybrids often show a yield heterosis of up to 400% of the better parent. Table 1 presents yield data of 13 hybrids and their parents in a test in which the spacing was kept at 90 cm x 50 cm with two plants per hill.

Table 1. Seed yield of hybrid safflower and parents under wide spacing.

Serial no.	Pedigree	Yield kg/ha	Serial no.	Pedigree	Yield kg/ha
1.	749-1 x B 3-1-10	5,473	16.	NS 520	1,840
2.	NS 14 x EC 32012	5,308	17.	168	1,802
3.	B 8-5-5 x N 62-8	3,309	18.	108-6	1,704
4.	NS 133 x 1016	3,210	19.	749-1	1,630
5.	1016 x NS 52	3,102	20.	EC 31367	1,522
6.	NS 133 x B 3-1-10	2,922	21.	NS 572	1,309
7.	NS 133 x NS 661	2,840	22.	N 62-8	1,296
8.	NS 83 x EC 31367	2,593	23.	NS 661	1,111
9.	168 x 108-6	2,423	24.	B 3-1-10	988
10.	108-6 x 168	2,037	25.	B 8-5-5	768
11.	NS 133 x NS 520	1,988	26.	1016	728
12.	NS 572 x N 62-8	1,900	27.	EC 32012	707
13.	764 x NS 488-1	1,671	28.	764	667
14.	NS 14	1,951	29.	NS 133	457
15.	NS 83	1,852	30.	NS 488-1	444

Hybrids do not give exceptionally high yield under normal spacing (50 x 20 cm). A multilocational test involving 75 locations around our research station showed that the experimental hybrid N 62-8 x NS 133 out-yielded the elite varieties under adverse conditions but yielded less than the elite varieties when growing conditions were good. In overall mean yield, there was no difference between the hybrid and the elite varieties. Results of this series of experiments are presented in Table 2.

Table 2. Seed yield (kg/ha) of a safflower hybrid, its parents and two elite varieties (mean of 75 tests).

Entry	Yield
Mean of 2 elite varieties	1,504
N 62-8 x NS 133	1,502
N 62-8	1,365
NS 133	987
LSD (0.05)	26

YIELD STABILITY OF HYBRIDS

N 62-8, one of the entries included in the multilocational tests, is the localvariety. Because it is supposed to be adapted to growing under the local conditions, it was assumed that the yield recorded by N 62-8 at each location would serve as an indicator of the growing conditions at that location. It was further assumed that the regression of yield of the hybrid and of the elite varieties upon the yield of N 62-8 would therefore give information about the response of the hybrid and the elite varieties to different growing conditions. The regression equations were as follows:

$$\text{Hybrid yield} = 526 + 0.72X \text{ and elite yield} = 184 + 0.97X$$

(where X = yield of N 62-8 in kg/ha)

Solving the above equations for different values of X shows that the hybrid gives a higher yield than the elite varieties up to about 1,000 kg/ha of N 62-8, whereas above this level the elite varieties give higher yields than the hybrid. The hybrid thus shows less yield fluctuation than the elite varieties. The lower value of the regression coefficient of the hybrid also indicates the same characteristic (regression coefficients were significant at P = 0.01 level in both cases).

CORRELATIONS BETWEEN YIELD AND MORPHOLOGICAL CHARACTERS

Table 3 presents data regarding correlations between seed yield and some morphological characters in the case of hybrid safflower. These calculations were based on data collected from 5 experimental layouts containing a total of 57 hybrids and their parents, planted in randomized complete blocks with 2 to 4 replicates. The spacing was 90 x 45 cm.

Data presented in Table 3 show that seed weight per capitulum was the most important factor followed by capitula per plant. The importance of seed weight per capitulum shows that improper seed setting was a serious problem at this location and varieties showing good seed set gave high yield.

Table 3. Correlation coefficient values between yield and some morphological characters of hybrid safflower.

Parameter	Correlation coefficient	Significance level
Days to flower	0	n.s.
Plant height	0.48	0.01
Primary branches/plant	0.10	n.s.
Capitula/plant	0.48	0.01
Capitulum diameter	0.20	n.s.
Seeds/capitulum	0.43	0.01
Seed weight/capitulum	0.56	0.01
100-seed weight	0.11	n.s.

INFLUENCE OF PARENTS UPON CHARACTERS OF HYBRIDS

Using the data from the same layout as above, multiple regression equations were established to describe the relationship between hybrids and parents for a number of quantitative characters. These equations are presented in Table 4 along with results of analysis of variance of the regressions (1). In all equations X_1 and X_2 denote values shown by parents with higher and lower values respectively. It would be seen from these equations that none of the characters showed a clear cut dominance. The two most important characters, namely number of capitula per plant and seed weight per capitulum, were influenced to a greater extent by X_1 than X_2.

Table 4. Regression equations showing influence of parents on characters of hybrid (X_1=parent with higher value; X_2=parent with lower value). F values in excess of 3.17 and 5.01 are significant at 0.05 and 0.01 levels respectively.

Parameter and regression equation	ANOVA for regression				
	Source	d.f.	S.S.	M.S.	F
Days to flower = $0.23X_1+0.29X_2+38.94$	Total	56	575.51		
	Regression	2	107.77	53.89	6.22
	Deviations	54	467.63	8.66	
Plant height cm = $0.27X_1+0.53X_2+21.23$	Total	56	5342.08		
	Regression	2	691.66	345.86	4.02
	Deviations	54	4650.42	86.12	
Primary branches/plant = $0.91X_1-0.11X_2+4.45$	Total	56	828.52		
	Regression	2	392.36	196.18	24.29
	Deviations	54	436.16	0.08	
Capitula/plant = $0.37X_1+0.16X_2+56.58$	Total	56	37780.01		
	Regression	2	5952.69	2976.34	5.05
	Deviations	54	31827.32	589.39	
Capitulum diameter cm = $0.26X_1+0.52X_2+0.85$	Total	56	15.27		
	Regression	2	1.85	0.93	3.74
	Deviations	54	13.42	0.25	
Seeds/capitulum = $0.11X_1+0.75X_2+10.89$	Total	56	5815.68		
	Regression	2	1567.22	783.61	13.03
	Deviations	54	3248.46	60.16	
Seed weight g/capit. = $0.23X_1+0.12X_2+0.85$	Total	56	8.52		
	Regression	2	1.00	0.50	3.59
	Deviations	54	7.52	0.14	
100 seed weight g = $0.47X_1-0.05X_2+2.65$	Total	56	37.09		
	Regression	2	6.46	3.23	5.69
	Deviations	54	30.63	0.57	

HETEROSIS AT THE BIOCHEMICAL LEVEL

It was found in the course of plant pathological studies that varieties showing resistance to Alternaria leaf blight also showed a higher activity of the enzyme polyphenoloxydase. Because hybrids between resistant and susceptible parents were found to be resistant, a study was undertaken to determine the polyphenoloxydase activity of some hybrids and their parents. Data presented in Table 5 show that the hybrids possessed greater polyphenoloxydase activity than either of the parents. It is assumed that the higher enzyme activity is caused by isoenzyme complementation.

Table 5. Optical density of catechol solution at 420 nm, 30 minutes after addition of leaf extract to it. Higher values indicate higher activity of polyphenoloxydase.

Source of leaf extract	Field response to *Alternaria carthami*	Optical density
199920	Susceptible	0.01
EC 32012	Resistant	0.05
Hybrid	Resistant	0.11
N 62-8	Susceptible	0.00
NS 133	Resistant	0.02
Hybrid	Resistant	0.03
NS 133	Resistant	0.02
199935 C	Resistant	0.10
Hybrid	Resistant	0.20
N 62-8	Susceptible	0.00
B 8-5-5	Resistant	0.02
Hybrid	Resistant	0.19

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STUDIES OF F_2 POPULATIONS OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

Correlation studies based on constituents of F_2 populations showed that seed weight/capitulum was the character most highly correlated with yield ($r=0.69$), pointing to incomplete seed setting as being the most important limiting factor in this region, caused most probably by low insect pollinator activity. This finding makes self compatibility a major breeding objective at this location. Associations were also established between yield and some qualitative characters by comparing yield of pairs of neighboring plants possessing diametrically opposite qualities. While there was no difference in the yield of spiny and nonspiny plants, the following characters were found to be associated with high yield: large capitula, spherical capitula, involucral bracts restricted to the base of the capitulum, primary branches borne on the entire length of stem and angle between stem and primary branches $>45^{\circ}$. It is argued that correlation studies based on constituents of a segregating population are more reliable than those based on germplasm collections. In spite of the segregating nature of its constituents, an F_2 population often looks as uniform as a variety. This may be due to the fact that CV% values of plant height and capitulum diameter of F_2 were of the same magnitude as those of varieties. So far we have identified about 100 F_2 populations which, in addition to giving significantly higher yield than elite varieties, were also as uniform in appearance as a variety. The prospects of using F_2 populations for commercial safflower production are discussed.

A major breeding effort was undertaken at this Institute to develop hybrid safflower for commercial production. By using a new method of emasculation, in which anther dehiscence was prevented by artificially increasing the humidity around the capitulum, it became possible to obtain every year hybrid seed of several hundred combinations in sufficiently large quantities to conduct field trials with standard field plot design. A natural consequence of this exercise was generation of a large number of F_2 populations. The following studies were conducted with these populations.

VARIABILITY IN F_2 POPULATIONS

Although these populations were expected to show a very ragged appearance due to segregation in morphological characters and stages of development, we were surprised to observe that a vast majority of them looked as uniform as a variety. Assuming that the uniform appearance of these populations was due to synchronous development, equal height and uniform appearance of capitula of the constituent plants, coefficients of variations (CV%) were calculated for these parameters in the case of 21 F_2 populations and 9 varieties. Records kept in the case of 100 randomly selected plants from each population and variety served for these calculations. Results of this study (Table 1) reveal that the CV% values of F_2 were greater than those of the varieties in the case of only the days to flower. CV% shown by plant height and capitulum diameter was of the same magnitude as that of the varieties.

Table 1. Coefficients of variation for days to flower, plant height and capitulum diameter of 21 F_2 populations and 9 varieties.

	Days to flower	Plant height	Capitulum diameter
Mean CV% of 21 F_2 populations	4.23	17.70	17.60
Mean CV% of 9 varieties	1.32	13.77	17.32
Difference significant at P =	0.01	0.01	n.s.

ASSOCIATIONS BETWEEN YIELD AND MORPHOLOGICAL CHARACTERS

Correlation studies based on germplasm collections contain an inherent source of error due to the fact that well adapted local types often perform better than many of the exotic types. As a result, characters evolved exclusively in a particular geographic region and which therefor are restricted to a particular group of varieties only, may get unjustifiably labeled as being either positively or negatively correlated with yield. In the case of safflower, peninsular India is the only major center of cultivation in the tropics and it is also the only major area of production where safflower is grown as a winter crop. This automatically makes Indian varieties better adapted to short day conditions, while most of the exotic varieties are adapted to long day conditions. In addition, Indian varieties also show greater tolerance to aphids (Dactynotus carthami) than exotic varieties, because aphids attack safflower regularly in India. Owing to these reasons, Indian varieties generally yield higher than the exotic ones if the germplasm collection is tested under typical growing conditions in India. The negative or low correlation with yield shown by many characters found exclusively among exotic varieties may be due to this reason. Secondly, correlations can also show quite different trends, depending upon the composition of varieties used in the study.

Assuming that more meaningful correlations would be obtained from studies based on individual plants in segregating F_2 populations, a study was conducted with five F_2 populations planted in a randomized complete block design with three replications. Fifty plants were randomly selected in each plot and records were kept of yield per plant (Y), capitula per plant (CN), capitulum diameter (CD) and seed weight per capitulum (SW/C). Mutual correlation coefficients were calculated for different parameter pairs and the data were subjected to analysis of variance followed by F-test. It was found that the correlation coefficient values did not differ significantly from population to population. A part of the results, giving correlation coefficient values between yield and three components of yield are presented in Table 2. That table also contains correlation coefficient values shown by two sets of varieties and one set of F_1 hybrids. The data show that CN, CD and SW/C were all significantly and positively correlated with yield in F_1 as well as in F_2 populations. The varieties differed from these two in that the correlation between Y and CD was negative in one set of varieties, positive in the other and statistically significant in none of them. The first set of varieties contained a cross-section of our germplasm collection. The Indian varieties, which gave the highest yield in this set, had relatively small capitula. The second set of varieties, in which a positive correlation existed between Y and CD, was received

from the All India Coordinated Research Project on Oilseeds. Because it represented high yielding material generated under this project at various research stations within India, all the entries in it were adapted to local growing conditions.

Table 2. Correlation coefficients (r) values between yield and yield contributing characters of five F_2 populations, 2 sets of varieties and one set of F_1 hybrids (CN: capitula/plant; CD: capitulum diameter; SW/C: seed weight/capitulum).

Reference population	$r_{CN.Y}$	$r_{CD.Y}$	$r_{SW/C.Y}$
170274B x NS 133 (F_2)	0.69	0.38	0.72
N 62-8 x NS 1015 (F_2)	0.50	0.33	0.81
199911 x NS 133 (F_2)	0.64	0.32	0.53
237542 x NS 488-1 (F_2)	0.57	0.32	0.72
th 10 x NS 488-1 (F_2)	0.57	0.57	0.69
Mean of all F_2	0.60	0.38	0.69
60 varieties, cross-section of germplasm	0.46	-0.11	0.70
40 elite varieties from AICORPRO	0.41	0.13	0.56
96 F_1 hybrids	0.37	0.27	0.63

An interesting fact highlighted in this study is that, in all the cases, the seed weight per capitulum had the highest positive correlation with yield. In most of the correlation studies reported in the past (1, 2, 3, 4) capitula per plant was the character found to be most highly correlated with yield. The fact that seed weight per capitulum was repeatedly found by us to be the character most highly correlated with yield suggests that good seed set must be a critical factor at this location. It is quite likely that the activity of insect pollinators is inadequate at this location, so that genotypes with a relatively high degree of self compatibility give higher yields under this environment than those with a low degree of self compatibility. This finding points to an important selection criterion, namely good seed set under a selfing bag.

In addition to large capitula, exotic varieties also show a number of other characteristics not generally met with among Indian varieties. They are absence of spines on involucral bracts, branches borne only on the upper half of the stem and extremely narrow angle (less than 35°) between main axes and branches. Another interesting character that we observed in a few exotic varieties was that the free laminae of the involucral bracts, instead of covering the entire capitulum, were restricted to the base of the capitulum. Many Indian varieties show conical capitula as against spherical ones found in certain other varieties.

The effect of these characters on yield was studied with the help of about 250 F_2 populations, which showed good segregation for the one or the other of the above characters. Whenever such a population was identified, 10 pairs of plants were selected in it , taking care that the members of each pair represented the two extreme ends of the spectrum of segregation, that they occupied adjacent positions in the plot and that they did not

not come from any of the border rows. Seed of each member of the pair was bulked according to its character, so that two subsamples were obtained from each population, based on the presence or absence of a single characteristic. After calculating the mean yield per plant for the subsamples from each of the populations, the data were subjected to two statistical treatments.

Since there were several populations showing the same type of segregation, the data were subjected to analysis of variance followed by F test, whereby each F_2 population was considered to be a replication. The second technique was to study the correlation between the character and yield. In the case of quantitative characters like branch angle, capitulum diameter and number of primary branches, it was possible to juxtapose the yield values against the actual measurements of these parameters, but in qualitative characters like presence or absence of spines, it was necessary to give arbitrary numerical values to the characters before they could be used for calculating the correlations. Presence of spines on the involucral bracts, spherical capitulum shape and involucral bracts only at the capitulum base were therefore given the value of 1 while their contrasting counterparts were given the value of 0.

Results of these studies (Table 3) show that spines on involucral bracts do not contribute significantly to yield, while characters that did contribute to higher yield were large size of capitula, broad branch angle, primary branches on the entire length of the stem, spherical capitulum shape and the occurrence of involucral bracts only at the base of the capitulum.

Table 3. Effect of some capitulum and branch characters on seed yield of safflower.

Character	Value used for r calculation	Seed weight g/plant	Correlation coefficient with yield (r)
Involucral bracts spiny	1	2.74 n.s.	0.06 n.s.
Involucral bracts nonspiny	0	2.71	
Primary branches on entire stem	No. of	6.38**	0.35
Primary branches on upper stem half only	branches	3.97	
Branch angle greater than 45°	Actual	3.73**	0.49
Branch angle less than 35°	angle	2.52	
Involucral bracts on entire capitulum	1	2.57**	0.44
Involucral bracts at capitulum base only	0	8.01	
Capitulum spherical	1	2.47**	0.54
Capitulum conical	0	1.09	
Capitulum diameter greater than 2 cm	Actual	3.55**	0.43
Capitulum diameter smaller than 1.6 cm	diameter	1.78	

**Difference between counterparts significant at p = 0.01 level.
All r values significant at p = 0.01 except the value marked with n.s.
n.s.: significant at neither p = 0.01 nor p = 0.05 level.

The study presented here suggests a new way of investigating the effect of morphological characters on yield. Such investigations are normally undertaken with the help of isogenic lines, the development of which is time consuming and often also outside the scope of a commercial plant breeder. F_2 populations are, however, always available in any breeding programme and their use for this purpose would not pose difficulty for any breeder. In addition, isogenic lines test the effect of the given character only in a specific genetic background, whereas use of F_2 populations gives information about the effect of the concerned character in a large number of varied genetic backgrounds.

FEASIBILITY OF USING F_2 SEED FOR COMMERCIAL PRODUCTION

It has already been mentioned that many of the F_2 populations looked as uniform as varieties. Since many of them also proved to be quite high yielding, it was decided to test the yield of all F_2 material in order to identify high yielding populations. Each trial layout contained 15 to 25 F_2 populations and 5 controls (N 62-8 as local check, NS 133 as disease resistant check, Annigeri-1 and No. 83 as elite checks and N 62-8 x NS 133 as an experimental hybrid), planted in a randomized complete block design with 3 or 4 replicates. Each individual plot had a gross area of 15 m^2, out of which a net area of 10 m^2 was harvested. The row-to-row and plant-to-plant spacings were 50 and 20 cm respectively. Apart from recording seed yield, records were also kept of variability and disease infestation shown by each plot. Variability was graded visually on a scale ranging from 0 to 5, whereby 0 denoted a very high degree of uniformity in height, growth phases, flower color and branch and capitulum characteristics. Higher grades denoted a correspondingly greater uneven appearance of the plot. Disease infestation was also graded on a similar scale, in which 0 indicated complete freedom from disease, while the value 5 denoted total destruction of the plot by diseases. Alternaria leaf blight and root rot caused by Fusarium/Rhizoctonia complex were the main diseases that appeared regularly every year. Table 4 presents results of a typical F_2 yield trial, in which the first three entries gave significantly higher yields than the elite controls. In addition to high yield, entries No. 2 and 3 also show a very high degree of uniformity. In this way, about 100 combinations have so far been identified which give high yield combined with a uniform appearance in F_2 generation.

Use of F_2 populations for commercial production of safflower appears more attactive to us than that of F_1 hybrids, because production of certified F_2 seed on a large scale would be easier. The seed producer would use hand-pollinated F_1 seed as foundation seed, which he has only to grow under isolation and good management. Since cross-pollination is not mandatory, there would be no need to keep beehives in the seed production plots. F_1 seed to be used as foundation seed would be produced by plastic bag emasculation and hand pollination and its production can be organized on lines similar to those currently being used for hybrid production of cotton in India. It is estimated that this seed would cost about Rs.1000/kg (US$ 1 = Rs.8) and that the certified seed producer would need about 2.5 kg/ha of it to plant a crop at a spacing of 100 cm x 50 cm with 2 plants per hill. If the seed yield of this plot is assumed to be 2500 kg/ha and if the producer were to get Rs.6/kg (twice the cost of commercial safflower) for it, he earns a gross income of Rs.15000/ha. Deducting from this Rs.2500 towards the cost of seed and Rs.4000

Table 4. Seed yield, variability and disease intensity of 15 F_2 populations and five checks.

Sr. No.	Pedigree	Yield kg/ha	Variability grade	Disease intensity
1	NS 663 X N 62-8	1767	2.25	200
2	NS 678 X 749-1	1678	0.25	2.25
3	NS 1021 X B 3-8-7	1610	0.50	2.00
4	NS 1021 X 1016	1590	0.76	1.75
5	NS 1021 X EC 32012	1587	1.00	2.00
6	NS 1021 X N 62-8	1558	1.75	2.00
7	NS 661 X NS 87	1445	2.25	2.00
8	NS 663 X EC 32012	1445	2.25	1.75
9	NS 678 X 749-1	1433	0.75	2.00
10	NS 678 X APRR-2	1379	0.75	2.25
11	NS 1015 X EC 32012	1363	0.75	1.75
12	NS 1522 X N 62-8	1352	1.00	2.25
13	NS 1021 X NS 1533	1319	0.50	2.00
14	NS 663 X EC 32016	1306	0.50	1.75
15	NS 1021 X NS 488-1	1171	2.00	1.75
16	N 62-8 X NS 133 (F_1)	1411	1.50	2.00
17	No. 83	1215	1.00	2.25
18	Annigeri-1	1209	1.25	2.00
19	N 62-8	1081	1.00	2.00
20	NS 133	786	1.50	1.50
	$L.S.D._{0.05}$	370	0.72	n.s.

towards cost of cultivation, certification and incidentals, he would still make a handsome profit of Rs.8500/ha. After adding the processing, handling and marketing cost, it would be possible to make this seed available to the commercial producer at a price of Rs.10/kg, which is only 3.3 times the price of commercial safflower and comparable to the price of hybrid seed of sorghum or pearl millet. Seed of F_1 hybrid safflower, produced by using the available male sterility system, would have to be priced around Rs.25/kg, because of extremely low seed yields.

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BREEDING DISEASE RESISTANT SAFFLOWER FOR CULTIVATION IN THE DECCAN PENINSULA OF INDIA[1]

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ABSTRACT

Leaf blight caused by Alternaria carthami Chowdhuri, leaf spots caused by Cercospora carthami Sund. & Ramak. and by Ramularia carthami Zaprom., powdery mildew caused by Erysiphe cichoriacearum D. C. and wilt (root rot) caused by combined incidence of Fusarium oxysporum Sehl. ex Fries, Rhizoctonia bataticola Bult. and Rhizoctonia solani Kuhn were the fungal diseases occurring most commonly at this location. Adapted to being grown under cool and dry conditions of winter, the local Indian varieties are highly susceptible to all these diseases. Exotic sources of resistance were identified by screening a germplasm collection of about 1,500 accessions under field conditions. Epiphytotics occurred naturally in the rainy season and they could be artificially induced by heavy irrigation in the dry part of the year. Findings of the field studies were confirmed by studying spore germination of the pathogens in leaf extracts of the concerned plants. This paper presents a list of resistant accessions. F_1 hybrids produced by crossing locally adapted varieties with disease resistant exotics showed that, except for powdery mildew resistance, resistance to all other diseases was dominant. Powdery mildew resistance did not show clear dominance in all cases. Single plant selections were made in F_2 and, while selecting in F_3 families, emphasis was laid on overall resistance rather than on resistance to any single disease. Varieties have now been developed with higher yield and greater disease resistance than elite Indian varieties.

The Deccan peninsula of India is the only major safflower growing region in the world which falls in the tropics. The crop is planted in September to October, after the end of the monsoon rains, and it grows entirely on stored soil moisture. Being adapted to growing without irrigation in a relatively cool and dry environment, there was no need for this crop to develop disease resistance and all the local varieties are susceptible to a number of diseases. The most commonly observed fungal diseases in the western part of the Peninsula are: leaf blight caused by Alternaria carthami Chowdhuri; leaf spots caused by Cercospora carthami Sund. and Ramak. and by Ramularia carthami Zaprom.; powdery mildew caused by Erysiphe cichoriacearum D. C.; and wilt (root rot) caused by a combined infection of Fusarium oxysporum Sehl. ex. Fries, Rhizoctonia bataticola Bult. and Rhizoctonia solani Kuhn.

A five-year research project was started in 1974 under the sponsorship of the United States Department of Agriculture, to identify sources of disease resistance and to breed high yielding disease resistant varieties.

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IDENTIFICATION OF RESISTANT MATERIAL

A germplasm collection consisting of about 1,500 entries was subjected to screening for disease resistance under field conditions by planting them all the year round. The local variety N 62-8 served as the susceptible check in most of the cases. Natural epiphytotics occurred in the rainy season, and could be easily induced by irrigating the layout heavily in other seasons. In addition to field testing, use was also made of a new and highly quantitative screening technique called leaf extract bioassay (1). In this method spores of the pathogen are allowed to germinate in aqueous extracts of the leaves of the plant to be tested. Leaf extracts of susceptible varieties show higher germination percentage of the spores than those of resistant varieties.

No accession proved to be completely immune to any of the above diseases, but a number of entries showed a higher degree of resistance than the local varieties. These accessions are listed below.

(1) Resistant to Alternaria: NS 99A, NS 1015, NS 1021, NS 1542, NP 10, B 3-1-10, B 3-8-7, 221, 535, 711, EC 32012, EC 32016, EC 76730, 170080 D, 170274 B, 199935 C, 209281 A, 209287 A, 240409, 248362, 248632 B, 288837 A.

(2) Resistant to Ramularia: NS 483, NS 1015, B 3-1-10, 535, EC 11972, EC 32012, EC 42476, 181866 A, 183689 A, 199936 A, 209281, 240409, 248362 A, 248383, 248620 A.

(3) Resistant to Cercospora: 361, 500, 522, 533, 665, 667, 693, 1536, 1575, 84-9, 98-10-1, 342-5, 173883 A, 175624 D, 199828, 199892 A, 199925.

(4) Resistant to Erysiphe: NS 19, NS 92, NS 99A, NS 587, NS 1015, NS 1033, NS 1572, NS 1586, UP-5, 760, 1016, EC 76730, 209281 A, 209287 A, 237542 A, 247550 A.

(5) Resistant to Fusarium/Rhizoctonia complex: VFstp-1, 23-4, EC 31374, 193764, 193764 B, 209281, 209284 A, 240409, 248353, USB Safflower.

STUDIES OF F_1 PROGENY

A large number of crosses were undertaken between susceptible Indian varieties and resistant exotic ones, in order to develop new high yielding resistant lines. The hybrids were always tested along with their parents. Resistance to Alternaria leaf blight, Ramularia and Cercospora leaf spots and wilt was found to be dominant, while resistance to powdery mildew showed inconsistent inheritance. Data from a typical F_1 screening plot are presented in Table 1. It shows the reaction of 23 hybrid combinations and their parents to three diseases, which occurred during that season.

STUDIES OF F_2 PROGENY

An astonishing feature of the F_2 populations was that the individuals within a population often showed a great deal of uniformity, so that the pop-

Table 1. Reaction of 23 hybrids of safflower and their parents to *Alternaria* leaf blight, powdery mildew and root rot. *Alternaria* and powdery mildew were graded on a scale ranging from 0 (no disease) to 5 (plant completely covered by symptoms). Root rot incidence was recorded as P (presence of wilted plants) and A (absence of wilted plants).

Variety or hybrid	Alternaria	Powdery mildew	Root rot
NS 133	2.50	2.75	P
199920	2.00	3.80	A
NS 133 x 199920	1.80	1.00	A
NS 133	2.50	2.75	P
209287 A	0.50	2.60	P
NS 133 x 209287 A	0.20	0.40	A
NS 133	2.50	2.75	P
EC 32016	0.40	2.00	P
NS 133 x EC 32016	0.25	0.66	P
NS 133	2.50	2.75	P
209281	1.20	1.80	P
NS 133 x 209281	0.25	0.50	P
NS 133	2.50	2.75	P
EC 32012	0.40	2.00	P
NS 133 x EC 32012	0.40	0.60	P
NS 133	2.50	2.75	P
B 3-1-10	1.33	2.00	A
NS 133 x B 3-1-10	0.50	1.50	A
NS 133	2.50	2.75	P
199935 C	0.80	2.80	A
NS 133 x 199935 C	0.20	0.80	A
B 8-5-5	1.20	1.75	A
N 62-8	3.60	3.80	P
B 8-5-5 x N 62-8	0.20	1.00	A
B 8-5-5	1.20	1.75	A
199935C	0.80	2.60	A
B 8-5-5 x 199935 C	0.40	2.20	A
NS 147	1.60	1.80	P
N62-8	3.50	3.00	P
NS 147 x N 62-8	1.00	2.80	P
B 3-8-7	1.00	1.75	P
N 62-8	3.50	3.00	P
B 3-8-7 x N 62-8	1.40	4.00	P

Table 1. Continued.

Variety or hybrid	Alternaria	Powdery mildew	Root rot
B 8-5-5	1.20	1.75	A
B 3-1-10	0.80	1.40	P
B 8-5-5 x B 3-1-10	0.80	1.80	A
B 8-5-5	1.20	1.75	A
NS 133	2.50	2.75	P
B 8-5-5 x NS 133	0.40	0.60	A
B 3-1-10	1.00	1.40	A
N 62-8	2.50	3.00	P
N 3-1-10 x N 62-8	1.00	2.40	A
B 3-1-10	1.00	1.40	A
B 3-8-7	1.00	1.75	A
B 3-1-10 x B 3-8-7	0.80	1.40	A
N 62-8	3.50	3.00	P
Bijapur 13	0.60	3.60	P
N 62-8 x Bijapur 13	0.60	3.80	P
N 62-8	3.50	3.00	P
B 3-1-10	1.00	1.40	A
N 62-8 x B 3-1-10	0.75	2.50	A
VFstp-1 11-5	1.40	3.80	P
NS 1015	0.33	0.60	A
VFstp-1 11-5 x NS 1015	0.00	0.40	A
248362 A	0.80	2.40	A
NS 133	2.50	2.75	P
248362 A x NS 133	0.66	0.60	A
199920	0.80	4.80	P
EC 32012	1.40	2.00	P
199920 x EC 32012	1.60	3.20	A
NS 140 E	1.60	1.40	P
N 62-8	2.50	3.60	P
NS 140 E x N 62-8	1.40	2.60	A
199935 C	0.80	2.40	A
NS 133	2.50	2.75	P
199935 C x NS 133	0.60	0.60	A
199935 C	0.80	2.40	A
B 3-8-7	0.80	1.60	A
199935 C x B 3-8-7	0.60	2.20	A

ulation as a whole resembled a variety. We are therefore developing the concept of using F_2 populations for commercial production. Almost 600 F_2 populations were screened during 1979/80 in a total of 30 trial layouts. Each layout contained from 15 to 25 F_2 populations and 5 checks. In the course of this work we discovered 31 F_2 populations which gave significantly higher yield than the elite Indian varieties, and which also showed significantly lower incidence of diseases. Incidence of bacterial shoot rot caused by Pseudomonas syringae was also taken into account, while assessing the disease intensity of the plots. Table 2 presents the pedigrees and disease intensity ratings of the 31 populations.

Table 2. Pedigree of F_2 populations giving significantly higher seed yield and having significantly greater leaf blight resistance than elite Indian varieties.

Serial no.	Pedigree	Disease rating	Serial no.	Pedigree	Disease rating
1.	NS 133 x 577	2.66	17.	NS 663 x N 62-8	2.00
2.	ND 419 x EC 32012	2.66	18.	NS 678 x 749-1	2.25
3.	B 3-8-7 x NS 133	2.00	19.	N 62-8 x 364-15	2.00
4.	577 x EC 32012	2.33	20.	N 62-8 x NS 133	2.33
5.	704 x 709	2.33	21.	N 62-8 x 1575	2.33
6.	715 x NP 12	2.00	22.	B 3-8-7 x NP-10	1.33
7.	199920 x N 62-8	2.33	23.	82-1 x NS 520	2.00
8.	248374 x 1016	2.00	24.	388-4 x NP 10	2.00
9.	248813 x N 62-8	2.00	25.	388-4 x 570	2.00
10.	25-1-10 x NS 165	2.33	26.	APBR-4 x EC 32012	1.33
11.	209292 x NS 572	2.00	27.	199935 C x NS 665	1.50
12.	N 62-8 x 362-4	2.00	28.	EC 32012 x NS 1551	2.00
13.	NS 59 x EC 32012	2.00	29.	NS 133 x NS 340	2.00
14.	NS 64 x N 62-8	2.00	30.	NS 148 x NS 1561	2.50
15.	NS 519 x N 62-8	2.00	31.	NP 23 x N 62-8	1.66
16.	NS 572 x NS 517	2.25		Elite checks	3-4

HANDLING OF ADVANCED GENERATIONS

Single plant selections made in F_2 were grown as F_3 lines. No attempts were made to select single plants from this stage onwards, because it would have been impossible to handle all the individual progenies. Populations were tested in yield trials containing elite Indian varieties as checks, and those populations which gave significantly higher yield and showed significantly lower disease ratings were promoted to the next generation. The natural insect pollinator activity is quite low at our research station and it is assumed that a large majority of plants in the advanced generation possess a high degree of homozygosity. Since the bulk population base is high yielding, single plant selections made in these populations would most probably give even higher yield. Many of the populations look so homogenous that it may be possible to use them as such after removing a few off types.

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SAFFLOWER IN THE SUDAN

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ABSTRACT

Safflower has been grown for centuries in very small patches along the Nile in the Northern Province. Interest in growing the crop on a commercial scale started in the early fifties with the adoption of a diversification policy. However, its competition for water with wheat in the irrigated schemes and with horticultural crops in the Northern Region ruled out its cultivation under irrigation. Therefore, attention was focused on the central clay plain -- a vast expanse of about 25 million hectares with a summer rainfall of 500 to 800 mm, which falls mainly from June to October. At present, safflower production in the Sudan is negligible. However, it has been suggested for inclusion in the rotation of a number of new large scale rainfed mechanized schemes in the the central clay plain. Due to the lack of land leveling, the sensitivity of the crop to waterlogging and the relatively low temperature during November-January, late sowing (in September) was found to be better than early sowing (in June). In all trials the variety Gila outyielded other varieties in all locations. The highest yield reported under rainfed conditions was 1800 kg/ha. The main pest of safflower in the Sudan is the safflower fly (Acanthiophilus helianthi).

Safflower (Carthamus tinctorius L.) is known locally as 'Gurtum' and has been grown, to a very limited extent, for centuries along the Nile in the Northern Province of the Sudan. It was probably introduced from Egypt where it has been under cultivation for the last 4,000 years.

Interest in growing safflower on a commercial scale in the Sudan started in the early 1950's with the adoption of the crop diversification policy. A number of research stations started working on the crop, but the work of all stations lacked continuity. Safflower is not yet grown on a commercial scale, but it is considered as a potential crop and is included in the rotation of some of the new proposed rainfed projects. The present paper outlines the past, present and future of safflower in the Sudan.

HISTORY

According to Weiss (28), both the Latin name and the English name were derived from the Arabic language. He states that Carthamus is the latinized version of the Arabic word 'Gurtum' and the Arabic name 'Usfur' is probably the origin of the English word safflower.

The crop has been grown on a negligible scale in the Northern Province since time immemorial. It is still being grown around fields in northern parts of that province. In fact, N-10 (which is one of the parents of Gila and US-10) is a selection from N-852, an introduction to the U.S. from this area.

In the northern part of the Northern Province, the seeds (achenes) of safflower are fried with wheat seedsand offered in wedding ceremonies , and the mixture is known locally as 'Gallia' (25). They are also used to produce tar for leather treatment, while the flowers are dried, ground and mixed with other perfumes and the mixture is used as an ointment for ladies, especially brides (6).

The first trial to study the possibility of growing safflower on a commercial scale was conducted under irrigation in the Gezira Province in 1937. This trial involved an Indian variety which proved to be successful as a winter crop. A second trial, involving a number of introductions from USA, was carried out in 1947 in the same Province. The yields of these early trials are not available. Interest in safflower as an irrigated crop was aroused in 1950, when the Agricultural Research Committee selected five crops including safflower as most promising alternate crops for the Gezira Scheme. According to Ferguson (9), yields as high as 1800 kg/ha were obtained in a commercial trial at Wad Enau, Gezira Scheme. Later, safflower was introduced in the Central Rainland Research Station at Tozi as a potential cash crop which would fit the farming system of mechanized crop production. Intensive work was carried out at this station by W. M. Tahir and M. O. M. Salih between 1956 and 1961. However, experimental yields were rather inconsistent, fluctuating between 866 kg/ha in the 1956/57 season (27) to 203 kg/ha in 1959/60 (24). The reason for these yield differences could be attributed to fluctuations in the amount of stored moisture in the soil since safflower is sown in September, i.e., towards the end of the rainy season. For example, in 1959/60 Salih tested five varieties at Tozi, Dali and Mazmoum (630, 780 and 930 mm annual rainfall, respectively). The highest average yield of the five varieties (734 kg/ha) was obtained at Mazmoum and the lowest (203 kg/ha) at Tozi. The differences in mean yields were probably due to differences in rainfall. In the 1960's and 1970's, studies on safflower were conducted under irrigation at the Gezira Research Station, Khashm El Girba Research Station, Hudeiba Research Station, Sennar Research Station and the Faculty of Agriculture, under rainfed conditions at the Kenana Research Station and under flood irrigation in the Gash delta. However, these studies lacked continuity as will be clear from the summary of their results in the next section of this paper. Nevertheless, they indicated that safflower was successful as an irrigated winter crop in many parts of the country, e.g., the Northern Region (Northern and Nile Provinces), and the Central Region (especially the Gezira Scheme). But the main problem in the Northern Region is the shortage of land and the severe competition of more lucrative crops, namely pulses and horticultural crops. In the Central Region as well as in the Eastern Region (Khashm El Girba Scheme), the main difficulty of safflower is its competition for water with cotton and wheat.

Since safflower is known for its efficient use of soil moisture because of its deep tap root, studies at the Central Rainlands Research Station indicated that the crop is suitable for the Central Clay Plain as a late summer crop. This Plain comprises about 25 million hectares of heavy clay soils with a summer rainfall of 500-800 mm.

RESEARCH WORK

As mentioned previously, investigations on safflower were carried out during the 1960's and 1970's at various research stations representing differ- ecological zones. A summary of these studies is presented below:

Gezira Research Station (Lat. 14° 24' N, Long. 33° 31' E): Eight spiny varieties (including US-10 and Gila) were tested in 1966/67 at ridge spacings of 40, 60 and 80 cm in a split plot design (1). The seeds were sown continuously on top of the ridges, then thinned after three weeks to one plant every 10 cm. Nitrogen in the form of urea was applied at the rate of 84.6 kg N/ha at sowing. The plots were irrigated at two weeks intervals. Two sprayingsof Rogor/DDT mixture was effective in controlling the safflower fly and the American bollworm. The former attacked the plants after the rosette stage, followed by the American bollworm. The three different ridge spacings resulted in significant differences in plant population but the differences in yield were not significant. Gila was the highest yielding variety (2175 kg/ha).

In the following season, Nur (18) tested four spiny varieties (including Gila) on three ridge spacings (40, 60 and 80 cm) and at seven sowing dates (at 15 days intervals from July 1 to October 1). The earliest sowing (July 1) gave significantly higher yields than later dates. There was a sharp decline in yield from July 1 to July 15 and the yield remained at a similar level for August 1 and 15 sowings, then increased gradually in later sowing dates.

Nur (19) repeated this experiment using two spiny varieties (Gila and US-10) and two non-spiny varieties and seven sowing dates starting on September 1 at 15-day intervals. The effect of variety and sowing date on seed yield was highly significant. The best sowing date for the spiny varieties was November 1 and for the spineless varieties was October 1. Gila was the best yielding variety.

When the same experiment was repeated in the following season (20), ridge width, sowing date and the interaction, variety x sowing date, had a significant effect on seed yield.

Nur (21) subjected five safflower and five sunflower varieties to three methods of hull determination, namely the standard method of germinating the seed in distilled water, germinating the seed in hydrogen peroxide, and using a seed cutter manufactured locally. For safflower, the seed cutter method was positively correlated with the distilled water method ($r = 0.88$) and with the hydrogen peroxide method ($r = 0.97$). The author concluded that the seed cutter technique is more rapid and accurate for safflower and sunflower seeds.

The effect of nitrogen fertilization on two spiny varieties (Gila and US-10) and two spineless varieties was studied by Nur (22). He used three nitrogen levels (0, 42.3, 84.6 kg N/ha), and found that the fertilizer increased seed yield -- the third level gave about 100% increase over the control. The N fertilizer rate did not affect oil or hull percentages.

With regard to pests, the most serious ones in the Gezira Research Station were the safflower fly and the American bollworm (Heliothis armigera).

Sennar Research Station (Lat. 13° 33' N, Long. 33° 37' E): In the 1966/67 season seven varieties (including Gila and US-10) were used to study the effect of variety, sowing date, nitrogen fertilization and spacing on seed yield (2). Four sowing dates (October 30, November 14,

November 29 and December 14) and three spacings (40, 60 and 80 cm) were used. The best yields were obtained from the October 30 and November 14 sowings. Planting after November 14 resulted in a sharp decline in yield. Ridge spacing had no significant effect on yield though there was an indication of a drop in yield with wider spacings. There was no significant difference between the three fertilizer treatments (0, 42.3 and 84.6 kg N/ha.) This might have been due to the high initial fertility of the soil since it was cropped with cotton in the previous season when 95 kg of urea/ha were applied, and moreover groundnuts preceded cotton. In all trials, Gila gave the highest yield.

The experiment was repeated in the following season (3). After considering the results in the light of those of the previous season, the following conclusions were reached:

a) Earlier planting (October 30 and November 14) results in best yields.

b) For practical consideration, 60 cm ridge spacing may be more appropriate.

c) The small response to nitrogen does not justify its applications.

d) In all trials, the varieties Gila and US-10 gave the best performance.

In an experiment conducted to compare spineless introductions with Gila (4), Gila was the best.

Hudeiba Research Station (Lat. 17° 34' N, Long. 33° 56' E): Work on safflower at Hudeiba Research Station started in 1961 with a small variety trial during the winter, but yield data were not given. In 1963/64, eight varieties were tested. The highest yielder was US-10 and the lowest was Hudeiba Rsearch Station 866 (a spineless variety). The crop suffered serious damage by the safflower fly.

In 1964/65, six varieties (including Gila, US-10 and the local variety Debeira) were planted in early November at a seeding rate of 24 kg/ha (15). Growth was very good but there was severe early attack by the safflower fly which was controlled by two sprayings with sevin. The first attack resulted in complete destruction of the first formed heads in almost the entire population. Gila gave the highest yield (2200 kg/ha), followed by US-10. The local variety had the highest number of heads/plant but the smallest size of heads and the lowest number of seeds/head. The spineless variety (Hudeiba Res. Sta. 866) gave the lowest yield, and it had the lowest number of heads/plant but the highest number of seeds/head. In 1965/66, the trial was repeated and again Gila gave the highest yield among the six varieties (1681 kg/ha).

In 1966/67, six varieties (five spiny and one spineless) were tested and and the plots were split for flat versus ridge method of plantings. There was no effect of the method of planting on yield or yield components. The five spiny varieties (Gila, US-10, Debeira, HRS 1835 and HRS 1396) did not differ significantly in yield, but the spineless variety (HRS 866) was significantly lower (16).

Three new introductions (HRS 216, HRS 217 and HRS 218) were compared with

Gila in a variety trial. The three varieties had a higher yield than Gila but the difference was not signifiant.

In 1967/68, the previous season trials were repeated. In the first trial, involving six varieties and two methods of planting, the results were similar to those of the 1966/67 season, but Gila and US-10 were significantly higher yielding than Debeira. In the second trial, which included Gila and three new introductions, the highest yielding variety , HRS 217, was not significantly different in yield from Gila. However, both yielded higher than HRS 216 and HRS 218 (17).

Yassin et al (31) tested seven of the above-mentioned varieties (not including Debeira and HRS 866). HRS 216 gave a significantly lower yield than the other varieties. This experiment was repeated in 1969/70 but the trial was destroyed by wind (29). Again, the seven varieties were grown in 1970/71 in a 7 x 7 latin square. The leading varieties were US-10, HRS 217 and HRS 1396 which gave significantly higher yields than HRS 216 and HRS 218. Significant differences in number of heads/plant, number of seeds/head and seed weight were observed (30).

According to Siddig (26), the major pests on safflower at Hudeiba were:

a) Safflower fly: The larvae attacked the rosette stage and the plant reacted by producing side branches and wherever a growing point of such branches was attacked another was produced 5-7 cm below. This resulted in a reduction in the number of primary heads and an increase in the number of secondary and tertiary heads. The pest also attacked flower heads and in severe infestations no seed was produced. The infestation started two weeks after the appearance of the flowers and increased gradually to a maximum of 93% by the end of December.

b) Eublemma para: The trend of infestation was similar to that of the safflower fly. When heads were infested, the larvae fed on the developing seeds, leaving the testa intact.

c) Heliothis peltigra: This pest fed on leaves and buds causing serious damage. Seedling infestation took place during the early stages and amounted to 67%.

d) Bemisia tabaci: This insect caused yellowing, drying and falling of leaves. Sporophytic fungi grew on the resulting honey dew deposits.

Khashm El Girba Research Station (Lat. 15° 19' N, Long. 35° 36' E): Six varieties (Gila, US-10, Debeira, HRS 1396, HRS 1835 and HRS 866) and four sowing dates were compared by Khalifa (11, 12, 13) for three seasons. The differences between sowing dates and between varieties were highly significant but the interaction between sowing dates and varieties was signifianct only during the second season. The two October sowings were better than the two November sowing dates. The plants were attacked by the safflower fly and the American bollworm.

Gash Delta(Lat. 15° 50' N, Long. 36° 09' E): This is a flush irrigated delta in eastern Sudan, Mutwakil (17) tested five varieties in a 5 x 5 latin square. The highest yield was obtained from Gila. The experiment was severely attacked by the white fly (Bemisia tabaci).

In 1969/70, Yassin tested seven varieties and reported that poor yields

were obtained but trends were similar to those of the previous season. HRS 217 gave the highest yield, while HRS 216 and HRS 218 gave very poor yields.

Kenana Research Station (Lat. 12° 44' N, Long. 34° 07' E): This is the only research station that worked on rainfed safflower. It was established in 1963 to replace Tozi Research Station (which was opened in 1952). Work on safflower at this station started in 1963/64 season. During this season extremely poor post-sowing rains caused almost complete failure of the crop (8). The highest yield (190.5 kg/ha) was obtained from the September 1 sowing. In the following season (1964/65), growth and yield were quite satisfactory. The variety US-10 was sown under rain at weekly intervals from August 10 to September 14 (10). August 31, September 1 and September 14 sowing dates gave the highest yields, confirming previous findings at Tozi that September sowing gives the highest yields (24). Three varieties, Gila, Debeira and HRS 866 (spineless) were sown under irrigation at three monthly intervals from October 8 to December 6 and at three intra-row spacings of 7.5, 15 and 22.5 cm, all at the inter-row spacing of 60 cm. In general, winter sowing under irrigation outyielded the best treatment under rain by 87%. Highest yields were obtained with the earliest sowing (October 8). From October 8 onwards there was a fairly linear depression of yield with delay in sowing which averaged 13 kg/ha/day (10). The effect of spacing was not significant, but the intermediate spacing of 15 cm tended to give a higher yield. The plant population at this spacing (60 x 15 cm) was 90,000 plants/ha. Gila outyielded the other two varieties.

The effect of four watering intervals of 1, 2, 3 and 4 weeks on variety US-10 indicated that yields increased with longer watering intervals up to four weeks(10).

A pest survey in the 1964/65 season showed that the most serious pest was the American bollworm. Black aphid was common but was not associated with honey dew or leaf curl. The safflower fly was less frequent than the previous season. Minor insect pest included thrips, jassid, white fly, the cotton green bug (Nzara viridula) and spider mites (5).

According to Osman (23), nine varieties were tested for three seasons. In the 1973/74 season, the varieties were sown on November 1 and no fertilizer was used. None of the varieties significantly outyielded Gila. Generally, the varieties that gave comparatively higher yields had heavier heads and bigger seeds.

Faculty of Agriculture, Shambat (Lat. 15° 40' N, Long. 32° 32' E): El Saeed (6) studied the effects of seed size on oil content and seedling emergence in the local variety Debeira. He found that oil percentage was inversely related to seed size and this was attributed to the proportion of hull in large seeds. Plants from large seeds emerged earlier than those from small seeds when sown at 2.5 and 5 cm depths. In addition, plants from large seeds had greater dry weights and leaf areas than the others.

Khidir (14) studied the genetic variability and inter-relationship of 14 quantitative characters in 18 local and exotic varieties (including Gila, US-10 and two spineless varieties from Iran). Appreciable variability was

was displayed by all characters, especially seed (achene) yield and number of heads/plant. Seed yield gave a significant positive genotypic correlation with number of seeds/head, head width, bract width and oil content. The 100-seed weight was significantly and negatively correlated with the number of seeds/head and plant height at maturity. The genotypic correlations between yield per plant and four other traits (number of heads/plant, plant height, head width and bract width) were partitioned into direct and indirect effects. The highest direct positive contribution to yield was given by plant height which had also a positive indirect effect via number of heads. The direct effect of the number of heads/plant was negative and the indirect effect via head width was positive.

Current Status: At present there is no commercial production of safflower in the Sudan in spite of the scattered experimental efforts and the fact that the possibility of large scale production has been recognized for some time. There are a number of factors that hindered this development, namely:

a) Competition for water with other important crops, such as cotton, wheat, pulses and vegetables, when grown under irrigation.

b) Fluctuations in experimental yields, particularly under rainfed conditions.

c) Poor seed supply.

d) The problem of marketing.

e) Inadequate information on varietal and agronomic aspects.

f) Heavy infestation of safflower fly and susceptibility of the crop to waterlogging.

THE FUTURE OF SAFFLOWER IN THE SUDAN

There are a number of areas in the Sudan where environmental conditions are suitable for safflower production. Moreover, the machinery for land preparation, seeding and harvesting of sorghum could be used for safflower. However, its commercial production as an irrigated crop is highly unlikely because water, and not land, is the limiting factor. On the other hand, the crop can be successfully produced on a very large scale under rainfed conditions. There is, however, need for more intensive research, extension and credit and marketing facilities.

With the difficulties now encountered in harvesting of sesame (the main traditional oilseed crop under rainfed conditions), safflower may be the alternative or rather a supplement to ease the high demand for labour at the time of sesame harvesting. In addition, safflower can be promoted, at least as an emergency or stand-by crop, in the mechanized farming schemes, to be sown in areas which could not be planted in time (mainly July) to other crops (sorghum and sesame) due to delayed rains or very heavy rains, or in waterlogged depressions. These could amount to a sizable area. However, growing safflower for seed export may not be an attractive proposition to the farmers with all the transport difficulties that are plaguing the Sudan. Popularization of the oil for local consumption may be the answer.

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PATHOGEN VARIABILITY AND SAFFLOWER RESISTANCE

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ABSTRACT

Reactions of safflower cultivars and breeding lines in screening tests conducted in the greenhouse differentiated strains of Verticillium dahliae, races of Fusarium oxysporum f. sp. carthami and elucidated variability in virulence of isolates of Phytophthora species. Employment of representative isolates of strains and/or races of important pathogens in screening tests enhances identification of safflower germplasm resistant to major diseases and aids in understanding the reactions of germplasm in the field.

Pathogens causing major diseases of safflower often exist as races and/or strains. Severity of disease in safflower cultivars or selections caused by Puccinia carthami Cda. (rust) or Fusarium oxysporum f. sp. carthami Klis. & Hous. (wilt) depends on pathogenic races. Different strains or pathotypes of Verticillium dahliae Kleb. that infect safflower are present in naturally infested soils. Likewise several different Phytophthora species cause root and/or stem rot of safflower. Thus, the search for new resistant germplasm and re-evaluation of resistant germplasm to new races and pathotypes is conducted on a continuing basis. In research on these diseases, inoculation techniques were developed whereby the reactions of different safflower germplasm could be more precisely evaluated for resistance in reliable greenhouse tests after large-scale screening tests were performed in the field. Field tests often do not produce consistent results and fail to answer specific questions regarding the pathogen involved. This paper presents a resume of research dealing with resistance of safflower germplasm to Phytophthora species, V. dahliae, and F. oxysporum f. sp. carthami.

PHYTOPHTHORA ROOT AND STEM ROT

Phytophthora root and stem rot usually occurs in irrigated fields of susceptible and moderately resistant cultivars, in breeding nurseries and in field tests for evaluation of genetically diverse cultivars and breeding lines. Mortality of plants of certain cultivars with high resistance suggests that strains of certain Phytophthora species are more virulent than previously realized (8) or that several different Phytophthora species may cause the disease. It is logical to assume that such is the case where differences in resistance to root and stem rot are expressed by the same safflower cultivars in different production areas. The relative virulence of isolates of P. parasitica, P. cryptogea and P. drechsleri to safflower was evaluated by disease severity and general symptoms on plants of four safflower cultivars grown in pots in the greenhouse until they were 6 to 7 weeks old (3). Inoculum consisting of cultures grown on a medium composed of vermiculite, V-8 juice, and $CaCO_3$ was mixed with soil. To enhance stem infection the inoculum-soil mixture was spread on the soil surface. To induce infection of the roots the inoculum was placed in a hole extending from the soil surface into the root zone. The pots were irrigated and drained and kept at 21 C for 24 hours, then placed at 27 C and flooded for 24 hours. Water level of about 1 cm was maintained on the soil surface for stem infection

and at a level in the root zone for infection of roots only. The water was drained at the end of the flooding period and the pots were kept at 27 C for an additional 24 hours, then placed in the greenhouse and irrigated once daily thereafter.

Symptom development was similar in susceptible plants regardless of cultivar or Phytophthora species. The severity of disease caused by P. parasitica isolates in Table 1 is typical of the virulence of four isolates to the four safflower cultivars. Isolates of P. cryptogea caused severe disease on stems and mild to severe disease on the roots of N-10 and Gila plants. Except for 174 and 261, P. cryptogea isolates failed to cause root rot or stem rot of VFR 1 and US Biggs plants. Roots of Gila and VFR 1 plants were resistant to P. drechsleri isolate 266 but susceptible to 473. The two isolates caused severe stem rot on plants of both cultivars. US Biggs plants were resistant to root rot from P. drechsleri and only a few plants developed stem rot. The severity of disease caused by P. drechsleri and P. cryptogea isolates on roots and to a lesser extent on stems is attributed to differences in virulence. Highly virulent strains of the two species likely contribute to root and stem rot of resistant safflower in the field and may influence development of resistant cultivars. Improvement of resistance to Phytophthora root and stem rot requires screening of germplasm for resistance to the most virulent strains known and any new strains that might occur on safflower in nature.

Table 1. Reaction of four safflower cultivars to Phytophthora parasitica, P. drechsleri, and P. cryptogea at 27 C.

Phytophthora spp. and safflower isolate	Percentage of plants/cultivar dead from root or stem rot							
	N-10[a]		Gila		VFR 1		US Biggs	
	Root %	Stem %	Root %	Stem %	Root %	Stem %	Root %	Stem %
P. parasitica								
169	100	100	75	100	0	0	0	0
166	100	100	100	100	0	0	0	0
P. cryptogea								
265	16	100	0	75	0	0	0	0
162	58	100	8	100	0	0	0	0
165	100	100	75	100	0	0	0	0
261	100	100	83	100	0	75	0	0
174	100	100	100	100	100	100	0	83
P. drechsleri								
266	65	100	0	100	0	83	0	0
473	100	100	100	100	83	100	0	16

[a]Known reactions of cultivars to root rot caused by P. drechsleri: N-10, susceptible; Gila, moderately resistant; VFR 1, resistant; Biggs, resistant.

VERTICILLIUM WILT

Safflower fields in different geographic areas in the United States may be subject to infection by different pathotypes of V. dahliae. Susceptibility of safflower to Verticillium isolates that infect other crops (10) creates a crop rotation problem and limits expansion of safflower production which could be alleviated by resistant cultivars. Screening safflower for resistance in the field is effective for evaluating a large quantity of materials (9); however, unless the tests are conducted in different growing areas, resistance to different pathotypes may be overlooked and escape identification. Evaluation in the field should be supplemented by tests in the greenhouse in which plants are tested for resistance to specific pathotypes using an effective method of inoculation. Conventional methods of inoculating plants with V. dahliae by dipping roots in a spore suspension or culture homogenate, and by injecting stems with conidial suspensions are effective. However, a more natural method of inoculation was sought in this study, that would minimize injury to roots. V. dahliae strains T-1 (severe on cotton) isolated from safflower, and SS-4 (mild on cotton) isolated from cotton (SS-4 obtained from W. C. Schnathorst) were grown in a medium composed of vermiculite and V-8 juice for 14 days at 24 C. Seeds were planted in the vermiculite and the plants were transplanted to loam soil. Plants were kept in a growth chamber illuminated (21,000 lux) for 14 hours daily at 21 ± 1 C for 7 days, then at day and night temperatures of 28 ± and 21 ± 1 C, respectively, for 14 days. Plants were then transferred to the greenhouse at average ambient night and day temperatures of 21 and 28 C, respectively. Disease was rated on a scale of 0-5 with 0 = no symptoms and 5 = dead plants.

Symptoms developed rapidly at day temperatures of 28 C and death of plants occurred within 4 to 8 weeks. Plants of some safflower introductions developed severe disease (4.0 and 5.0) from infection by T-1 and SS-4, but a majority of the introductions were moderately resistant (2.0 and 3.0) (Table 2). Cultivars and breeding lines were similar in their resistance to SS-4, but they varied from highly susceptible to highly resistant to T-1. VFR 1 and VFstp 1 had high resistance to T-1 (Table 3). Their susceptibility to SS-4 in these tests suggests that they were previously selected for resistance principally to T-1. Some introduced cultivars and breeding lines showed no significant difference in resistance to T-1 and SS-4, whereas reactions of other differentiated the two pathotypes (Table 3). Differential reactions of PI209285 and Gila were the reverse of VFR 1 and VFstp 1 reactions. Although germplasm with resistance to T-1 is available, identification of other sources of resistance would provide a broader genetic base for breeding programs. Germplasm with resistance to SS-4 is needed. Safflower introductions with a disease index of 2.0 might be of value for improving resistance to SS-4 in a breeding program. A search for germplasm resistant to T-1 and SS-4 should probably concentrate on introductions in the World Safflower Collection since only a few of those have been evaluated for resistance to both pathotypes.

FUSARIUM WILT

Fusarium wilt was recognized as a disease of safflower in California in 1962 (4). It became a major disease in the Sacramento Valley by 1968 as spread of the pathogen was enhanced by irrigation and flood waters, farm machines, and infected seed. The World Safflower Collection was screened

Table 2. Distribution of safflower introductions, cultivars and breeding lines by disease reaction to Verticillium dahliae.

Entries	V. dahliae	Number of entries/disease rating[a] 0	1.0	2.0	3.0	4.0	5.0
Safflower plant	T-1	0	0	6	6	3	4
introductions	SS-4	0	1	4	10	3	1
Cultivars and	T-1	1	2	2	2	0	2
breeding lines	SS-4	0	0	0	9	0	0

[a]Rounded to nearest whole number.

Table 3. Reaction of selected safflower cultivars, breeding lines, and introductions to Verticillium dahliae.

Entry	Isolate and disease index[a] T-1	SS-4
VFR-1	0.0	3.0
VFstp-1	0.3	3.0
14-5	1.1	2.6
PI 251,398	1.5	2.1
PI 306,596	3.0	3.3
PI 209,285	3.6	1.4
Gila	5.0	3.0
PI 250,823	5.0	5.0

[a]Disease index: 0 = no symptoms; 1, 2, 3 and 4 = chlorosis and necrosis of leaves on 1/4, 1/2, 3/4 and all of the plant, respectively; 5 = dead plants (LSD 0.01 = 1.0).

for resistance in a field test in 1967 and 1968 (7). Many safflower introductions that were highly resistant to wilt comprised a germplasm pool. Other introductions showed a variable reaction which suggested the existence of pathogenic races. A greenhouse test was developed for which a standard inoculum procedure consisted of mixing of infested autoclaved wheat grain with autoclaved soil at a rate of 1.5 g inoculum/100 g soil. Seeds were planted in inoculum-free soil covering the infested soil. Tests with selected safflower introductions and cultivars distinguished three pathogenic races in 1970 (5, 6). Numerous introductions were resistant to each of the three races; however, each subsequent new race significantly reduced the germplasm pool.

In 1973 an increase in wilt incidence was attributed to a fourth pathogenic race (2), subsequently differentiated in greenhouse tests (Table 4). Several sources ofresistance to races 1, 2 and 3 were susceptible to race 4 in greenhouse tests. High plant mortality from race 4 made it difficult

Table 4. Differential reaction of safflower cultivars to isolates of Fusarium oxysporum f. sp. carthami.

Race	No. of isolates	Cultivar			
		Gila	N-6	US Biggs	UC-41[a]
1	12	100[b]	0	0	0
2	13	100	100	0	0
3	2	100	100	100	0
4	8	100	100	100	100

[a]Selection from PI 304,447

[b]Percentage of dead or diseased plants of 50-70 plants/cultivar-isolate combination.

to determine the value of introductions as a source of resistant plants using standard inoculum. Thus, inoculum was changed from infested grain to suspensions of spores (conidia) from cultures on grain. Spores washed from the grain were concentrated at 250,000/ml. Ten milliliters of suspension were pipetted/row before seeds were planted. A soil and sand mixture (1:1, v:v) served as the planting base. Nineteen safflower introductions were evaluated for resistance. Plants of four introductions were resistant but plant mortality ranged from 4 to 58% among other introductions (Table 5). In subsequent tests with seeds from surviving plants, selections from 14 introductions were resistant. Selections from introductions offer a genetic base from which materials can be selected by plant breeders for incorporating resistant genes into cultivars and breeding lines. Resistance to race 3 in a breeding line and four introductions was reported as conditioned by a single major gene with a minor gene for resistance also present (1). Resistance to race 4 in two introductions as indicated by segregating F_2 populations is conditioned by a single major gene (Klisiewicz and Urie, unpublished).

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Table 5. Reactions of safflower introductions and selections of introductions to Fusarium oxysporum f. sp. carthami race 4, their leaf spininess and oil content.

Introduction	Selection	Spine index[a]	% oil	% Dead or diseased plants from: Seed from introduction plants in field	% Dead or diseased plants from: Seed from selections in greenhouse
PI 250,010	3992	1	29	0	0
PI 250,538	4297	0	28	0	0
PI 250,608	4305	0	31	0	0
PI 250,079	4309	0	33	0	0
PI 250,539	4298	0	30	4	0
PI 306,596	4343	0	32	5	0
PI 250,828	4046	1	33	7	0
PI 250,827	4011	0	33	13	0
PI 253,387	4258	0	29	22	0
PI 251,398	4022	1	29	24	0
PI 250,830	3133	1	27	31	0
PI 209,288	3238	1	32	33	0
PI 250,823	4043	0	30	40	0
PI 250,523	3119	1	30	58	0
PI 250,824	4009	0	34	28	5
PI 251,462	4142	1	32	29	5
PI 175,624	3478	1	35	19	5
PI 250,007	4039	0	36	27	10
PI 251,288	4308	0	28	24	16
PI 304,447	UC41	0		100	

[a]Spine index: 0 = spineless; 1 = spiny.

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GENETIC STUDIES IN SAFFLOWER (CARTHAMUS TINCTORIUS L.)

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ABSTRACT

Genetic studies on safflower at Hyderabad, India, have indicated considerable positive association of yield with number of primary branches, secondary branches and number of heads per plant. Significant negative correlations were observed between number of seeds per plant, plant height and height of main head. High heritabilities were also observed in the case of number of secondary branches and number of heads per plant besides mean height of the main head. The studies indicate that selection for increased number of primary branches, secondary branches and heads per plant should prove useful to the breeder for increasing the yields in safflower.

Discriminant function was used in plant selection by Smith (4) and it became a handy tool to select promising lines in the breeding material. The relative genetic and economic values of different metric traits, particularly yield and yield components and their association, should be understood before a successful breeding programme is launched. The present study was, therefore, taken up in safflower, a promising oilseed crop, where relatively little information is available along these lines.

MATERIALS AND METHODS

Thirteen different cultivars were grown in a randomized block design with four replicationsduring Rabi, 1973-74. Observations were recorded on random samples of plants on yield per plant (Y), plant height (HT), height at which the main head appears (HM), primary branches (PB), secondary branches (SB), heads per plant (HP) and seeds per plant (SP). The analysis of variance, correlations and regressions were calculated as given by Goulden (3) and Burton (2).

RESULTS

The analysis of variance for different characters studied and the mean values are presented in Table 1. Significant differences between cultivars were observed for mean height of plants, height of main head, number of secondary branches and number of heads per plant. However, mean yield per plant, number of primary branches and number of seeds per plant did not vary significantly. Heritability estimates were very high, 69.0, 66.8 and 69.4% for mean height of main head, number of secondary branches and average number of heads per plant respectively, while heritability estimates for other characters were of a lower magnitude (Table 4).

Correlations at the phenotypic, genotypic and environmental levels are presented in Table 2. The data indicate that yield was positively correlated with all the traits studied at the phenotypic level, while at the genotypic level, negative correlations were present between yield and

Table 1. Mean values for different traits and analysis of variance.

Sel. No.	Variety	Yield per plant (g)	Plant height (cm)	Height main head (cm)	No. primary branches	No. secondary branches	No. heads per plant	No. seeds per plant
1	SF-5	20.9	69.2	65.1	13.0	26.2	39.4	44
2	SF-11	16.7	68.7	63.1	11.8	20.8	32.7	34
3	431	22.6	69.4	65.4	13.6	22.7	35.3	47
4	437	23.3	76.5	71.3	13.5	20.8	32.8	46
5	438	30.5	72.2	66.7	15.6	29.6	44.8	64
6	N-7	21.6	73.3	68.8	16.1	26.4	41.7	39
7	N-25	29.3	75.4	74.5	18.1	32.0	47.4	57
8	N-80	23.5	71.9	71.6	15.3	32.2	45.5	48
9	143-20	31.9	75.4	69.4	17.2	33.5	48.9	71
10	319-12	24.7	75.9	70.9	13.7	23.5	36.9	50
11	N-62-8	33.1	77.3	72.2	17.9	35.4	55.7	63
12	6503	19.3	87.0	82.2	14.5	13.6	27.1	54
13	7-13-3	23.2	81.0	76.5	12.3	16.9	27.6	45
	CD 5%	10.3	10.3	8.4	NS	11.2	13.8	NS
	S.E.±	5.1	5.0	4.1	2.0	5.5	6.8	10.7

Table 2. Phenotypic, genotypic and error correlations and regression coefficients between seed yield and other variables.

Characters	Correlation coefficients			Regression coefficients		
	P	G	E	P	G	E
Mean height	0.0759	-0.4017	0.5537	0.0750	-0.3857	0.5630
Height of main head	0.0767	-0.2584	0.5666	0.0743	-0.2105	0.7086
No. of primary branches	0.7415	0.7626	0.7216	1.8654	1.9422	1.7962
No. of secondary branches	0.7607	0.8310	0.6953	0.5723	0.5330	0.6514
No. of heads per plant	0.7962	0.8193	0.8064	0.4647	0.4004	0.6110
No. of seeds per plant	0.8796	0.9402	0.8246	0.0430	0.0472	0.0394

mean plant height and yield vs height of main head indicating that the characters are not heritable and environmental effects are greater. The environmental (error) correlations were positive in all cases indicating the influence of environment. The amount or degree of relationship also being a product of genotype x environment, these values also varied significantly. Regression values presented in Table 2 further show that mean height and height of the main head negatively affected yield at the genotypic level and hence their negative role in selection. All other characters studied have exhibited a positive regression effect on yield at the phenotypic, genotypic and environmental levels indicating that these traits may be used to develop a selection index.

The inter-component correlations (Table 3) indicated a significant positive correlation between mean height and height of main head at the phenotypic and environmental levels. Plant height and primary branches were negatively associated at the genotypic level while height of the main head and number of primary branches were also negatively correlated. There was a significant negative correlation between number of secondary branches and height of the main head, indicating a reduction in one with an increase in the other. Also present was a highly significant positive correlation between number of primaries and number of secondaries, both at the phenotypic and genotypic levels, indicating that this trait is amenable to selection.

Table 3. Inter-component correlations

Characters			X_2	X_3	X_4	X_5	X_6
Mean height	X_1	P	0.9437**	0.0313	-0.4074	-0.3014	0.2929
		G	1.0000**	-0.3695	-0.8992**	-0.7630**	0.0887
		E	0.8670**	0.4230	0.2978	0.4013	0.4885
Height of main head	X_2	P		0.1267	-0.3002	-0.2214	0.2607
		G		-0.2062	-0.6389**	-0.5526**	0.1239
		E		0.6060**	0.4174	0.5248*	0.4667
Mean number of primary branches	X_3	P			0.8058**	0.8616**	0.6780**
		G			0.9322**	0.9453**	0.7071**
		E			0.6722	0.7951**	0.6523*
Mean number of secondary branches	X_4	P				0.9819**	0.5544**
		G				1.0000**	0.4992
		E				0.9206**	0.6562*
Mean number of heads	X_5	P					0.6053**
		G					0.5476**
		E					0.7273**

Number of heads per plant was significantly and negatively correlated with mean plant height and height of main head, indicating a reduction in one with an increase in the other. However, significant positive correlations were present between number of heads per plant and number of primary and secondary branches at the phenotypic, genotypic and environmental levels,

indicating that selection for improvement can be practiced in common. Number of seeds per plant was significantly correlated with number of primaries, secondaries and number of heads per plant , indicating that an improvement in any of them would ultimately lead to increased seed production per plant and thus total yield.

Heritabilities for different traits are given in Table 4.

Table 4. Heritability for different traits.

Index		Heritability (%)
Y	Grain yield	48.57
X_1	Mean plant height	51.43
X_2	Mean height of main head	69.01
X_3	Mean number of primary branches	47.41
X_4	Mean number of secondary branches	66.84
X_5	Mean number of heads per plant	69.44
X_6	Number of seeds per plant	46.15

DISCUSSION

The value of a plant may be expressed as a linear function of its traits which will be the best available guide to the genetic value of each line. Yield is the product of interaction of a genotype in a given environment, the phenotype being formed by a number of observable traits in a particular envrionment. Yield component analysis by association studies, regression equations and selection indices provides a better chance of understanding the interactions among themselves and a workable basis for selection in a set of genotypes. Yield component studies in safflower, in the present case utilizing correlations and regressions, have indicated considerable positive association with and regression on the number of primary branches, secondary branches and number of heads per plant. Height of plant and height of main head had little or no association with yield and yield components. These findings are in agreement with those of Ashri (1).

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CYTOGENETIC STUDIES IN SAFFLOWER (CARTHAMUS TINCTORIUS L.)

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ABSTRACT

The karyotype of safflower cultivar I.C. 11842 was established following standardization of an efficient squash technique. Sixty-two translocation heterozygotes were isolated in M_1 of a gamma irradiated plus sodium azide treated population and their cytological behavior analyzed. Subsequently ten translocation homozygotes were established. The chromosomes interchanged were 6-8 (line 58), 1-3 (line 66), 3-12 (line 123), 3-10 (line 131), 3-6 (line 153), 4-6 (line 186), 4-8 (line 197), 3-8 (lines 208 and 279), and 5-7 (line 290). The segment interchanges were not random. Primary and tertiary trisomics were isolated in the progenies of the translocation heterozygotes. The translocation homozygotes and the aneuploids are being used for assigning genes to chromosomes.

Cultivated safflower (Carthamus tinctorius L.) is emerging as an important oil crop particularly for rainfed areas. Inheritance of qualitative as well as quantitative traits, cytogenetic make-up and biosystematic relationships in the genus have been reported (2, 3, 4, 5, 8, 9, 10, 19). However, a limited attempt has been made to assign genes to chromosomes in this crop. Estilai and Knowles (4) isolated one primary trisomic in the progeny of an open-pollinated triploid plant and described its meiotic behavior. They did not identify the additional chromosome presumably because the chromosomes are relatively short and more or less of equal size (10).

Pillai, Kumar and Singh (11, 12) and Singh, Pillai and Kumar (16) developed suitable methods for study of safflower chromosomes and described the karyotype and further induced and described a set of translocation homozygotes in a safflower cultivar 'I.C. 11842'. In this communication we present a brief review of the production, isolation, characterization and use of the various cytogenetic stocks established at Banara Hindu University, Varanasi, in chromosome mapping and improvement of safflower.

MATERIAL AND METHODS

The technique for preparation and study of somatic chromosomes has been described by Pillai, Kumar and Singh (11). It may briefly be described as follows:

Root tips of safflower cultivar I.C. 11842 were grown at 28 C, collected and pretreated in 0.002 M 8-hydroxyquinoline for 3 hr at 10 C, fixed in methanol-acetic acid (1:1) for 20 hr at 10 C and then in a mixture of isopropyl alcohol: propionic acid: solvent ether: acetone (6:3:1:1 v/v) at 10 C for 72 hr, washed in distilled water, stored in 75% ethyl alcohol, hydrolysed in 1N HCl at 60 C for 5 minutes, stained in freshly prepared Feulgen reagent for 30 minutes at 28 C, and finally squashed in 1% aceto-orcein.

The length (in μ) of each chromosome, the relative length (L%) expressed expressed as a percentage of the total length of the diploid complement and the ratio between the long arm and short arm of the chromosome (Pa-value) were recorded.

Chromosomal aberations, particularly translocations were induced by treating the seeds with gamma rays, 30 to 45 kr being most effective. Pollen sterility, metaphase I (MI) analysis, breeding tests and karyotype analysis were used to isolate translocation heterozygotes and homozygotes (12, 16).

Tetraploids were induced by treating potted seedlings at room temperature (28 C) with 0.1% aqueous solution of colchicine for 60 hr.

Microsporocytes were collected around 8 AM in modified Pienaar's (13) fixative (6 parts absolute ethyl alcohol: 3 parts chloroform: 2 parts acetic acid) from each treated plant and 10 standard normal plants. Pollen stainability, used as an indirect measure of pollen fertility, was determined by squeezing mature anthers into a drop of glycerine and 1% aceto-carmine (1:1). For meiotic preparations, PMCs were squashed in a drop of 1% aceto-carmine. Observations were recorded on meiotic chromosome configurations, chiasma frequency, disjunction and micronuclei.

RESULTS AND DISCUSSION

Karyotype Analysis

The 12 pairs of chromosomes were classified and numbered from 1 to 12 on the basis of their descending order of length, centromere position and presence of satellites (Fig. 1). The absolute chromosome length varied from 3.52 to 2.05μ, the average being 2.90μ. The arm ratios ranged from 1.25 to 4.50. The centromere was mostly median to submedian, being subterminal in two pairs of chromosomes. There were 3 pairs of sat-chromosomes, the nucleolus being organised by the short arm.

The sat-chromosomes (Class A) were easily separated from the nine pairs of non-sat-chromosomes (Class B) and accurate measurements permitted arrangements of chromosomes in descending order of size. The first three pairs were sat-chromosomes. There was high similarity in the L% and Pa-values of 1 with 2, 4 with 5, 7 with 8 and 9 with 10. Thus, for the purpose of gross identification, these chromosomes were placed into four distinct groups. A karyotype formula, as given below, was arrived at:

$$K(n=12) = 2A_1^{ST} + 1A_2^{SM} + 2B_1^{SM} + 1B_2^{SM} + 2B_3^{SM} + 2B_4^{SM} + 1B_5^{SM} + 1B_6^{SM}$$

The symbols A_1, A_2, B_1, B_2, B_3, B_4, B_5, and B_6 represent chromosome pairs 1 and 2, 3, 4 and 5, 6, 7 and 8, 9 and 10, 11, and 12, respectively, where ST and SM stand for sub-terminal and sub-medium centromere position, respectively.

Except for the sat-chromosomes 1 and 2, all the chromosome pairs had median to sub-median centromeres. The differences in total length, and Pa-values of the longest and shortest chromosomes of the complement were rather small. It is suggested that safflower possesses a symmetrical karyotype which is considered as a generalized (primitive) type (18).

Knowles and Schank (10) found that the somatic chromosomes of *C. nitidus* Boiss. were almost similar to those of *C. tinctorius*, except that the sat-chromosome of the former appeared to be longer. We found three sat-chromosomes against only one reported by the earlier workers. The detailed karyotype analysis, including measurement of chromosome length and arm ratios was helpful in the identification of translocation homozygotes.

Thus, the technique adapted in our laboratory overcame the difficulties in resolving somatic chromosomes of safflower encountered by earlier workers (4, 10).

Translocations

Sixty-two translocations, 42 being simple interchanges, were isolated in the M_1 generation of gamma-irradiated populations. The pollen sterility of the interchange heterozygotes ranged from 1 to 99.6% with an average of 53.76%; 10 of the translocation heterozygotes showed pollen sterility comparable to the standard normal. The simple interchange heterozygotes at MI in 59% of the cells had 12 II (Fig. 2), but in the remaining 41% cells had characteristic chain and ring multivalents, mostly quadrivalents (Fig. 3). Chain configurations (Fig. 4) were in excess of the rings (Fig. 5) in most of the translocations. Alternate orientation of the quadrivalents was most common.

Thirteen of the 62 interchanges showed below 50% pollen sterility, i.e., less than the expected while 10 had pollen sterility ranging from 1 to 10%, which is comparable to that of the standard normal (1 to 4%). Low sterility (high stainability) in the translocation heterozygotes may be ascribed to directional disjunction, i.e., an excess of alternate disjunction at the cost of adjacent ones with little or no incidence of crossing over in the interstitial segments as was also observed in several other crops (1, 6, 17). Further, exchange of small segments with large ones and/or exchanges among small segments would result in frequent chain multivalents which are amenable to greater frequency of alternate disjunction and the interstial segment being small would have low frequency of crossing over and thus low sterility. In the present investigation, a majority of the interchanges, particularly those with high pollen stainability were characterised by chain configurations associated preferably with alternate disjunction. A preponderance of alternate disjunction in chain quadrivalents was also observed in other crops and this was attributed to the greater flexibility of chains. The high fertility translocation heterozygotes may be maintained in safflower populations. These can also be exploited for the production of segmental duplications (7).

From the 42 simple translocation heterozygotes ten translocation homozygotes were established. The chromosomes involved in each interchange homozygote were identified through karyotype analysis by comparing the relative chromosome length (I%) and arm ratio (Pa-value) with that of the standard I.C. 11842. The chromosomes interchanged were 6-8 (line 58) 1-3 (line 66), 3-12 (line 123), 3-10 (line 131), 3-6 (line 153), 4-6 (line 186), 4-8 (line 197), 3-8 (lines 208, 279) and 5-9 (line 290). The segment interchanges were not random, chromosome 3 (sat-chromosome) being involved in six of the ten translocations.

The isolation of the translocation homozygotes was based on the fact that the karyomorphology of the translocated chromosomes would be different from the standard chromosomes, barring highly symmetrical exchanges. Karyotype analysis is efficient only when the segments interchanged are considerably different in length or the exchange is between distinct regions, like that bearing a satellite. In the present case, it was effective in discerning the interchanged chromosomes since most of the interchanges involved unequal segments.

Additional translocation homozygotes, especially those involving the chromosomes 2, 7, 9, and 11 which were found not be be involved in the above listed stocks, are being isolated. Suitable crosses of marker stocks for thin hull, cup-leaf, spineless, fasciated capitulum and other traits have been crossed with the translocation stocks for chromosome mapping.

Induced Unreduced Microspore and Origin of Triploid

Three M_1 mutants showed unreduced microspores. These plants had two pairs of chromosomes involved in a translocation, and had a high pollen sterility (80-88%). A few shrivelled seeds were harvested, but none germinated. Other than poor growth, the plants appeared normal morphologically.

In the normal material, karyokinesis was characterized by the reduction division being perpendicular to the plane of equational division and cytokinesis started after the completion of the second division (Fig. 6), resulting in the formation of normal tetrads (Fig. 7).

In contrast, the mutants showed varying degrees of abnormalities in the shape of PMCs, anaphase I and II disjunctions, and subsequently in the production of microspores. On an average, 83% of the PMCs were spindle-shaped with isobilateral arrangement of the four nuclei (Fig. 8). Frequency of dyads, triads and tetrads were 17, 32 and 34%, respectively. Total absence of equational wall, resulting in the formation of two restitution nuclei, was observed (Fig. 9). Fusion of the two haploid nuclei, before or at the time of cytokinesis, apparently caused the doubling of the chromatin material (Fig. 10).

To investigate the mechanism of the formation of unreduced microspores, chromosomes at anaphase I and II and the mode of spindle orientation were analysed critically. From Fig. 11 and 12 it is evident that chromosome distribution at anaphase I and II was abnormal, resulting in the production of two adjacent haploid nuclei which fused ultimately. Such a condition led to the formation of triads. Fig. 13 and 14 lend support to the mode visualized for the origin of the unreduced gametes. In these figures it may be seen that the plane of the two divisions was not perpendicular to each other, unlike the normal case. This favoured the occurrence of two haploid nuclei without a reductional wall which fused to produce diploid microspores (Fig. 15, 16). Isolation of a triploid plant (Fig. 17) from the population may be explained due to fusion of such unreduced gametes with normal gametes.

According to Rhoades and Dempsey (15) unreduced gametes could arise in various ways: (i) somatic doubling in the sporogenous cells to form tetraploid tissue, (ii) doubling in the gametophytic generation, (iii) supression of the first nuclear division followed by a normal second division, (iv) a normal first division with the omission of the second division, and (v) a normal first division with chromosome replication occurring during interphase to form dyads in each sister cell followedby the second meiotic division. Results obtained in the present study are in favour of the fourth possibility where either the chromosomes did not separate in second division or equational wall failed to form and the formation of a reductional wall resulted in two unreduced spores per PMC.

One more possible reason for the formation of unreduced gametes may be added to the five possibilities suggested by Rhoades and Dempsey (15). It was observed that haploid gametes may fuse due to aberrant spindle mechanism and cytokinesis. In the present study spindle formation at anaphase I and II was oblique to the plane of normal division. This was accompanied by the failure of reductional walls which probably enhanced the chances of fusion of the two hoploid nuclei. Further, the observations have clearly indicated that cyto- and karyokinesis at anaphase I and II were independent of each other. Similar results were reported by Ramanna (14) in potato.

Induced Tetraploidy

Eight viable tetraploids were isolated which were morphologically distinct from the normal diploids. In general, tetraploids were vigorous in growth characters and stomata size. The eight polyploids did not differ from each other.

Mean frequency of univalents, bivalents and higher chromosome associations, chiasma frequency and pollen sterility in the induced polyploids are given in Table 1. The occurrence of univalents, bivalents, trivalents and quadrivalents ranged from 0 to 3, 5 to 22, 0 to 3 and 0 to 9, respectively, and the corresponding averages were 0.32, 16.40, 0.32 and 2.02. It may be noted that the tetraploids, in general, showed a preponderance of bivalents, whereas trivalents were rare. The chiasma frequency among the tetraploids was almost alike, but it was higher than that in the diploids. Anaphase I movements were normal. Pollen sterility in the tetraploids ranged from 9 to 41.5% with an average of 24.29% against 3.9% in the normal diploid. In some colchicine treated plants, pollen sterility ranged from 14.3 to 37.1% even though the chromosomes had not doubled. Direct action of colchicine was manifested through the occurrence of rudimentary anthers also.

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TABLE 1. Chromosome configurations, chiasma frequency and pollen sterility of the tetraploids

Culture No.	Univalents/ PMC	Bivalents/PMC		Trivalents/ PMC	Quadrivalents/ PMC	Chiasma Freq./PMC	Chiasma freq./ chromosome	Pollen sterility
		Ring II	Rod II					
2-16	0.21	17.08	5.00	0.21	0.79	42.86	0.890	41.50
3-16	0.17	18.82	3.55	0.17	0.64	44.27	0.920	33.30
3-17	Nil	18.20	3.00	Nil	1.40	45.00	0.940	24.50
5-2a	1.50	8.00	1.00	1.5	6.00	45.30	0.940	23.10
5-1a	0.10	19.60	3.40	0.10	0.40	45.30	0.940	13.10
7-2b	Nil	18.30	3.50	Nil	1.10	44.50	0.930	22.64
7-4b	Nil	20.80	2.40	Nil	0.40	45.80	0.950	9.00
8-11	0.60	10.40	2.00	0.6	5.40	44.20	0.920	27.20
Average	0.32	16.40	2.98	0.32	2.02	44.65	0.920	24.29
Control	Nil	9.00	3.00	Nil	Nil	21.00	0.875	3.90

LEGENDS OF FIGURES

Karyotype Analysis

Fig. 1. Karyotype analysis of normal safflower cultivar I.C. 11842.

Translocations

Fig. 2. Translocation heterozygotes -- 12 II

Fig. 3. Translocation heterozygotes -- 10 II + 1 IV

Fig. 4. Translocation heterozygotes -- 10 II + 1 C_4

Fig. 5. Translocation heterozygotes -- 10 II + 1 C_4

Induced unreduced microspore and origin of triploid

Fig. 6. Normal (second division A-II)

Fig. 7. Normal tetrad

Fig. 8. Mutant: spindle-shaped PMC with isobilateral arrangement of the four nuclei

Fig. 9. Mutant: Absence of equatorial wall -- two restitution nuclei.

Fig. 10. Mutant: Fusion of two haploid nuclei.

Fig. 11. Mutant: Abnormal A-I chromosome distribution.

Fig. 12. Mutant: Abnormal A-II chromosome distribution.

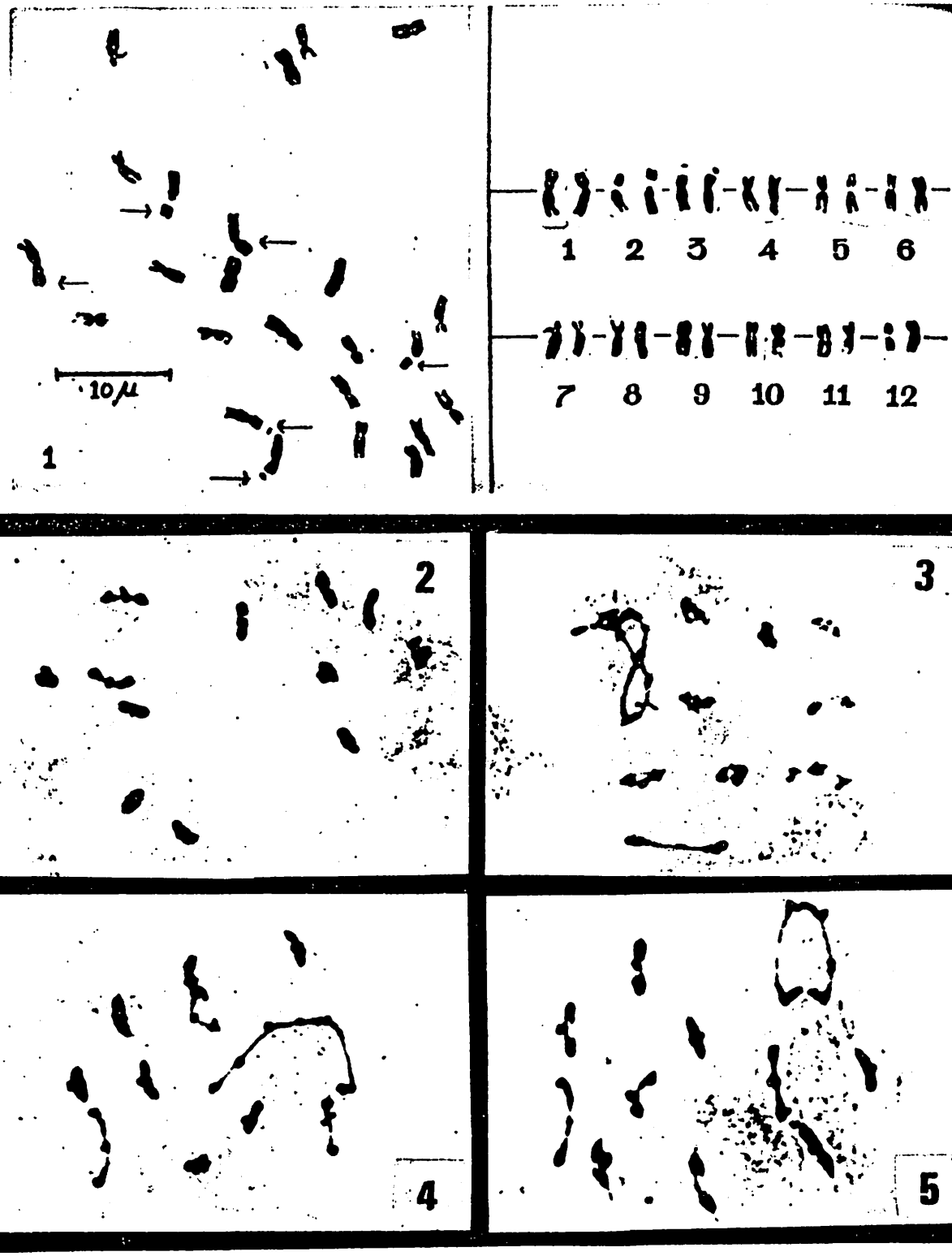
Fig. 13. Mutant: Abnormal second division

Fig. 14. Mutant: Abnormal second division

Fig. 15. Mutant: Formation of triad -- unreduced gamete in the middle

Fig. 16. Mutant: Unreduced microspore

Fig. 17. Mutant: Isolation of triploid -- root tip chromosome ($3n = 36$)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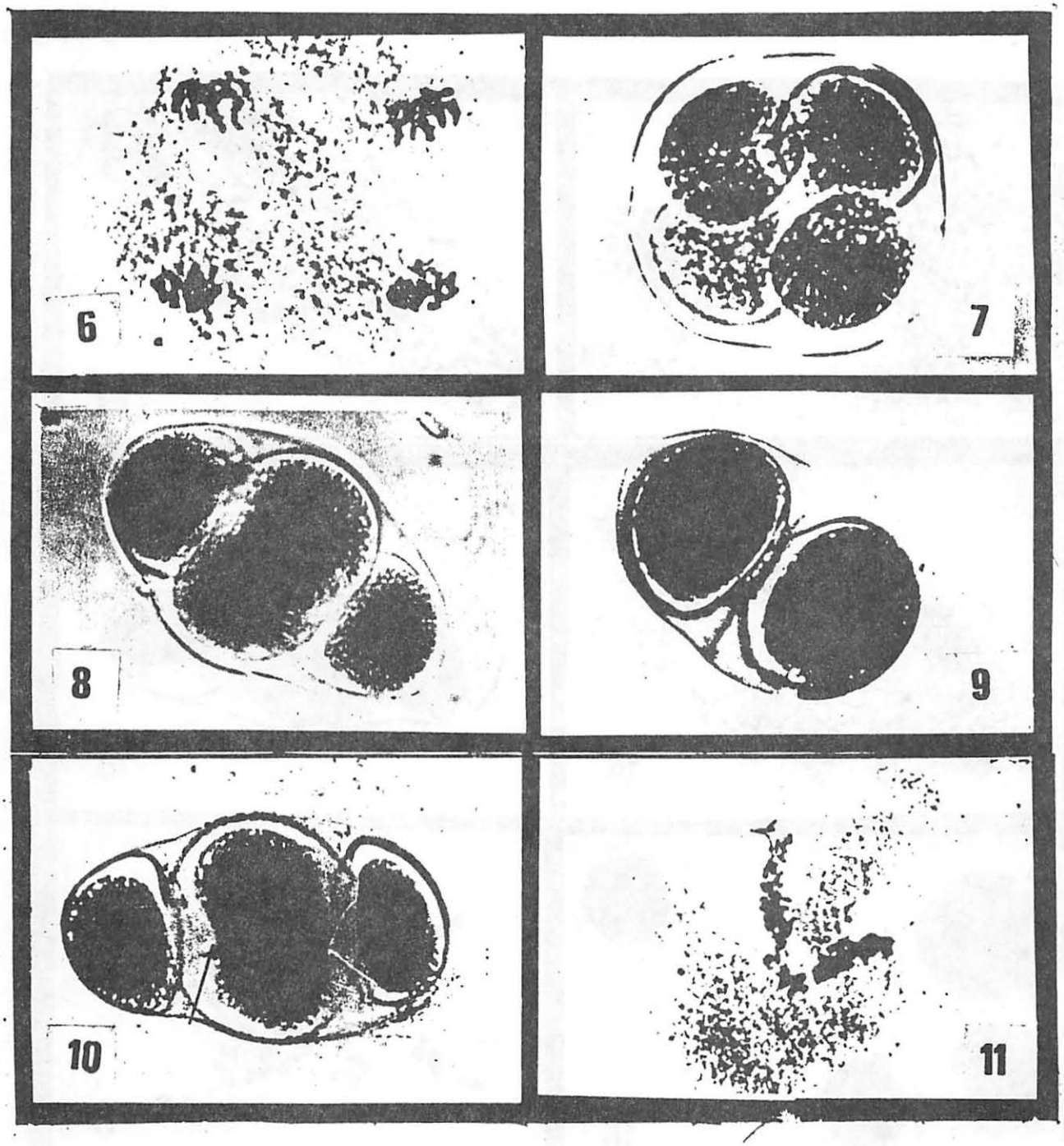
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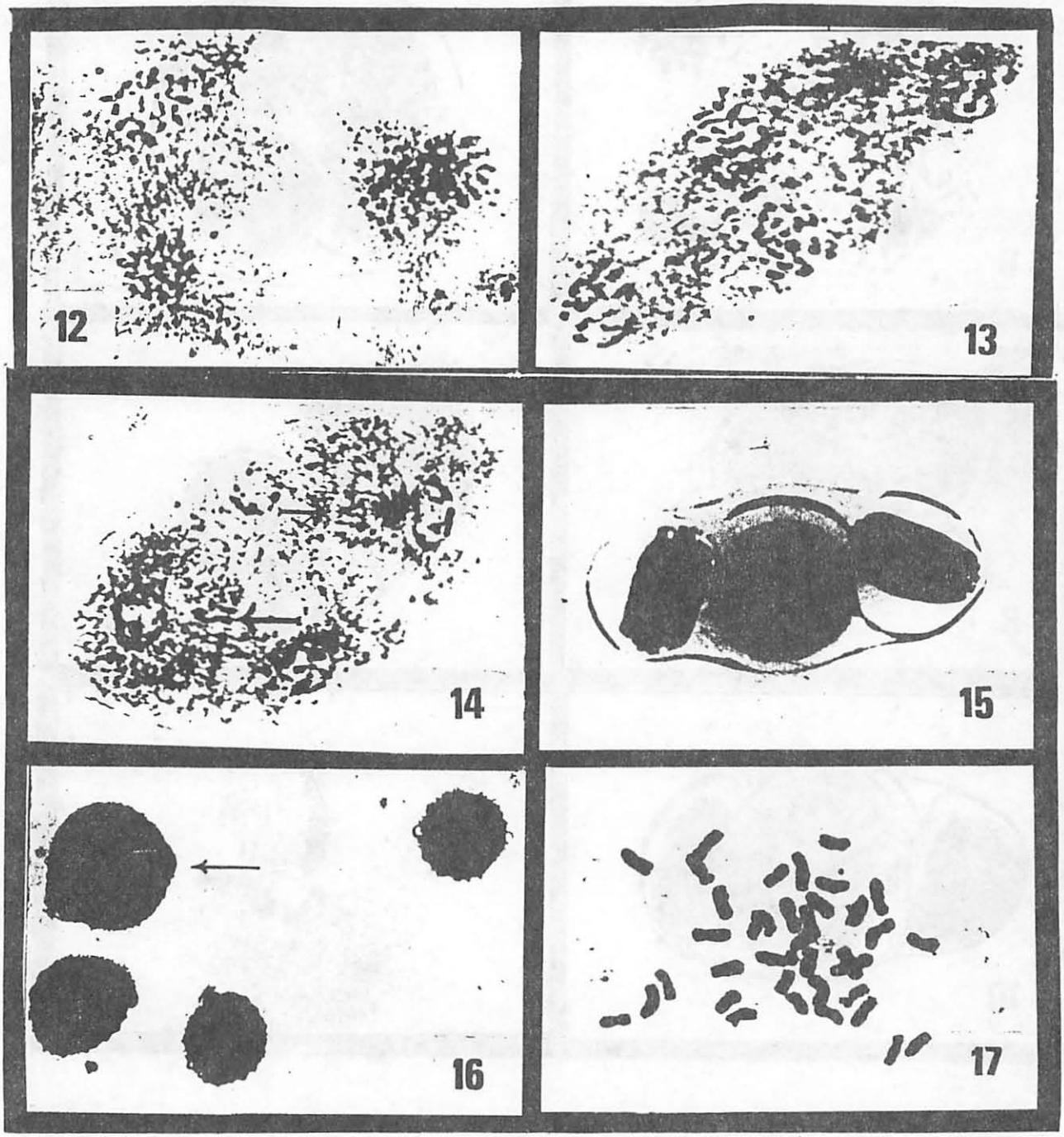
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SAFFLOWER BREEDING AND CULTIVATION IN INDIA

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ABSTRACT

India is one of the leading producers of safflower (Carthamus tinctorius L.) in the world and Maharashtra State has the largest acreage. The demand for safflower oil is increasing due to its polyunsaturated nature. As such, acreage under safflower cultivation is rapidly increasing, spreading both abroad as well as within India. It has been found to be drought resistant and can be grown not only on saline soils but also can stand saline-water irrigation tolerably well. Accordingly, its cultivation is picking up rapidly in the state of Rajasthan. Experiments conducted under dryland conditions in Udaipur reveal a yield potential of 33.3 q/ha against an average of 6-12 q/ha.

Safflower (Carthamus tinctorius L.), belonging to the family Compositae, has been grown for centuries in small patches in different parts of India, particularly in the states of Maharashtra, Karnataka, Andhra Pradesh, Orissa, Madhya Pradesh and Bihar. Safflower in India has been used mostly as a dye for food and clothing, but rarely as a cooking medium. As a cooking medium its importance increased only after its polyunsaturated nature came to be known. However, safflower is a minor oilseed in terms of total production. In world trade, India is the leading producer followed by the USA where production has been on the increase due to increased demand for the oil. Safflower production in India remained constant in the past but has increased considerably in recent years, and has made a dent into dry areas. In Rajasthan its introduction is recent, but it is spreading at a rapid rate. The area and production of safflower is given in Table 1. Chemical characteristics of the oil are given in Table 2.

Table 1. Safflower area and production in India.

	Area (thousand hectares)		Production (thousand tons)	
State	1977-78	1978-79	1977-78	1978-79
Andhra Pradesh	26.4	28.5	6.5	6.4
Bihar	0.6	0.6*	0.3	0.3*
Karnataka	159.7	168.2	37.1	38.1
Madhya Pradesh	1.2	0.9	0.2	0.2
Maharashtra	515.0	513.9	142.2	169.2
Orissa	3.6	4.5	1.5	1.9

*Previous year's data

Table 2. Chemical characteristics of safflower oil in comparison with other vegetable oils (11).

Characteristic	Normal[a]	Variant	Olive	Corn	Soya	Peanut	Linseed
Iodine value (wijs)	140-145	91-101	84-86	116-130	131-140	89-96	175-190
Color (Gardner)	6-10	-	-	-	8-11	-	8-11
Acid value	0.3-3.0	-	0.2-6.0	0.2-6.0	0.8-3.0	0.8-6.0	0.7-4.0
Saturated fatty acids[b]	6	4-8	12	14	14	18	10
Unsaturated fatty acids[b]							
Oleic	10-20	74-79	82	30	28	61	20
Linoleic	70-80	11-19	6	56	50	21	20
Linolenic	0	0	0	0	8	0	51
Grams of oil to give 100 gms of linoleic acid	145	-	1760	189	212	500	524
Calories in oil sufficient to give 100 gms of linoleic acid	130	-	1585	170	164	450	472

[a]=Average analysis of commercial safflower seed.
[b]=Percentage of total fatty acids.

IMPORTANCE

Safflower is becoming an important oilseed in view of the large quantity of polyunsaturated fatty acids contained in its oil and also because it augments the oil pool of the country. Major oilseeds are not able to meet the country's needs.

The safflower plant survives drought conditions. This is probably because of the fact that its roots go deep down in the soil and extract and utilize water available in the subsoil for its growth and development. It has also been reported that it can withstand salinity. As such it would be a useful crop to grow in saline soils as well as in command areas where salinity is gradually increasing and spreading. The average yield reported varies from 6 to 12 q/ha, but it appears that its full genetical potential has not been realized. The experiments conducted under All India Co-ordinated Research Project for dryland at Udaipur have given as high a yield as 44.3 q/ha. However, it may be pointed out that this crop is particularly sensitive to weather conditions. It has been observed that if there is adequate rainfall and plenty of moisture available in the soil at the time of germination, then it gives a high yield. Thus, one must guarantee the availability of moisture, particularly at the time of germination and initial stages of development. It is necessary to ensure that the roots penetrate deeper layers of the soil for sufficient absorption of water and better utilization of nutrients for further development of the plant. The data presented in Table 3 gives an idea about the yield in consecutive years taking into consideration the date of sowing as well as the rainfall during the growth period.

Table 3. Yield, date of sowing, date of harvest and rainfall during 1976-1980.

Character	1976	1977	1978	1979	1980
Average seed yield (q/ha)	12.8	6.1	6.8	40.7	23.5
Date of sowing[a]	11/10/75	25/9/76	22/9/77	16/10/78	3/11/79
Date of harvest	31/3/76	25/4/77	23/4/78	19/4/79	3/5/80
Rainfall during crop growth (mm)	59.7	110.6	Nil	50.8	177.4
Seed yield range (q/ha)	--	--	--	33.4-44.9	18.0-36.4

[a]Day/month/year.

REVIEW OF WORK

Safflower is a member of the family Compositae and has a capitulum as an inflorescence. The plant is 130-150 cm tall, and has a tap root with many laterals. The stem is long, stiff, solid, with many branches. The extent of growth and branching greatly depends on the environment.

Darlington and Janaki-Amal (3) reported $2n = 24$ as the chromosome number for C. tinctorius. Richharia and Kotwal (9) also reported $2n = 24$ without any exception. Subramanyam (10) carried out a karyotypic analysis of the somatic chromosome complement of C. tinctorius, C. caeruleus and C. lanatus. The somatic chromosome number of C. caeruleus was reported for the first time as $2n = 24$. A new tetraploid of C. lanatus with $2n = 48$ was identified. This was distinct from the karyotype having $2n = 64$ as reported earlier by Poddubanja (5).

Rai (6) reported that safflower showed reduced germination under saline conditions. He opined that reduction in germination under saline conditions could be due to increased osmotic pressure in the soil solution which may have consequently resulted in diminishing the absorption rate causing moisture stress in the seed. He further suggested that reduction in germination could also be due to the seed embryo. However, despite the reduction in seed germination, an increase was obtained in straw and seed yield in almost all the saline water treatments. The results of these experiments lead to the conclusion that irrigation with saline water may be injurious for germination, but the seeds that germinate respond positively to the application of saline water. Advantage can be taken of this information and the seed rate manipulated so as to give an optimum plant stand to enable the crop to be grown profitably. The results obtained by Rai (6) in regard to effect of saline water irrigation on germination and yield are presented in Table 4. He also observed the response of different varieties to application of saline water (Table 5). Earlier, Boyko and Boyko (2) mentioned that safflower was a very tolerant crop as it was grown extensively in certain countries under irrigation with undiluted sea water having a salt concentration up to 36,000 ppm. However, he also mentioned that germination was affected.

Table 4. Effect of saline-water irrigation on germination and yield in safflower (Rai, 1977).

EC of irrigation water (mmhos/cm at 25 C)	Soil salinity at post crop harvest E Ce (mmhos/cm)		pH (1:2)		Seed germination (%)		Straw yield/ha (q)		Grain yield/ha (q)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	1973-74	1974-75	1973-74	1974-75	1973-74	1974-75
Control (2.1)	4.8	3.6	8.8	8.8	69.00	75.10	49.79	63.92	14.92	9.35
4	6.0	5.1	9.1	8.7	68.40	78.77	51.55	73.78	13.95	10.35
6	-	-	-	-	65.60	-	53.65	-	14.01	-
8	16.8	8.4	9.0	8.8	66.73	51.53	56.45	74.24	16.22	11.45
12	16.0	12.0	8.6	8.8	-	36.33	-	82.34	-	13.52
SEm+	-	-	-	-	4.44	3.20	4.88	13.84	2.05	0.93
CD at 5%	-	-	-	-	NS	7.80	NS	NS	NS	2.29

Table 5. Varietal tolerance in safflower to the application of saline water (Rai, 1977).

Variety	Seed germination (%)			Straw yield/ha (q)			Grain yield/ha (q)		
	1973-74	1974-75		1973-74	1974-75		1973-74	1974-75	
S 2-27	72.56	68.25	-10.08	52.21	70.35	+ 5.95	15.19	9.95	+ 0.49
S 3-16	53.50	58.25	-27.41	50.04	68.40	+ 0.67	16.36	14.18	+ 0.78
S 4-35	53.50	64.67	-10.99	51.55	71.93	+ 1.00	16.05	13.26	+ 2.33
S 7-8-3	54.19	61.62	-11.74	55.10	70.63	+21.93	14.30	13.55	+ 4.02
IC 11842	66.88	62.50	-13.83	49.33	76.30	+21.04	13.40	10.92	+ 4.66
SF 5	82.81	57.17	- 8.83	58.01	74.72	+ 5.39	16.69	10.18	+ 3.25
500	73.75	58.83	-12.17	45.23	71.76	+20.43	12.65	10.44	+ 2.11
6401	72.68	57.50	-21.16	39.05	46.58	- 6.43	9.20	7.28	+ 0.42
6515	86.06	56.75	-17.91	67.98	108.42	- 1.84	19.59	11.05	- 2.89
N 7	58.38	58.50	-12.50	46.35	76.58	-28.32	14.31	10.87	+ 3.01
SEm+	3.82	4.65		4.47	7.60		2.12	1.29	
CD at 5%	7.49	8.09		8.77	15.22		4.17	2.58	

+ or - sign indicates respective mean deviation from the control.

FUTURE PROSPECTS

Safflower has a bright future in India and particularly in those states which frequently suffer from drought, lack fresh water or where only saline water is available for crop production. In this connection, particular mention may be made of Rajasthan, Madhya Pradesh, Maharashtra and Andhra Pradesh. Three-fourths of the area of Rajasthan receives very low amounts of rainfall. As such, safflower would be a useful crop for the state. In addition most of the wells in the state have saline water which could profitably be utilized for growing safflower. This would to a certain extent help in reducing the shortage of edible oils. Similar conditions prevail in the states of Maharashtra, Madhya Pradesh and Andhra Pradesh. In these states too, safflower cultivation could be encouraged. In Maharashtra this crop has a bright future, particularly in coastal areas where saline seawater could be utilized for irrigation as mentioned by Boyko and Boyko (2).

Not much work has been done on the breeding aspects of this crop for evolving high yielding varieties since the scientists working in the field of oilseeds were mostly directing their energies towards the improvement of major oilseeds. However, some improved varieties do exist. Nevertheless, the work of developing new improved varieties and analysis of yield contributing characters have recently been taken up by scientists in various agricultural universities. Attempts are also being made to evaluate a large world collection of safflower germplasm available in this country.

Ashri et al. (1) found three major yield contributing characters, viz., number of heads per plant, number of seeds per head and seed weight. Patil and Jadav (4), while studying varietal differences in yield of safflower, reported that secondary heads contributed most towards yield because of their greater number, and there was not much difference in yield per head. They further showed that in addition to number of heads borne by the plant, the potential of the heads in terms of seed size and seed number is also an important yield contributing factor.

In Rajasthan germplasm collection work has also been taken up at the Agricultural Research Stations at Kota and Sumerpur. These two stations have isolated some very useful material which needs trial and testing on an extensive scale before improved varieties are released.

The studies of Rao and Seshadri (7) and Rathore et al. (8) have indicated that varieties with spines give higher yield than spineless varieties. This fact needs to be verified further. The spines are useful since this plant is usually grown as a border and provides protection against animals grazing into the fields and damaging more lucrative crops grown by the farmers. However, if the spines are positively correlated with higher yields this character could be used as a marker in breeding work. Spines are a xerophytic character conferring an advantage to the oilseed in drought-prone areas. This needs evaluation and study.

It has been reported that the safflower oil cake is commercially less valued because of the large amount of fiber present in it. In view of this, attempts need to be made to breed varieties having seeds with thinner hulls which would reduce the excessive fiber content in the cake and make it commercially acceptable.

The above studies reveal that safflower cultivation has good prospects in India in view of the increasing demand for its oil, and also on account of chronic shortages in the country of cooking media having a polyunsaturated nature. Its ability to tolerate drought and saline conditions and to utilize the saline water for irrigation purposes confers on it an added advantage. Accordingly, immediate steps need to be taken to make a detailed study of this crop as a basis for developing varieties for our specific needs.

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POTENTIAL OF SAFFLOWER (CARTHAMUS TINCTORIUS L.) IN ITALY: FIRST YEAR OF STUDY

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ABSTRACT

Results are presented of an experimental trial carried out simultaneously in eight locations of central and southern Italy. A comparison of six safflower varieties was made under a wide range of environmental conditions in order to identify areas which have potential for safflower production. Results from the first year of joint research show good promise for the introduction of safflower in the south while the establishment of safflower as a crop in central Italy appears limited.

SOWING TIMES AND PLANT POPULATIONS OF SAFFLOWER (CARTHAMUS TINCTORIUS L.) IN SICILY

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ABSTRACT

Investigations were carried out in 1979 and 1980 on the influence of combinations of sowing time (from December to April) and plant populations (30, 60 and 90 plants/m^2) on growth and yield of safflower. At selected times, from day of emergence to harvest, plants of each combination were harvested and dry weights and leaf areas were recorded. Classical methods of growth analysis were performed on the data.

The rates of dry matter production and leaf area accretion were both affected by climatic conditions. Higher yield appeared to be more closely related to higher water availability during the seed-filling period.

CORRELATION AND PATH COEFFICIENT ANALYSIS OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) FODDER IN RAINFED CONDITIONS

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ABSTRACT

Dual purpose (green fodder and ratoon seed) safflower is promising in north Indian rainfed regions. Therefore, in order to ease selection, the relative importance of green fodder contributing characters was estimated by adopting path coefficient analysis. The maximum positive direct effect of stem weight (9.802) with negative estimates for dry matter, leaf number and area suggested the promise of formulating a plant ideotype with increased leaf area, plant height, leaf number and *in vitro* dry matter digestibility.

Dual purpose (fodder and ratoon seed) safflower genotypes gave high and stable yields in rainfed conditions (11). With fodder harvested 100 days from seeding, EC 100602 as a dual purpose genotype indicated economically sound and extendable prospects in rainfed conditions (15). Therefore, it was desirable to assess the relative importance of characteristics contributing to fodder yield.

MATERIALS AND METHODS

In all, 24 promising dual purpose safflower strains were raised (6 x 4 m plot; spacings 40 x 10-15 cm) during 1974-75 in a randomized block design with three replications. Ten competitive plants were studied for fodder yield and its contributing characters (Table 1). Ten leaves/genotype/plant/replication were outlined and areas measured by a planimeter. The protein content (%; (8)) and *in vitro* dry matter digestibility (IVDMD; (19, 3)) from random sample/treatment were determined. Data for protein content and IVDMD were transformed to inverse sine (6). The averages were used for estimating correlation coefficients (r) at genotypic (g) and phenotypic (ph) levels (5), path coefficients (4) at g level, genotypic and phenotypic coefficient of variability (CV), heritability (broad sense, H) and genetic advance (Gs; (1)).

RESULTS AND DISCUSSION

With genetic diversity between dual purpose and seed alone genotype (10), isolation of high yielding and stable strains (11) and economic feasibility (15), in rainfed conditions, it was desirable to estimate direct and indirect effects and genetic parameters (H and Gs) of fodder yield contributing characters in order to facilitate selection (Table 2). The r_g estimates, denoting pleiotopic and linkage effects and additive genetic components of covariance, are influenced by environment (5) and have population specificity (12). Further, r_g estimates gain importance with high heritability (5). With these considerations in view, the parameters have been presented in Tables 1 and 3.

Table 1. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficient between safflower fodder yield and its contributing characters.

Sl. no.	Character	1	2	3	4	5	6	7	8	9
1.	Fodder yield per plant	-	0.949*	0.888*	0.551*	1.060*	1.016*	0.244	0.767*	-0.126
2.	Dry matter per plant	0.997*	-	0.928*	0.613*	1.021*	1.004*	0.265	-1.267*	-0.057
3.	Plant height	0.776*	0.772*	-	0.708*	0.956*	0.939*	-0.129	-1.207*	-0.379
4.	Leaf number per plant	0.642*	0.674*	0.720*	-	0.531*	0.593*	-0.586*	-0.790*	0.110
5.	Leaf weight per plant	0.939*	0.992*	0.588*	0.505*	-	1.036*	0.345	-1.516*	-0.052
6.	Stem weight per plant	0.964*	0.944*	0.826*	0.648*	0.867*	-	0.191	-1.342*	-0.200
7.	Leaf area	0.269	0.227	0.020	-0.140	0.344	0.236	-	-0.055	0.190
8.	Protein %	0.380	-0.113	-0.309	-0.002	-0.026	-0.166	-0.071	-	0.795*
9.	IVDMD %	-0.090	-0.104	-0.123	0.077	-0.093	-0.091	-0.021	0.170	-

* significance at 1% level.

Table 2. Direct and indirect effects on safflower fodder yield at genotypic level

Sl. no.	Characters	Effects on green fodder yield									r_g with fodder yield
		Direct effect	Indirect effects via character 2	3	4	5	6	7	8	9	
2.	Dry matter	-2.977	-	-0.942	-2.784	-0.639	9.802	-1.006	-0.380	-0.123	0.949*
3.	Plant height	-1.015	2.763	-	-3.216	-0.611	9.204	0.490	-0.380	-0.821	0.888*
4.	Leaf number/ plant	-4.542	-1.825	-0.719	-	-0.339	5.813	2.226	-0.300	0.238	0.551*
5.	Leaf weight/ plant	- 0.639	-2.977	-0.970	-2.412	-	9.802	-1.310	-0.380	-0.113	1.000*
6.	Stem weight/ plant	9.802	-2.977	-0.953	-2.693	-0.639	-	-0.725	-0.380	-0.433	1.000*
7.	Leaf area	-3.798	-0.789	0.131	2.662	-0.220	1.872	-	-0.025	0.412	0.244
8.	Protein	0.380	2.977	1.015	3.588	0.639	-9.802	-0.247	-	1.722	0.767*
9.	IVDMD	2.166	0.170	0.385	-0.500	0.033	-1.960	-0.722	0.302	-	-0.126

Table 3. Estimates of genetic parameters for quantitative characters in safflower green fodder yield/plant

Sl.	Parameters	Fodder yield	Dry matter	Plant height	leaf number	Leaf weight	Stem weight	Leaf area	Protein %	IVDMD
1.	Mean	95.008	16.949	69.111	22.233	47.681	46.994	42.315	14.139	78.974
	± SE	18.299	3.155	5.905	1.198	9.113	10.897	4.510	1.056	1.375
2.	Error CV %	33.361	32.246	14.799	9.331	33.104	40.162	18.461	12.935	3.016
3.	GCV	22.112	21.579	19.032	8.527	13.642	28.413	6.890	5.951	3.350
4.	PCV	40.024	38.800	24.109	12.641	35.805	49.197	19.705	14.237	4.507
5.	H	30.523	30.932	62.320	45.499	14.517	33.356	12.26	17.473	55.233
6.	Gs % mean	25.166	24.723	30.951	11.848	10.708	33.805	4.963	6.505	5.128

The r_g and r_{ph} estimates between green fodder yield and its contributory characters (except leaf area and IVDMD) were highly significant and positive. These two traits, in general, had no significant association with other characters except a negative r_g estimate between leaf area and leaf number indicating the usually observed antagonism. The other positive r_g estimates for protein and IVDMD and for protein and fodder yield signified useful relationships. The remaining r_g estimates were significant and negative. The corresponding r_{ph} values were not significant. These antagonisms needed the path coefficient approach for clear comprehension.

Stem weight and IVDMD had positive direct effects on green fodder yield, the remaining characters, notably dry matter, leaf number and leaf area, had negative effects. This suggested that stem weight tended to have a major contribution to fodder yield. This is unpromising fodder nutrition. Therefore, two approaches can be: thick planting and isolation of fodder yielding genotypes. The first approach is antagonistic for ratoon seed yield due to etiolation and likely lodging due to high wind during winter. Apart from this, there is a limit for productive plant population/unit area with limited soil moisture in rainfed conditions, more so when the safflower life cycle in northwestern India is about 180 days. Therefore, the second alternative is promising and genotypes, namely EC 100586 (1.50), EC 100583 (1.85), EC 100602 (2.35) and EC 100591 (1.55) with reasonably high leaf:stem ratios are available. Interestingly, the dual purpose genotype EC 100602 (16.2% protein; 78.1% IVDMD) was economically sound (15). The visual observations indicated that higher number of larger and functional leaves, especially near the ground, can be a criterion for such isolations. The positive indirect effects of leaf number and leaf area also supported this relationship. Another course with relatively less antagonism would be increasing leaf area to use positive indirect effects due to plant height, leaf number, stem weight and IVDMD. The estimation of safflower leaf area *in situ* by linear measurement is rather easy (13). Yet another proposal is the quick estimation of protein content, using the positive direct and indirect effects on protein content of plant height, leaf number, leaf weight and leaf area.

The low GCV estimates indicated the desirability of genetically diverse germplasm. Mehrotra (9) has summarized Ashri's (2) proposals to identify countries with respect to specific characters. It is hoped that this would ease germplasm collection. The low H estimates for yield and yield contributing characters and negative associations have disadvantages during selection. Singh (16, 17) suggested that disadvantages due to low heritability can be compensated by imposing restrictions during selection. Thus, an approach of balanced selection/improvement in simultaneously selected characters can be achieved by choosing suitable combinations of economic weights with some loss in overall genetic gain due to restriction (18). Therefore, a stepladder approach (14) would be useful in creating meaningful material by converging desired gene combinations and linkages (7).

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REAPPRAISAL OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) BREEDING FOR RAINFED CONDITIONS

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ABSTRACT

Safflower (*Carthamus tinctorius* L.) is raised in ever-changing rainfed agroecosystems. Its poor productivity is due to low plant population per unit area at harvest and poor development of yield contributing characters. Therefore, reappraisal of safflower breeding procedures is desirable. The following recommendations are made:

a) The poor germination due to moisture and temperature stresses during planting could be ameliorated by quickly isolating genotypes with positively skewed and peaked germination rate and high germination percentage in laboratory simulated moisture and temperature stresses.

b) The present view favored multilocation testing of promising material in space and time to isolate phenotypically stable and high yielding genotypes. Data so obtained could be used for studying heritability, genetic advance, genetic diversity, correlation coefficients and path analysis, and plant ideotypes in space and time for selection and hybridization programs.

c) With the importance of soil moisture and atmospheric stresses in formulating safflower ideotypes, two agroecologically different situations were considered and the characteristics of the likely desirable plant type for each situation were described. The roles of individual plant efficiency and population efficiency as they contribute to yield in different rainfed situations were developed.

Because safflower is a self-fertilized crop the best approaches in developing populations for selecting desirable safflower material for different rainfed agrosystems are intensive hybridization programs involving multilocation testing at every stage, increasing the genetic base, and fixing additive gene effects from divergent sources.

Statistics of safflower in India are: area 650,000 ha; production 210,000 metric tons; and productivity 338 kg/ha. Therefore, with little chance of increasing the area of production in semiarid tropical regions, increased productivity is necessary to meet increasing demand. Safflower with long vegetative phase (130-135 days) and succulent and leafy development in some genotypes has shown promise for nutritious fodder and ratoon seed (12). Green fodder is generally not available in rainfed regions during the winter season. These dual purpose genotypes are stable yielding (15) in nontraditional regions. India, a center of origin of safflower (18), has vast genotypic variability.

Successful breeding programs recognize the problems and assets associated with safflower. Mehrotra (12) suggested those in Table 1.

Table 1. Problems and assets of safflower.

Problems	Assets
1. Trend for location specific varietal adaptation (19) and thermosensitivity limits adaptability.	1. Remarkable drought and frost tolerance, and regeneration after frost damage.
2. Staggering/poor germination associated with high temperature and moisture stresses give unproductive plant populations/unit area.	2. Genetic variability for disease and pest resistance is available (2).
3. Low harvest index fluctuates in space and time.	3. Amenability of yield contributing agronomic practices to support non-cash/low cost production technology (13).
4. Vulnerability to diseases and pests decrease productivity.	4. Remarkable adaptability for latitude, altitude, salinity, alkalinity and acid soils, rainfall (650-1000 mm/year), and profile depth (19).

The characteristics mentioned in Table 1 indicate the desirability of a multidisciplinary approach in safflower improvement programs. Further, even with a regional list of improved varieties in India, low productivity could be due to a weak agricultural extension link between research workers and farmers and lack of extensive seed multiplication programs (12). The yield depression due to lack of trace elements cannot be ruled out.

Essentially, crop survival in rainfed conditions involves the economic use of stored bio-water during stresses (1). Besides this, characteristics conferring drought tolerance generally do not utilize productive rainfed seasons (6).

Two divergent views for choosing environments for rainfed crop breeding include: the utilization of the driest environment (7); and the breeding in optimum conditions to gain the expressions of high heritability and genetic advance for productivity because of high positive correlation between performance in optimum and stress agroenvironments. Early matur-

ing, stable and reasonably productive genotypes in space and time can be selection criteria (6, 11, 12).

The diversified interactions of agroecosystems in rainfed regions are due to differences in the soil-plant-atmosphere continuum. Along with climatic factors such as erratic moisture and temperature stresses during the crop cycle, soil properties (sandy loam to clay, alkalinity/salinity, profile depth and fertility) influence germination rate and percentage, plant development, seed filling, maturity and productivity. Further, there is a trend to use varieties developed in favorable environments (i.e., without water stress and with adequate fertility) in location/region specific rainfed conditions negating the very objective of such programs because of adverse genotype-environment interactions for yield and its contributing characters.

PLANT IDEOTYPE CONSIDERATIONS

Usually fertile and water retentive heavy soils suffer from low infiltration of often torrential rainfall and slow release of water for plant use. These soils do not permit deep roots and crack upon drying which prunes roots, thus reducing water availability. Apart from this, less diurnal temperature differences are unfavorable for biomass accumulation (10) and with the above mentioned factors, the developmental conditions are harsh. Under these situations, intuitively, the alternative considerations for a safflower ideotype can be:

1. Synchronous germination, early vigor and flowering followed by high number of capitula/plant on primary and secondary branches, large number of seeds/capitulum, and early maturity. This consideration is based on per plant efficiency.

2. With population efficiency, along with above-mentioned characteristics in greater intensities, the likely useful change can be low capitula number/plant mainly on primary branches. Probably thermal insensitivity during germination, flowering and seed filling stages would be demanding. The choice of these alternatives would depend on the severity of the habitat.

Another agroecosystem can be deep loam soil with a high infiltration rate and quick release of moisture. The magnitude of diurnal temperature differences favor biomass accumulation, and long crop cycle is possibly due to delayed temperature rise. This situation calls for increasing productivity by favorable manipulation of harvest index (5). The speculation for the ideotype is: synchronous germination with 60-65 days vegetative phase (without the consideration of safflower fodder) for the reasonable development of yield contributing characters and reasonably prolonged flowering duration. Thermal insensitivity will be essential. In case the frequency of frost is high, with relatively longer winter season the consideration can favor long-phase (130-140 days) for fodder and ratoon seed. The distribution of capitula (with large number of seeds) can be on primary and secondary branches. The extent of their distribution on tertiary branches can be judged by analysing number of seed bearing capitula/total capitula.

In brief, it appears that while varietal development based on population efficiency suits southern India, per plant efficiency can do good in

northern India. The association of leaf spininess with yield (2) suggests its utility in ideotype consideration.

Even when increased seed size may be due to increase in hull thickness, and does not indicate oil content increase, yet its consideration should be backed by population specific correlation and path coefficient studies because of its antagonism with yield (19) and yield contributing characters (16). Thus contrary to Hall et al. (6), these studies should be encouraged for further refinement of above suggested plant ideotypes, and to discourage selection based on one or a few questionable characters (12).

GENOTYPE-ENVIRONMENT INTERACTIONS

The g x e interaction studies, though significant in crop improvement (3, 4, 12), are time consuming and costly. The scope for economy exists in manipulating agronomical inputs (15) like planting dates, fertilizer and irrigation schedules and by considering border and middle plot yields (12) for unilocation testing of large genetically diverse populations. The judicious applications of these differentials help in identifying photo- and/or thermo-insensitive genotypes and likely useful agronomic practice for one or a group of genotypes. These important considerations can be verified by considering differentials like latitude and altitude in space and time experiments. These approaches provide unique opportunities for provisional allocation of genotypes to different locations/regions to economize further testing. Yet another outcome will be a trend for productive plant ideotype and identification of genetically diverse stable material for crossing.

BREEDING SAFFLOWER FOR YIELD

The above-mentioned approaches will indicate the strong and weak attributes of existing germplasm, and the need will be for removing weaknesses by diversifying collections. Mehrotra (12) has described these sources (2).

Safflower is mainly autogamous (12), therefore, with the presence of antagonistic tight linkages, locking of genetic variability and absence of desirable genes with diverging problems, a well conceived crossing program will be desirable. Present approaches for easy and quick emasculation (9), Nimbkar Agric. Res. Inst., Phaltan, Maharashtra, India) and oil estimation (17) make this process of selection easier. The following brief (8) suggests a likely useful program (12):

1. Testing of a large range of material against a heterozygous tester -- a double cross from genetically diverse well adapted parents.

2. Multilocation testing of topcrosses. In case sufficient seed is a problem, their F_2 seed should be used. This will help in identifying parents for the crossing program.

3. Make crosses between genetically diverse lines and F_1 or F_2 populations.

4. Multilocation testing of the F_2 with parental lines and the best available checks will provide a basis for rejecting unproductive crosses. It will be desirable to effect multiple crosses, utilizing the best F_1 combinations to have populations with a wide genetic base. The advantage

is that a "wide range of the attributes and gene systems contributing to yield and adaptation are brought together for exploitation." Parallel to this program, diallel or partial diallel analysis for obtaining information on general and specific combining ability effects, magnitude of additive complementary epistatic effects, which are fixable components of genetic variation, should be attempted.

5. The selected cross combinations can be treated in the following three ways:

a) Selecting cross combinations which have shown considerable residual heterosis in F_2 and have given yields equal to or superior to the best check. This material can be sifted for superior yielding pure lines.

b) Adoption of biparental crosses in F_2 to accumulate favorable and fixable gene effects.

c) Select F_1's whose F_2's gave superior performance in multilocation testing. Use parents in multiple crossing and building up panmictic populations with the help of genetic or chemically induced male sterility. This will tend to release locked up genetic variability through recombinations between linked genes.

6. Make selections in the usual way.

This productive program of work can support new cropping patterns and safflower cultivation in nontraditional regions. Under these circumstances, it will be useful to watch the changing patterns of disease and pest problems.

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PHENOTYPIC STABILITY STUDIES IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) FOR GREEN FODDER AND RATOON SEED YIELDS IN RAINFED CONDITIONS OF HISSAR

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ABSTRACT

Certain semispiny types of safflower (*Carthamus tinctorius* L.) showed promise for both green fodder and ratoon seed yields at Hissar because of their long vegetative phase (130-140 days), their regenerability, and their abundant succulent leaves. The changes in rainfed agroecosystems due to erratic rainfall distribution pattern in space and time necessitated the isolation of phenotypically stable high yielding dual purpose genotypes. The other aim was to judge the efficacy of management in creating environmental differentials to facilitate these studies.

Safflower as a drought tolerant *rabi* (October - March/April) edible oil yielding rainfed crop is raised in southern and northeastern Indian states. Certain juicy and leafy semispiny genotypes were promising for nutritious fodder and ratoon seed yields in erratic rainfed conditions of Hissar (7, 8). Since green fodder is not available for the choicest breeds of dairy animals during rainfed winter seasons, identification of high and stable yielding dual purpose genotypes is desirable for increasing productivity and stabilizing incomes of farmers faced with agroproduction risks. Another aim was to test the efficacy of creating environments by manipulating managerial input and thus supplementing and economizing space and time experiments by unilocation testing. Besides this, diverse production from a source is a useful proposition (11).

MATERIALS AND METHODS

Fifteen promising dual purpose safflower strains were included in a randomized block design with three replications during 1974-75, 1975-76 and 1976-77. The plot size, 12 x 4 m with 40 x 10-15 cm spacings, accomodated fodder harvests 90, 100 and 110 days after planting. However, during 1974-75, only 100-day fodder harvests could be taken and ratoon seed yields were not available due to intense drought. Linearly transformed data were processed for stability parameter estimates (3).

RESULTS AND DISCUSSION

Genotype x environment interactions (g x e int.) are essential in crop improvement programs (2, 5). Pooled ANOVA (Table 1) for green fodder and ratoon seed yields indicated the significance for genotypes, environment (linear) and g x e int. (linear). The significance of pooled deviation for ratoon seed yield suggested genetic variability (9, 10). Along with these inferences, considerable magnitude for environmental additive effects for fodder and ratoon seed yields (Table 2) not only supported the logistic for such unilocation testing but also suggested that for ratoon seed yield, a favorable environment was that provided the 90-day harvest. The inverse

Table 1. Pooled ANOVA of safflower genotypes for fodder (q/ha) and ratoon seed (kg/ha) yields

Sources of variation	Fodder yield DF	Fodder yield MS	Ratoon seed yield DF	Ratoon seed yield MS
Total	104		89	
Genotype (g, MS_1)	14	3355.29**	14	117578.07**
Environments (e)	6	41835.83**	5	1562483.00**
(g x e)	84	694.49	70	23235.60**
e + (g x e)	90	3437.24**	75	125865.45**
e (linear)	1	251012.58**	1	7813419.00**
g x e (linear) (MS_2)	14	1818.74**	14	20225.75**
Pooled deviation (MS_3)	75	438.36	60	22388.82**
Pooled error	196	853.43	168	8498.34
MS_1/MS_3		F = 3.93**		13.83**
MS_2/MS_3		F = 4.15**		0.90 NS

* and ** denote significant at 5 and 1 per cent levels

Table 2. Environmental additive index for safflower fodder and ratoon seed yields

Yield	Environments						
	1974-75	1975-76			1976-77		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Green fodder	-25.67	-9.20	40.40	95.07	-50.93	-42.13	15.53
Ratoon seed	-	448.40	-49.07	-441.40	224.07	76.07	-258.07
Fodder harvest days	100	90	100	110	90	100	110

relationship between fodder and ratoon seed yields existed because delayed fodder harvesting with increasing moisture stress resulted in low ratoon seed yield. The economically viable compromise favored a 100-day fodder harvest (11) because spines stiffened later. This scheme has the distribution of fodder over time which can be extended further by manipulating planting dates. The opportunities offered are: (1) seed alone; (2) fodder and ratoon seed; and (3) two fodder harvests, and users have the choice of manipulating the above mentioned inverse relationship.

With regard to stability parameters, Eberhart and Russell (3) suggested the use of linear and non-linear components of g x e int. for isolating stable genotypes.Paroda and Mehrotra (10) advocated for linear regression (bi) to measure response and deviation from regression (s^2di) to indicate stability of genotype. Thus, a genotype with high yield (μ + di; (1)) and bi not significantly different from unity (non-responsiveness) and low estimate of deviation from bi (predictability) was considered desirable for rainfed conditions (9).

The stability parameters for fodder and ratoon seed yields indicated that with the exception of EC 100583, EC 36340 and S 144 for fodder, bi estimates for both characters were not significantly different from unity. The SE bi estimates were mostly low. Thus, EC 38478, EC 35737, EC 100602 and IC 11175 were useful dual purpose strains for rainfed condtions. Among these, EC 100602 indicated extendable economical promise (11). The genotype S 144 was interesting because with the highest green fodder yield and reasonably good ratoon seed productivity it could not qualify for rainfed conditions because its bi was significantly different from unity. This expression therefore indicated the utility of this study.

The highly significant correlation coefficient estimates (r) between μ + di and bi, s^2di and bi, and μ + di and s^2di were similar for fodder and ratoon seed yields (Table 3). The significant positive r estimates between μ + di and bi suggested the trend for high *per se* yield and responsiveness. The significant negative estimates for the remaining two associations indicated that with high *per se* yield responsiveness, the predictability would tend to increase. These expressions suggest the suitability of dual purpose safflower in relatively favorable environments (limited irrigation and fertilizer use). This suggests the utility of a production oriented agronomical package of practices. The phenotypically yield stable dual purpose safflower genotypes for rainfed conditions can be identified by evaluating genetically diverse populations. The selection of genotypes suitable for fodder is relatively easy because of genetic diversity of this group (6). Therefore, it is desirable to confine selection to the semi-spiny group for high *per se* fodder yield and regenerability in regions having high magnitude of diurnal temperature differences during the vegetative phase because it will favor biomass accumulation (4).

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Table 3: Phenotypic stability parameters for safflower green fodder and ratoon seed yields in rainfed conditions

SL no.	Genotype	Green fodder				Ratoon seed			
		μ+di (Q/ha)	bi	s^2di	SEb_i	μ+di (kg/ha)	bi	s^2di	SEbi
1.	EC 100570	195	0.9885*	-11508	0.0674	754	0.8197*	-60214	0.1715
2.	S 144	249	0.5200*	-10129	0.2355	1119	0.9902*	-55682	0.1953
3.	EC 38478	202	0.9864*	-11012	0.0518	1120	0.9326*	-70009	0.1031
4.	EC 35737	194	0.9474*	-10739	0.1380	1141	1.1885+	-66545	0.1314
5.	EC 100583	188	1.8293*	-10693	0.1476	792	0.4640	-17576	0.3336
6.	EC 36340	167	0.5668*	-10523	0.1788	1152	0.8715*	-65946	0.1357
7.	IC 11175	200	1.2713*	-10370	0.2027	1187	1.2089*	-66313	0.1653
8.	EC 100596	173	1.0763*	-10697	0.1468	1154	1.4290*	-74341	0.0480
9.	EC 100602	225	1.1597*	-10747	0.1363	1077	1.2030*	-68993	0.1121
10.	EC 100589	174	0.8607*	-10284	0.2150	1084	1.1430*	-65591	0.1382
11.	EC 42478	201	0.9271*	-10413	0.1963	1095	1.0720*	-28912	0.2992
12.	EC 27250	170	1.2039*	-10579	0.1691	927	0.9417*	-12315	0.3484
13.	EC 100588	200	0.8757*	-10861	0.1083	942	1.1483*	-42084	0.2534
14.	EC 100583	177	0.7900*	-10485	0.1850	979	0.9743*	-63698	0.1508
15.	7-13-3 (Control)	200	0.9970*	-10774	0.1301	917	0.8992*	-44061	0.2458
	Mean	194				1029			
	SE ±	16				53			
	CD 5%	31.2				106			
	CV %	15.1				9.1			
r(μ+di and bi)		0.9477*				0.9271*			
r(s^2di and bi)		-0.9250*				-0.9560*			
r(μ+di and s^2di)		-0.9575*				-0.9574*			

+ and * significant at 5 and 1 per cent levels.
Underlined significantly different from 1.

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SAFFLOWER IN CANADA -- PAST, PRESENT, FUTURE

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ABSTRACT

In trying to become self-sufficient in industrial and edible oils, the Canadian Government initiated safflower research during World War II. From an "environmental study" of six cultivars at six locations across Canada undertaken in 1941, the prairies were identified as having the greatest potential. Agriculture Canada at Lethbridge and Ottawa and the University of Saskatchewan at Saskatoon undertook varietal trials, planting date tests, and disease identification. Most frequently identified diseases included head rot (Sclerotinia sclerotiorum), leaf spot (Alternaria carthami), and also, under irrigation at Lethbridge, root rot (Pythium sp.). Small-scale breeding programs, initiated during the 1950's but terminated by the mid-1960's, have been reinitiated recently at Lethbridge.

Commercial production has been erratic, with interest in safflower being high when sales of cereals were low. However, production declined sharply when results were poor the preceding years. For example, 6,000 ha in 1957 were following by 18,000 ha in 1958, but poor yields (630 kg/ha) and oil content, as well as expanding production and export in California, resulted in virtual disappearance of the crop in Canada by 1962. Another upswing resulted in 40,000 ha of safflower being planted in 1971; but this crop was a disaster due to late maturity and disease. Thus, in 1972, only 3,600 ha were planted and since then only an occasional farmer with ready access to processing in Montana has grown safflower.

If the new breeding program is sustained at an appropriate level, and early, highly disease tolerant varieties can be released, production in Canada could be renewed in the 1990's.

In gathering information on the safflower situation in Canada, I relied heavily on personal communication with people in research, extension and agri-business, as well as using conventional published sources. The information was collected during the periods 1969-70 and 1978-81. Several of the people consulted also were responsible for my receiving the lines which form the core of the current safflower program at Lethbridge. All of these contributions are hereby gratefully acknowledged.

A list of references is given, but sources of information have not been identified in the text.

COMMERCIAL

Commercial safflower production began in Canada in 1943.[1] Since then, the acreage has varied greatly but was as high as 45,000 acres in the late 1950's.[2] Yields have been likewise variable, but averaged as high as 1,200 lb/acre on non-irrigated land. The crop was grown mainly for export

to Japan. Though prices were initially attractive, they declined as production increased in the U. S., mainly in California. This was partly due to the fact that Canadian safflower averaged only 30% oil, compared to 38% for Californian safflower. Premiums were paid for safflower of over 34% oil. With the cost of moving Canadian grain through the Rockies, California had an additional economic advantage over the Canadian prairies.

During the late 1950's and early 1960's, there was some local processing.[3] Western Canadian Seed Processors[4] in Lethbridge, the Alberta Linseed Oil Company in Medicine Hat, and the processing plant in Culbertson, Montana[5] were involved in contracting and processing Canadian safflower. Low yields, due in part to a high percentage of empty heads and a short growing season, coupled with the poor competitive position with California, resulted in Canadian production dwindling to almost nil by 1962.

A market surplus of traditional cereals during the late 1960's caused a resurgence of interest in safflower. In 1971, there were 40,000 acres in south-central Saskatchewan[6] and 55,000 acres in southeastern Alberta. The Saskatchewan production was contracted[7] to the Culbertson plant while the Alberta production was contracted[8] for export to Japan. In a survey of 26 growers, it was found that yields ranged from 400 to 1,300 lb/acre, with 95% of the crop grown on summerfallow. Only five percent of the fields were sprayed with herbicides and only 10% fertilized. Major problems identified by farmers surveyed were weeds and dockage, late maturity and marketing. One of the marketing problems was that the average distance for the crop to be hauled to Culbertson was 175 miles. Two-thirds of the farmers felt that the crop had potential; one-third felt that it had a very good potential.

In the early 1970's, the Alberta experience was not favorable. Yields and test weights were low, averaging only 400 lb/acre and 30 lb/bu. The minimum grade acceptable is 38 lb/bu and premiums are paid above 44. The reason for the poor performance was linked to heavy root-rot infestation.

Since 1972, only a few farmers closest to Culbertson have grown safflower.

RESEARCH

The first yield tests of safflower in Canada were conducted by the Cereal Division of the Central Experimental Farm at Ottawa in 1936. Four Indian lines, obtained from Montana[9], were included in this test. This original group of cultivars was followed by introductions from Europe and Asia.

In order to become more self-sufficient in vegetable oils during World War II, the Canadian government initiated a study in 1941 to determine where safflower had potential. Each of six cultivars was grown at each of six sites.[10] The three prairie locations gave the best yields, with the highest at Lethbridge.

During the remainder of the 1940's and the early 1950's, more locations in the prairies became involved in safflower testing. Besides the federal research stations, the universities of Manitoba and Saskatchewan also undertook varietal tests. Many of the improved Nebraska strains from C. E. Claassen were included. Three Canadian sites were included in Claassen's 1950-51 "Co-op regional nursery", which covered 20 sites in total. Ottawa, Altona, and Lethbridge were included. At Lethbridge in

1950, dryland yields were 1,050 lb/acre at 35% oil, while yields of irrigated plots were 530 lb/acre at just 28% oil. The irrigated plots were heavily root-rot infested.

Safflower evaluation in southern Alberta was done at four sites and included varietal tests on irrigated land and dryland, and planting date trials.[11] Variability in days to maturity was greater between seasons than between varieties. For example, in 1942, varieties averaged 127 days to maturity and in 1942, 150 days. Seeding from late April to early May gave the highest yields and seedlings were found to be as cold tolerant as those of cereals. For the irrigated trials, usually only one irrigation was given during early June or early July. In 1951, all varieties failed to mature.[12]

A modest safflower breeding program was started at the University of Saskatchewan in 1952.[13] About 900 single plant selections were made from Indian lines. This was followed by hundreds of introductions from 12 countries. Plants with rust tolerance and pythium resistance were selected and in 1953, a 96 cultivar yield test was conducted. This project was terminated when the breeder, B. C. Jenkins, changed positions to start up a triticale program at the University of Manitoba.

An oilseed breeding program with emphasis on safflower was started at Lethbridge in 1958. This project was terminated when the breeder, S. Pawlowski, was transferred to rapeseed breeding in Saskatoon in 1966. By that time, two cultivars were considered ready for release, one being early and the other being higher yielding than the standard U.S. cultivars. During this period, Pawlowski determined that low specific gravity was closely associated with high oil content. He developed a specific gravity index and a density-gradient tube for selecting in segregating generations.

There was a small breeding program at Ottawa in the late 1950's, but this was short-lived.

During the 1970's, safflower was used in a number of studies relating to animal nutrition. Sosulski and Sarmar (1973) at the University of Saskatchewan concluded that oilseed meals and protein isolates of safflower, sunflower and flax have low essential amino acid indices and protein scores because of deficiencies in lysine. All three were relatively high in non-essential arginine, aspartic acid, and glutamic acid. Varietal differences in amino acid composition were much greater in soybean, rapeseed and sunflower than in flax and safflower. Diverse studies on rats were also conducted at the Animal Research Institute in Ottawa to test the effects of different oils on cardiac necrosis. Safflower oil and hydrogenated coconut oil gave lower incidences of lesions than other oils tested.

DISEASES

Rust

Washings of seeds in 1942 at Ottawa from plants grown at Brooks, Alberta in 1939 showed rust spores. The seed source was believed to have been Hungary. In 1942, varietal differences in susceptibility to *Puccinia carthami* were observed at Saskatoon and Morden. Seed sources were implicated in the transmission of rust. Uredinia and telia were identified as the only known spore stages. In 1943, with a slight general infection

at Lethbridge, it was found that some teliospores could germinate within a few days after maturing, without previous exposure to freezing. This rust was found to be capable of infecting the cornflower, Centaurea cyaness. In 1953, safflower grown in Altona on safflower stubble, was severely infested with rust. In 1955, W. E. Sackston identified two races of rust in his tests at Morden. In 1958, a severe incidence of rust was found in southern Alberta.

Alternaria leaf spot

Severe leaf spotting on some safflower leaves in Ottawa in 1943 was attributed to Macrosporium or Alternaria carthami. The latter was confirmed, using spore dimensions.[14] In 1953, extensive spotting on safflower leaves was caused by Alternaria tenuis, and in 1954, caused by Alternaria carthami.[15] In 1958, traces of A. carthami in five of fifteen fields examined gave the first record of this disease in southern Alberta. In 1971, all seven fields inspected in southwestern Saskatchewan showed traces to moderate infections of A. carthami.

Pythium and other root rots

In 1935, an unidentified root rot affected a safflower plant in a garden in Alberta. In 1945, a root rot, suspected of being a Fusarium sp. was isolated from infected plants at Lethbridge. Three percent of the plants died. Pythium root rot has been repeatedly identified in irrigated trials at Lethbridge since 1950. Dryland trials show no infection but under irrigation, damage is generally severe. Symptoms are similar to those of Phytophthora drechsleri reported from Nebraska. Although damage was 100% in some cultivars, N3, N5, N8, W-014, 520 and Indian were identified as highly resistant to Pythium in irrigated trials at Lethbridge. A disease survey of 15 safflower fields in southern Alberta in 1958 showed some root rot caused by Rhizoctonia solani. Fusarium spp. were consistently isolated from trace amounts of root rots that caused above-ground necroses in about half of twelve inspected fields in Saskatchewan in 1970 and 1971.

Sclerotinia head rot

In 1951, all of the lines tested at Saskatoon were susceptible to Sclerotinia sclerotiorum. Furthermore, isolations of sclerotia from rape and sweet clover proved to be pathogenic on safflower.

Seedling and head blights and wilt

Since 1943, Botrytis cinerea has been identified as the causal agent for seedling blight at Ottawa. Seedlings are usually heavily infected and heads turn brown. Wet weather at blossom time helps to contribute to infection of head blight by both B. cinerea and Fusarium spp.

Seed treatment

In 1970 and 1971, pathogenic fungi were identified on safflower seed taken from farmers' fields.[16] All samples contained Alternaria carthami and infection of untreated seed ranged from 2% to 95%. Surface-disinfecting seed with 0.6% chlorine for 20 minutes reduced infection only slightly. Alternaria raphani was isolated in low amounts from two samples. Five samples had from 0.5% to 17.5% of seeds affected by the Botrytis fungus.

Surface-disinfection still permitted up to 10.5% of one sample to be affected. Isolates from safflower were found to be highly virulent on seedlings of rape and flax. Fusarium roseum infected four of the samples, from 0,5% to 20%. Surface-disinfection was effective in removing all fungal spores.

FUTURE PROSPECTS

At present, the only commercial safflower production in Canada is by a few farmers with ready access to the processing plant at Culbertson, Montana.

Unless suitable varieties that mature in our short season and have reasonable disease tolerance can be developed, no major sustained production can be expected in Canada. Certain specialty uses, such as bird seed and dried flower arrangements may result in short-term or small-scale production.

With suitable varieties, the future could be quite bright. The processors in Culbertson are interested, as are other contracting firms. The increasing land prices in California favor increasing inland production, especially on dryland.

In 1978, I began working on New Crops breeding and management at Lethbridge. Half of my time is allocated to soybeans and about one quarter to safflower introduction, observation, and breeding.[17] Introductions include materials from the U.S., Iran, Turkey and India.[18] A bulk of S. Pawlowski's Lethbridge advanced lines was sent to me from Saskatoon. Material has been grown out under irrigated and dryland conditions at several locations over the past three years. Observations on agronomic characters and disease reaction have been made. Since none of the selections warrant release, this testing serves only to identify parents for crosses.

Winter safflower introductions from Iran and Turkey were twice fall-seeded. Temperatures of -10 to -15 C killed all seedlings. These lines were seeded in the spring of 1980 and a great diversity of characters were observed: from quite short to almost 2 m tall; from very spiny to almost spineless; and flower colors ranging from yellow to red. Some lines with relatively low incidences of rust, sclerotinia and leaf spot were also identified.

Earliness is our primary breeding goal at Lethbridge. The Mexican Dwarf line has a low year-to-year variation for maturity and may have potential as a parent. Single-plant selections from the Lethbridge advanced-line bulk have also been made. Some of the resulting lines are almost as early as the Mexican Dwarf.

In southern Alberta, May 1 is the target seeding date. The average date of the first killing frost in the fall is September 27.[19] But, in order to minimize risk to an acceptable level, we must have a variety that will reach maturity ten days before the average killing frost, i.e., by September 17, or 140 days from seeding.

Only the Mexican Dwarf and the earliest selections from the Lethbridge bulk are safe. Incorporation of this level of earliness into potential varieties has been initiated and it is only a matter of time until an acceptably early cultivar is developed.

Rust, caused by Puccinia carthami, has been a severe problem, and the Mexican Dwarf is among the most susceptible lines. Sources of resistance, like PCA, have been free of rust, so we are trying to combine this rust resistance with early maturity. Sclerotinia sclerotiorum is also a problem, but to date we have found no resistant lines. Some lines with lower levels of infection were found[20], and these selections will be field tested during 1981.

Our Lethbridge breeding program is just beginning, with the earliest crosses being grown out in the earliest segregating generations. When early, disease tolerant varieties are produced and released, production can be renewed free from most of the problems that beset farmers from the 1950's to early 1970's.

NOTES

1. The first commercial safflower in Canada was a 10 acre field in Barons, Alberta, in 1943.

2. 1957 - 15,000 acres of N10 in southeastern Alberta.
   1958 - 18,000 acres in Alberta and 27,000 acres in Saskatchewan

3. In the early 1950's about 250 tons of safflower were processed by the Co-op Vegetable Oils of Altona, Manitoba.

4. Present name is Canbra Foods. Its predecessor, WCSP, processed about 500 to 800 tons for each of the two years 1957 and 1958.

5. Processing plant in Culbertson: built during the 1950's by the Chemurgy Project, ownership changed to Pacific Vegetable Oils, then to P. J. Anderson and Sons, and is currently owned by Continental Grain Co.

6. One report places this in 1970, with 24,000 acres in 1971 and 9,000 acres in 1972.

7. The main Saskatchewan contractor for P. J. Anderson and Sons was R. X. Stroeter.

8. The main Alberta contractor was G. Arsene.

9. Indian lines: Type 1, 6, 14 and 25 were obtained from A. H. Rehbein, of Lambert, Montana.

10. Locations included in the 1941 "Environmental study", from east to west: Fredericton, New Brunswick; Ottawa, Ontario; Morden, Manitoba; Indian Head, Saskatchewan; Lethbridge, Alberta; Agassiz, B.C.

11. These Lethbridge trials were conducted by W. D. Hay.

12. From 1953 to 1955, varietal trials conducted by B. Stefansson at the University of Manitoba, Winnipeg, had very erratic yields due to poor seed set and later maturity.

13. The Saskatchewan Research Council assisted in the funding of this program.

14. This confirmation occurred in 1954.

15. Small, circular, yellowish-brown to brown spots later coalesced into elongated spots about one cm long.

16. This study was conducted in Saskatchewan by G. A. Petrie.

17. The safflower breeding program has been aided by a project grant starting in 1979 of the government of Alberta's Farming for the Future scheme.

18. Introductions include lines sent through Drs. P. F. Knowles, A. L. Urie, G. A. White and J. Bergman in the U.S.; Dr. A. D. Karve in India; and Dr. A. J. Klassen in Canada.

19. Temperatures of -2.2 C or 28 F are used to indicate "killing frost."

20. Lines with lower levels of infection were early or late maturing. They could thus have effectively avoided the worst infection weather in this way. In other crops, resistance-breeding to Sclerotinia sclerotiorum has generally not been promising.

PERSONAL COMMUNICATIONS

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ADAPTABILITY OF SAFFLOWER (CARTHAMUS TINCTORIUS L.) GENOTYPES TO IRAQ

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ABSTRACT

In this study seven safflower genotypes, along with the check cultivar, Gila, were evaluated for their adaptability to conditions in Iraq, through a multi-location-year testing program, resulting in ten environments in all. The environments spanned a wide range as indicated by the general seed yields obtained, ranging from 3.3 to 0.17 t/ha. There was a significant interaction between genotypes and environments. From an analysis of stability parameters it is concluded that genotype US-10 was well suited for situations of advanced agronomy with input-intensive conditions of culture, and that the genotypes D-51-667 and D-51-531 were more stable with predictable performances and hence recommended for all situations. The currently recommended genotype, Gila, was found to be adaptive but less predictable, and hence its replacement is suggested. Data from four of the environments, characterized by irrigated-high yield, irrigated-low yield, rainfed-high yield and rainfed-low yield, were subjected to path coefficient analyses to study the relationship of three yield-determining traits with seed yield. It was found that under irrigated-high yield conditions seed yield was predominantly determined by number of heads per plant, while under rainfed-high yield conditions it was determined by the number of seeds per plant. Under low yield conditions, seed yield was determined predominantly by seed weight irrespective of the water availability. The implications of these findings in choice of genotype and with formulation of crop management optima are discussed.

In its attempts at attaining self-sufficiency in indigenous production of vegetable oils Iraq is widening the crop source base for edible oils. Safflower (Carthamus tinctorius L.) is considered to have good potential in this regard. Its main favorable points are (i) feasibility for autumn planting thus benefiting from the winter rains, in contrast to sesame, sunflower, soybean or corn which being summer season crops depend on irrigation, (ii) low water requirement, (iii) relative tolerance to soil salinity and weed competition, (iv) adaptability to the use of machinery for small grains for planting, interculture and harvesting -- this is of significance since the existing farm machinery is predominantly for cereal crops like wheat and barley, (v) good quality oil and useful meal. The major minus points are (i) competing for land with cereals like wheat and barley, (ii) susceptibility to frost and the Heliothis pest, (iii) absence of recommendations regarding cultivar and management practices, particularly for northern Iraq which in view of its winter rains constitutes the major target area for safflower cultivation. Currently in Iraq, safflower is being raised only in a small area (less than 200 ha), but the potential area is estimated to be 12,500 ha. An expansion of this magnitude calls for the rapid formulation of cultivar recommendation with improved cultivars bred abroad, and location-specific crop management optima. In the past there were scattered attempts to introduce the crop and assess its potential. The cultivar 'Gila' was found to be the most promising, and

recommendations on the date of planting, seeding rates and inter-row spacings, and the number of irrigations required have been made (3, 4). But these assessments were made at single locations only in and around Baghdad rather than in the northern regions. The present study reports on results from a multilocation testing program involving four locations in the north and one each in central and southern Iraq, evaluating seven cultivars along with Gila, the recommended cultivar, as the check.

MATERIAL AND METHODS

Seven cultivars along with Gila the recommended cultivar as the check were grown during three seasons, 1977-78, 1978-79, and 1979-80 (Y_1, Y_2 and Y_3) at six locations. The locations (L_1....L_6) are identified in Table 1 along with some climatological features, and the cultivars (V_1....V_8) in Table 2 along with some major morphological and yield data as observed in one of the centers. At all locations but one, the trials were laid out in randomized blocks with four replications. At L_5 the tests were conducted in all the three years, at L_3 and L_4 for two years each, Y_1, Y_2 and Y_2, Y_3 respectively, and at L_1, L_2 and L_6 for one year (Y_2) only, thus constituting 10 environments in all. The conditions of culture and other experimental and management details are given in Table 3. The trials were autumn sown and late spring or summer harvested. All field operations were manual.

Observations were recorded on a plot basis for emergence, plant stand in terms of number of plants harvested, dates of flower initiation, full bloom, completion of flowering and maturity. Five representative plants were selected from the middle row and recorded for height at maturity, number of branches per plant, number of heads per plant, number of seeds per head and single plant yield. The last parameter was also scored by dividing the net plot yield by plant stand, as a check. Seed weights were recorded from random samples of 100 seeds from the bulk harvest of the net plots. Oil content estimates were obtained by the Soxhlet's method from duplicate samples similarly drawn. The data were subjected to conventional analyses of variance, and 'F' tests of significance. For estimating the stability parameters, calculated seed yields in metric tons per hectare were used. The methods of both Finlay and Wilkinson (7) and Eberhart and Russell (6) were used. Regression and correlations were estimated by the analyses of covariance, and by paired mean values averaged over replications. Path coefficients were estimated, on a single plant basis by the elimination procedure of simultaneous equations set up for this purpose by Dewey and Lu (5). Number of heads per plant, number of seeds per head and weight of 100 seeds were considered as direct components of yield of seeds per plant. Plant height was considered as an indirect component and was used in only one case, in the place of number of seeds per head. Missing plot values were estimated by the iterative method suggested by Snedecor and Cochrane (12). Tests of significance were at the probability level of $P = 0.05$.

Only the data for seed yield, in connection with the stability analyses and seed yield, number of heads per plant, number of seeds per head, 100 seed weight and height in connection with path analyses are presented in this report. Results of the other observations will be discussed elsewhere.

Table 1. Identities of locations involved and some of their climatalogical features

Location	Latitude	Longitude	height above MSL. in metres	Annual Mean Temperatures °C @ Max.	Min.	Annual Mean rainfall @ in mm.
1. Dohok (L_1)	36°52"N	43°02"E	860	24.0	10.0	596
2. Telafar (L_2)	36°22"N	42°29"E	273	26.0	11.5	300
3. Nineveh (L_3)	36°19"N	43°09"E	223	28.2	11.7	392
4. Kirkuk (L_4)	35°28"N	44°24"E	331	27.8	11.9	382
5. Baghdad (L_5)	33°20"N	44°24"E	34	30.5	15.1	152
6. Diwaniya (L_6)	31°59"N	44°59"E	20	32.1	17.6	139

@ Mean for a 30 year period.

Table 2. Identities of genotypes studied, along with some morphological features as observed at Baghdad (E_8).

Genotypes	Seed yield in kg/ha	Number of branches per plant	Number of heads per plant	Number of seeds per head	Height in cms.	Weight of 100 seeds in gms.	Oil content %
(1) D-51-531 (V_1)	2491	13	28.8	49.75	148	3.06	34.93
(2) D-51-632 (V_2)	2689	14	29.5	44.50	147	3.41	29.99
(3) D-51-669 (V_3)	2451	18	37.3	48.00	157	3.18	33.60
(4) Oleic Leed (V_4)	2410	13	29.5	36.50	138	3.73	37.71
(5) V-51-333 (V_5)	2461	15	28.0	36.50	145	3.70	31.69
(6) D-51-667 (V_6)	2628	9	20.3	43.75	152	3.76	31.40
(7) U.S.-10 (V_7)	2956	12	26.5	41.75	131	4.07	36.61
(8) Gila (V_8)	2754	11	29.5	40.75	142	3.84	32.44
General mean	2605	13.1	28.7	42.69	145.03	3.59	33.55
C.V. %	9.6	22.9	20.7	18.30	73	8.8	2.88
L.S.D.	304.2	4.42	8.7	—	10.43	0.81	7.43
P	0.10	0.05	0.10	—	0.10	0.01	0.01

Table 3. Conditions of experimental culture and identities of the environments.

Locations (L)	Duhok	Telafar	Nineveh		Kirkuk		Baghdad			Diwaniya
Years (Y)	78–79	78–79	77–78	79–80	78–79	79–80	77–78	78–79	79–80	78–79
Environment No.	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}
(1) Layout design	RBD	RBD	RBD	RBD	RBD	RBD	RBD	RBD	RBD	RBD
(2) date of planting	12 Dec	09 Dec	08 Dec	11 Dec	26 Nov	25 Nov	01 Dec	06 Dec	18 Nov	23 Dec
(3) net plot size (m^2)	9	12	10	9	9	9	10	10	10	9
(4) row to row distance (cms)	45	60	50	45	45	45	50	50	50	50
(5) Replications	4	4	4	4	4	4	3	4	4	4
(6) Fertilization										
N-kg/ha	40	80	80	80	80	80	80	80	80	80
P-kg/ha	40	40	40	40	40	40	40	40	40	40
(7) Irrigations (no)	-	-	-	-	13	13	17	15	20	12
(8) Date of harvest	24 July	12 July	14 July	20 July	25 June	23 June	11 June	19 June	7 June	30 June
(9) Environment index	-1.5117	-1.5717	-0.0917	+1.0053	+0.0833	+0.0683	+0.3609	+0.8923	+0.4543	+0.3143

RESULTS

The mean seed yields (tons/ha) obtained in the different environments are presented in Table 4. It will be seen that the genotypes differed significantly from each other in six environments. Individual yield performances ranged from 3.305 t/ha for V_7 at E_4 to 0.167 t/ha for V_3 at E_1. Considering the mean performance over the environments the seed yields ranged from 1.9 t/ha for V_7 to 1.5 t/ha for V_3. The mean performance of all the genotypes in different environments ranged from 2.7 t/ha for E_4 to 0.1 t/ha for E_2. Thus it can be considered that the sample of environments under study is representative of a fairly wide spectrum of environments under which safflower cultivation can be evaluated in Iraq, for identifying potential areas for commercial culture.

In Table 5 the analysis of variance of the pooled data for seed yield (t/ha) is given. It is seen that all the effects are significant, that due to environments being very highly significant while V x E interaction is significant at P = 0.05. Since the proposed analysis for stability would be relevant only in the presence of strong V x E interaction, the mean values over replications at each environment were treated as individual observations and subjected to analysis of variance which is presented in Table 6. In this also it is seen that the mean square values are the highest for environments, next highest for genotypes and lowest for the interaction between the two. In this analysis there is no provision to estimate the mean square for pooled error and hence for conducting the F tests. Bartlett's test for the homogeneity of error variances of the 10 environments indicated them to be highly heterogenous (chi square for 9 d.f. = 181.9). Consequently, the data (means over replications at each environment) were subjected to weighed analysis of variance using replication x reciprocal of error mean square values as weights. The analysis, presented in Table 7, indicated interaction effects to be highly significant (chi square value for 10.1 d.f. = 177.2). Hence it is considered appropriate to proceed with analysis of stability of genotypes. The stability analysis was carried out according to the model of Eberhart and Russell (6). The regression of performance of each genotype under different environments on the environmental means over all the genotypes , 'b' values, the mean square deviations ($\bar{S}_d^2$) from linear regression, along with means yields (t/ha) are presented in Table 8. The F tests of individual deviations from linear regression are given in the last column of this table. It is seen that with reference to mean seed yields, genotypes V_7 and V_8 gave significantly higher yields than the general mean yield of all the genotypes while V_3 and V_4 were significantly lower. The coefficient of regression was higher than unity for V_7 and not significantly different from unity for the rest of the genotypes. Except for three genotypes, V_4, V_5 and V_8, the deviation from linear regression was not significantly different from zero. The analysis of variance for the means, given in Table 6, is further partitioned into various components in Table 9. Tested against pooled deviation the ms due to genotypes was significant (MS_1/MS_3), while individual genotypes did not differ for their regression on the environmental index (MS_2/MS_3). Stability parameters were also estimated using the model of Finlay and Wilkinson (7). The coefficients of regression, their standard errors, along with yield values are given in Table 10. Mean values averaged over replications at each environment were used for estimating 'b' values. The marginal discrepancies between these estimates and the previous ones are due to correction of mean values to the first decimal. It will be seen from the

Table 4. Mean seed yields (t/ha) of 8 safflower genotypes (V_1 to V_8) at 10 environments (E_1 to E_{10})

	Genotypes	Environments										
		E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}	Means
(1)	V_1	0.192	0.098	1.645	2.639	1.528	1.650	2.344	2.491	2.221	2.107	1.691
(2)	V_2	0.254	0.104	1.480	2.333	1.963	1.497	2.235	2.688	2.081	2.115	1.675
(3)	V_3	0.167	0.069	1.431	2.527	1.677	1.673	2.158	2.451	1.880	1.915	1.595
(4)	V_4	0.191	0.133	2.028	3.028	1.274	2.016	1.481	2.410	2.139	1.625	1.632
(5)	V_5	0.198	0.058	0.906	2.250	1.991	1.798	2.126	2.461	2.301	2.085	1.617
(6)	V_6	0.239	0.148	1.729	2.472	1.845	1.683	2.119	2.627	2.626	2.055	1.754
(7)	V_7	0.173	0.291	1.904	3.305	2.237	1.971	1.922	2.956	2.389	1.987	1.913
(8)	V_8	0.193	0.288	1.849	3.194	1.855	1.961	2.204	2.753	1.700	2.290	1.823
	Mean	0.201	0.141	1.622	2.718	1.796	1.781	2.073	2.605	2.167	2.022	1.713
	CV%	34.4	24.7	12.0	21.6	7.9	14.2	9.9	9.6	23.2	13.9	
	LSD	NS	0.069	0.431	NS	0.285	0.308	0.555	0.304	NS	NS	
	P	—	0.01	0.005	—	0.01	0.10	0.005	0.10	—	—	

Table 5. Analysis of variance of pooled data for seed yield in 10 environments

Due to	DF	SS	MS	Variance Ratio tested against Error MS	Variance Ratio tested against VXE MS
Genotypes (V)	7	9.0235	1.2891	-	9.4 **
Environments (E)	9	223.5067	24.8341	-	181.5 ***
Replications in environment	29 @	16.5497	0.5707	-	4.17 **
V x E	63	8.6203	0.1368	1.49 *	-
Error	203	18.6003	0.0916		
Total	311 @	276.3006			

(@ The decrease in the degrees of freedom is due to there being only 3 replications in E_7 and one missing plot value in E_9).

Table 6. ANOVA for seed yield: mean data averaged over replications.

Due to	DF	SS	MS
Genotypes	7	0.8544	0.1220
Environments	9	56.1222	6.2358
V x E (Interaction)	63	3.6830	0.05846
Total	79	60.6596	

Table 7. Weighted ANOVA for seed yield: mean data averaged over replications

Due to	SS.	chi square value
Genotypes	169.8678	
Ervironments	13571.7175	
V x E (Interaction)	305.9547	177.21 ** (df 10.1)

Table 8. Regression values (b) and the mean square deviations from linear regression $\bar{S}^2_{\bar{d}}$ of 8 genotypes

Genotype	Mean seed yield t/ha	'b'	$\bar{S}^2_{\bar{d}}$
(1) V_1	1.691	1.0028	-0.00672
(2) V_2	1.675	0.9668	+0.00354
(3) V_3	1.595	0.9581	-0.01455
(4) V_4	1.632	0.9649	+0.10908 **
(5) V_5	1.617	0.9605	+0.06537 **
(6) V_6	1.754	0.9902	+0.01076
(7) V_7	1.913	1.1102	+0.02395
(8) V_8	1.823	1.0444	+0.06330 **
Mean	1.704	0.9997	
S.E.	0.078	0.0888	

Table 9. Partitioned ANOVA of mean seed yield averaged over replications

Due to	DF.	SS.	MS.	
Total	79	60.659603	-	
Genotypes	7	0.8544	0.122057	MS_1
Environments + (V x E)	72	59.80520		
Environments linear	1	56.14192		
V x E (linear)	7	0.131936	0.01885	MS_2
Pooled deviation	64	3.5040	0.05531	MS_3
V_1	8	0.12950103		
V_2	8	0.21162127		
V_3	8	0.06687214		
V_4	8	1.05592156		
V_5	8	0.70619039		
V_6	8	0.26937777		
V_7	8	0.37482437		
V_8	8	0.68967152		

$MS_1/MS_3 = 2.2$ *
$MS_2/MS_3 = 0.3$ NS.

Table 10. Regression of genotype mean seed yields on mean environment yields (Finlay and Wilkinson, 1963), and their standard errors.

Genotypes	'b'	S_b	Mean seed yield t/ha
V_1	1.0075	0.0384	1.651
V_2	0.9763	0.0601	1.632
V_3	0.9758	0.0524	1.508
V_4	0.9396	0.1081	1.576
V_5	0.9659	0.0953	1.577
V_6	0.9980	0.0580	1.707
V_7	1.1006	0.0716	1.865
V_8	1.0428	0.0801	1.796

data that 'US-10' has a 'b' value higher than unity while the rest of the genotypes have regression values not significantly different from unity. Considering mean yields, US-10, Gila, 'D-51-667' and 'D-51-531' significantly outyielded the rest. The first three genotypes also gave yields higher than the general mean yield (1.664 t/ha).

The crop season during 1978-79 experienced variable rainfall in the northern rainfed zone. Environment E_4 (Nineveh) received 450 mm of rainfall while E_1 (Duhok) received less than 250 mm. On the other hand, the two irrigated trials during that year gave markedly differing seed yields, high in E_8 (Baghdad) and low in E_5 (Kirkuk). This was presumably due to factors other than water stress and to management practices. This situation offered an opportunity to study the components of yield under different environmental conditions of culture. This was studied through an analysis of correlations between single plant seed yield (X_4) on the one hand and the number of heads per plant (X_1), number of seeds per head (X_2), and the weight of 100 seeds (X_3) on the other. Results from path coefficient analysis to estimate the direct and indirect effects of these yield components are presented in Table 11 and in Fig. 1. In one case, E_8, plant height, an indirect component of seed yield, was taken in the place of number of seeds per head. The basic data for these estimations were collected from five plants randomly sampled from the net plot.

The sum of direct and indirect correlations can be equated to genotypic correlation between seed yield and the other characters under study. Under conditions of adequate water supply, either from irrigation or from adequate precipitation, and when other factors of soil, season and management favor high seed yields, seed yield is determined positively by the number of heads per plant while seed weight has little, or even a negative influence on seed yield. On the other hand, when water is limiting, or when other factors are unfavorable, seed yield is positively influenced by seed weight rather than by the number of heads per plant. It should also be noticed that, in all cases, a high value for residual effects (R) was obtained, indicating the inadequacy of the number of traits in accounting for the variations in associations. More characters influencing seed yield, both directly and indirectly, should be considered.

DISCUSSION

Stability and Adaptability

When a crop like safflower, well established elsewhere, is being introduced into a new area, the obvious initial step is to evaluate high yielding exotic cultivars in a multi-location testing program. While such a program, ideally, should be quite extensive both in space and in time, rapid decision making on the cultivar choice is facilitated if its adaptability to the new area of introduction could be assessed in a short time. For this, the estimation of stability parameters offers a useful aid. The terms "adaptability" and "stability" are at times used synonymously, as also with different connotations. It is desirable to define precisely what is being sought. In a study like the present one, the main objective is to identify the cultivar(s) whose yield performance in a wide range of environments is consistently above average and economically profitable.

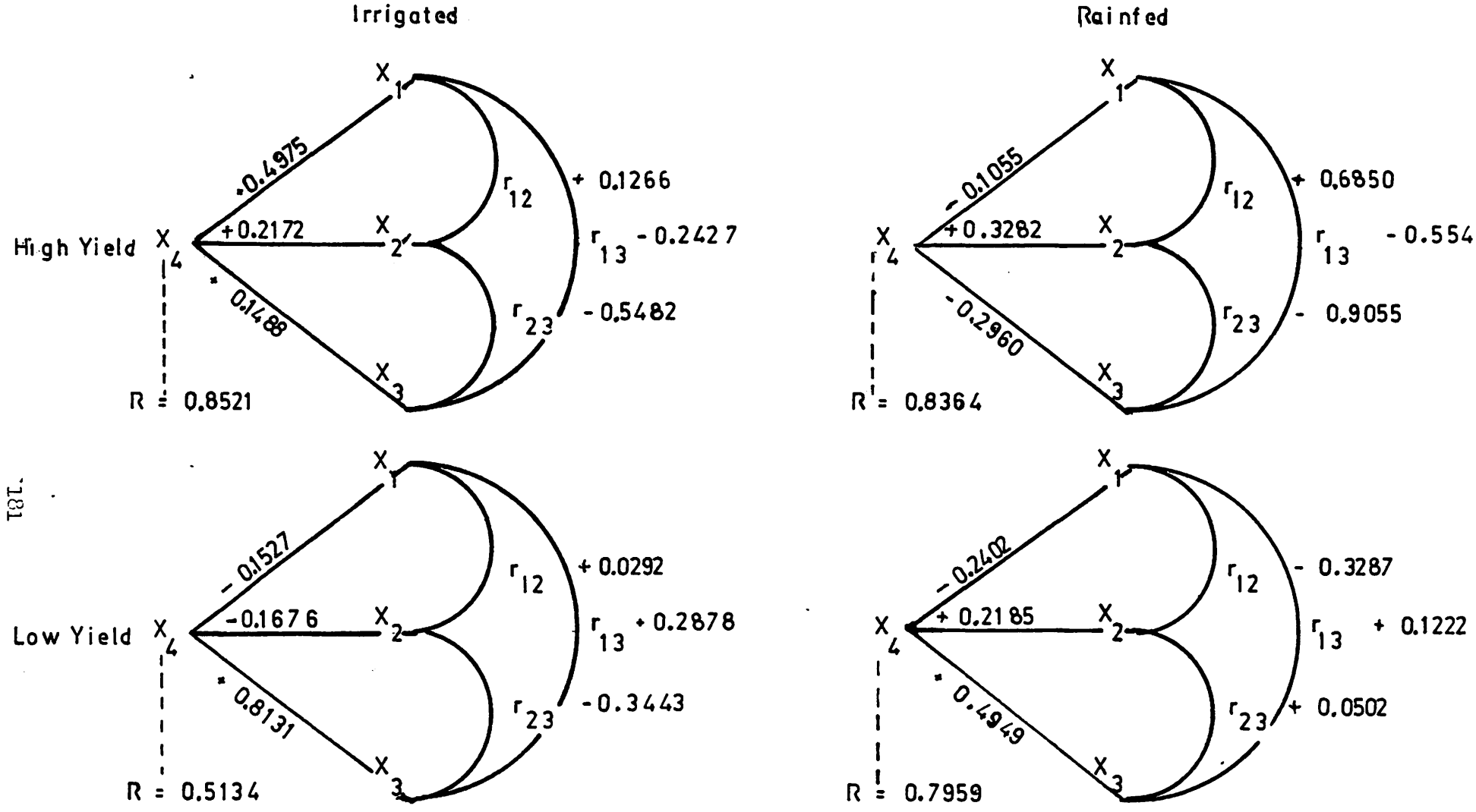
The interaction between genotypes and environments, measured in terms of

Table 11. Path correlation coefficients indicating direct (underlined) and indirect effects of yield components on seed yield under different production systems.

Production system	Characters	No. of heads/plant X_1	No. of seeds/head X_2	100 seed weight X_3	Genotypic correlation with yield
A. Irrigated-High yield (E_9=Baghdad)	X_1	+0.4975	+0.0282	-0.0357	+0.4900
	X_2'	+0.0646	+0.2172	-0.0818	+0.2000
	X_3.	-0.1194	-0.1194	+0.1488	-0.09
B. Irrigated-Low yield (E_6 = Kirkuk)	X_1	-0.1527	-0.0049	+0.2340	+0.0764
	X_2	-0.0045	-0.1676	-0.2780	-0.4520
	X_3	-0.0439	+0.0577	+0.8131	+0.8269
C. Rainfed-high yields (E_4 = Nineveh)	X_1	-0.1055	+0.2232	+0.1642	+0.2819
	X_2	-0.0723	+0.3282	+0.2680	+0.5239
	X_3.	+0.0585	-0.2972	-0.2960	-0.5346
D. Rainfed-low yield (E_1 = Dahok)	X_1	-0.2402	-0.0718	+0.0605	-0.2515
	X_2	+0.0789	+0.2185	+0.0248	+0.3222
	X_3.	-0.0293	+0.0109	+0.4949	+0.4765

(Under A, X_2' is plant height instead of no. of seeds/head).

PATH ANALYSES OF YIELD COMPONENTS UNDER DIFFERENT PRODUCTION SYSTEMS IN SAFFLOWER



X_1 = No of heads / plant. $X_{2'}$ = Plant height. X_4 = Seed yield.

X_2 = No of seeds / head. X_3 = 100 seed weight. R = Residual.

linear regression of the performance of individual genotypes in a given environment on the mean performance of all the genotypes in that environment has been used in plant breeding programs to assess adaptability of genotypes. Originally proposed by Finlay and Wilkinson (7), this method has undergone several modifications and refinements (6, 8, 10, 11). As per the model of Eberhart and Russell (6), which is followed in the present study, a desirable genotype is one that shows a high mean yield, unit regression coefficient, and deviation from regression as small as possible. On this basis, from the data presented in Table 8, it can be concluded that genotypes US-10 and Gila with significantly higher seed yields than the general mean, are the most desirable. In the same category are D-51-667 and D-51-531. However, distinctions can be made among these genotypes. For instance, US-10 with a regression coefficient higher than unity is identified as a genotype suited for favorable conditions of culture, while the other three with unit regression coefficients can be considered as genotypes with stable performance over a wide range of environments. An exception to this is Gila with its significant value for deviation from regression, invalidating linear prediction. On the same basis, genotypes 'Oleic Leed' and 'V-51-333' are unstable and unpredictable and hence undesirable. We thus conclude from this analysis that for input-intensive conditions with reference to water supply (from irrigations or assured rainfall), nutrient supply, weed and disease control, and favorable weather conditions, the genotype to be recommended is US-10. For other areas when one or more of these factors are not optimal, the genotypes to be recommended are D-51-667 and D-51-531. It is worth noting that Gila, the currently recommended genotype, does not qualify as appropriate for any region on account of its lack of predictability.

Conclusions very similar to the above can be drawn from a study of the results on the model of Finlay and Wilkinson (7). On this model a genotype with mean yield and regression greater than the average is considered well adapted specifically for high yielding environments under input-intensive and favorable soil and seasonal conditions. On this basis, US-10 with its highest mean yield and regression higher than unity is again identified as a genotype to be recommended for such areas. Genotypes Gila, D-51-667 and D-51-531, with regression and mean yields not significantly different from US-10, can be considered as well adapted to a wider range of environments. On this model, a genotype with greater than average yield and lower than average regression is considered well adapted to low yielding environments. Genotype V-51-333 would have been classified thus, had it not failed to meet these criteria marginally. The rest of the genotypes do not appear to be of consequence. Particularly Oleic Leed and D-51-669 should be discarded on the basis of poor mean values. Although the above conclusions on the basis of the two models appear similar, it is necessary to point out the differences in the connotations of the stability parameters implied. In the first model, the regression coefficient is a parameter of response, and the deviation from regression ($\bar{S}_d^2$) is the parameter for stability. When the deviation is not significantly different from zero and the regression is higher than unity, the genotype is considered to be more responsive and hence recommended for highly favorable environments. A lower value of 'b', around unity, would imply less response to environmental changes and therefore better adaptation. Accordingly, a genotype with $\bar{S}_d^2 = 0$, whose performance can be predicted, is said to be stable. Here stability means predictability of performance. On the other hand, in the second model, stability is in-

terpreted as consistency of performance of a genotype over varying environments, and is measured by the regression coefficients. Thus, a stable genotype is one for which the regression coefficient does not differ from zero, within the limits of sampling error. The distinctions between the two interpretations should be carefully noted.

Seed Yield and Its Components

It is well known that seed yield in small grain annual crops has low heritability. Yield determining traits, particularly those with high heritability values, implying consistent genetic expression over a range of environments, are more useful in selection programs. Further, a knowledge of how yield is genetically structured, under input-intensive conditions of culture, offers scope for cultivar and crop management manipulations.

In this study, data from four environments out of the ten were used to analyze the seed yield (X_4) and its relation to three of its direct components, viz., number of heads per plant (X_1), number of seeds per head (X_2) and weight of 100 seeds (X_3). The four environments constituted two major groups, of two each irrigated and rainfed, viz., Baghdad (E_9) and Kirkuk(E_6) in the former, and Nineveh (E_4) and Duhok (E_1) in the latter. Within each group, the first mentioned gave high single plant seed yields and the second, low yields. Path coefficient analyses of the relationship between seed yield on the one hand and three other traits on the other, under the four situations, gave interesting results. In only one situation (irrigated-high yield) seed yield was positively associated with number of heads per plant (genotypic correlation = 0.49); in the other three situations the association was negative and low. This suggests that under highly favorable conditions either genotypes with high number of heads per plant (D-51-669 with 37.3 heads) or management conditions favoring high head number, may be recommended. Gilbert and Tucker (9) observed that higher rates of nitrogen application maximized head numbers. With reference to number of seeds per head, its association with seed yield was positive under the rainfed situations, both high and low yield, while it was negative under the irrigated-low yield situation. Data are not available for the irrigated-high yield situation. The trait, number of seeds per head, was not found to be variable amongst the genotypes studied (Table 2). But it was noticed by Gilbert and Tucker (9) that lower nitrogen fertilization (56 kg/ha) maximized seeds per head. Abel (2) observed that larger populations per unit area obtained by denser plantings (430,547 plants/ha) resulted in lower numbers of seeds per head than in thinner plantings (258,328 plants/ha). The association between seed weight and seed yield as revealed by path coefficient analysis is instructive. This relationship is found to be high and positive under low yield conditions, both irrigated and rainfed (genotypic correlations were respectively 0.8269 and 0.4765), while under high yield conditions, it was low and negative under irrigation, and high and negative under assured rainfall (-0.09 and -0.5346 respectively). It should be noted that the direct association between seed weight and yield was positive in all the situations except high yield rainfed conditions. In the exceptional case this is compounded by negative effects via number of seeds per head to result in a negative genotypic correlation of -0.5346. Examination of individual location data reveals that the genotype US-10, which has a 100-seed weight significantly higher than the rest in general and at three of the locations under consideration, was significantly lower

than three other genotypes, viz., V-51-333, D-51-531 and D-51-669, at the high yield rainfed situation. The general mean for 100-seed weight was also very high for this center. It is, therefore, reasonable to conclude that under conditions favoring high yield, seed weight only marginally influences seed yield, while under low yield conditions it is highly positively associated with seed yield. Under the latter situation this trait appears to be the single dominant determinant of seed yield, and hence the options for its manipulation either by choice of genotypes or by management practices should be carefully considered. The genotypes under study, except for US-10, did not differ amongst themselves significantly. It was observed by Abel (2) that seed weight did not differ under the two population densities studied by him. On the other hand, rapid increase in the day temperature at the grain formation stage could result in a rapid decrease in seed weight. Abel (1) noticed that in a location with a temperature regime of 2 C warmer, flowering was 4 days earlier than in two other centers at the same latitude. In our experiments, with dates of planting as the variable, Gila had a 100-seed weight of 4.0 g when planted on the 3rd of November, then progressively declined to 3.0 g at later dates of planting of 20 days interval, up to the 6th of March. Thus the main management option available for manipulation of seed yield via seed weight under stress conditions appears to be the planting date rather than the genotype or density of planting.

From the above, it appears that, from the viewpoint of adaptability of genotypes as well as from choice of cultivars and crop management optima, a study of how seed yield is genetically structured through the path coefficient analyses is desirable. It should also be pointed out that the high residual values noted in this study indicate the need to include more traits in the analyses.

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GENETICS OF SOME QUANTITATIVE CHARACTERS IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

Genetic architecture of yield, oil percent and seven other variables related to fitness and productivity were investigated in an 11 x 11 diallel cross of safflower (*Carthamus tinctorius* L.) through application of combining ability analysis as well as graphical and components of genetic variance approaches. The studies revealed a preponderance of nonadditive gene action for yield/plant, number of capitula/plant and yield per capitulum and additive gene action for plant height, number of primary branches/plant, flowering time, size of seed, diameter of capitulum, and seed oil percent. Nonallelic interactions also influenced the expression of plant height, flowering time, capitula number, diameter and weight of capitulum and yield per plant. The results suggested the occurrence of overdominance for yield/plant, incomplete dominance to overdominance for number and weight of capitula and partial dominance for others. High expression of characters was governed by dominant alleles for yield/plant, recessive genes for percent oil, plant height and time of flowering and both recessive and dominant factors in case of other variables. Indigenous lines possessed a high frequency of desirable alleles for yield and undesirable alleles for oil content unlike high oil types which showed a reverse pattern. Heritability in the narrow sense was very low for yield, moderately low for weight and number of capitula and very high for other traits. Average levels of heterosis were very high for yield/plant and yield per capitulum, moderate for number of branches and capitula per plant, low for capitulum diameter, and negligible for others. Genetic diversity of parents influenced the extent of heterotic responses for yields. Reciprocal differences were, in general, low albeit significant for various characters. Parental means served as good indicators of their combining ability for all characters. All high oil lines except 'VFstp 1' displayed poor combining ability for yield per plant. Evidently the crop offers considerable scope for raising its per hectare yields of seed and oil through breeding efforts, provided we are also able to exploit successfully the unfixable component of heritable variance available for yield and its components.

Genetic improvements of safflower yields have been achieved so far primarily through use of breeding methodologies otherwise suited to self-pollinated crops. Genetic information on quantitative characters of economic importance in safflower which has been gaining considerable importance as an oilseed crop both in its traditional areas of culture in Asia, Africa and also in several other parts of the world such as USA, Mexico, Australia (2, 6, 19, 22, 25) is too meager to suggest the adequacy or otherwise of the breeding strategies currently adopted for its genetic amelioration. Studies were, therefore, undertaken to obtain basic information on the inheritance of yield, oil percent and various other characters related to productivity and adaptability in the crop by applying various diallel approaches (9, 10, 13).

MATERIALS AND METHODS

The experimental material for the present investigations was comprised of all possible crosses among a set of 11 parents involving six cultures from USA, viz., 'US 104', 'Gila' and four hull mutants ('AC 1', 'Rh 4', 'VFstp 1' and 'th 5') and five from indigenous germplasm collections ('A 1', 'S 144', '6', 'Tara' and '129-2'). Among the natives: A 1 is a popular cultivar from the principal safflower growing areas of the country; Tara and S 144 are elite high yielding types in advanced stages of testing; 6 is a nearly nonspiny bold (large) seeded type; 129-2 is a bold headed derivative from the cross between A 1 and AC 1. All parents and F_1's were raised on deep black soils of the Center's research farm (latitude: 15°09'N; longitude: 76°51'E) under conditions of limited irrigation during the winter 1979-80. The soils are inherently low in nitrogen and phosphorus but rich in potash. Parents and their F_1 diallel crosses were planted in double and single rows respectively of 3 m length using a randomized block design with two replications. Uniform spacings of 45 cm between rows and 30 cm between plants were used. The crop received a basal dose of 40 kg N and 40 kg P_2O_5/ha. All biometrical observations on parents and the F_1's were recorded on five randomly selected competitive plants from each plot. Percent oil in the achene was determined by a Nuclear Magnetic Resonance Spectrometer (NMR). Observations on diameter of capitulum and days to first flowering were based on the terminal capitulum borne on the main axis. Yield per capitulum was computed from plant yield/number of effective capitula per plant. All statistical and genetic analyses were carried out using plot means based on five plants. Adequate crossed (F_1) seed could not be produced in any of the cross combinations involving th 5 as male parent. In order to overcome this difficulty and extract full information from the studies, the available data were analysed as a 10 x 10 full diallel cross (excluding th 5) and also as a 11 x 11 half diallel cross (including th 5). Griffing's (9) model-1, methods 1 and 2, were used for the analysis of combining ability. Wr/Vr graphs were constructed after the procedure outlined by Jinks and Hayman (13) and Hayman (10). Estimates of variance components were based on Hayman's (10) method.

RESULTS AND DISCUSSION

Heterosis and combining ability

Analysis of variance revealed significant genetic differences among parents as well as hybrids in the material for all nine characters studied (Table 1). As judged from the level of significance and the percent contribution of parents vs hybrids comparison to total sum of squares of progenies, heterosis was quite substantial for yield/plant, moderate to large for branch number, number of capitula, yield/capitulum and capitulum diameter but low or negligible for other traits. The prevalence of such hybrid advantages for productivity and related components is also indicated from the frequency of occurrence, range and overall levels of heterosis in the present material (Table 2) as well as a host of other reports on the nature and extent of heterosis in the crop (5, 21, 23, 24, 27, 28).

The mean sum of squares due to general combining ability (GCA) and specific combining ability (SCA) in the analysis of combining ability based on Griffing's (9) model 1, methods 1 and 2, were highly significant for various characters (Table 1). However, the relative proportion of SCA to

Table 1. Combining ability analysis of variance for various agronomic attributes in safflower[1]

Source of variation		df	CHARACTERS (Mean sum of squares)								
			Plant height	Days to 1st flowering	Number of primary branches/ plant	Number of capitula/ plant	Diameter of primary capitulum ($\times 10^{-2}$)	Yield per capitulum ($\times 10^{-2}$)	100-seed weight	% Oil	Yield/plant
Parents	1)	9	355.2**	52.7**	39.2**	172.1**	19.4**	10.4**	4.4**	66.4**	124.6**
	2)	10	336.9**	48.1**	39.5**	172.6**	19.6**	11.0**	4.3**	85.6**	137.6**
Hybrids	1)	39	193.0**	24.3**	16.7**	148.8**	8.2**	13.9**	1.0**	25.4**	379.8**
	2)	54	166.2**	20.0**	14.6**	105.8**	7.1**	11.2**	0.9**	26.0**	149.0**
Parents vs Hybrids	1)	1	2.4	11.1*	26.9**	351.7**	58.1**	83.9**	0.06	13.5**	1992.3**
	2)	1	0.3	16.9**	41.6**	559.7**	82.6**	98.3**	0.03	0.05	2450.0**
Error	1)	99	9.40	2.00	2.02	22.21	1.20	1.22	0.11	0.48	15.24
	2)	65	6.21	1.38	1.30	13.71	0.67	0.51	0.07	0.23	9.65
GCA	1)	9	933.58**	109.70**	73.63**	446.20**	38.98**	50.79**	5.85**	133.00**	446.73**
	2)	10	531.54**	64.46**	45.65**	247.30**	24.22**	26.15**	3.68**	94.45**	224.33**
SCA	1)	45	26.64**	4.18**	4.14**	42.93**	1.89**	4.26**	0.19**	3.79**	107.43**
	2)	55	15.59**	2.62**	2.81**	27.78**	1.56**	2.65**	0.15**	3.32**	67.12**
Reciprocal effects	1)	45	12.82**	3.27**	1.86**	36.06**	0.99**	1.34**	0.11**	1.50**	23.49**
Error	1)	99	4.70	1.00	1.01	11.10	0.60	0.61	0.06	0.24	7.62
	2)	65	3.10	0.69	0.65	6.86	0.33	0.25	0.04	0.11	4.83
σ^2_s/σ^2_g	1)		0.46	0.59	0.86	1.46	0.67	1.45	0.47	0.53	4.55
	2)		0.31	0.39	0.63	1.13	0.67	1.20	0.41	0.44	3.69

[1] df = Degrees of freedom; 1 = 10 x 10 Full diallel cross; 2 = 11 x 11 Half diallel set

Table 2. Performance of hybrids in relation to their parents in a diallel cross of safflower

Characters	Mean of parents	Mean of hybrids	Heterosis percent: Over mid parent Range	Over mid parent Mean	Over superior parent Range	Over superior parent Mean	% of F_1's with means* 1	2	3
1. Plant height (cm)	82.7	83.1	-27.9 to 13.1	0.3	- 6.8 to 39.0	10.2	30	3.3	18.9
2. Days to 1st flowering	74.1	73.3	- 8.8 to	-1.1	- 5.0 to	2.9	30	1.1	13.3
3. Primary branch number	13.1	14.4	-33.9 to 61.9	10.8	-47.4 to 43.5	-6.2	40	8.9	36.7
4. Number of capitula per plant	32.9	37.3	-36.0 to 63.9	14.2	-45.0 to 44.8	-1.1	40	12.2	44.4
5. Diameter of primary capitulum (cm)	2.2	2.4	-10.9 to 20.8	7.4	-18.0 to 16.8	0.5	44.4	10.0	60.0
6. Yield per capitulum (g)	0.6	0.8	-31.9 to 133.3	36.6	-49.5 to 125.4	26.2	52.2	26.7	63.3
7. 100-seed weight (g)	4.3	4.2	-33.9 to 34.5	-0.9	-46.3 to 25.8	-14.8	27.8	2.2	18.9
8. % oil	33.1	34.0	-15.8 to 23.9	2.9	-25.6 to 20.8	-6.2	60	14.4	23.3
9. Yield/plant (g)	18.3	28.8	-27.5 to 242.6	62.6	-46.3 to 193.1	34.3	71.1	50.0	72.2

* 1. Significantly deviating from M.P. 2. Significantly greater than S. P.
3. Equal to or greater than S.P.

GCA variances suggested a preponderance of dominance genetic variances for yield, number of capitula, and yield per capitulum, and additive and additive x additive epistatic interactions for plant height, branch number, time of flowering, capitulum diameter, seed weight and oil percent. Although reciprocal differences were significant for most of the characters in the material they accounted for a negligible portion of the total variability. Apparently, maternal influences play little or no role in the character expression of safflower as demonstrated by several other investigators in the past (15, 16, 27, 28). Although significant differences were noticed in the material for their combining ability effects, none of the lines tested exhibited desirable GCA effects for yield, oil percent and their related agronomic attributes. Thus, most of the high oil lines which otherwise displayed highly significant and positive combining ability effects for seed oil content suffered from adverse or extremely low GCA effects for yield/plant. On the other hand, the high yielding native cultivars such as A 1 were handicapped by poor phenotypic performance associated with unfavorable combining ability for oil percent in the achene. Among the various reduced hull lines assessed for their combining ability, VFstp 1 possessed desirable combining ability for yield, oil percent and a number of other characters like diameter of capitulum, yield per capitulum, and hence forms a potential source in breeding for high yields and oil output. The correlation between parental ranking for GCA effects andtheir corresponding phenotypic performance was highly significant and positive for all the variables. Parental means can therefore be used as a reliable guide to their breeding potential for any given character in the crop, at least in eliminating a large number of poor lines in the initial phase of the breeding program.

Graphic analysis

Hayman's (10) test of t^2 was not significant for any of the characters except yield/capitulum. Therefore, the data provided adequate justification for the extension of the diallel model to the material in question. Variance (Vr) and covariance (Wr) graphs are depicted in Fig. 1 for some growth and developmental traits and in Fig. 2 for yield, oil percent and their components. The slope of the regression line, $b_{Wr/Vr}$, showed a significant departure from zero for all nine variables. Its value equalled or closely approached unity for seed weight, oil percent and branch number, but deviated considerably from one for several others in general and yield/plant and capitulum diameter in particular. The sign and magnitude of Wr intercept values for various characters pointed out the operation of extremely low levels of partial dominance bordering on complete dominance in case of capitulum diameter and yield/capitulum, overdominance for yield/plant and a fairly high degree of incomplete dominance for others. These results therefore provide strong indications for the involvement of additive gene action in the inheritance of seed size, oil content, time of flowering and plant height when compared to yield/plant, number of capitula, yield per capitulum and diameter of capitulum, for which the non-additive genetic effects were quite pronounced. As reflected by the distribution of parental arrays with respect to the theoretical line of unit slope in the Wr/Vr graphs, non-allelic effects detected in the material weremostly made up of the complementary type of interactions in the case of yield per plant, number of capitula and yield per capitulum, and duplicate interactions in case of capitulum diameter, plant height and flowering time. An examination of the relative position of parental arrays from the point of origin in the Wr/Vr graphs brought out the presence of

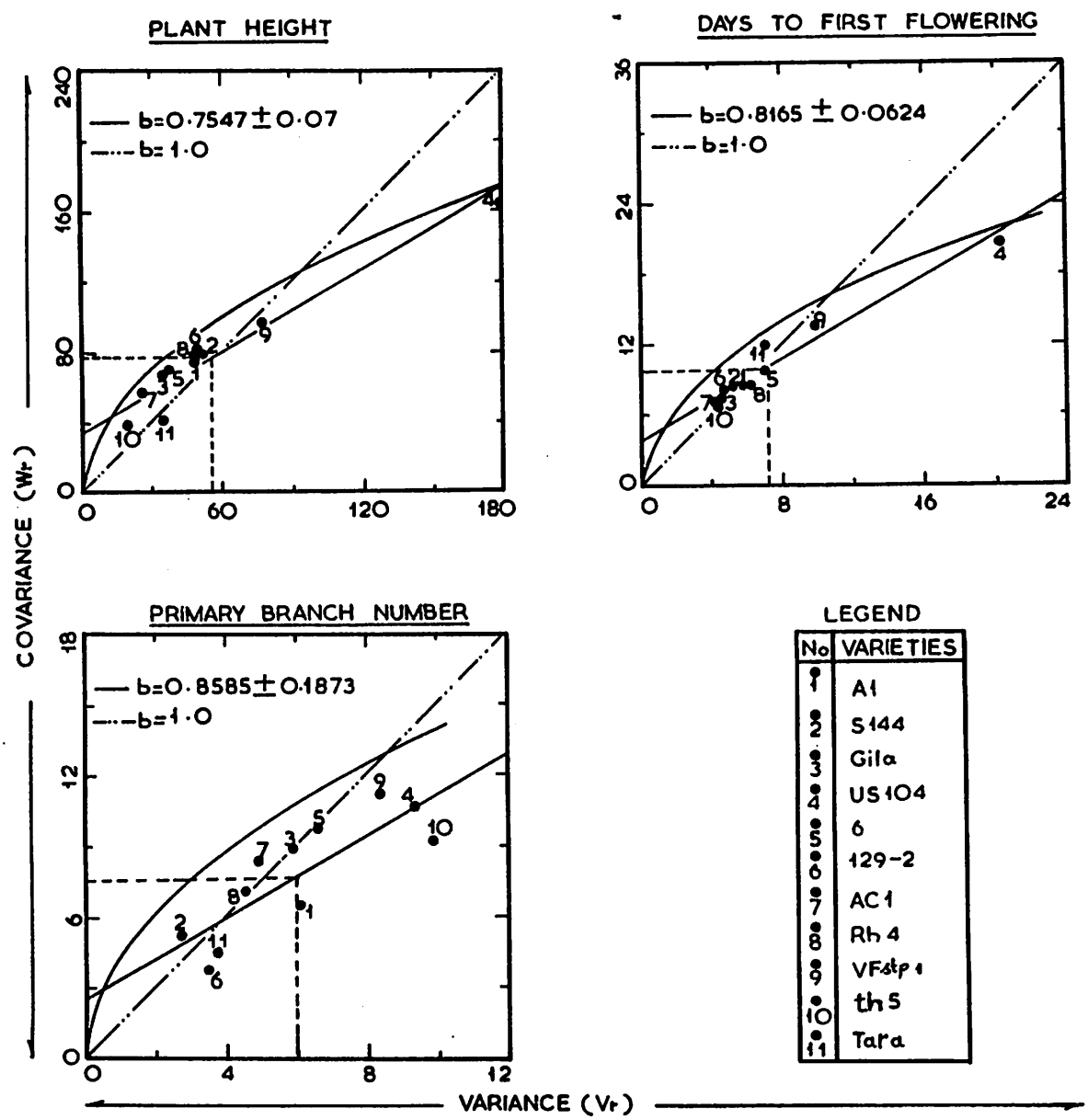

FIG. 1. VARIANCE-COVARIANCE GRAPHS FOR SOME GROWTH AND DEVELOPMENTAL CHARACTERS IN A 11 X 11 DIALLEL CROSS.

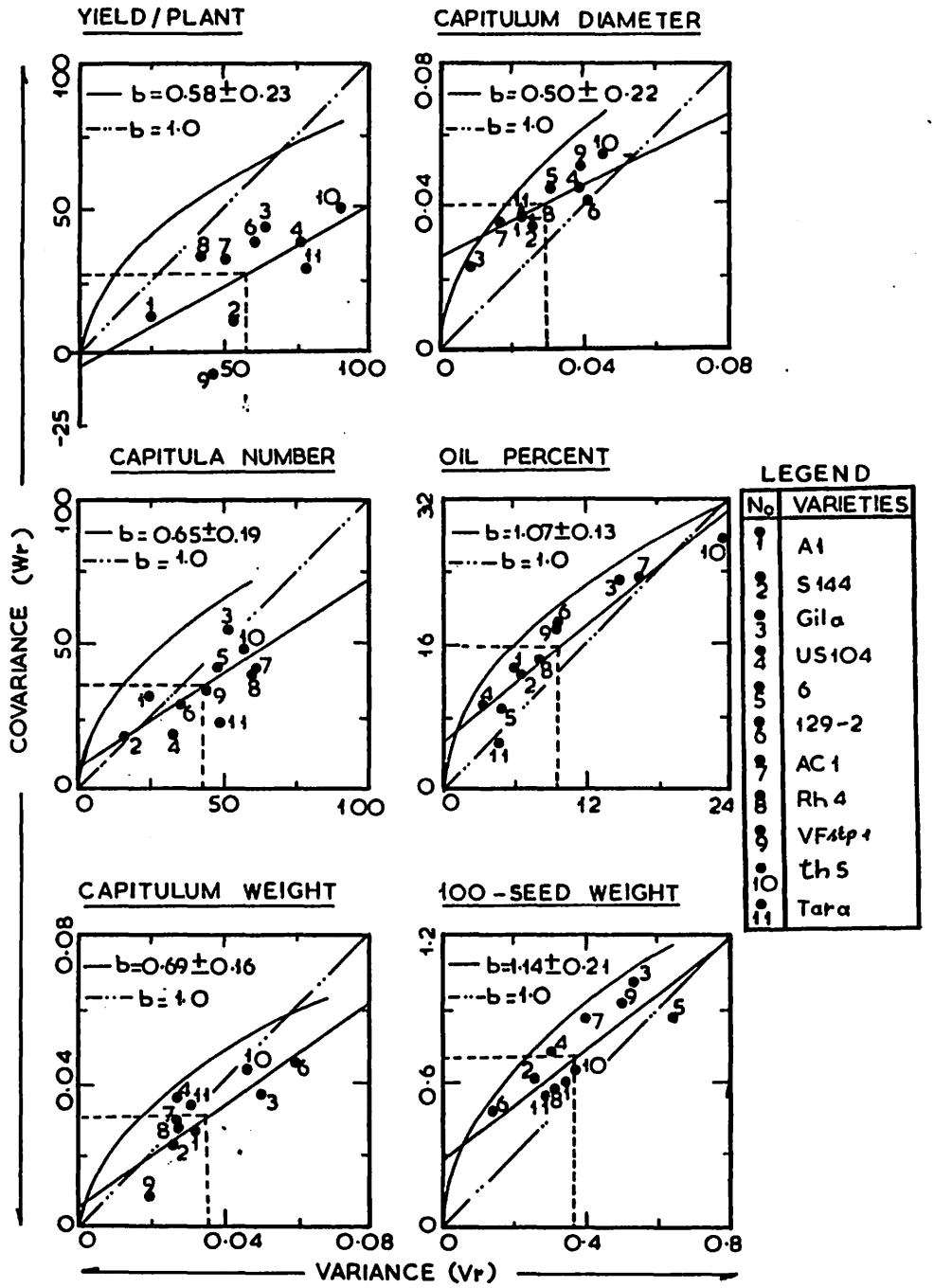

FIG.2, VARIANCE-COVARIANCE GRAPHS FOR YIELD, PERCENT OIL AND THEIR COMPONENTS IN A 11X11 DIALLEL CROSS.

considerable variations in their order of dominance. Maximum number of dominant alleles were present among the parental lines: th 5 and AC 1 for flowering time and plant height; 129-2 and S 144 for primary branch number; S 144 and US 104 for number of capitula; Gila and AC 1 for capitulum diameter; VFstp 1 for yield/capitulum; 129-2 and Tara for seed size; Tara and US 104 for oil percent; and A 1 and VFstp 1 for yield per plant (Fig. 1 and 2). On the other hand, recessive alleles were more frequent than dominant alleles for branch number, plant height and flowering time in US 104 and VFstp 1 and for yield and oil percent in th 5. The proportion of recessive alleles for oil content in the hull mutants were on the whole higher than their thick hull counterparts which highlights the role of pericarp thickness in influencing genetic variability for oil content in the crop. Generally, a higher concentration of favorable alleles for oil content in most of the reduced hull lines was accompanied by a large number of undesirable genes for productivity. The indigenous material on the other hand presented a diametrically opposite pattern of distribution of genes for the above two characters.

Components of variation

Component analysis revealed the existence of significant and fairly large amounts of additive (D) and dominance genetic influence (H1 and H2) for all variables (Table 3). The estimates of dominance variances surpassed the fixable component (D) for yield/plant, number of capitula and yield/capitulum. In contrast to the above characters, the additive component of variation constituted a major portion of the total genetic variability for seed weight, oil percent, capitulum diameter, plant height and time of flowering.

The average measure of dominance $(H1/D)^{0.5}$ suggested the occurrence of overdominance for yield and variable levels of partial dominance for plant height, time of flowering, branch number, seed weight, oil percent, as was observed in case of Wr/Vr graphs. The graphical approach indicated partial dominance for capitula number and more or less complete dominance for yield/capitulum, whereas components of variance method suggested involvement of low levels of overdominance for both the above characters. Such variations in the degree of dominance between the two approaches are not unexpected as the variance component method furnishes only an overall estimate of dominance. It is, however, quite likely that the observed overdominance in some of the above characters is more a result of bias arising out of complementary epistatic effects in their expression than true overdominance. The distribution of positive and negative genes in the parental population was highly asymmetrical for a majority of the traits as revealed by the observed inequalities between H1 and H2 and the deviation of $H2/4H1$ from the expected value of 0.25. The values of KD/KR in excess of 1 for allcharacters other than yield/capitulum indicated a preponderance of dominant genes in the parental material for the above group of variables. The direction and magnitude of 'F' also revealed a similar pattern of distribution. In contrast to available reports which suggested polygenic inheritance for yield and its direct or indirect components (1, 15, 28) the number of effective groups of genes did not exceed four for any of the characters investigated in the present studies. Obviously the use of the relationship h^2/H_2 grossly underestimated the actual number of genes in the material since it provides no information about the groups of genes showing little or no dominance (8).

Table 3. Estimates of genetic components of variation and related ratios for some important characters in safflower

Genetic parameters & their ratios	Characters+								
	Plant height cm	Days to 1st flowering	No.of primary branches/plant	No.of capitula/plant	Diameter of primary capitulum ($x10^{-2}$)	Yield per-capitulum ($x\ 10^{-2}$)	100-seed weight	% Oil	Yield/plant
D	165.4** ±10.4	23.3** ±0.9	19.1** ±1.0	78.9** ±7.1	9.3** ±0.4	6.0** ±0.6	2.1** ±0.1	42.7** ±1.3	69.5** ±11.7
H_1	71.7** ±21.4	10.6** ±1.8	10.9** ±2.1	96.3** ±14.6	4.6** ±0.8	7.3** ±1.2	0.8** ±0.1	18.5** ±3.7	179.8** ±24.9
H_2	48.2** ±18.0	7.7** ±1.6	9.2** ±1.8	81.1** ±12.3	4.0** ±0.7	5.3** ±1.0	0.4** ±0.1	10.6** ±3.1	150.0** ±21.2
F	22.8 ±23.7	6.8** ±2.1	7.5** ±2.4	18.4 ±16.2	2.8** ±0.9	-0.1 ±1.3	1.5** ±0.2	22.8** ±4.1	26.7 ±27.0
h^2	-1.0 ±12.0	2.8** ±1.0	7.3** ±1.2	98.5** ±8.2	14.7** ±0.5	13.1** ±0.7	-0.01 ±0.08	-0.03 ±2.1	355.6** ±14.2
E	3.09 ±3.0	0.7** ±0.3	0.6* ±0.3	7.4** ±2.0	0.3** ±0.1	0.2 ±0.2	0.04* ±0.02	0.1 ±1.6	5.1 ±3.5
$(H_1/D)^{0.5}$	0.66	0.67	0.76	1.11	0.71	1.11	0.61	0.66	1.61
$H_2/4H_1$	0.17	0.18	0.21	0.21	0.22	0.18	0.13	0.14	0.21
$\frac{(4DH_1)^{\frac{1}{2}}+F}{(4DH_1)^{\frac{1}{2}}-F}$	1.23	1.55	1.70	1.24	1.55	0.98	3.88	2.36	1.27
Correlation (Yr+Vr: Yr)	0.80**	0.72*	0.14	-0.29	-0.05	-0.33	0.14	0.81**	-0.68**
h^2/H_2	-0.02	0.36	0.79	1.21	3.66	2.46	-0.02	0	2.37
Heritability(:S)	0.73	0.78	0.76	0.42	0.75	0.43	1.38	1.10	0.29

+Order of characters same as in Table 1

The correlation coefficient between parental performance (Yr) and their dominance order (Wr+Vr) was negative and significant for yield/plant, positive and significant for flowering time, plant height, and oil content, while it was extremely low and non-significant for the rest of the traits. It would therefore appear that genes controlling superior character expression in safflower are recessive for plant height, time of flowering, and oil content, dominant for yield per plant, and both dominant and recessive for other characters. The above dominance relations were also confirmed from the results of graphical and combining ability analysis which showed superior or inferior performance of lines otherwise carrying a high or low proportion of recessive alleles in case of flowering time, plant height and oil content, and dominant alleles in case of yield/plant. The sign and magnitude of net directional dominance (h^2) did not, however, support the above conclusions for the bulk of characters, probably because of unequal distribution of genes detected in the parental population. A few others also indicated the existence of directional dominance towards early flowering and maturity (16) or one of their components, namely short rosette period (29), larger and heavier seeds (15) and higher yields (6). In case of plant height the present studies showed partial dominance of short types over tall types as against Kotecha and Zimmerman (15) who noticed a reverse trend in the material examined by them. Hence, this aspect needs further study.

Narrow sense estimates of heritability which were obtained, based on calculations of Crumpacker and Allard (4), were relatively low for yield, number of capitula, yield/capitulum, but very high for various other traits whose expressions were governed by additive gene action. A large number of earlier workers also reported low heritability associated with strong environmental influences for yield and number of capitula, and moderate to high heritability for other traits (1, 15, 17).

The choice of breeding techniques in any crop improvement program largely depends upon a knowledge of the genetic system governing the inheritance of the character(s). In contrast to morphological characters which have been investigated extensively for their inheritance pattern, very few published reports are available on the genetics of quantitative characters of economic importance in the crop (1, 6, 15, 16). Most of these genetic investigations are based on the estimates of gene effects obtained for some specific character or characters in some selected cross or cross combinations involving two or three parents. The above investigators attributed the observed variability among generation means to additive (16) or non-allelic effects (1, 6) other than dominance in case of flowering and maturity time (6, 16), additive and epistatic effects in case of seed size (6, 15) and dominance influences in the case of yield/plant (6). Yermanos et al (28) implicated the role of additive gene action without any apparent dominance in the genetic control of seed oil content as they failed to detect any significant deviation of F_1 and F_2 means from their respective mid-parents. In the present material all the three diallel analytical approaches, viz., graphical method, component analysis of variance and combining ability analysis, including the results of heterosis, pointed out that a preponderant portion of heritable variation is due to non-additive gene action associated with overdominance for yield per plant and different degrees of dominance ranging from partial dominance to overdominance for number of capitula and yield/capitulum. Nevertheless, considerable additive and additive-epistatic components of variation are also available for selection in the above characters. Unlike yield and its

major contributing characters, a number of other variables such as plant height, time of flowering, seed size, and percent oil were primarily influenced by additive gene action apart from a high degree of heritability, and hence offer substantial scope for their improvement through direct selection. A number of published reports on the extent of heritability, predicted genetic advances (1, 14, 17), direction and magnitude of heterotic effects (5, 21, 24, 27, 28)also lend support to the conclusions arrived above on the mode of inheritance for most of the characters. The nature of gene action observed for various characters in the present material is fully in accordance with earlier genetic investigations for yield (6) and oil (28), while it is at variance with others in case of plant height, time of flowering and seed weight (1, 6, 16), a result of differences in the methodologies used by various workers, restricted genetic diversity of the parental materials tested, and genotype-environmental interactions.

The foregoing results suggest that any major genetic improvements for yield in safflower should come from simultaneous exploitation of both the fixable and nonfixable components of genetic variation rather than additive genetic variances alone. This is best achieved by resorting to more efficient breeding methodologies such as recurrent selection, biparental mating designs and diallel selective mating methods (7, 12) rather than the conventional pedigree or backcross methods employed so far. The recent discovery of simple monogenic recessive genes for male sterility by Heaton and Knowles (11) makes it possible to achieve such a massive gene flow without any serious difficulties despite its predominantly inbred nature (25). Since positive and negative alleles appear to be asymmetrically distributed for most of the agronomic characters in this material as well as in the world germplasm collections (2), use of population approaches would also greatly help in bringing together favorable alleles for components of yield and oil from diverse sources into productive backgrounds through increased recombination frequency, and break-up of undesirable linkages, consequently releasing a wealth of hidden variability for selection of superior genotypes and populations in the crop. As none of the parental lines in the material showed a reasonable compromise between components of yield and those for oil, it would be worthwhile to involve proven good combiners for yield, oil and their principal components in any such population improvement schemes.

The crop also offers considerable scope for the exploitation of dominance variances, which are quite pronounced, through production of hybrids on a commercial scale. In fact, the most heterotic and productive hybrid in the material outyielded its superior parent by as much as 119% and the best standard check by 70%. Rubis (21) and Urie and Zimmer (24) and a few others in the past have also demonstrated the occurrence of such high levels of heterosis for yields in the crop. Invariably the best hybrids in the material involved crosses between genetically diverse parents (20) and/or between native and exotic types. This and similar other reports in safflower (26) as well as other crops (18) emphasize the importance of genetic diversity in heterosis breeding. Although there is as yet no way to capitalize on such a tremendous potential hybrid vigor in the crop, it would nevertheless be rewarding to intensify the search for cheap, inexpensive and effective devices to make hybrid safflower a reality in the near future.

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METHODS OF CULTURING SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) IN THE SEMI-ARID REGION OF ISRAEL[1]

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ABSTRACT

During two years of trials, various combinations of planting date, inter-row spacing and within-row stand of safflower (*Carthamus tinctorius* L.) were tested. Yield was only slightly, or not at all, depressed by delaying planting until late February. Within-row stand (in the range of 10-20 seeds per meter) did not affect yields, due to full compensation in the yield of a single plant by an increase in head number, while other yield components remained unchanged. Increasing the space between rows resulted in lower yields. In that case there was only partial compensation, consisting mainly of increased number of heads per plant and, to a lesser extent, an increased number of seeds per head and increased seed size. Delaying planting to late February, and using half the usual seed quantity (12 instead of 24 kg/ha), seems to be the most promising planting method for the semi-arid region of Israel.

Safflower (*Carthamus tinctorius* L.) is commonly grown in the semi-arid region of Israel under dry farming conditions. The average rainfall in this area ranges between 250 and 350 mm per year and most of it falls after the crop is planted in mid-December. Moreover, the frequency of very dry years, in which an economic yield is not obtained, is rather high.

Delaying sowing to a date by which most of the rain has fallen, helps the farmer to decide whether to sow on sufficient soil water reserves or to leave the field fallow. However, delaying the time of sowing results in smaller-branched plants which may respond differently to the common stand of about 60 seedlings per square meter (in rows spaced 30 cm apart).

In order to study the effect of planting dates and stands on safflower yield under semi-arid conditions, five experiments were carried out during 1978/79 - 1980/81.

MATERIALS AND METHODS

Trials were carried out at two locations: Lakhish, with an average annual rainfall of 350 mm; and Gilat, with an average annual rainfall of 250 mm. In 1978/79 the experiments were carried out in Gilat only, and in 1979/80 and 1980/81 at both locations. In all cases the 'Local' cultivar was used.

Planting dates were planned to be in mid-December, mid-January and mid-February, but due to problems associated with the rains, the actual planting dates were as given in Table 1.

In 1978/79 only the effect of planting date was tested, in the usual stand (60 plants/m^2, rows 30 cm apart). Seeds were to be planted at an average

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[1]Report No. 159-E, 1981 series.

Table 1. Planting dates in three years and two locations.

Location	Planting order	Year 1978/79	1979/80	1980/81
Gilat	1st	18.XII	25.XII	5.I
	2nd	31.I	20.I	25.I
	3rd	1.III	24.II	16.II
Lakhish	1st		23.XII	24.XII
	2nd		18.I	21.I
	3rd		12.III	15.II

soil moisture typical for the date of planting. To ensure this condition, the depth of the moist profile was measured before planting and the soil profile was saturated to the typical depth for that date. Actually the moist profile depths were 25, 45 and 60 cm before the first, second and third planting dates, respectively, due to 54 mm of irrigation applied to the second-planting-date plots in January, and 60 mm of irrigation applied to the third-planting-date plots in February. In addition, early planted seeds (18.XII.1978) were germinated by 25 mm of irrigation given immediately after planting. All the plots were irrigated on 8.III.1979 with 30 mm. Details of rainfall distribution and supplementary irrigation are given in Table 2.

Table 2. Rainfall and irrigation (underlined) in Gilat (1978/79).

Planting date	Before planting (mm) Nov.	Dec.	Jan.	Feb.	Sub-total	After planting (mm) Dec.	Jan.	Feb.	March	Total (mm)
18.XII.78	12	43			55		49	14	71 +<u>30</u>	219
18.XII.78[1]	12	43			55	<u>25</u>	49	14	71 +<u>30</u>	244
31.I.79	12	43	49 +<u>54</u>		158			14	71 +<u>30</u>	273
1.III.79	12	43	49	14 +<u>60</u>	178				71 +<u>30</u>	279

[1]Germinated with a 25 mm irrigation.

In 1979/80 the effects of both planting date and seeding rate were tested in a four-split-blocks design. Six combinations of between-row spaces (30, 60 or 90 cm) and within-row stand (10 or 20 plants per meter) treatments were randomly located as subplots, while planting dates were the main plots. In 1980/81 the effects of planting date and seeding rate were tested again in a four-split-blocks design. Planting dates were the main plots and seeding rates, only as between-row-spaces (30, 60 or 90 cm in Gilat, and 30, 45, 60 or 75 in Lakhish), were the subplots. In an additional four blocks in Gilat, a late irrigation of 30 mm was applied on 7.IV.1981.

In all cases, cultivation practices other than those mentioned above (such as fertilization, pest control, etc.) were as usual in the commercial fields in those regions. Plots ranged in size between 50 and 120 m^2 and they were harvested by an experimental combine.

In 1979/80 in Gilat, all the plants from 2 meters in a central row in every plot were hand-harvested for yield components' determination.

RESULTS

Gilat, 1978/79

Delaying the planting resulted in smaller plants (Table 3). Yield level was very low. The highest yield was achieved in early irrigation-germinated plots. Of the ungerminated treatments the highest yield was achieved from the second planting date and the lowest from the first planting date.

Table 3. Height and yield of safflower planted on three planting dates (Gilat, 1978/79). Values followed by the same letter are not significantly different (P = 0.05)

Planting date	Plant height (cm)	Yield (kg/ha)
18.XII.78	82.5 b	141 a
18.XII.78[1]	98.8 a	422 a
31.I.79	76.3 b	353 ab
1.III.79	58.8 c	203 ab

[1] Germinated with 25 mm.

Gilat, 1979/80

Delaying the planting had only a slight effect on the flowering date (Table 4). Flowering date was not affected by planting rate. Plants responded to a delay in planting by reduced height. Increasing the distance between rows resulted in increased branching of the plants.

Table 4. Flowering date, plant height and rainfall for three planting dates (Gilat, 1979/80).

Planting date	Flowering date	Plant height (cm)	Rainfall (mm)	
			Before planting	After planting
25.XII.79	11.V.80	106	117	222
20.I.80	15.V.80	81	159	180
24.II.80	23.V.80	63	270	69

No difference existed between the yields of the within-row high-density and low-density treatments (Table 5). Yields of the second planting date were lowest for all the planting dates examined, but the differences due to the date of planting were not significant. There was a significant decrease in the yields due to an increase in between-row space. Plants compensated for most of the increase in the space either between rows or within the row by increasing their yields (Table 6). Differences between plant yields for the three planting dates were generally small and inconsistent. The compensatory mechanism acted mainly through increasing the

Table 5. Yields (kg/ha) of plots with different planting stands, spacing and planting date treatments (Gilat, 1979/80). Values followed by different letters are significantly different (P=0.05).

Between-row spacing (cm)	Within-row stand (m^{-1})	Planting date			
		25.XII.79	20.I.80	24.II.80	Mean
30	10	1220	970	1100	
	20	1080	870	1080	
	Mean				1050 a
60	10	1130	770	1010	
	20	1080	870	970	
	Mean				970 b
90	10	860	550	800	
	20	900	740	850	
	Mean				780 c

Table 6. Yield per plant (g) with different planting stands, spacing and planting date treatments (Gilat, 1979/80). Values followed by different letters are significantly different (P = 0.05).

Between-row spacing (cm)	Within-row stand (m^{-1})	Planting date			
		25.XII.79	20.I.80	24.II.80	Mean
30	10	2.56	3.54	3.59	
	20	1.53	1.41	2.72	
	Mean				2.56 c
60	10	6.30	4.54	6.97	
	20	2.88	4.70	3.70	
	Mean				4.85 b
90	10	8.94	8.72	10.69	
	20	5.01	6.69	4.43	
	Mean				7.41 a

Table 7. Yield components of plants grown under various spacing conditions (Gilat, 1979/80). Values followed by the same letter are not significantly different (P = 0.05).

Between-row spacing (cm)	Within-row stand (m^{-1})	Seeds per head	Heads per plant	Weight per seed (mg)
30	10	16.2	4.8	38.2
	20	14.4	3.0	36.6
	Mean	15.3 b	3.9 c	37.4 b
60	10	17.8	8.3	38.9
	20	17.7	5.1	38.3
	Mean	17.7 a	6.7 b	38.6 ab
90	10	18.2	12.5	39.5
	20	19.2	6.8	39.9
	Mean	18.7	9.6 a	39.7 a

the number of heads per plant due to increased space between plants and, to a lesser extent, through an increase in the number of seeds per head and in seed weight (Table 7).

Lakhish, 1979/80

The response of plant height and flowering date to planting date in Lakhish (Table 8) was similar to that described above for Gilat.

Table 8. Flowering date, plant height and rainfall for three planting dates (Lakhish, 1979/80).

Planting date	Plant height (cm)	Flowering date	Rainfall (mm)	
			Before planting	After planting
23.XII.79	116	9.V.80	187	393
18.I.80	94	16.V.80	294	286
12.III.80	68	30.V.80	522	58

The plots from the second planting outyielded the early-planted plots by 15% (average) and the late-planted plots by 74% (average) (Table 9). The advantage of the mid-planted plots existed in all the stands and spacings examined, but was most pronounced at high within-row densities. Yields were significantly increased by decreasing the between-row spaces. There was no relation between the within-row stand and the yield.

Table 9. Yields (kg/ha) of plots with different planting stands, spacing and planting date treatments (Lakhish, 1979/80). Means (space/date) followed by different letters are significantly different (P = 0.05).

Between-row spacing (cm)	Within-row stand (m^{-1})	Planting date			
		23.XII.79	18.I.80	12.III.80	Mean
30	10	2810	3190	1950	
	20	2310	3040	2000	
	Mean				2550 a
60	10	2470	2570	1390	
	20	2460	3030	1540	
	Mean				2240 b
90	10	2180	2200	1200	
	20	2170	2460	1400	
	Mean				1940 c
Mean		2400 b	2750 a	1580 c	

Seed weight increased significantly with a delay in the planting, being 40.3, 41.3 and 45.5 mg for the early, middle and late planting dates, respectively. Seed weight was similar in the small and intermediate between-row spacings (41.6 and 42.0 mg, respectively), but significantly higher at the 90-cm spacing (43.5 mg).

Gilat and Lakhish, 1980/81

The results of these trials will be available after completion of the harvesting in the summer of 1981.

DISCUSSION

Delaying planting to a date by which most of the rains have already fallen is of help in making the decision as to whether to sow on sufficient soil water reserves or to leave the field fallow. Two years of trials in the semi-arid region of Israel showed that such a delay is not necessarily related to a decrease in the subsequent yield. Moreover, in two cases (Gilat, 1978/79 and Lakhish, 1979/80), delaying planting to the middle or end of January resulted in the highest yield. In the other case (Gilat, 1979/80), the yields of the late-planted (end of February) plots were no worse than those of plots planted two months earlier, even though about 80% of the water for the late-planted crop came from soil reserves.

Unfortunately, the rainfall in 1978/79 and in 1979/80 was not typical for this region. The 1978/79 rainfall was far below average, February being almost completely dry. This led to the decision to irrigate with 30 mm in order to save the plants, but it was done when drought damage had already occurred. Moreover, there were two periods of very high temperatures: 2-3.IV.1979 and 27-30.IV.1979. The second high-temperature period coincided with flowering, and presumably resulted in reduced seed set. In 1978/79 the number of seeds per head was one-half to one-third that in 1979/80. On the other hand, 1979/80 was extraordinarily wet and could hardly represent dryland conditions.

Delaying the planting date caused small, branched plants rather than the tall ones common in the December planting. These plants could respond differently to a change in the common planting rate of about 25 kg/ha in rows 30 cm apart. There was no effect from halving the within-row density from 20 to 10 seeds per 1-m row. These results are in agreement with those of Riveland et al. (1). Since yields were not affected by reduced densities in wet years, wider spaces can be used, so that in dry years there will be reduced plant competition for water.

There was a significant response of reduced yields due to row spacing. We assume that the plants in the wider row spacing could not exploit fully the water reserves in such a year, especially in Lakhish. At both locations, although yields were significantly reduced due to row spacing, there was a large degree of compensation by increasing the yield per plant. This compensation was achieved mainly through the number of heads per plant, and the possibility of compensating through the other yield components (number of seeds per head, and seed weight) seemed to be quite limited. Our opinion is that, in a typical dry year, a spacing wider than the common 30 cm may be advantageous because of the high compensation ability of the safflower plant.

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DEVELOPMENT OF ROOT ROT RESISTANCE IN SAFFLOWER BY INTROGRESSIVE HYBRIDIZATION AND THIN-HULL FACILITATED RECURRENT SELECTION

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ABSTRACT

In 1970 a special program was initiated at the Yuma Experimental Station to develop high resistance to Phytophthora root rot. The root rot nursery was planted in the same field continuously year after year. The nursery was stressed for moisture for four weeks prior to flowering and then in early flowering was maintained in a flooded condition for four to five days. Under this treatment all commercial safflower varieties used as checks were 100% killed. The Arizona Wild Composite was used to set up a recurrent selection population using the thth genotype to promote a true intercrossing population. In 1972, the first year that flooding was changed from 24 hours to four days, only .01% of the population (10 plants in 2 acres) survived. In 1980, after five cycles of recurrent selection, some parent-progeny rows have shown as high as 9% survival.

The development of high resistance to Phytophthora root rot of safflower is especially necessary wehre safflower is grown under irrigation. Commercial varieties which are supposedly resistant to Phytophthora root rot are often killed in the low end of the field where irrigation water stands. There is a special need to develop varieties which will survive with no losses under these conditions.

The research program reported here is actually a combination of two separate programs. One program is the development of a wild composite to introgress genes from wild species into domestic safflower to create new recombinations. The second program is the development of a technique to create a high selection pressure to select new genetic recombinations that would have high resistance to Phytophthora root rot.

MATERIALS AND METHODS

Development of Arizona Wild Composite

In 1965, Plant Introductions of 12 Carthamus species (alexandrinus, arborescens, baeticus, caeruleus, dentatus, flavescens, glaucus, lanatus, oxyacantha, palaestinus, syriacus, and tenuis) other than C. tinctorius were planted in 25-foot plots in an observation nursery in Tucson, Arizona. Every third row across the field was planted to the variety, A4138, a thin-hull line of C. tinctorius. This line functioned like a female row on which interspecific crosses could be made by bee activity (2). Because so many of the wild species flower much later than C. tinctorius sections of the A4138 row were planted three weeks later than the regular planting date. At harvest, that planted at the regular date was labeled as "A4138 early" and that planted later as "A4138 late."

In 1966 the A4138 early and A4138 late were planted as male rows and A4138 thin-hull was planted again as female rows. The A4138 early had approximately 20% crossing and A4138 late had approximately 80% crossing. The thin-hull selfs in the male rows were rogued out and only F_1 plant remained. At harvest the male rows were harvested in bulk as (A4138 x Wild bulk) F_2 and the female rows as (A4138 x Wild bulk) BC_1. There was very little F_2 seed obtained because most of the F_1 plants were sterile.

In 1967 the F_2's and BC_1's were planted as male rows and A4138 thin-hull was again planted as female rows. At harvest time all the populations were harvested as a bulk population and labelled Arizona Wild Composite.

Technique to select for high root rot resistance

Production of safflower under irrigation first became possible in Arizona with the development of root rot resistant varieties (3). However, even with improved varieties there is usually some losses on the lower end of the field where irrigation water stands for a day or more. It was first suggested from research in California that stressing for moisture and then flooding was effective for selecting for higher resistance to Phytophthora root rot (1).

In 1970 a root rot nursery was initiated at the Yuma Branch Station where soil is very heavy and high temperatures of over 90 F always occurs at flowering time. A nursery site was selected where safflower could be planted continuously year after year and where irrigation water could be run continuously for several days. In 1970 and 1971 the nursery was flooded for 48 hours. In 1972 the flooding time was increased to 4 days to obtain higher selection pressure.

In 1970 when the root rot nursery was initiated many commercial varieties and breeding selections were tested. This included the California "Biggs" selections from P.I. 250724, P.I. 251981, and P.I. 253538. The Arizona Wild Composite and selections from it showed very high resistance in 1970 and 1971 and since 1972 the total program has been concentrated on this population. Check varieties are planted after every fourth row of nursery. Several different varieties including N10, Gila and Royal have been used as check varieties; however, since 1972 the variety Royal has been used as the standard check variety.

Thin-hull facilitated recurrent selection

The use of the thin-hull gene in a safflower population provides for a very high amount of crossing (2). The thin-hull plants in the Arizona Wild Composite show a very high crossability, with most plants tested showing 98 to 100% crossed seed. The population is made up of three types of individuals, namely, th,th, th,Th, and Th,Th. The th,th plants are crossed by both th and Th pollen and

produce th,th and th,Th plants for the next generation. The th,Th plants are mostly selfed and produce th,th, th,Th, and Th,Th plants for the next generation. The Th,Th plants are mostly selfed and produce Th,Th plants for the next generation.

In absence of random mating, natural selection would gradually eliminate the thin-hull plants; however, in this program there is a high selection pressure to favor thin-hull plants for the next generation. Individual plants are harvested for both selfed and open-pollinated seed and the open-pollinated seed is planted back in progeny rows.

In the root rot nursery the flood treatment is applied in mid-May when safflower is in the early to mid-flowering time. The surviving thin-hull plants are crossed partly by pollen from the whole nursery before the flood treatment, but mostly by pollen from other surviving plants. Therefore, a cycle of recurrent selection is completed in one year. The intense selection of resistant individuals takes place by the flood treatment and the intercrossing of the surviving selections takes place by the crossability of the surviving thin-hull plants which are mostly outcrossed.

RESULTS AND DISCUSSION

Arizona Wild Composite

The exact germplasm source of the Arizona Wild Composite is not known. From the variability of the plant and seed characteristics and from the characteristics of the original F_1's in 1966 it appears that most of introgressive germplasm came from C. flavescens and C. oxyacantha. However, it was evident from the leaf, spine and flower characteristics of the original F_1 population that there were crosses to many of the other species too. Most of these more variable F_1's were sterile but they could have contributed some pollen that would have backcrossed to the thin-hull line and thus introgressed germplasm from these species.

There are two selection pressures that affect the present genetic composition of the Arizona Wild Composite. There is increased gene frequency for root rot resistance because of the flood treatment and there is increased gene frequency for more normal seed characteristics because of selection for seed type at planting time. In spite of these selection pressures the Arizona Wild Composite is a popula - tion that is very heterozygous and heterogeneous. It varies in rosetteness, earliness, spininess, flower color, seed size, seed shape, seed color, hull type, hull percentage, and many other characteristics.

Because of the many new recombinations, this composite is actually a new germplasm not available from any other source.

Root Rot Resistance

In 1970 and 1971 when the root rot nursery was first initiated all the commercial varieties and most of the breeding selections,

including the California "Biggs" selections, were very susceptible and were 99 to 100% killed. The Arizona Wild Composite and selections from it were the only entries which showed resistance. Because this resistance was so high, in 1972 the flooding treatment was increased from 2 days to 4 days in an attempt to increase the selection pressure for gene frequency for root rot resistance. The selection pressure was so high that there were only seven line plants at harvest time from a population of approximately 10,000 (see Table 1). In most breeding experiments one would consider this selection pressure as too high which would result in narrowing the variability and decreasing the chances of further improvement. However, in this case these plants were apparently very heterozygous and different from each other so that their progenies several generations later have resulted in a population that is extremely heterozygous and heterogeneous.

Table 1. Plant survival in safflower root rot nursery in each of five cycles of recurrent selections for root rot resistance, Yuma Branch Station, Yuma, Arizona.

Year	Live plants at harvest Number	Live plants[1/] at harvest %	Live plants in best plots %
1972	7	.07	14.0
1974	23	.30	7.0
1975	103	1.50	50.0
1977	583	5.00	45.0
1980	1473	15.02	85.0

1/ The nursery is one acre in size and each year consists of approximately 10,000 plants. Actual counts have been taken on number of plants surviving each year and the percentage shown is an estimate based on the possible 10,000 plants.

The increase in gene frequency for root rot resistance after five cycles of recurrent selections is shown in Table 1. Increasing the survival in the population from .07% to 15.02% is a 20,000% increase. In 1980 the best plots showed as high as 85% survival; apparently, it would be possible to obtain by selfing pure lines which would have very

high resistance. It should be noted in Table 1 that only five years are shown from nine possible years. The nursery was planted all nine years. The criteria for a successful nursery is that the check row of Royal is 100% killed. If, for any reason, these criteria are not met no selections are harvested and the nursery is repeated the following year with remnant seed.

There is the question whether one is actually selecting for root rot resistance or a "drowning resistance." This was tested in 1979 and 1980 by doubling the size of the root rot nursery by adding two adjacent borders not previously planted to safflower. Arizona Wild Composite was planted in bulk and Royal was planted as check rows. The 4-day flood treatment was applied to all the nursery. In the regular nursery Royal was 100% killed; whereas, in the new area it was only 50% killed. It is quite apparent that the Phytophthora organism had built-up in the soil where safflower was grown continuously. In the new area the organism was apparently present but at a very low concentration.

Recurrent selection and introgressive hybridization

The male sterile characteristics is used in many crops as a mechanism to provide a large amount of intercrossing. In safflower the thin-hull gene is in every way as effective but even more valuable because thin-hull plants can be selfed and maintained.

In this study it was impossible to determine which wild species actually crossed to the C. tinctorius thin-hull line. A future study should be made with each species one at a time. Using bee pollination many thousands of pollinations can be made and it is possible that crosses may be accomplished which hand crossing may have determined was not possible. It is possible to obtain F_1's from two species having unlike chromosome numbers. Even though the F_1 is sterile it is possible to obtain some good pollen so that with thousands of pollinations a backcross is accomplished. One eventually ends up with a C. tinctorius background with very small amounts of another species.

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THE INHERITANCE OF LEAF-SHAPE IN SAFFLOWER (CARTHAMUS TINCTORIUS L.)

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ABSTRACT

Three leaf-shape types, namely cuneate (30), obovate (29A) and lyrate (48) were crossed in a diallel fashion. Leaf-shape is found to be governed by three factors, designated as Cu, Ob and L. The order of dominance is cuneate > obovate > lyrate. The cuneate in a cross with the obovate type gives 12 cuneate: 4 obovate in F_2 and in backcrosses with parents 30 and 29A show a close fit to a 1 cuneate: 1 obovate ratio. The cuneate in a cross with lyrate produces all three leaf-shapes, cuneate, obovate and lyrate in a ratio of 9:6:1 in F_2 and in a backcross of the F_1 with cuneate produces all cuneate, and in backcrosses of the F_1 with lyrate, progenies segregate 1 cuneate: 2 obovate: 1 lyrate. The F_2 progenies of the cross obovate x lyrate show a close fit to 15 obovate: 1 lyrate and backcrosses with lyrate and obovate types give 3 obovate: 1 lyrate and all obovate, respectively. The genotypes assigned to the parents are CuCuobobll (cuneate, 30), CuCuobobLL or cucuObObll (obovate, 29A) and cucuobobll (lyrate, 48). Dominant alleles Cu and Ob interact to produce cuneate type leaf and absence of any of these gives obovate. The relationships of leaf-shape with flower color, hull types and other traits are in progress.

Studies on the establishment of cytogenetic stocks in safflower in this laboratory had resulted in a large number of translocation lines (1, 4) and possible translocation break-points were determined on the basis of karyotypic analysis (1, 2). However, these break-points could not be confirmed through linkage study due to lack of suitable genetic markers. Various types of leaf morphology were observed in the safflower germplasm collections, but no study has been made as yet regarding their inheritance and chromosome mapping. With a view to developing linkage testers, a study on the inheritance pattern of various qualitative traits is in progress at this laboratory. The present communication deals with the inheritance of leaf shape in safflower (Carthamus tinctorius L.).

MATERIALS AND METHODS

Three lines of safflower with distinct leaf shape, namely 29A (obovate), 48 (lyrate), and 30 (cuneate) were chosen (3) and crossed in all possible combinations. F_1, F_2 and backcrosses to either parents (BC_1 and BC_2) were produced in each of the three crosses and were grown with their respective parents in a compact family block design with four replications at B.H.U. Research Farm, Varanasi, during 1978-79. Plants were spaced 20 cm apart within the rows and 45 cm apart between the rows. Individual plants were scored for leaf shapes and data were analysed statistically using chi-square techniques to test the goodness of fit to expected ratios.

RESULTS AND DISCUSSION

The morphology of leaves in the three parents are presented in Table 1 and Fig. 1. The parent 29A had obovate leaf shape, dentate margins and acute apex, parent 48 had lyrate leaf shape, serrated margin and acute to sub-acute leaf apex, and parent 30 showed cuneate leaf shape, spiny margin and acute to subacute leaf apex.

Table 1. Leaf morphology in three lines of safflower.

S. No.	Lines	Leaf morphology		
		Shape	Margin	Apex
1.	29A	obovate	dentate	acute
2.	48	lyrate	serrate	acute to subacute
3.	30	cuneate	spiny	acute to subacute

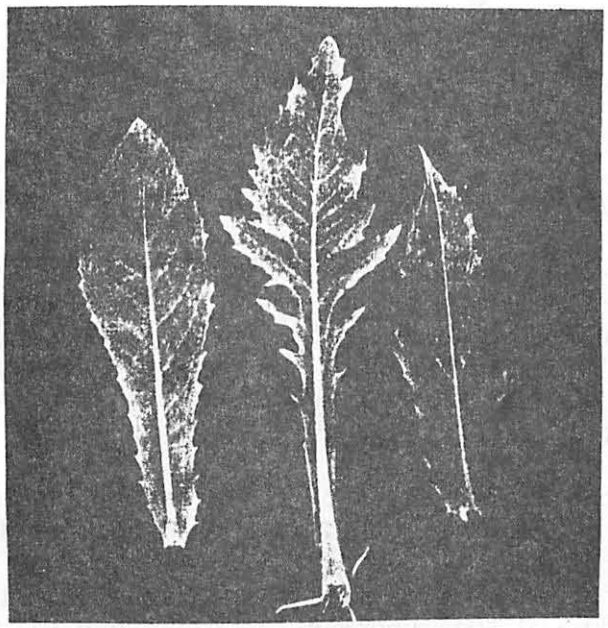

Fig. 1. Leaf shape of, left to right, 29A (obovate), 48 (lyrate) and 30 (cuneate).

In cross 30 (cuneate) x 29A (obovate) (Table 2), all F_1 plants showed cuneate type of leaf shape. The F_2 showed a close fit to the ratio 12 cuneate: 4 obovate (X^2 = 0.333, P = 0.50 - 0,70). A backcross of F_1 with with the parent 30 (cuneate) produced all cuneate type, while with the parent 29A (obovate), plants segregated 1 cuneate: 1 obovate (X^2 = 0.178, P = 0.70 - 0.50).

The cross 30 (cuneate) x 48 (lyrate) (Table 3) produced all cuneate type leaf shape in F_1, while in the F_2 there were three classes which showed

Table 2. Segregation pattern of leaf shape in safflower - cross 30 x 29A (cuneate x obovate).

Generation	No. of plants		Ratio	X^2	P
	Cuneate	Obovate			
F_1	All	-	-	-	-
F2	295	105	12:4	0.333	0.70-0.50
BC to 30	All	-	-	-	-
BC to 29A	98	102	1:1	0.178	0.70-0.50

Table 3. Segregation pattern of leaf shape in safflower - cross 30 x 48 (cuneate x lyrate).

Generation	No. of plants			Ratio	X^2	P
	Cuneate	Obovate	Lyrate			
F_1	190	-	-	-	-	-
F2	265	184	31	9:6:1	0.214	0.70-0.50
BC to 30	109	-	-	-	-	-
BC to 48	86	182	92	1:2:1	0.466	0.50-0.30

a good fit to the ratio 9 (cuneate): 6 (obovate): 1 (lyrate) (X^2 = 0.214, P = 0.70 - 0.50). The backcross with the parent 30 showed all cuneate type and with the parent 48 gave three types of leaf shapes in the ratio of 1 (cuneate): 2 (obovate): 1 (lyrate) (X^2 = 0.466, P = 0.50 - 0.30).

On the other hand, the F_1 progenies of the cross 48 (lyrate) x 29A (obovate) were all obovate type (Table 4). The F_2 showed a close fit to the ratio 15 (obovate): 1 (lyrate) (X^2 = 0.890, P = 0.50 - 0.30). The backcross with the parent 48 showed a close fit to the ratio of 3 (obovate): 1 (lyrate) (X^2 = 0.646, P = 0.30 - 0.50), whereas the backcross with parent 29A resulted in all obovate types.

The study showed that possibly three pairs of alleles, designated as CuCu, ObOb and LL were involved in the control of the three types of leaf shapes in the present materials. Factors CuCu and ObOb interacted and produced cuneate type while an absence of any of these two resulted in the appearance of obovate leaf shape, thereby suggesting the dominance of cuneate over obovate. The lyrate leaf type was found to be recessive to both cuneate and obovate leaf types and, as expected, in all cases where dominant alleles of any of these three factors (CuCu, ObOb, LL) were present, lyrate leaf shape was not seen. This suggested the possible genotypes for the lyrate type (Parent 48) as cucuobobll (triple recessive). Based

Table 4. Segregation pattern of leaf shape in safflower - cross 48 x 29A (lyrate x obovate).

Generation	No. of plants		Ratio	χ^2	P
	Lyrate	Obovate			
F1	184	-	-	-	-
F2	445	35	15:1	0.890	0.50-0.30
BC to 48	103	29	3:1	0.646	0.50-0.30
BC to 29A	149	-	-	-	-

on the segregation patterns described above, the genotypes of the other parents were as follows: Parent 30 (cuneate) = CuCuObObll; and Parent 29A (obovate) = CuCuobobLL or cucuObObLL. The order of dominance thus was cuneate > obovate > lyrate.

Further studies regarding linkage relationships of the leaf shapes and their relationships with other qualitative traits such as flower color, hull type, leaf margin, leaf apex and quantitative traits such as capitulum type are in progress.

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A HALF SEED ASSAY FOR SCREENING SAFFLOWER LINES FOR HIGH LYSINE AND METHIONINE

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ABSTRACT

A petri dish assay using Pedicoccus mesenteroides, a lysine requiring bacterium, was used to screen approximately 1300 lines of the 1973 world safflower collection in search of introductions producing seed high in lysine. Half seeds were also assayed for methionine using a similar method. The introductions highest in lysine and/or methionine were crossed to commercial cultivars. The F_2 seed was also assayed for high lysine and/or methionine. Based on these assays, several lines were found to produce high lysine-methionine seed. This research study will be continued in 1981.

Soybean is a crop valued for its oil content as well as the high protein meal. The dual use of this crop provides a somewhat stable economic base. Safflower and sunflower seed meals, after oil extraction, are low in certain essential amino acids, thus reducing their value as feed supplements for livestock fed on cereals such as corn, barley and sorghum (Table 1).

Table 1. Amino acid composition of feedstuffs (% as fed).

Meal	Lysine	Methionine	Threonine	Tryptophan
Soybean meal (44% protein)	2.9	0.65	1.8	0.63
Soybean meal dehulled (47.5% protein	3.2	0.72	2.0	0.64
Safflower meal (22% protein)	0.7	0.33	0.5	0.26
Safflower meal dehulled (42% protein)	1.3	0.69	1.3	0.6
Sunflower meal + hulls (21% protein)	0.95	0.57	1.0	0.45
Safflower meal (dehulled) as a % of soy meal (44%)	45	106	72	41

Current prices of soybean meal in Montana are about $300/ton + $50. In comparison, the 22% protein safflower meal brings about $80/ton. A relatively small part of this difference ($20 - $30/ton) is made up by shipping costs of soybean meal from Midwest states. Most of the price differential is due to the difference in nutritional value which reduces

the usefulness of, and demand for, safflower meal. Soybean meal contains highly digestible protein and is relatively well-balanced in essential amino acids; hence, this meal can be added as a sole supplemental protein to animals fed on a cereal diet. The lysine and methionine of soybean meal are usually the first amino acids to become limiting in soy-corn, soy-sorghum, or soy-barley diets.

Safflower meal, even when dehulled, is low in lysine (45% of soymeal), threonine (72% of soymeal), and tryptophan (41 % of soymeal) (Table 1). Both meals are equally low in methionine. There are possible genetic solutions to this safflower meal problem. One is to breed in a greater protein yield per acre. The second, and more feasible solution, is to genetically select for higher levels of the essential amino acids lysine, methionine, and threonine. This approach, in turn, has three avenues: 1) selectively breed higher free amino acid levels of all three amino acids; 2) look for varieties with proteins that are disproportionately high in all three of these amino acids; and 3) ferment safflower meal with Lactobacilli capable of excreting high amounts of lysine and methionine.

We have already initiated research into this problem and have: 1) comleted development of a rapid and inexpensive half-seed assay of lysine, methionine, and tryptophan; 2) compared 1,341 safflower lines for relative levels of lysine and methionine - twelve lines were high in both lysine and methionine, and about 200 lines high in one or the other (Table 2); 3) crossed various combinations of promising lines and carried crosses to F_2; 4) compared lysine and methionine levels of these lines, sorting high lines into segregating lines and uniformly high lines; 5) compared the highest two lines with the cultivar 'S-208' for total protein and for lysine and methionine using amino acid analysis; and 6) fermented safflower meal with normal Lactobacilli and mutant lysine and methionine excreting Lactobacilli - this will be reported elsewhere.

MATERIALS AND METHODS

A non-destructive determination of lysine or other nutritionally essential amino acids in half-seeds of safflower was developed in our laboratory. The assay permits rapid screening of large numbers of plump seeds for those containing high lysine or methionine.

The surface of safflower seed harbors various undesirable fungi and bacteria, some of which grow well in the agar use in this assay. To combat this, the seeds were heat-treated in water for 30 minutes at 50 C. After drying, they were soaked in 5% sodium hypochlorite (Clorox bleach) for 3 min, followed by a soaking in 250 ppm benomyl (a.i.) (Dupont) solution for another 3 min, and subsequently dried on paper towels.

Following this seed treatment, the safflower seeds were cut transversely, dehulled, and the top half placed on Lysine Assay Medium (Difco) containing 0.15% Nobel agar (Difco) which had been cooled and seeded with 10^5 cells/ml of Pediococcus cerevisiae Balcke (formerly Leuconostoc mesenteroides strain ATACC/8042 and available from Difco). This bacterium was previously grown in Lysine Assay Broth containing 10 µg/ml lysine followed by 2 centrifugal washings with Lysine Assay Broth. The top half of the seed was placed on lysine assay agar seeded with Pediococcus cerevisae,

which requires the appropriate amino acid for methionine assay medium. The bottom half of the seed was kept until the assay was read and then it was planted, if desirable. Similarly, experiments were done with one-quarter seed being used for methionine and the other quarter for lysine.

We first developed the assay for barley where high lysine lines already existed. In the case of these lines, growth of the bacteria in a zone around the seed is approximately proportional to the amount of lysine released from the half-seed. Normal lines have very small amounts of such lysine, as compared to certain mutants.

Zones of bacterial growth appear by 19 hours and do not expand appreciably for the next day. The optimal time to record zone size is after 48 hours.

A diverse collection of 1,341 safflower lines were compared on lysine and methionine assay agar. Four seeds were sterilized, as above, cut in half, and placed on lysine or methionine assay agar.

For amino acid analysis, seeds were ground, oil was extracted with hexane, and the resultant meal was assayed for amino acids after a 24-hour 6N-HCl hydrolisis at 110 C by AAA laboratories, Mercer Island, Washington 98040.

RESULTS

Preliminary survey

Four seeds from each of 1,341 safflower lines from the world collection were assayed for the presence of soluble lysine or methionine. The results of this initial survey are given in Table 2.

Table 2. Assay of safflower lines for high levels of lysine or methionine.

	Number of lines
High lysine only	137
High methionine only	100
High lysine and methionine	12
Total lines surveyed	1,341

Further breeding

Crosses were made between lines from each of the groups in Table 2, and F_2 progeny were screened again with the plate assay. The seeds were screened from each of 90 F_2 populations. A few crosses showed segregation for lysine or methionine production, and some crosses gave uniformly higher levels of either or both amino acids. Either of two parents were usually necessary for high lysine.

Amino acid analysis

Amino acid analysis after dehulling and oil extraction was performed on meals from three lines, S-208 and two two experimental lines derived from crosses, 6105-2 and 6110-5.

Table 3. Amino acid analysis of safflower lines.

	Cultivar or line source		
Amino acid	S-208	6105-2	6110-5
Lysine	1.53	1.59	1.76
Isoleucine	1.80	2.21	2.13
Leucine	3.19	3.88	3.72
Methionine	.89	.79	.84
Phenylalanine	2.22	2.87	2.68
Threonine	1.76	1.89	1.93
Tyrosine	1.55	1.96	1.89
Protein (% w/w)	47.3	58.7	57.8

DISCUSSION

The findings in this preliminary study are as follows: 1) safflower seeds vary in amount of lysine and methionine that diffuses from a cut seed; 2) lines appear to differ in lysine and in methionine content, some consistently high, some appearing to segregate; 3) lysine and methionine content are not linked, in the sense that either can be high and only rarely both are high; 4) certain lines may be of value if breeding for lysine or methionine is desired; 5) amino acid analysis shows that two mutant "high lysine" lines were higher in protein (ca 58%) than the standard line S-208 with ca. 47% protein; 6) amino acid analysis revealed that specific amino acid percentages differed among the three lines; 7) protein quality, in terms of lysine, was not changed appreciably.

The half-seed assay for lysine and methionine that was developed can permit rapid analysis of large numbers of seed. Lines can be found that are uniformly higher in one or both of these amino acids. Amino acid analysis of only two F_2 selections was performed and altered ratios of amino acids were found. Additional breeding and analysis may reveal lines with meals that are of higher nutritional value than meals from current safflower lines.

PROBLEMS AND PROSPECTS OF SAFFLOWER CULTIVATION IN THE STATE OF MADHYA PRADESH, INDIA

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ABSTRACT

The performance of safflower (Carthamus tinctorius L.) in the centrally situated state of Madhya Pradesh of India, where it is not grown traditionally, appeared to be reasonably satisfactory. For rainfed cultivation with medium inputs and agronomic practices, plant type with spiny leaves, medium in-plant characters such as maturity, height, branching pattern, and head size, and seed weight showing minimum variation in seed number in different heads, appeared to be promising. An approach to solve the problem of germinability under receding soil moisture conditions with a view to obtain optimum plant stand, ultimately increasing the total yield, is discussed. Certain germplasm lines have been observed to be tolerant to diseases like powdery mildew and rust under field conditions. Observations recorded on selfing and crossing techniques are discussed. Efforts are underway to popularize safflower variety JSF-1, developed at this center, with farmers.

Unlike other safflower (Carthamus tinctorius L.) growing states in India, viz., Maharashtra, Andhra Pradesh and Karnataka, the state of Madhya Pradesh is characterized by a wide range in agroclimatic conditions (Table 1). The area and production in diverse environmental conditions (Table 2) could be of great significance with regard to adopting a strategy to plan a crop improvement program. The evaluation of safflower formed a part of the Dryland Project at Indore since 1971, but a regular problem-based approach began in September, 1979, with the All India Coordinated Project for intensification of research on safflower at the J. N. Agricultural University, Indore, with financial aid from the International Development Research Centre, Canada.

Table 1. Soil type, rainfall and cropping pattern in different regions of Madhya Pradesh.

S. No.	Region	Soil type	Rainfall	Main crops
			cm	
1.	Northern and central	Medium black to mixed red and black and alluvial	80-140	Sorghum and wheat
2.	Western	Medium black	80-100	Cotton and rice
3.	South central	Deep black to light black	100-120	Rice, sorghum and cotton
4.	Eastern	Red and yellow	140-160	Rice

Table 2. Safflower growing districts of Madhya Pradesh.

S. No.	District	Soil type	Area under safflower (ha)	Average yield (kg/ha)	Main crops
1.	Seoni	light black	268	179	rice and sorghum
2.	Durg	red & yellow	108	194	rice
3.	Raipur	red & yellow	69	130	rice
4.	Bilaspur	red & yellow	48	125	rice
5.	Rajnandgaon	red & yellow	47	85	rice
6.	Chhindwara	light black	44	159	sorghum
7.	Balaghat	red & yellow	24	208	rice
8.	Hoshangabad	deep black	24	208	wheat
9.	Indore	medium black	22	227	wheat & cotton
10.	Mandla	gravelly	19	105	rice
11.	Khandwa	medium black	18	222	cotton

Increasing the oil yield is the major objective in this crop. This can be achieved either by increasing seed yield without a change in oil content or by significantly raising the oil content in the improved varieties of safflower. The problems encountered in the crop and their solution are described below.

LOW YIELD POTENTIAL AND ADAPTATION IN DIVERSE CLIMATIC CONDITIONS

Safflower is not traditionally grown in the State of Madhya Pradesh. The average yield in general is very low in the small safflower growing pockets of the state (Table 2). However, the yield evaluation trials conducted during 1979-80 in the IDRC All India Coordinated Safflower Research Program (Table 3) have indicated that, with better management practices, yield levels of 17 Q/ha could be obtained exclusively under dry conditions. Variety JSF-1, developed at this Center, gave an average yield of 1000 to 1500 kg/ha under dry conditions (Table 4). This variety, attaining a height of 65-70 cm, matures in 150 days and contains 30% oil. This variety has given the highest yield in All India initial evaluation trials conducted during 1980. The selection for high seed yield appeared to be effective as a few promising strains, yielding higher than JSF-1, have been identified in a preliminary trial during 1980.

IDENTIFICATION OF A SUITABLE PLANT TYPE

In broad terms there are three plant types, viz., short bushy, short compact (broom shaped) and tall lanky. Each plant type has the following structural variations: 1) branching variable at different levels; 2) variable angle of branching; 3) variable in secondary and tertiary terminals that ultimately determine the number of capitula; the heads, varying considerably in number, in turn are large, medium and small in size, and are found to be variable from open (like sunflower) to absolutely closed and never opening types. The seed number and size vary in different heads.

Table 3. Average yield of evaluation trials during 1979 and 1980.

Trial	Yield, 1979		Yield 1980	
	Average	Range	Average	Range
	kg/ha		kg/ha	
PVT	2131**	1573-2601	1325*	503-1751
IET	1946**	1041-2541	2004**	1277-2902
CVT	2021**	895-2488	1566**	538-2219
NYET	-	-	1772**	1233-2078

*Exclusively under dry condition.
**With one protective irrigation for germination.

Table 4. Performance of promising safflower varieties in different trials during 1980.

Trial	Variety	Plant height (cm)	Branches/ plant	Heads per plant	100-seed weight (g)	Seed yield kg/ha	SE	CV%	CD5%
PVT	JSF-16	66	16	96	7.44	1751	NS	-	NS
	JSF-13	73	9	23	6.21	1725			
	JSF-1	63	10	44	8.10	1451			
IYET	JSF-1	72	7	25	8.34	2902	NS	-	NS
	BLY-1002	87	10	34	4.04	2555			
CVT	K-1	83	13	65	4.75	2219	NS	-	NS
	JSF-1	60	11	61	7.06	2181			
	JSF-3	71	12	53	7.48	2164			
NYET	S-144	74	9	46	5.87	2078	163	18.4	480
	83	84	8	29	7.41	2038			
	JSF-1	64	8	47	7.01	1945			

The study of the available germplasm of safflower led to the isolation of 17 diverse types. The yield component study in these types (Table 5) indicates that the more the number of branches or number of heads per plant the more is the number of barren heads or heads with reduced number of seeds.

Considering all these observations, it appears that the spiny plant type, not very bushy or compact, with medium plant characters like maturity, plant height, branching pattern, head size, seed weight and showing minimum variation in seed number in different heads appeared to be ideal for cultivation under stress environment. These findings are being used in planning a hybridization program so as to develop an ideal plant type with higher yield potential.

Table 5. The diverse types of safflower.

S. No.	Plant height (cm)	Branches/ plant	Heads/ plant	Seeds/ head	Barren heads/ plant	100-seed weight (g)	Seed yield/ plant (g)
1	42.0	5	5	59.0	nil	6.66	25
2	52.5	20	108	32.5	9	5.52	180
3	57.5	12	32	9.4	5	8.18	255
4	61.5	9	24	28.6	nil	4.98	31
5	63.0	21	97	12.3	4	4.34	109
6	67.5	18	68	15.7	nil	7.14	72
7	68.0	20	45	51.9	nil	4.25	95
8	68.0	18	41	18.2	nil	8.50	61
9	68.0	11	33	38.7	2	4.99	69
10	68.5	15	34	21.9	1	6.22	46
11	68.5	9	21	19.6	nil	9.41	106
12	87.5	7	12	17.7	2	4.39	9
13	96.5	19	122	53.5	2	4.18	297
14	105.0	30	130	30.4	7	4.05	154
15	123.5	20	64	63.6	2	4.45	186
16	125.5	35	143	30.2	6	3.40	236
17	132.5	42	248	14.0	93	5.10	224

PROBLEMS AT THE REPRODUCTIVE PHASE

Considerable self pollination was observed to take place in safflower at Indore in most of the types grown side by side even in the presence of adequate bee population. In a large population of JSF-1, grown from open-pollinated seed, less than 0.5% cross-pollinated plants were observed, which indicated a preponderance of self-pollination in this crop. A study of seed setting in different bags also revealed that self-pollination is much more common in safflower. Maximum setting selfed seed was recorded on using nylon netting bags (Table 6). This uncertainty in the mode of pollination coupled with certain plant characters like size and position of the head on the plant appears to be responsible for the generally observed low seed setting in different heads. Further, quite a few small and underdeveloped seeds were found. Such seeds generally have very low germinability. The observations further indicated that natural seed setting, as well as that with controlled pollination, was relatively higher in heads situated at the lower portion of the plant than at apical ends. It was observed that seed setting in larger heads with controlled pollination was less than 5%. The unequal translocation of limited moisture and food material to heads and florets situated at different positions might be the reason for poor seed setting.

Table 6. Seed setting of safflower under different selfing bags.

S. No.	Kind of bag	Number of seeds/head
1	polythene	2.1
2	brown paper	8.7
3	butter paper	7.2
4	muslin cloth	11.3
5	nylon netting	14.6

LOW PLANT STAND IN STRESS CONDITIONS

Although safflower is considerable resistant to soil moisture stress, the rapidly depleted soil moisture at the time of sowing was observed to affect its germination and final stand, resulting in poor yield. In order to estimate the losses due to poor stand, a simple preliminary experiment with six treatments as given Table 7 was conducted in two environments: one stressed (completely under dry condition); and the other nonstressed (one protective irrigation for ensuring good germination and stand). The results showed that a yield increase of 21% (it barely missed statistical significance at 5%) was obtained in the non-stressed environment because of optimum plant stand which is usually difficult to attain under dry conditions.

PEST AND DISEASE PROBLEMS

The sucking aphid (Macrosiphum solidaginis) causes considerable damage to the crop in late plantings as compared to planting by the end of September to the first week of October. There appears to be no tolerant source available in the germplasm stocks at Indore.

The major disease problems in safflower have been powdery mildew caused by Erysiphe cichoracearum and rust caused by Puccinia carthami. A large number of entries in the coordinated varietal trials and also those in the germplasm nursery have been screened for their relative reaction to rust (Table 8) and powdery mildew (Table 9) under field conditions. Of particular interest has been the observation that powdery mildew was a major problem in dry conditions and rust the major problem under irrigation. Strains FT21, HUS-277 and MYT-28 were observed to be free of rust.

PROSPECTS OF SAFFLOWER CULTIVATION

The extension service and the research work has to go hand in hand to bring about the real impact of technological advancement on farmers' fields. This is particularly important in the case of safflower, since it is a new crop to Madhya Pradesh. Initially the spiny nature of safflower did pose difficulties in manual harvesting and threshing. Also, with the limited produce, marketing was a problem, Intensive extension efforts through on-farm trials and demonstrations, motivating the farmers through constant training and visits, field day celebrations and the use of audiovisual aids, including 16 mm film available on the subject produced by Malwa Nirman Udyog, Indore has helped the extension agency of

Table 7. Performance of safflower variety JSF-1 under stressed and non-stressed environments.

S No.	Treatment	Plant height (cm)		Branches/ plant		Heads/ plant		100-seed weight (g)		Seed yield/plant (g)		Seed yield kg/ha	
		E1	E2	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2
1.	Farmer's practice of cultivation	51	64	15	15	99	46	7.65	9.40	96	66	775	1375
2.	Improved method of cultivation except optimum time of sowing	58	67	17	10	56	22	8.05	8.5o	56	27	1o37	1650
3.	Improved method of cultivation except optimum spacing	53	64	19	18	153	95	8.97	7.50	80	93	1030	1125
4.	Improved method of cultivation except fertilizer	50	63	16	16	75	57	6.18	7.95	149	73	850	1100
5.	Improved method of cultivation except plant protection	59	65	19	18	130	52	9.00	7.98	97	75	1000	1444
6.	Complete improved method of cultivation	64	62	21	20	99	81	7.09	8.50	80	119	1650	1700
	Mean	56	64*	16	16	101**	59	7.82	8.31	93	75	1157	1399
	% increase		(14.3)		(12.5)		(71.2)		(6.3)		(24.0)		(20.9)

E1-Stress environment
E2-Nonstress environment
*Significant at 5% level
**Significant at 1% level

Table 8. Screening of safflower germplasm lines to rust (Puccinia carthami).

Number of lines screened	371
Number of lines resistant	50
Number of lines moderately resistant	253
Number of lines moderately susceptible	64
Number of lines susceptible	4

Table 9. Reaction of certain safflower lines to powdery mildew (Erysiphe cichoracearum.

S. No.	Entry	Reaction
1.	JSF-1909	Free from disease
2.	JL 2	Free from disease
3.	JSF-1039	Free from disease
4.	JSF-1907	Free from disease
5.	JL 28-1	Free from disease
6.	JSF-1037	Free from disease
7.	No. 29-1	Free from disease
8.	Type 65	Free from disease
9.	JSF-2	Free from disease
10.	JSF-1021	Free from disease
11.	JSF-17	Free from disease
12.	JSF-13	Moderately susceptible

the University and the State Government in making an initial breakthrough. The cultivators have started taking up safflower cultivation and are willing to continue with this crop. Having been convinced on the suitability and utility of safflower as an oil crop, the State Government of Madhya Pradesh has drawn up a program with complete infrastructure to cover 2.0 lakh hectares in the next five years and will try to achieve a production level of 5 quintals per hectare.

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ECONOMIC PROSPECTS OF SAFFLOWER FODDER AND RATOON SEED IN NORTHERN INDIA

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ABSTRACT

In order to test the economic feasibility of safflower fodder and ratoon seed production in rainfed conditions, 15 promising strains were raised in winter season during 1975-76 and 1976-77 with 40:30:0 basal application of N and P_2O_5. Variety-wise production functions were fitted by regressing yields of fodder harvested at 90, 100 and 110 days and ratoon seed with plants/ha. The genotype EC 100602 was found promising because of its return of Rs 2462.56 per ha with 90 and 100-day fodder harvests.

The significance of safflower as a widely adaptable, edible oil yielding rainfed winter season (October-March/April) crop of southern India (area 650,000 ha; production 210,000 metric tons; productivity 338 kg/ha) is evident (7). Its poor productivity could be due to poor management and random droughts during the crop cycle because of erratic rainfall distribution resulting in low productive plant population/unit area. In rainfed northern India, it is raised in soil moisture conserved during the highly skewed rainy season in a 100 percent cropping pattern. The long vegetative phase (130-140 days) and succulent vegetative development in some safflower genotypes has indicated promise for much needed green fodder. High and stable yielding dual purpose (green fodder and ratoon seed) genotypes exist (2). Its fodder is nutritious (1, 3) and acceptable to animals if the harvest is up to 90-100 days from planting. In order to substantiate its extension in rainfed regions, this paper aims to report on a study of the economics of safflower fodder and ratoon seed production in north Indian rainfed conditions.

MATERIAL AND METHODS

Fifteen dual purpose promising genotypes raised (basal application of 40 kg N and 30 kg P_2O_5 per ha) in rainfed conditions at Hissar (29° 10' N; 75° 44' E; 221 m alt.) during 1975-76 and 1976-77 in a randomized block design with 3 replications (18 x 4 m plot size partitioned equally for 90, 100 and 110 days fodder harvest from planting) were observed for plant population and fodder/ratoon seed yields. Data were linearly transformed on a ha basis. The correlation coefficient and regression of plant population on green fodder/ratoon seed yields were used for selecting genotypes and managements for studying economics.

RESULTS AND DISCUSSION

The production function of the most promising genotype EC 100602 is presented in Table 1. With 163,667 plants/ha, this strain yielded 190 Q/ha green fodder at 90-day harvest. The ratoon seed yield with these parameters was 11 Q/ha. Another alternative provided by this variety was 224 Q/ha of fodder (167,355 plants/ha) and 15 Q/ha ratoon seed yield (159,068 plants/ha) in a 100-day fodder harvest. Thus, even with a lesser plant

Table 1. Safflower green fodder and ratoon seed yield production functions for promising propositions

Strain	Fodder harvested (days after planting)	r	r^2	Regression equation
		(i) Green fodder yield		
EC 100602	90	0.6350	0.4032	Y = 91.4131 + 0.0006x
EC 100602	100	0.7788	0.6066	Y = 39.3291 + 0.0011**
		(ii) Ratoon seed yield		
EC 100602	90	0.9010	0.8118	Y = 8.9007 + 0.00001x*
EC 100602	100	0.2077	0.4558	Y = 11.9817 + 0.00002x

** and * significant at 10 and 5 per cent.

Table 2. Economics (per hectare) of safflower cultivation as a fodder and ratoon seed crop.

Items	Number/ quantity	Value (rupees)
Preparatory tillage	3	218.12
Ploughing and planking		
Sowing	1	22.07
Seed (kg)	20	200.00
Fertiliser : Nutrient (kg)		
(a) Nitrogen	40	132.00
(b) Phosphatic : P_2O_5 (kg)	30	138.00
Harvesting & threshing	2	704.20
Interest on working capital @ 12% per annum		42.43
Rental value of land		580.62
Total cost		2037.44

Production	Alternative I	Alternative II
Variety EC 100602	(90 days)	(100 days)
Fodder (Q/ha)	190	224
Ratoon seed (Q/ha)	11	15
Value (Rs)		
Fodder	2850	3360
Ratoon seed	1650	2250
Net return/ha : Rs.	2462.56	3572.56
US $ (= Rs. 8)	308.00	447.00

population there was gainful production. The economics for these alternatives in Table 2 indicated a net profit of Rs 2,462.56 (= US$308) and Rs 3,572.56 (= US$447) respectively. These profits are at least 3 times higher than any winter crop (4, 6) including wheat (5) in north India. These findings open new vistas in increasing and stabilizing production and incomes of rainfed farmers often faced with extreme weather oriented agricultural production risks. The policy implication of this finding is that concerted efforts by research organizations are needed to support the proposals for the diversified agricultural products from a source in rainfed conditions.

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POPULATION IMPROVEMENT IN SAFFLOWER (CARTHAMUS TINCTORIUS L.)

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ABSTRACT

Mean, range, genetic variability, heritability, and genetic advance for earliness, plant height, number of primary branches, number of capitula per plant, size of main capitulum, number of seeds in the main capitulum, yield per plant, 100-seed weight and oil content were estimated in biparental progenies (North Carolina Mating Design II) and the corresponding F_3 progenies in three diverse crosses of safflower (Carthamus tinctorius L.). The intermated progenies, in general, had larger means, range, variance and genetic advance as compared with the F_3's. The progenies isolated from the intermated populations gave higher performance for yield, productivity and oil content than those derived through selfing. Population improvement method should thus be preferred over the pedigree method for rational genetic improvement of yield and quality of safflower populations.

Safflower (Carthamus tinctorius L.) is essentially a selfer, although cross-pollination ranging up to 5% has been found. Breeding methods such as pedigree and backcross methods, routinely used in improvement of self-pollinated crops, have been widely used in improvement of safflower. Although effective in their own right, the conventional methods impose restrictions on recombinations, retain undesirable tight linkages, and exploit only the fixable gene effects.

Population improvement, in contrast to the pedigree selection, is essentially a recurrent selection scheme which envisages intermating of early generation segregants (selected or nonselected) which not only elevates the genetic ceilings of the population but also retains high variability for selection to be effective over several cycles.

Intercrossing in early segregating generations helps reassemble adaptive genes capable of functioning in a balanced polygenic system. The probability that any single plant in F_2 of a cross would carry all or most of the potentially coadapted genes is rather remote. Hence, strict inbreeding or pure line selection from early generations will not produce the best balanced genotypes. Intermating of the segregants in early generations, particularly of the selected ones, magnifies the chances of reassembling the maximum number of potentially useful genes and leads to isolation of stable and widely adapted genotypes.

Based on the above considerations the present paper reports on the effect of intermating in F_2 on the mean, variance, heritability and genetic advance in three diverse crosses of safflower and examines the efficacy of population improvement in a normally self-pollinated crop.

MATERIALS AND METHODS

Three elite and diverse cultivars of safflower were selected from the germplasm collection maintained at B. H. U., Varanasi (27° N, 83° E). The main characteristic features of the cultivars are given in Table 1.

Table 1. Characteristic features of the parents

Characters	Cultivars		
	EC 27807 (designated as No. 30)	S-59-21 (designated as No. 48	Mutant of IC 11842 (designated as No. 29A)
Earliness of flowering	Medium	Late	Early
Plant height	Medium (average 120 cm)	Tall (average 140 cm)	Dwarf (average (80 cm)
Days to maturity (from flowering)	Late	Early	Medium
Number of primary branches	Low (non-synchronous)	High (Synchronous)	Medium (Synchronous)
Number of capitulum per plant	Low	High	Average
Seed yield per plant	High	Low	Medium
Stem thickness	Thick (Strong)	Medium (Moderate)	Thin (Weak)
Hull (%)	High	Low	Medium
Oil content (%)	Medium	High	Low

All possible nonreciprocal crosses were made among the three parents. From about 500 F_2 plants of each cross 64 plants were randomly allotted to 8 sub-sets of 8 plants each. Following the North Carolina Mating Design II (NCM II) approach (2), within each sub-set 4 plants were designated as male and 4 as female parents . All possible 16 crosses were made within each, yielding 16 full-sib families. Eight parent plants were selfed to form 8 selfed families. Likewise, 128 full-sib families and the corresponding 64 selfs were produced.

The NCM II progenies along with the corresponding F_3's and the original parents were grown in a randomized block design with 3 replications. Each plot had 12 plants spaced at 45 cm between the rows and 15 cm within the

rows. Observations on days to flowering, plant height, number of primary branches, number of capitula, size of main capitulum, number of seeds in the main capitulum, seed yield per plant, 100-seed weight and oil percentage were recorded on 10 plants per plot, excluding the end plants wherever possible.

Following the routine analysis of variance, the estimates of total genetic variance, heritability (broad sense) and genetic advance in the NCM II and F_3 progenies were obtained following the method described by Comstock and Robinson (3).

Heritability in broad sense (H) = $\hat{\sigma}^2_G / (\hat{\sigma}^2_G + \hat{\sigma}^2_e)$

Genetic advance (G.A.) $\doteq$ $K.H.\sigma_P$

Genetic advance in per cent of mean = $\frac{G.A. \times 100}{\text{Mean } (\bar{x})}$

where, $\hat{\sigma}^2_e$ = Error variance

$\hat{\sigma}^2_G$ = Total genetic variance

K = Selection differential (2.06 at 5% selection intensity)

σ_P = Phenotypic standard deviation

H = Heritability

RESULTS

Means of NCM II and F_3 Progenies

The overall mean and range of means for the NCM II and corresponding F_3 progenies are given in Table 2.

The means of the NCM II progenies were higher than the F_3 progenies for yield and yield components in all the crosses, except for capitulum number in the cross 30 x 29A. The intermated progenies were earlier as well as dwarfer than the selfed progenies, except in the cross 30 x 48 whereas on an average first flower in the NCM II progenies appeared 5 days later than that in the F_3's.

The differences of means were higher in the crosses 30 x 29A and 48 x 29A when compared with those in the cross 30 x 48. Not only the means, the

Table 2. Mean performance and range (in parentheses) in NCM II and corresponding F_3 progenies for nine characters in three crosses of safflower

Crosses & Progenies / Character	30 x 29A		48 x 29A		30 x 48	
	NCM II	F_3	NCM II	F_3	NCM II	F_3
Days to Flowering	111.7 (101.3-128.6)	115.6 (110.4-122.6)	109.6 (105.4-130.1)	118.4 (114.3-128.3)	119.3 (112.3-123.3)	114.9 (113.6-119.5)
Plant height	110.7 (91.5-132.5)	112.3 (114.5-131.0)	105.6 (95.6-145.6	121.5 (101.5-141.6)	124.5 (119.5-151.5)	128.6 (121.5-156.6)
No. of Primary branches	7.5 (5.5-9.7)	6.4 (5.4-8.8)	13.5 (7.3-14.9)	11.2 (7.2-13.4)	14.4 (8.2-18.5)	10.3 (6.4-11.6)
No. of capitulum	13.7 (11.9-38.1)	16.5 (7.6-24.9)	17.2 (7.8-31.7	15.5 (6.6-34.1)	19.7 (4.8-41.8)	18.1 (5.1-22.8)
Size of main capitulum (cm)	2.9 (2.2-3.9)	2.6 (2.3-3.0)	2.4 (2.0-2.5)	2.1 (2.0-2.3)	3.5 (2.1-3.9)	3.0 (2.3-3.1)
Seeds/main capitulum	59.3 (18.2-101.6)	41.5 (13.7-58.4)	32.7 (8.2-51.0)	26.6 (8.5-41.5)	41.4 (10.8-98.8)	35.7 (8.7-39.5)
Yield/plant (gm)	21.5 (14.1-33.7)	19.3 (9.4-24.8)	19.5 (9.5-21.4)	12.4 (8.4-18.6)	17.9 (8.9-25.1)	16.3 (8.6-21.3)
100-seed wt. (gm)	5.5 (4.9-8.1)	5.0 (4.9-6.2)	5.0 (2.5-6.3)	4.0 (2.5-5.8)	5.6 (3.1-6.1)	5.4 (3.4-5.5)
Oil content (%)	32.7 (28.7-36.4)	30.1 (26.6-33.8)	35.7 (29.8-39.2)	32.3 (27.4-35.2)	35.2 (26.6-37.4)	31.9 (26.2-39.6)

Table 3. Genetic variance, heritability, and genetic advance in NCM II and F_3 progenies for nine characters in three crosses of safflower

Cross	Characters	Genetic variance		Heritability		Genetic advance	
		NCM II	F_3	NCM II	F_3	NCM II	F_3
1	2	3	4	5	6	7	8
30 x 29A	Days to flowering	18.798	13.654**	73.744	76.258	7.669	6.648
	Plant height	50.261	0.573	70.797	2.514	12.288	0.247
	No. of primary branches	1.160**	0.410	69.503	56.164	1.849	0.989
	No. of capitula	15.206	11.829**	68.690	50.431	6.658	5.032
	Size of main capitulum	0.048**	0.003	81.356	42.857	0.405	0.074
	No. of seeds in main capitulum	97.878	61.080**	70.255	93.583	17.083	15.574
	Yield per plant	21.534**	6.999**	79.365	74.789	8.516	4.695
	100-seed weight	0.093	0.505	73.228	7.013	0.538	0.388
	Oil content	4.108	1.629**	70.621	61.986	3.508	2.070
48 x 29A	Days to flowering	24.172	15.459**	75.705	85.612	8.812	7.495
	Plant height	561.620**	14.791**	92.907	45.842	47.057	5.364
	No. of primary branches	6.591**	0.831**	86.666	75.614	4.923	1.633
	No. of capitulum	33.339	8.068**	90.479	80.809	11.314	5.261
	Size of main capitulum	0.082**	0.004	94.253	50.000	0.573	0.121
	No. of seeds in main capitulum	83.146**	33.623	83.036	73.565	17.118	10.245
	Yield per plant	18.544**	3.927**	82.079	58.840	8.037	3.132

ranges for the different characters, in the three crosses in the intermated progenies, in general, were larger than those in the corresponding F_3 progenies. Further, the lowest as well as highest values for a given character recorded in the inter-crossed progenies were also correspondingly lower and greater than the F_3's.

Total Genetic Variance (σ_G^2), Heritability and Genetic Advance in NCM II and Corresponding F_3 Progenies

Estimates of genetic variance, heritability and genetic advance in the NCM II and the corresponding F_3 progenies for the nine characters are presented in Table 3.

Genetic Variance. The NCM progenies showed significant genetic variance for number of primary branches, size of main capitulum and yield per plant in the cross 30 x 29A; for all the characters, except oil content, in the cross 48 x 29A; and for plant height, capitulum size, seeds per capitulum, yield per plant, 100-seed weight and oil content in the cross 30 x 48. As regards the F_3 progenies, they showed significant genetic variances for all the characters in the cross 30 x 48; all but two characters, plant height and 100-seed weight, in the cross 30 x 29A; and for 6 of the 9 characters, namely, days to flowering, plant height, number of primary branches, number of capitula, yield per plant and 100-seed weight in the cross 48 x 29A.

The magnitudes of genetic variance (σ_G^2) were higher in the NCM II progenies as compared to the F_3 for all the characters and in all the crosses.

Heritability (broad sense). The heritability estimates in the NCM II progenies ranged from 60.6% for days to flowering in the cross 30 x 48 to 90% for size of main capitulum in the same cross. For F_3 progenies the estimates ranged from as low as 2.6% for plant height in the cross 30 x 29A to as high as 96.7% for number of capitula in the cross 30 x 48.

The relative magnitudes of the heritability estimates over the two sets of progenies varied from cross to cross. For the crosses 30 x 29A and 48 x 29A, the heritability estimates were usually higher in the NCM II progenies when compared with the F_3 progenies, except for days to flowering and seeds per capitulum in the cross 30 x 29A. The reverse was the trend for the cross 30 x 48. The heritability estimates were higher in the F_3 progenies than in the NCM II for all the characters, except for the size of the main capitulum.

Genetic Advance. The estimates of expected genetic advance for the nine characters were invariably larger in the NCM II progenies as compared with the F_3's in the crosses 30 x 29A and 48 x 29A. In the cross 30 x 48, the expected genetic advance in the intermated progenies (NCM II) was larger than the corresponding F_3's for 6 characters, namely, plant height, number of primary branches, capitulum size, seeds per capitulum, yield per plant and 100-seed weight, whereas the reverse was the case for the three remaining characters, namely, days to flowering, number of capitula, and oil content. It may be noted that in the cross 30 x 48 the estimates of heritability for the different characters were higher in the F_3 progenies as compared with the NCM II.

DISCUSSION

In general, the intermated progenies showed higher means than the corresponding selfs (F_3's) for all the characters except days to flowering and plant height in the three crosses. Since earliness and dwarf plant habit are preferred characters, the means for these characters also improved in the intermated progenies. It suggested accumulation of favorable genes through intermating.

Although well documented in case of cross-pollinated crops, larger means of intermated progenies as compared to the selfs have also been reported in self-pollinated crops. Matzinger et al. (10) and Mazinger (9) reported larger means among full-sib progenies (NCM II) over corresponding F_3's for six characters studied in flue-cured varieties of Nicotiana tabacum. Similarly, Gill et al. (6), Randhawa and Gill (13), and Singh and Dwivedi (16) in wheat reported higher means and heritability in biparental progenies as compared to the selfs for all the characters studied.

Along with the improvement in means of the intermated progenies the genetic variance also increased, providing continuing scope for further selection gains.

Assuming a simple genetic model, in the absence of linkage and epistasis, genotypic effect of a population (gi) may be expressed as follows: $gi = \mu + da + ha$. The expected mean and genetic variances of F_2, F_3, and BIP's produced from F_3 progenies are given in Table 4.

Table 4. Expected mean and genetic variances of F_2, BIP and F_3 progenies

Generation	Statistic[1]			
	Mean	D	H	$(h)^2$
F_2	1/2 h	1/2	1/4	1/4
F_3	1/4 h	3/4	3/16	1/16
$V1F_3$		1/2	1/16	
$V2F_3$		1/4	1/8	
BIP	1/2 h	1/2	1/4	1/4
V1BIP		1/4	1/16	
V2BIP		1/4	3/16	

h = dominance effect
D = additive genetic variance
H = dominance genetic variance
$V1F_3$ = variance of F_3 means
$V2F_3$ = mean variance of F_3 progenies
V1BIP = variance of BIP means
V2BIP = mean variance of BIP progenies
$(h)^2$ = contribution of the overall mean to the free variation

It is obvious from Table 4 that in the absence of nonadditive effects, means of F_2, BIP, and F_3 progenies will be alike, barring population size and differential retention of the genotypes. However, in the presence of a nonadditive effect, the population mean of BIP families would be higher than those of the F_3's. Sahu (15) reported significant nonadditive effects in the same populations which may partly account for the higher mean of the BIP's.

Under breeding programs, if the inferior types are eliminated in each cycle and only the selected segregates are intercrossed, considering that additive and additive x additive components are predominant (15) and heritability is high, the mean of the BIP would still be greater. Further, possible breakage of undesirable linkages, as envisaged under intermating, would contribute positively in the desired direction.

The variations in gene and genotype frequencies are the basis of genetic variability in a given population. Selfing or intercrossing affect the segregation and recombination frequencies and thus the redistribution of the initial variability in different forms. In the absence of mutation, random drift, selection, and migration, the total variability remains unchanged.

The variation in any given generation, assuming no linkage and interaction, as shown in Table 4, may be written as $xD + yH + z(h)^2$, where $x + y + z = 1$ (Mather, 1949). In any breeding system, the coefficients should add to 1; however, their relative values will change under different mating systems. For example, in F_3, $x + y + z = 3/4 + 3/16 + 1/16 = 1$, whereas the corresponding values for BIP are $1/2 + 1/4 + 1/4 = 1$, the same as in F_2. In case random mating is ensured in the subsequent generations, the overall picture will remain unchanged. Under the selfing series, the proportion of loci that are heterozygous is halved in each generation. Hence in F_n a proportion, $(1/2)^{n-1}$, of the loci will be heterozygous and $1 - (1/2)^{n-1}$ homozygous.

When n becomes large, as the case in routine pedigree method of selection, the generation will of course consist of true breeding lines, its mean will be mid-parent value and its heritable variation will be D. It is thus obvious that under strict selfing, irrespective of the significance of the non-additive components, only D is exploited and dominance effects remain unutilized.

In the present study, the higher variance in the BIP's as compared to the F_3's is attributed to significant dominance and epistatic effects, possibly to breakage of linkage and appearance of transgressive segregates.

Jensen (8) pointed out three main disadvantages of conventional breeding systems, namely, 1) limited size of the gene pool utilization, 2) restrictions of genetic variability and recombination potential through intensive inbreeding, and 3) the absence of intercrossing among hybrid progenies. With linkage, homozygosity increases much faster and genetic recombination between linked loci is restricted to a greater extent in the conventional breeding techniques of self-pollinated crops. He proposed a diallel selective mating system to overcome these limitations. The procedure permits use of wide sources of germplasm, input of parents at any stage of breeding, creation of persistent gene pools, breaking of linkage blocks and freeing of genetic variability, and general fostering

of genetic recombination. Later, Jensen in association with Redden (14) demonstrated in wheat and barley that responses to selection were greater in the intermated populations than in the selfed series. It may be noted that in the present study also the expected genetic advance in the BIP's was larger than in the corresponding selfs.

Miller and Rawlings (12) and Meredith and Bridge (11) provided experimental evidences regarding the usefulness and effectiveness of random crossing for increasing recombination in hybrid populations of cotton, a self-pollinated crop under the conditions where studied.

The findings of the present study as well as those cited above suggest that a suitable form of recurrent selection which aims at increasing the frequency of desirable genes and genotypes and simultaneously maintains variability for selection to be effective over generations would be the most suitable breeding method for improving safflower populations. Effective random cross-pollination is a prerequisite for adopting recurrent selection. This difficulty can be overcome by the use of genetic male sterility. Kumar (personal communication) recovered a genic male-sterile line in a mutagen treated safflower population at BHU, Varanasi.

Gilmore (7) suggested methods of using male sterility for improvement of naturally self-pollinated species through recurrent selection. Application of genetic male sterility to recurrent selection was also proposed for other crops such as sorghum and soybean (1, 4). Fujimaki (5) proposed a model of recurrent selection for rice improvement through the use of a recessive male-sterile line (induced by artificial mutation).

The superiority of intermating over selfing in accumulating favorable genes for yield and oil content was evident from the mean performance of the three best progenies isolated from the NCM II and the corresponding F_3 progenies (Table 5). The average yield and oil content of the top three progenies was higher in the NCM II than in the F_3.

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Table 5. Performance of three best selected progenies isolated from the intercrossed and the F_3 populations.

Cross	Culture number	Yield/ plant (g)	Oil content (%)	100-seed weight (g)
Cross 30 x 29A				
NCM II	30-3	42.55	30.00	4.37
	41-1	42.00	35.50	3.50
	40-7	26.50	31.68	4.30
F_3	12-1	31.27	30.13	4.85
	21-6	26.78	30.56	4.36
	28-7	22.66	28.52	4.30
Cross 48 x 29A				
NCM II	3-7	34.42	35.33	4.56
	13-1	33.00	32.00	4.70
	16-2	31.10	32.87	4.20
F_3	40-7	31.05	29.55	3.84
	43-2	26.37	32.44	4.12
	41-1	20.78	30.81	3.95
Cross 30 x 48				
NCM II	7-5	40.50	41.40	4.30
	19-2	36.20	35.20	4.60
	15-1	26.20	39.00	4.26
F_3	37-1	36.70	36.70	4.43
	37-7	33.70	36.69	2.75
	34-1	29.55	32.65	3.88

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GENETIC RESOURCES OF SAFFLOWER GERMPLASM COLLECTION

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ABSTRACT

Safflower is gaining increasingly high importance as a leading rainfed oilseed crop. Introduction of high-yielding and oil-rich cultivars into traditional areas of cultivation in regions of diversity of this crop is causing erosion of landraces.

Diverse safflower genepools are found in Southwest Asia, the Mediterranean, Eastern Africa, the Indian sub-continent and the Far East. A large collection of safflower and its wild relatives (ca 2,500) is maintained at the USDA Western Regional Plant Introduction Station, Pullman, Washington, USA (duplicates of this collection are in Israel). The other important collections are in India (ca. 1,500), Iran (ca. 1,000), USSR (ca. 400) and China.

An appraisal of geographical representation has revealed gaps in the collections. The important areas for further collecting are those where primitive cultivars are still grown in China, parts of the Indian subcontinent, southwest Asia, the Mediterranean, Ethiopia, Sudan and Kenya. The related wild species of Carthamus also need to be collected from the areas of their distribution.

Using the collections at Banaras Hindu University, Varanasi, India, the efficacy of storing the data in a machine-readable form and further analyzing the collections for character associations and genetic divergence has been demonstrated.

Except for the USDA collections, most of the others have only been partially evaluated. An agreed list of descriptors has to be devised to facilitate standard recording, storage, retrieval and exchange of information. Passport, characterization and preliminary evaluation descriptors are proposed.

Safflower (Carthamus tinctorius L.), although an old domesticate, is a relatively new crop. Knowles (6) identified eight centres of cultivation of this crop. The regions and countries were: 1) India, Bangladesh, Pakistan; 2) Iran, Afghanistan; 3) Israel, Jordan, Syria; 4) Turkey; 5) Egypt; 6) Ethiopia; 7) Kenya; 8) Portugal, Spain, France, Morocco. For the past 3 or 4 decades the crop has been commercially produced also in USA, Mexico and Australia. Judged from the extent of diversity and the intensity of occurrence of closely related forms, the Near East/Middle East is regarded as the primary center of diversity of safflower.

In the Indian subcontinent safflower has been under cultivation, mostly as a border or a mixed crop, for hundreds of years both for dye and oil. But in recent years because of its adaptability to rainfed and semi-arid conditions it is becoming the predominant winter oilseed crop of drylands.

In India alone it occupies more than 0.7 m ha, the highest hectarage in the world. However, productivity as well as oil content of the cultivars in India and other developing countries, which constitute the centers of diversity, are much lower than those in the developed countries. The per hectare oil yield of safflower in India is almost one-third of that in the USA. The average seed yield in India is about 0.6 t/ha against 1.5 to 2 t/ha in California. The oil percent of Indian cultivars is around 28-30% against 38% of the US cultivars. The need for improving yield and oil content in the cultivars of the Indian subcontinent and other adjoining countries can hardly be overemphasized. This can mainly be attained through ordering desirable germplasms in efficient breeding programs resulting in evolution of suitable plant types for monoculture as well as for mixed and multiple croppings, combining high yield, high oil content and resistance to diseases and pests and stress conditions.

CURRENT STATUS OF THE GENETIC RESOURCES

Safflower is an introduced crop in the New World. Therefore, other than the improved cultivars, very little in the form of other categories of germplasm is expected from those countries. In the Old World, South Asia, Near and Middle East, northeast Africa and part of southwest Europe are the centers of diversity and cultivation of safflower. Other than in the Indian subcontinent, the crop is still a minor and marginal crop in other Old World countries. Therefore the variation which is released due to domestication under varying agro-ecological conditions is much more prevalent in India than anywhere else. On the other hand, wild species and weedy relatives of safflower are encountered primarily in the Near East.

Safflower research and development has not received adequate attention in its place of origin. But in the past 3 or 4 decades in USA, Mexico, Australia, and India, a concerted effort in evolving acceptable safflower cultivars included collection, conservation, evaluation, and utilization of germplasm as the foremost activity. In the US, as reiterated by Knowles (7), the main reasons for collecting and conserving safflower from all over the world were: 1) to make available the material to the Old World (the scientists in the Old World were not much concerned with the safflower germplasm which surrounded them); and 2) to meet the needs in the US, particularly for disease and pest resistance, tolerance to stress conditions, oil content, and quality of oil and protein meal.

The success story of commercializing safflower in California, primarily through the efforts of Rabak (8), Claassen (2), and Knowles (3), activated the scientists in the recognized old centers of safflower cultivation to promote research and development activities. In the process, seeds of high yielding cultivars developed in the New World, mostly the California cultivars, and especially UC-1 (4), were introduced and sometimes adopted in the Old World, including India. However, in India none of the introduced cultivars emerged as a major cultivar; nevertheless, these constitute valable gene pools and have been extensively used in breeding programs. Attendant to the large-scale adoption of high yielding cultivars was the erosion of the indigenous land races and primitive cultivars which constitute valuable gene pools, particularly for adaptation to diverse and stress conditions, resistance to diseases and pests, oil content, protein content (in seed cake), fatty acid composition, and amino acid profile. However, dedicated efforts of Knowles and his students, particularly Ashri (1), made timely collections of safflower germplasms from the primary and secondary

centers of diversity. This world collection (numbering around 2,500 accessions) of safflower has been evaluated, catalogued, and stored with the USDA and duplicated at Hebrew University, Rehovot, Israel. This collection has already yielded sources of resistance to diseases and pests and altered quality and quantity of the oil (7, 11), and has been made available to all who wanted to use them.

The collaborative approach in evaluation of USDA safflower collections of Ashri in Israel together with Knowles of California and Zimmer and Urie of Utah (1) resulted in analyses of the taxonomic and evolutionary relations and genotype-environment interactions. It also helped in standardizing the screening procedures and data processing.

THE RESOURCES IN THE INDIAN SUBCONTINENT

As noted earlier, the world's largest hectarage under safflower occurs in India. As an oilseed crop, safflower is cultivated in the States of Maharashtra, Gujrat, Madhya Pradesh, Mysore, Tamilnadu, Bengal, Bihar, Uttar Pradesh, Andhra Pradesh and parts of Haryana and Punjab. Bengal, Bihar, Uttar Pradesh, Haryana and Punjab grew it in the past for dye as well. The soil and moisture regimes under which safflower is grown are highly diverse, ranging from sandy infertile soils to black cotton soils. It is valued for its tolerance to drought and thus is ideally suited to rainfed areas where other oilseed crops cannot be grown successfully. When grown as a mixed crop with other rabi (winter season) cereals it thrives well under irrigated conditions as well. It fits into rotations with a variety of crops.

Commensurate with diverse cultivation situations, specific types adapted to distinct agro-ecological zones encountered in the country have evolved. The predominant cultivars are mostly the selections from the land races and the primitive varieties. Some of the commonly known cultivars are: Niphad 630, Niphad 62-6, Annigeri 300, Annigeri 482-1, N 7, N.P. 30, N. P. 18, C.T. 11, C.T. 66, C.T. 68, Pusa No. 1, Pusa No. 28, T. 56, T. 39, K-1, Tara and Manjira. The last three cultivars are of recent origin and because of their high yield, high oil content (up to 33%) are recommended for large-scale cultivation. With the modernization of agriculture, abandoning of mixed cropping of safflower with the cereals and the accent on popularizing high yielding newly evolved cultivars as a monocrop under rainfed conditions, the endemic variability is eroding fast.

Realizing the importance of germplasms in breeding programs and considering the high rate of erosion, the Indian Council of Agricultural Research under its coordinated safflower project, and the concerned universities made determined efforts to collect, conserve, evaluate, document, and utilize the indigenous variability. Today, in India, more than one center maintains around 1,000 accessions. Allowing for duplicates in the various collections, it is estimated that there would be around 1,500-2,000 distinct accessions in India. Actually, around one-third of the USDA collection is from India.

Under this nationwide movement for rescuing the variability, the Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi (27° N, 83° E), launched a vigorous safflower project in the year 1974. In later sections the details of the BHU collections will be enumerated.

Bangladesh and even the bordering areas of Western Burma possess unique variability, particularly for tolerance to hot and humid conditions. But no systematic collection of safflower by the local scientists has been undertaken. However, 53 collections from Bangladesh are represented in USDA collections. The Indian collectors have discovered lines low in linoleic acid from areas adjoining to Bangladesh, and thus it is presumed that more collections from the bordering areas in Bangladesh would reveal interesting genotypes for fatty acid composition of the oil. No serious effort has been made to obtain collections in Sri Lanka; even the USDA collections do not include Sri Lankan safflower.

Pakistan, particularly the northwestern region bordering Afghanistan and the southeastern region bordering Gujrat (India), must possess valuable variability for safflower. Since the crop is not given high commercial importance in that country, its rich genetic resources will disappear soon, if not captured in time. Fortunately Knowles has collected safflower in Pakistan and around 40 accessions are maintained with the USDA.

THE BENASAS HINDU UNIVERSITY COLLECTIONS

Size

The Centre holds (short-term storage) 531 accessions. Seven percent of the accessions are duplicates. The state and country-wise breakup is as below:

State/country	No. of accessions
Maharashtra	150
Gujrat	53
Madhya Pradesh	30
Mysore	28
Tamilnadu	23
Bihar	23
Bengal	18
Haryana and Punjab	12
Uttar Pradesh	138
Exotic (USA, Israel, Iran)	56
Total	531

Gaps in the Collection

An appraisal of the geographical respresentation and the extent of canvassing done in the potential pockets of unique gene pools in the South Asian collections revealed serious collection gaps. The priority areas for collections are the Western Ghats and tribal areas of the arid and semi-arid tracts of Maharashtra, Madhya Pradesh, Bihar, Eastern Uttar Pradesh and Assam in India, Pakistan, whole of Sri Lanka, Bangladesh, and Burma. Similar gaps are likely to exist in the other centers of diversity and "Centers of Cultivation," particularly Southwest Asia, Ethiopia and Sudan. Wild and weedy forms, which often constitute valuable gene sources for resistance and adaptation to adversities, are poorly represented even in the international collections.

Evaluation and Documentation

Preliminary evaluation of all the accessions has been undertaken. Three

hundred of the accessions have been evaluated at least for two seasons, 1977-78 and 1978-79. The design followed was an augmented randomized block design with two running checks, cv. IC 11844 and K-1, after every ten lines of the accessions. Data were recorded on the following characters:

- Branching pattern
- Plant conformation
- Leaf shape
- Leaf margin
- Spininess
- Corolla color
- Capitula shape before flowering
- Number of primary branches
- Number of seconday branches
- Plant height (cm)
- Number of capitula per plant
- Diameter of primary capitulum (mm)
- Average weight(g)/capitulum (based on 5 capitula)
- Number of days from planting to flowering
- Number of days from flowering to maturity
- Seeds per capitulum (mean based on 5 heads)
- 100-seed weight (g)
- Yield per plant (g)
- Oil content (percent)
- Iodine value
- Reaction to Alternaria
- Reaction to rust
- Reaction to wilt
- Reaction to powdery mildew
- Reaction to safflower fly

All the data have been stored in a machine readable form. The Statistical Analysis System (SAS) of North Carolina was followed. The system was also used to demonstrate its efficacy in locating duplicates and in searching for accessions possessing specific attributes.

The number of lines which showed distinct promise for one or the other characters are given below:

Character	No. of lines	Remarks
Early maturity (< 160 days)	6	For multiple cropping, it is an important character.
Compact and tall	9	Desired for intercropping
Dwarf (< 90 cm)	5	Desired for intensive cropping
> 10 primary branches	15	
> 20 capitula/plant	21	
> 40 seeds/capitulum	17	
> 5.5 g weight/100 seeds	12	
> 30 g/plant seed yield	3	
> 40% oil content	7	Indian cultivars are generally low in oil
Thin hull	2	
< 20% linoleic acid	4	Mostly from eastern India, one from California (UC-1). This character is desired for using safflower oil for cooking purposes.
> 75% linoleic acid	6	Suited for industrial use.
Res. to Alternaria	3	Alternaria occurs in epidemic form in eastern India and the susceptible varieties are almost killed.
Res. to rust	18	
Res. to powdery mildew	14	

VARIABILITY, CHARACTER ASSOCIATIONS AND PATH ANALYSIS

Based on the preliminary screening and geographical representation, 220 lines, indigenous and exotic, were subjected to variance and covariance analysis. Nine important yield characteristics were studied. A suitable computer program was available with the Indian Agricultural Statistics Research Institute (IASRI), New Delhi. The estimates of mean, variation, heritability and genetic advance are given in Table 1. The correlation coefficients among the nine characters are presented in Table 2, and the path coefficient analysis (direct and indirect effects) are given in Table 3.

The highlights of the results may be summarized as follows: Significant differences among the lines were observed for all the traits, viz., days to 50% flowering, days to maturity, plant height, number of primary branches, number of capitula/plant, number of seed/capitulum, 100-seed weight, seed yield/plant and oil content. Seed yield/plant and number of seeds/capitulum showed maximum variability while days to maturity had minimum variation. Plant height, number of seeds/capitulum, and oil content had high heritability; genetic advance as a percent of the mean was maximum for number of seeds/capitulum. Plant height and number of seeds/capitulum showed high positive correlations with seed yield and oil content at both genotypic and phenotypic levels, whereas days to 50% flowering and days to maturity showed a positive correlation only at the genotypic level. Oil content was also noted to be associated with seed yield. Path coefficient analysis for yield indicated that number of seeds/capitulum and plant height were the most important components of seed yield. Days to maturity contributed towards yield mainly via plant height. Oil content had a direct effect on yield. Results suggested that simultaneous selection for more seeds/capitulum, tallness and late maturity would result in an appreciable advance in yield coupled with high oil content. However, for intensive cropping, tall and late maturing types are undesirable. Therefore, through recombination breeding, as shown by Sahu (10), early maturing, medium-tall cultivars with large heads could be evolved.

DIVERGENCE ANALYSIS

Multivariate or any other form of divergence analysis in germplasm collections is widely advocated. D^2- analysis and canonical analysis (9) were used to quantify the degree of divergence and to assess the relative contribution to yield and yield components towards total variability in 50 accessions. The lines on the basis of D^2 estimates were catalogued into 12 clusters of which each of the three clusters had a single line (Table 4).

Days to 50% flowering, plant height, number of primary branches, number of capitula/plant, number of seeds/capitulum, seed yield/plant, and oil content contributed more towards total divergence. The first two canonical roots accounted for 69% and the first five for 92% of the variability (Table 5). The clustering obtained through group constellation made in two-dimensional space using the first two roots showed close agreement with that obtained in D^2 analysis. Number of seeds/capitulum, oil content, plant height, and size of capitulum were important in vector I and plant height, days to 50% flowering, and seed yield in vector II.

Table 1. Mean, phenotypic and genotypic coefficients of variation, heritability and genetic advance for nine characters in safflower

Characters	Mean	Range	Coefficients of variation		Per cent heritability	Expected genetic advance	Expected genetic advance as per cent of mean
			Phenotypic	Genotypic			
1. Days to 50% flowering	126.19±3.85	116 -138.5	4.07	2.70	43.85	4.64	3.68
2. Days to maturity	167.80±1.90	164 -172.5	1.24	0.51	16.80	0.72	0.43
3. Plant height(cm)	119.72±6.79	89.2-164.0	9.72	7.90	66.05	15.83	13.22
4. Number of primary branches	6.42±1.17	4.5-10.9	20.73	9.72	21.98	0.60	9.38
5. Number of capitula/plant	13.67±3.88	7.2-22.9	30.96	18.27	35.74	3.07	22.49
6. Number of seeds/ capitulum	21.03±3.55	11.06-43.18	32.06	27.24	72.20	10.03	47.69
7. 100-seed weight (g)	4.06±0.50	2.30-5.56	16.60	11.02	44.09	0.61	15.07
8. Seed yield per plant (g)	8.66±2.87	4.07-26.39	40.44	23.10	32.63	2.35	27.18
9. Oil content (%)	29.74±2.27	25.39-40.09	14.31	12.10	71.41	6.26	21.05

Table 2. Genotypic and phenotypic (in parentheses) correlations between nine characters in safflower

Character	Days to maturity	Plant height	Number of primary branches	Number of capitula/ plant	Number of seeds per capitulum	100-seed weight	Seed yield/ plant	Oil content
Days to 50% flowering	0.703** (0.232**)	0.856** (0.409**)	0.129 (-0.038)	0.136 (-0.062)	0.391** (0.317**)	-0.272** (-0.110)	0.439** (0.140)	0.420** (0.245**)
Days to maturity		0.737** (0.213**)	-0.081 (-0.151*)	-0.291** (-0.130)	0.580** (0.174**)	0.040 (0.029)	0.570** (0.051)	0.284** (0.119)
Plant height			-0.271** (0.030)	-0.323** (0.080)	0.727** (0.567**)	-0.180** (-0.033)	0.550** (0.407**)	0.342** (0.234**)
Number of primary branches				0.832** (0.849**)	-0.325** (-0.119)	-0.212** (-0.102)	-0.093 (0.311**)	-0.074 (-0.029)
Number of capitula per plant					-0.507** (-0.138*)	-0.329** (-0.083)	-0.293** (0.316**)	-0.158** (-0.032)
Number of seeds per capitulum						-0.455** (-0.196**)	0.675** (0.496**)	0.527** (0.387**)
100-seed weight							-0.051 (0.174**)	-0.214** (-0.068)
Seed yield per plant								0.427** (0.227**)

*, ** Signigicant at P = 0.05 and 0.01, respectively

Table 3. Path coefficient analysis showing direct and indirect effects of eight variables of seeds yield in safflower

Characters	Days to 50% flower-ing	Days to maturity	Plant height	Number of primary branches	Number of capitu-la/plant	Number of seeds/ capitulum	100-seed weight	Oil content	Correla-tion 'r' with yield
Days to 50% flowering	-0.886	0.247	0.797	0.018	0.053	0.105	-0.066	0.171	0.439**
Days to maturity	-0.623	0.352	0.686	-0.011	-0.114	0.155	0.009	0.116	0.570**
Plant height	-0.758	0.259	0.931	-0.039	-0.126	0.195	-0.044	0.132	0.550**
Number of primary branches	-0.114	-0.028	-0.252	0.143	0.326	-0.087	-0.051	-0.030	-0.093
Number of capitula per plant	-0.120	-0.102	-0.301	0.119	0.391	-0.136	-0.080	-0.064	-0.293**
Number of seeds per capitulum	-0.346	0.204	0.678	-0.046	-0.198	0.268	-0.111	0.225	0.675**
100-seed weight	0.241	0.014	-0.168	-0.030	-0.129	-0.132	0.243	-0.087	-0.051
Oil content	-0.399	0.100	0.302	-0.011	-0.062	0.141	-0.052	0.408	0.427**

** Significant at P = 0.01

Table 4. Distribution of 50 lines in different clusters

Clusters	Lines number	Number of lines included
A	S12, S14, S9, S8, S5, S13, S10, S7, S28, S37, S2	11
B	S49, S43, S34, S29, S44, S35, S40, S48	8
C	S20, S21, S31, S23	4
D	S16, S42, S3, S47, S22, S50, S33, S25, S30, S45, S46	11
E	S39, S19, S38	3
F	S41, S1	2
G	S36, S32, S4	3
H	S18, S17	2
I	S15, S6, S24	3
J	S26	1
K	S27	1
L	S11	1

Table 5. Canonical roots, vectors and the percentage sum of squares accounted by first five roots

	Canonical Vector i										Root λ i	% sum of square to i
1	0.114	0.026	0.416	-0.107	-0.103	0.306	0.578	-0.112	0.210	0.552	912.28	54.63
2	0.408	0.109	0.678	0.193	-0.084	-0.249	-0.452	0.089	0.204	-0.027	241.45	14.46
3	0.155	0.077	-0.287	0.280	0.205	-0.513	-0.049	0.052	-0.157	0.688	188.99	11.32
4	-0.145	0.071	-0.155	-0.404	-0.034	0.354	-0.546	0.357	0.258	0.408	112.24	6.72
5	0.001	-0.053	-0.239	0.482	0.282	0.203	-0.052	-0.256	0.718	-0.055	80.28	4.80
										$\Sigma \lambda i$	1670.04	
										Σ Ri	134.8	8.07

The D^2 multivariate analysis of divergence and the studies on character associations and path coefficient analysis in the safflower collection at BHU, as presented above, suggest that systematically recorded data on a suitably laid out trial of germplasm collections not only help in cataloguing the information but can also be subjected to statistical analyses which yield valuable information for further use of collections and also for making additional collections.

DESCRIPTORS FOR SAFFLOWER

Internationally agreed lists of descriptors are a prerequisite for uniform recording, storage, retrieval and exchange of information. A list of descriptors has been agreed on by an IBPGR Working Group Meeting which met July 17-18, 1981.

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STATUS OF SAFFLOWER RESEARCH IN INDIA

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ABSTRACT

Safflower (Carthamus tinctorius L.) ranks fourth among the edible oilseed crops in India. The crop contributes about 4.14% (0.72 m ha) to the area and 2.18% (0.22 m ton) to the production of the total oilseeds in the country. The overall growth rates of all India hectarage, production and productivity have indicated a positive and significant trend. The research work on safflower dates back to circa 1900 A.D.; however, intensive research work on safflower commenced in 1969 when the crop was brought into the fold of the All India Coordinated Research Project on Oilseeds.

Research is in progress on the development of high yielding, high oil content cultivars possessing field tolerance to rust, Alternaria and aphid attack for different agroclimatic situations and for development of agroprotection technology. In all about 14 high yielding cultivars have been released/identified for cultivation in different states. Sources of resistance to Alternaria carthami Chowdhary, Puccinia carthami (Hutz.) Corda and Dactynotus carthami H.R.L. have been identified and are being further evaluated. Three-year multilocation experiments have revealed a substantial yield increase of 28 to 104% by adopting improved cultural practices over farmers' practices. Effective control measures for important diseases (Alternaria, rust) and insect pests (aphids) have been worked out for different climatic zones. The low productivity is ascribed to nonplanting of the crop on time, low or no application of plant nutrients and nonprotection of crops against maladies. Future research strategy has been outlined.

POSITION OF SAFFLOWER AMONG OILSEED CROPS

Safflower (Carthamus tinctorius L.) ranks fourth among annual oilseed crops in India, after peanut, rapeseed and sesame. The crop contributes about 4.14% (0.72 m ha) to the area and 2.18% (0.22 m tons) to the production of total oilseeds in the country (4). Its cultivation is concentrated mainly in the states of Maharashtra, Karnataka and Andhra Pradesh. The overall growth rates of area, production and productivity during the past 1½ decades have been positive and significant. Among the states, both Madhya Pradesh and Karnataka have shown positive trends both in area and production.

The research work on safflower dates back to circa 1900 A.D., when work on collection of land races and popular cultures was initiated at the Indian Agricultural Research Institute, then at Pusa (Bihar). However, intensive research work on safflower commenced from the year 1969 as part of the Fourth Five-Year Plan, when the crop was brought into the fold of the All India Coordinated Research Project on Oilseeds, with one main center at Jalgaon (Maharashtra) and a few more trial centers in the states of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu with the objective of developing high yielding cultivars to fit existing cropping patterns (7). Control of safflower rust was the second objective of safflower research.

OBJECTIVES OF RESEARCH ON SAFFLOWER

The program has since been enlarged and redefined to cover additional problems such as 1) higher seed yield and oil content, 2) drought and salinity tolerance, 3)evolution of high yielding synthetics and composites, 4) cultivars for short growing season, for irrigated conditions and fodder use, 5) evolution of a suitable package of practices, cropping systems, etc., for different agro-climatic regions, 6) evolution of cultivars with insect and disease resistance, 7) screening of germplasm for rust, leaf spot and aphids, 8) chemical control of foliar diseases and pests and 9) a survey of important pests and diseases in the safflower growing regions of the country.

The evaluation of cultivars is done in several stages before they are recommended for release by: initial yield evaluation (2 years); coordinated cultivar trials (2-3 years); national yield evaluation trials (1-2 years); minikit trial (1 year); and half-field demonstration trial (1 year).

SOME ACHIEVEMENTS OF THE COORDINATED RESEARCH PROJECT

Germplasm collection

Germplasm received from different countries like USA, Italy, Greece, Turkey, Iraq and Australia is maintained and evaluated at various centers in the country as given below: Rajendranagar (2500), Jalgaon (2252), Annigeri (1587), Coimbatore (1460), Phaltan (800), Akola (700), Varanasi (500) and Indore (400). In all there are about 3000 entries of both indigenous and exotic origin in the collection of germplasm excluding the possible duplicates present at different centers (AICORPO, 1978-79, 1979-80).

Evolution of high yielding cultivars/cultures of safflower

Research is in progress on the evolution of high yielding cultivars suitable for different situations. In all about 14 high yielding cultivars have been released/identified for cultivation in different states, the details of which are furnished in Table 1. Intensive research work is in progress at eight of the ICAR sponsored institutes viz. Rajendranagar (A.P.), Annigeri (Karnataka), Jalgaon, Phaltan and Solapur (Maharashtra), Coimbatore (T.N.), Indore (M.P.) and Varanasi (U.P.). The material generated at these centers will be evaluated at 16 other centers in addition to the above listed ones. Further, some lines which are high yielding, high oil content and rust resistant are in the advanced stages of their evaluation in the coordinated trials (2, 5, 6, AICORPO, 1979-80).

Sources of resistance to diseases and pests

In order to provide greater stability to oilseed production, emphasis on breeding for stable disease and pest resistance has been stressed at various institutions. These sources of resistance (Table 2) would be utilized for breeding cultivars with greater resistance. However, many of the sources mentioned are still under evaluation and not confirmed finally. In this context basic research in disciplines like cytogenetics, plant pathology, microbiology, plant physiology and biochemistry and survey for collection of germplasm and disease/pest occurrence is in progress at Jalgaon, Rajendranagar, Phaltan, and Jabalpur centers. A National Research Centre for Safflower is proposed in the next Five-Year Plan for in-depth studies on overall improvement of safflower research.

Table 1. Salient features of cultivars recommended/identified for cultivation in different states of India.

State	Name of the cultivar	Duration days	Yield kg/ha	Special features
Andhra Pradesh	Manjira	105	670-1590	Medium height (75-80 cm), woody stem, flowers yellow (fresh) and orange when dry, seeds pearly white cypsela (no persistent pappus), early maturing, high yielding.
Bihar	59-2-1	160	1100	Tall, dome-shaped plant, seed dull white.
Karnataka	A-1	120	800-850	High yielding, does well in deep black cotton soils, responds to irrigation and fertilizers, dull white seed.
	A-300	125	750-800	- do -, creamy white seed.
	S-144	135-145	1000-1200 2000*	Drought tolerant, responds well to irrigation.
Madhya Pradesh	JSF-1	120-130	950-1100	Partially resistant to aphids, high oil content.
	NP-18	146	770	--
Maharashtra	Tara	122-125	1200-1400	Semi-erect, responds to closer spacing.
	N-62-8	130-135	100-1250	Responds well to wider spacing in medium to heavy soils, white seed, yellow flowers turning to red on fading instead of orange color.
	Nagpur-7	140-150	1000-1250	White flowered, creamy white bold seeds.
Tamil Nadu	CO-1	120-125	800	Tolerant to Alternaria leaf spot, moderately resistant to wilt, non-spiny, suitable for mixed cropping with cotton.
Uttar Pradesh	Local-1	108-160	900-1600	Late maturing cultivar.
	29-A	140	2500*	Responds well to irrigation.
	T-65	180-190	1200-1500	Resistant to Ramularia leaf spot and successfully escapes attacks of rust. Large capitulum bearing 60-70 seeds, yellow florets turn to orange red after fertilization.

* Under irrigation.

The average oil content of the cultivars ranges from 30.0 to 35.8%.

Table 2. Sources of resistance to attack by economically important diseases and pests of safflower.

Name of disease/pest	No.	Sources/lines	Name of reporting center and year
Diseases			
Leaf spot (Alternaria carthami)	4	SF-1206-1, SF-1203-1, SF-1160-1, SF-1183	Rajendranagar, APAU, Hyderabad, 1978-79.
	2	HUS-304, HUS-305	BHU, Varanasi, 1979-80.
	1	431	CSAUAT, Kanpur, 1979-80.
Rust (Puccinia carthami)	6	431, 436, 504, 6426, 6432, 6433	CSAUAT, Kanpur, 1978-79.
	19	SF-1949, SF-1954, SF-1955 SF-1956, SF-1957, SF-1959 SF-1966, SF-1971, N-1-1-5-2 N-1-15-1, PI-195,895-1, APRR-1, APRR-2, APRR-3, APRR-4, APRR-5, MYT-28, MYT-36, MYT-38	Rajendranagar, APAU, Hyderabad, 1978-79.
	8	SF-1956-1, GPB-15, 16, 17A, 19-1, 21-1, 27, 32	Rajendranagar, APAU, Hyderabad, 1979-80.
Pests			
Aphids (Dactynotus carthami)	2	677-1, 713-1	Rajendranagar, APAU, Hyderabad, 1978-79.
	4	x-23, x-24, x-21, x-21-1, y/y	Rajendranagar, APAU. Hyderabad, 1979-80.
	4	JLA-21, 216, 219, 457	Jalgaon, MPKV, 1978-79.
	1	NS-488-1	Phaltan, MARI, 1978-79.

Agroprotection technology

Losses in the yields of oilseed crops due to attack by diseases and pests are far greater than in other crops like cereals, despite the number of vermins/pathogens being less. The high yielding cultivars often require protection against diseases and pests because most of the cultivars do not possess resistance. The Coordinated Project from the very beginning has worked towards the development of suitable control measures against economically important diseases/pests keeping in view the economic condition of a small farmer. Such control measures evolved through testing at several places as listed in Table 3 (8).

Agroproduction technology

Time of sowing. Sowing of safflower during the first fortnight of October is optimum for Rajendranagar, Annigeri and Bellary (S. India); Jalgaon and Solapur (W. India); and Kanpur (N. India); second fortnight of October for Varanasi (N.E. India); and the first week of November for Coimbatore regions (S. India) in case of normal onset of the monsoon. If the monsoon is delayed and chances of failure of rains after sowing exists, planting should be done in early winter with one preplanting

Table 3. Recommended control measures against economically important diseases/pests of safflower (AICORPO, 1978-79, 1979-80).

Name of disease/pest	Control measures
Diseases	
Rust (*Puccinia carthami*)	Seed treatment with Daconil or Bavistin (0.3%) or Difolatan (0.3%) or M.B.C. (0.3%) checks the incidence. Spray wettable sulfur (0.3%) or Daconil (0.2%) or Bayleton (0.1%), or Dithane M-45 (0.25%)
Leaf spot (*Alternaria carthami*)	1) Seed treatment with Dithane M-45 (0.03%) or Thiram or Captan (0.02%) 2) Spray Mancozeb (0.25%) or Bavistin (0.1%) or Benlate (0.1%) or Bayleton (0.17%)
Cercospora leaf spot (*Cercospora carthami*)	Spray copper oxychloride (0.3%) or Bavistin (0.1%) or Difolaton (0.2%) or Benlate (0.1%)
Pests	
Aphids (*Dactynotus carthami*)	1) Spray Dimethoate or Phosolone or Monocrotophos or Endosulfan or Quinalphos (0.05%) or 2) Dust Carbaryl (5%) or Quinalphos (1.5%) or Endosulfan (4%) @ 20 kg/ha or Phosolone @ 1 kg a.i. per ha.
Thrips and safflower bud fly	Spray Dimethoate or Phosolone or Endosulfan (0.05%)

irrigation. If the early stoppage of rains occurs towards the end of the monsoon, early planting of a pure crop is recommended (3).

Thinning. The highest yields have been realized when the crop was thinned at 10 days after germination at Jalgaon and Rajendranagar centers.

Fertilizer application. Safflower responds well to major nutrients like N and P. Under irrigated conditions a response occurs up to 40-80 kg N and 20-40 kg P_2O_5/ha, while under rainfed conditions it responds to 20-40 kg N and 20-25 P_2O_5/ha. No response to the application of potash and micronutrients has been noticed in a majority of areas.

Water management. In spite of its drought hardiness and ability to withstand adverse climates, safflower does respond to irrigation. If water is available, irrigation should be applied at the critical physiological stages of crop growth such as flowering and seed filling (AICORPO 1976-77). However, there is a response only for 2 to 4 irrigations in different agroclimates at the 4-6 leaf stage, branching, flowering and grain development stages, corresponding approximately to 3, 10, 13 and 16 weeks after sowing the crop.

Cropping systems. The prominent cropping systems prevalent in different regions of the country are listed on the following page:

Region	Research station	Best crop sequence recommended	
		Monsoon	Winter
		Double cropping	
Coimbatore	Coimbatore	Sorghum	Safflower
Chhotanagar	Kanke	Rice	Safflower
Western Maharashtra	Jalgaon	Green gram/sorghum	Safflower
Western Maharashtra	Akola	Sorghum/green gram	Safflower
Delhi	Delhi	Maize	Safflower
Hyderabad	Rajendranagar	Sorghum	Safflower
Indore	Indore	Cowpea/sorghum	Safflower
Bundelkhand	Jhansi	Sorghum	Safflower
Central U. P.	Kanpur	Sorghum/green gram	Safflower
		Intercropping	
Western Maharashtra	Jalgaon	Paired row planting of safflower	
Hyderabad	Rajendranagar	Safflower + Bengal gram (1 : 2)	
Eastern U. P.	Varanasi	Safflower + Bengal gram (2 : 1)	
Dharwar	Annigeri	Safflower + wheat	
Central U. P.	Kanpur	Bengal gram + safflower	
Tamil Nadu	Coimbatore	Safflower + Bengal gram	

Safflower, due to its deep root system, low input requirement, lesser attacks by pests and diseases beside being drought tolerant, has been found to be a good substitute for Bengal gram, cotton, mustard, barley, winter sorghum, sunflower, pennisetum and wheat under rainfed conditions in different localities of the country (3, AICORPO, 1979-80).

Harvesting mechanism. Due to its spiny nature, safflower is harvested manually during early hours of the day as the dew will soften the spiny leaves and capitula and eases the operation of harvesting. Research is underway to evolve suitable machinery for harvesting safflower.

Package of practices. Results of multilocation experiments (1977 to 1979) over a large area have revealed a substantial yield increase of 28 to 104% by adopting a recommended package of practices over farmers' practices (Table 4). Among the factors studied, time of sowing, fertilizer application and plant protection have been identified as major factors responsible for higher yields (AICORPO, 1979-80).

CAUSES OF LOW PRODUCTIVITY

The low productivity of safflower in various regions of the country is ascribed to the following factors based on a critical analysis of the situation:

1) Nonplanting of safflower on time.
2) Low or no application of plant nutrients.

Table 4. Impact of package of practices on the yield (kg/ha) of safflower (AICORPO, 1979-80)

Treatments	1979-80 Kanpur	1978-79 1979-80 Anni-geri	1978-79 1979-80 Indore	1978-79 Akola	Rajen-dra-nagar*	Jal-gaon*	Coim-batore*
Cultivator's method	1338 (32)	736 (51)	1482 (29)	435 (41)	768 (43)	874 (22)	1103 (28)
Improved method (IM) with whole package	1974	1503	2086	735	1349	1123	1524
IM except optimum time of sowing	--	1296 (14)	2148 (+13)	541 (26)	858 (36)	1308 (+16)	959 (37)
IM except optimum spacing	1742 (12)	1596 (+6)	2309 (+11)	583 (21)	1116 (17)	1011 (10)	1222 (20)
IM except fertilizers	1224 (38)	1304 (13)	1815 (13)	658 (10)	982 (27)	838 (25)	1138 (25)
IM except plant protection	1711 (14)	1278 (15)	1962 (6)	640 (13)	969 (28)	962 (14)	921 (40)
IM except weeding and hoeing	--	1488 (1)	1978 (5)	451 (39)	579 (57)	1383 (+23)	775 (49)
IM except nipping	--	1586 (6)	2863 (+28)	655 (11)	916 (32)	1330 (+18)	1096 (28)
IM except seed treatment	--	1512 (+1)	2430 (+16)	700 (5)	783 (42)	1424 (+27)	1011 (34)

Figures in parentheses indicate percent loss over all package of practices.
* Figures are based on the average of three years data (1977-78 to 1979-80).

3) Nonprotection of crops against pests like aphids and diseases.

4) Lack of resistant/high yielding/input responsive cultivars for various situations.

5) Cultivation of safflower in regions with poor or uncertain rainfall.

STRATEGY FOR FUTURE RESEARCH

The research needs of safflower in future decades have been identified as:

1) Breeding stable cultivars resistant to various maladies, by introducing sources of resistance.

2) Intensified basic research in various disciplines, surveys, collections, maintenance, evaluation of germplasm, and identification of disease/pest occurrence.

3) Evolution of high yielding synthetics/composites, thin hulled cultivars with high oil and low hull content and earliness, and fodder purpose cultivars.

4) Development of scientific cropping systems including safflower, and crop substitution in traditional and nontraditional safflower growing regions like Chhotanagpur and Sundarban areas.

5) Development of cropping systems in saline alkali problem soils, in tail end areas of canal irrigation in black soils, and also where rainfall is scanty by replacing less remunerative cotton.

6) Development of effective machinery for dehulling seeds.

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SAFFLOWER -- A NEW OILSEED CROP IN THAILAND

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ABSTRACT ONLY

A study was made of a collection of 161 varieties of safflower introduced from India, Pakistan, Iran and USA for a period of three years (1976-1978. This project has been financed by and ARS USDA Contract (No. 12-14-0605-112) under the title "Research on Comparative Evaluation of Safflower, Castorbean and Sunflower as Replacement Crops for Opium Poppy in Thailand." This project will determine if an improved variety would be adapted to that area, so it might be used to improve the native or local varieties. Promising varieties were put in regional tests to discover their adaptability to the varied climatic and soil conditions. Among the crops subjected to regional tests, some varieties were found worthy of further study.

BREEDING FOR RESISTANCE IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) TO WILT CAUSED BY *FUSARIUM OXYSPORUM* F. SP. *CARTHAMI*

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ABSTRACT

Fusarium wilt resistance is essential for safflower production in some areas of the Sacramento River Valley and Delta of California. Genes for resistance were introduced into high seed yield, high seed oil content adapted cultivars. Selection and evaluation were conducted under field conditions for five annual cycles. The procedure designed for this breeding program is effective for incorporation of wilt resistance as well as other desired agronomic characteristics and disease resistance into a wide range of genetic sources in safflower.

In 1962, a new disease on safflower was discovered in California in two separate safflower growing areas of the Sacramento Valley. The primary symptom was wilting of the infected plants regardless of the stage of growth at which disease symptoms became obvious. Emerging seedlings as well as plants in the bud stage expressed wilting symptoms. Another characteristic symptom on diseased plants was a unilateral or one-sided yellowing of the cotyledons and lower leaves followed by wilting. Yellowing of the lower leaves occurred and progressed upward on one side or sector of the plant. Regardless of the stage of growth of the plant at the time symptoms appeared, the affected portion of the leaves gradually turned tan in color and died. If the infection occurred in a plant in the seedling or rosette stage, the disease usually progressed, affecting all of the leaves and resulted in death of the entire plant. Distinct stunting also occurred if infection occurred early in the life cycle of the plant.

However, on plants that were 30 to 45 days old when the first disease symptoms appeared on the lower leaves, only the lateral branches on one side of the plant might be killed while the remainder of the plant appeared healthy and free of the disease.

The vascular bundles of both the root and the stem had a characteristic brown discoloration. If the plant was affected on only one side, then the pattern was for the brown discoloration to be present in the vascular bundles on the same side in both the root and stem. On plants in full flower, the disease was characterized by all gradations of symptoms ranging from death to one or two sickle shaped leaves on the lower portion of the plant.

When the disease progressed to the flowering head, distortion, blighting and reduced seed yield usually occurred. All symptoms were indicative of the disruption of the normal flow of nutrients and liquids in the infected plant.

The causal agent for this disease of safflower was identified as a wilt causing fungus, *Fusarium oxysporum* Schlect., by Klisiewicz and Houston in 1962 and the *Forma specialis* as *carthami* was designated by these researchers in 1963. Isolates of the fungus from safflower were only pathogenic on species of *Carthamus*.

Even though the disease was first observed in areas that periodically were flooded in winter, it subsequently was discovered in production areas along the Sacramento River and in some areas of the Delta where flooding did not occur. In 1975 a breeding program was initiated at Cal/West Seeds with the objective to incorporate resistance to Fusarium wilt into high seed yield, high seed oil, and rust resistant adapted cultivars. The procedures for the program included greenhouse and field screening for resistance with the field serving as the selection location in cycles 2 through 5.

The sources of resistance germplasm were primarily materials that trace to two P.I.'s, numbers 250,882 and 251,267.

A number of criteria were set forth in the identification and selection of a field test site. These included the following:

1. History of Fusarium wilt of safflower.
2. Available on a multi-year basis -- to enhance the level of the fungus in the soil, and to provide an optimum environment for race evolution.
3. Source of irrigation water for winter flooding of the test site -- to control soil- and debris-borne inoculum of rust.
4. High yield capability of the soil -- to develop high yielding cultivars adapted to conditions in which producers will optimize production inputs.
5. Good moisture holding capabilities of the soil -- to permit late planting to provide soil temperatures higher than 10 C on May 1, and to ensure above average seed yield.

Prior experience had clearly demonstrated that one control measure of soil-borne inoculum of rust is flooding of the soil for at least a minimum of 24 hours. This procedure has been highly successful in this program.

Various authors have speculated that Fusarium wilt of safflower probably was spread by flood waters and by infected seed. I would like to further speculate that the fungus was naturally present in many of the areas where the disease became epidemic prior to the introduction of safflower into the production system. It was only after safflower was grown for a few times on the land that the organism built up to a level sufficient to attack a significant number of plants in the field. Thus, this is one reason why the test site is planted in alternate years to safflower. It also is one means of monitoring any significant shift in the physiological races.

The incidence of infection by Fusarium is substantially enhanced if the soil temperature is at least 10 C. Usually in the lower Sacramento Valley the soil temperature is at or above this level by May 1 so the planting date for the nursery has been regularly accomplished very near this date. The loss of virtually all plants of the susceptible check in the seedling or before the rosette stage has clearly demonstrated that this temperature is more or less optimum and reduces the number of escapes to a minimum.

The field layout procedures are as follows:

1. Breeding nurseries:
   a. Plant in 50-cm rows.
   b. Plant a susceptible check in every third row.

c. Plant approximately 45 seeds in the breeding row -- counting healthy and infected seedlings and plants is greatly enhanced.

2. Yield trials:
   a. Two-row yield plots with rows 50 cm apart.
   b. Common border of resistant check between each plot.
   c. Regular spacing between each 20 entries one row of a susceptible check cultivar.

Considerable progress in the development, selection and testing of improved cultivars has been accomplished. Three new selections with about 95% wilt resistant plants, high seed yield and high seed oil content have been advanced to the seedstocks program. Seed yield and seed oil content have been confirmed in non-Fusarium infested soil. In addition, near immunity for the leaf phase of safflower rust has been attained. Preliminary data strongly suggest that some of these selections from this program have resistance to Verticillium wilt of safflower.

The procedures for seedstock increases are as follow:

1. First stage increase: Greenhouse production in Fusarium-free potting mix using selfed seed of the selected line. This seed is indexed on a single-plant basis.

2. Second stage increase: Field production in areas where Fusarium wilt has not been observed or recorded.

Even though this selection program has been designed to enhance possible shifts in races, the data show there has not been any change in the level of resistance in the advanced lines. It can be reasonably concluded that the race complex is not shifting significantly.

TISSUE SPECIFICTY OF GENES CONDITIONING RESISTANCE IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.) TO *PHYTOPHTHORA DRECHSLERI* TUCKER

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ABSTRACT

The tissue specificity of three genes conditioning resistance in safflower (*Carthamus tinctorius* L.) to *Phytophthora drechsleri* Tucker was determined from the reactions of roots, hypocotyls, cotyledons, and stems of several cultivars to inoculation with a virulent isolate (ATCC 28200) of the pathogen. All of the tissues of the cultivar Nebraska 10 were highly susceptible whereas those of USB were resistant. The tissue reactions of VFR-1, LMVFP-1, Gila, and US 10 indicated that the dominant gene conditioning root resistance does not determine resistance in any of the other tissues. Similarly, the dominant gene that conditions cotyledon resistance and the recessive gene that conditions hypocotyl resistance do not determine stem resistance.

Phytophthora root and stem rot is an important disease of irrigated safflower (*Carthamus tinctorius* L.) in several parts of the world (5,11). This disease has been shown to be incited in nature by *Phytophthora drechsleri* Tucker, *P. cryptogea* Pethyb. and Laff., *P. parasitica* Dast., *P. cactorum* (Leb. & Cohn) Schroet., and *P. palmivora* Butler (1,2,6). *P. drechsleri* has been reported to be the causal agent in most studies. *P. drechsleri* and *P. cryptogea* appear to be species most virulent on safflower.

Phytophthora rot was the most important disease of safflower in the United States in 1950 when approximately 100,000 acres of the crop were cultivated. The disease caused extensive losses of susceptible varieties in irrigated sections of the Imperial Valley of California (6). It appeared that further interest in the crop in many areas would be jeopardized until resistant varieties became available. Production was limited for several years to dry land and sub irrigated land.

Performance tests indicated that the varieties Nebraska 8 and Western Oilseeds 14 possessed sufficient resistance for production on furrow-irrigated land. Unfortunately, these varieties had lower bushel weight, poorer yielding ability, less early vigor, less firing resistance, and later maturity than the susceptible varieties Nebraska 10 and Pacific 1. The backcross method was used to transfer resistance from Western Oilseeds 14 to Nebraska 10 and to develop the varieties Gila (4) and US 10 (7,10). These varieties, agronomically similar to Nebraska 10 and with resistance similar to that of Western Oilseeds 14, were found to be suitable for irrigated culture, provided they were subirrigated or grown on beds and furrow-irrigated for recommended durations. Their culture on heavy, flood-irrigated soils was not successful because of Phytophthora rot (11).

Field tests in Utah indicated that the safflower cultivar Biggs possessed sufficient resistance for production under flood irrigation in some areas (11). Wound inoculation of either the hypocotyl or the first internode of epicotyl tissue of adult greenhouse plants differentiated the high level of resistance of Biggs from lower levels. Several inbred lines derived from the cross Biggs x Nebraska 10 possessed hypocotyl resistance but not epicotyl resistance.

The reaction of safflower cultivars to Phytophthora rot under the various cultural conditions and inoculation methods described above indicated that different genetic factors condition resistance in different tissues.

ROOT RESISTANCE

The root and hypocotyl resistance of VFR-1 safflower to P. drechsleri was determined by growing plants in infested soil with and without flood-irrigation and by wound-inoculating the hypocotyl. Plants grew to maturity in infested soil without flooding. Both flooding and wound-inoculation resulted in hypocotyl and stem infection and subsequent death.

Inheritance of resistance to root rot was studied in F_1, F_2, and BC_1 progenies derived from a cross between VFR-1 and the susceptible cultivar Nebraska-10. The reactions indicated that resistance is conditioned by a single dominant factor (8).

HYPOCOTYL RESISTANCE

In this inheritance study Biggs was used as the female parent in crosses with the susceptible cultivar Nebraska-10. Both parents, F_1, F_2 and progenies from backcrosses of F_1 plants to both parents were tested in the greenhouse with a virulent isolate of P. drechsleri. Plants were inoculated 7 weeks after emergence by smearing inoculum into a 7-mm incision made half-way through the hypocotyl just below the soil surface.

The F_1 plants were as susceptible as the susceptible parent. The segregation ratio for Phytophthora rot susceptibility and resistance was in good agreement to a 3:1 ratio. Data obtained from backcrossing F_1 plants to each parent substantiated the hypothesis that resistance is conditioned primarily by a single-factor pair exhibiting complete recessiveness (10).

COTYLEDON RESISTANCE

In young alfalfa seedlings the reaction of cotyledons to Phytophthora megasperma Drechsler parallels tap- and lateral-root reactions of older plants (3). Cotyledons were susceptible to P. drechsleri in the safflower cultivar Nebraska-10, that also has susceptible root and hypocotyl tissues; and in Gila and US-10, that have susceptible hypocotyls but resistant roots. Cotyledons of VFR-1, root tissue resistant and hypocotyl tissue susceptible, and USB, both root and hypocotyl tissues resistant, were resistant. The cotyledon reactions of the F_1, F_2, and BC_1 progenies derived from a VFR-1 x Nebraska-10 cross indicated that resistance is conditioned by a single dominant factor.

STEM RESISTANCE

Distinct differences in hypocotyl and epicotyl reactions to P. drechsleri of inbred lines derived from Biggs x Nebraska-10 indicate that resistance

reactions in these two tissues are not conditioned by the same factor. Preliminary data obtained from stem inoculations of the F_1 and F_2 generations from Biggs x Nebraska-10 with the highly virulent isolate (ATCC 28200) of P. drechsleri indicate that stem resistance is conditioned by two recessive factor pairs. Preliminary data obtained from stem inoculations using less virulent isolates of P. drechsleri and isolates of P. cryptogea indicate the existence of other factors that condition stem resistance.

CONCLUSIONS

Breeding safflower for root, hypocotyl, and stem resistance to Phytophthora rot is complicated by the fact that resistance in each of these tissues is conditioned by different factors. Breeding is also complicated by the fact that several different species of Phytophthora may incite the disease, the existence of pathogenic races within the species (9), and that related pathogens such as Pythium can incite a similar disease (12).

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CONTINUED STUDIES ON INHERITANCE OF PARTIAL HULL IN SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

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ABSTRACT

In 1976 a new hull character in safflower was identified as "partial hull." Homozygous partial hull plants produce approximately 40% white seeds and 60% partially dark seeds. Most of the white seeds also have small, dark "blotches." Partial hull (*parpar*) is recessive to normal hull but inherited independently of recessive thin hull (*thth*) and striped hull (*stpstp*). There was some difficulty in classification and deficiencies in recessive classes but additional crosses indicated that these problems were due to minor modifying factors. When partial hull was crossed with UC1, a cultivar with completely white, normal hull, F_1's were white hulled with a slight expression of blotched and partially dark hulls. F_2's segregated in a 3:1 ratio of white to partial hull with some gradation of expression in both classes. F_3's from the white hull class contained both homozygous white hull and heterozygous white hull/partial hull families. F_3's from the partial hull class bred true for partial hull but again with gradations of expression. When partial hull was crossed with "reduced hull," a germplasm release with 50-70% completely white hulls but an intermediate expression of blotches and partially dark hulls, F_1's had slightly more white hull expression than the reduced hull parent. F_2's segregated in a 3:1 ratio of reduced to partial hulls with a slight but consistent deficiency in the partial hull class. There was some gradation of expression in the reduced hull F_2's but not in the partial hull class. When partial hull was crossed to 14-5, a germplasm release with a moderately thick striped hull, F_1's were white hulled with a slight partial expression. F_2's segregated in a 9:3:3:1 ratio of white, partial, striped, and partial-striped hull. Segregations of F_3 families verified F_2 data although there was a deficiency of partial-striped hull types in some segregating families. A good fit to the 9:3:3:1 ratio was obtained in F_2 when partial hull was crossed to another striped hull parent. When partial hull was crossed with thin hull, F_1's were white hulled with some partial expression. F_2's segregated in a 9:3:4 ratio of white, partial and thin hull. F_3's verified F_2 data.

The pericarp (hull) of safflower seed is high in fiber and contains very little oil whereas the kernel (embryo) portion of the seed is high in oil and protein. There is a high negative correlation between oil percentage and hull percentage (2, 3). Reducing the hull portion of the seed would increase product value and, if yield were not reduced, would result in production of more oil and protein per hectare.

Ebert and Knowles (1) found the hull types striped (*stpstp*) and thin hull (*thth*) to be recessive to normal hull but inherited independently of one another. Urie and Zimmer (4) described a "reduced hull" character in which the outer layer of the pericarp is very thin, thus exposing the dark underlying phytomelanin layer on 30 to 50% of the seeds while the

remainder are completely white. Difficulty was encountered in classifying the seed types produced on F_2 plants from normal by reduced hull crosses but normal hull did appear to be dominant or partially dominant depending upon the parent used in the cross.

MATERIALS AND METHODS

A new pericarp type was found in an F_4 plant progeny row from the cross UC-1 x Leed[3]. It was designated "partial hull" (5). Homozygous partial hull plants produce approximately 40% white seeds and 60% partially dark seeds. The dark areas may vary from 25% to nearly all of the total area of the pericarp except for the tip of the seed which is always white. Most of the white seeds also have small, dark blotches occupying less than 25% of the total area of the pericarp. As an aid in classification, seeds were identified as completely white, blotched or partially dark, with blotched and partially dark combined and labeled "percent expression" (Table 1). Other hull types used in crosses of this study are also described in Table 1.

Table 1. Pericarp expression of parents used in crosses.

Parent	Pericarp type	Pericarp expression in %			Percent expression[1/]
		White	Blotched	Partially dark	
UC-1	white (normal)	96	3	1	4
Partial hull	partial	5	33	62	95
Improved partial	partial	0	6	94	100
Reduced hull-1	reduced	73	20	7	27
Reduced hull-2	reduced	64	24	12	36
Reduced hull-3	reduced	53	31	16	47
Reduced hull-4	reduced	48	37	15	52
14-5	striped	60	40	0	40
AC-1	striped	60	40	0	40
S541	striped	6	79	15	94
Thin hull	thin	0	0	100	100

[1/] blotched plus partially dark

RESULTS

When a partial hull type was crossed with UC-1, a cultivar with white normal hull, F_1's were white hulled with some plants having a few blotched and partially dark seeds. F_2's segregated in a 3:1 ratio of white to partial hull types (Table 2), but with gradation of expression in both classes (Fig. 1). F_2's which had less than 60% expression were classified as normal hull, and those with greater than 60% as partial hull (Fig. 1). F_3's from the white hull class contained both uniformly white hull and segregating white hull/partial hull families. F_3's from the partial hull class

Table 2. F_2 segregation for pericarp types in a cross of UC-1 (white, thick pericarp) by partial hull.

Cross No.	Pericarp type		Fit to 3:1 ratio	
	White	Partial	χ^2	P exceeds
57	30	13	0.628	.40
58	80	18	2.299	.10
59	58	19	0.004	.90
60	44	13	0.146	.70
61	39	12	0.059	.80
62	37	15	0.410	.50
Total	288	90	0.285	.50
Heterogeneity			3.261	.60

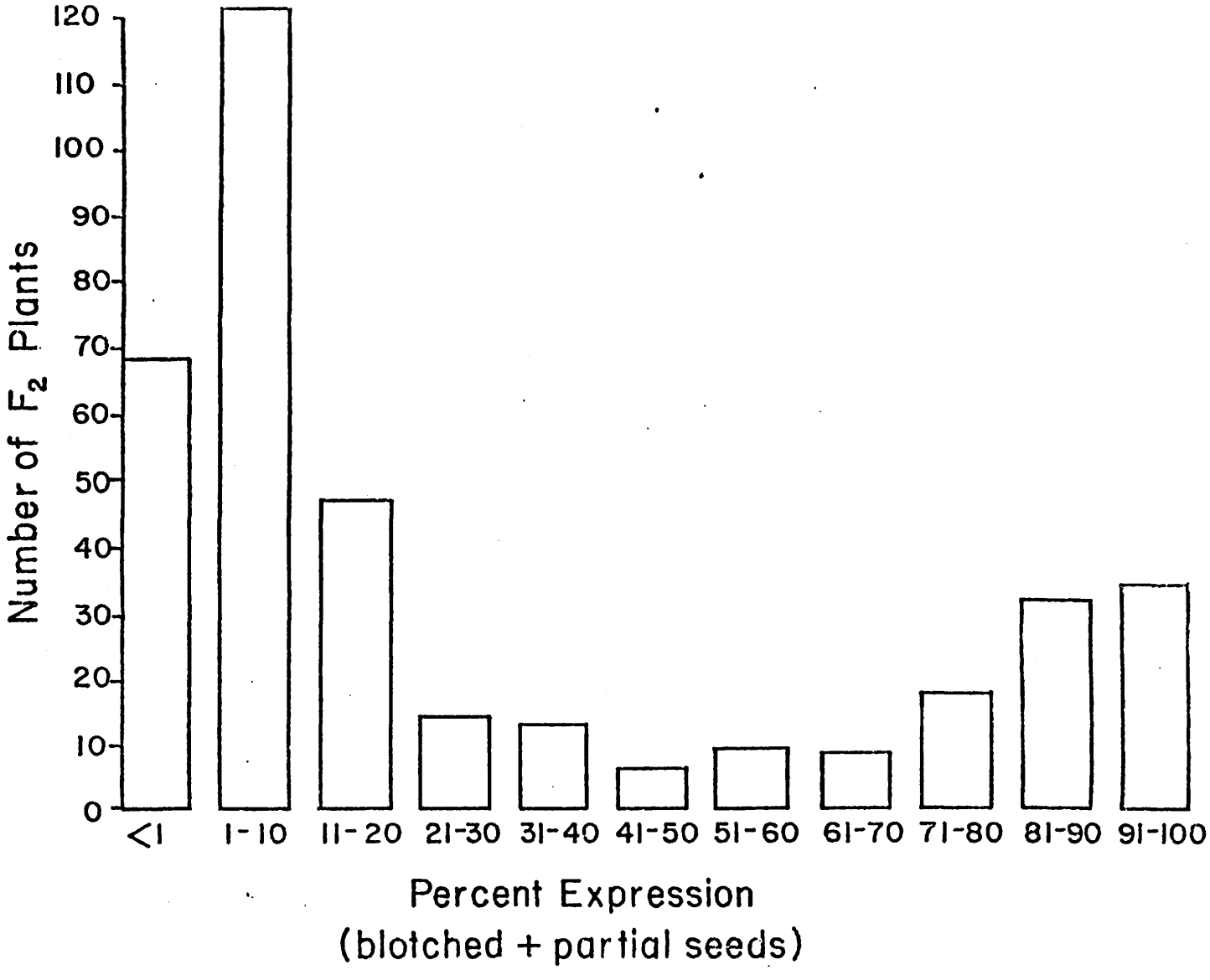

Fig. 1. Hull expression of F_2 plants from six UC-1 x partial hull crosses.

bred true for partial but with gradation in expression. I am suggesting the symbol parpar for the partial hull genotype.

When partial hull and reduced hull types were crossed, some F_1's had slightly morewhite expression than reduced hull parents (Fig. 2). F_2's segregated in a 3:1 ratio of reduced to partial hulls (Table 3) with a slight but consistent deficiency in the partial class. There was some gradation of expression in the reduced class but not in the partial hull class (Fig. 3). The F_2's having 61-70% expression were classified as reduced hull since there was a clear break between 70 and 90% expression (Fig. 3).

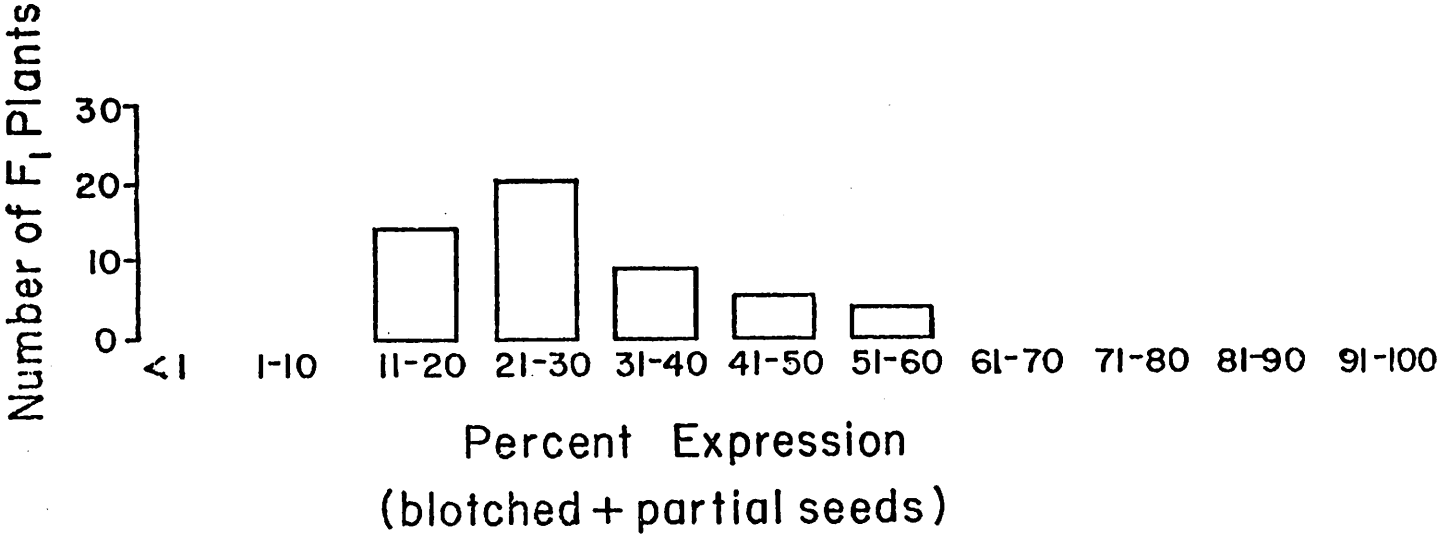

Fig. 2. Hull expression of F_1 plants from crosses of reduced hull x partial hull.

Table 3. F_2 segregations of pericarp types in crosses of partial hull x Reduced Hull-1, -2, -3 and -4.

	Pericarp type		Fit to 3:1 ratio	
Cross	Reduced	Partial	x^2	P exceeds
RH-1 x Par	167	45	1.610	.20
Par x RH-1	124	37	0.349	.50
RH-2 x Par	164	52	0.099	.70
Par x RH-2	211	71	0.044	.80
RH-3 x Par	291	79	2.628	.10
Par x RH-3	98	28	0.519	.40
RH-4 x Par	231	71	0.357	.50
Par x RH-4	83	25	0.197	.60
Pooled	1369	408	3.833	.05
Heterogeneity			1.970	.95

When partial hull and improved partial hull types were crossed with the striped hull parents 14-5, S541 and AC-1, F_1's were white hulled with some expression of blotched and partially dark seeds. F_2's segregated in a 9:3:3:1 ratio of white, partial, striped and partial-striped respectively (Table 4). There was some deficiency in the striped and partial-striped classes in all 5 crosses; however, on average there was no deficiency in the partial class (partial + partial-striped). Ebert and Knowles (1) did not detect any deficiency in the F_2 striped hull class when normal hull was crossed with striped hull. Crosses involving the striped hull parent AC-1 have more deficiency in the striped hull class than other crosses (Table 4). All the expected hull classes were recovered in F_3 families from normal and striped F_2 classes but actual ratios were not established. The partial-striped class bred true in F_3 with some gradation of expression. When partial hull F_2's from the partial hull by 14-5 cross were grown in F_3, nine families bred true for partial hull and 13 families segregated for partial and partial-striped hull (Chi square = 0.524, P exceeds 0.40 for the expected 1:2 ratio). Several of the segregating families had a severe deficiency in the partial-striped class but rows 30, 32 and 43 had a good fit to the 3:1 ratio (Table 5). Sterile plants were noted in F_3 rows but were not necessarily associated with just the families deficient in partial-striped plants. AC-1 was used as a parent in the development of 14-5, thus the level of deficiencies in the striped class associated with crosses involving both 14-5 and AC-1 in F_2 and F_3 (Tables 4 and 5) may indicate that the deficiencies are unique when AC-1 is used as a parent.

Table 4. F_2 segregations for pericarp types in crosses of Partial and Improved Partial by striped hull parents.

Parents	Pericarp types				Fit to 9:3:3:1			
					Pooled		Heterogeneity	
	White	Partial	Stripe	Partial stripe	X^2	P	X^2	P
Partial x 14-5 (2 crosses)	152	57	43	15	2.155	.50	5.293	.10
Partial x S541 (6 crosses)	325	103	97	28	2.327	.50	21.501	.10
Improved Partial x S541 (8 crosses)	372	139	119	40	1.926	.50	9.178	.95
Improved Partial x AC-1 (2 crosses)	76	23	12	3	8.826	.02	1.364	.70
Partial x AC-1 (7 crosses)	272	92	72	16	8.983	.02	16.991	.50

When partial hull and thin hull types were crossed, F_1's were white with some expression of blotched and partially dark seeds. F_2 segregation fits a 9:3:4 ratio of white, partial and thin hull (Table 6). The double recessive partial-thin hull class could not be positively identified in F_2 or F_3; however, there was a low frequency of dark thin hull types. All the expected seed classes were recovered in F_3 families from white, partial and thin hull F_2's but actual ratios were not established.

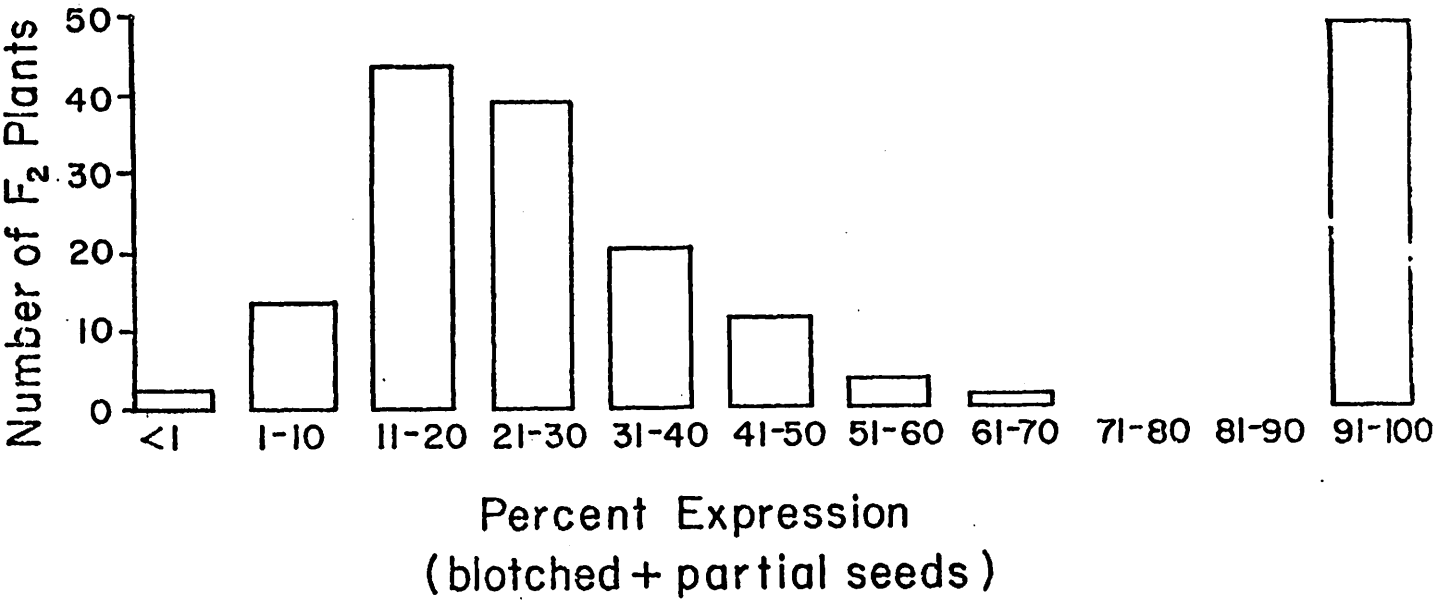

Fig. 3. Hull expression of F_2 plants from crosses of reduced hull x partial hull.

Table 5. Segregations for partial and partial-stripe pericarp types from 13 partial hull, F2's observed to be segregating in the F_3 generation from the Partial Hull by 14-5 cross.

F_3 row	Pericarp type		Fit to 3:1 ratio	
	artial	Partial-striped	x^2	P exceeds
2	41	9	1.310	.20
3	49	10	2.039	.10
4	48	7	4.410	.025
7	48	2	11.760	.0005
10	46	3	9.300	.001
11	54	6	7.200	.005
12	48	9	2.570	.10
22	9	2	0.272	.60
25	57	8	5.590	.01
29	68	7	9.810	.001
30	45	16	0.049	.80
32	50	19	0.236	.60
43	35	13	0.111	.70
Pooled	598	111	32.798	--
Heterogeneity			21.859	.02

Table 6. F_2 segregations for pericarp types from a cross of partial hull and thin hull.

Cross No.	Pericarp type			Fit to 9:3:4 ratio	
	White	Partial	Thin	χ^2	P exceeds
35	22	7	7	0.604	.70
36	17	9	13	2.560	.20
38	20	8	8	0.568	.70
42	15	7	5	1.200	.50
43	11	4	5	0.023	.95
47	19	7	6	0.721	.60
48	16	9	5	2.900	.05
Pooled	120	51	49	3.067	.20
Heterogeneity				5.508	.90

DISCUSSION

Partial hull (parpar) is recessive to normal hull (ParPar) and reduced hull but inherited independently of the striped (stpstp) and thin hull (thth) genes. The known relationships between the various genes conditioning pericarp type are summarized in Table 7. The type of parents used may influence "level of expression" of the partial hull gene in filial generations. Seeds from small heads on partial hull plants have a higher level of expression than seeds from larger heads. Environmental factors such as defoliation and arrested seed development shortly after flowering can cause fluctuations in hull thickness (2, 3). Moisture stress and diseases such as Verticillium wilt may alter hull thickness. Foliar rust reduced hull thickness (6).

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Table 7. Known F_2 ratios when 5 pericarp types were crossed in all combinations.

Cross	F_2 ratio
normal x reduced	could not classify (see text)
normal x partial	3 normal:1 partial
normal x striped (1)	3 normal: 1 striped
normal x thin (1)	3 normal:1 thin hulled
reduced x partial	3 reduced:1 partial
reduced x striped[1]	3 reduced:1 striped
reduced x thin[1]	3 reduced:1 thin
partial x striped	9 normal:3 partial:3 striped:1 partial striped
striped x thin (1)	9 normal:3 thin:4 striped and striped thin
partial x thin	9 normal:3 partial: 4 thin and partial thin

[1] Unpublished data.

DISTRIBUTION, UTILIZATION AND HISTORY OF CULTIVATION OF SAFFLOWER IN CHINA

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ABSTRACT

Safflower appears to have been grown as a cultivated crop for a long period in China. During the Han dynasty, more than two thousand years ago, it was introduced into this country where it has been grown for its dried flowers which are used as a herbaceous medicine. Safflower is extensively distributed over nearly all the provinces of China, but most of the production is concentrated in the Provinces of Sichuan, Honan and Xinjiang.

Owing to its medical action of invigorating blood flow, eliminating stasis to facilitate menstration and reducing or dissolving the extravasated blood, the main use of the dried flowers in China is in preparing drugs for curing diseases of women, coronary heart diseases, muscular fatigue, etc. In ancient time, its culture as dye, chiefly used to color textiles, prevailed in China, but since the much cheaper synthetic dyes replaced this herbaceous dye, only some small local districts, e.g. Xinjiang, still use safflower dye in coloring food and confections. But in Xinjiang, however, safflower is cultivated as an oil crop, its oil being used for edible purposes as well as for medical purposes.

HISTORY OF SAFFLOWER CULTIVATION IN CHINA

Safflower cultivation in China dates back more than two thousand years. In the 16th century Chinese pharmacological encylopedia "Ben Cas Gang Mu" (1) or the "Compendium of Materia Medica", safflower was called "red lan-hua" because it had oblong lanceolate leaves. To give reasons for the name, the "Ben Cao Tu Jing" (2), an illustrated ancient annotation book of Chinese medicines, described the plant under the name of "red lan-hua", stating that safflower was easily found in many places of "Wei". The place of "Wei" refers to a present day area covering the provinces of Shaanxi and Henan along the middle and lower reaches of the Yellow River and part of Anhui Province, on the north side of the Huai River. The safflower seeds, sown in cultivated fields in winter, would not emerge until spring. Summer was the flowering time. The flower heads were surrounded by prickly bracts. The plant produced white seeds, which were no larger than small red beans. The leaves were very much like those of the Lan (Eupatorium, a species of Compositae). Thus, the safflower plant was also called "lan-hua."

Questioning when safflower was introduced into China, the Chinese pharmacologist and physician, Li Shi Zhen (3) (1,518-1,593 A.D.) quoted these words from the book "Bo Wu Zhi" (4): Zhang Qian (5) (? -114 B.C. got the safflower seeds in the Western Regions (today's Xinjiang and an area to the west). Historically Zhang Qian was twice sent as a diplomatic envoy to the Western Regions between 138 B.C. and 115 B.C. in the Western Han Dynasty (206 B.C. to 24 A.D.). This proved that safflower has long been planted in China.

DISTRIBUTION OF SAFFLOWER IN CHINA

Thanks to long-term cultivation in China safflower is widely distributed. Besides its major producing region -- Xinjiang, Henan and Sichuen provinces -- it is also planted in the following provinces, autonomous regions and cities: Heilongjiang, Jiling, Liaoning, Inner Mongolia, Shaanxi, Gansu, Hebei, Shandong, Shanxi, Jiangsu, Zhejiang, Anhui, Fujian, Guangdong, Guangxi, Hunan, Hubei, Jiangxi, Guizhou, Quinghai, Yunnan, Tianjin, Beijing and Shanghai. Nearly 90% of the provinces of China grow safflower for different purposes.

By a rough estimate in 1979 the national safflower area reached 35,788 hectares and the annual output of the dry flower totaled 1,500 tons (Table 1). Accounting for an average yield of seeds is difficult, because it would vary with different producing districts and the environment of such a large area as China. However, the area under cultivation in China has increased from 3,841 ha in 1950 to 35,788 in 1979.

By analyzing the different purposes for cultivation we may evidently know that in the northern and northwestern parts of China most of the farmers are interested in growing dry flower because the lesser precipitation in the blooming period could contribute to the good quality of products for dyeing. Since some of the southern provinces have sufficient rainfall in the growing season, they mostly plant for harvesting the seed. The average yield in Xinjiang Province was 538.5 kg/ha in 1978.

Henan Province had 2,924 ha in 1978 which yielded 20 tons of dry flower. In its top-yield year, 1960, this province gathered 680 tons of dry flower from 4956 ha. Anyang, Shangqiu and Xinxiang are the principal producing areas.

The producing areas of Sichuan Province are Jinyang, Ziyang and Jintang, with an area of 1,737 ha in 1978.

Xinjiang has increased production in the past few years. There were 2,667 ha in 1960, which was expanded to 18,107 ha in 1978 with the output of seed being 9,324 tons. There was a large increase in the regional cultivation last year. The area totaled 24,667 ha, and the output was 13,444 tons, accounting for 538.5 kg/ha. The dry flower output reached 870 tons in all. The major producing areas are Changji and Tacheng Counties, Ili prefecture and the Mongolian prefecture of Bayingolin in the autonomous region.

The area in Shanxi Province, mainly in Ruicheng County, was 76 ha in 1979, which yielded 7000 kg of dry flower.

Cixi and Yuyao Counties in Zhejiang Province and Xiapu County in Fujian Province are also producing areas. There is less production in other areas.

UTILIZATION OF SAFFLOWER

The dry flowers of safflower are used as a herbal medicine with its efficacy in restoring normal blood circulation, boosting the regulation of nerve activity, and regenerating blood. This had been recorded in detail in many ancient traditional Chinese medicine works, such as the "Tang Ben Cao" (6), "Kai Bao Ben Cao" (7), "Ben Cao Meng Jian" (8), "Gang Mu" (9), "Ben Cao Zheng" (10), "Ben Cao Yan Yi Bu Yi" (11), "Ben Cao Jing Shu" (12) and

Table 1. The areas of safflower cultivation in China.

Provinces	1950	1960	1970	1975	1978	1979
Anhui	248.3	2000	800	254.3	980	1333.3
Beijing (Peking)	--	5.4	--	--	2.6	400
Fujian	--	10.3	--	13.3	164.6	100
Gansu	--	333.6	--	26.6	60.3	68.7
Guizhou	--	197.8	1440.7	18.0	15.1	6.7
Guangdong	--	--	--	--	--	9.5
Hebei	--	520.1	44.7	--	970.9	6.0
Heilongjiang	15.6	213.3	--	191.3	447.2	333.3
Henan	1994.8	4956.3	3527.8	2787	2924.3	5933.3
Hubei	372.5	133.3	179.1	170.9	161.7	155.5
Hunan	--	--	14.3	--	18.3	9.5
Inner Mongolia	--	1133.2	--	28.3	47.9	22.0
Jiangsu	149.1	1564.7	787.2	471.7	697.1	800
Jiangxi	43.1	2241.5	622.6	427.3	689.3	81.2
Jilin	--	80	686.7	36.7	79.1	8.6
Liaoning	--	1200	17	68.6	73.9	10.8
Sichuan	844.8	666.7	1356.9	1700.9	1736.7	1493.3
Shaanxi	--	246.3	--	13.3	--	26.7
Shandong	--	--	--	--	--	20.5
Shanxi	--	1677.2	142.5	101.7	4.7	76
Shanghai	20	60.8	69	79.3	100.9	63
Tianjin	--	139.5	--	14.7	85.7	1.6
Xinjiang	--	2666.7	--	--	18106.7	24667
Yunnan	100	153.3	170.7	180.0	234.3	66.3
Zhejiang	53.2	266.7	112.4	159.1	275.6	101.6
Total	3841.3	20466.7	9971.6	6743.0	27876.9	35788.4

"Ben Cao Hui Yen" (13), etc., some of them being written 1,000 years ago.

The therapeutic results proved by some recent clinical experience are as follows:

1) For curing heart diseases, the dry flower is used to treat both coronary heart diseases in the first two periods and angina pectoris. The drug is characterized by: a) its efficacy, since 75.6% of the patients who have taken it improved during their first-period treatment; b) it keeps its stability longer than nitroglycerine whose result will disappear when the patient stops taking the chemical drug; and c) it provides the same result for sufferers of high blood pressure and has very few side effects.

2) In treating muscular strain its cure rate reaches 90.8%. The safflower is still a notable drug for treating many other diseases, e.g. the hypodermic congestion caused by bedsores, breaks and sprains, and oedema and abdominal distention.

Safflower is also used as a dye to stain silks and clothes and as a substance to make cosmetics. This was well recorded in the book "Ben Cao Tu Jing". It says: "The native dry flowers of safflower through processing yield the true saffron dye and rouge." "The colors of what was stained with the dye is very beautiful" says the Annals of Jiangyang County in Sichuen Province. These indicate the use of the flower in ancient times. But now it is not a common practice to use flowers of safflower as a source of dye. Only in some places in Qinghai and Xinjiang Provinces do people often color and flavor their steamed foods with the powdered flowers during festivals.

Safflower seed is a good source of oil which is widely used in cooking oil. Usually the seed is processed by local methods. About 50 years ago, people at Dunhuang, in Gansu Province, planted safflower as an oil crop while the plant was regarded as an important one for this purpose in Xinjiang. The oil, which is rich in the unsaturated linoleic acid, will reduce cholesterol in plasma and is a preventative of arteriosclerosis. Certain medical reports indicate that the sufferers of high blood pressure are seldom found in communities which adopt safflower oil for cooking.

During hot summers, the local people in Dunhuang County, Gansu Province, feed their camels and domestic animals with the safflower oil because the oil is refreshing and reduces internal heat in a manner similar to that of rhubarb.

Now in the Khotan area of Xinjiang Province some Uygur people like to make their traditional baked food, called "Nang" in the Uygur language, with corn flour mixed with the dried, powdered flowers. The food provides them protein. The safflower seeds are sometimes used as fodder and organic fertilizer in some places in Sichuan and Fujian Provinces.

The seedlings of safflower can also be eaten as a vegetable. An Ancient Chinese medicine book entitled "Jiu Huang Ben Cao" (14) remarked that the plant was known under the name of the "safflower vegetable". Residents in an area in Gansu Province often make the safflower seed sprout so as to eat the tender vegetable.

China has a long history of safflower cultivation over a vast territory. It is one of the world's centers of cultivation. Through long-term selection both by nature and humans, different varieties and lines have been produced, which provide a very rich gene pool. Strengthening research on germplasm of safflower and cultivation is a significant business not only for the development of the Chinese economy but for the improvement of safflower cultivation in other countries.

(1) Ben Cas Gang Mu = 本草纲目
(2) Ben Cao Tu Jing = 本草图经
(3) Li Shi Zhen = 李时珍
(4) Bo Wu Zhi = 博物志
(5) Zhang Qian = 張騫
(6) Tang Ben Cao = 唐本草
(7) Kai Bao Ben Cao = 开宝本草
(8) Ben Cao Meng Jian = 本草蒙鑑
(9) Gang Mu = 纲目
(10) Ben Cao Zheng = 本草正
(11) Ben Cao Yan Yi Bu Yi = 本草衍义补遗
(12) Ben Cao Jing Shu = 本草经疏
(13) Ben Cao Hui Yen = 本草汇言
(14) Jiu Huang Ben Cao = 救荒本草

INDEX OF PAPERS BY SUBJECT MATTER

OILSEED RESEARCH AT THE UNIVERSITY OF CALIFORNIA AT DAVIS

Tour July 14, 1981

Research on oilseeds at the University of California is conducted by both University and USDA personnel. University personnel are as follows:

P. F. Knowles assisted by D. B. Cohen: Primarily involved in research on safflower and Brassica species, and secondarily on sunflower and soybeans.

D. A. Phillips: Soybeans with delayed leaf senescence
T. L. Rost, Botany Department: Jojoba
R. N. Campbell, Plant Pathologist: Diseases of Brassica
USDA personnel are as follows:
B. H. Beard assisted by B. Keesling: Primarily involved in sunflower and soybean research
A. L. Urie: Working mainly on safflower and sunflower
J. M. Klisiewicz, Plant Pathologist: Primarily interested in diseases of safflower, but working also on diseases of other oilseed crops

The emphasis of both University and USDA programs has been on germplasm development, interspecific hybridization and basic research. Very little attention has been given to cultivar development, except with those crops where breeders with commercial companies are not involved. Private breeders in California are active in cultivar development of both safflower and sunflower, but not soybeans and Brassica species.

At one time both the University and USDA were active in research on flaxseed for oil, but such research ceased with the disappearance of flax as a commercial crop in California. Likewise, both the University and USDA worked on castor beans when it was a crop in California.

The field tour on July 14 is scheduled to make the following stops:

BLOCK E-2

B. H. Beard: Research on Sunflower and Soybeans

Sunflower research under my direction consists of assembly and maintenance of a working wild Helianthus collection, germplasm development providing a random gene flow from the wild species into a domestic background, use of embryo culture to produce controlled species crosses and to decrease generation time on backcrossing situations, study the phylogenetic relationships of the wild species through chromosome translocations in F_1 plants, inheritance studies of special characteristics and development of isogenic lines with special characters.

Soybean research includes studies to develop adapted dual purpose cultivars suitable for use as a green vegetable, for making tofu, or for crushing for oil. These varieties must also have spidermite resistance, and tolerance to excessive boron.

BLOCK E-1

A. L. Urie: Research on Sunflower and Safflower

We are completing a major safflower study on inheritance of partial hull this year. F_3's from UC-1 x partial, reduced-hull x partial and striped x partial are being grown to verify F_2 ratios. Inheritance of a seed character designated "brown partial" is also being grown in F_3 rows. A demonstration block of selected plant introductions, most of the breeding lines and varieties is included.

Studies to determine the effects of charcoal rot on sunflowers are in progress. We are varying dates of planting, using resistant and susceptible hybrids, and combining a spray treatment to control a stem borer which may be associated with the stalk rot problem. An induced mutation study on both sunflower and safflower has been initiated and M_1 and M_2 generations are being grown at Davis this summer. Effects of three levels of irradiation can be observed in the field.

BLOCK E-1

P. F. Knowles and D. B. Cohen: Research on Safflower

In the field are a great many F_3 progenies from studies of the inheritance of plant height, flower color, seed color, and fatty acid composition of the seed oil. Genotypes include the following: variations in branching habit; brittle stem types; Mexican Dwarf and segregates of crosses of Mexican Dwarf to other genotypes; tetraploid types; and closed flower types.

BLOCK A-3

P. D. Turano and P. F. Knowles: Guayule (Parthenium argentatum)

Guayule is a native of the deserts of north-central Mexico and southwestern Texas. Interest in research on, and commercial development of, guayule as a source of rubber has been revived in recent years after a long lapse since shortly after World War II. The rubber is produced in cells of the bark of stems and leaves. Under study at UCD, with financial support from the California State Department of Food and Agriculture, are evaluations of varieties and responses of guayule to fertilizers, herbicides and irrigation schedules. The nursery was established from transplants in mid-May, 1980, so the plants are 14 months of age. Harvests are scheduled for the fall of 1982 or 1983. Dr. Ali Estilai of the Agronomy and Range Science Department is stationed at the USDA Cotton Research Station at Shafter, where he is 1) comparing diploids and natural and artificial polyploids, 2) developing interspecific hybrids, and 3) evaluating selections and cultivars.

Grown during the winter, and not
available for viewing in the summer

P. F. Knowles and D. B. Cohen: Species of *Brassica*

There has been very little interest in the United States in research on *Brassica* species as a source of oil. So it is not surprising to learn that UCD has the largest US program of field research on *Brassica* since its inception in 1977. Emphasis has been placed on the introduction and evaluation of germplasm from several countries. Most promising agronomically are south Asian forms of brown mustard (*B. juncea*) and Ethiopian mustard (*B. carinata*).

Graduate Students Working on Oilseed and Rubber Crops
in the Department of Agronomy and Range Science

J. M. Chandler: Interspecific hybridization of *Helianthus*.

D. B. Cohen: Evaluation of rapeseed and mustard species.

J. Fernandez-Martin: Inheritance in sunflower.

S. Futehally: Inheritance of very high levels of linoleic acid in safflower seed oil.

D. L. George: Studies on reduced seed set in sunflower.

R. O. Pierce: Inheritance of delayed leaf senescence in soybeans.

M. A. Rana: Analysis of variation in brown mustard (*Brassica juncea*).

P. D. Turano: Evaluations of guayule in northern California.

FIRST INTERNATIONAL SAFFLOWER CONFERENCE

Post-Conference Tour

July 16, 1981

The post-conference tour has two purposes: 1) to learn something about production practices for safflower in north-central California; and 2) to examine breeding porgrams of companies in the Davis-Dixon-Woodland area. The Conference is indebted to the following who have participated in the organization and execution of the tour.

T. C. (Tom) Heaton, Research Director, SeedTec International, P. O. Box 2210, Woodland, CA 95695

A. B. (Barney) Hill, Research Director, Cargill Research Farm, 8615 Robbin Road, Dixon, CA 95620

D. L. (Don) Smith, Research Director, Cal/West Seed Company, P. O. Box 1428, Woodland, CA 95695.

A. L. (Lee) Urie, USDA Research Agronomist, Department of Agronomy and Range Science, University of California, Davis, CA 95616.

The tour will travel through West Sacramento to the Clarksburg area south of Sacramento and west of the Sacramento River where satellite nurseries of Cal/West Seed Company and SeedTec International are located. The next stop will be the Cargill Research Farm between Davis and Dixon, where there will be a stop for lunch. After lunch there will be visits to research farms of Cal/West Seed Company and SeedTec International near Woodland. The tour will conclude with a short journey north of Woodland to Knight's Landing.

The California Crop and Livestock Reporting Service reports the following (May 22, 1981) for safflower:

1980 SAFFLOWER PRODUCTION TOTALED 126,000 TONS

Safflower produced by California farmers in 1980 totaled 126,000 tons, 5 percent above the 120,000 tons harvested in 1979. The 105,000 acres harvested was the smallest acreage since 1976. Yields in 1980 averaged 2,400 pounds per acre, 45 percent above 1979 yields and the highest yield on record since estimates began in 1950.

SAFFLOWER: Acreage, yield, production, price and value, California, 1966-1980

Year	Acreage		Yield per acre harvested	Production	Price per ton 1/	Value of Production
	Planted	Harvested				
	Acres	Acres	Pounds	Tons	Dollars	Dollars
1966	352,000	341,000	2,000	341,000	98	33,418,000
1967	311,000	300,000	1,850	278,000	87	24,186,000
1968	170,000	165,000	2,170	179,000	82	14,678,000
1969	228,000	216,000	2,009	217,000	85	18,445,000
1970	214,000	201,000	1,870	188,000	95	17,860,000
1971	248,000	242,000	1,959	237,000	104	24,648,000
1972	241,000	235,000	1,710	201,000	113	22,713,000
1973	151,000	145,000	1,697	123,000	166	20,418,000
1974	160,000	159,000	1,950	155,000	354	54,870,000
1975	147,000	146,000	2,219	162,000	243	39,366,000
1976	55,000	54,000	2,148	58,000	243	14,094,000
1977	135,000	130,000	2,138	139,000	246	34,194,000
1978	180,000	170,000	1,529	130,000	230	29,900,000
1979	150,000	145,000	1,655	120,000	255	30,600,000
1980	106,000	105,000	2,400	126,000	280	35,280,000

1/ Season average price received by farmers is based on the first delivery point.

FIRST INTERNATIONAL SAFFLOWER CONFERENCE

University of California, Davis
July 12-16, 1981

SAFFLOWER SEED KIT

From time to time the University of California and the USDA jointly or separately have released germplasm to plant breeders. We have decided to make the more recent releases available to researchers at the Conference. A few of the releases were developed elsewhere, and are included because of their proven value as cultivars or as parents in breeding programs. Because of limited quantities of seed only about 25 seeds of each entry are supplied.

The list of entries is given below.

Identity	Description or Source
Partial Hull	Germplasm release, 1977
RH-1	Reduced Hull-1 (Crop Sci. 10:732, 1970)
RH-2	" -2 " "
RH-3	" -3 " "
RH-4	" -4 " "
Mexican Dwarf	Very early and short
UC-1	High oleic type (Crop Sci. 6:641, 1966)
N-10	Superior Nebraska selection (Crop Sci. 4:446, 1964)
Gila	Superior cultivar released by the University of Arizona
Oleic Leed	USDA high oleic cultivar (Crop Sci. 19:747, 1979)
N-4051	Nebraska disease-resistant line
PCOy	USDA rust immune line (Crop Sci. 10:463, 1970)
N-1	USDA seedling rust resistant line
14-5	USDA root rot-resistant line (Crop Sci. 20:115-116, 1980)
th-10	USDA very thin hull line (Crop Sci. 10:463, 1970)
th-5	" " " " " " " "
Rust-Vert	Bulk of rust and verticillium wilt-resistant F_3 lines
USB	USDA Phytophthora root rot-resistant line identified at the Biggs Rice Station
UC-148	Genetic male-sterile line (Crop Sci. 20:554, 1980)
UC-149	" " " " " " " "
UC-150 to UC-164:	Lines with tolerance or resistance to Phytophthora root rot (Crop Sci. 21:226-229, 1981)
UC-150	From Afghanistan
UC-151	From Sudan
UC-152	From Turkey
UC-153	From Turkey

Identity	Description or Source
UC-154	From Egypt
UC-155	From Iran
UC-156	From Iraq
UC-157	From Australia
UC-158	From Afghanistan
UC-159	From Turkey
UC-160	From Turkey
UC-161	From Turkey
UC-162	From Turkey
UC-163	From India
UC-164	From Iran
UC-165 to UC-170	Lines with some resistance to thrips (Frankliniella occidentalis Perg)
UC-165	P.I. 269,870 from Pakistan
UC-166 to UC-170	Selections from the nursery in 1971 which had a mixed ancestry, some probably carrying genes from wild species

A. L. Urie, USDA
P.F. Knowles, UCD

SAFFLOWER WORKSHOP AND DISCUSSION SESSIONS

Following the First International Conference held at the University of California at Davis, July 12-16, a Safflower Workshop was held at the same location, July 17-18. In attendance were:

L. C. Alonso, Spain
N. M. Anishetty, FAO, Rome
A. Ashri, Israel
B. R. Barwale, India
D. F. Beech, Australia
A. Bozzini, FAO, Rome
W. A. Ceron, Chile
D. B. Cohen, USA
A. M. Davis, USA
S. C. Devi, India
J. Fernandez-M., Spain
T. C. Heaton, USA
A. Heritage, Australia
A. B. Hill, USA
A. H. Chaudhry, Pakistan
A. D. Karve, FAO, Burma
J. M. Klisiewicz, USA
P. F. Knowles, USA
H. H. Mundel, Canada
S. S. Rajan, FAO, Iraq
R. G. Rao, India
D. D. Rubis, USA
V. N. Shroff, India
R. B. Singh, FAO, Thailand
D. L. Smith, USA
S. X. Yu, P. R. China

The agenda was as follows:

Topic	Discussion leaders
Present germplasm collections and preservation	A. M. Davis
Germplasm collection needs by plant type and/or area	A. Ashri A. D. Karve
Development of descriptors	R. B. Singh, N. M. Anishetty
Sites for major germplasm repositories	N. M. Anishetty
Gene symbols and genetic stocks	D. D. Rubis
Research priorities	S. S. Rajan, A. M. El Zarka
International tests	A. Bozzini, O. M. Khidir

The discussions of the workshop and prior discussions during the conference were consolidated into separate sections which follow.

CONSTRAINTS IN SAFFLOWER PRODUCTION AND RESEARCH TO REMOVE THEM

In many areas safflower is a minor crop and may even be considered as an "endangered species" because of the constraints on production and because research has been so reduced in amount. In more or less descending order of priority the following were identified and discussed. Needs of both the farmer with a small holding and the farmer with a large fully mechanized operation were identified.

1. Susceptibility to diseases and insect pests.

Safflower, a crop developed from wild species of desert or arid environments, has proved to be very susceptible to: foliar diseases favored by moist atmospheres; root rotting organisms, in particular those most serious

under irrigation; and a large number of insects, particularly those of the Old World where safflower and its related species evolved. With greater resistance to those diseases and insects, safflower production would occupy a much larger area than at present.

Research to remove the above constraints will require the joint efforts of the breeder and plant pathologist/entomologist. A first step is the development of accurate tests that quickly measure the resistance of a large number of genotypes. An understanding of the inheritance of resistance in the host and inheritance of virulence and nonvirulence of different physiologic races of the pathogen/insect will be needed.

a) Susceptibility to foliar diseases. Foliar diseases have been particularly serious in areas with rainfall from the late bud stage to maturity. Most serious and widespread is leaf blight caused by Alternaria carthami (see Harrigan et al., pp. 64-69). Other foliar diseases are incited by Ramularia carthami, Cercospora carthami, Botrytis cinerea, Pseudomonas syringae, and Puccinia carthami.

b) Susceptibility to root rotting organisms. In particular, species of Phytophthora have been serious in many areas (see Harrigan et al., pp. 64-69, Klisiewicz, pp. 116-121, Rubis, pp. 205-209, and Thomas, pp. 261-263). Potentially more serious than at present is wilt caused by both Fusarium oxysporum f. sp. carthami and Verticillium dahliae (see Klisiewicz, pp. 116-121).

c) Susceptibility to insects. Most serious in limiting safflower distribution has been the safflower fly (Acanthiophilus helianthi) which is still confined to Asia, Europe and Africa. Aphid is a major constraint to production in India and Spain. Thrips (Frankliniella spp.) have been a worldwide problem.

2. Developmental Pattern

a) Early maturity. In general safflower has been limited to areas with a growing season of at least 120 days. Development of cultivars that mature three to four weeks earlier than those commercially grown in the U.S. would make safflower more competitive with wheat and would permit increased production of safflower in Canada (see Mundel, pp. 160-168). Because of its later maturity, it has not been possible to use safflower very widely in double cropping systems.

In spite of a search for earlier types not much progress has been made. Unfortunately the earliness of the cultivar 'Mexican Dwarf' has always been associated in inheritance with short stature and low yield. Evaluations of germplasm and products of mutation breeding should always involve a search for earlier types.

b) Duration of the rosette stage. During the rosette period weeds have frequently overgrown the safflower, resulting in poorly developed safflower plants giving low yields. However, in northwestern India and northern Pakistan wild safflower (C. oxyacantha), locally called "pohli", has profited from its long rosette period. As a serious weed in wheat, it does not develop stems until wheat harvest is underway or completed. Then, stems grow rapidly providing in many cases solid stands of wild safflower. Apparently the roots of wild safflower penetrate deeply in the soil beyond those of wheat, enabling this weed to serve in a sense as a "second crop."

Perhaps a genotype of domesticated safflower might serve in a similar way as a second crop. In any case more research is needed into the merit (or lack of merit) of the rosette stage of safflower.

c) Lack of dormancy at maturity. A serious constraint on production of safflower in the northern Great Plains of the U.S. has been germination of mature seed in heads of standing plants following rains lasting more than 24 hours. Obviously this has adversely affected quantity and quality of the harvest.

A thorough evaluation of germplasm resources should uncover genotypes with a short period of seed dormancy at maturity. If that fails, related wild species, in particular C. flavescens, should provide the necessary dormancy.

3. The morphological ideotype

Obviously the ideal ideotype will vary with different environments and agricultural practices. However, more research is needed to identify the best ideotype, at least in areas where safflower is an important crop. Some traits needing more evaluation are discussed below.

a) Angle of branching. Most commerecial cultivars have spreading branches with the angle to the main stem varying between 45 and 60°. However, the branch angle may vary from 20° (appressed) to 90° (spreading). There has been speculation that appressed types will permit denser stands with more heads per hectare. In addition, appressed types would be easier to harvest mechanically or by hand. Research should measure the merits of appressed branching, as other traits such as bract development, spines and head size are modified.

b) Spines. Where safflower is hand harvested, the spines present on most commercial cultivars have discouraged production. Spineless cultivars have generally been lower in yield/ha of seed and oil. There is evidence that spines provide protection from bird and rodent damage. A more thorough evaluation is needed of genotypes with different degrees of spininess. Because spines are absent on lower leaves and increase in amount up the stem, a genotype with some combination of reduced spines and perhaps with appressed branching would be acceptable for hand harvesting.

c) Seed hull. The well developed hull of early cultivars tested in the U.S. was a constraint to production because such types had oil contents lower than 30%. With reductions in hull thickness, oil contents have increased, Urie's partial hull types with genotype parpar (pp. 264-271) providing the possibility that future cultivars will have 50% oil. There is a choice of striped or smooth hulls, and hulls without the melanin pigment present in all commercially grown cultivars. Research should continue to evaluate changes in the amounts and character of hulls as they relate to yield and quality of both oil and protein, without losing sight of the effects of such changes on losses of seed to birds and seed damage from mechanical harvesters.

d) Other morphological features. Though not recognized as constraints to production, other morphological traits require study. Among these would be: general architecture of the plant between densely branched, short bushy types with small heads to tall types with few branches, and often bearing large heads; bract development, realizing that they are related

to light interception and seed nourishment; head size; and level of female-sterile florets around the periphery of the head.

4. Resistance to stress

a) Increased resistance to drought. Although safflower is rated as a drought-resistant crop, such resistance is due in large part to its deep root system. It is not more efficient than other crops in use of water. Research should identify genotypes more efficient in water use considering production under both dryland farming and in environments where limited amounts of irrigation water are available.

b) Greater resistance to salinity. Although safflower has shown tolerance to salinity (see Devi and Rao, pp. 40-48), greater tolerance is needed, particularly because safflower has often been grown in dryland and irrigated areas subject to increasing salinity. More evaluations of an array of germplasm under saline conditions are needed.

c) Greater resistance to cold. With greater resistance to cold, true winter types might be possible, in which case safflower would be competitive with winter wheat. Research should identify the limits of cold tolerance that are possible considering both genotypes of cultivated safflower and gene recombinations from crosses of cultivated safflower with wild species.

OTHER RESEARCH OF HIGH PRIORITY

1. Increase yields through genetic manipulation

For several years in the U.S. the yield plateau of safflower has not changed appreciably, though it is recognized that new cultivars have higher oil contents and have contributed to the maintenance of yield because of their resistance to disease. Where disease is not a factor, Gila is still one of the higher yielding cultivars. Research that might raise the yield plateau is discussed below.

a) Change in ideotype. There is a need to examine the potential of changes in the morphology of the plant (see above) and physiological characteristics as they affect yield, particularly under optimum environmental conditions.

b) Heterosis. Research should continue in the development of hybrid cultivars dependent on the use of cms male-sterile types (A. B. Hill of Cargill Incorporated is evaluating such cultivars which trace back to his interspecific crosses -- see pp. 82-83).

c) Interspecific hybridization and cytogenetics. Research should continue to explore the potentials of interspecific hybridization (see Heaton, pp. 70-73) with or without the induction of polyploidy. Cytological changes in chromosome structures (see Kumar et al., pp. 126-136) should be encouraged.

d) Genetic engineering. Genetic engineering techniques, particularly if combined with mutagenesis, should be thoroughly evaluated.

2. Production/physiological research

a) Cropping systems. Research is needed to identify niches in cropping systems where safflower can be used. An example in southern Pakistan (Chaudhry, pp. 23-27) is the possible use of safflower during the winter and spring on land that lies idle between summer crops of rice. Such research may require evaluation of genotypes of other crops in the cropping system. Can safflower be used as a companion or relay crop?

b) Water management. As genotypes are identified or developed with greater tolerance to root rotting organisms, there will be a need for research to determine the best use of water for different soil-climate environments.

c) Weed control. Research is needed into integrated weed control, involving the use of cropping systems, tillage and herbicides.

d) Photoperiod and thermal reactions. More information is needed on responses of different genotypes to different day lengths under different temperatures. Are day-length insensitive types needed?

e) Allelopathy. Does safflower roots or safflower residues adversely affect the growth of other crops plants, and vice versa?

3. Product-related research

a) Modification of fatty acid composition of the oil. Two oil types are needed, one essentially pure for linoleic acid, and the other pure for oleic acid. The next major step will be the development of types with fatty acids not now present in safflower oil. Of interest would be oils having high levels of short chain saturated fatty acids, since such oils could substitute for coconut oil.

b) Modification of amino acid composition of the meal. Continuation of the work by Sands et al. (see pp. 214-217) should yield safflower types with increased levels of lysine and other amino acids.

c) Elimination of toxic substances in the meal. Two toxic substances, matairesinol mono-glucoside and lignan glucoside have been found in safflower meal. While not adversely affecting meal use in a serious way, they should be removed. The variation of these substances in different genotypes is not known.

d) Product markers. As product variants are developed, there will be a need for markers to identify them. Such markers would be flower color, leaf morphology, and seed color. Seed color in segregating populations from crosses to wild species have ranged from almost black, through many shades of brown, buff, light purple, and different degrees of speckling and mottling.

4. Utilization research

a) Oils. As oils are developed with radically different fatty acid composition, they should be evaluated for both edible and industrial uses.

b) Toxic substances. Research into techniques of processing may provide a reduction in levels of different toxic ingredients in the meal.

c) Hulls. Research should provide better use of the hulls, either as fuel or as raw material for structural applications.

d) Fodder. Research should continued into the combined use of safflower for grazing and seed production (see Singh and Mehrotra, pp.225-227).

GERMPLASM

Though much had been done in germplasm collection and evaluation (see Singh et al., pp.238-249) the Conference was strongly of the opinion that germplasm needs had a very high priority. It expressed gratitude to the International Board for Plant Genetic Resources (IBPGR) for its interest in germplasm collection, preservation, description and evaluation. Discussions are summarized below.

1. Collections

a) Additional areas. The Conference was unanimous in recommending that collections of Carthamus tinctorius should continue, particularly in areas from which collections are scarce. In descending order of priority the following were listed: Peoples' Republic of China; East Africa, including Kenya, Ethiopia and the Sudan; south Asia, including northern and tribal areas of India and Pakistan; Bangladesh and Burma; Southeast Asia; and Japan and Korea.

b) Wild species. Wherever possible wild species should be collected, particularly in the Middle East and islands of the Mediterranian Sea. It was stressed that safflower breeders will draw increasingly on genes in the wild species, moreso as genetic engineering techniques are perfected for use on safflower.

2. Conservation

The Conference recommended to IBPGR that the following be designated as global repositories:

a) USDA Regional Plant Introduction Station, Washington State University, Pullman, WA 99164. It should receive all collections, and should serve as a central data bank.

b) National Bureau of Plant Genetic Resources, Indian Agricultural Research Institute, New Delhi 110 012, India.

3. Descriptors

The Conference discussed and amended the draft list of descriptors prepared by Dr. N. M. Anishetty, Assistant Executive Secretary, IBPGR, and Dr. R. B. Singh. It unanimously recommended that the final version be published by IBPGR.

4. Evaluation and utilization

a) Plant introduction and conservation stations. Such stations should have responsibility for initial evaluations and descriptions of collections.

a) Evaluations made elsewhere. Increasingly germplasm collections will be evaluated by researchers worldwide, often in a search for resistance to diseases, insects and other plant pests. Such evaluations should be channeled to national plant introduction stations and global repositories (see above).

c) Germplasm pools. The Conference expressed interest in germplasm pools such as that developed by Rubis (pp. 205-209). Hope was expressed that other germplasm pools of a similar nature might be developed and made available to other safflower researchers.

5. Genetic stocks.

Under the leadership of Dr. D. D. Rubis there was the following discussion of genetic stocks.

a) Gene symbols. With increasing numbers of genes being identified that affect morphology, physiology and disease and insect resistance, it was felt that they should be standardized and catalogued. Rules may be necessary in proposing symbols.

b) Preservation of genetic stocks. With genetic stocks often being identified in short-term studies (many by graduate students working for M.S. and Ph.D. degrees), and with other changes in research personnel, there was danger that useful genetic stocks would be lost. There was need for their preservation by a special agency, probably a plant introduction station.

c) Chromosome stocks. It was felt that these (see Kumar et al., pp. 126-136) needed the same attention as genetic stocks.

INTERNATIONAL NEEDS

1. International trials

It was recommended that standardized international safflower trials be developed. This was recognized as a long-standing need. It was felt that FAO should take the lead in developing such trials, which should be patterned after successful trials used for other crops. FAO should: develop and provide field books; appoint a coordinator; provide for statistical analyses; and distribute an annual report. Funds should be provided for: procurement and distribution of seed; correspondence; and a modest amount of travel for the coordinator.

2. Newsletter

A suggestion that a safflower newsletter be developed received strong support from several Conference members. Suggested items to be included in

the newsletter would be:

a) Status of research, including changes in personnel.

b) Results of international safflower tests.

c) Abstracts of published papers and theses.

d) Titles of relevant books.

e) New or improved safflower nursery and laboratory equipment.

f) Notices of new cultivar or germplasm releases, including the availability of genetic stocks.

g) Commercial developments involving safflower.

h) Status of diseases, insects and other pests affecting safflower.

It was suggested that it be published initially once a year, probably in November or December. No estimate was made on the cost of a newsletter. It was hoped that initially the cost would be borne by FAO. The name CARDI, for Carthamus Research and Development Information, was suggested. The names of A. D. Karve and P. F. Knowles were advanced as editors.

3. International safflower research institute

Hope was expressed that an international safflower research institute would one day be developed that would undertake an international improvement program on safflower. However, it was generally felt that safflower was not important enough as a crop to generate support for such an institute.

4. Future international safflower conferences

It was felt that another international safflower conference should be held in four to six years.

a) Location. It was felt that it should be in an area where safflower is grown commercially and where active research programs are under way. The location should provide conference facilities and ready access by air. It should be timed to permit examination of safflower during or just after flowering. The following countries and locations were suggested:

Cordoba, Spain, about mid-June.

Aurangabad, India, in January or early February.

Australia, in mid-October.

b) Funding. Some support funds should be sought from FAO, IBPGR and industry.

c) Organizing committee. The following names were suggested for consideration: A. D. Karve; T. C. Heaton; J. Fernandez-Martinez; D. F. Beech; and P. F. Knowles.

AWARDS

Two awards were made at the Conference. Their purpose was to recognize persons who had a long history of association with safflower in research and crop development. The awards consisted of plaques listing briefly the contributions of each person.

CARL E. CLAASSEN -- INNOVATIVE OILSEED SCIENTIST AND AGRIBUSINESS LEADER

Dr. Carl E. Claassen was born on a farm in Kansas in 1915. He received his B. S. degree in Agronomy from Kansas State University in 1939, an M.S. degree in Agronomy from Washington State University in 1941, and a Ph.D. degree in Genetics from the University of Nebraska in 1948.

He held the position of Associate Agronomist (Research) at the University of Nebraska from 1942 to 1950. In that capacity, he directed research on oilseed crops, including safflower, sunflowers, castor beans, sesame, and many other potential new crops for Nebraska.

In 1950, Dr. Claassen and his partner, Albert Hoffman, moved to California and formed the Western Oilseeds Company in Woodland, California. This partnership was dissolved in 1954, and was reconstituted as Pacific Oilseeds Incorporated (POI). Dr. Claassen has held the position of President since the company's inception. He long has been an active participant in the West Coast Oilseed Development Council, which has as its objective the improvement of the oilseed industry through research and cooperation.

Dr. Claassen was the leader in establishing safflower as a commercial crop in the United States. Through his exceptional ability as a plant breeder, he shared with his plant breeding staff the development of improved safflower varieties adapted and used for commercial production in various regions of the world. Internationally, he organized subsidiary oilseed companies in the Republic of South Africa (Saffola Seeds Pty. Ltd.); Spain (Semillas Pacifico, S.A.); and Mexico (Semillas Nacionales, S.A.). Since 1965, he has been involved in the development of an intensive oilseed sunflower breeding and testing program spanning four continents.

Internationally, Pacific Oilseeds Incorporated has become one of the largest producers of hybrid sunflower seed. It has fully staffed research programs at Woodland, California, Hereford, Texas, Kempton Park, Republic of South Africa, and Sevilla, Spain. Its main product lines are hybrid sunflower, hybrid sorghum, safflower, and hybrid corn. These products are distributed through both Pacific Oilseeds Incorporated of Woodland, California, and its subsidiary, WAC Seeds, Inc. of Hereford, Texas. In late 1980, POI was reorganized and named SeedTek International, Inc. The Company's headquarters remain in Woodland, California, with Dr. Claassen as Chairman of the Board of Directors.

PAULDEN F. KNOWLES -- SCIENTIST, TEACHER AND ADMINISTRATOR

Professor Paulden (Paul) F. Knowles was born in 1916 at Unity, Saskatchewan, Canada. He earned the degrees of B.S.A. and M.Sc. in Field Husbandry in 1938 and 1940, respectively, at the University of Saskatchewan at Saskatoon. In 1943, the University of California at Berkeley conferred upon him the Ph.D. degree in Genetics.

After service with the Canadian Army Operational Research Group (1943-46), he served as: Assistant and Associate Professor of Crop Science, University of Alberta, Edmonton (1946-47); and Assistant, Associate and Professor of Agronomy, University of California, Davis (1948-present). He served as Chairman, Department of Agronomy and Range Science, University of California, Davis (1970-75), and as USDA Advisor on Oil Crops to the Agricultural Research Council, Government of Pakistan, Islamabad, Pakistan (1975-77).

Soon after he was appointed at UCD, Dr. Knowles initiated tests with safflower to demonstrate its potential in California. He has long worked closely with private industry and the UC Agricultural Extension Service in promoting the commercial development of safflower. He is responsible for the introduction of the high oleic gene (ol) into safflower in the U.S. and released the first high oleic cultivar, UC-1. His interest in the Carthamus genus prompted him to embark overseas on germplasm exploration trips in 1958, 1964-65, and 1975, traversing 20 Mediterranean, Middle East, Asian and African countries. In all, he is responsible for about 90% of the USDA World Collection of safflower. From these collections, there has been identified germplasm sources resistant to Fusarium wilt, Verticillium wilt, rust, Phytophthora root rot, winter types, additional genes changing fatty acid composition of the oil, and higher levels of seed lysine. Knowledge of the genus Carthamus has increased substantially as a result of his studies of: the interrelationship of several of the species and their contributions to the evolutionary processes; the identification and analyses of centers of diversity; and the modes of inheritance of genes affecting characters ranging from fatty acid composition of seed oil to gross plant and cellular morphology.

Students, both undergraduate and graduate, have always been an integral part of his professional and everyday life, participating with him in his laboratory and field research activities, publishing endeavors, and social activities. Persons from virtually all corners of the world have sought him as an innovative teacher, counsellor, and esteemed mentor.

Dissemination of knowledge has been important to Dr. Knowles. Besides numerous technical and non-technical papers and bulletins, he has written chapters for several books, has co-written a book entitled "Introduction to Plant Breeding" and has been sought to give guest lectures, seminars, and symposium presentations.

He served effectively as Chairman of his department through a period of change in the University of California at much personal sacrifice to his own research activities. He was one of the prime movers of discussions that led to the establishment of the California Chapter of the American Society of Agronomy. He participated in the development of a research committee in the California Seed Association and served as its first Chairman in 1970-71. In 1972 he was named by his peers as a Fellow in the American Society of Agronomy. His willingness to serve others truly makes him worthy of special recognition.

ACKNOWLEDGEMENTS

The Conference is indebted to and thanks the following:
For provision of the reception on July 12, 1981:

Cal/West Seeds, Woodland, California
Cargill, Incorporated, West Sacramento, California
Pacific Vegetable Oil Corporation, San Francisco, California
Western Crop Development Council

For the folders containing the programs, abstracts, etc., and for the preparation of the logo of the conference:

SeedTec International, Woodland, California

For provision of travel and other expenses for some delegates to the Conference and for provision of financial support for secretarial work and publication of proceedings of the Conference and Workshop.

Food and Agriculture Organization, Rome

For participation in the field tour and provision of refreshments on July 16, 1981.

Cal/West Seeds
Cargill Incorporated
SeedTec International

For provision of a site for the meetings and all other arrangements necessary for a conference. The University of California at Davis through the following:

The Conference Center
The secretarial staff of the Agronomy and Range Science Department
The staff of Tercero
The Faculty Club
Reprographics
Visual Media of Cooperative Extension
The Garage

For leadership in providing the Ladies Program

Mrs. Terry Claassen
Mrs. Dodie Knowles

RESOLUTIONS

The following resolutions prepared by the Resolutions Committee (R. B. Singh, K. J. Jackson, and N. M. Anishetty) were unanimously approved by the delegates:

1. Its appreciation of the untiring work and unparalleled leadership of Professor P. F. Knowles for conceiving, planning, and finally organizing the First International Safflower Conference which emerged as a great successful event.

2. Appreciation for the members of the Organizing Committee for staging this Conference.

3. Thanks to Dean C. E. Hess for delivering the inaugral address.

4. Gratitude to Deputy Secretary US Department of Agriculture, Mr. R. E. Lyng, for his gracious presence and the address entitled "Late Developments in US Agricultural World Trade."

5. Thanks to the University of California, Davis, for the use of facilities on the campus. Further, Professor Knowles is requested to convey the appreciation of all the delegates to the persons at the campus who have rendered help in innumerable ways.

6. Thankful support of FAO and the International Board for Plant Genetic Resources (IBPGR) for interest and support, in particular for providing travel grants and funds for publishing proceedings of the Conference and their commitment to promote the cause of safflower at the international level.

7. Kind support of the Western Crop Development Council for their participation and cosponsorship.

8. The generous hospitality and contributions of the commercial safflower organizations in California which have aided the success of the Conference.

9. Appreciation for the friendly and efficient handling of the many demands of the delegates by the Conference Secretariat greatly supplemented the overall efforts in making the Conference a great success.

ROSTER OF ATTENDANCE

Abuelgasim, El Hag H., UC Davis, 1850 Hanover Drive #143, Davis, CA 95616.

Alonso, Luis Carlos, Koipesol S.A., Avda. Ramon y Cajal 1, Sevilla-5, Spain.

Amen, William J., Hybrid Sunflower Services, 913 Peachwood Court, Modesto, CA 95350.

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Ashri, Amram, Faculty of Agriculture, The Hebrew University, P.O. Box 12, Rehovot, Israel.

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