GENETIC VARIABILITY AND CORRELATION STUDIES IN SAFFLOWER

(Carthamus tinctorius L.)

BY

RAJU MALLIKARJUN MANE

B.Sc. (Agri.)

DISSERTATION

Submitted to the
Marathwada Agricultural University
in partial fulfilment of the requirement
for the degree of

MASTER OF SCIENCE
(Agriculture)

IN

AGRICULTURAL BOTANY
(GENETICS AND PLANT BREEDING)

DEPARTMENT OF BOTANY
MARATHWADA AGRICULTURAL UNIVERSITY
PARBHANI - 431 402 (M.S) INDIA

1997

Affectionately Dedicated

to

My Beloved parents

and

Rajani

CANDIDATES DECLARATION

I hereby declare that the dissertation or a part thereof has not been previously submitted by me for a degree of any University

Parbhani

Date : 10|6|97

(R.M. Mane)

Dr. A.A. Chavan
M.Sc. (Agri), Ph.D.
Assistant Professor,
Department of Genetics and
Plant breeding,
College of Agriculture,
M.A.U., Parbhani.
(431 402) (M.S.)

CERTIFICATE - I

This is to certify that Shri. **Raju Mallikarjun Mane** has satisfactorily prosecuted his course of research for a period not less than four semesters and that the dissertation entitled **"GENETIC VARIABILITY AND CORRELATION STUDIES IN SAFFLOWER (*Carthamus tinctorius* L.)** submitted by him is the result of original research work and is of sufficiently high standard to warrant it's presentation to the examination. I also certify that the dissertation or part thereof has not been previously submitted by him for the award of a degree of any University.

PLACE : PARBHANI

DATE : 10-6-1997

(Dr. A.A. Chavan)
Research Guide.

CERTIFICATE - II

This is to certify that the dissertation entitled **"GENETIC VARIABILITY AND CORRELATION STUDIES IN SAFFLOWER (*Carthamus tinctorius* L.)** submitted by **Shri. Raju Mallikarjun Mane** to the Marathwada Agricultural University, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (Agriclture)** in the subject of **Agricultural Botany (Genetics and Plant breeding)** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

External Examiner
(Dr. S.T. BORIKAR)

(Dr. A.A. Chavan)
Research Guide

Advisors :

Dr. V.D. Patil

Prof. V.V.Kale

Dr. D.N. Hedgire

Dr. R.K. Bhalerao

Associate Dean and Principal
College of Agriculture.
M.A.U., Parbhani. 431 402.

ACKNOWLEDGEMENT

"There always are in the world a few inspired men whose acquitance is beyound price".
- Ploto.

Formal and dead words cannot carry the fragnance of emotioins with them, still they are the only available means of expressing emotions in such formal acknowledgement.

Through the medium of such words, I must express my heartly feelings of gratitude towards my guide Dr. A.A. Chavan, Assistant Professor, Department of Genetics and plant Breeding, Marathwada Agricultural University, Parbhani for his countinuous inspiring and scholastic guidance, sustained interest and constant encouragement throughout the course of this investigation. This led to the final shaping of this dissertation. No words will sufficient to express my heartful gratitudes and feelings, I feel I should ever be greatful to him.

I woe my deepest sense of gratitdes to my advisory committee member Dr. V.D. Patil, Head, Dept. of Genetics and Plant Breeding, M.A.U. Parbhani for his valuable guidance and suggestions during the course of this investigation.

I am very much thankful to Dr. M.B. Misal, Associate professor, Dr. I.A. Madrap, Associate professor, Shri. U.V. Kale , Assistant professor, Shri. B.M. Joshi, Assistant professor and Shri. S.B. Chaulwar, Assistant professor, the staff members of the Dept. of Genetics and Plant Breeding for their valuable guidance and suggestions during the course of this investigation.

I wish to place my sincere thanks to Shri. U.V. Kale, Assistant Professor Dept of Genetics and plant Breeding, Dr. R.K. Bhalerao; Assistant Professor Dept of plant physiology and Dr. D.N. Hedgire, Assistant Professor Dept. of Agricultural Economics, M.A.U. Parbhani for kind consenting to be members of advisory committee and their valuable suggestions during the conduct of the research.

My cordial thanks are due to Mr. Muli, Mr. Maniyar and Mr. Harkal and all other staff members of Dept. of Genetics and plant Breeding, college of Agriculture, Parbhani.

I greatfully acknowledge the valuable suggestions exteneded by Shri. H.S. Acharya Asst. Prof. Dept. of Agricultural Economics and Statistics and the members of Triveni computers, Parbhani who helped me in analysing the experimental results.

My thanks are due to my friends Shri. J.P. Gole, P.A. Dalvi, M.S. Ukrande, S.B. Mane, D.S. Phad, S.S.

Hadole for their constant help during the study and preparation of this thesis. I also thanks my friends N.S. Kamble, P.S. Kamble, N.S. Deshpande, S.V. Tate, M.M. Sonkamble, P.B. Khandekar, S.D. Joshi for their timely help during present investigation and stay at Parbhani.

I would like to utilize this very apportunity to express my heartiest gratitude to my everloving parents, Shri. Mallikarjun Mane and Sow. Bhivarabai Mane who have shaped my life and lead me from better to best.

It is pleasure to mention my gratitude to my elder brother Shri. Dilipkumar Mane along with full co-operation of my sister-in-law Sow. Jyoti Mane.

I express my deep sense of appreciation to my beloved aunt Smt. Vithabai Mane and my younger brother Prithviraj Mane for their inspiring encouragement thoughout the study.

PARBHANI

DATE : 10/6/97

(Raju. M. Mane)

CONTENTS

LIST OF TABLES

INTRODUCTION

I. INTRODUCTION

India is one of the largest oilseed crops growing country in the world. Oilseed crops plays important role in the agricultural economy of India. India has 20.8 per cent of world area under oilseed crops which accounts 10 per cent worlds oilseed production. The productivity level per hectare of oil seeds are one third of worlds best level (The Hindu Survey of Indian Agriculture, 94-95).

In India, area under oilseed crops was 13 per cent of gross cropped area accounting 5 per cent of gross national income and 10 per cent of agricultural product with productivity potential of 685 kg/ha. (The Hindu survey of Indian agriculture, 1994-95).

In Maharashtra area under safflower was 5.84 lakh ha. with production of 3.98 lakh tonnes. The average productivity was 681 kg/ha during 1993-94. (Epitome of agriculture, 1993-94). The major safflower growing states are Maharashtra, Karnataka, Andhra pradesh accounting for nearly 98 per cent of total area in country.

Total production from oilseed crops increased from 21.45 Million Tonnes (1994-95) to 22.90 Million Tonnes (1995-96). Though oilseed production witnessed a sharp increase, India is the lrgest importer of oils. The production of edible oil was 65.50 lakh tonnes and demand was 72.54 lakh tonnes during the year 1994-95, with a shortfall of 7.04 lakh tonnes. To bridge the gap between demand and supply of present days, it is essential to increase production by bringing more area under oilseed crop as well as to raise their production potential. In India productivity of oilseeds is lower because oilseed crops are grown on marginal and submarginal land as rainfed crop with no adoption of improved package of agronomical practices.

Amongst oilseed crops, safflower (Carthamus tinctorius L.) has assumed much prominance. It contains about the 26-32 per cent oil and defeated cake contains 18.24 per cent proteins. Safflower oil contains about 75 per cent polyunsaturated fatty acid, Linoleic acid which helps in lowering cholesterol level in human blood.

Safflower is mainly grown as a rainfed crop in rabi season on residual soil moisture. Safflower is grown on marginal and submarginal soils, resulting in poor productivity. It is a rabi crop and requires bright sunny days with least humidity. Sown on light or sandy soils but heavy soils with better water holding capacity are preferably good. Although it is a drought resistant crop, average productivity per unit area is very low, (400-500 kg/ha). It is therefore necessary to boost up productivity by increasing more area under this crop and to bring more area under irrigation. This could be achieved by exploiting heterosis or by developing varieties through systematic breeding programmes suitable for rainfed as well as irrigated conditions.

Many scientists have reported high heterosis for yield and yield contributing characters but it was not exploited due to limitation in seed production. Jambhale and Nerkar (1985), has reported genetic male sterility governed by dominant gene which segregated into 1:1 ratio for male sterility. The use of this type of male sterility has got limitation for want of sterility linked marker gene but it can be used to develop number of lines with high heterosis for further selection for improvement of yield.

The safflower improvement programme may find an important place in near future by incorporation of male sterility in different genetic background and crosses with the diverse genotypes may throw variability in segregating generation which may in turn can be utilized in development of varieties. In applied plant breeding, success of the programme may be anticipated, if the genetic variability of different selection is known well in advance. The correlation and path analysis provide information on genetic association of yield and different yield contributing characters, which in turn are useful in developing breeding strategies. The comparative analysis of these parameters under dry land and irrigated conditions is useful in observing the performance of the selection across both conditions.

Using male sterility different crosses were made and stabilized fertile selections for different characters were considered for present study with the following objectives.

1. To estimate genetic variability for yield and yield related characters under rainfed and irrigated conditions.

2. To study association of yield and yield contributing characters under rainfed as well as irrigated conditions.

3. To study yield performance of different genotypes under rainfed and irrigated conditions.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Literature on population improvement, genetic variability, heritability, genetic advance, correlation and path analysis, performance of different safflower genotypes under different environment is refered in following sections.

2.1 Population improvement.

Cytoplasmic-genetic male sterility played an important role in exploitation of heterosis in many cultivated crops. This male sterility system has been also utilised for population improvement programme in sorghum (Dogget, 1968) . In safflower genetic male sterility system controlled by recessive gene was reported by Heaton and Knowles (1982), whereas the male sterility reported by Joshi et al. (1983) has found to be controlled by a dominant gene. The approaches for using both types of sterility systems in population breeding have been given by Nerkar and Jambale (1985).

Structural male sterility in safflower caused by a pleotrophic effect of the thin hull gene 'th' on endothecial cell wall thickening in the anther was reported by Ebert and Knowles (1966). This type of sterility was sensitive to environmental effects on the mechanism of anther dehiscence. Therefore the attempts of hybrid seed production were unsuccessful (Urie and Zimmer, 1970).

Sterile variants having thick twisted unbranched stem with solitary terminal capitulum were reported in safflower as spontaneous mutants (Deshpande, 1940). It was monogenic recessive in inheritance in the progeny of natural hybrid. Sterile mutants having monogenic recessive inheritance were reported by Claassean (1952). These male sterility systems offer promise in practical safflower breeding, for development of hybrid or in population improvement programme.

The reports in cross pollinated species shows that recurrent selection is effective for improving the means of quantitative traits and for providing continued genetic variability for long term selection (Hallauer, 1981). The same is true for self pollinated crops (Brim and Butron, 1979; Kenoworthy and Brim 1979). Because of practical limitations on population size, recurrent selection using a male sterile gene is the most effective method for promoting recombination and for gradually increasing the proportion of desirable segregates necessary to achive complex breeding goals.

2.2 Genetic variability :

The magnitude of genetic variability in the breeding material determines the speed and precision of the improvement programme. Therefore, it is essential to quantify the variability, magnitude of heritable and non-heritable components in the breeding material.

Comstock *et al*. (1958) stated that the relative amount of heritable portion of variation can be assessed through heritability percentage.

Argikar and Solanki. (1958) reported wide range of variability for characters viz, plant height at first branch, days to first flowering, days to maturity, number of branches per plant, 100-seed weight and seed yield per plant. Ashri *et al*. (1974) observed substantial genetic variability for mean seed yield per plant and three major yield components viz, number of heads per plant, number of seeds per head and 100-seed weight.

Khidir (1974) observed highest coefficient of variation for seed yield per plant and number of capitula per plant. More or less equal phenotypic and genotypic coefficient of variation values were observed for number of primary branches, plant height, number of bracts per capitulum and bract size whereas coefficient of variation values for capitulum size and 100-seed weight were low.

Mathur *et al*. (1976) reported considerable amount of variability for plant height, days to maturity and days to flowering, number of primary branches, number of capitulum per plant, 100-seed weight, number of seeds per capitulum and seed yield per plant.

Yazadi Samadi *et al*. (1976) notified considerable variability for plant height, number of seeds per capitulum, days to flowering, number of capitula per plant, 100-seed weight and seed yield per plant.

Thombre and Joshi (1977) reported very high values for genotypic coefficient of variability for plant height at first branch above ground level, number of branches per plant, days to first flower and seed yield per plant.

Deokar and Patil (1978) observed high values of genotypic and phenotypic variances for number of seeds per capitulum and lowest for number of primary branches per plant. High values of these parameters were also observed for plant height and 1000-seed weight. High value of genotypic coeffiecient of variability was observed for number of seeds per capitulum and number of secondary branches. The coefficient of phenotypic and genotypic variability in respect of plant height, days to maturity, number of seeds per capitulum, 1000-seed weight and yield per plant did not differ much in their magnitude indicating utility of phenotypic values of these characters in making selections.

Makne *et al*. (1979) reported low genetic coefficient of variation in safflower for most of the characters. The characters number of seeds per capitulum, capitulum size, 100-seed weight shown little differences in genotypic and phenotypic coefficient of variation indicating that these characters responded less to environmental factors.

Ranga rao et al (1980) observed moderate to high coefficient of variation for height of branching, seed number per capitulum, number of capitula per plant and seed yield per plant while low to negligible coefficient of variation for days to flowering, days to maturity, capitulum diameter and oil percentage.

Kambale et al (1984). Analysis of variance for yield and important yield contributing traits indicated the expression of large variability in irrigated as well as in rainfed condition. In general mean squares for different characters were comparatively higher in irrigated crop than rainfed one. In both moisture regimes the genotypic coefficient of variation was lower than phenotypic coefficient of variation values indicating role of environment in expression of the character studied. Under both the condition genotypic coefficient of variation and phenotypic coefficient of variation values for pods per plant and 100-seed weight were high and close to each other indicating that phenotypic selection will be effective in these characters. Similarly, consistent genotypic coefficient of variation values for pods per plant, 100-seed weight and days to maturity under both the conditions indicated the least environmental effect over genotypic coefficient of variation values in these characters. In present study, under both environments pods per plant, 100-seed weight and seed yield showed high heritability estimates coupled with high expected genetic advance.

Deokar et al (1985) reported wide range of variability for plant height, number of capitula per plant and seed yield per plant in the study of 38 indigenous and exotic varieties. The range of genotypic coefficient of variation was from 34 for hull content to 29.39 for seed yield per plant.

Challwar (1986) reported high coefficient of variability estimates for characters primary and secondary branches, capitula per plant and seeds per capitulum.

Pawar (1990) reported substantial amount of genetic variability in segregating population of safflower. The characters primary branches, secondary branches, capitula per plant and seed yield per plant showed a wide range of variation.

Lakha et al (1992) reported that the primary branches, days to maturity, secondary branches, capitulum per plant and number of seeds per capitulum are the major yield contributing characters.

Bargale and Billore (1992) Multivariate analysis was done to find out genetic divergence among 28 feba-beans population comprising 7 parents and 21 hybrids and grouped them under better management condition (E_1 Irrigated with fertilizer application) and poor management condition (E_2-rainfed without fertilizer). Geographical distribution had no relation with genetic divergence.

Singh _et al_ (1993) analysis of variance showed significant difference for number of days to maturity, capitula number and capitulum diameter. genotypic coefficient of variation and phenotypic coefficient of variation ranged from 0.36 and 2.51 for number of days to 50 per cent flowering to 51.61 and 88.55 for seed yield per plant.

Reddy and Gupta (1992) evaluated fourty six diverse genotypes of groundnut for variability, heritability, genetic advance and character association under rainfed, rainfed but supplemented with life saving irrigation and irrigation condition during kharif-1986. Analysis of variance showed significant differences among genotypes for all the characters studied. The phenotypic coefficient of variation is higher than genotypic coefficient variation for all characters. Higher genotypic coefficient of variation and phenotypic coefficient of variation under irrigated condition indicate maximum potential or variability of a genotype can be expressed only under optimum environmental condition. The heritability estimates were high for all characters in all 3 environment except Kernel yield in rainfed condition.

Ghorpade et al. (1993) assessed variability for 8 yield components in 98 germplasm accesions and five control varieties. Variability was high for seed yield, number of primary and secondary branches per plant, number of effective capitula. The seed yield was highest in GMV-398.

Parmeshwarappa et al. (1993) conducted study on 225 diverse cultivars of Black gram grown in summer and kharif season of 1987-88. The analysis of variance revealed significant differences for all the characters studied in different season.

2.3 Heritability and genetic advance :

Heritability determines the portion of genetic variance to the total phenotypic variance which in turn determines the success of selection in the breeding programme.

Johnson et al (1955) reported that the heritability estimates along with the genetic advance would be more useful in predicting yield under phenotypic selection than heritability estimates alone.

Hanson et al. (1956) studied the populations of Korean lespedeza, F_2 families, in the F_3 and F_4

generations grown at two locations revealed the following factors : Genotype year interaction relatively large; seed yield generally more heritable than total yield, heritability of vigour lower for spores on July, 1 than those on August 15, and exceptionally low genetic coefficient of variation and heratability of vigour spores for the population segregating for procumbency.

Mathur *et al*. (1976) reported that genetic advance was high for seed yield and number of seeds per capitulum; and medium to low for other characters. Similarly, Thombre and Joshi (1977) reported high values of heritability and expected genetic advance for the characters number of branches per plant, seeds per capitulum, capitulum number, 1000-seed weight and days to first flower, indicating the control of additive gene action for these characters.

Sengupta and Bhattacharya (1979) analysed the data on yield and 4 component traits from 137 forms and observed that plant height at maturity gave high estimates for broad sense heritability genetic advance. Selection for height should increase capitulum number per plant which was highly correlated with yield and moderately with height.

Makne *et al*. (1979) reported broad sense heritability which was highest for 1000-seed weight followed by height and number of seeds per capitulum.

Estimated genetic advance was highest for number of seed per capitulum.

Ramesh *et al*. (1980) observed significant differences amongst ten varieties for seven characters studied in rabi season 1977-78. The highest heritability estimates were observed for number of seeds per capitulum, days to flowering and 1000-seed weight.

Kamble *et al*. (1984) studied genetic variability in chickpea under irrigated and rainfed condition and reported that pods per plant, 100 seed weight and seed yield showed high heritability estimates coupled with expected genetic advance in both the condition.

Narkhede *et al*. (1985) reported relatively high genetic advance and heritability values for yield per plant, seed per capitulum, capitulum per plant and number of primary branches.

Makne *et al*. (1985) evaluated twenty eight cultivars at three sites and estimated heritability and genetic advance for seven traits. The characters viz. Plant height,number of seeds per capitulum and 1000 seed weight were little affected by environmental effects. Heritability estimates indicated that individual selection was a suitable approach to the improvement of all traits except seed yield. Genetic advance was perticularly high for number of seed per capitulum .

Gupta and Singh (1990) studied 45 F_1's from a ten parent diallel without reciprocals and data was analysed to obtan information on heritability, genetic advance and correlation on seed yield, its components and oil content. High heritability and high genetic advance were reported for primary branches per plant, seed yield, oil content, capitula per plant and 100-seed weight in both generation.

Patil et al. (1991) studied 11 yield components in 6 genotypically diverse parents of safflower and their 15 F_2 hybrids from crosses in half diallel. High values for heritability (broad sense) and genetic advance were associated with characters 1000-seed weight and number of capitula per plant which also had high coefficient of variation.

Lakha et al. (1992) derived information on genetic variability, heritability, genotypic and phenotypic correlation from data on seed yield and ten related charaters in twenty two safflower selections in F_4 generations grown during Rabi 1987-88. Number of seed per capitulum and seed yield were highly heritable characters.

Patil et al. (1992) obtained information on variation, heritability and genetic advance from data on 8 yield related traits in 34 cultivars of safflower. Heritability estimates were highest for days to maturity followed by days to 50 per cent flowering, plant height and seed yield.

2.4 Correlation and path analysis :

Correlation coefficient measures the intensity of association between two characters. Association analysis between quantitative characters is important because it indicates the change brought out in them when selection pressure applied on one character even though the other character is not subjected to any selection. The measured relationship is vital in planning the efficient breeding programme for improvement of one or more economic characters which are known to be dependent on two or more metric traits.

Johnson et al. (1955) evaluated two populations of F_3 line of soybean in the F_4 generation. He reported that genotypic correlation among characters for which selection is practised may have important implication in breeding procedures, they pointed out that effective selection for yield in soybean is more difficult and requires more replications over years, locations and individual tests than selection for other important characters.

Dewey and Lu . (1959) evaluated eighty one progenies of crested wheat grass during 1955 and 1957 and calculated genotypic and phenotypic correlation coefficients for all combinations between seed size, spikelets per spike, fertility, seed weight per spike, plant size and seed yield. The phenotypic and genotypic correlations agreed closely. High genotypic correlation were found for fertility and plant size. He used the method of path coefficient to partition the correlation coefficeints into their components which showed that fertility and plant size were the factors exerting the greatest influence both direct and indirect on seed yield.

Abel (1969) reported significant and positive correlation of yield per plant with capitulum number per plant, seed per capitulum with canopy length, canopy width, seed weight and branches per plant. The most important yield character was capitula per plant.

Ashri et al. (1974) studied genotypic correlation coefficient which revealed that height, number of days to first flower, number of capitula per plant, number of seeds per capitulum, capitulum size,1000-seed weight had shown positive and significant correlation with yield per plant. But yield was negatively correlated with number of primary branches per plant and bracts per capitulum.

Khidir (1974) reported positive correlation of number of seeds per capitula, capitula width and oil content with seed yield. The test weight was negatively correlated with number of seeds per capitulum and plant height.

Alba and Greco. (1977) studied character association in safflower. The number of seeds per capitulum were positively correlated with number of branches and number of capitula per plant.

Makne et al.(1979) studied genetic variability and character association in safflower which revealed that, seed yield showed a positive and significant correlation with plant height, number of capitula per plant, number of seeds per capitulum, capitulum size and 1000-seed weight.

Thombre and Joshi (1981) reported positive genotypic correlation coefficient between yield and its components viz. branch number per plant, number of days to first flower and seed number per capitulum had main direct positive effects on yield.

Paliwal and Solanki (1984) observed that number of capitula per plant and 100-seed weight were significantly and positively correlated with seed yield per plant, whereas 100-seed weight was negatively associated with number of capitula per plant.

Shiv Raju (1984) evaluated the breeding material over two seasons kharif 1983 and summer 1984.

The correlation studies indicated that seed yield was positively correlated with head diameter, plant height, leaf area and leaf number in both seasons. Higher positive direct as well as indirect effects on seed yield was exerted by head diameter and leaf area respectively.

Patil (1985) reported phenotypic, genotypic and environmental correlation coefficient between yield per plant and six of its components in fourty genetically diverse varieties. There was a positive correlation at both phenotypic and genotypic levels between 1000-seed weight and several other characters including yield per plant.

Malleshappa et al. (1989) obtained information on yield correlation from data on eight components in fifty F_4 progenies. Yield per capitulum and plant height makes the greatest direct contribution to yield.

Patil et al. (1990) derived information on yield correlation from data on eight yield related traits in thirty genotypes of safflower grown at Akola in Rabi, 1984. Path analysis indicated that capitulum weight per plant made the greatest direct contribution to yield per plant. Capitulum weight per plant and seed weight per plant had the greatest indirect contribution.

Reddy et al. (1992) studied correlation on yield and its eight yield components in 50 genotypes during 1990-91. The number of capitula per plant, seeds per capitulum and 100-seed weight were major contributors to yield.

Reddy *et al.* (1992) evaluated fourty six diverse genotypes of groundnut for variability, heritability, genetic advance and character association under entirely rainfed, rainfed but supplimented with life saving irrigation and irrigation condition during kharif 1986. The results of correlation studies under three environments revealed that threre were more or less similar trends of association among all yield contributing characters. Among three environments crop sown under irrigated condition showed better performance.

Lakha et al (1992) correlation studies supported the recommendation that the number of secondary branches, number of capitula per plant, number of seeds per capitulum and test weight were suitable selection criteria for improvement of seed yield in safflower.

Parmeshwarappa *et al.* (1993). studied the genetic divergence and character association of 225 diverse cultivars of black gram in summer and kharif season of 1987-88. The character association study revealed that plant height, pod length, seed per pod, branches per plant, biological yield per plant shows significant correlation with seed yield in both environments, while in kharif, number of pod cluster per plant and pods per plant shows positive association with seed yield. Days to 50 per cent flowering had a positive association with days to first poding and days to maturity in both environments. In kharif days to 50 per cent flowering was negatively correlated with pod length and harvest index suggesting that any increase in number of days required to flower would result in corresponding reduction in pod length and harvest index.

Dahiphale and Pawar (1993). conducted investigation during Rabi 1983-84 and with four levels of irrigation schedule for safflower in 1984-85. Persual of data indicated that all the characters viz. plant height, dry matter, grain per head, diameter of head, weight of head, per cent filled grains per plant and test weight showed significant positive correlation with seed yield per plant. In both the season strong and positive correlation between 1000-seed weight and seed yield was also noticed.

Madrap et al. (1993). reported the results on path analysis in sunflower among ten yield and its components under three different environments viz. E_1 Kharif, E_2 Rabi, E_3 summer, which showed that the yield per plant exhibited positive and significant association with developed seed percentage, test weight and harvest index in all the three environment. Days to 50 per cent flowering, days to maturity, plant height in E_2 and E_3 showed positive and significant association with yield. The path coefficient analysis at genotypic level revealed that the harvest index followed by developed seed percentage and highest direct influence on grain yield in all the three environment. Next important character influencing grain yield directly was plant height. All other characters had least direct effect on yield. Though the character days to 50 per cent flowering and days to maturity had least direct contribution to grain yield, these traits had affected grain yield indirectly through plant height.

Singh, et al. (1993). reported correlation which showed that seed yield per plant had non-significant positive correlation with number of days to maturity and plant height. The days required for 50 per cent flowering and number of primary branches had negative correlation with seed yield.

Ghongade et al. (1993) conducted correlation study which revealed that the days to 50 per cent flowering had negative correlation with seed yield at both phenotypic and genotypic level. Highest positive direct effect on seed yield was observed due to number of capitula per plant , followed by seeds per primary and secondary capitulum. Highest positive indirect effect on yield was observed due to secondary branches per plant via capitula number per plant.

Nie *et al*. (1993) conducted path analysis on nine cultivars of safflower and reported that seed weight per plant had greater effect on seed yield followed by non effective cone number per plant. Reduction of non-effective cone number per plant was suggested to be the most appropriate strategy in the breeding programme for increased seed yield (CAAS).

Acharya *et al*. (1994) reported that in general correlation at the genotypic level were higher than those at phenotypic level. Seed yield per plant was positively correlated with seed weight, capitula per plant, and seed filling period. Path analysis revealed that seed weight had maximum direct positive effect on seed yield. The difference in yield potential of high and low yielding genotype was due to differences in seed weight and capitula per plant.

MATERIALS AND METHODS

III. MATERIALS AND METHODS

3.1 Experimental material

The experimental material comprised of 30 diverse genotypes (selections) developed at the department of genetics and plant breeding M.A.U. Parbhani. The experimental material includes two checks, i.e. Bhima and Sharda. The selections were derived from the crosses of male sterile lines with the varieties. The fertile selections were stabilized for different characters. The selection studied are as follows.

Sr.No.	Selection Number	Sr.No.	Selection Number
1	S-2	17	S-12-3
2	S-2-1	18	S-12-4
3	S-2-2	19	S-12-5
4	S-2-3	20	S-12-6
5	S-4	21	S-13
6	S-5-1	22	S-13-1
7	S-5-2	23	S-13-2
8	S-5-3	24	S-13-3
9	S-8	25	S-13-4
10	S-8-1	26	S-13-5
11	S-8-2	27	S-13-6
12	S-8-4	28	S-14
13	S-9	29	S-14-1
14	S-12	30	S-14-2
15	S-12-1	31	Bhima (c)
16	S-12-2	32	Sharda (c)

3.2 Experimental methods

3.2.1 Layout and sowing

The experimental material consisted of thirty diverse selections and two checks viz. Bhima and Sharda of safflower and these were grown in Rabi season 1996-97 under rainfed and irrigated conditions at the experimental farm of Department of Genetics and plant Breeding, M.A.U. Parbhani.

The experimental material was sown on 9th October 1996 in a randomised block design with two replications in both the environments. Each entry was planted in a 3 rows plot of 3 meter length with 45 X 15 cm spacing. Fertilizers were applied @ 50 kg N + 25 kg P_2O_5 per hectare at the time of sowing. Two hand weedings were carried out, first at 20 days after sowing and second at 45 days after sowing. Two irrigations were given as first at 45 and second at 75 days after sowing to the crop grown in irrigated condition. Two sprayings of Endosulphon 35 Ec and one dusting of BHC was done for control of aphids.

3.2.2 Observations :

Randomly five plants were selected from each treatment for recording observations. Observations were recorded separately on each selected plants for both rainfed and irrigated conditions. Average value for each character was compared from these plants separately for each genotype. Following observations were recorded.

3.2.2.1 Days to 50 % flowering :

Days required from sowing to flowering, an approximately 50 per cent plants in each treatment were recorded.

3.2.2.2 Days to complete maturity :

Days required for complete maturity of plants were recorded.

3.2.2.3. Plant height (cm) :

Average plant height of mature plant was recorded in cm from the base of the plant to the main capitulum of the main shoot.

3.2.2.4. Number of primary branches :

At maturity the main effective branches on main shoot were counted as primary branches from each of the selected plant.

3.2.2.5 Number of secondary branches :

At maturity total number of effective branches developed from primary branches were recorded as secondary branches.

3.2.2.6 Number of capsules per plant :

Total number of capsules bearing seeds (effective capitula) were counted per plant at maturity.

3.2.2.7 Number of seeds per capsule :

On each plant seeds from five capsules were counted and average number of seeds per capitulum were taken.

3.2.2.8 100-seed weight (g) :

One hundred well filled seeds were counted randomly, from bulk of each treatment and their weight was recorded.

3.2.2.9 Yield per plant (g) :

The capsules of five observational plants were threashed separately and average weight of seed per plant was measured in gram.

3.3 Statistical methods :

3.3.1 Analysis of variance.

For testing significance of results the data were subjected to analysis of variance method. Mean values of the plants selected in each replication were used for statistical analysis. The analysis of variance is set out under ANOVA table.

Anova table :

Sr No.	Source of variation	d.f	M.S.S.	variance ratio 'f' observed	'f'
1.	Replication	(r-1)	$\sigma^2 e+R\sigma^2 g$		
2.	Treatment	(t-1)	$\sigma^2 e+G\sigma^2 r$		
3.	Error	(r-1)(t-1)	$\sigma^2 e$		
	Total	(rt-1)			

Standard error (SE) = $\sqrt{EMSS/r}$.

Where,

EMSS = error mean sum of squares

r = number of replications.

Crtitical differnece (CD) = S.E. X $\sqrt{2}$ X 't'

Where,

't' = table value of 't' at error d.f.

3.3.2 Genetic variability :

various parameters of genetic variability were calculated by using appropriate formulae.

1. Genoytpic variance (σ^2 g)

$$\sigma^2 g = \frac{Trmss - Emss}{r}$$

2. Phenotypic variance (σ^2 P)

$$\sigma^2 P = \sigma^2 g + \text{error variance } (\sigma^2 e)$$

Where,

σ^2 e = mss due to error.

3. Phenotypic coefficient of variation.

$$PCV = \frac{\sqrt{\sigma^2 P}}{\bar{X}} \times 100$$

4. Genotypic coefficient of variation

$$GCV = \frac{\sqrt{\sigma^2 G}}{\bar{X}} \times 100$$

Where,

σ^2 g = genotypic variance

σ^2 P = phenotypic variance

$\bar{X}$ = general or grand mean of characters.

Phenotypic and genotypic coefficient of variability (PCV and GCV) were calculated according to the formulae given above.

5. Heritability (Broad sense) was calcualted according to the method suggested by Hanson et al. (1956) for each character as :

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where $\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

$$\text{Genetic advance} = h^2 \, K \, \sigma P$$

Where,

h^2 = heritability

k = selection differential at 5 % selection intensity, it is 2.06

σp = Phenotypic standard deviation

Genetic advance in percentage (EGA) expressed in terms of mean is calculated as :

$$EGA = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = Genetic advance
$\bar{X}$ = General or grand mean of character.

3.3.3 Correlation :

Covariances were calculated for all characters to findout correlations among the characters. The inter-relationship of different yield contributing characters at genotypic and phenotypic levels was worked out according to Johnson <u>et al</u>. (1955).

Genotypic correlation coefficient (rg_{xy})

$$rg_{xy} = \frac{Cov\ (g_x \times g_y)}{\sqrt{(\sigma^2 g_x \times \sigma^2 g_y)}}$$

Where,

Cov (g_x g_y) = Genotypic covariance between character x and y.t

$\delta^2 g_x$ & $\delta^2 g_y$ = Genotypic variance of character x and y respectively.

Similarly,

phenotypic correlation coefficient (rP_{xy})

$$rP_{xy} = \frac{Cov\ (P_x.P_y)}{\sqrt{(\delta^2 P_x . \delta^2 P_y)}}$$

Where,

Cov ($P_x.P_y$) = phenotypic coveriance between characters x and y

$\delta^2 P_x$ and $\delta^2 P_y$ = phenotypic variance of character x and y

3.3.4 Path analysis :

Correlation does not provide an exact picture of the relative importance of direct and indirect influence of each of the component characters. The path coefficient analysis, a cause of effect relationship provide knowledge of relative importance of each of the component character.

The path coefficient analysis was carried out according to Dewey and Lu (1959). The direct path coefficients were calculated by solving the following set of 'p' simultenious equation by the abbreviated doolittle technique.

$$P_{01} + P_{02} + r_{12} + \cdots\cdots\cdots\cdots P_{op}\ r_{1p} = r_{o1}$$

$$P_{01}r_{12} + P_{02} + \cdots\cdots\cdots\cdots P_{op}\ r_{2p} = r_{o2}$$

$$P_{01}r_{10} + P_{02}\ r_{2p} + \cdots\cdots\cdots\cdots P_{op} = r_{op}$$

$P_{o1}, P_{o2}, \ldots\ldots\ldots P_{op}$ are the path effects of 1,2,...p variables on 'o' variable.

$r_{12}, r_{13} \ldots\ldots r_{1p} \ldots\ldots r_{Op}$ (p-1) are the possible correlation coefficients between various independent variables and $r_{o1}, r_{o2} \ldots r_{op}$ are the correlations of independent variables with dependent variable.

The direct effect of i^{th} variable via j^{th} variable was wored out as $(P_{oj} \times P_{ij})$.

From the simultenious equation, it is clear that the correlation coefficient is the sum of direct and indirect path coefficients.

Residual effect was calculated as under :

$$P^2 ox = 1 - (P^2_{o1} + 2P_{o1} P_{o2} r_{12} + 2P_{o1} P_{o3} r_{13} + P^2_{o2} + 2p_{o2} P_{o3} r_{23} + \ldots\ldots\ldots\ldots\ldots P^2 op)$$

$$\text{Residual factor} = \sqrt{P^2 ox}$$

RESULTS

IV. RESULTS

The analysis of variance showed significant differences among the genotypes for all the characters studied in both the environments (Table 1).

Mean data on genotypes was analysed as per standard procedure and are presented under the following major headings.

i) Mean performance,

ii) Genetic variability,

iii) Correlation and

iv) Path coefficient analysis for yield and yield contributing characters.

4.1 Mean performance :

The mean performance of the genotypes studied in two environments are given in the table 2.

4.1.1 Yield and yield components :

4.1.1.1 Days to 50 per cent flowering.

Under rainfed environment early flowering was observed in S-13-3 (75.20 days), S-13-6 (79.40 days), S-8-1 (80.10 days) and S-14-2 (80.20 days). Whereas under irrigated condition, the genotype S-14-2 (83.50 days) was earlier for 50 per cent flowering than other selections viz S-8-1 (85.00 days), S-14 (85.60 days) and S-9 (86.20 days) also showed early flowering.

Table 1 : Analysis of variance for different characters in safflower under irrigated and rainfed condition.

Source of variation	d.f.	Envoro-nment	Mean sum of squares								
			Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of capsules per plant	Number of seeds per capusules	Test weight (g)	Seed yield per plant (g)
Replication	1	I	9.84	1.00	5.64	4.30	1.80	3.46	3.02	0.64	1.05
		R	10.72	3.51	8.55	3.61	1.75	6.63	1.26	0.18	2.50
Treatments	31	I	20.84**	17.03**	61.41**	6.70**	22.94**	38.35**	47.58**	0.31*	17.03**
		R	18.21**	15.29**	62.37**	5.17**	20.04**	27.25**	43.61**	0.23*	15.94**
Error	31	I	1.91	2.00	1.53	1.00	1.14	1.74	1.88	0.16	2.30
		R	2.30	1.96	2.28	0.86	0.90	2.01	1.91	0.11	1.08

* and ** Significant at 5 and 1 per cent level respectively
I = Irrigated condition
R = Rainfed condition

Table 2 : Mean performance for different yield contributing characters of safflower under irrigated and rainfed condition.

Sr NO.	Sel. no.	Envt.	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	number of capsules per plant	Number of seeds per capsule	Test weight (g)	seed yield per plant (g)
1	2		3	4	5	6	7	8	9	10	11
1.	S-2	I	90.80	142.50	89.90	14.10	26.90	36.20	32.60	5.80	34.70
		R	84.80	138.00	84.90	13.50	20.90	28.10	28.60	2.51	25.70
2.	S-2-1	I	92.50	146.00	83.70	13.40	22.60	32.50	27.10	5.81	31.30
		R	86.80	137.50	80.00	07.50	10.90	25.40	20.40	5.12	20.50
3.	S-2-2	I	89.60	144.60	91.50	13.50	18.50	29.20	34.00	5.72	33.60
		R	86.20	137.30	80.30	09.30	13.80	21.60	25.20	5.60	23.40
4.	S-2-3	I	89.00	138.40	87.70	13.80	21.90	30.50	20.10	5.50	27.90
		R	82.50	133.00	77.80	10.80	15.50	25.20	25.00	5.24	20.70
5.	S-4	I	90.50	143.60	89.60	13.80	22.10	32.70	28.00	5.60	29.30
		R	84.80	136.50	85.50	09.10	14.20	20.10	24.30	5.10	18.70
6.	S-5-1	I	93.70	144.30	85.30	13.40	19.80	29.60	29.20	6.16	32.40
		R	82.20	136.60	81.10	09.50	16.20	24.20	19.00	5.50	22.50
7.	S-5-2	I	92.20	143.30	88.00	13.60	23.80	33.60	22.60	5.52	26.20
		R	86.80	129.60	72.70	08.90	10.900	18.10	18.90	4.76	16.80
8.	S-5-3	I	90.80	139.00	94.60	13.10	20.20	28.10	28.30	5.40	27.70
		R	82.60	135.00	85.60	07.30	11.40	17.60	26.70	5.10	19.10
9.	S-8	I	88.50	140.00	87.20	14.80	21.50	33.60	28.50	6.04	29.20
		R	85.00	136.00	75.30	12.30	19.90	27.50	18.60	5.40	18.90
10.	S-8-1	I	85.00	144.10	77.20	14.10	21.20	27.10	25.10	5.32	25.70
		R	80.10	137.10	72.20	10.10	15.20	19.10	21.10	5.02	16.70
11.	S-8-2	I	89.30	149.80	83.20	08.80	14.30	19.60	29.60	5.00	25.90
		R	86.00	137.00	77.40	07.70	12.90	17.70	25.90	4.90	17.00
12.	S-8-4	I	88.20	143.60	90.10	13.60	22.20	32.20	24.00	5.80	31.50
		R	84.00	135.60	84.80	08.50	17.60	24.50	24.60	5.30	22.90
13.	S-9	I	88.20	140.50	89.40	09.70	15.90	25.80	36.60	5.10	26.00
		R	84.60	136.80	83.00	09.50	17.80	23.70	30.30	4.62	17.20

Table 2 contd...

1	2		3	4	5	6	7	8	9	10	11
14.	S-12	I	87.50	144.30	77.80	11.80	17.80	24.60	32.70	5.28	26.90
		R	83.50	137.30	73.30	07.80	11.80	16.60	28.70	4.98	17.80
15.	S-12-1	I	89.60	145.00	94.60	11.90	18.40	28.60	34.30	5.22	27.00
		R	85.30	136.30	89.50	06.70	11.30	15.60	27.60	4.90	16.90
16.	S-12-2	I	91.20	138.10	73.70	09.80	13.40	24.10	19.80	5.80	24.80
		R	88.60	136.30	70.70	11.80	10.80	20.20	15.40	5.20	15.60
17.	S-12-3	I	93.80	140.60	77.70	12.90	16.90	26.10	22.90	5.90	25.80
		R	90.00	136.60	75.50	09.60	14.30	23.10	14.40	5.05	14.60
18.	S-12-4	I	89.80	147.00	84.50	12.30	17.80	26.60	30.60	5.56	29.10
		R	84.90	136.60	82.50	09.70	16.60	24.70	24.00	5.30	20.40
19.	S-12-5	I	92.20	144.00	88.70	17.00	26.30	36.40	23.10	5.86	28.90
		R	86.50	139.00	83.30	09.40	16.60	24.50	23.10	5.50	22.30
20.	S-12-6	I	89.50	144.00	88.50	12.40	20.70	30.40	34.50	5.10	27.70
		R	86.50	137.00	76.50	08.90	13.20	19.90	32.60	4.70	20.20
21.	S-13	I	93.00	140.10	77.50	11.70	17.30	26.10	16.40	6.20	23.80
		R	85.60	132.60	70.10	07.70	10.40	17.20	15.00	5.40	15.80
22.	S-13-1	I	97.20	144.30	89.60	14.90	20.80	32.10	19.40	6.32	24.60
		R	82.80	138.00	82.50	07.90	13.40	20.60	18.60	6.12	18.00
23.	S13-2	I	88.80	142.60	80.40	12.90	23.70	29.60	28.90	5.18	26.90
		R	82.80	135.60	75.40	08.80	17.70	21.60	24.90	4.83	17.90
24.	S-13-3	I	93.50	144.60	81.50	13.00	19.20	27.90	24.40	5.70	24.20
		R	75.20	133.40	80.10	09.20	10.90	16.80	25.60	5.30	18.90
25.	S-13-4	I	86.80	144.60	86.80	13.40	23.30	28.10	29.60	6.41	29.50
		R	83.20	137.00	77.30	11.00	10.90	24.40	19.10	5.50	20.40

Table 2 contd...

1	2		3	4	5	6	7	8	9	10	11
26.	S-13-5	I	86.60	139.10	85.80	11.40	23.40	30.30	31.80	5.60	34.30
		R	80.30	134.60	82.30	09.40	20.40	26.30	27.60	5.50	25.30
27.	S-13-6	I	89.50	144.60	90.30	12.60	23.60	32.50	28.70	5.60	31.90
		R	79.40	137.60	86.50	08.40	12.50	21.20	30.00	5.40	24.60
28.	S-14	I	85.60	139.50	89.00	09.40	13.60	20.60	28.60	5.25	28.10
		R	85.30	138.00	86.70	08.20	16.10	23.50	22.10	5.40	21.30
29.	S-14-1	I	88.30	141.50	88.70	10.20	19.10	26.50	24.10	5.50	30.30
		R	83.80	134.00	77.60	08.30	11.80	18.60	26.60	5.20	20.10
30.	S-14-2	I	83.50	140.40	85.10	13.30	16.90	22.75	30.60	5.42	27.80
		R	80.20	130.00	84.50	08.40	14.70	18.40	25.15	4.80	18.80
31.	BHIMA(c)	I	89.80	142.50	88.00	13.40	20.40	30.30	29.60	5.20	29.90
		R	87.40	140.00	82.30	10.30	16.40	23.50	26.20	5.16	22.40
32.	SHARDA(c)	I	85.86	138.00	89.00	11.80	18.20	28.20	26.40	5.60	26.90
		R	83.60	136.00	82.40	09.60	14.80	21.30	24.30	5.40	19.90
S.E.		I	0.97	1.00	0.87	0.70	0.75	0.93	0.97	0.28	1.07
		R	1.07	0.91	1.06	0.65	0.67	1.00	0.97	0.23	0.73
C.D.		I	2.82	2.88	2.52	2.03	2.18	2.69	2.79	0.83	3.09
		R	3.09	2.85	3.08	1.89	1.94	2.89	2.82	0.69	2.12

4.1.1.2 Days to maturity :

As regards to days required for complete maturity the selection, S-8-2 (149.80 days) taken maximum days to maturity. Late maturity was also recorded by S-12-4 (147 days) and S-2-1 (146 days) under irrigated condition. The genotype S-12-5 (139 days) recorded maximum days to maturity followed by S-13-1 and S-14 (138 days) under rainfed condition. Early maturity was recorded by S-12-2 (138.10 days), S-2-3 (138.40 days) and S-13-5 (139.10 days) under irrigated condition. Similarly under rainfed condition, early maturity was recorded by the genotypes, S-14-2 (130.00 days), S-13 (132.60 days), S-2-3 (133.00 days) and S-13-3 (133.40 days).

4.1.1.3 Plant height (cm)

Maximum plant height was recorded by S-12-1 (94.60 cm) and S-5-3 (94.60 cm), followed by S-2-2 (91.50 cm) and S-13-6 (90.30 cm) under irrigated condition. In rainfed condition the genotypes, S-12-1 (89.50 cm), S-14-1 (86.70 cm) and S-13-6 (86.50 cm) recorded the highest plant height. Lower plant height was recorded by S-12-2 (73.70 cm) and S-8-1 (77.20 cm) under irrigated condition. Whereas selections, S-13 (70.10 cm), S-12-2 (70.70 cm) and S-8-1 (72.20 cm) recorded lower plant height under rainfed condition.

4.1.1.4 Number of primary branches :

Significantly more number of primary branches were observed by the selections, S-12-5 (17) and S-13-1 (14.90) than the check Bhima (13.40) and Sharda (11.80) under irrigated condition. While under rainfed condition, maximum number of primary branches were recorded by the selections, S-2 (13.50) and S-8 (12.30).

4.1.1.5 Number of secondary branches :

Among the selections the S-2 (26.90) recorded highest number of secondary branches under irrigated condition as well as rainfed condition. Higher performance was also recorded by the selections, S-12-5 (26.30), S-5-2 (23.80) under irrigated condition and by selections, viz S-13-5 (20.40) and S-8 (19.90) under rainfed condition.

4.1.1.6 Number of capsules per plant :

Significantly the highest number of capsules per plant were recorded by selections, S-12-5 (36.40), S-2 (36.20), S-8 and S-5-2 (33.60) under irrigated condition and by selections, S-2 (28.10), S-8 (27.50) and S-13-5 (26.30) under rainfed condition.

4.1.1.7 Number of seeds per capitulum :

The highest number of seeds per capitulum were recorded by the selection , S-9 (36.60) was followed by S-12-6 (34.50), S-12-1 (34.30) and S-2-2 (34.00) under irrigated condition, whereas selections S-12-6 (32.60), S-9 (30.30), S-13-6 (30.00) and S-2 (28.60) recorded more seeds per capitulum under rainfed condition.

4.1.1.8 Test weight (g) :

Among all the genotypes, the selections, S-13-1 (6.12 g) recorded highest test weight followed by S-2-3 (5.60 g) and S-13-4 (5.50 g) under rainfed condition. Under irrigated condition, selections, S-13-4 (6.41 g), S-13-1 (6.32 g) and S-13 (6.20g) recorded higher test weight than rest of the selections.

4.1.1.9 Seed yield per plant (g) :

The highest seed yield per plant was recorded by the selection S-2 (34.70 g) under irrigated and by S-2 (25.70 g) under rainfed condition. The selections,S-13-5 (34.30 g), S-2-2 (33.60 g), S-5-1 (32.40 g) and S-2-1 (31.30 g) recorded more seed yield per plant over both checks under irrigated condition; whereas under rainfed condition, selections, S-13-5 (25.30 g), S-13-6 (24.60 g) and S-2-2 (23.40 g) had recorded higher seed yield over both checks.

4.2 Genetic parameters :

The characters under investigation were analysed for genotypic variance ($б^2$ g), phenotypic variance ($б^2$ p), genotypic coefficient of variability (Gcv), phenotypic coefficient of variability (Pcv), heritability (B.S.) and the expected genetic advance (EGA) for irrigated as well as rainfed condition. The results are presented in table 3.

4.2.1 Days to 50 per cent flowering :

The range of days to 50 per cent flowering was from 83.50 days (S-14-2) to 97.20 days (S-13-1) under irrigated condition. The range for this trait was 75.20 days (S-13-3) to 90.00 days (S-12-3) under rainfed condition. Genotypic variance was lower than the phenotypic variance under both the conditions. The genotypic coefficient of variation (3.44 per cent and 3.34 per cent) and phenotypic coefficient of variation (3.77 per cent and 3.79 per cent) were low for irrigated and rainfed conditions respectively. The heritability estimates were high for irrigated condition (83.20 per cent) as well as rainfed condition (77.56 per cent) coupled with low expected genetic advance (6.47 per cent) under irrigated and (6.06 per cent) under rainfed condition.

Table 3 : Parameters of genetic variability for yield and yield contributing characters in safflower under irrigated and rainfed condition.

Sr No.	Characters	Environment	Range	General mean	Genotypic variacne (6^2 g)	Phenpotypic variance (6^2 p)	GCV	PCV	Heritability (%)	EGA (%)
1	Days to 50 % Flowering	I	83.50 - 97.20	89.27	9.46	11.37	3.44	3.77	83.20	6.47
		R	75.20 - 90.00	84.36	7.95	10.25	3.34	3.79	77.56	6.06
2	Days to maturity	I	138.10 -149.80	142.61	7.51	9.51	1.92	2.16	78.96	3.45
		R	130.00 -139.00	136.13	6.66	8.62	1.89	2.15	77.72	3.44
3	Plant height (cm)	I	73.70 - 94.60	84.90	29.94	31.47	6.44	6.60	95.13	12.92
		R	70.10 - 89.50	80.03	30.04	32.32	6.84	7.10	92.94	13.98
4	Number of primary branches	I	8.80 - 17.00	12.48	2.85	3.85	13.52	15.72	74.02	23.94
		R	6.70 - 13.50	9.17	2.15	3.01	15.99	18.91	71.42	27.75
5	Number of secondary branches	I	13.40 - 26.90	19.84	10.90	12.04	16.64	17.48	90.53	32.52
		R	10.40 - 20.90	14.50	9.57	10.47	21.33	22.31	91.40	41.94
6	Number of capusules per plant	I	19.60 - 36.40	28.39	18.30	20.04	15.06	15.76	91.31	29.61
		R	15.60 - 28.10	21.65	12.62	14.63	16.40	17.66	86.62	31.48
7	Number of seeds per capsules	I	16.40 - 36.60	27.36	22.85	24.73	17.47	18.17	92.39	34.57
		R	14.40 - 32.60	24.01	20.85	22.76	19.01	19.86	91.60	37.48
8	Test weight (g)	I	5.00 - 6.41	5.55	0.07	0.23	4.76	8.64	30.43	5.30
		R	4.62 - 6.12	5.27	0.06	0.17	4.64	7.87	35.29	5.60
9	Seed yield per plant (g)	I	23.80 - 34.70	28.38	7.36	9.66	9.55	10.95	76.19	17.40
		R	14.60 - 25.70	19.63	7.43	8.51	13.88	14.86	87.30	26.65

I = Irrigated condition : R = Rainfed condition

4.2.2 Days to maturity :

The character varied from 138.10 days (S-12-2) to 149.80 days (S-8-2) under irrigated condition whereas under rainfed condition range was from 130 days (S-14-2) to 139 days (S-12-5) under rainfed condition. The genotypic variance and phenotypic variance values were low for both the conditions (1.92 per cent and 1.89 per cent). Phenotypic coefficient of variation (2.16 and 2.15 per cent) were relatively low for irrigated and rainfed conditions respectively. Higher heritability estimates were observed under irrigated condition (78.96 per cent) as well as under rainfed condition (77.72 per cent). Low expected genetic advance 3.45 and 3.44 per cent was observed under irrigated and rainfed conditions respectively.

4.2.3 Plant height (cm) :

A wider range of variation was observed under irrigated condition 73.70 cm (S-12-1) to 94.60 cm (S-5-3). Similarly under rainfed condition the character ranged from 70.10 cm (S-13) to 89.50 cm (S-12-1). The genotypic and phenotypic variance values were very high for both conditions. The genotypic coefficient of variations were 6.44 per cent for irrigated and 6.84 for rainfed conditions. Similar results were observed for phenotypic coefficient of variation under irrigated condition (6.60 per cent) and rainfed condition (7.10

per cent). Very high heritability estimates were observed under irrigated condition (95.13 per cent) as well as rainfed condition (92.94 per cent). The expected genetic advance was also high (12.92 and 13.58 per cent) under irrigated as well as rainfed condition.

4.2.4 Number of primary branches :

The character was ranged from 8.80 (S-8-2) to 17.00 (S-12-5) under irrigated condition and from 6.70 (S-12-1) to 13.50 (S-2) under rainfed condition, The genotypic variance was lower than phenotypic variance under both the conditions. The genotypic coefficient of variation was 13.52 per cent and 15.99 per cent under irrigated and rainfed conditions respectively. The phenotypic coefficient of variation were higher than genotypic coefficient of variation under irrigated condition (15.72 per cent) as well as rainfed condition (18.91 per cent). High heritability estimates were recorded under irrigated condition (74.02 per cent) and rainfed condition (71.42 per cent). The expected genetic advance was high under both irrigated condition (23.94) per cent) as well as rainfed condition (27.75 per cent) for number of primary branches.

4.2.5 Number of secondary branches :

The character varied from 13.40 (S-12-2) to 26.90 (S-2) under irrigated condition and under rainfed condition the range was from 10.40 (S-13) to 20.90 (S-2). Moderate genotypic variance and phenotypic variance were observed under both the conditions. The genotypic coefficient of variation was high under irrigated condition (16.64 per cent) and rainfed condition (21.33 per cent). The phenotypic coefficient of variation was also high under irrigated condition (17.84 per cent) and rainfed condition (22.31 per cent). Higher heritability estimates were observed under irrigated condition (90.53 per cent) as well as rainfed condition (91.40 per cent). The expected genetic advance was also high under irrigated condition (32.52 per cent) as well as under rainfed condition (41.94 per cent) for number of secondary branches.

4.2.6 Number of capsules per plant :

A wide range of variation was observed under irrigated condition from 19.60 (S-8-2) to 36.40 (S-12-5) and under rainfed condition from 15.60 (S-12-1) to 28.10 (S- 2). Moderate genotypic variance and phenotypic variance were recorded by this character under both conditions. The higher genotypic coefficient of variation (15.46 per cent and 17.66 per cent) were observed under irrigated condition and rainfed condition respectively. Higher heritability estimates under irrigated condition (91.31 per cent) and rainfed condition (86.62 per cent) coupled with high expected genetic advance under irrigated condition (29.61 per cent) and rainfed condition (31.48 per cent) were observed for number of capsules per plant.

4.2.7 Number of seeds per capitulum :

The character was ranged from 16.40 (S-13) to 36.60 (S-9) under irrigated condition and 14.40 (S-12-3) to 32.60 (S-12-6) under rainfed condition. The genotypic and phenotypic variance was very high under both irrigated condition as well as rainfed condition. The genotypic coefficient of variation was also high under irrigated condition (16.40 per cent) as well as rainfed condition (19.01 per cent). Similarly high phenotypic coefficient of variation for irrigated condition (18.17 per cent) and rainfed condition (19.86 per cent) was observed. High heritability was recorded under irrigated condition (92.39 per cent) as well as rainfed condition (91.60 per cent). Higher expected genetic advance was recorded under irrigated condition (34.57 per cent) as well as rainfed condition (37.48 per cent) for number of seeds per capitulum.

4.2.8 Test weight (g) :

The range for test weight were varied from 5.00 g (S-8-2) to 6.41 g (S-13-4) under irrigated condition and 4.62g (S-9) to 6.12g (S-13-1) under rainfed condition. The genotypic variance and phenotypic variances were relatively low for both conditions. The genotypic coefficient of variation (4.76 per cent and 4.64 per cent) and phenotypic coefficient of variation (8.64 per cent and 7.87 per cent) were observed for irrigated condition and rainfed conditions respectively. The lower heritability estimates (30.43 per cent and 35.29 per cent) coupled with low expected genetic advance (5.30 per cent and 5.60 per cent) were observed for irrigated condition and rainfed condition respectively.

4.2.9 Seed yield per plant (g) :

A wide range for seed yield per plant from 23.80 g (S-13) to 34.70 g (S-2) under irrigated condition and from 14.60 g (S-12-3) to 25.70 g (S-2) under rainfed condition was observed for mean seed yield per plant. Genotypic variance and phenotypic variance were low, but phenotypic variance was higher than genotypic variance. The genotypic coefficient of variation recorded were 9.55 per cent under irrigated condition and 13.88 per cent under rainfed condition. Similarly the phenotypic coefficient of variation under irrigated condition (10.95 per cent) and under rainfed condition (14.86 per cent) were observed. Expected genetic advance under irrigated condition (17.14 per cent) and under rainfed condition (26.65 per cent) were observed for the character seed yield per plant.

4.3 Correlation

Genotypic and phenotypic correlations were calculated among the eight characters with the seed yield per plant and are presented in table 4 and 5 respectively.

The results revealed that, the days to 50 per cent flowering was positively correlated with days to maturity at genotypic as well as phenotypic level under both environment. Whereas test weight was positively correlated with days to flowering only at genotypic level under both conditions. Days to 50 per cent flowering also positively and significantly correlated with number of primary branches and number of capsules per plant at both level under irrigated condition only. The significant and negative association between days to 50 per cent flowering and number of seeds per capsule was observed under both environments at both levels.

The character, days to maturity was positively and significantly correlated with number of seeds per capsule under irrigated condition, whereas the it was positively and significanly correlated with test weight under rainfed condition at genotypic level only.

The character, plant height was positively correlated with number of capsules per plant and seed yield per plant under both the condition and at both

Table 4 : Genotypic correlation of yield with other yield components in safflower under irrigated and rainfed condition.

Sr No.	Characters	Environment	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of capsules per plant	Number of seeds per capusules	Test weight (g)	Seed yield per plant (g)
1	Days to 50 % Flowering	I	1.000	0.383^{*}	-0.063	0.465	0.358^{*}	0.493^{**}	-0.517^{**}	0.718^{**}	-0.100
		R	1.000	0.381^{*}	-0.260	0.243	0.069	0.245	-0.567^{**}	0.384^{*}	-0.172
2	Days to maturity	I		1.000	0.274	0.287	0.195	0.181	0.409^{*}	0.216	0.099
		R		1.000	0.266	0.023	0.217	0.184	0.142	0.383^{*}	0.115
3	Plant height (cm)	I			1.000	0.089	0.326	0.399^{*}	0.504^{**}	0.219	0.480^{**}
		R			1.000	0.063	0.303	0.449^{**}	0.325	0.337	0.604^{**}
4	Number of primary branches	I				1.000	0.749^{**}	0.847^{**}	-0.128	0.982^{**}	0.272
		R				1.000	0.686^{**}	0.826^{**}	-0.427^{*}	0.692^{**}	0.295
5	Number of secondary branches	I					1.000	0.974^{**}	-0.035	0.626^{**}	0.530^{**}
		R					1.000	0.918^{**}	-0.133	0.359^{*}	0.539^{**}
6	Number of capusules per plant	I						1.000	-0.085	0.710^{**}	0.491^{**}
		R						1.000	-0.314	0.606^{**}	0.487^{**}
7	Number of seeds per capsules	I							1.000	-0.228	0.499^{**}
		R							1.000	-0.351^{*}	0.398^{*}
8	Test weight (g)	I								1.000	0.546^{**}
		R								1.000	0.437^{**}

* and ** significant at 5 and 1 per cent level respectively.
I = Irrigated condition
R = Rainfed condition

Table 5 : Phenotypic correlation of yield with other yield components in safflower under irrigated and rainfed condition.

Sr No.	Characters	Enviro- nment	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of capsules per plant	Number of seeds per capusules	Test weight (g)	Seed yield per plant (g)
1	Days to 50 % Flowering	I	1.000	0.347*	-0.093	0.414*	0.329	0.434*	-0.467**	0.272	-0.112
		R	1.000	0.400*	-0.252	0.233	0.101	0.267	-0.514**	0.118	-0.229
2	Days to maturity	I		1.000	0.213	0.201	0.122	0.130	0.332	0.153	0.087
		R		1.000	0.207	0.105	0.142	0.142	0.084	0.217	0.111
3	Plant height (cm)	I			1.000	0.064	0.297	0.383*	0.485**	0.140	0.469**
		R			1.000	0.093	0.271	0.370*	0.319	0.228	0.556**
4	Number of primary branches	I				1.000	0.697**	0.713**	-0.153	0.244	0.163
		R				1.000	0.605**	0.727**	-0.399*	0.216	0.152
5	Number of secon- dary branches	I					1.000	0.881**	-0.050	0.212	0.420*
		R					1.000	0.814**	-0.134	0.113	0.436**
6	Number of capus- ules per plant	I						1.000	-0.324	0.191	0.371*
		R						1.000	-0.084	0.332	0.400*
7	Number of seeds per capsules	I							1.000	-0.059	0.398*
		R							1.000	-0.023	0.431*
8	Test weight (g)	I								1.000	0.188
		R								1.000	0.356*

* and ** significant at 5 and 1 per cent level respectively.
I = Irrigated condition
R = Rainfed condition

levels; whereas it was positively and significantly correlated with number of seeds per capsule at both levels under irrigated condition only.

Number of primary branches exhibited positive and significant correlation at genotypic and phenotypic level with number of secondary branches and number of capsules per plant under both conditions, whereas it was positively and significantly correlated at genotypic level with test weight under both condtions. The correlation of this character with number of seeds per capsule was significant and negative under rainfed condition at both levels.

The character number of secondary branches exhibited significant and positive correlation with number of capsules per plant and seed yield per plant at genotypic as well as phenotypic level under both conditions. Similar correlation was observed for this trait with test weight at genotypic level under both conditions.

The number of capsules per plant exhibited the positive and significant correlation with seed yield per plant at genotypic and phenotypic levels under irrgated as well as rainfed conditions. The similar correlation of number of seed per capsule with seed yield was noticed. The test weight exhibited the positive and significant correlation with grain yield under irrigated as well as rainfed condition at genotypic level but at phenotypic level this association was positive and significant under rainfed condition only.

4.4 Path analysis:

Genotypic and phenotypic path analysis between yield and yield contributing characters were carried out by using genotypic and phenotypic correlation coefficients and are presented in table 6 and 7 respectively.

Results of path coefficient analysis revealed that the highest positive direct effect of number of secondary branches on seed yield was observed at genotypic level followed by traits, viz. capsules per plant, test weight, number of seeds per capitulum, plant height and days to maturity under irrigated as well as under rainfed condition. Whereas at phenotypic level, the highest and positive direct effect was recorded by the character number of seeds per capsule followed by number of secondary branches, number of capsules per plant, plant height and test weight under irrigated condition. The second highest positive direct effect was exerted by number of seeds per capsule followed by test weight, number of secondary branches, number of capsules per plant and plant height under rainfed condition at phenotypic level. In general the direct effect of all the characters under study were higher

Table 6 : Direct and indirect effects (genotypic) of yield components on yield under irrigated and rainfed condition.

Sr No.	Characters	Environment	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of capsules per plant	Number of seeds per capusules	Test weight (g)	**Genotypic correlation with yield**
1	Days to 50 % Flowering	I	**-0.064**	0.438	0.252	0.131	0.161	-0.304	-0.436	-0.279	-0.100
		R	**-0.019**	0.337	0.185	0.121	0.366	-0.399	-0.462	-0.301	-0.171
2	Days to maturity	I	-0.319	**0.132**	0.258	0.229	0.376	-0.700	0.543	-0.421	0.098
		R	-0.377	**0.156**	0.275	0.249	0.216	-0.441	0.527	-0.490	0.115
3	Plant height (cm)	I	-0.101	0.828	**0.361**	0.387	0.213	-1.335	0.324	-0.197	0.480
		R	-0.060	0.673	**0.384**	0.228	0.279	-1.031	0.224	-0.093	0.604
4	Number of primary branches	I	-0.207	0.250	0.141	**-1.340**	1.644	-0.182	-0.120	0.087	0.271
		R	-0.156	0.239	0.181	**-1.300**	1.284	-0.005	-0.059	0.110	0.294
5	Number of secondary branches	I	-0.140	0.192	0.153	0.224	**1.211**	0.636	-1.171	-0.574	0.530
		R	-0.486	0.116	0.205	0.247	**1.098**	0.776	-1.113	-0.304	0.539
6	Number of capusules per plant	I	-0.330	0.165	0.187	0.309	0.262	**1.076**	-0.394	-0.784	0.491
		R	-0.157	0.190	0.302	0.380	0.360	**1.061**	-0.285	-1.364	0.487
7	Number of seeds per capsules	I	0.140	-0.432	0.213	-0.218	-0.512	0.429	**0.543**	0.336	0.498
		R	0.426	-0.549	0.209	-0.266	-0.696	0.431	**0.540**	0.302	0.397
8	Test weight (g)	I	-0.155	1.207	0.203	0.486	0.009	-1.742	-0.195	**0.732**	0.545
		R	-0.271	0.828	0.320	0.262	0.012	-1.430	-0.332	**1.048**	0.437

Residual factor = I = irrigated condition = 0.342 R = Rainfed condition = 0.429

Table 7 : Direct and indirect effects (phenotypic) of yield components on yield under irrigated and rainfed condition.

Sr No.	Characters	Environment	Days to 50 % flowering	Days to maturity	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of capsules per plant	Number of seeds per capusules	Test weight (g)	**Phenotypic correlation with yield**
1	Days to 50 % Flowering	I	**-0.032**	-0.037	-0.010	-0.050	0.012	0.168	-0.192	0.030	-0.111
		R	**-0.023**	-0.039	-0.105	-0.023	0.030	0.058	-0.163	0.035	-0.230
2	Days to maturity	I	-0.010	**-0.118**	0.024	-0.027	0.044	0.020	0.136	0.017	0.087
		R	-0.009	**-0.098**	0.045	-0.005	0.042	0.036	0.034	0.065	0.110
3	Plant height (cm)	I	0.003	0.200	**0.115**	-0.008	0.108	0.060	0.015	-0.025	0.468
		R	0.005	0.131	**0.217**	-0.009	0.081	0.080	0.070	-0.020	0.555
4	Number of primary branches	I	-0.013	-0.023	0.227	**-0.837**	0.501	0.312	-0.063	0.058	0.162
		R	-0.004	-0.006	0.220	**-0.801**	0.484	0.358	-0.164	0.065	0.152
5	Number of secondary branches	I	-0.010	-0.014	0.034	-0.096	**0.365**	0.138	-0.020	0.023	0.419
		R	-0.002	-0.013	0.056	-0.061	**0.298**	0.176	-0.055	0.036	0.435
6	Number of capusules per plant	I	-0.014	-0.015	0.044	-0.098	0.101	**0.357**	-0.034	0.028	0.370
		R	-0.006	-0.013	0.087	-0.073	0.233	**0.247**	-0.133	0.057	0.399
7	Number of seeds per capsules	I	0.015	-0.039	0.055	-0.045	0.018	-0.023	**0.413**	0.003	0.397
		R	0.012	-0.008	0.062	0.004	0.036	-0.070	**0.412**	-0.017	0.431
8	Test weight (g)	I	-0.018	-0.028	0.016	-0.037	0.076	0.056	0.011	**0.111**	0.187
		R	-0.030	-0.041	0.049	-0.021	0.033	0.041	0.024	**0.301**	0.356

Residual factor : I = Irrigated codition = 0.486 R = rainfed condition = 0.546

under irrigated condition than that of rainfed condition except for the test weight and plant height, which were higher under rainfed condition at genotypic level as well as phenotypic level. The days to 50 per cent flowering and number of primary branches exhibited negative direct effect on seed yield under both conditions at genotypic as well as phenotypic level.

The maximum indirect effect was exerted by primary branches through number of secondary branches on seed yield under both environments at both levels. The high positive indirect contribution by days to 50 per cent flowering, through days to maturity followed by plant height, number of secondary branches and primary branches was observed under irrigated condition at genotypic level. Whereas it was followed by number of secondary branches, days to maturity and plant height under rainfed condition at genotypic level. The character, days to 50 per cent flowering recorded the highest indirect effect through number of capsules per plant, test weight and number of secondary branches under both conditions at phenotypic level.

Days to maturity recorded the highest positive indierect effect through number of seeds per capsule followed by secondary branches, plant height and number of primary branches under irrigated condition, whereas it had recorded the highest positive indirect effect through number of seeds per capsule followed by plant height, number of primary branches and number of secondary branches at genotypic level under rainfed condition. This trait had recorded the highest positive indirect effect at phenotypic level through number of seeds per capsules, number of secondary branches, number of capsules per plant under irrigated condition. Under rainfed condition the highest indirect contribution was through test weight followed by number of secondary branches, number of seeds per capsule and number of capsules per plant.

The maximum indirect effect was exhibited by plant height through days to maturity, number of primary branches, number of seeds per capsule and number of secondary branches under both environments at genotypic level. While at phenotypic level, it was through days to maturity, number of secondary branches, number of capsules per plant and number of seeds per capsule under both environments.

The number of primary branches exerted maximum positive indirect effect on seed yield through number of secondary branches followed by days to maturity, plant height and test weight under irrigated as well as rainfed condition at genotypic level. At phenotypic level it had recorded high indirect effect through number of primary branches, number of capsules per plant, test weight and plant height under both environments.

The highest positive indirect effect was exerted by number of secondary branches on seed yield through number of capsules per plant followed by number of primary branches, days to maturity and plant height at genotpic level under irrigated as well as rainfed conditions. While at phenotypic level, it was through number of capsules per plant, plant height and test weight under both enviroulments.

Number of capsules per plant recorded the highest indirect positive effect on seed yield through number of primary branches, number of secondary branches and plant height at genotypic level under irrigated and rainfed conditions. At phenotypic level high indirect contribution to seed yield was through number of secondary branches followed by plant height and test weight under both environments.

The character, number of seeds per capsule had exerted maximum indirect positive contribution to seed yield through number of capsules per plant followed by test weight, days to 50 per cent flowering and plant height at genotypic level under both envirionments. Whereas at phenotypic level, it exerted through plant height, and number of secondary branches under irrigated as well as rainfed condition. Test weight exhibited the highest indirect and positive effect on seed yield through the characters days to maturity, number of primary branches and plant height at genotypic level under both environments. At phenotypic level, the character exerted maximum indirect effect through number of secondary branches followed by number of capsules per plant, plant height and number of seeds per capsule under irrigated condition, while under rainfed condition it had exerted through plant height followed by number of secondary branches and number of seeds per capsule at phenotypic level.

Residual effect observed was 0.342 and 0.420 under irrigated and rainfed conditions. The variables explain about 60 per cent and 58 per cent variability in the yield under irrigated and rainfed conditions respectively.

DISCUSSION

V. DISCUSSION

Commercial exploitation of heterosis in many of the important field crops led to the remarkable increase in the productivity in last fifteen years. Many scientists have reported high heterosis for yield and yield contributing characters in these crops but it was not exploited due to absence of suitable male sterility systems or due to problems in large scale seed production. However, in safflower genetic male sterility system controlled by recessive gene was reported by Heaton and Knowles (1982), and one reported by Joshi _et_ _al_. (1983) had found to be controlled by a dominant gene. Nerkar and Jambhale (1985) discussed possible approaches to use both types of male sterility systems in population breeding.

The safflower improvement programme may find an important place in near future by incorporation of male sterility in different genetic background and crosses with the diverse genotypes may throw variability in segregating generation which may in turn can be utilized in development of varieties.

In applied plant breeding, success of the programme may be anticipated, if the genetic variability in different parents is known well in advance. The correlation and path analysis provide information on genetic association of yield and yield contributing characters, which in turn are useful in developing breeding strategies. On this background the present investigation was undertaken.

The experimental material consists of total 30 diverse genotypes and two checks i.e. Bhima and Sharda, were sown in two environments viz. irrigated and rainfed conditions. The genotypes were evaluated in randomised block design. The studies were made on variability, heritability, correlation and path analysis under both environments. The results of present study are discussed below.

5.1 Analysis of variance:

The analysis of variance (RBD) showed significant differences among the genotypes to all the characters studied in both environments, indicated that there was adequate variability for all characters under study.

5.2 Mean performance

The saffolwer selection S-2 recorded the highest seed yield under irrigated (34.70 g) as well as under rainfed condition (25.70 g). The selections S-13-5 (34.30 g), S-2-2 (33.60 g) and S-5-1 (32.40 g) were significantly superior over check Bhima (29.90 g) and sharda (26.40 g) under irrigated condition. Whereas under rainfed condition, selection S-13-5 (25.30 g), followed by S-13-6 (24.60g) and S-2-2 (23.40 g) were higher in seed yield over checks, Bhima (22.40 g) and Sharda (19.90 g). These selections also recorded high values for most of the yield components in both environments. In general the mean performance of all genotypes under irrigated condition was higher than that of under rainfed condition.Thus all these selections showing high yield potential need to be tested for their further performances over locations and seasons.

5.3 Genetic variability

The prerequisite for a breeder to quantify the existing variability in to its forms as fixable and nonfixable for effective selection. Genetic component of variation is most important in breeding programme which is governed by additive and additive x additive types of gene action and is fixable. Prepotancy of a character depends on the magnitude of additive gene action. In the present study, efforts are made to analyse the components of variability in the segregating genotypes with reference to the future breeding programme.

5.3.1 Range of variability :

In general, the range of variability was considerable for majority of the characters under both envirionments. Range of variation was more for the characters, viz. days to 50 per cent flowering, plant height, number of primary branches, number of secondary branches, number of capsules per plant, number of seeds per capsule and seed yield per plant (g) under both irrigated as well as rainfed conditions. Wide range of variation for different yield contributing characters in safflower have been reported by Argikar et al. (1958), Ashri et al. (1974), Mathur et al.(1976), Yazadi et al. (1976), Challwar (1986), Singh et al. (1993), Lakha et al. (1992) and Ghorpade et al. (1993). Lakha (1989) indicated the presence of substantial genetic diversity between the strains for yield characters.

Phenotypic variances were higher than the genotypic variances for all the characters under both environments. But differences between them under irrigated as well as rainfed condition were of lower magnitude, indicating that the characters were less affectd by the environment. High genotypic and phenotypic variances were observed for the characters plant height followed by number of seeds per capsule, number of capsules per plant, number of secondary branches, days to 50 per cent flowering and seed yield per plant under both enviroments. The present finding are in agreement with those of Patil et al.(1992) and Lakha et al. (1992). Deokar and Patil (1978) also observed high values of genotypic and phenotypic variances for number of seeds per capsule and plant height (cm). The lowest genotypic and phenotypic variances were observed for the charcters, test weight

(g) and number of primary branches under both environments. These findings are in confirmity with the findings of Lakha _et al_. (1992) and Deokar and Patil (1978) respectively.

5.3.2 Genotypic and phenotypic coefficient of variation.

The selection under field condition may be strongly influenced by the environmental factors affecting the progress in improvement programme. In the present studies, the genotypic coefficient of variability estimates were lower than the phenotypic coefficient of variability for all characters under both environments. Though the phenotypic coefficients of variation were greater than genotypic coefficient of variation, the differences between them were of lower magnitude i.e. they are more or less close to each other. This relationship indicated that there was small effect of environment on these characters and phenotypic selection for these characters may be effective.

In present study, high genotypic and phenotypic coefficients of variation were observed for the characters viz. number of secondary branches, number of seeds per capsule, number of primary branches, number of capsules per plant under both environments. The character seed yield per plant showed higher genotypic coefficient of variation and phenotypic coefficient of variation under rainfed condition than irrigated condition, indicating more variability for this trait under rainfed condition. The results are in agreement with those of Narkhede et al. (1985), Challwar (1986), Lakha et al. (1992), Patil et al. (1992). The lowest genotypic and phenotypic coefficients of variation were observed for days to 50 per cent flowering, test weight and days to maturity under both environments. Similar results were reported by Patil et al. (1992), for days to 50 per cent flowering and days to maturity and by Khidir (1974) for test weight.

High genotypic and phenotypic coefficients of variability for the characters, viz. number of seeds per capsule, number of secondary branches, number of primary branches, number of capsules per plant and seed yield per plant under both environments suggests their utility in making selections.

5.3.3 Heritability and genetic advance.

The charcters, plant height, number of secondary branches, number of capsules per plant, number of seeds per capsule recorded higher (>80 per cent) broad sense heritability under both envirionements, whereas the characters, days to 50 per cent flowering and grain yield showed high heritability under irrigated condition and rainfed condition respectively, indicating greater scope for selection in improvement of these traits.

High heritability estimates were reported for plant height and number of seeds per capsule by Makne et al.(1985), for seed yield by Mathur et al. (1976), for capsule per plant by Narkhede et al. (1985) and Patil et al. (1991) and for number of branches by Thombre and Joshi (1977).

The characters number of primary branches, days to 50 per cent flowering and days to maturity recorded medium heritability (70 to 80 per cent) while the character test weight recorded low heritability (< 70 per cent) under both environments. Similar results for heritability of these traits were reported by Mathur et al. (1976).

Johnson et al.(1955) suggested that the heritability estimates along with genetic advance would be more useful in predicting yield under phenotypic selection than heritability estimates alone.

High heritability estimates coupled with high expected genetic advance were observed for characters, number of secondary branches, number of seeds per capsule, plant height and number of capsules per plant under both conditions. Similar findings were reported by Lakha et al. (1992) for number of secondary branches, Thombre and Joshi (1977) for number of capsules per plant, Sengupta and Battacharya (1979) and Makne et al (1985) for plant height and by Kambale et al. (1984), Narkhede *et al*. (1985), Gupta and Singh (1990) and Patil *et al*. (1991) for number of capsules per plant.

Thus from the foregoing discussion it is cleared that the characters viz. number of secondary branches, number of seeds per capsule, number of capsules per plant and plant height recorded high heritability and high expected genetic advance, indicating the presence of additive gene action and effectiveness of phenotypic selection. Thus while exploiting genetic variability a due weightage should be given to these characters.

5.4 Correlation

Yield is a complex character and depend on the other agromorphological characters. Explaination of relationship of these traits with yield gives the fair idea about their importance in the breeding programme and contribution towards yield. In present investigation, genotypic and phenotypic correlations were calculated for yield and yield components under irrigated and rainfed condition.

The characters, plant height, number of secondary branches , number of capsules per plant, number of seeds per capsule and test weight (g) possesed significant and positive correlation with seed yield (g) under both environments at genotypic level. Similar associations were observed for these characters with seed yield at phenotypic level, under both conditions except test weight which was positively and significantly correlated with yield under rainfed condition only. Makne _et_ _al_. (1985) reported significant correlation of seed yield with test weight (g), seeds per capsule and capsules per plant under three environments, Lakha _et_ _al_. (1992) for number of secondary branches, number of capitula per plant and number of seeds per capitulum, Acharya _et_ _al_.(1994) for test weight and Dahiphale and Pawar (1993) for plant height.

Inter-character correlation at genotypic level showed positve and significant correlation with days to maturity and test weight under both conditions and with number of secondary branches and number of capsules per plant under irrigated condition. Whereas, days to 50 per cent flowering showed negative correlation with number of seeds per capsule at both levels and under both conditions.

Days to maturity showed positive and significant correlation with number of seeds per capsule and test weight under irrigated as well as rainfed condition respectively. Plant height also showed positive and significant correlation with number of capsules per plant under both environments and with number of seeds per capsule under irrigated condition. Similar findings for these traits were reported by Lakha (1989).

Number of primary branches exhibited close association with number of secondary branches and number of capsules per plant at both levels and under both conditions indicating that they had certain inherant relationship with each other. Similar, findings were reported by Lakha et al. (1992). The positive and significant correlation existed between number of secondary branches and number of capsules per plant, in turn, their association with seed yield was positive and significant under both the conditions at genotypic and phenotypic level.

Number of capsules per plant exhibited negative and nonsignificant correlation with number of seeds per capsule. The results are in agreement with those of Paliwal and Solanki (1984) and Lakha (1989). Number of seeds per capsule showed negative correlation with test weight at both levels and under both conditions. The similar correlations for these traits were reported by Khidir (1974).

Generally, magnitude of correlation observed under irrigated condition were higher than rainfed condition. Almost similar trends had been observed at genotypic level but with higher degree and phenotypic correlations were found random in degree and direction. Thus it is important to note that the characters, plant height, number of secondary branches, number of seeds per capsule, number of capsules per plant were positively correlated with seed yield (g) and had high estimates of heritability and genetic advance. These traits could be considered as important traits for improving seed yield in safflower.

5.5 Path analysis:

Considering the genotypic and phenotypic correlations path analysis was carried out. As important yield components are either positively or negatively correlated with grain yield, a better under standing of direct and indirect influence of various charcters on yield would be emerged from the path coefficient analysis.

The present results revealed that plant height showed highly significant and positive association at genotypic level under both environments with seed yield. This significant correlation could be explained by the direct effect of plant height and its indirect effect through days to maturity, number of primary and secondary branches and number of seeds per capsule. Indirect effect through other components were merely negative. Malleshappa <u>et</u> <u>al</u>.(1989) reported postive direct effect of plant height to the seed yield.

Number of primary branches showed negative direct effect at both levels and under both conditions. Though, its direct effect was negative its indirect effect through number of secondary branches was comparatively high, indicating its mere indirect condtribution to the seed yield. These findindgs are in confirmity with that of Lakha et al. (1992).

Number of secondary branches showed highly significant and positve correlation with seed yield under both environments which would be explained by its positive direct effect and indirect effect through number of capsules per plant, number of primary branches, days to maturity and plant height. The positive direct effect of secondary branches through capsules per plant was reported by Ghongade et al. (1993). Significant and positive correlation of number of capsules per plant with seed yield under both environments could be explained by its positive direct effect and indirect effect via. plant height and number of primary branches. Similarly, Thombre and Joshi.(1981) and Reddy et al.(1992) reported positive direct effect of number of capsules per plant to the yield.

The character, test weight also possesed positive and significant correlation with seed yield which would again be explained by its positive effect and indirect effect through days to maturity and plant height. The reslults are in confirmity with those of Patil et al. (1990) and Acharya et al (1994).

Days to 50 per cent flowering and days to maturity showed negative and positive but non-significant effects, respectively, though their contribution is negative and weak, these traits affected grain yield indirectly through plant height, number of primary branches and number of secondary branches to the seed yield. Similar results were reported by Madrap _et al._ (1993).

The results indicates that plant height, number of secondary branches, number of capsules per plant, number of seeds per capsule and test weight had strong association with seed yield and also showed the highest direct positive constribution through indirect effects of other component traits showing positive correlation with seed yield. This indicated that direct selection for plant height, number of secondary branches, number of capsules per plant, number of seeds per capsule and test weight will enhance the breeding efficiency for seed yield in safflower.

The medium residual factors explain that variables studied found about 66 per cent and 58 per cent variablility under irrigated and rainfed condition. The reason seems to be a very low and non-significant correlation of days to 50 per cent flowering, days to maturity and number of primary branches with seed yield. Besides, some other factors which have not been considered here needs to be included in this analysis to account fully for the variation in yield.

SUMMARY
AND
CONCLUSION

VI. SUMMARY

The present investigation was undertaken with the objects of estimating genetic variability for yield and yield contributing characters, to study association of yield and yield contributing characters and to study the performance of different genotypes of safflower (*Carthamus tinctorius* L.) under two environments. It was sought through growing 30 selections and two checks in a randomised block design with two replications, in two environments viz. irrigated and rainfed conditions. All the 32 genotypes were grown at Parbhani in heavy soil on 9th October 1996.

Estimates of variability were done as per the standardised statistical methods of RBD analysis. Genetic advance was estimated as per the method suggested by Hanson *et al*. (1956) and correlation coefficient were calculated according to Johnson *et al*. (1955). Component analysis was worked out according to Dewey and Lu (1959). The experimental findings are summarised below.

1. Analysis of variance showed sufficient genetic variability in the selections for all the characters under irrigated as well as rainfed conditions.

2. There were less variation for days to maturity among genotypes under both conditions.

3. Maximum number of secondary branches were recorded by the selections viz.S-2, S-12-5 and S-5-2 under irrigated condition, while selection S-2, S-13-5 and S-8 under rainfed condition. The highest number of capsules was also recorded in selections viz. S-12-5, S-2 and S-8 under irrigated condition, while in selections S-2, S-8, S-13-5 under rainfed condition.

4. Number of seeds per capsule was the highest in selections, viz. S-9, S-12-6 and S-12-1 under irrigated condition whereas in selections S-12-6, S-9, and S-13-6 under rainfed condition.

5. The selections viz. S-2, S-13-5, S-2-2, and S-5-1 showed higher yield under irrigated condition. Whereas under rainfed condition selections S-2, S-13-5, S-13-6 and S-2-2 showed maximum seed yield. Therefore all selections were superior to Bhima and Sharda under both conditions.

6. The range of variation for days to 50 per cent flowering, plant height, number of primary branches, number of secondary branches, number of capsules per plant, number of seeds per capsule and seed yield per plant was more.

7. High genotypic coefficient of variability were observed for number of primary branches, number of secondary branches, number of capsules per plant, number of seeds per capsule and seed yield per plant under both environments.

8. High heritability coupled with high expected genetic advance was observed for plant height, number of secondary branches, number of capsules per plant, number of seeds per capsule and seed yield per plant under both conditions.

9. Correlation studies indicated the importance of number of secondary branches, number of capsules per plant, test weight, number of seeds per capsule and plant height in the seed yield under irrigated as well as rainfed conditions.

10. The path coefficient analysis revealed the maximum contribution of plant height,number of secondary branches, number of capsules per plant, number of seeds per capsule and test weight to the seed yield.

CONCLUSION

The selections viz, S-2, S-13-5, S-2-2 and S-5-1 under irrigated condition and the selections S-2, S-13-5, S-13-6 and S-2-2 under rainfed condition showed better performance for yield and yield contributing characters viz, number of secondary branches, number of capusules per plant, test weight, number of seeds per capsule and plant height. These characters also showed positive correlation with seed yield thorugh their direct and indirect effects and also showed high heritability coupled with high genetic advance. Hence the direct selection for these characters of safflower genotypes will increase the breeding efficiency under both environments.

LITERATURE CITED

LITERATURE CITED

* Abel, G.H. 1969. An analysis of components in safflower. 3rd safflower research conference proceeding. Univ. of California; 18-22.

Acharya, S., Dhaduk, L.K. and Maliwal, G.L. 1994. Path analysis in safflower (Carthamus tinctorius L.) under conserved moisture condition. Gujrat agric. Univ. Res. J; 20 :154-157.

* Alba, E. and Greco, I. 1977. Analysis of some characters which influence seed oil content in safflower. Anaali della facolta Li. Agaria Univ. di-beri; 29 :391-396.

Argikar, G.P. and Solanki, M.S.1958. Study of growth habits in safflower. Oil seed J; 2 :13-17.

Ashri, A., Zimmer, O.E., Urie, A.L., Cahaner, A. and Marani, A. 1974. Evaluation of world collection of safflower (Carthamus tinctorius L.) VI yield and yield components and their relationship. Crop.Sci; 14:799-802.

Bargale, M. and Billore, S.P. 1992. Genetic divergence and hybrid performance over environment in feba-bean. J. Maharashtra agric. Univ; 17 :428-430.

Brim, C.A. and Burton, J.W. 1979. Recurrent selection in soybean. II selection for increased per cent protein in seed. Crop. sci; 19 :494-495.

* Claassean, C.E. 1952. Inheritance of sterility for flower colour, spineleness, attached pappus and rust resistance in safflower (Carthamus tinctorius L.). Nebr. Agric. Expt. Stn. Bull; 171:28.

Comstock, R.E., Kelleher, T. and Morrow, E.B. 1958. Genetic variation in an asexual species, the garden straw berry. Genetics; 43 :634-646.

Challwar, M.M. 1986. Variability studies in safflower. M.Sc. (Agri) Dissertation submitted to M.A.U. Parbhani.

* Deshpande, R. B. 1940. A sterile mutunt in safflower. Curr. sci; 9 :370-371.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components in crested wheat grass seed production. Agron. J; 515-518.

Dogget, H. 1968. Mass selection systems for sorghum. Crop sci; 8:391-392.

Dahiphale, V.V. and Pawar, K.R. 1993. Correlation studies in safflower. J. Maharashtra agric univ; 18 :291-292.

Deokar, A.B. and Patil, F.B. 1978. Analysis of parameters in some Indian varieties of safflower. J. Maharashtra agric. Univ; 3 :69-70.

Deokar, A.B., Patil, F.B., Shinde, P.B. and Mulik, S.P. 1985. Genetic analysis of yield components in safflower. Andhra agric. J; 32:119-121.

Ebert, W.W. and Knowles, P.F. 1966. Inheritance of pericarp types sterility and dwarfness in safflower crosses. Crop. sci; 6 :579-582.

Ghorpade, P.S., Tambe, S.J., Shinde, P.B. and Zope, R.E. 1993. Variability pattern in agromorphological characters in safflower. Indian J. Genet.Plant Breed. 53 :264-266.

Gupta, R.K. and Singh, S.P. 1990. Genetic studies in relation to the improvement of oil content and seed yield in safflower. Genetica (Beograd); 22 : 83-90.

Ghongade, R.A., Joshi, B.P. and Navale, P.A. 1993. Correlation and path analysis of some yield components in safflower. J. Maharashta agric. Univ; 18:240-243.

Hanson, G.W., Robinson, H.F. and Comstock, R.E. 1956. Biometrical studies of yield in segregating population of korean lespedeza. Agron. J; 48:268-272.

Hallauer, A.R. 1981. Selection and breeding methods. In frey, K.J. (ed) plant breeding II, Iowa state univ. press Amer; 3-55.

Heaton, I.C. and Knowles, P.F. 1982. Inheritance of male sterility in safflower. Crop sci. 22 :520-522.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955. Genotypic and phenotypic correlations in soybean and their implications in selection. Agron. J; 47:477-485.

Joshi, B.M., Nerkar, Y.S. and Jambhale, N.D. 1983. Induced male sterility in safflower. J. Maharashtra agric. Univ; 8:194-195.

Jambhale, N.D. and Nerkar, Y.S. 1985. An induced dominant gene controlling male sterility in safflower. J. plant Breed; 95 :185-188.

Khidir, M.O. 1974. Genetic variability and inter-relationship of some quantitative characters in safflower. Indian J. agric. Sci; 83 :197-202.

Kenowarthy, W.J. and Brim, C.A. 1979. Recurrent selection in soybean. I seed yield. Crop sci; 19 :315-318.

Kambale, K.R., Patil, V.D. and Nerkar, Y.S. 1984. Genetic variability in chickpea under rainfed and irrigated condition. J. Maharashtra agric. Univ; 9 :284-286.

Lakha, N.M. 1989. Jentic variability in safflower. M.Sc. (Agri) dissertation submitted to M.A.U. Parbhani.

Lakha, N.M., Patil, V.D., Nerkar, Y.S. and Mahajan, A.R. 1992. Genetic variability and correlation studies in safflower. J. Maharashtra agic. Univ; 17:318-320.

Mathur, J.R., Tikka, S.B.S., Sharma, B.K., Singh, S.P. and Dashora, S.L. 1976. Genetic variability and character association in safflower. Indian J. agric. sci; 49 :766-768.

Makne, V.G., Patil, V.D. and Choudhari, V.P. 1979. Genetic variability and character association in safflower. Indian J. Agric. Sci. :49, 766-768.

Makne, V.G., Borikar, S.T. and Patil, V.D. 1985. Estimation of genetic variability and inter-relationship of yield components in safflower. Acta agronomica academiae scientiorum. Hungaricae; 34 :143-147.

Malleshappa, C., Gaud, J.V. and Patil, S.S. 1989. Path analysis for seed yield in safflower. J. Maharashtra agric. Univ; 14 :231-232.

Madrap, I.A., Nerkar, Y.S. and Makne, V.G. 1993. Genotypic correlation and path analysis studies under three environments in sunflower.J. Maharashtra agric. univ; 18 :471-472.

Narkhade, B.N., Patil, J.V. and Deokar, A.B. 1985. Estimates of variability parameters in safflower. J. Maharashtra agric. Univ; 10 :97-98.

* Nie, Z., Chen, F.T. and chi, Z.C. 1993. Analysis of characters related to yield in safflower.Oil crops in China; 3 : 26-29.

Paliwal, R.V. and Solanki, R.S. 1984. Path coefficient analysis of some components in safflower. Madras agric. Univ. J; 71 :257-258.

Pawar, D.T. 1990. Genetic variability and genetic advance in early segregating generation of safflower. M.Sc. (Agri.) dissertation submitted to M.A.U. Parbhani.

Parmeshwarappa, S.G., Patil, S.G., Salimath, P.M. and Parmeshwarappa, R. 1993. Genetic divergence and character association of black gram in different environment. J. Maharashtra agric. Univ; 18 :139-140.

Patil, F.B. 1985. Correlation of some yield components in safflower. J. Maharashtra agric. Univ; 10 :82-83.

Patil, B.R., Deshmukh, S.G. and Deshmukh, M.P. 1990. Studies on correlation and path analysis in safflower. Annals plant physiol; 4 :85-91.

Patil, S.C., Patil, F.B.,Kognole, A.A. and More, A.C. 1991. Analysis of variability and heritability in safflower. J. Maharashtra agric. Univ; 16:269-270.

Patil, A.M., Patil, D.S. and Deokar,A.B. 1992. Character association and component analysis in safflower. J. Maharashtra agric. Univ; 17 :139-140.

Ramesh, K.V., Itnal, C.J. Desai, G.S. and Sajtan, G.C. 1980. Genetic variability and correlation studies in some quantitative characters in safflower. Curr. Res. Univ. of Agric. Sci. Banglore; 9: 15-17.

Ranga Rao, Ramchandram, M. and Sharma, J.R. 1980. Multivariate analysis of genetic divergence in safflower. Indian J. Genet; 40 :73-75.

Reddy, K.R. and Gupta, R.V.S. 1992. Variability and inter-relationship of yield and its components characters in groundnut.J. Maharashtra agric. Univ; 17 :224-226.

Reddy, D.M., Sakhare, R.S., Kamble, J.C. and Rathod, T.H. 1992. Correlation and path analysis in safflower. New agriculturists; 3 :209-212.

Sengupta, K. and Bhattacharya, B. 1979. Variability in safflower. Indian agriculturists; 23 :173-178.

Shiv Raju, N. 1984. Heterosis, inbreeding depession, correlation and path coefficient analysis in selected cross combination of sunflower. (Helianthus annus L.) Mysore J. agric. sci; 22 :145-146.

Singh, V. Dembare, A.J. Despande, M.B. and Nimbkar, N. 1993. Variability and character association in safflower. J. Maharashtra agric. Univ; 18:483-484.

Thombre, M.V. and Joshi, B.P. 1977. A biometrical approach to selection problems in sunflower (Cathamus tinctorius L.) varieties. J. Maharashtra agric. Univ; 2:1-4.

Thombre, M.V. and Joshi, B.P. 1981. Correlation and path analysis in safflower varieties. J.Maharashtra agric. Univ; 6 : 191-193.

Urie, A.L. and Zimmer, D.E. 1970. Yield reduction in safflower hybrids caused by female selfs. Crop sci; 10 :419-422.

* Yazadi samadi, B., Zali, A.A. and Amirshashi, M.C. 1976. Evaluation of 1777 safflower varieties and lines for their agronomic traits. American society of Agronomy; 67.

* Originals not seen.