GENETIC VARIABILITY IN SEGREGATING GENERATION (F_3) OF SAFFLOWER (*Carthamus tinctorius* L.) WITH SPECIAL REFERENCE TO *FUSARIUM* WILT RESISTANCE

BY

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2004

Affectionately
Dedicated
To My
DADA, AAI
&
SISTERS, DAJI

CANDIDATE'S DECLARATION

I, hereby declare that this dissertation

or part thereof, has not been

previously submitted by

me for a degree of

any University.

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CERTIFICATE-I

This is to certify that ***Shri JAGTAP PRASHANT KHANDERAO*** has satisfactorily prosecuted his course and research for a period of not less than four semesters and that the dissertation entitled **"GENETIC VARIABILITY IN SEGREGATING GENERATION (F_3) OF SAFFLOWER (*Carthamus tinctorius* L.) WITH SPECIAL REFERENCE TO *FUSARIUM* WILT RESISTANCE"** 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 a degree of any university.

Place : PARBHANI
Date : 02 / 7 /2004

(Dr. B.M. Joshi)
Research Guide

CERTIFICATE-II

This is to certify that the dissertation entitled "**GENETIC VARIABILITY IN SEGREGATING GENERATION (F_3) OF SAFFLOWER (*Carthamus tinctorius* L.) WITH SPECIAL REFERENCE TO *FUSARIUM* WILT RESISTANCE**" submitted by ***Shri JAGTAP PRASHANT KHANDERAO*** to the Marathwada Agricultural University, Parbhani in partial fulfilment of the requirement for the degree of ***MASTER OF SCIENCE (Agriculture)*** 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.

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P.K.Jagtap

PARBHANI **(JAGTAP P. K.)**

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ABBREVIATIONS

h^2	=	heritability
d.f.	=	degree of freedom
cm	=	centimeter(s)
m	=	meter(s)
EGA	=	Expected genetic advance
et al.	=	and other
Fig.	=	Figure
g	=	gram (s)
GCV	=	genotypic coefficient of variance
GM	=	General mean
G	=	genotypic correlation
ha	=	hectare
kg	=	kilogram (s)
q	=	quintal
L	=	litre(s)
ml	=	mililitre(s)
%	=	per cent
viz.,	=	videlicet (namely)
N	=	North
/	=	per
h	=	hours
SE	=	Standard error
CD	=	Critical difference
CV	=	Coefficient of variation
ed	=	edited(by)
pp	=	pages
P	=	phenotypic correlation
PCV	=	phenotypic correlation of variance
lit	=	liter(s)
No.	=	number
R	=	Residual effect

Introduction

Chapter-I

INTRODUCTION

Safflower is one of the very ancient crop in India. It was referred to as "Kusumbha" in ancient Sanskrit literature. The crop was grown and exploited for various products such as oil, petals and other floral parts for nutrition, colouring of food products, garments, animal feed, medicine etc.

Besides India, countries like Mexico, U.S.A., Ethiopia, Australia, Spain, China, U.S.S.R., Argentina, Portugal etc. grow this crop.

India holds a premier position in the global oilseed scenario. India has 14 per cent of world area under oilseed crops which accounts 8 per cent worlds oilseed production (Hegde, 2002).

Globally safflower is grown in about 1.2 million hectares with annual production of 0.79 million tonnes. India ranks first in the world in the production of safflower, with about half of the world production, followed by U.S.A. with about 14 thousand tonnes annually. Recently area under safflower is 403 lakh ha with production of 2 lakh tonnes with a low average productivity of only 465 kg/ha (Anonymous, 2003).

In India, oilseeds are the second largest agricultural commodity after cereals and occupying about 13.5 per cent of the country's gross cropped area and accounting for nearly 5 per cent of gross national product and 10 per cent of value of all agricultural product (Hegde, 2000).

Though safflower can be cultivated profitably in parts of Madhya Pradesh, South Eastern Rajasthan, Eastern Uttar Pradesh, West Bengal, Orissa and Tamil Nadu, the crop is mainly confined to vertisols of peninsular India. Maharashtra and Karnataka are the two most important

safflower growing states accounting for 72 and 23 per cent of area and 63 and 35 per cent of production respectively.

Safflower seed contains 26 to 30 per cent oil and defatted cake contains 18 to 24 per cent protein. Safflower has recently gained importance as a healthy oil because of its higher content of linoleic acid (70-80 %) as compared to other vegetable oils viz., corn (56 %), soybean (50%), peanut (21 %), linseed (20 %), sesamum (35-47 %), sunflower (44.75 %), Rape seed (12.16 %) which can effectively control heart blood vessel disease (Goud *et al.*, 1997).

Safflower is grown predominantly as a ranifed crop during winter (*rabi*) season, both as pure as well as an intercrop with other *rabi* crops like sorghum, Bengal gram and wheat.

Many scientists have reported high heterosis for yield and yield contributing characters but is was not exploited due to limitation of seed production. Jambhale and Nerkar (1985) has reported genetic male sterility governed by dominant genes which segregated into 1:1 ratio for male sterility. The use of this type of male sterility has got limitations 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.

Though safflower has rich genetic base, the yield level was not demonstrating peak expression due to inherent disease problem of wilt caused by *Fusarium oxysporum* f.s. *carthami* Klisiewicz and Houston.

Fusarium wilt is appearing every year in the Marathwada region and also increasing because of continuous use of same field for safflower cultivation (Anonymous, 1987 and 1989).

However, high incidence and intensity of *Fusarium* wilt posing a new threat for successful and profitable cultivation and production in Marathwada region. Losses due to *Fusarium* wilt disease have been reported to the tune of 44 per cent (Jackson, 1985).

Wilt of safflower caused by *Fusarium oxysporum* Schlechi is the most important disease of the crop in India (Sastry and Ramchandram, 1992), Egypt (Zayed *et al.*, 1980) and U.S.A. (Kliesiewicz and Houston, 1962). The disease is now known to be endemic in the Indian Deccan Plateau (17-29°E and 70-74°N) with reports of upto 80 per cent incidence resulting in heavy yield losses, particularly under irrigated crop culture (Sastry and Ramchandram, 1992).

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 characters for 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.

On the other hand, for reducing the wilt incidence, crop rotation, use of systemic fungicides (Kalpana Sastry and Jayaraman, 1993; Chakrabarti and Basuchaudhary, 1979) and wilt tolerant varieties (Kalpana Sastry and Ramachandran, 1992) hold some promise.

In order to bring productivity and hectarage on tract, intensive efforts are being made by Ministry of Agriculture, Govt. of India and Maharashtra State, Department of Agriculture, AICRP and Agricultural Universities in India to pin point the major factors congenial for the diseases and for its effective control through genetically rich varieties available in India.

Therefore, the present investigation was undertaken to assess the genetic variability in segregating generation (F3) of safflower with special reference to *Fusarium* wilt resistance with following objectives:

1. To study genetic variability for yield and yield contributing characters.
2. To study the character association between yield and yield components
3. Screening of breeding material for *Fusarium* wilt by water culture technique.

Review of Literature

Chapter II

REVIEW OF LITERATURE

Male sterility in general is of great importance in exploitation of hybrid vigour as well as in population breeding programme. In safflower genetic male sterility system was controlled by recessive gene was reported by Heaton and Knowles (1980). Joshi *et al.* (1983) isolated male sterility which was found to be controlled by a dominant gene (Jambhale and Nerkar, 1985).

Nerkar and Jambhale (1985) reported that in the absence of cytoplasmic – genetic male sterility system, the available genetic male sterility system can be used for commercial exploitation of heterosis and in the population improvement programme.

In the present chapter the pertinent review on genetic variability, correlation coefficient and path coefficient analysis is reported as follow,

2.1 Genetic variability

Variability is the important characteristics of any population. The magnitude of genetic variability in the breeding materials determines the speed and precision of the improvement programme in a particular crop. A population with higher variability provides grater opportunity for improvement.

Several reports on genetic variability in safflower are available. However, only few of them are reviewed here.

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

Argikar and Solanki (1958) reported wide rang 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.

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 where as 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.

Yazdi Samadi *et al.*, (1976) noticed 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.

Ghanavati and Knowles (1977) developed 51 lines from the population received from the north western Iran. These lines showed considerable variation for winter hardiness, seed yield, number of capitula per plant and 100-seed weight indicating the scope for the genetic improvement of the crop.

Stoenescu (1977) exhibited highest variation for number of capitula per plant and number of seeds per capitulum in 1000 lines of safflower.

Thombre and Joshi (1977) reported high value 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 parameter were also observed for plant height and 1000-seed weight. High value of genotypic coefficient 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 safflower height, days to maturity, number of seeds per capitula, 1000-seed weight and yield per plant did not differ much in their magnitude indicating utility of phenotypic values of these characters in making selection.

Makne *et al.*, (1979) reported lower genetic coefficient of variation in safflower for most of the characters. The characters viz., 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.

Deokar *et al.* (1985) reported wide range of variability for plant height, number of capitulum per plant, 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.

Makne *et al.*; (1985) studied the genetic variability in respect of safflower at the three locations. They observed a wide range of variability for all characters at all the locations except for 100-seed weight.

Three characters viz., seeds per capitulum, seed yield per plant and 100-seed weight had high values for the genotypic coefficient of variability.

Narkhede *et al.*, (1985) observed the range for genetic coefficient of variation was from 3.4 for hull content to 29.3 for seed yield per plant, seeds per capitulum, capitula per plant and number of primary branches.

Reddy (1985) recorded considerable variation for seed yield, number of heads per plant, number of seeds per head and number of secondary branches. Number of heads per plant and number of seeds per head were the most important yield components in safflower.

Challawar (1986) reported high coefficient of variability estimates for characters primary and secondary branches, capitula per plant and seed 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 pant showed a wide range of variation.

Hudge *et al.* (1991) reported that yield component for four safflower genotypes grown during 1986. Annegiri-1 gave the highest seed yield (7.25 gm/per plant)

Reddy (1991) reported wide range of variation for most of the characters in F_3 and F_4 generations of safflower for number of primary and secondary branches per plant , number of capitula per plant and yield per plant.

Lakha (1992) information on genetic variability, heritability and genotypic and phenotyic correlation is derived from data of seed yield and 10 related characters in 22 safflower (*Carthamus tinctorius* L.) selections in the F_4 generations grown during *rabi* 1987-88. Number of

seeds per capitulum and seed yield were highly heritable characters. Correlation studies supported the recommendations.

Prakash and Prakash (1993) studied yield structure analysis of oil yield in safflower (*Carthamus tinctorius* L.) A 6 x 6 partial diallel set of 15 F_1 hybrids of 6 elite lines with high oil content, parental lines and local control Annegiri-1 were evaluated for 6 yield components, and seed oil content and oil yield per plant during winter 1989 at Annegiri, India. Additive and dominant genetic effects were equally important for most traits, including seed and oil yield per plant.

Ghorpade *et al.* (1993) reported variability for 8 yield components were assessed in 98 germplasm accessions and 5 control varieties. Variability was high for seed yield, number of primary and secondary breaches per plant and number of effective capitula, seed yield per plant was highest in GMU-398.

Singh (1993) in their study of analysis of variance showed that significant differences 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.

Subhalaxmi *et.al* (1995) reported information on variability and yield correlation by studying on eight yield related characters in 28 *Carthamus tinctorius* L genotypes grown in rainfed and irrigated cropping.

Anonymous (1996) reported variability for different characters in safflower in advance varietal trial on hybrid trial at Hyderabad in DSH-107, DSH-116, DSH-129 and DSH-130. Oil content was 33.1 per cent, 30.9 per cent, 27.1 per cent, and 27.1 per cent respectively. Hull content was 45,44,48 and 52 per cent, volume weight 451,472,523,508 gm/lit. Biological yield was 4871,5072,4549 and 6199 kg/ha and harvest index 30.4,32.3,40.2 and 33.8 per cent respectively in the above genotypes.

Anonymous (1998) reported variability for different characters in safflower in advanced varietal trial at Hyderabad in JLSF-324, JLSF-344 and NARI-2, Oil content was 24.4 per cent, 23.7 per cent and 25 per cent respectively. Hull content was 53.1, 50.4 and 50.3 per cent. Biological yield as 6113, 3504 and 1913 kg/ha respectively and harvest index 21.3, 23.6 and 26.1 percent respectively in the above genotypes.

Patil (1998) reported the presence of substantial genetic variability in the genotypes studied. The range varied from 6.20 for days to maturity to 29 for seed yield per plant. The value of GCV and PCV for number of effective capitula per plant, seed yield per plant, number of primary branches and number of secondary branches was more.

Choudhary *et al.* (1999) observed high phenotypic and genotypic variation in seed yield per plant, number of capitula per plant and plant height. High phenotypic coefficient of variation and genotypic coefficient of variation values were observed for number of capitula per plant and plant height.

Mane (1999) reported highest phenotypic coefficient of variation for number of seeds per capsule (18.17) followed by number of secondary branches (17.48).

Senapati *et al.*, (1999) reported high phenotypic and genotypic variances in seed volume weight and minimum in biological yield. The PCV had high estimates than the corresponding GCV. Number of capitula per plant and days to maturity showed the highest and lowest PCV and GCV.

Lahane *et al.* (1999) showed high genotypic coefficient of variation for number of seeds per capitulum, number of capitula per plant, number of branches per plant and test weight.

Parmeshwarappa *et al.*, (2000) reported increase in genetic variability due to intermating, positive and significant shift were observed

in the association of capitula weight and number of capitula with seed yield. Significant alterations were found in respect of capitula number and weight, kernal and oil content and capitulum size and seed number.

2.2 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.

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

Abel (1976) reported high, broad sense heritability for 1000 seed weight, moderate for plant height, number of primary branches per plant and low for capitulum size and seed number per capitulum.

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 viz., number of branches per plant, seed per capitulum, capitulum number, 100 seed weight and days to first flowering, indicating the control of additive gene action.

Mathur *et al.* (1976) reported high broad sense heritability for the characters such as days to flowering (98.18 %), seed yield per plant (94.73 %) and number of seeds per capitula (87.78 %) and moderate heritability values for number of capitula per plant and plant height, low heritability values for test weight in safflower.

Deokar and Patil (1978) reported high genetic advance for the characters plant height, number of seeds per capitulum and 1000 seed weight indicating these characters are less influenced by the environment.

Sengupta and Bhattacharya (1979) analysed the data on yield and 4 components traits from 137 forms and observed that plant height at maturity gave high estimates for broad sense heritability and genetic advance. Selection for height showed 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 seeds per capitulum.

Channeshappa (1980) reported high broad sense heritability values for the characters oil content, 100 seed weight and plant height in safflower.

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.

Kotecha (1981) reported moderate heritability values for number of seeds per capitulum and seed yield per plant. Very high heritability values for oil per cent and 100-seed weight and high heritability for capitulum size and low heritability for seed yield per plant were observed in safflower.

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 particularly high for number of seeds per capitulum.

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

Gupta and Singh (1990) studied 45 F_1's from a ten parent diallel without reciprocals and data was analyzed to obtain information on heritability, genetic advance and correlation on seed yield, it's 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 characters in twenty two safflower selections in F_4 generations grown during *rabi* 1987-88. Number of seeds 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 % flowering, plant height and seed yield.

Pandya *et al.* (1996) reported highest genetic coefficient of variation for grain yield per plant, number of capitula per plant, 100-seed weight and number of secondary branches per plant. High heritability was

recorded for days to 50 % flowering, grain yield per plant, 100-seed weight, number of capitula per plant and plant height. Grain yield per plant, number of capitula per plant and 100-seed weight had high genetic advance coupled with high heritability.

Patil (1998) observed high heritability coupled with high genetic advance for seed yield per plant, plant height and number of seeds per capitulum.

Choudhary *et al.* (1999) reported that characters like plant height, 100-seed weight and seed yield per plant showed high heritability. Seed yield per plant, plant height number of capitula per plant were having higher degree of genetic advance with high heritability value.

Mane *et al.* (1999) reported high heritability estimates with high genetic advance for characters viz., number of secondary branches, number of seeds per capsule, plant height and number of capitula per plant.

Senapati *et al.* (1999) observed that heritability estimates were higher in all traits except days to 50 per cent flowering and maturity. The expected genetic advance was the highest for yield per plant and lowest for days to maturity.

2.3 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 lines of soybean in F_4 generation. He reported that genetic correlation among

characters for which selection is practiced may have important implication in breeding procedures, they painted out that effective selection for yield in soybean is more different and requires more replications over years, locations and individuals tests that selection for other important characters.

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 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 capitulum, capitula width and oil content with seed yield. The test weight was negatively correlated with number of seeds per capitulum and plant height.

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. Similar findings were reported by Rao *et al.* (1979), Sengupta and Bhattacharya (1979) and Solanki *et al.* (1979).

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.

Ramchandran and Goud (1982) reported significant positive association of seed yield per capitulum, stem girth, plant height, diameter of capitulum per plant, total number of capitulum in grain yield. The direct effect of these components were high.

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.

Patil *et al.* (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.

Shymali *et al.* (1986) reported positive and significant correlation of seed yield per plant with number of capitulum per plant, seed per capitulum and seed weight.

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.

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.

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.

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 the seed weight had maximum direct positive effect on seed yield. The difference in yield potential of high and low yield genotype was due to differences in seed weight and capitula per plant.

Subhalakshmi *et al.* (1995) studied 28 genotypes of safflower and reported that the simple correlation between yield and six components indicated wide variation in inter-relationship of characters. The number of branches and number of heads per plant were inter-related.

Patil (1998) observed a positive association among the traits viz., number of primary branches per plant, number of secondary branches

per plant, number of seeds per capitulum, number of capitula per plant and 100-seed weight and their positive association with seed yield was also noted. Path analysis indicated that due weightage should be given to 100 seed weight, number of capitula per plant and number of primary branches per plant during selection.

Choudhary *et al.* (1999) reported positive and significant correlation between number of primary branches with number of capitula per plant at both levels. Path coefficient analysis revealed that 100-seed weight, number of primary branches per plant and days to 50 per cent flowering were having maximum direct contributions towards seed yield per plant. Number of capitula per plant was found to have negative effect on seed yield.

Senapati *et al.* (1999) reported that yield showed high positive correlations with number of capitula per plant and biological yield. Plant height, branches per plant and 100-seed weight showed positive correlations with yield. It was concluded that selection should be based on number of capitula per plant, 100-seed weight and yield per plant.

Lahane *et al.* (1999) revealed that number of seeds per capitulum exhibited positive and significant correlation with seed yield per plant and oil content. The other characters showed non-significant correlation with seed yield per plant.

Kubsad *et al.* (2000) revealed that seed yield exhibited higher positive association with 100-seed weight (0.410) followed by seeds per main capitulum (0.374), dry matter per plant (0.367). Path analysis showed that dry matter per plant (0.457) had maximum contribution towards seed yield per plant which was closely followed by seeds per main capitulum (0.421), 100-seed weight (0.294)and diameter of main capitulum.

Omidi tabrizi (2000) confirmed that the yield of plant was significantly correlated with biomass, number of heads, 100-seed weight,

number of secondary branches and oil yield per plant. The highest correlation coefficient was obtained between yield of plant and yield of plot (0.97). Path analysis showed that the highest direct effect on seed and oil yield per plant corresponded to biomass which was indirectly influenced by number of heads per plant. The seed yield had highest direct effect on oil yield.

2.4 Screening by water culture technique

Fusarium wilt being a soil borne disease, it is very difficult to manage by chemical means. Therefore to find out good sources of resistant genotypes and breeding resistant varieties will be the solution to minimise economic losses. Success in evolving breeding resistant varieties against soil borne pathogens largely depends upon the efficiency of the screening technique or method used.

Numerous workers employed various laboratory as well as field technique in identifying the sources of resistant genotypes. The available review on this aspects is cited.

Knowles et al. (1968) examined several seed samples of safflower (*Carthamus tinctorius* L.) for *F. oxysporum* f. s.p. *carthami* under laboratory conditions and reported that genetic stock numbers 4(-2) –4(-6) were resistant to wilt pathogen.

Klisiewicz and Thomas (1970b) screened various breeding material for reaction of *Fusarium oxysporum* f. sp. *Carthami* causing wilt and observed that there were two different pathogen races on the basis of reaction on the breeding lines. They reported that Nebraska 4051 was resistant to both pathogens races.

Klisiewicz and Thomas (1970c) further carried out screening work of various safflower genotypes. Again they reported the presence of third pathogenic race which A-14154, 49 and 2151 were good sources of resistance to all three races.

Wilt pathogen mainly being soil borne could be controlled by host resistance in past. Introduction, selection, hybridization and mutation were traditionally accepted methods of using host resistance (Agrios, 1973).

High rate of tylose formation to block further invasion of vascular pathogen was supposed to be the indication of high level of host resistance (Agrios, 1973).

Thomas and Hill (1977) studied the effect of the plant age on reaction of eight safflower cultivars to *Fusarium* wilt. He compared the inoculation of plant by planting seed in infected soil and plants grown 21 days in non infected soils and then inoculated by root deep procedure. He observed 4 types of reaction of susceptibility and resistance on the basis of cultivar reactions. He finally concluded that inoculation of plant at both the agencies needed to evaluate cultivar resistance accurately.

Nirmal (1985) screened 52 safflower varieties for resistance against *Fusarium* wilt and reported that NS 1016, HOP 22, MVT 28, BLY 211, BLY 1080 were resistant to diseases and further noted the moderately resistant reaction of N 248, JLSF 7L and HOP 116.

Pedgaonkar and Mayee (1989) screened 34 safflower genotypes in vitro by water culture technique and in vivo in side pot. JLSF 88 and N 248 showed 20 and 40 per cent wilting respectively as against 100 % wilting in all other genotypes tested by water culture technique. However, in field tests none of the accessions was free from wilt. However, 14 cultivars were moderately resistant and 13 were tolerant.

Nagale (1989) screened 34 safflower genotypes against *Fusarium* wilt by water culture technique and reported that none of the genotypes had shown resistant type of reaction. However, JLSF 88, 708, CTV 9, N 887, NES 29-75, CTV 88, BLY 652, N 62-8, JLSF 80, JLF 98 were observed tolerant (40% wilt mortality) cultivars Annegiri NC 1582-2,

Tora and JLSF 94 were susceptible and remaining 20 were high susceptible.

Phad and Jagtap (1990) screened safflower germplasm lines against wilt disease and reported that lines SSF 16, JSI 9, BS 506, B 20, WA 300, SSF 48, NS 10-60, NS 90 A, JLSF 47, P 57-2 had shown tolerant reaction. Other germplasm lines showed high susceptibility where NS 133 (check) showed 40% wilting.

Deokar (1993) screened 170 safflower genotypes against *Fusarium oxysporum* f. sp. *carthami* by water culture technique and found that five genotypes viz., GMU 849, 850, 861, 875 and CTV 218 were free from wilt reaction while seven genotypes viz., GMU 841, 509, 946, 1415, 1469, 1518 and 1582 were moderately resistant. Genotype GMU 1071 was observed to be tolerant. Rest of the genotypes recorded susceptible and highly susceptible reaction.

Materials and Methods

Chapter-III

MATERIALS AND METHODS

3.1 Experimental material

The experimental materials comprised of F_3 progenies of 8 genotypes along with 2 checks viz., local check (LC) Sharda and national check (NC) Annegiri-1 with 3 replications and further screening of breeding material for *Fusarium* wilt by water culture technique as suggested by Nene *et al.* (1981) for screening chickpea wilt. The experiment was conducted at farm of Department of Genetics and Plant Breeding, Marathwada Agricultural University, Parbhani.

The list of the F_3 progenies.

Sr. No.	Crosses	No. of selections
1.	MS 11 x A2	25
2.	MS 11 x GMU 1735	25
3	CTH 25 x JLSF 325	25
4	Sel 7 x GMU 1751	25
5	MS 11 x PH-3	25
6	JLSF 341 x A1	25
7	MS 11 x IV 92-2-2	25
8	MS 11 x GMU 1962	25
9	Sharda (LC)	10
10	Annegiri-1 (LC)	

3.2 Experimental methods

3.2.1 Layout and sowing

Eight F_3 progenies along with 2 check varieties i.e. Annegiri-1 and Sharda, were grown in rabi season 2003-04 under irrigated conditions

in randomised block design with three replications at the experimental farm of Department of Genetics and Plant Breeding, M.A.U., Parbhani. The experimental details were as follows.

Number of F_3 progenies	:	08
Checks	:	02
Row to row distance	:	45 cm
Plant to plant distance	:	20 cm
Fertilizer dose (irrigated)	:	As per recommended dose (60:40:40 kg/ha)
Experimental design	:	Randomised block design
Replications	:	03
Plot size	:	Gross 2.70 m x 5.00 m Net 1.80 m x 4.60 m

The experimentals material was sown on 17th October 2003 in a randomised block design with 3 replications under irrigated conditions. Two hand weedings were carried out, first at 20 days after sowing and 2nd at 45 days after sowing. Two irrigations were given as first at 45 and second at 75 days after sowing of the crop. Two spraying of endosulfan 35 EC and one spray of bavistin was done to control aphids and leaf diseases, respectively.

3.3 Screening of breeding material by water culture technique

Out of the 10 genotypes studied for genetic variability, only 4 genotypes and their parents were subjected to wilt screening purpose. Those were as follows.

1.	MS 11	Female
2.	GMU 1735	Male
3.	GMU 1962	Male
4.	IV 92-2-2	Male
5.	A2	Male

F_3 progenies

6. Sterile 11 x A2
7. Sterile 11 x GMU 1735
8. Sterile 11 x GMU 1962
9. Sterile 11 x IV 92-2-2

3.3.1 Isolation of fungus

Fungus was isolated by usual laboratory method by inoculating the soil incubated seeds of above listed material on *Fusarium* specific medium, after sterilization with 0.1 % HgCl2 and passing through 3 changes of sterile water and finally the isolated fungus was identified as *Fusarium oxysporum* f. sp. carthami.

3.3.2 Screening of safflower genotypes against *Fusarium* wilt by water culture technique

To find out sources of resistance in various genotypes against wilt diseases, generally sick plot or pot screening techniques are used. These techniques are laborious and time consuming. Therefore, to know disease reaction of various cultivars and to standardise quick method for screening safflower genotypes against *Fusarium* wilt disease, a water culture technique as suggested by Nene *et al.* (1981) for screening the chickpea wilt (*Fusarium oxysporum* f. sp. ciceri) was tried.

The 10 to 12 days old seedling already raised in sterilized sand were carefully uprooted. Such seedlings were washed in running tap water and then rinsed with sterile distilled water. One seedling was transplanted into each test tube containing 2.5 % concentration of culture. Sixteen seedling of each breeding material were used and also non inoculated seedling of each test line as control.

3.3.3 Observation taken in laboratory

Seedling mortality

Observations were recorded for seedling mortality (wilting) upto 4 days in *Fusarium* culture. Disease intensity score was recorded as per disease rating suggested by Mayee and Datar (1986).

3.4 Field observations

Randomly 25 plants were selected from each treatment for recording observations. Observations were recorded separately on each selected plant. Average value for each character was compared from these plants separately for each genotype. Following observations were recorded.

3.4.1 Days to 50 per cent flowering

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

3.4.2 Days to complete maturity

Average number of days required for complete maturity of plants were recorded.

3.4.3 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.

3.4.4 Number of primary branches per plant

At the maturity, total number of effective branches on mainstem shoot were counted as primary branches from each of the selected plant.

3.4.5 Number of secondary branches per plant

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

3.4.6 Number of capitula per plant

Total number of capsules were recorded per plant at maturity.

3.4.7 Number of seeds per capsules

On each plant seeds from five capsules were counted and average number of seeds per capsule was computed.

3.4.8 Test weight (g)

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

3.4.9 Oil content (%)

Oil content (%) is determined by using Soxhlet's procedure.

3.3.10 Harvest index (%)

It is the ratio of seed yield to biological yield expressed in percentage.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

3.4.11 Volume weight of seeds (g/lit)

Seeds filled in a measuring cylinder or a beaker of a one liter capacity and find out the weight of the liter of seeds where the quantity of the seed is less, 500 or 100 ml measuring cylinder or beaker used and expressed the volume weight in g/liter.

3.4.12 Seed yield per plant (g)

The capsules of twenty five randomly selected plants were threshed separately and average weight of the seeds per plant was calculated. Similarly, the per plot yield was recorded.

3.5 Statistical methods

3.5.1 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 :

Sr. No.	Source of variation	d.f.	MSS	Variance ratio 'F' observed	Table 'F'
1.	Replication	(r-1)	$\sigma^2e + r\sigma^2g$		
2.	Treatment	(t-1)	$\sigma^2e + r\sigma^2g$		
3.	Error	(r-1) (t-1)	σ^2e		
	Total	(rt-1)			

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

Where,

EMSS = error mean sum of squares

r = number of replication

Critical difference (CD) = S.E. x $\sqrt{2}$ x 't'

Where

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

3.5.2 Genetic variability

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

1. Genotypic variance (σ^2g)

$$\sigma^2g = \frac{TRMSS - EMSS}{r}$$

2. Phenotypic variance (σ^2p)

$\sigma^2p = \sigma^2g$ + error variance (σ^2e)

where,

σ^2e = MSS due to error

3. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{x}} \times 100$$

4. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100$$

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

$\bar{x}$ = general or grand mean of character

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

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

Where,

$\sigma^2 g$ = genotypic variance

$\sigma^2 p$ = phenotypic variance

$$\text{Genetic advance} = h^2 \times K \times \sqrt{\sigma p}$$

Where,

h^2 (b.s.) = heritability

K = selection difference at 5 per cent 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

3.5.3 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 level was worked out according to Johnson *et al.* (1955).

Genotypic correlation coefficient rg_{xy}

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

Where,

Cov ($g_X g_Y$) = Genotypic covariance between character x and y.t.

$\sigma^2 g_X$ and $\sigma^2 g_Y$ = genotype variance of character x and y respectively.

Similarly,

Phenotypic correlation coefficient (rP_{xy})

$$rP_{XY} = \frac{Cov\ (P_x \cdot P_y)}{\sqrt{\sigma^2 P_x \cdot \sigma^2 P_y}}$$

where,

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

$\sigma^2 p_x$ and $\sigma^2 p_y$ = phenotypic variance of characters x and y.

3.5.4 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 coefficient were calculated by solving the following set of 'p' simultaneous equation by the abbreviated Doolittle technique.

$P_{01} + P_{02} + r_{12} + \ldots\ldots\ldots\ldots P_{op}\, r_{ip} = r_{0i}$

$P_{01}\, r_{12} + P_{02} + \ldots\ldots\ldots\ldots P_{op}\, r_{2p} = r_{02}$

$P_{o1} r_{10} + P_{02} r_{2p} + \ldots\ldots\ldots\ldots P_{op} = r_{op}$

P_{o1}, P_{02} ..... P_{op} are the path effect of 1, 2 ..... p variables, on 'o' variable.

r_{12}, r_{13} ..... r_{1p} ..... r_{op} (p-1) are the possible correlation coefficient between various independent variable and r_{01}, r_{02} ..... r_{op} are the correlation of independent variables with dependant variable.

The direct effect of i^{th} variable via j^{th} variable was worked out as (P_{oj} x P_{ij})

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

Residual effect was calculated as under.

$P^2ox = 1 - (P^2_{01} + {}^2P_{01}P_{02}r_{12} + 2P_{01}\, Po_3\, r_{13} + P^2o_2 + 2P_{02}\, P_{03}\, r_{23} + \ldots\ldots\ldots\ldots P^2op)$.

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

Results

Chapter-IV

RESULTS

The present investigation was undertaken with 8 F_3 progenies and two check varieties viz., Sharda and Annegiri-1 in safflower (*Carthamus tinctorius* L.).

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

1. Mean performance
2. Genetic variability
3. Correlation
4. Path coefficient analysis for yield and yield contributing characters
5. Screening of breeding material for *Fusarium* wilt by water culture technique

The analysis of variance revealed that differences among the F_3 progenies in respect of all the characters studied were significant (Table 1).

4.1 Mean performance

The mean performance of the F_3 progenies studied are given in the Table 2.

4.1.1 Yield and yield components

4.1.1.1 Days to 50 per cent flowering

Days to 50 per cent flowering ranged from 88.66 to 97.66 days with mean of 92.35 days.

Table 1 : Analysis of variance for different characters in F_3 generation of safflower

Source of variance	d.f.	Mean sum of squares											
		Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Seed yield/ plant (g)
Replications	2	10.82	8.55	0.23	0.46	0.013	0.019	0.037	0.024	0.28	1.61	10.03	0.39
Treatments	9	28.84*	63.54**	466.94**	7.28**	48.53**	54.06**	82.58**	0.14*	8.09**	12.53**	1899.1**	53.97**
Error	18	10.29	15.58	0.819	0.35	1.29	1.92	2.72	0.057	1.72	1.19	78.62	6.081

* and ** indicates significance at 5 and 1 per cent level respectively.

Table 2 : Mean performance of F_3 progenies for yield and yield contributing characters in safflower

Sr No	Materials	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Seed yield/ plant (g)
1.	MS 11 x A2	97.66	139.67	102.43	8.63	14.24	32.63	45.23	5.40	27.83	29.18	605.73	41.06
2.	MS 11 x GMU 1735	96.33	133.33	101.35	10.86	22.10	31.10	42.06	5.10	29.60	30.37	597.53	37.80
3.	CTH 25 x JLSF 325	88.66	140.33	96.90	9.88	13.10	31.76	43.00	5.02	28.76	29.61	590.87	38.56
4.	Sel. 7 x GMU 1751	93.50	140.33	89.33	10.44	21.10	31.83	45.60	5.30	28.63	25.88	601.37	39.90
5.	MS 11 x PH-3	90.66	138.33	77.90	9.00	13.53	29.63	40.60	4.80	30.90	27.41	571.53	36.53
6.	JLSF 341 x A1	91.83	138.00	74.40	9.58	21.08	30.13	41.26	4.80	30.06	32.22	567.80	37.26
7.	MS 11 x IV 92-2-2	90.33	129.33	74.44	6.08	12.28	27.46	39.56	5.00	31.23	28.10	557.47	34.40
8.	MS 11 x GMU 1962	91.16	132.33	79.22	6.91	11.17	25.60	39.10	4.83	32.20	26.18	554.97	31.53
9.	Sharda	88.66	128.50	70.18	7.71	15.43	19.43	29.73	4.96	32.20	26.18	537.73	28.46
10.	Annegiri-1	94.66	139.00	72.56	7.77	17.31	23.90	31.76	5.33	32.33	28.97	540.40	30.36
	G.M.	92.35	135.92	83.87	8.69	16.13	28.35	39.79	5.05	30.37	28.89	572.54	35.59
	SE ±	1.85	2.27	0.52	0.34	0.65	0.80	0.95	0.13	0.75	0.63	5.11	1.42
	CD at 5%	5.49	6.76	1.55	1.01	1.95	2.37	2.82	0.41	2.24	1.87	15.18	4.22

Among the progenies of F_3's, CTH 25 x JLSF 325 had shown earliest values for days to 50 per cent flowering (88.66 days) while the F_3 progeny of MS 11 x A2 was found late (97.66 days).

The F_3 progenies viz., CTH 25 x JLSF 325 (88.66 days), MS 11 x IV 92-2-2 (90.33 days), MS 11 x PH-3 (90.66 days), MS 11 x GMU 1962 (91.16 days), JLSF 341 x A1 (91.83 days) and selection 7 x GMU 1751 (93.50 days) exhibited earliness than the national check Annegiri-1 (94.66 days) while only CTH 25 x JLSF 325 (88.66 days) exhibited coincidence with the earlier check Sharda (88.66 days).

4.1.1.2 Days to maturity

Days to maturity ranged from 128.50 to 140.33 days with mean of 135.92 days. The progeny of MS 11 x IV 92-2-2 (129.33 days) was found earlier than all the progenies. The CTH 25 x JLSF 325 (140.33 days), Selection 7 x GMU 1751 (140.33 days) were late in maturity.

The segregating progenies viz., MS 11 x IV 92-2-2 (129.33 days), MS 11 x GMU 1962 (132.33 days), MS 11 x GMU 1735 (133.33 days), JLSF 341 x A1 (138.00 days) and MS 11 x PH-3 (138.33 days) matured earlier than the national check Annegiri-1 (139.00)and were late than local check Sharda (128.50 days).

4.1.1.3 Plant height (cm)

Wide variation was observed for plant height which ranged from 70.18 to 102.43 cm with a general mean of 83.87 cm. The plant height of checks viz., Sharda and Annegiri-1 were 70.18 and 72.56 cm respectively. Plant height recorded by all the F_3 progenies viz., MS 11 x A2 (102.43 cm), MS 11 x GMU 1735 (101.35 cm), CTH 25 x JLSF 325

(96.90 cm), Selection 7 x GMU 1751 (89.33 cm), MS 11 x GMU 1962 (79.22 cm), MS 11 x PH-3 (77.90 cm), MS 11 x IV 92-2-2 (74.44 cm) and JLSF 341 x A1 (74.40 cm).and were found more than both checks .

4.1.1.4 Number of primary branches

Number of primary branches per plant ranged from 6.08 to 10.86 with a general mean of 8.69. Sharda and Annegiri-1 had 7.71 and 7.77 number of primary branches per plant respectively. Significantly more number of primary branches per plant were observed by F_3 progeny derived from cross MS 11 x GMU 1735 (10.86), selection 7 x GMU 1751 (10.44), CTH-25 X JLSF-325 (9.88), JLSF-341 X A-1 (9.58), MS 11 X PH-3 (9.00) and MS 11 X A2 (8.63) than both the checks and are at par with both the checks.

Only two progenies viz., MS 11 x IV 92-2-2 (6.08) and MS 11 x GMU 1962 (6.91) observed lower number of primary branches per plant than both the checks.

4.1.1.5 Number of secondary branches

Number of secondary branches per plant ranged from 11.17 to 22.10 with a general mean of 16.13. The progenies derived from cross MS 11 x GMU 1735 (22.10), selection 7 x GMU 1751 (21.10) and JLSF-341 X A1 (21.08) recorded significantly more number of secondary branches per plant than the national check Annegiri-1 (17.31) and local check Sharda (15.43).

Less number of secondary branches per plant were recorded by F_3 progenies of the crosses MS 11 x GMU 1962 (11.17), MS 11 x IV 92-2-2 (12.28), CTH 25 x JLSF 325 (13.10) and MS 11 x PH-3 (13.53).

4.1.1.6 Number of capitula per plant

Number of capitula ranged from 19.43 to 32.63 with a general mean of 28.35. The segregating progenies were found significantly superior in respect of number of capitula per plant than Annegiri -1 (NC) and Sharda (LC) except the progeny MS 11 X GMU 1962 (25.60). Highest number of capitula per plant recorded by the progeny MS 11 X A2 (32.63) than both the checks.

4.1.1.7 Number of seeds per capitulum

Number of seeds per capsules ranged from 29.73 to 45.60 with an average value of 39.79. All the F_3 progenies were recorded significantly more number of seeds per capsules than both checks Sharda (29.73) and Annegiri-1 (31.76).

Among the progenies, highest number of seeds per capsule were recorded by the progeny Selection 7 x GMU 1751 (45.60) while lowest number of seeds per capsule was recorded by the progeny MS 11 x GMU 1962 (39.10).

4.1.1.8 Test weight (g)

Test weight ranged from 4.80 to 5.40 g with a general mean of 5.05 g. The progeny MS 11 X A2 (5.40 g) was recorded significantly more test weight than Sharda (LC) followed by selection 7 x GMU 1751 (5.30 g) and MS 11 X GMU 1735 (5.10 g) while all other progenies had less test weight than both the checks.

4.1.1.9 Oil content

Oil content ranged from 27.83 to 32.33 per cent with an average value of 30.37 per cent. The oil content recorded by the F_3

progeny derived from the cross MS 11 X GMU 1962 (32.20 per cent) was similar to the local check Sharda (32.20 per cent) while rest of the genotypes showing lower oil content than both the checks.

4.1.1.10 Harvest index (%)

The harvest index ranged from 25.88 to 32.22 per cent with a general mean of 28.89.

The genotypes viz., JLSF-341 X A1 (32.22 %), MS 11 X GMU 1735 (30.37 %), CTH-25 X JLSF-325 (29.61 %) MS 11 X A2 (29.18 %) and MS11XIV 92-2-2 (28.10 %) were found significantly superior in respect of harvest index than local check Sharda (26.18 %).

Only one progeny JLSF-341 X A1 showed significantly higher harvest index than national check Annegiri -1 (28.97 %)

4.1.1.11 Volume weight of seeds (g/litre)

Volume weight of seed varied from 537.73 to 605.73 g/litre with a general mean of 572.54.

The checks viz., Sharda and Annegiri-1 had 537.73 g/litre and 540.40 g/litre volume weight. All the F_3 genotypes were found significantly superior over both the checks in respect of volume weight of seeds (g/l) except MS 11 X GMU 1962. Amongest all the genotypes, MS 11 x A2 (605.73 g/l) showed highest volume weight.

4.1.1.12 Seed yield per plant (g)

Seed yield per plant ranged from 28.46 to 41.06 g with a general mean of 35.59 g.

The F_3 progenies viz., MS 11 x A2 (41.06 g), Sel. 7 x GMU 1751 (39.90 g), CTH 25 x JLSF 325 (38.56 g), MS 11 x GMU 1735 (37.80

g), JLSF 341 x A1 (37.26 g), MS 11 x PH-3 (36.53 g) and MS 11 x IV 92-2-2 (34.40 g) were found significantly superior for seed yield/plant than checks Annegiri-1 (30.36 g) and Sharda (28.46 g).

4.2 Genetic parameters

The character under investigation were analysed for genotypic variance ($\sigma 2g$), phenotypic variance ($\sigma 2p$), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and expected genetic advance (EGA) and are presented in Table 3.

4.2.1 Days to 50% flowering

It is revealed from table that the range for days to 50% flowering was from 88.66 to 97.66 days. Genotypic variance (6.17) was lower than phenotypic variance (16.51). The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were 2.69 and 4.40 per cent, respectively. Low heritability estimates (37.5 per cent) coupled with low expected genetic advance were observed.

4.2.2 Days to maturity

The character varied from 128.50 to 140.33 days. GCV and PCV for days to maturity were 2.94 and 4.13 per cent, respectively. Genotypic and phenotypic variance values were 15.96 and 31.51 respectively. Medium heritability estimates (50.6) coupled with low expected genetic advance (4.31) were observed.

4.2.3 Plant height

A wide range of variation was observed for this trait and ranged from 70.18 to 102.43 cm. The genotypic and phenotypic variance were very high (155.32 and 156.16 respectively). The genotypic and

Table 3: Parameters of genetic variability for yield and yield contributing characters in safflower

Sr. No.	Characters	Range	General mean	Genotypic variance (6^2g)	Phenotypic variance (6^2p)	GCV (%)	PCV (%)	Herita-bility (%)	Genetic advance	EGA (%)
1.	Days to 50 % flowering	88.66 – 97.66	92.35	6.17	16.51	2.69	4.40	37.5	3.14	3.40
2.	Days to maturity	128.50-140.33	135.92	15.96	31.51	2.94	4.13	50.6	5.86	4.31
3.	Plant height (cm)	70.18-102.43	83.87	155.32	156.16	14.86	14.90	99.5	25.61	30.53
4.	Number of primary branches per plant	6.08-10.86	8.69	2.31	2.66	17.49	18.77	86.8	2.92	33.60
5.	Number of secondary branches per plant	11.17-22.10	16.13	15.73	17.03	24.59	25.59	92.4	7.86	48.72
6.	Number of capitula per plant	19.43-32.63	28.35	17.36	19.30	14.70	15.50	90.0	8.15	28.74
7.	Number of seeds per capitulum	29.73-45.60	39.79	26.63	29.32	12.97	13.61	90.7	10.12	25.43
8.	Test weight (g)	4.80-5.40	5.05	0.030	0.08	3.46	5.88	34.7	0.21	4.15
9.	Oil content (%)	27.83-32.33	30.37	2.12	3.84	4.80	6.46	55.2	2.23	7.34
10.	Harvest index (%)	25.88-32.22	28.89	3.78	4.97	6.73	7.72	75.9	3.49	12.08
11.	Volume wt. (g/l)	537.73-605.73	572.54	606.10	684.61	4.30	4.57	88.5	47.75	8.30
12	Seed yield/plant (g)	28.46-41.06	35.59	15.97	22.03	11.23	13.19	72.4	7.00	19.66

phenotypic coefficient of variation for plant height were 14.86 and 14.90, respectively. Highest estimates of heritability (99.5 per cent) coupled with high expected genetic advance (30.53 per cent) were observed.

4.2.4 Number of primary branches per plant

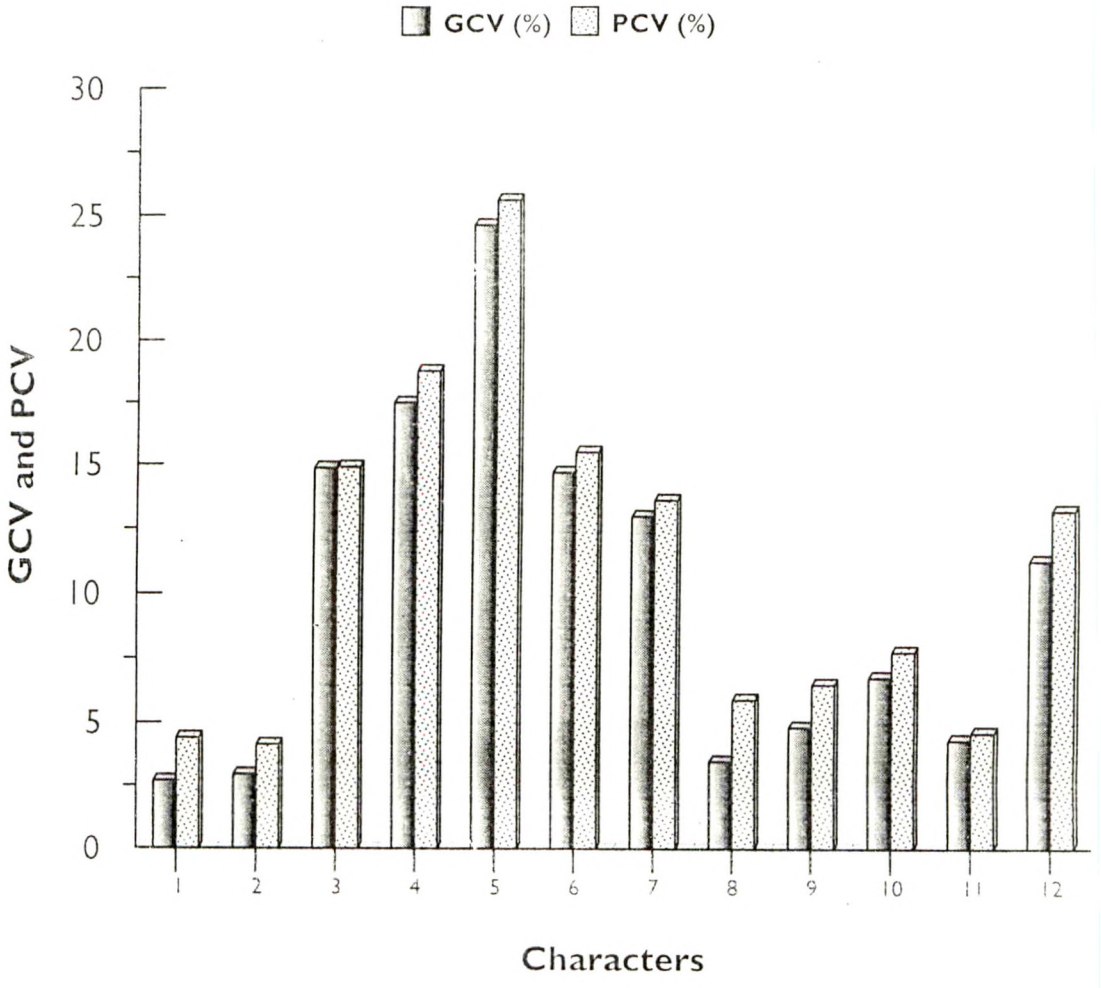
It is evident from Table 3 that number of primary branches per plant ranged from 6.08 to 10.86. The phenotypic variance (2.66) was higher than genotypic variance (2.31). Genotypic coefficient of variation (17.49 per cent) was lower than phenotypic coefficient of variation (18.17 per cent). Higher estimates of heritability (86.8 per cent) coupled with high expected genetic advance (33.60 per cent) were recorded.

4.2.5 Number of secondary branches per plant

Variation for the number of secondary branches per plant was ranging from 11.17 to 22.10. Genotypic variance (15.73) was lower than phenotypic variance (17.03). Genotypic and phenotypic coefficient of variation were 24.59 and 25.59 per cent, respectively. High heritability estimates (92.4 per cent) coupled with high expected genetic advance (48.72 per cent) were recorded.

4.2.6 Number of capitula per plant

A wide range of variation was observed for this character and was ranging from 19.43 to 32.63. The value for genotypic and phenotypic variance for the number of capitula per plant were 17.36 and 19.30 respectively. Genotypic and phenotypic coefficient of variation were 14.70 and 15.50 per cent, respectively. High heritability estimates (90 per cent) coupled with high expected genetic advance (28.74 per cent) were observed.



1. Days to 50 % flowering
2. Days to maturity
3. Plant height (cm)
4. Number of primary branches per plant
5. Number of secondary branches per plant
6. Number of capitula per plant
7. Number of seed per capitulum
8. Test weight (gm)
9. Oil content (%)
10. Harvest index (%)
11. Volume weight (g/lit)
12. Seed yield per plant (gm)

Fig. 1. Genotypic and phenotypic coefficients of variance for yield and its contributing components

4.2.7 Number of seeds per capitulum

The character number of seeds per capitulum has range from 29.73 to 45.60 with an average value of 39.79. Genotypic variance (26.63) was lower than phenotypic variance (29.32). Genotypic and phenotypic coefficient of variation were 12.97 and 13.61, respectively. High heritability estimate (90.7 per cent) coupled with high expected genetic advance (25.43 per cent).

4.2.8 Test weight (g)

The range for the test weight varied from 4.80 to 5.40 g. Low genotypic (0.030) and phenotypic variance (0.08) were observed. Genotypic coefficient of variation (3.46 per cent) was lower than phenotypic coefficient variation (5.88 per cent). The moderate heritability estimate (34.7 per cent) coupled with low expected genetic advance (4.15 per cent) were observed.

4.2.9 Oil content (per cent)

The range for oil content varied from 27.83 to 32.33 per cent. The genotypic variance (2.12) and phenotypic variance (3.84) were low. Genotypic coefficient of variation (4.80 per cent) were lower than phenotypic coefficient of variation (6.46 per cent). High heritability estimates (55.2 per cent) coupled with low expected genetic advance (7.34 per cent) were observed.

4.2.10 Harvest index (%)

Range for harvest index varied from 25.88 to 32.22 per cent. Genotypic (3.78) and phenotypic (4.97) variance were lower. Genotypic coefficient of variation (6.73) was lower than phenotypic coefficient of

variation (7.72 per cent). High heritability estimates (75.9) coupled with low expected genetic advance (12.08 per cent) were observed.

4.2.11 Volume weight (g/l)

There was wide range for volume weight which varied from 537.73 to 605.73 g/l. Genotypic variance (606.10) and phenotypic variance (684.61) were very high. Genotypic and phenotypic coefficient of variation were 4.30 and 4.57 per cent, respectively. High heritability estimate (88.5 per cent) coupled with low expected genetic advance (8.30 per cent) was observed for volume weight.

4.2.12 Seed yield per plant (g)

A wide range for seed yield per plant from 28.46 to 41.06 g was observed. The genotypic and phenotypic variance were moderate 15.97 and 22.03, respectively. Genotypic and phenotypic coefficient of variation were 11.23 and 13.19 per cent, respectively. High heritability estimates (72.4 per cent) coupled with moderate expected genetic advance (19.66 per cent) were observed.

4.3 Correlation

Genotypic and phenotypic correlations were calculated among 11 characters with seed yield per plant and are presented in Table 4 and 5, respectively.

The results revealed that days to 50 per cent flowering was positively and significantly correlated with plant height (G=0.663) and test weight (G=0.782) only at genotypic level while significant correlation had not observed at phenotypic level, and negatively correlated with oil content at both genotypic (G=-0.372) and phenotypic level (P=-0.477). The

characters viz., days to maturity, number of primary and secondary branches, number of capsules, number of seeds per capsule, harvest index and volume weight were positively correlated with days to 50% flowering at both genotypic and phenotypic level.

The character days to maturity had significantly positive correlation with number of capitula per plant (G=0.691) at genotypic level while significantly negative correlation with oil content (P=-0.663) and positively correlated with seed yield per plant (P=0.657) at phenotypic level.

The character plant height (cm) showed significant positive association with number of capitula per plant (G=0.763, P=0.742), number of seeds per capsule (G=0.735, P=0.718), volume weight (G=0.920, P=0.886) and seed yield per plant (G=0.807, P=0.720) at genotypic as well as phenotypic levels and significant negative association with oil content (G=-0.928 P=-0.733) at both genotypic and phenotypic levels.

Number of primary branches per plant exhibited positive and significant correlation with number of secondary branches (G=0.714, P=0.712), volume weight (G=0.715, P=0.728) and seed yield per plant (G=0.657, P=0.673 P) at both levels and had significant positive association with number of capitula per plant (P=0.644) only at phenotypic level. Number of primary branches exhibited significant negative correlation with oil content (G=-0.692, P=-0.675) at both genotypic and phenotypic level. However, number of secondary branches per plant had positive correlation with characters viz., number of capitula per plant, number of seeds per capsule, test weight, harvest index and volume weight at both genotypic

Table 4 : Genotypic correlation of yield with yield contributing characters in safflower

Sr No	Characters	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Seed yield/ plant (g)
1.	Days to 50 % flowering	**1.000**	0.145	0.663*	0.292	0.513	0.468	0.368	0.782*	-0.372	0.178	0.552	0.424
2.	Days to maturity		**1.000**	0.465	0.591	0.224	0.691*	0.536	0.349	-0.557	0.011	0.561	0.624
3.	Plant height (cm)			**1.000**	0.626	0.176	0.763*	0.735*	0.579	-0.928**	0.155	0.920**	0.807**
4.	No. of primary branches /plant				**1.000**	0.714*	0.631	0.522	0.154	-0.692*	0.053	0.715*	0.657*
5.	No. of secondary branches/ plant					**1.000**	0.236	0.136	0.287	-0.272	0.062	0.295	0.262
6.	No. of capitula/plant						**1.000**	0.957**	0.184	-0.919**	0.252	0.914**	0.991**
7.	No. of seeds / capitulum							**1.000**	0.109	-0.893**	0.189	0.907**	0.959**
8.	Test weight (g)								**1.000**	-0.366	-0.403	0.405	0.231
9.	Oil content (%)									**1.000**	0.013	-0.988**	-0.955**
10.	Harvest index (%)										**1.000**	0.033	0.094
11.	Volume wt. (g/l)											**1.000**	0.956**
12.	Seed yield/plant(g)												**1.000**

* and ** indicates 5 and 1 per cent level respectively.

Table 5 : Phenotypic correlation of yield with yield contributing characters in safflower

Sr No	Characters	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Seed yield/ plant (g)
1.	Days to 50 % flowering	**1.000**	0.536	0.441	0.362	0.418	0.384	0.335	0.624	-0.477	0.227	0.464	0.447
2.	Days to maturity		**1.000**	0.372	0.588	0.297	0.610	0.513	0.437	-0.663*	0.211	0.557	0.657*
3.	Plant height (cm)			**1.000**	0.605	0.186	0.742*	0.718*	0.371	-0.733*	0.151	0.886**	0.720*
4.	No. of primary branches /plant				**1.000**	0.712*	0.644*	0.551	0.199	-0.675*	0.113	0.728*	0.673*
5.	No. of secondary branches/ plant					**1.000**	0.282	0.189	0.224	-0.343	0.114	0.344	0.338
6.	No. of capitula/plant						**1.000**	0.959**	0.249	-0.840**	0.263	0.916**	0.952**
7.	Number of seeds per capitulum							**1.000**	0.199	-0.821**	0.206	0.911**	0.926**
8.	Test weight (g)								**1.000**	-0.489	-0.204	0.383	0.349
9.	Oil content (%)									**1.000**	-0.109	-0.916**	-0.950**
10.	Harvest index (%)										**1.000**	0.089	0.163
11.	Volume wt. (g/l)											**1.000**	0.942**
12.	Seed yield/plant(g)												**1.000**

* and ** indicates 5 and 1 per cent level respectively.

and phenotypic level and negative correlation with oil content at both genotypic and phenotypic level.

Number of capitula per plant exhibited positive and significant association with number seeds per capsules (G=0.957, P=0.959), volume weight (G=0.914, P=0.916) and seed yield per plant (G=0.991, P=0.952) at both genotypic and phenotypic level while significant negative association had observed with oil content (G=-0.919, P=-0.840) at both genotypic and phenotypic level.

Number of seeds per capitula showed positive and significant correlation with volume weight (G=0.907, P=0.911) and seed yield per plant (G=0.959, P=0.926) at both genotypic and phenotypic level. However, negative and significant correlation observed with oil content at genotypic and phenotypic level G=(-0.893, P=-0.821). The character test weight showed positive correlation with volume weight and seed yield per plant while the same character showing negative correlation with oil content and harvest index at both the level.

Oil content exhibited significant negative correlation with volume weight (G=-0.988, P=-0.916) and seed yield per plant (G=-0.955, P=-0.950) at both genotypic and phenotypic level. Harvest index showed positive correlation with volume weight and seed yield per plant at both genotypic and phenotypic level while character volume weight showed significant positive correlation with seed yield per plant at both the levels (G=0.956, P=0.942).

4.4 Path analysis

Genotypic and phenotypic path analysis between yield and yield contributing characters were carried out using genotypic and phenotypic correlations and are presented in Table 6 and 7, respectively.

The results of path coefficient analysis revealed that volume weight exerted the highest positive direct effect (G=0.744, P=0.766) on seed yield per plant at both genotypic and phenotypic level followed by number of capitula per plant (G=0.709, P=0.567), days to 50% flowering (G=0.039, P=0.051) and harvest index (G=0.003, P=0.006), while other characters viz., days to maturity, number of secondary branches per plant, test weight, number of primary branches per plant, oil content, number of seeds per capsules and plant height exerted negative direct effect on seed yield per plant.

At genotypic level, highest negative direct effect on seed yield was recorded by plant height (G=-0.403) followed by number of seeds per capsule (G=-0.358), oil content (G=-0.357) and number of primary branches per plant (G=-0.096).

While at phenotypic level, highest negative direct effect was exerted by oil content (P=-0.397), followed by plant height (P=-0.364), number of seeds per capsule (P=-0.316), number of primary branches per plant (P=-0.113) and test weight (P=-0.086).

The maximum indirect effect was exhibited by number of capitula per plant through volume weight, oil content and days to 50% flowering at both the levels. The characters days to 50% flowering, days to maturity, plant height, number of primary and secondary branches per plant

Table 6 : Direct and indirect effect (genotypic) of yield components on yield in safflower

Sr No	Characters	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Genotypic correlation with Seed yield/ plant (g)
1.	Days to 50 % flowering	**0.039**	-0.004	-0.267	-0.028	-0.016	0.332	-0.132	-0.045	0.133	0.001	0.411	0.424
2.	Days to maturity	0.006	**-0.025**	-0.188	-0.057	-0.007	0.491	-0.192	-0.020	0.199	0.000	0.417	0.624
3.	Plant height (cm)	0.026	-0.012	**-0.403**	-0.060	-0.006	0.541	-0.263	-0.033	0.331	0.002	0.684	0.807
4.	No. of primary branches /plant	0.012	-0.015	-0.253	**-0.096**	-0.023	0.448	-0.187	-0.009	0.247	0.001	0.532	0.657
5.	No. of secondary branches/ plant	0.020	-0.006	-0.071	-0.069	**-0.032**	0.167	-0.049	-0.016	0.097	0.001	0.220	0.262
6.	Number of capitula per plant	0.018	-0.017	-0.308	-0.061	-0.008	**0.709**	-0.343	-0.011	0.328	0.004	0.680	0.991
7.	Number of seeds per capitulum	0.015	-0.013	-0.296	-0.050	-0.004	0.679	**-0.358**	-0.006	0.319	-0.002	0.675	0.959
8.	Test weight (g)	0.031	-0.009	-0.233	-0.015	-0.009	0.131	-0.039	**-0.057**	0.131	-0.002	0.302	0.231
9.	Oil content (%)	-0.015	0.014	0.374	0.067	0.009	-0.652	0.320	0.021	**-0.357**	0.000	-0.736	-0.955
10.	Harvest index (%)	0.007	-0.001	-0.062	-0.005	-0.002	0.179	-0.068	0.023	-0.005	**0.003**	0.025	0.094
11.	Volume wt. (g/l)	0.022	-0.014	-0.371	-0.069	-0.009	0.648	-0.325	-0.023	0.353	0.000	**0.744**	0.956

Residual effect 0.032

Table 7 : Direct and indirect effect (Phenotypic) of yield components on yield in safflower

Sr No	Characters	Days to 50 % flower-ing	Days to maturity	Plant height (cm)	No. of primary branches per plant	No. of secondary branches per plant	No. of capitula per plant	No. of seeds per capitulum	Test weight (g)	Oil content (%)	Harvest index (%)	Vol. weight (g/l)	Phenotypic correlation with Seed yield/ plant (g)
1.	Days to 50 % flowering	**0.051**	0.001	-0.160	-0.041	-0.007	0.218	-0.106	-0.054	0.189	0.001	0.355	0.447
2.	Days to maturity	0.027	**-0.001**	-0.135	-0.066	-0.005	0.346	-0.162	-0.038	0.263	0.001	0.427	0.657
3.	Plant height (cm)	0.023	0.000	**-0.364**	-0.068	-0.003	0.421	-0.227	-0.032	0.291	0.001	0.678	0.720
4.	No. of primary branches /plant	0.019	-0.002	-0.220	**-0.113**	-0.012	0.365	-0.174	-0.017	0.268	0.001	0.558	0.673
5.	No. of secondary branches/ plant	0.021	0.001	-0.068	-0.080	**-0.017**	0.160	-0.060	-0.019	0.136	0.001	0.263	0.338
6.	Number of capitula per plant	0.020	0.000	-0.270	-0.073	-0.005	**0.567**	-0.303	-0.021	0.334	0.002	0.701	0.952
7.	Number of seeds per capitulum	0.017	-0.001	-0.261	-0.062	-0.003	0.544	**-0.316**	-0.017	0.326	0.001	0.698	0.926
8.	Test weight (g)	0.032	0.000	-0.135	-0.022	-0.004	0.141	-0.063	**-0.086**	0.194	-0.001	0.293	0.349
9.	Oil content (%)	-0.024	-0.001	0.267	0.076	0.006	-0.476	0.259	0.042	**-0.397**	-0.001	-0.701	-0.950
10.	Harvest index (%)	0.012	0.002	-0.055	-0.013	-0.002	0.149	-0.065	0.018	0.043	**0.006**	0.068	0.163
11.	Volume wt. (g/l)	0.024	0.000	-0.322	-0.082	-0.006	0.519	-0.288	-0.033	0.363	0.001	**0.766**	0.942

Residual effect 0.046

recorded the highest positive indirect effect on seed yield through volume weight followed by number of capitula per plant, oil content and days to 50% flowering at genotypic as well as phenotypic level while other characters showing negative indirect effect.

At genotypic and phenotypic level, number of capitula per plant exhibited positive indirect effect on seed yield through volume weight (G=0.680, P=0.701), oil content (G=0.328, P=0.334), days to 50% flowering (G=0.018, P=0.020) and negative indirect effect through rest of the characters.

The character number of seeds per capsule recorded highest positive indirect effect on seed yield through number of capitula per plant (G=0.679) followed by volume weight (G=0.675), oil content (G=0.319) and days to 50% flowering (G=0.015) at genotypic level while at phenotypic level, highest positive indirect effect through volume weight (P=0.698) followed by number of capitula per plant (P=0.544) and days to 50% flowering (P=0.017) were observed.

Test weight exerted highest positive indirect effect on seed yield through volume weight (G=0.302, P=0.293) at both the levels followed by oil content (G=0.131, P=0.194) and number of capitula per plant (G=0.131, P=0.141).

Oil content exhibited highest positive indirect effect on seed yield through plant height (G=0.374, P=0.267) followed by number of seeds per capsule (G=0.320, P=0.259), number of primary branches per plant (G=0.067, P=0.076) and test weight (G=0.021, P=0.042) at both the levels.

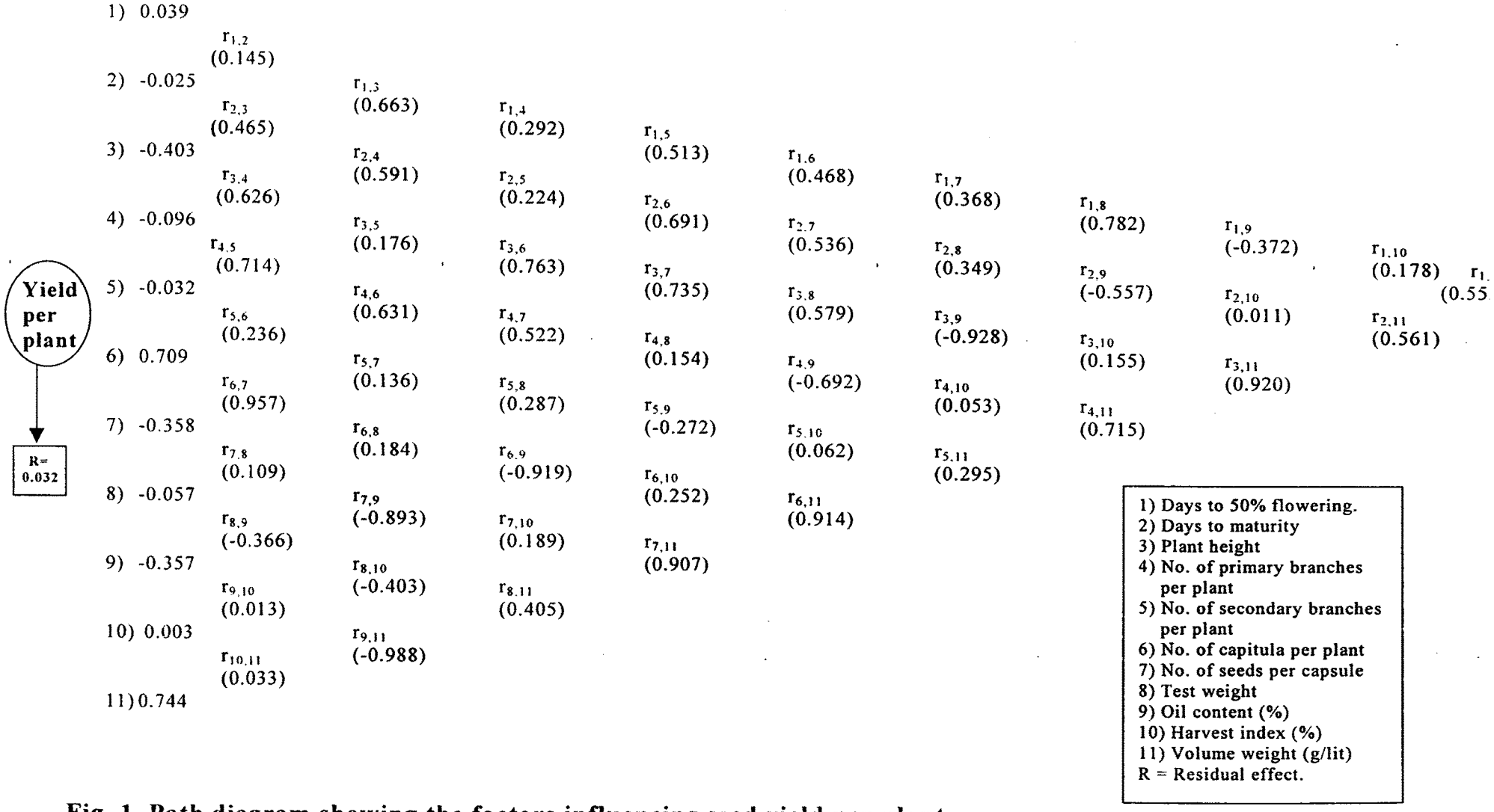


Fig. 1. Path diagram showing the factors influencing seed yield per plant.

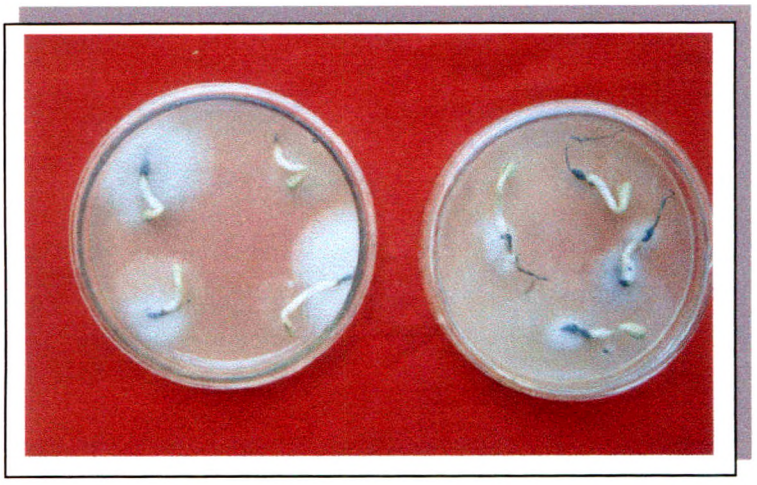
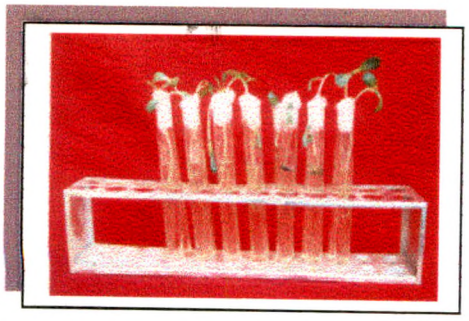


Plate 1. Culture of *Fusarium oxysporum* f.sp. *carthami* grown on *Fusarium* specific medium

Plate 2. Raising of seedling in sterilized sand substrate



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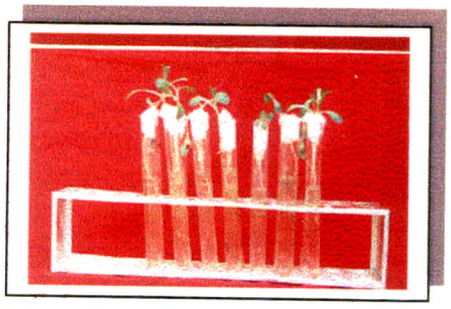
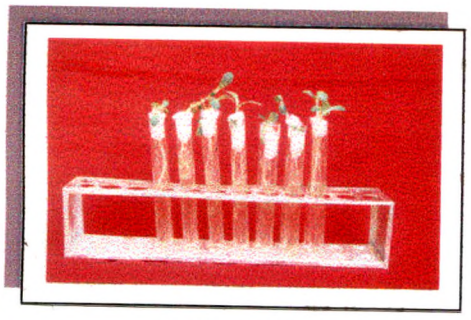
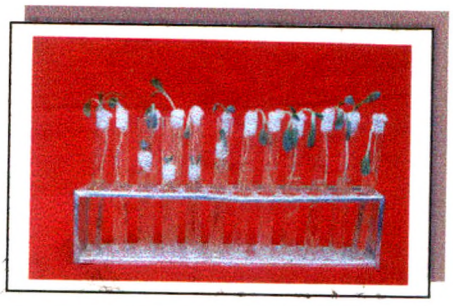


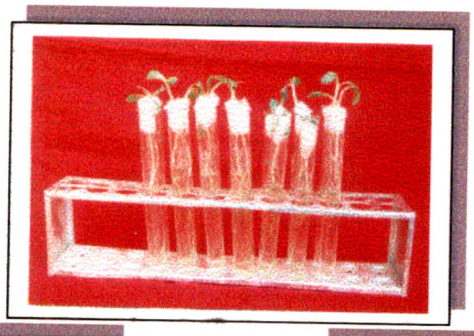
MS 11 x A_2



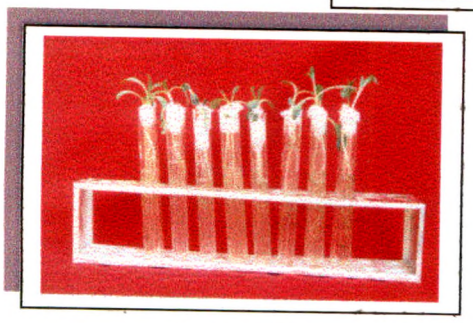
GMU 1962



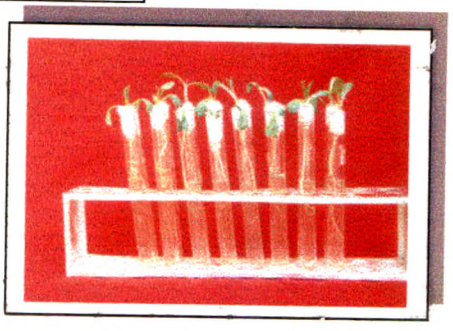
MS 11 x GMU 1962



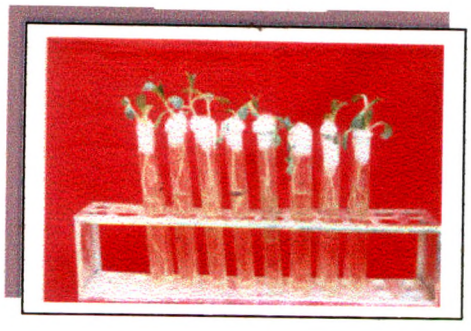
MS 11



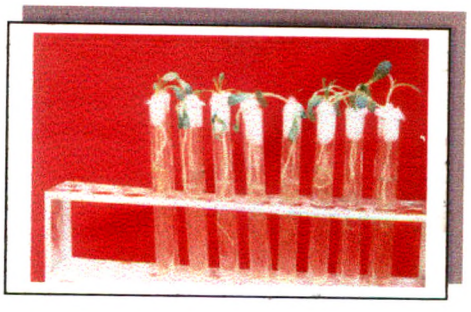
GMU 1735



MS 11 x GMU 1735



IV 92-2-2



MS 11 x IV 92-2-2

Plate 3. Testing of the seedling by 2.5 % water culture technique

Harvest index recorded the highest positive indirect effect on seed yield through number of capitula per plant (G=0.179, P=0.149) followed by volume weight (G=0.025, P=0.068), test weight (G=0.023, P=0.018) and days to 50% flowering (G=0.007, P=0.012) at genotypic as well as phenotypic level. The character volume weight showed highest positive indirect effect on seed yield through number of capitula per plant (G=0.648, P=0.519) followed by oil content (G=0.353, P=0.363) and days to 50% flowering (G=0.022, P=0.024).

4.5 Analysis for screening of breeding material for *Fusarium* wilt (seedling mortality)

None of the genotypes showed resistance type of reaction out of four crosses and their parents studied for screening purpose (Table 8).

However, 2 parents (MS 11, IV 92-2-2) and two crosses (MS 11 x A2, MS 11 x GMU 1735) were expressed 18.75 % seedling mortality, while all other parents (A2, GMU 1962, GMU 1735) and crosses (MS 11 x GMU 1962, MS 11 x IV 92-2-2) were showed 31.25 % seedling mortality. This technique seems to be suitable for preliminary screening of safflower genotypes and needs field confirmation.

Table 8. **Screening of breeding material for *Fusarium* wilt by water culture technique.**

Materials screened	No. of seedlings survived in water culture (2.5 % concentration) after 4 days	No. of seedlings died in water culture after 4 days
MS 11	13 (81.25)	3 (18.75)
A2	11 (68.75)	5 (31.25)
GMU 1962	11 (68.75)	5 (31.25)
GMU 1735	11 (68.75)	5 (31.25)
IV 92-2-2	13 (81.25)	3 (18.75)
MS 11 x A2	13 (81.25)	3 (18.75)
MS 11 x GMU 1962	11 (68.75)	5 (31.25)
MS 11 x GMU 1735	13 (81.25)	3 (18.75)
MS 11 x IV 92-2-2	11 (68.75)	5 (31.25)

Figures in parentheses are in percentage values.

Discussion

Chapter-V

DISCUSSION

Commercial exploitation of heterosis in many important field crops lead to a remarkable increase in the productivity in last fifteen years. Many scientists have reported high heterosis for yield and yield contributing characters, in different crops but it is not exploited in safflower due to absence of suitable male sterility systems or due to problems in large scale seed production. Recently genetic male sterility system controlled by recessive gene (Heaton and Knowles, 1982) and dominant gene (Joshi *et al.* 1983) are being used in the hybrid development programmes. The productivity in safflower is stagnated may be due to that it is grown on residual soil moisture and less success in development of high yielding varieties. The release of hybrids in safflower yet to witness the increased productivity. The available genetic male sterility system can also be used in population improvement programme (Nerkar and Jambhale, 1985). They discussed the possible approaches to use both types of male sterility systems in population breeding.

Fusarium wilt is appearing every year in the Marathwada region and also increasing because of continuous use of same field for safflower cultivation (Anonymous, 1987, 1989).

However, high incidence and intensity of *Fusarium* wilt become a new threat for successful and profitable cultivation and production in Marathwada region. Losses due to *Fusarium* wilt disease has been reported to the tune of 44 per cent (Jackson, 1985). The disease is now known to be endemic in the Indian Deccan Plateau with reports of

upto 80 per cent incidence resulting in heavy yield losses, particularly under irrigated crop culture (Kalpana Sastry, 1992).

Success of plant breeding programme depends upon the extent of genetic variability, its proper assessment and utilization for selection purpose or for hybridization. The correlation and path analysis provide information on genetic association of yield and yield contributing characters which in term are useful in developing breeding strategies and selection criteria. Screening of the breeding material for *Fusarium* wilt by water culture technique is found to be a good and quick method and also useful in discarding highly susceptible variety at initial stages and also reduced the laborious work in the field. The present investigation was undertaken on above background.

5.1.1 Analysis of variance

The analysis of variance for the character days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, number of capitula per plant, number of seeds per capitulum, test weight (g), oil content (%),harvest index (%), volume weight (g/l) and seed yield per plant (g) showed significant genotypic differences indicating presence of variability among the progenies selected for the study (Table 1).

5.2 Mean performance

The mean performance of the different characters studied is presented in Table 2.

The F_3 progeny, CTH 25 x JLSF 325 (88.66 days) was early for 50 per cent flowering while MS 11 x IV 92-2-2 found to be earlier (129.33) in maturity. Among the F_3 progenies, Selection 7 x GMU 1751 (89.33 cm), MS 11 x GMU 1962 (79.22 cm), MS 11 x PH-3 (77.90 cm),

MS 11 x IV 92-2-2 (74.44 cm). JLSF 341 x A1 (74.40 cm) were considerably dwarf. In the present study in general the plant height differences were not much evident.

Primary and secondary branches per plant are the important yield contributing characters in safflower. However, in the present study F_3 progenies derived from crosses MS 11 x GMU 1735 (10.86), selection-7 x GMU 1751 (10.44), CTH 25 x JLSF 325 (9.88), JLSF 341 x A1 (9.58), MS 11 x PH-3 (9.00) showed significantly more number of primary branches per plant than checks Sharda and Annegiri-1. Pawar (1990), Reddy (1993) and Ghorpade (1993) also reported the importance of number of primary and secondary branches per plant, number of capitula per plant and yield per plant. The maximum number of secondary branches per plant were observed in F_3 progenies derived from the crosses MS 11 x GMU 1735 (22.10), Selection 7 x GMU 1751 (21.10), JLSF 341 x A1 (21.08), MS 11 x PH-3 (13.53) and CTH 25 x JLSF 325 (13.10).

Five F_3 progenies recorded more number of capitula per plant than checks. The F_3 progenies derived from cross MS 11 x A2 (32.63), Selection 7 x GMU 1751 (31.83). CTH 25 x JLSF 325 (31.76), MS 11 x GMU 1735 (31.10) and JLSF 341 x A1 (30.13) showed more number of capitula per plant. Number of capitula per plant and size of capitula are considered as important yield contributing characters in safflower. Mathur *et al.* (1976), Pandya (1988) also reported importance of capitula per plant in safflower in contributing yield.

In the present study, six F_3 progenies recorded more number of seeds per capitulum than checks. The maximum number of seeds per capitulum were observed in progenies Selection 7 x GMU 1751 (45.60) followed by MS 11 x A2 (45.23), CTH 25 x JLSF 325 (43.00). MS 11 x

GMU 1735 (42.06). JLSF 341 x A1 (41.26) and MS 11 x PH-3 (40.60). Reddy (1985) and Challawar (1986) showed that number of seeds per capitulam was the most important yield component in safflower. Highest test weight was recorded in F_3 progeny from the crosses MS 11 x A2 (5.40 g) followed by selection 7 x GMU 1751 (5.30 g) and MS 11 x GMU 1735 (5.10 g).

Among F_3 progenies, both the checks recorded highest oil content viz., Sharda (32.20 %) and Annegiri-1 (32.33 %) while low oil content were recorded by F_3 progeny derived from the crosses MS11 x A2 (27.83 %), Selection 7 x GMU 1751 (28.63 %) and CTH 25 x JLSF 325 (28.76 %).

All the genotypes showed higher volume weight than both the checks. Among the F_3 progenies, four progenies recorded maximum volume weight viz., MS 11 x A 2 (605.73 g/l) followed by Selection 7 x GMU 1751 (601.37 g/l), MS 11 x GMU 1735 (597.53 g/l) and CTH 25 x JLSF 325 (590.87 g/l).

Among the F_3 progenies, MS 11 x A2 (41.06 g) recorded highest seed yield per plant and other progenies of the crosses Selection 7 x GMU 1751 (39.90 g), CTH 25 x JLSF 325 (38.56 g), MS 11 x GMU 1735 (37.80 g), JLSF 341 x A1 (37.26 g) and MS 11 x PH-3 (36.53 g) were significantly superior than both the checks. Whereas 8 F_3 progenies were at par with both the checks. Similar findings have been reported by Mathur (1976), Yazdi Samadi et al. (1976), Deokar et al. (1985), Patil *et al.* (1994) and Patil *et al.* (1998).

5.3 Genetic variability

Genetic variability is a prerequisite in crop improvement programme. The breeder has to quantify the fixable and non fixable

component of variation for an effective selection programme. Prepotency of a character depends upon the magnitude of additive gene action. In the present study efforts have been made to analyse the components of variability in the F_3 progenies with reference to future breeding programme.

5.3.1 Range of variability

In general wide range of variability was observed for majority of the characters. Range of variation on the basis of mean was more for the characters plant height, number of primary branches per plant, number of secondary branches per plant, number of capitula per plant, number of seeds per capitulum, volume weight and seed yield per plant. Wide range of variation for different yield contributing characters in safflower have been reported by several workers including Argikar *et al.* (1958), Ashri *et al.* (1974), Deokar and Patil (1985), Reddy *et al.* (1985), Lakh *et al.* (1992), Ghorpade *et al.* (1993) and Patil (1998) indicated the presence of substantial genetic diversity between strains for yield characters.

Phenotypic variances values were higher than the genotypic variances in all the characters. High genotypic and phenotypic variances were observed for the character volume weight followed by plant height, number of seeds per capsules, number of capsules per plant, days to maturity, seed yield per plant and number of secondary branches. The present findings 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 plant height. The lowest genotypic and phenotypic variances were observed for the characters 100 seed weight, and number of primary branches per plant. Lakha *et al.* (1992) and Deokar and Patil (1978) reported similar findings for test weight and number of primary branches.

5.3.2 Genotypic and phenotypic coefficient of variation

The selection under field condition may be strongly influenced by environmental factors affecting the progress in the improvement programme. Similarly if the character is governed by dominant gene action, the situation becomes more complicated. The progress of selection is reduced.

In the present studies, the genotypic coefficient of variability estimates were lower than phenotypic coefficient of variability for all the characters. Though the phenotypic coefficient of variation were greater than genotypic coefficient of variation, the differences between them were of lower in magnitude. This relationship indicated that there was small effect of environment on these characters and phenotypic selection for such characters may be effective.

In the present study, high estimates of genotypic and phenotypic coefficient of variation were observed for number of secondary branches per plant, number of primary branches per plant, number of capitula per plant, number of seeds per plant, seed yield per plant, plant height. For the rest of the characters genotypic and phenotypic coefficient of variations were low. The low genotypic coefficient of variability estimates than phenotypic coefficient of variability indicated that these characters to some extent are influenced by environment and phenotypic selection will be ineffective. High values of phenotypic coefficient of variation were also reported by Makne *et al.* (1979) and Challawar (1986) for yield and yield components. The results are in agreement with those of Narkhede *et al.* (1985), Patil *et al.* (1992) and Choudhary *et al.* (1999). The low genotypic and phenotypic coefficient of variation were observed for days to 50 per cent flowering, days to maturity, 100 seed weight, harvest

index and volume weight. 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. Makne (1979) reported low genetic coefficient of variation in safflower for most of the characters. Ranga Rao *et al.* (1980) observed moderate to high coefficient of variation for plant height, seeds per capsule, number of capsules per plant and seed yield per plant. The characters which have less influence of environment may be improved by simple selection methods such as mass selection or pureline selection. The above results of various scientists are in agreement with present studies.

5.3.3 Heritability and genetic advance

The heritability estimates along with expected genetic advance are more useful in predicting yield under phenotypic selection than heritability estimates alone (Johnson *et al.*, 1955). The broad sense heritability estimates are always of higher magnitude than narrow sense heritability estimates. Therefore, it should be regarded as crude estimates of gene action, operating for a particular characters and the inferences drawn to be viewed accordingly. In the present study the range of heritability 34.7 per cent for test weight (g) to 99.5 per cent for plant height (cm).

The character plant height (99.5 per cent), number of primary branches per plant (86.8 per cent), number of secondary branches per plant (92.4 per cent), number of capitula per plant (90.0 per cent), number of seeds per capsule (90.7 per cent), and volume weight (88.5 per cent) recorded higher (> 80%) broad sense heritability. 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 the capsules per plant by Narkhede *et al.* (1985) and Patil *et al.* (1994), for number of

branches per plant by Thombare and Joshi (1977) and grain yield per plant by Pandya *et al.* (1996).

Low heritability for yield and yield contributing characters suggested the non additive control of gene action. Selection for such characters then become different as they are influenced by the environment. In the present study for all the important characters the heritability estimates are very high. However, as in broad sense heritability the contribution of dominance and epistasis also included. Such estimates alone does not hold the repeatability of expression of characters in the selection programme. Similarly, broad sense heritability estimates are prone to changes from location to location and interaction with environment. The heritability estimates for yield contributing characters were also reported by Johnson *et al.* (1955), Yazadi Samadi *et al.* (1976), Makne *et al.* (1979), Sengupta and Bhattacharya (1979), Pawar (1990), Lakha *et al.* (1992) and Patil (1998).

High heritability estimates coupled with high expected genetic advance were observed for the characters plant height, number of secondary branches per plant, number of seeds per plant, number of capitula per plant, volume weight, number of primary branches per plant and seed yield per plant indicates additive gene effect. These were reported by Lakha *et al.* (1992) for number of secondary branches per plant. Thombare and Joshi (1977) for number of capsules per plant, Sengupta and Bhattacharya (1979) and Makne *et al.* (1985) for plant height, Kamble *et al.* (1984), Narkhede *et al.* (1985) for seed yield per plant, Makne *et al.* (1979), Narkhede *et al.* (1985) for seeds per capitulum, Choudhary *et al.* (1999) for seed yield per plant, number of capitula per plant and plant height.

Thus from the foregoing discussion, it is clear that the characters plant height, number of secondary branches per plant, number of seeds per plant, number of capitula per plant, volume weight, number of primary branches per plant and seed yield per plant 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

Correlation coefficient is an important statistical content which indicates the degree of association among the various characters. Seed yield is a complex character and depends on the other agronomic trait. Therefore, in the crop improvement programme, to study the relationship of different agronomic characters with each other and their relation with yield become more important. It is also essential to find out the relative contribution of each component characters in yield so as to give weightage during selection. The value of correlation coefficient cannot be constant everywhere. It vary considerably according to the kind of material handed, mode of observation, cultural practices and environmental conditions in which material is grown. Even though the material is the same, the environment including fertilization, plant population, cultural practices change the value of correlation coefficient considerably (Raut, 2002). In present investigation gentoypic and phenotypic correlations were calculated for yield and yield components.

The characters plant height, number of primary branches per plant, number of capsules per plant, number of seeds per capsule and volume weight showed positive and significant correlation with seed yield

at both genotypic and phenotypic levels while the characters days to maturity showed positive and significant correlation with seed yield only at phenotypic level. Makne *et al.* (1985) reported significant correlation of seed yield with capsules per plant. Similarly, Lakha (1992) for number of secondary branches and number of capitula per plant, Acharya *et al.* (1994) and Senapati *et al.* (1999) for number of capitula per plant.

Days to 50 per cent flowering were positively and significantly associated with plant height, test weight (g), at genotypic level. Similar findings were reported by Patil (1998) and Choudhary *et al.* (1999).

Days to maturity showed positive and significant correlation with number of capitula per plant at genotypic level, while the same character exhibited positive and significant correlation with seed yield but significant and negative correlation with oil content (%) and at phenotypic level.

The character plant height (cm) showed positive and significant correlation with number of capitula per plant, number of seeds per capsule, volume weight (g/l), seed yield at both genotypic as well as phenotypic level, while exhibited significant but negative correlation with oil content (%). Ashri et al. (1974) and Makne et al. (1979) reported significant correlation of plant height, days to maturity with seed yield per plant.

Number of primary branches exhibited positive significant correlation with number of secondary branches, volume weight (g/l), seed yield per plant (g) at both genotypic and phenotypic level, but at phenotypic level, positive and significantly correlated with number of capsules per plant. However, number of primary branches exhibited negative and

significant correlation with oil content at both genotypic and phenotypic level. Similar findings were reported by Abel (1969) and Patil (1990) and Pawar (1990) and Patil (1992) reported significant and positive correlation of yield with number of capsules and branches per plant.

Number of capitula per plant exhibited positive and significant correlation with number of seeds per capsule, volume weight and seed yield per plant at both genotypic and phenotypic level but showed negative and significant correlation with oil content at both the levels. The results are in agreement with those of Abel (1969), Makne (1979), Paliwal and Solanki (1984), Lakha (1989). Similar association for these trait were reported by Khidir (1974).

Number of seeds per capsules showed positive and significant correlation with volume weight and seed yield per plant but significant and negative correlation with oil content at both genotypic as well as phenotypic level.

Oil content exhibited negative and significant correlation with volume weight and seed yield per plant at both genotypic and phenotypic level. Similar finding were reported by Gupta *et al.* (1990). Character volume weight showed positive and significant correlation with seed yield per plant.

It is important to note that the character number of primary branches and secondary branches per plant, number of capitula per plant, number of seeds per capsules and volume weight were positively correlated with seed yield per plant. These traits can be considered as important character for improving seed yield in safflower. Abel (1969), Malleshappa et al. (1989) and Reddy et al. (1992) reported the similar findings.

5.5 Path analysis

Path coefficient analysis is a standardized partial regression analysis which permits the separation of correlation coefficient into measure of direct and indirect effect. Seed yield is the product of interaction of component traits. Apart from correlation studies, path coefficient analysis is important to obtain information about different ways in which the component characters influence seed yield. This helps in giving the weightage to particular character during the selection.

The path analysis indicated that the character volume weight exerted the highest direct effect followed by number of capitula per plant, days to 50% flowering and harvest index at genotypic level. Kubsad *et al.* (2000), Challawar (1986), Subhalakshmi and Sivsubramanian (1995) and Ghongade *et al.* (1993) also reported the importance of these characters in path analysis, indicated that number of capitula per plant and diameter of capitulum exerted the highest direct effect on seed yield.

The character plant height, number of primary branches per plant, number of seeds per capsule and oil content showed negative direct effect but their indirect effect through number of capitula per plant, was comparatively high indicating its more indirect contribution. These findings are in confirmity with Pawar (1990) and Lakha *et al.* (1992).

Significant and positive correlation of number of capitula per plant with seed yield could be explained by its positive direct effect and indirect effect via volume weight, oil content and days to 50% flowering. Similar reports have been given by Thombare and Joshi (1981) and Reddy *et al.* (1992).

The character days to 50% flowering and secondary branches per plant possessed positive correlation with seed yield, which could be

again explained by its direct effect and indirect effect via volume weight, number of capitula per plant, and oil content. This results are in conformity with those of Acharya *et al.* (1994). Choudhary *et al.* (1999) and Kubsad *et al.* (2000).

The present investigation clearly revealed that the characters viz., volume weight, number of capitula per plant, days to 50% flowering and number of secondary branches per plant had strongly association with seed yield and also showed the highest direct effect and indirect effect via other component traits. These indicated that direct selection for these characters will enhance the breeding efficiency for seed yield in safflower.

The residual factor (0.032) explain that variables studied were showing high genotypic variability. The reason seem to be a very high and significant correlation of plant height (cm), number of primary branches per plant, number of capitula per plant, number of seeds per capsule, oil content (%) and volume weight (g/l). Besides some other factors which have not been considered and needs to be included in this analysis to account fully for variation in yield. Similar findings were reported by Bodhwad (1999).

5.6 Screening of breeding material by water culture technique for *Fusarium* wilt disease

Four selected crosses with their parents as mentioned earlier were screened using water culture technique as suggested by Nene et al. (1981) for screening chickpea wilt. The results showed slight differences in wilting reaction when seedling were exposed to 4 days. None of the genotypes was found to be free from wilt.. Two parents viz., MS 11, IV 92-2-2 and crosses (MS 11 x A2, MS 11 x GMU 1735) were expressed 18.75 % seedling mortality. While rest of the parents (A2, GMU 1062, GMU 1735) and crosses (MS 11 x GMU 1962, MS 11 x IV 92-2-2) were

recorded 31.25 per cent seedling mortality (wilting) indicting that genotype showing 18.75 per cent mortality had some resistance capacity than the other showing 31.25 per cent mortality (Table 8). Irrespective of purelines or their hybrids, pure lines as well as hybrids had shown approximately 75 % survival and 25 % mortality indicating predomination of 75 % avirulent population having gene 'AA' for avirulence with dominance. The pure lines as well as hybrids had shown 25 % mortality indicating interaction with only 25 % virulent recessive population 'aa'.

Many workers employed various techniques like sick soil in pots, developing sick plots in field or under natural conditions for screening germplasm and elite cultivars (Knowles *et al.* 1968; Klisiewicz, 1975; Thomas and Hill, 1977; Klisiewicz and Urie, 1982; Nirmal, 1985; Mehetre, 1988; Gore, 1998; Somwanshi, 2000). For quick and preliminary screening, Pedgoankar and Mayee (1988) used water culture technique in laboratory and reported that JLSF 88 and N 48 showed 20 and 40 per cent wilting respectively in tested genotypes.

However, water culture technique for preliminary screening was found to be good and quick method as suggested. This technique is also useful in discarding highly susceptible materials at initial stages and also reduce the laborious work in field. It could be stated that prior to screening of various elite material in sick plot, the material should be screened by water culture technique which would reduce the extra laborious work and manageable research programme in the field.

Summary and Conclusion

Chapter-VI

SUMMARY AND CONCLUSIONS

The present investigation was undertaken with the objective to estimate genetic variability for yield and yield contributing characters, association among yield attributing characters and screening of breeding material for *Fusarium* wilt by water culture technique in F_3 progeny of safflower (*Carthamus tinctorius* L.). The experiment was conducted with 8 F_3 progenies and two checks in randomised block design with three replications. Results obtained are as follows.

1. Analysis of variance showed significantly genotypic variability for all the characters.
2. Single F_3 progeny of a cross MS 11 x IV 92-2-2 showed early maturity (129.33 days) while MS 11 x GMU 1962 (132.33 days), MS 11 x GMU 1735 (133.33 days), JLSF 341 x A1 (138.00 days) matured earlier than national check Annegiri-1 (139.00).
3. Maximum number of primary branches were recorded by F_3 progenies of the crosses viz., MS 11 x GMU 1735 (10.86), Selection 7 x GMU 1751 (10.44), CTH 25 x JLSF 325 (9.88) and JLSF 341 x A1 (9.58) and MS 11 x PH-3 (9.00),
4. Maximum number of secondary branches per plant were recorded by F_3 progenies of the crosses MS 11 x GMU 1735 (22.10) Selection 7 x GMU 1751 (21.10) and JLSF 341 x A1 (21.08).
5. The higher number of capitula per plant were recorded in F_3 progenies of the crosses MS 11 x A2 (32.63) Selection 7 x GMU

1751 (31.83), CTH 25 x JLSF 325 (31.76), MS 11 x GMU 1735 (31.10) and JLSF 341 x A1 (30.13).

6. Number of seeds per capsules were higher in the progenies. Selection 7 x GMU 1751 (45.60), MS 11 x A2 (45.23), CTH 25 x JLSF 325 (43.00), MS 11 x GMU 1735 (42.06) JLSF 341 x A1 (41.26) and MS 11 x PH-3 (40.60).

7. The F_3 progenies of the crosses MS 11 x A2 (5.40), selection 7 x GMU 1751 (5.30 g), MS 11 x GMU 1735 (5.10) CTH 25 x JLSF 325 (5.02g) and MS 11 x IV 92-2-2 (5.00 g) showed higher test weight.

8. High oil content was recorded by the F_3 progenies of the crosses MS 11 x GMU 1962 (32.20 per cent), MS 11 x IV 92-2-2 (31.23 per cent), MS 11 x PH-3 (30.90 per cent) and JLSF 341 x A1 (30.06 per cent).

9. Maximum volume weight were observed in the genotypes *viz.*, MS 11 x A2 (605.73 g/l), Selection 7 x GMU 1751 (601.37 g/l), MS 11 x GMU 1735 (597.53 g/l), CTH 25 x JLSF 325 (590.87 g/l) and MS 11 x PH-3 (571.53 g/l) as compared to checks Sharda (537.73 g/l) and Annegiri-1 (540.40 g/l).

10. The F_3 progenies of the crosses were found high yielder viz., MS 11 x A2 (41.06 g/plant), Selection 7 x GMU 1751 (39.9 g/plant), CTH 25 x JLSF 325 (38.56 g/plant), MS 11 x GMU 1735 (37.80 g/plant), JLSF 341 x A1 (37.26 g/plant) and MS 11 x PH-3 (36.53 g/plant) as compared to Annegiri-1 (30.36 g/plant) and Sharda (28.46 g/plant).

11. The range of variation for days to maturity, plant height, number of primary and secondary branches per plant, number of capitula per

plant, number of seeds per capsule, volume weight and yield per plant were more.

12. High phenotypic and genotypic coefficient of variation were observed for number of secondary branches, number of primary branches, number of capitula per plant, number of seeds per capsule and seed yield per plant.

13. High heritability coupled with high expected genetic advance was observed for plant height, number of secondary branches, number of seeds per capsule, number of capitula per plant, number of primary branches per plant, volume weight and seed yield per plant.

14. Correlation studies indicated the importance of number of capitula per plant, number of seeds per capsule, volume weight, number of primary branches per plant, plant height and days to maturity.

15. The path coefficient analysis revealed the maximum contribution of volume weight, number of capitula per plant, days to 50% flowering, harvest index and number of secondary branches per plant.

16. Regarding screening of the breeding material for *Fusarium* wilt to disease by water culture technique showed that none of the genotype was showing resistance type of reaction. However, F_3 progenies from the crosses MS 11 x A2 and MS 11 x GMU 1735 were expressed less seedling mortality than MS 11 x GMU 1962 and MS 11 x IV 92-2-2.

CONCLUSION

The present study revealed that the F_3 progenies of the crosses MS 11 x A2, Selection 7 x GMU 1751, CTH 25 x JLSF 325 and MS 11 x GMU 1735 showed better performance for yield and yield contributing characters viz., number of primary branches, number of secondary branches per plant, number of capitula per plant, number of seeds per capsule, test weight and also volume weight. These characters also showed positive correlation with seed yield through their direct and indirect effects and also most of these characters exhibited high heritability coupled with high expected genetic advance. Hence, direct selection from segregating population of above crosses derivatives will be helpful for isolating desirable individuals for their evaluation and release.

However, among the four crosses selected for screening technique, no one showed resistance type of reaction. Two of them viz., MS 11 x A2 and MS 11 x GMU 1735 expressed less seedling mortality than others viz., MS 11 x GMU 1962 and MS 11 x IV 92-2-2.

In future, to evolve resistance lines for *Fusarium* wilt, incorporation of such moderately resistant genotypes in the breeding programme must be necessary which will increase the breeding efficiency as well as the yield level.

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*Originals not seen.

Appendix

APPENDIX-I

Constituent of different culture media

Potal dextrose agar medium	Peeled sliced potato	200 g
	Dextorse	20 g
	Agar	20 g
	Distilled water	1000 g
Potato dextrose brooth	Peeled sliced potato	200 g
	Dextorse	20 g
	Distilled water	1000 g
Special media for *Fusarium* (Kerr, 1963)	Agar	20 g
	Sodium nitrate	10 g
	Potassium phosphate	5 g
	Potassium chloride	0.02 g
	Magnesium sulphate	2.50 g
	Sucrose	50 g
	PCNB	100 ppm
	Streptomycin	50 ppm
	Rose bengal	50 ppm