STABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRAITS IN SAFFLOWER *(Carthamus tinctorius L.)*

BY

SANJAY YADAV P

B.Sc. (Agri.)

DISSERTATION

Submitted to the

Vasantrao Naik Marathwada Krishi Vidyapeeth

in partial fulfillment of the

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DEPARTMENT OF AGRICULTURAL BOTANY

VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH, PARBHANI 431 402 (M.S.), INDIA.

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2017

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.

Place : Parbhani
Date : …../…../2017

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CERTIFICATE - I

This is to certify that the dissertation entitled **"STABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRITS IN SAFFLOWER (*Carthamus tinctorius* L.)"** submitted to Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in the subject of **AGRICULTURAL BOTANY (GENETICS AND PLANT BREEDING)** embodies the results of bonafide research work carried out by **Mr. SANJAY YADAV P.,** under my guidance and supervision and that no part of this dissertation has been submitted for any degree.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place: Parbhani **(Dr. R. C. MAHAJAN)**

Date **…./…./**2017 Research Guide

CERTIFICATE – II

This is to certify that the dissertation entitled **"STABILITY ANALYSIS FOR YIELD AND YIELD CONTRIBUTING TRITS IN SAFFLOWER (*Carthamus tinctorius* L.)"** submitted by **Mr. SANJAY YADAV P** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani in partial fulfillment 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 viva-voce examination in collaboration with the external examiner.

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"All power is within you,

You can do anything and everything, believe in that,

Do not believe that you are weak. Stand up and express the divinity within you"

*- **Swami Vivekananda***

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ABBREVIATIONS

%	-	Percentage
/	-	Per
@	-	At the rate of
bi	-	Regression coefficient
C.D.	-	Critical Difference
Ch	-	Check
cm	-	Centimeter(s)
cm^2	-	Centimeter square
C.V.	-	Coefficient of variation
d.f.	-	Degrees of freedom
E1	-	Environment (Parbhani)
E2	-	Environment (Latur)
E3	-	Environment (Badnapur)
E4	-	Environment (Somanathpur)
et al.,	-	and other co-workers
Fig.	-	Figure
g	-	Gram
G	-	Genotypic Correlation
GM	-	Grand Mean
ha	-	hectare
M S S	-	Mean sum of squares
No.	-	Number (s)
P	-	Phenotypic Correlation
r	-	Correlation coefficient
SE	-	Standard Error
S^2di	-	Deviation from regression
viz.,	-	Videlicet (namely)
Xi	-	Mean performance

Introduction

CHAPTER I

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the most important *rabi* oilseed crop of India and has generated considerable interest in recent years due to its versatile nature and superior yield potential under limited moisture conditions.

The oil seeds scenario of India has undergone drastic change in recent years due to various incentive and institutional support given by the government for development of this sector. After Technology Mission on Oilseeds (T.M.O.) between 1985- 86 and 1996-1997, area under oilseeds was increased from 19.0 to 26.21 million ha, production from 10.83 to 24.96 MT, productivity increased from 570 to 931 kg ha^{-1} and the level of self sufficiency increased from 69 to 87 *per cent.* (Anon, 2015)

Safflower (*Carthamus tinctorius* L.) is an important *rabi* oilseed crop of Maharashtra. Apart from its superior adaptability to scanty moisture conditions, it produces oil rich in polyunsaturated fatty acids (Linoleic acid, 78%) which play an important role in reducing the blood cholesterol level and considered as a healthy cooking medium. The flower can be used in herbal tea preparation. The petal contains yellow and red pigment, safflower glycocide and safflower benzyle glycocide respectively. The dye is also used for colouring medicinal formulations and tablets besides its use in textile industries for colouring clothes. Safflower meal is the key product of industry. The meal left after oil extraction is used as animal feed. The cake contains about 7.9% N, 22% P_20_5 and 1.9% K_20 and its application as manure greatly improves the physical properties of soil.

India rank first in the world in the production of safflower. At present India and china are the only the major producer of safflower in world. India has 60 *per cent* of world acreage and account for 50 *per cent* of world production having productivity of 515 kg/ha and 343 kg/ha for India and

Maharashtra respectively. Safflower production of India is 0.9 lakh ton under 1.749 lakh ha area and production of Maharashtra 0.36 lakh ton under 1.05 lakh ha area. (Anon, 2015).

In India, Maharashtra and Karnataka are the two most important safflower growing states accounting for 63 and 23 *per cent* of area and 53 and 33 *per cent* of production respectively. Out of total area contributed by Maharashtra state, Marathwada contributes about 40.45 *per cent* of acreage in safflower.

Safflower is drought tolerant because of its strong and deep penetrating tap root system. It remains succulent in early stages of growth and assumes xerophytic nature at later stages and thus considerably reduces moisture loss by the plant. Indeed, safflower is a poor and small farmer's crops owing its low input requirements in terms of irrigation as well as fertilizers, least susceptibility to pest and diseases, high adaptability to adverse ecological conditions like drought and frost, capacity to sustain in soil ranging from sandy loam to black cotton and tolerance to moderate salinity and alkalinity of the soil. It is one of the good crops in sequence cropping system.

In recent years, efforts are being made to improve the productivity of this crop through the use of high yielding varieties and improved crop production technology. Although varietal improvement programme has positive improvement in boosting the yield production of safflower the yield of safflower has been stagnating in the past few years due to lack of suitable high yielding varieties with resistance to major biotic and abiotic stresses. To evolve cultivars with high yield potential, it becomes necessary to study the extent of variability in the available germplasm. The effectiveness of selection depends on the magnitude of variability for yield and component traits. The variety developed should show stable performance under different agroclimatic environments, especially in India where a wide range of agroclimatic conditions are prevailing. A variety is said to be stable which can adjust it's phenotypic and genotypic status in response to changing environments. The

G X E interaction studies are of major importance in the crop improvement programme upon the integration of physiological process during the course of development.

Many methods such as ecovalence (Wrike, 1962) stability variance (Shukla, 1972), coefficient of determination (Pinthus, 1973), regression approach (Eberhart and Russell, 1966) etc. with suitable parameters are available to provide necessary criteria to rank varieties for stability. Eberhart and Russell's model (1966) is the most popular.

In the present investigation, ten new developed genotypes along with two check varieties were evaluated at four diverse environments with following objectives:

Objectives:

1. To study the stability performance of different safflower genotypes for grain yield and its components under different environments.
2. To study the extent of genotypic and phenotypic association of grain yield with its components.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

2.1 Mean performance for yield contributing characters

Khidir (1974) studied eighteen varieties of safflower in a randomized block design with five replications. Data on fourteen quantitative characters were recorded. Appreciable variability was displayed by all characters, especially yield and number of heads/plant. The heritability estimates ranged between 65 and 98%.

Reddy *et al*. (2004) analyzed genetic parameters of 25 cross progenies of safflower which revealed high estimates of genotypic coefficient variation and phenotypic coefficient variation for seed yield per plant. Number of seeds per capitulum, number of secondary branches, number of primary branches, test weight and seed yield per plant, indicating that simple selection could be effective for improving seed yield and its attributes. High heritability coupled with high genetic advance was observed for test weight, seed yield per plant and number of seeds per capitulum indicated that these characters are governed by additive gene effect and additive x additive epistatic interactions and thus ensured reliability for direct selection in safflower**.**

Fatemeh *et al.* (2007) studied the genetic diversity in safflower in sixteen selected lines derived from landraces. Days to emergence, days to initial flowering, days to flowering, days to maturity, plant height, branches per plant, capitula per plant, seeds per capitulum, 100-seed weight, seed yield per plant, seed yield were evaluated in this study. Genetic diversity of the genotypes was assessed by RAPD markers. The results indicated significant differences among genotypes for the agro-morphological traits.

Shivani *et al*. (2010) conducted variability and association studies in a set of 75 germplasm lines of safflower received from DOR, Hyderabad. Sufficient variability was present in the germplasm for number of capitula per plant, number of seeds per capitulum and seed yield (kg/ha). The 100 seed weight (g) had high heritability coupled with high genetic advance whereas plant height and number of capitula per plant had high heritability with moderate genetic advance.

Gopal *et al*. (2015) evaluated one hundred and fifty safflower germplasm lines and five checks for yield and yield related components. Analysis of variance and mean performance for seed yield and its components revealed significant differences among all the germplasm lines for all characters there by indicating presence of variability in genotypes. Effect on seed yield per plant was exhibited by the character; number of effective capitula per plant followed by days to maturity and number of secondary branches per plant.

Pavithra *et al*. (2016) studied one hundred and fifty germplasm accessions obtained from the Directorate of Oilseeds Research, Hyderabad and seven check varieties. A wide range of variability for all the traits was observed. The range of genotypic coefficient of variability varied from 1.54 for oil content to 32.34 for petal yield. The genotypic and phenotypic coefficient of variation was low for plant height, rosette period, days to fifty *per cent* flowering, days to maturity, capitulum diameter, test weight, volume weight, oil content and hull percentage. Low GCV as compared to PCV was observed for all the traits. However, there was relatively a wider gap between GCV and PCV for the traits capitula per plant, number of seeds per capitulum, petal yield, biological yield, harvest index and seed yield indicating the higher magnitude of environmental effect on these traits.

Belete (2017) studied to identify germplasm accessions with desirable agro morphological characters among the 36 accessions evaluated at two locations. The combined analysis of variance showed that accessions were significantly different in characters recorded. This study shows the genetic variation in agro-morphological characters of the accessions, which could be used for selection/breeding programme of safflower. Seed yield can be improved through early generation selection, but other characters should be improved through advanced generation selection.

2.2 Stability parameters for yield contributing characters

The study of stability gives an idea about the genotypic variation and differential response of the genotypes to varying environments which helps to isolate widely adopted genotypes and specific varieties for specific environments as well. The desirable genotypes may show low genotype x environment interaction for agriculturally important characters and on the other hands, may be more flexible for other characters. Such genotypes are said to be well buffered as they can adjust their genotypic and phenotypic states in response to the changing environmental conditions a phenomenon called as genetic homeostasis (Lerner, 1954). Further an ideal variety is one which performs fairly well under average or poor environments and also responds to favorable environments. The evaluation of genotype and environment interaction gives an idea of stability of population under study. Selection for stability is not possible until a model with suitable parameters is available to provide the criteria necessary to rank the genotypes for stability (Finlay and Wilkinson, 1963).

Eberhart and Russell (1966) and Perkins and Jinks (1968) suggested different models to estimate genotype x environment interaction and stability parameters regarding individual genotype when the experiment is conducted over years or locations. Further Eberhart and Russell (1966) elaborated and made further improvement in stability analysis by partitioning the genotype environment interaction of each variety into two parts *viz.,* 1. Slope of regression line and 2. Deviation from the regression line. In this model, the total variance is first divided into two components i.e., 1. Genotypes and 2. Environments + Interaction. The second component i.e., Environments Interaction is further divided into three components *viz*., a. Environment (linear) b. G X E linear and c. Pooled deviation. The sum of square due to pooled deviation is further divided into sum of square due to individual genotype.

Abel and Driscoll (1976) studied the components of seed yield *viz.,* heads per unit area, seeds per head and seed weight of safflower. They observed least environmental effect on seed weight. However, heads per unit area and seeds per head were more flexible under different environment. Line A-1 186-1 was among five highest yielding genotypes at nearly all locations and for all planting dates, indicating the highest adaptation to the range of environments.

Makne and Sharma (1979) observed highly significant G x E interaction in 28 genotypes of safflower at three locations. Genotypes *viz*., Royal JL-3, PI 304451. PI-250713, PI-306,992, PYT-74, No. 273, BS -338, and No. 319-12 were found to have good adaptability for characters under study.

Ranga Rao and Ramchandram (1979) studied the various components related to both fitness and productivity in safflower. They reported marked differences among genotypes and environments for all the variables studied period from planting to rosette, flowering and maturity and more particularly seed size and hull percent exhibited relatively high degree of stability unlike yield and its principle components. In general, the exotic material showed poor adaptability to Indian conditions. Interrelation among various stability parameters for yield with those of its components characters revealed hardly any barriers in developing early lines combining relatively high responsiveness for flowering- maturity and hull content.

Narkhede *et al*. (1984) evaluated 10 varieties of safflower for their stability of seed yield. They observed significant genotype x environment interaction (G x E). The linear components of G x E interaction were significant and thus the performance of genotype across the environments could be predicted. The pooled deviation attributable to the non linear regression was not significant. The stability analysis based on regression co-efficient index revealed that genotypes B-263-2A, No. 168, No. 83 and Bhima were adapted to all environments.

Pandya (1988) studies stability of 50 hybrids and 15 parental lines in lour different environments and observed that the parental lines MS-104, MS-105, Annigiri, JLSF-88 and Bhima and nine hybrids proposed average stability across the environments.

Chaudhary and Meharotra (1989) evaluated fifteen genotypes of safflower for stability of fodder yield and seed yield of ratoon crop under rainfed condition. They reported seven genotypes as stable across the environment for fodder yield. Six genotypes were stable, however EC 35737 and IC-11175 were stable for both characters and satisfy the need for cultivation with limited irrigation facilities for rainfed condition.

Narkhede and Patil (1990) studied nine genotypes of safflower for their stability. They observed the absence of g x e interaction for all traits. The linear portion of g x e interaction was significant and also of greater magnitude than that of non linear portion.

Pandya *et al.* (1991) evaluated fifty hybrids and fifteen, parents across four environments for seed yield and four yield components. They noticed both predictable (linear) and unpredictable (non linear; portion of g x e interaction were found to be present in the hybrids. Some of the highly heterotic hybrids also showed good average stability across the environments.

Patil *et al.* (1992) evaluated seven varieties of safflower at five location under rainfed conditions and another eight varieties were tested under irrigated conditions at four locations. They observed significant genotype differences and genotype x environment interactions were identified for seed yield. SSF-31 was the most stable genotype under fluctuating environmental conditions. Bhima and JLSF-88 were considered the most desirable genotype for irrigated and favorable environments and JLSF-198A and NRS-209 for less favorable conditions.

Manjare (1993) studied stability of 32 hybrids in three environments and observed highly significant genotype x environment interaction for all the characters under study. Among the promising hybrids majority of them showed above average stability, indicating their better performance in poor environment.

Nagaraj (1994) studied seven cultivars from different locations for oil content. Data presented shows that safflower crop grown under Hyderabad and Raichur conditions was more productive and had higher oil content. Varieties like. HUS-315, SI-144 and Bhima were more promising for higher oil productivity.

Uma and Patil (1994) studied nine promising genotype of safflowers and evaluated them for their stability for seed yield in three different saline environments. Genotypes like A-l. Nira and Manijira were stable with high mean yield and average response to the changes in the environmental conditions. Hence, their Exploitation in a breeding programme will help in improving the productivity of this crop.

Hedge *et al.* (1997) studied nine safflower hybrids and three varieties for five stability parameters at eight locations and found significant variations of genotype x environment interaction for yield and yield components. The mean performance over environments, hybrid DSH-116, DSH-135 and variety A-l were responsive and stable for yield. Hybrid DSH-128 was specially adapted to unfavorable environments, whereas MKH-11 produced high seed yields in favorable environments. DSH-113, DSH-1 16, DSH-130 and released variety HUS-305 were well adapted and stable in all environments for oil content.

Mandal and Banerjee (1997) information on stability is derived five yield related traits in the F_2 progenies of 10 elite cross combination of safflower grown over an array of saline environments. They observed environment and genotype x environment interaction that F_2 progenies of two were found to possess high seed and oil with high stability.

Manjare (1997) information on stability is derived from eight yield related traits in twelve safflower varieties. They studied genotype x environment (G x E) interaction was significant for all the characters. The linear component of the environment was also significant for all the character except for number of primary branches per plant and number of secondary branches/plant. G x E (linear) interaction was significant for seed yield per plant and number of seeds per capitulum on primary and secondary branches. Bhima was most stable safflower variety.

Patil (1997) evaluated twenty five genotype of safflower in four environments under rainfed as well as irrigate condition. The genotypes, Girna, Bhima. SSF-135 and JLSF-327 were found more responsive and stable across the environments.

Patil and Zope (1997) evaluated twenty five genotypes of safflower under four micro environments for seed yield. Significant genotype x environment interaction was observed. The genotypes Girna, Bhima, SSF-135 and JLSF-327 were most responsive and stable. They observed stability parameters were to be governed by different gene or genes in combination in safflower.

Patil *et al.* (1999) evaluated fifty elite genotype of safflower in nine environments. Results indicated that significant variation in respect of genotypes, environments and genotype environment (GE) interaction for seed yield, days to rosette termination, day to flowering and days to maturity. Considering the mean performance over environments, the genotypes, among dwarf for days to rosette termination; CTV-12, CTV-28, CTV-38 and JLA-480 for days to flowering; CTV-27 CTV-31 CTV-34 and CTV-42 for days to maturity and A-l and JLSF-19A for seed yield were responsive and possess average stability.

Rudra Naik *et al.* (2005) eleven promising genotypes along with two checks were evaluated in three different locations tor stability under moisture stress condition. Variance due to genotypes environments was significant for all the characters except oil. While genotypes X environment interaction was significant only for seed yield considering all the stability. Considering all the stability parameters, 08-20, OK-102 and 918 had better stability over the environment under moisture stress condition's Based on stability parameters and overall mean the genotype; 08-20, 08102 and 91-8 were identical as stable performers under moisture stress conditions.

Mahasi *et al.* (2006) evaluated thirty-six safflower cultivars for their phenotypic traits in Katumani, Kinamba, Lanet and Naivashna, Kenya and found genotype x environment interaction can be useful in the identification of high yielding genotypes with stable performance. Different genotypes reacted differently to varying seasons as indicated by the highly significant genotype x environment interaction, hence environmental effects are important in understanding plant growth and should be given consideration in safflower breeding programmes.

Omidi (2006) evaluated ten winter safflower cultivars and lines in three different environmental condition in Iran, conducting an F test of different source of variation revealed that the effect of genotype x year x location interaction was significant (P <1%). Analysis of the grain and oil yields using the Eberhart and Russell method showed significant difference for the main effects of genotype an genotype x environment (linear) interactions and non significant difference, for deviation from regression

Rao *et al.* (2007) evaluated nine safflower genotypes for and its components under three environments in Chhattisgarh. Variance due to the genotypes (G), environment (E) and G x E (linear) component were highly significant for number of capitula plant $^{-1}$, hull percentage and seed yield plant $^{-1}$ (g). The genotype Sharda was found to be desirable and stably for total yield plant^{-1}, while the genotype S-144 was suitable for favorable environment. The genotype Manjira found to be stable for oil content.

Abdulahi *et al*. (2007) studied 16 safflower (*Carthamus spp.*) genotypes that have both high and stable yield performance across different environments through nonparametric measures and study on the relationship among nonparametric stability statistics. Results of nonparametric tests of G x E interaction indicated the presence of both crossover and usual crossover interactions and genotypes varied significantly for the grain yield. Rank Sum (RS), were associated with high yield, but the other nonparametric stability methods were not significantly correlated with mean yield. Measure for general adaptability (TOP) high value indicates widely adapted genotype, according to TOP measure the genotypes G7 followed by G4 and G16 were relatively adapted. Regarding to RS and TOP, G16 (PI-537598) was the best genotype.

Akmal *et al.* (2008) tested the nine elite genotypes $_0$f safflower along with a check (Thori-78) for seed yield at seven diverse environment of Pakistan during 2003-04 and 2004-05. The pooled analysis of variance showed highly significant differences among the genotypes (G), environment (E) and G x E interaction suggesting differential responses of the genotypes and the need for the stability analysis. The genotypes SAF-30 and SAF-33 may perform better under high yielding environment. Whereas, SAF-35 was found to be suitable for low yielding environments.

Omidi (2008) evaluated seven spring safflower cultivars and lines in five different environmental conditions at Karaj, Isfahan, Eslamabad and Zaran in Iran, the effect of genotype x year x location interaction was significant ($P < 1\%$). The new line l.L.11 with its high grain and oil yields and stability was selected as a desirable genotype.

Pourdad and Mohammadi (2008) studied the AMMI analysis showed that 83.78% of the total sum squares (SS) was attributable to environmental effects, only 1.37 and 14.85% to genotype and GE interaction, effects respectively. The results showed none of the parametric statistics per se was useful for selecting high yielding and stable genotypes. By simultaneous selection for yield and stability the genotypes G-9, G-10 and G-11 were the best whereas, the G-l and G-17 with the highest yield performance were the most instable in conclusion; both of yield and stability should be considered simultaneously to exploit the useful effect of GE interaction and to make selection of the genotype more precise and refined.

Parameshwar *et al.* (2009) an was carried but involving seven genotype and five check varieties during *rabi* 2006-2007 at three different location to know the magnitude of variability present and to assess the stability of genotype for yield and yield components, on the basis of genotype for majority of characters with higher mean performance across to the environments.

Jamshidmoghaddam and Pourdad (2013) studied to analyze GEI (genotype x environment interaction) on seed yield of 18 spine safflower genotypes at three locations, by the additive main effects and multiplicative interaction (AMMI) model, and second to compare AMMI-derived stability statistics with several stability different methods, and two stability analysis approaches the yield-stability (Ysi) and the GGE (genotype + genotype x environment) biplot that are widely used to identify high-yielding and stable genotypes. The results of the AMMI analysis showed that main effects due to genotype, environment, and GEI were significant (P\0.01). According to most stability statistics of AMMI analyses, genotypes G5 and G14 were the most stable genotypes across environments.

Bahmankar *et al*. (2014) studied 20 different safflower genotypes and noticed phenotypic correlation which indicated that seed yield per plants had highly positive correlation with 1000-seed weight (r=0.79**), main head diameter (r=0.77**) and heads per plants (r=0.49*). Stepwise multiple linear regression interpretation also indicated that 90% of variation in seed yield attributed to variation which arose from 1000-seed weight, heads per plants, main head diameter and plant height characters.

Hamza (2014) studied stability of local and exotic safflower genotypes and the association among stability measures. Six safflower genotypes were cultivated under twelve environments. The used stability parameters were mean squares due to deviations from regression (S2d), regression coefficients (bi) and the three non-parametric measures S1, S2 and S3. The exotic cultivar Demo-137 was found to be the most stable genotype for seed and oil yields ha^{-1} followed by the Line-1697.

Ahmad *et al.* (2016) evaluated sixteen promising genotypes including one check were evaluated for the assessment of stability in seed yield and yield contributing traits of safflower. Variances due to genotypes and environment were significant for most of the characters while genotype x environment interaction was significant for seed yield, number of capitula /plant and number of seeds /capitulum. GMU-2724 was concluded the most ideal.

Ebrahimi *et al*. (2016) studied genotype x environment interaction, stability and adaptation of a worldwide germplasm of safflower (*Carthamus tinctorius L.*) for seed and oil yield by conducting experiments at seven environments using 100 safflower genotypes. In the present study, the additive main effects and multiplicative interaction (AMMI) model was employed. The results of the AMMI analysis showed that the main effects due to genotype, environment, and GEI as well as the first four interaction principle component axes were significant for both seed and oil yield. The AMMI biplot determined genotypes G65 (originating from USA) and G40 (originating from Tajikistan) as the superior to be grown under drought stress conditions.

2.3 Association study for yield and yield contributing characters

2.3.1 Correlations among yield and yield component traits

Knowledge on correlation would facilitate proper interpretation of results and provide a basis for planning efficient selection programmes. The association among various characters in safflower has been studied by a number of investigators and the same is reviewed below.

Khidir (1974) showed that working with eighteen varieties of safflower noticed significant positive association between seed yield with number of seeds per capitulum, capitulum width, bract width, while 100 seed weight was significantly and negatively correlated with seed number per capitulum and plant height.

Ranga Rao *et al*. (1977) analyzed inter-relationship of various component characters with yield and oil content using 215 entries of safflower from India and USA. The correlation of capsule number per plant and capsule weight with yield per plant was positive and pronounced. Seed size had little effect on yield while seed number exerted a positive influence, whereas, a highly significant and negative association was found between oil and hull content.

Makne and Sharma (1979) found strong positive and significant correlations between yield with plant height (Sengupta and Bhattacharya, 1979), number of capitula per plant (Quillanton Villarred and Perezzonzelez, 1979), number of seeds per capitulum, capitulum size and 1000 seed weight in 71 selected indigenous and exotic germplasm lines of safflower. All these studies indicated that "plant height at maturity" could be effectively utilized for improvement of seed yield. From a study with sixteen Indian varieties of safflower, (Ramesh *et al.,* 1980) reported significant genotypic correlation between seed yield per plant with number of branches and 100 seed weight. Kotecha (1981) observed positive correlations in two F_2 segregating populations, between seed yield and capitulum number.

Thombre and Joshi (1981) study involving fifty exotic and indigenous varieties of safflower, observed positive and significant genotypic correlations for seed yield with branches per plant, number of days to first flower and seeds per capitulum.

Parameshwarappa (1981) noticed significant positive correlation of seed yield with number of capitula, 100 seed weight, hull content, number of secondary branches and stem girth while oil content had negative correlation with seed yield and hull content. Among the yield component a strong association of number of secondary branches with number of capitula per plant was observed. Plant height showed high values of correlation with stem girth; capitulum diameter with seeds per head hull content with 1000 seed weight.

Patil (1985) The strong and positive correlation of yield per plant with number of primary and secondary branches, capitula number per plant and 1000 seed weight were noticed both at genotypic and phenotypic levels in a study involving genetically divergent varieties. However, correlation between 1000 seed weight and oil per cent and days to 50 per cent flowering and seed yield were negative.

Jadhav *et al.* (1992) seed yield per plant was positively associated with number of seeds per capitulum, plant spread, number of capitula and dry matter per plant. On the other hand, number of primary branches per plant, seeds per capitulum and 1000 seed weight were negatively associated with seed yield.

Hudge *et al.* (1993) noticed positive and significant correlation of seed yield with number of capitula per plant and 100 seed weight in four safflower genotypes. The total dry weight exhibited positive and significant association with oil content. Singh *et al.* (1993) reported that seed yield per plant has significant positive correlation with days to maturity and plant height.

Ekshinge *et al* (1994) and Pascual-Villalobos and Albyrquerque (1996) from a study with different varieties found significant positive correlation of seed yield with plant height, number of branches and number of capitula per plant.

Subbalakshmi and Sivasubramanian (1995) in a study involving twenty-eight diverse genotypes of safflower noticed the positive interrelationship between number of branches and number of heads per plant.

Pandya *et al.* (1996) observed positive and significant association between seed yield and number of capitula per plant, 100 seed weight and number of seeds per capitulum. From a study with M2, F2, I-2M2 and the triple cross F2 populations, Patil *et al.* (1997) observed strongest positive association of seed with number of capitula per plant followed by 100 seed weight and number of branches per plant. The number of capitula was negatively associated with the diameter of capitulum, which was in turn positively related to the seed number. The number of seeds per capitulum was negatively associated with 100 seed weight and the number of capitula per plant.

Meghannavar *et al.* (1998) revealed that seed yield was strongly and positively associated with capitula weight, number of capitula, capitula size and number of seeds per capitulum but negatively associated with oil content. Hull content was positively associated with seed yield but negatively associated with oil content.

Patil and Deshmukh (1998) from a study with 150 germplasm collections reported significant positive association among 100 seed weight, capitula per plant, primary and secondary branches per plant and seeds per capitulum with seed yield.

Chavan *et al.* (1999) indicated that plant height was positively and significantly correlated with number of seeds per capsule and number of primary and secondary branches showed significant and positive correlation with number of capsules per plant under both rainfed and irrigated conditions.

Senapati *et al.* (1999) observed in a study involving 17 genotypes including two checks, high positive correlations with capitula per plant, biological yield and 100 seed weight.

Anjani (2000) recorded information on yield correlations on yield components in 100 accessions of safflower.

Kubsad *et al*. (2000) noticed that the highest association was observed between seed yield and 100 seed weight.

Malleshappa (2000) revealed that seed yield was strongly and positively associated with capitula number and test weight but negatively associated with seed number and capitulum diameter which are important components of oil content.

Bagheri *et al.* (2001) revealed that plant yield was highly and positively correlated with capsule diameter, days to first flowering, number of seeds per capsule, number of capsules per plant and seed weight of capsule. Correlation between 1000 seed weight and seed oil content was negative.

Dalvi *et al*. (2005) studied the relationship among yield and its componts. The seed yield of plant was significant and positively correlated with the number of primary branches, number of secondary branches, number of capitula per plant and number of effective capitula per plant at both phenotypic and genotypic levels while test weight showed positive significant correlation with seed yield at the genotypic levels. The association both test weight and number of seeds per capsule was negatively significant at genotypic level. The number of effective capitulum existed the highest positive direct effect of seed yield followed by days to 50% flowering number of secondary branches test weight, seed density and plant height. The number of secondary braches showed positive direct effect on seed yield. The indirect effective number of secondary branches through number effective capitula was highest.

Lakshyadeep *et al*. (2005) revealed that significant and positive correlation with seed yield per plant, number of capitula per plant weight per capitulum and number of primary branches. The direct selection for number of capitula per plant and indirect selection was most effective for weight per capitulum and number of leaves on main axis after branching would be effective in yield improvement programmes in safflower.

Mahasi *et al.* (2006)evaluated thirty-six safflower accessions for phenotypic traits The path analysis of yield components revealed that components with the highest correlation to yield also had the highest direct effect to yield i.e., primary branches, capitula/plant, effective capitula, seeds/capitula and 100 seed weight. Two approaches can be suggested in selecting genotypes for specific traits to improve seed yield in safflower.

Jawanjal *et al.* (2006) the experiment material comprised of five crosses having six generation (P_1, P_2, F_1, F_2, BC_1, BC_2) was evaluated for yield and yield contributing character safflowers. Number of capitula per plant number primary braches per plant number of secondary braches per plant days to 50 per cent flowering and number off seeds per capitulum was significant positive correlation with seed yield. Path analysis for yield indicated high direct effect for number of secondary branches per plant followed by days to maturity.

Kumari and Ravikumar (2010) studies field were conducted in Dharwad, to analyze the yield contributing characters of safflower genotypes Al and A2, crossed with *Carthamus palaestinus* and *C. glaucus* using correlation and path analyses observation were recorded for plant height, days to first flowering, number of branches per plant, number of capitula per plant, capitulum diameter, number of seeds per capitulum, test weight volume weight and seed yield per plant. Results showed that the number of capitula per plant, of branches per plant, capitulum diameter plant height or seeds per capitulum, capitulum diameter, test weight, volume weight and seed yield per plant had direct effect.

Ahmadzadeh *et al.* (2012) studied the phenotypic correlation among the traits and their path coefficient were estimated in both condition positive and significant correlations were observed between grain yield and days to maturity, number of seed per head, plant height, hectoliter weight biological yield and oil yield. Positive direct effects were exhibited for plant height, 100 seed weight hectoliter weight on grain yield under irrigated conditions. In case of drought stress condition grain yield was positively and significantly correlated with number of seeds per head effective head weight plant weight harvest index and oil yield positive direct effects were observed for number of seeds per head. 100 seed weight, days to 50 per cent flowering on grain yield and negative direct effect was observed for days to maturity on grain yield under drought stress conditions.

Tamoor Hussain *et al*. (2014) evaluated twenty genotypes of safflower and noticed that grain yield (kg/ha) correlated significantly and positively with plant height, boll diameter, number of grains per boll, 1000 grain weight and days to maturity.

Pavithra *et al*. (2016) evaluated one hundred and fifty safflower germplasm accessions and results revealed significant positive correlation between seed yield per plant and other characters like plant height, capitula per plant, number of seeds per capitulum, biological yield and harvest index and significant negatively with rosette period, days to 50% flowering and days to maturity.

Pushpavalli *et al*. (2016) evaluated twenty safflower germplasm lines and found Significant differences existed among the germplasm lines for all the characters studied. Seed yield/plant exhibited positive and significant correlation with number of seeds/capsule and 100-seed weight.

2.3.2 Path coefficient analysis

Yield is a complex character which is influenced by many yield contributing characters both through direct and indirect effects. Generally direct selection for yield is not sufficiently effective due to its low heritability and it is desirable to select indirectly through component traits for yield improvement. Here path analysis helps to resolve the correlation indicating direct and indirect effects of various component characters on seed yield. The technique of path analysis was first developed by Wright (1921) and still considered as a valuable tool in detecting the real merit of characters contributing to yield.

Khidir (1974) and Meharothra and Jain (1976) in their studies involving 18 and 24 varieties, respectively noticed that plant height was the only character to exert highest direct positive effect on seed yield although it had a negative influence on seed yield via capitulum width.

Mathur *et al.* (1976) observed the greater direct effect of capitulum width on seed yield by seed weight, plant height, height of branching, branch length and days to 50 per cent flowering.

Ranga Rao *et al.* (1977) opined that seed number and seed weight are the most important characters influencing the seed yield per plant directly. The hull content per cent influenced seed yield both directly and through indirect paths. The indirect effect was through capitulum weight and oil per cent. The combined negative indirect effects of oil content through hull per cent and capitula weight outweighed its positive direct contribution, there by resulting in a negative phenotypic association of oil content with seed yield.

Thombre and Joshi (1981) found that number of seeds per capitulum had a direct positive effect on seed yield followed by days to first flower and 1000 seed weight. The negative direct effects of branches per plant, 1000 seed weight and capitula per plant was masked by positive indirect effects of seeds per capitulum.

Channeshappa *et al.* (1984) concluded that direct selection for oil content is not effective but it could be achieved indirectly though selection for reduced hull content.

Malleshappa *et al.* (1989) studied the yield per capitulum, plant height and capitula per plant exhibits greater contribution towards yield.

Patil *et al.* (1990) observed that the capitula weight per plant was responsible for greatest direct contribution towards yield per plant. Jadhav *et al.* (1992), Reddy *et al.* (1992) and Ghongade *et al.* (1993a) observed that the number of seeds per plant, number of capitula per plant, 100 seed weight and number of seeds per capitulum had the highest positive direct influence on seed yield.

Prakash and Prakash (1993) noticed that capitula number and seed yield per plant were main contribution to oil yield per plant. It was suggested that biparental mating followed by recurrent selection might produce superior recombinants with higher yield. Path coefficient analysis revealed that seed weight had maximum direct positive effect on seed yield.

Pandya *et al.* (1996) the number of capitula per plant, 100 seed weight and number of seeds per capitulum were the direct contributors to the seed yield (Patil *et al.*1997 and Meghannavar *et al.,* 1998). The indirect positive effect of plant height and number of branches throughout number of capitula per plant on seed yield was also observed.

Veena (1997) and Bagawan (1998) indicated that the number of capitula per plant, capitulum diameter, number of seeds per capitulum and 100 seed weight contribute directly towards seed yield per plant. They also reported that number of branches contribute indirectly through number of seeds per capitulum towards seed yield per plant.

Patil and Deshmukh (1998) and Patil (1998) revealed highest direct effect of 100 seed weight followed by number of capitula per plant, number of primary and secondary branches per plant and seeds per capitulum towards seed yield.

Chavan *et al.* (1999) revealed that plant height, number of secondary branches, number of capsules and number of seeds / capsule showed highest positive direct effects on seed yield.

Malleshappa (2000) revealed that characters *viz.,* number of capitula, test weight and number of seeds per capitulum were reliable components influencing seed yield directly.

Bagheri *et al.* (2001) indicated that number of capsules per plant had the highest direct effect on plant yield. It exerted a large indirect effect by increasing seed weight of a capsule.

Lakshyadeep *et al.* (2005) revealed the significant and positive correlation with seed yield per plant number of capitula per plant weight per capitulum and number of primary braches. The direct selection for number of capitula per plant and indirect selection per plant and indirect selection was most effective for weight per capitulum and number of laves on mean axis after branching would be effective in yield improvement programmes in safflower.

Pahlavani *et al.* (2005) evaluated ten breeding lines of safflower (*Carthamus tinctorius* L.) from Iran in respect to technological and morphological traits for their utilization aspects in both food industry and agricultural applications. A considerable variation was found among the genotypes for hull, protein and oil content, iodine value, plant height, seed yield per plant, number of heads per plant and 100-seed weight. Oil content of seeds had a positive and considerable correlation with Iodine value and plant height and also, a negative correlation with seed yield per plant. The protein content also recorded the highest positive association with oil content followed by plant height. Seed yield per plant showed positive and considerable correlation with hull content and number of days to 50 per cent flowering and a considerable negative correlation with protein content of seeds. The results suggest that evaluated breeding lines of safflower could be valuable materials for breeding programs in which the main goals are improving oil yield and oil quality. The low correlation between oil content and seed yield in this study implied that it is possible to improve the seed yield and oil content simultaneously) in safflower. Also, the results of this study) indicated that improvement of seed yield could be achieved by selection for number of days to flowering.

Diwakar *et al.* (2006) revealed that number of effective capitula per plant had maximum positive direct effect followed b) number of tilled seed in main capitulum on seed yield. Days to 50% flowering and plant height exhibited negative direct effect on seed yield.

Bidgoli *et al.* (2006) studied six safflower genotypes involving 17 characters and reported significant correlation of seed yield with total biomass.

stem yield, capitulum diameter, 1000-seed weight, seed weight per capitulum distance between ground level and the first fertile branch, number of days to the beginning of branching and flowering duration. Total biomass, seed weight per capitulum, distance between ground level and the first fertile branch, 1000-seed weight and flowering duration had substantial direct effects on seed yield, whereas significant negative correlation was observed between number of days to the beginning of branching, distance between ground level, the first fertile branch and seed yield. Results suggested that total biomass and number of days to the beginning of branching are primary selection criteria for improving seed yield in safflower.

Arslan (2007) revealed that the seed yield was determined by head diameter, heads per plant and seeds per head medicating that these characters had height positive significant direct effect on seed yield.

Golparvar and Pirbalouti (2009) studies the important seed and oil yield components in safflower result of correction, regression and path analysis designed trails 1000- seed weight and seed number per plant had considered able. Positive and direct effects on plant seed yield and largest amount of variation existing in this traits.

Naik *et al.* (2009) studied Biparental mating (BIP) in the F2 population in safflower path coefficient analysis revealed that direct effect with respect to the number of seed per capitula, 100 seed weight and volume weight towards seed yield were enhanced by BIP.

Topal *et al*. (2010) studies direct and indirect effect estimated with parametric and non parametric path analysis. The direct effect of on yield and indirect effect of number of seed per head on seed yield via oil yield were found large it concluded that oil content, number of seed / head and plant. Heights were important selection characters for seed yield of safflower under drought conditions.

Behnam *et al.* (2011) to evaluate the correlation between yield and other quantitative traits in safflower correlation analysis revealed significant correlation between oil and seed yield in normal and stress conditions. The result indicated that the stress tolerance index, geometric mean, productivity and arithmetic mean, productivity could be used for selection of drought tolerant genotypes. According to the path analysis in a normal and stressed conditions seed yield had highest and positive direct effect on oil yield. Path showed the highest and positive direct effect on seed yield through number of heard per plant 1000 seed weight, while ii stressed conditions. 1000 seed weight and number of seed per head showing the highest direct effect on seed yield.

Ravikumar and Roopa (2010) found a strong positive correlation between seed yield per plant and number of capitula per plant, number of branches per plant and test weight was observed. The number of capitula had highly significant and positive correlation with number of branches. Further, the capitulum diameter was strongly associated with seeds per capitulum. Positive but non-significant correlation was observed between volume weight and seed yield per plant, which is an important character, which contributes for oil content. The test weight had positive association with seeds per capitulum and seed yield. Such positive shifts in correlation between seed yield and test weight may probably be due to positive association of seed number, which is again a determinant character for high seed yield and oil content as increased number of seeds is always associated with high oil content. Thus in order to achieve simultaneous improvement for seed yield and oil content increased seed number in the capitulum is a pre-requisite. Among, the different characters studied for the direct as well indirect contribution towards seed yield, the direct effect of number of capitula was more pronounced followed by test weight, plant height and capitulum diameter**.** Several other characters *viz.,* capitulum diameter and test weight contribute indirectly through capitulum number.

Bahmankar *et al*. (2014) evaluated 20 different safflower genotypes and strongly suggested that 1000-seed weight; heads per plants and main head diameter contain positive direct effect on seed yield.

Tamoor Hussain *et al.* (2014) revealed highest and positive direct effect of number of grains per boll followed by 1000 grain weight and plant height on grain yield (kg/ha).

Pavithra *et al.* (2016) revealed that like plant height, capitula per plant, number of seeds per capitulum, biological yield and harvest index exhibited positive direct effect on seed yield except days to maturity.

Pushpavalli *et al*. (2016) evaluated twenty safflower germplasm lines and indicated that 100-seed weight exhibited maximum direct effect followed by number of seeds per capsule.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled "Stability analysis for yield and yield contributing traits in safflower (*Carthamus tinctorius* L.) was undertaken at AICRP on Safflower Parbhani, Oilseeds Research Station, Latur, Pulses Research Station, Badnapur and ARS Somanathpur (Udgir) during *rabi* 2016. The experimental details regarding materials and methods used are described in following lines.

3.1 Experimental materials

Ten safflower genotypes along with two check varieties *viz*., PBNS-12 and Sharda were obtained from AICRP on Safflower, Parbhani. Genotypes were sown at four location *viz.,* AICRP on Safflower Parbhani, Oilseeds Research Station, Latur, Pulses Research Station, Badnapur and ARS Somanathpur (Udgir) during *rabi* 2016.

The details of genotypes included in experiment have been shown in Table 1.

Table 1 : **Name of genotypes**

Sl. No.	**Genotypes**	**Sl. No.**	**Genotypes**
1	PBNS -128	**7**	PBNS -152
2	PBNS -129	**8**	PBNS -153
3	PBNS -130	**9**	PBNS -154
4	PBNS -137	**10**	PBNS -150
5	PBNS -138	**11**	PBNS -12 (check)
6	PBNS -151	**12**	Sharda (check)

3.2 Experimental methods

The experimental material was evaluated in Randomized Block Design (R.B.D.) with 3 replications at AICRP on Safflower, Parbhani (E_1), Oilseeds Research Station, Latur (E_2), Pulses Research Station, Badanapur (E_3), and ARS Somanathpur Udgir (E_4).

1 Experimental Design: Randomized Block Design

2. Spacing

i)	Row to row distance (cm)	:	45
ii)	Plant to Plant distance (cm)	:	25
3.	Replications	:	3
4.	Number of rows per plot	:	5
5.	Plot size	:	Net - 2.25 x 3.5
		:	Gross - 3.15 x 4
6.	Fertilizer dose	:	60:40:20 NPK kg per hectare

3.3 Observations recorded

Five plants were selected from each treatment randomly for recording observations. Average value of each character was determined from these observational plants except of days to 50 *per cent* flowering and days to maturity. Observations were recorded on following biometrical traits.

1. Days to 50 *per cent* flowering (days)

Number of days required from sowing to the flowering of approximately 50 *per c*ent plants in each genotype were recorded.

2. Days to maturity (days)

Number of days from sowing to complete drying of plants in each entry were recorded.

3. Plant height at maturity (cm)

The height of the mature plant was recorded in centimeter from the base of plant surface to tip of main shoot.

4. Number of primary branches per plant

Number of branches on main shoot plant^{-1} was counted and recorded as number of primary branches

5. Number of secondary branches per plant

Number of branches on primary branches was counted and recorded as number of secondary branches.

6. Number of capitula per plant

Number of capitula on main shoot and on all branches were counted and summed up.

7. Number of seeds per capitulum

Average numbers of seeds from selected capitulum were counted.

8. Chlorophyll content (Leaf spad readings)

Chlorophyll content of leaves from selected plants were recorded by Spadmeter

9. Oil content (%)

Oil content of seed was determined over nuclear magnetic resonance (NMR). The analytical work was done at AICRP on Safflower, Parbhani.

10. 100- seed weight (g)

Weight of randomly sampled 100 seeds from each of the genotype was recorded in gram.

11. Seed yield per plant (g)

Yield in gram of plants selected for above observation was recorded and average value was calculated.

12. Seed yield per plot (g)

Seed yield per plot was recorded from the selected plants and average value was calculated.

13. Harvest index (%)

The seed yield relative to the biological yield per plant was taken as harvest index and the same was expressed as percentage.

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

3.4 Statistical analysis

The statistical analysis for 12 genotypes was carried out as detailed below.

3.4.1 Mean

The mean value for each character was worked out by dividing the total by corresponding number of observations.

$$\bar{X} = \frac{\sum x}{n}$$

Where,

$\sum x$ = Total of all observations for the character

n = Number of observations

3.4.2 Analysis of variances

The mean data collected on five competitive plants in each replication on each line were subjected to analysis of variance location wise as per the method described by Panse and Sukhatme (1985).

$$Y_{ij} = m + G_j + E_{ij}$$

Where,

Y_{ij} = observed value of j^{th} genotype in i^{th} replication.

m = general mean

G_j = effect of j^{th} genotypes

E_{ij} = uncontrolled variation associated with j^{th} genotype in i^{th} replication.

The analysis of variance will take the following form

Source of variation	**d.f.**	**M.S.**	**Expected mean square**
Replication	(r-1)	MS_1	$\delta^2e + g\,\delta^2r$
Genotypes	(g-1)	MS_2	$\delta^2e + r\,\delta^2g$
Error	(r-1) (g-1)	MS_3	δ^2e

Where,

r = number of replication

g = number of genotypes

δ^2e = error variance

δ^2g = genotype variance

δ^2r = replication variance

3.4.3 Stability analysis

The stability analysis was performed for the characters under study separately using the model of Eberhart and Russell (1966).

3.4.3.1 Pooled analysis of variance

The pooled analysis of variance was carried out as per the standard procedure given by Singh and Choudhary (1977) from mean over replications of each environment for ten characters. The forms of analysis of variance are as follows.

Analysis of variance for pooled data.

Source of variation	d.f.	M.S.	Expected mean square
Environments	(E-1)	MS_1	$\delta^2e + rg\,\delta^2E$
Genotypes	(g-1)	MS_2	$\delta^2e + r\,\delta^2gE + rEK^2g$
Genotypes x environments	(E-1) (g-1)	MS_3	$\delta^2e + r\,\delta^2gE$
Pooled error	E(g-1) (r-1)	MS_4	δ^2e

Where,

r = number of replication

g = number of genotypes

K = variance component of fixed affects

E = number of environments

The mean sum of squares due to genotypes and environments were tested against mean sum of squares due to genotypes x environments. However, the mean sum of squares due to genotype x environments were tested against mean sum of squares for pooled error.

3.4.3.2 Estimates of stability parameters

The stability parameters are defined with the following model,

$Y_{ij} = \mu i + bi\ I_j + d_{ij}$

Where,

Y_{ij}	=	variety mean of the i^{th} genotype in the j^{th} environment (i = 1, 2, ..., g and j = 1, 2, ..., E).
μi	=	mean of the i^{th} genotype over all environment.
bi	=	regression coefficients that measures the response of the i^{th} genotype to varying environments.
I_j	=	environmental index obtained as the mean of all the genotypes in j^{th} environment minus the grand mean.
d_{ij}	=	deviation from regression of the i^{th} genotype in the j^{th} environment.

3.4.3.3 Environmental index (I_j)

$I_j = (\Sigma_i Y_{ij}/g) - (\Sigma_i \Sigma_j\ .\ Y_{ij}/ge)$

Where,

I_j	=	environmental index
$\Sigma_i Y_{ij}$	=	summation of all the genotypes for j^{th} environment.
g	=	number of genotypes
$\Sigma_i \Sigma_j\ Y_{ij}$	=	summation of all the genotypes over all the environment
ge	=	number of genotypes x number of environments

3.4.3.4 Regression coefficient (bi)

The first stability parameter is a regression coefficient. The regression coefficient of the varietal mean on environmental index was estimated for each genotypes in the experiment as follows.

$$bi = \Sigma_j Y_{ij} I_j / \Sigma_j I^2_j$$

Where,

$\Sigma_j Y_{ij} . I_j$ = sum of products and

$\Sigma_j I^2_j$ = sum of square for environmental index.

The appropriate analysis of variance is given in following table with this model the sum of squares due to environment and genotype x environment are partitioned into environment (linear), genotype x environment (linear) and deviation from the regression.

Analysis of variance for stability parameters.

Source of variation	**d.f.**	**sum of squares**
Total	(ge-1)	$\Sigma_i\Sigma_j Y^2_{ij}$ - C.F.
Genotypes (g)	(g-1)	$\Sigma j\ Y^2_i/e$ - C.F.
Environments (E) + genotypes x environment	g (e-1)	$\Sigma_i\Sigma_j Y^2_{ij} - \Sigma Y^2_i/e$
Environment (linear)	1	$[1/g (\Sigma_j Y_{.j} I_j)^2]/ \Sigma_j I^2_j$
Genotype x environment (linear)	(g-1)	$\Sigma_i [(\Sigma_j Y_{ij}\ I_j)^2 / \Sigma_j I^2_j]$ - Env. (linear) S.S.
Pooled deviations	g (e-2)	$\Sigma_i\Sigma_j \delta^2_{ij}$
Genotype-1 . . . Genotype (g)	(e-2) (e-2)	$[\Sigma_j Y^2_{ij} - (Y^2_{i.}/e)] - [(\Sigma_j Y_{ij}I_j)^2 / \Sigma_j I_j^2]$ $[\Sigma_j Y^2_{gj} - (Y^2_{g.}/e)] - [(\Sigma_j Y_{gj}I_j)^2 / \Sigma_j I_j^2]$
Pooled error	e (r-1) (g-1)	Pooled replication x genotype S.S. over environments.

Where,

g = number of genotypes

e = number of environments

r = number of replication

i = environmental index

Y_{ij} = Basic observation i.e. mean of the i^{th} genotype over replication in j^{th} environment.

3.4.3.5 Deviation from regression

The performance of each genotype can be predicted by using the estimated parameter.

$$S^2di = [\Sigma_j \delta^2_{ij}/ (s-2)] - [Se^2/r]$$

and $$\Sigma_j \delta^2_{ij} = [(\Sigma_j Y^2_{ij} - Y^2_i) / t] - [(\Sigma_j Y_{ij}.I_j)^2 / \Sigma_j.I^2_j]$$

Where,

Se^2/r = estimate of pooled error.

3.4.3.6 Test of significance

i) In order to test the significance of the difference among the genotypes mean i.e. $H_0 = \mu 1 = \mu 2 = \mu 3 = ... = \mu n$. The appropriate 'F' test is defined as

$$F = MS_1 / MS_3$$

ii) To test that the genotypes do not differ from their regression on the environmental index i.e. $H_0 = b1 = b2 = b3 = ... = bn$. The test is as $F = MS_2 / MS_3$

Thus all the variances can be tested against pooled deviation mean squares (MS_3).

iii) Pooled deviation can be tested as

$$F = MS_3 / MS_4$$

iv) The deviation from regression (i.e. significance of S^2di) can tested by

$$F = [(\Sigma_j \delta^2_{ij})/e-2] / \text{pooled error}$$

Where,

$\Sigma_j \delta^2_{ij}$ = variance due to deviation from regression e = number of environments

v) The deviation of bi values from zero tested using 't' test for null hypothesis.

$$t = (b_i - 0) / S.E.(b_i)$$

Where,

S.E. (b_i) = standard error of b_i.

If bi is significant, its significant deviation from unity was tested by following formula.

3.4.4 Correlation coefficient

a. Estimation of components of variation.

The phenotypic and genotypic variances were calculated by using the respective mean square values from the variance table (Johnson *et al.*, 1955).

Environmental variance $\delta^2 e$ = EMS

Genotypic variance $\delta^2 g = \dfrac{\text{GMS - EMS}}{r}$

Phenotypic variance $\delta^2 p = \delta 2g + \delta^2 e$

b. Estimation of covariances

Analysis of covarianee between all the pairs of the characters under study was carried out as per the procedure of analysis of variance and covariance as described by Singh and Choudhari (1977) as under

Environmental covariance (e^{Cov} 12) = EMP

GMP – EMP

Genotypic covariance (g^{Cov} 12) = $\dfrac{\text{------------------------}}{r}$

Phenotypic covarianee (g^{Cov} 12) = e^{Cov} 12 + g^{Cov} 12

The appropriate variances and covariances were used to calculate phenotypic and genotypic correlation coefficients (Johnson, *et al.* 1955).

$$\text{Phenotypic correlation coefficient (rp)} = \frac{p^{Cov}\ 12}{\sqrt{(\delta^2 p_1)\ (\delta^2 p_2)}}$$

were derived as p^r 12

Where,

p^r 12 = Phenotypic correlation between character 1 and 2

p^{Cov} 12 = Phenotypic covariance between character 1 and 2.

$\delta^2 p_1$, $\delta^2 p_2$ = Phenotypic variances of between character 1 and 2.

Genotypic correlation coefficient (r) were obtained by the formula

$$g^r\ 12 = \frac{g^{Cov}\ 12}{\sqrt{(\delta^2 g)(\delta^2 g_2)}}$$

Where,

g^r 12 = Genotypic correlation between characters 1 and 2, respectively

g^{Cov} 12 = Genotypic covariance between characters 1 and 2, respectively.

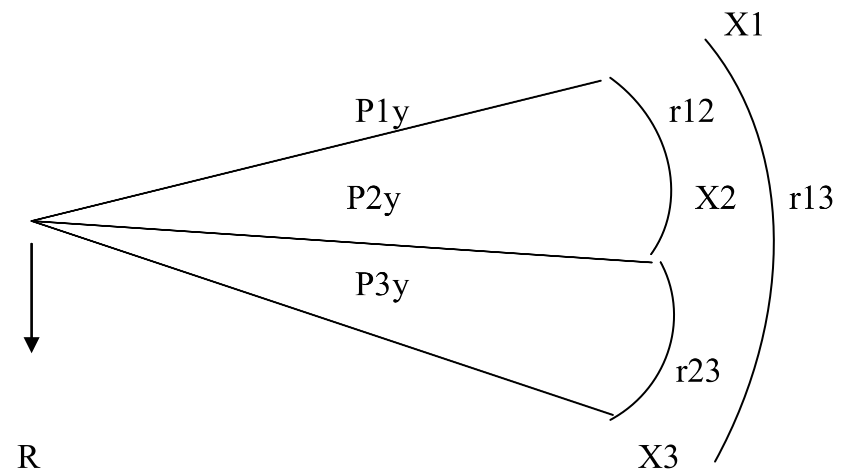
$\delta^2 g_1$ $\delta^2 g_2$ = Genotypic variance between characters 1 and 2, respectively.

Significance of the various correlation coefficients was tested from the statistical table of correlation coefficients at 1 and 5 per cent level of significance (Snedecor and Cochran, 1967).

3.4.5 Path analysis

The genotypic correlation coefficients between yield and its components were further partitioned into direct and indirect effects with the help of path coefficient analysis originally suggested by Sewall Wright (1921) and further outlined by Dewey and Lu (1959).

The first step in path analysis is to prepare the path diagram based on cause and effect relationship. In the present study, path diagram was prepared by taking yield as effect i.e. the function of various components like xl, x2, x3 and these components show following type of association with each other.



Path diagram showing the factors influencing yield

In path diagram, the seed cotton yield is the result of Xl, X2, X3 and some other undefined factors designated by R. The double arrowed lines indicates mutual association as measured by correlation coefficient (ry) and the single arrowed line represent direct influence as measured by path coefficient (P_{ij}).

Direct and indirect contribution of eight variables to seed cotton yield were calculated by solving a set of simultaneous equations of the form as per Dewey and Lu (1959).

my = pny + rn2p2y + rn3p3y+……

Where,

Rny	=	represents correction coefficient between one component and seed cotton yield
m2	=	represents correlation coefficient between that character and each of other components
pny	=	represents path coefficient between that characters and seed cotton yield.

Matrix- A **Matrix- B**

$$\begin{pmatrix} r1, y \\ r2, y \\ . \\ . \\ . \\ . \\ rn,y \end{pmatrix} \quad \begin{pmatrix} P1 \\ P2 \\ . \\ . \\ . \\ . \\ Pn \end{pmatrix} \qquad \begin{pmatrix} r1,1 \;\; r1,2 \ldots r1,n \\ r2,1 \;\; r2,2 \ldots r2,n \\ . \\ . \\ . \\ . \\ rn,1 \;\; rn,2 \ldots .1 \end{pmatrix}$$

The B matrix was inverted (B^{-1}) and path coefficients (P_{ij}) were obtained as

$$Pij = A \times B^{-1}$$

The coefficients P1, P2 ……. Pn are estimates of direct effects of character while the indirect effects of i^{th} character on seed cotton yield character through j^{th} character is $r_{ij}P_{ij}$

The residual factor i.e. variation in yield unaccounted by these associations, was calculated from following formula.

$$\text{Residual factor (Rx)} = \sqrt{1 - R^2}$$

Where,

R^2 = (P1y, r1y + P2y, r2y + ………+ Pny, rny)

Where,

P1y, P2y …… Pny = path values

r1y,r2y …….. rny = correlation coefficients

c

Results

CHAPTER IV

RESULTS

The investigation entitled “Stability analysis for yield and yield contributing traits in safflower (*Carthamus tinctorius* L.)” was conducted using twelve genotypes of diverse origin in four environment *viz*., Parbhani (E_1), Latur (E_2), Badnapur (E_3) and Somanathpur (E_4) during *rabi* 2016. All the genotypes were grown in three replications and observations were recorded for thirteen characters. The results obtained on mean performance, analysis of variances, stability parameters and correlation and path analysis for thirteen traits are presented in following lines.

4.1 Analysis of variance

The analysis of variance for all thirteen characters over different environments was significant. This indicated that material selected for study is variable and there is scope for further study (Table 4.1)

4.2 Mean performance

Ten genotypes of safflower were analyzed locations wise to find out the performance of genotypes across four locations for thirteen characters. The values of mean for different traits are presented in Tables 4.2.

4.2.1 Days to 50 *per cent* flowering (days)

The mean value for days to 50 *per cent* flowering varied from 90.76 (PBNS-150) to 96.73 days (PBNS-153) days with average mean 94.06 days in E_1, while, in E_2 it ranged from 83.66 (PBNS-137) to 89.667 days (PBNS-153) with a mean value of 85.72 days. In E_3 environment, days to 50 *per cent* flowering ranged from 86.66 (PBNS-150) to 93.76 days (PBNS-130) with a mean value of 90.23 days. In E_4 environment, it ranged from 80.33 (PBNS-151) to 85.66 days (PBNS-154). The pooled mean for days to 50 *per cent* flowering varied from 86.77 (PBNS-150) to 90.6 days (PBNS-153) with a general mean of 88.31 days. The genotypes PBNS-151 (80.33) and PBNS-137 (83.66) were observed to flower earliest, while, the genotype PBNS-12 (96.1) exhibited late flowering.

4.2.2 Days to maturity (days)

The mean value for days to maturity varied from 129.66 (PBNS-150) to 137.66 days (PBNS-129) with a mean of 134.01 days in E_1, while in E_2, mean ranged from 116.66 (PBNS-150) to 122 days (PBNS-152) with a mean of 119.52 days. In E_3 environment, mean ranged from 125 (PBNS-12) to 135 days (PBNS-153) with mean value 130.13 days. While, in E_4 environment it was ranged from 129.66 (PBNS-150) to 136.66 days (PBNS-151) with mean 133.08 days. The pooled mean for days to maturity varied from 125.75 (PBNS-150) to 131.43 days (PBNS-153) with a general mean of 139.18 days. The number of days to maturity was maximum for genotype PBNS-153 (131.43 days), followed by 130.75 days for PBNS-151, 130.70 days for Sharda and lower early in maturity were found in PBNS-137 (128.51 days), PBNS-12 (126.47 days) and PBNS-150 (125.75 days).

4.2.3 Plant height (cm)

In environment E_1, plant height ranged from 79.66 (PBNS-129) to 110.33 cm (PBNS-154) with a mean of 99.13 cm, in E_2 environment, the range was 89.66 (PBNS-129) to 105 cm (PBNS-152) with mean 95.66 cm. Under environment E_3, the range for plant height was from 70.66 (PBNS-129) to 101 cm (PBNS-154) with mean 88.25 cm. In environment E_4, plant height ranged from 82.33 (PBNS-128) and (PBNS-151) to 91 cm (PBNS-154). The pooled mean over environments for plant height varied from 80.66 (PBNS-129) to 98.66 cm (PBNS -154) with a mean of 92.05 cm. The genotype PBNS-129 (80.667cm) and PBNS-128 (81.91 cm) exhibited lowest plant height, while PBNS-154 (98.66 cm) and PBNS-152 (98.61 cm) were found for highest plant height.

4.2.4 Number of Primary branches per plant

The number of primary branches was ranged from 8.66 (PBNS-128) to 15.33 (PBNS-151), in environment E_1 with a mean of 11.27. In E_2 environment, the range was from 5.66 (PBNS-137) to 10 (PBNS-151) with a mean of 7.77 branches per plant. Under environment E_3, the range for number of primary branches per plant was 6 (PBNS-152) to 12.33 (PBNS-151) with a general mean of 8.86. While, primary branches per plant under environment E_4 was ranged from 6 (PBNS-138) to 10.66 (Sharda). Pooled mean over environments ranged from 7.66 (PBNS-152) to 11.25 (PBNS-151) with general mean 8.86. The genotypes PBNS-151 (11.25), PBNS-153 (10.16) and Sharda exhibited highest number of primary branches per plant.

4.2.5 Number of Secondary branches per plant

In environment E_1, the number of secondary branches was ranged from 14.33 (PBNS-137) to 29.66 (PBNS-151), with a mean of 22.08. In E_2 environment, the range was 14.66 (PBNS-137) and (PBNS-150) to 27 (PBNS-151) with a mean of 18.97 secondary branches per plant. Under environment E_3, the range was 12.66 (PBNS- 129) to 26.66 (PBNS-151) with general mean of 18.36. While, secondary branches per plant under environment E_4 was ranged from 13.33 (PBNS-12) to 21.33 (Sharda). Pooled mean over environments ranged from 15 (PBNS-137) to 24.66 (PBNS-151) with a general mean of 19.11. The genotypes PBNS-151 (24.66), PBNS-153 (21.66) and Sharda exhibited highest number of secondary branches per plant.

4.2.6 Number of capitula per plant

The mean value for number of capitula per plant ranged from 18.33 (PBNS-137) to 35.33 (PBNS-12) with mean 25.38 in environment E_1. In E_2 environment, the range was 11.66 (PBNS-129) to 21 (PBNS-12) with a general mean of 16.05. Under environment E_3, the value ranged from 13.66 (PBNS-129) and (PBNS-152) to 30.66 (PBNS-151) with a general mean of 22.02. While, in environment E_4, the range was 12 (PBNS-12) to 24.33 (Sharda) with general mean of 18.55. The pooled mean over environments for number of capitula ranged from 16.08 (PBNS-137) to 24.41 (PBNS-151) with a mean of 20.50. The genotypes PBNS-151 (24.41), PBNS-153 (24) and PBNS-12 (23.75) were observed for highest number of capitula per plant.

4.2.7 Number of seeds per capitulum

In environment E_1, the mean value for number of seed per capitulum was ranged from 23 (PBNS-130) to 33.66 (PBNS-151) with general mean 28.33 numbers of seed per capitulum. In E_2 environment, the range was

22 (PBNS-152) to 32.33 (PBNS-151) with a mean value of 28.66 numbers of seed per capitula. Under environment E_3, the value ranged from 24.33 (PBNS-150) to 32 (PBNS-151) with a general mean of 28.22 number of seed per capitulum. While, in E_4 environment values ranged from 20.33 (PBNS-128) to 25.66 (PBNS-154) with general mean 21.88. The pooled mean value ranged from 24.75 (PBNS-130) to 29.91 (PBNS-151) with mean 26.77 number of seeds per capitulum. The genotypes PBNS-151 (29.91), PBNS-153 (28.5) and PBNS-128 (27.58) exhibited highest for number of seeds per capitulum.

4.2.8 100-seed weight (g)

The mean value for 100-seed weight ranged from 5.19 (PBNS-154) to 6.85 g (PBNS-138) with a general mean of 6.01 g in environment E_1. In E_2 environment, the range was 4.88 (PBNS-154) to 6.78 g (PBNS-138) with general mean 6.01 g. Under environment E_3, the value ranged from 4.98 (PBNS-154) to 6.92 g (PBNS-128) with mean 5.90 g. While, in E_4 environment, it was ranged from 5.23 (PBNS-154) to 6.66 g (PBNS-137) with mean 5.97 g.

The pooled mean over environments for 100-seed weight ranged from 5.02 (PBNS-154), to 6.66 g (PBNS-128) with general mean 5.96 g. The genotypes PBNS-128 and PBNS-138 (6.66 g), PBNS-129 (6.35 g) and PBNS-137 (6.38 g) observed for higher 100-seed weight.

4.2.9 Chlorophyll content (Leaf spad readings)

In environment E_1, the mean value for chlorophyll content ranged from 52.9 (PBNS-129) to 72 units (PBNS-151) with a general mean of 64.53 units. In E_2 environment, the range was 51.3 (PBNS-129) to 69.5 units (PBNS-154) with mean 63.02 units. Under environment E_3, the value ranged from 50.86 (PBNS-129) to 72.03 units (PBNS-152) with general mean of 64.19 units. However, in E_4 environment chlorophyll content ranged from 49.06 (PBNS-129) to 71.1 units (PBNS-151) with a mean of 62.71 units. The pooled mean values ranged from 51.03 (PBNS-129) to 70.91 units (PBNS-152) with mean 59.39 units. The genotypes PBNS-151 (70.91), PBNS-12 (70.90) and PBNS-152 (70.2) recorded higher chlorophyll content over all environments.

4.2.10 Oil content (%)

In environment E_1, the mean value for oil content ranged from 26.5 (PBNS-129) to 31.433 *per cent* (PBNS-153) with a general mean value of 28.19 *per cent*. In E_2 environment, the range was 26.73 (PBNS-129) to 30.83 *per cent* (PBNS-153) with mean 28.25 *per cent*. Under environment E_3, the value ranged from 26.23 (PBNS-151) to 31.33 *per cent* (PBNS-152) with general mean 28.3 *per cent*. However, in E_4 environment oil content was highest in genotype PBNS-152 (31.24) and lowest in PBNS-128 (26.53) with a mean of 28.22. The pooled mean values ranged from 26.55 (PBNS-129) to 31.20 (PBNS-152) with mean 28.24 *per cent*. The genotypes PBNS-152 (31.20), PBNS-153 (30.57) and PBNS-150 (29.33) recorded higher oil content over all environments.

4.2.11 Harvest index (%)

In environment E_1, the mean value for harvest index ranged from 25.43 (PBNS-130) to 32.16 *per cent* (PBNS-12) with general mean 28.23 *per cent*. In E_2 environment, the range was 24.16 (PBNS-130) to 31.5 *per cent* (PBNS-151) with mean 28.18 *per cent*. Under environment E_3, the value ranged from 24.2 (PBNS-152) to 31.23 *per cent* (PBNS-12) with general mean of 27.94 *per cent*. However, in E_4 environment it was ranged from (25.36) PBNS-130 to (31.23) PBNS-12 with mean of 28.45 *per cent*.

Pooled mean values ranged from 25.78 (PBNS-130) to 31.17 *per cent* (PBNS-12) with a mean of 28.20 *per cent*. The genotype PBNS-12 (31.17%) recorded higher harvest index, followed by PBNS-151 (29.84%) and PBNS-128 (29.42%). However, PBNS-130 (25.78%) recorded lower harvest index over all environments.

4.2.12 Seed yield per plant (g)

The mean value for seed yield per plant ranged from 37.43 (PBNS-129) to 63.8 g (PBNS-151) with mean 49.82 g. In E_2 environment, the range was 38.66 (PBNS-154) to 58.66 g (PBNS-151) with a mean of 46.52 g. Under environment E_3, the value ranged from 49.66 (PBNS-152) to 75.33 g (PBNS-151) with a general mean of 57.58 g. However, in E_4 environment it was ranged from 37.66 (PBNS-138) to 45.33 g (PBNS-128) with general mean 41.97 g. The pooled mean over environments for seed yield per plant ranged from 43.41 (PBNS-152) to 59.95 g (PBNS-151) with a mean of 48.97 g. The genotypes PBNS-151 (59.95 g), PBNS-128 (56.6 g) and PBNS-12 (52.26 g) observed for highest seed yield per plant over all environments. Whereas, PBNS-152 (43.41 g) and PBNS-150 (45.20 g) recorded lowest seed yield per plant.

4.2.13 Seed yield per plot (g)

The mean value for seed yield per plot was ranged from 666 (PBNS-129) to 1127.66 g (PBNS-151) with a mean of 896.02 g in E_1. In E_2 environment, the range was 702.33 (PBNS-154) to 1057 g (PBNS-151) with mean 841.36 g. Under environment E_3, the value ranged from 841.33 (PBNS-152) to 1357.33 g (PBNS-151) with general mean 1040.94 g. While, in E_4 environment it was ranged from 680 (PBNS-138) to 898.33 g (Sharda) with general mean 755.41 g. The pooled mean over environments for seed yield per plant was ranged from 784.25 (PBNS-152) to 1073 g (PBNS-151) with a mean 883.45 g. The genotypes PBNS-151 (1073 g), PBNS-128 (1041 g) and PBNS-12 (939.25 g) recorded highest seed yield per plot over all environments. While, PBNS-129 (804.16 g) and PBNS-152 (784.25 g) recorded lowest seed yield per plot.

4.3 Analysis of variance for stability

The analysis of variances for stability as per Eberhart and Russell (1996) in respect of different traits are presented in table 4.3. Estimates of environment indices (Ij) are presented in Table 4.4.

It showed that E_1 (Parbhani) is favorable environment for all characters except oil content. Environment E_2 (Latur) environment is favorable for plant height, number of seeds per capitulum, 100-seed weight, chlorophyll and oil content. E_3 (Badnapur) environment was favorable for days to 50 *per cent* flowering, days to maturity, number of primary branches per plant, number of capitula per plant, number of seeds per capitulum, chlorophyll content, oil content, seed yield per plot and seed yield per plant. Environment

E_4 (Somanathpur) was found to be favorable only for days to maturity, 100-seed weight and harvest index.

Table 4.4 Estimates of environmental indices for each character under different environment

Observation	Environments			
	E_1	E_2	E_3	E_4
Days to 50% flowering	5.751	-2.596	1.913	-5.068
Plant Height (cm)	7.081	3.612	-3.805	-6.888
Days to maturity	4.827	-9.662	0.941	3.894
Primary branches/plant	2.417	-1.083	0	-1.333
Secondary branches/plant	2.972	-0.139	-0.75	-2.083
Number of capitula /plant	4.882	-4.451	1.521	-1.951
Number of seeds/capitulum	1.556	1.889	1.444	-4.889
100 seed weight (g)	0.003	0.005	-0.025	0.018
Chlorophyll content	0.02	0.059	0.051	-0.13
Oil content (%)	-0.049	0.012	0.059	-0.021
Harvest index (%)	0.033	-0.019	-0.261	0.247
Seed yield /plot (g)	12.59	-42.076	157.507	-128.021
Seed yield /plant (g)	0.846	-2.449	8.607	-7.004

The result of pooled analysis of variances over environments revealed that the variance due to genotypes were highly significant for all the characters except number of seeds per capitulum.

Variances due to environment were also significant for all characters except 100-seed weight, chlorophyll content, oil content and harvest index.

Whereas, for genotype x environment interaction variances was significant only for chlorophyll content.

The variances due to Environment + (Genotype x Environment) were highly significant for days to 50 *per cent* flowering, plant height, days to maturity, number of primary branches per plant, number of secondary branches per plant, number of seeds per capitulum, chlorophyll content, seed yield per plot and seed yield per plant. While, the Environment (linear) was highly significant for all characters, except 100-seed weight, oil content and harvest index.

The significance of G x E interaction (linear) for, number of primary branches per plant, number of secondary branches and chlorophyll content suggesting that, the genotypes differed greatly in their linear response to different environments.

The non-significance of G x E interaction (linear) for days to 50 *per cent* flowering, plant height, days to maturity, number of capitula per plant, number of seeds per capitulum, 100-seed weight, oil content, harvest index, seed yield per plot and seed yield per plant suggested that the genotypes for these characters were constant in their linear response to different environments.

Mean squares due to pooled deviation were found significant for days to 50% flowering, plant height, days to maturity, number of secondary branches per plant, number of capitula per plant, number of seeds per capitulum, seed yield per plot and seed yield per plant and non significant for of primary branches per plant, 100-seed weight, chlorophyll content, oil content and harvest index indicating that the genotypes varied considerably for stabilities and hence, prediction of their performance across environment for these traits is not possible.

4.4 Stability parameters

The stability was assessed by considering the mean performance of the genotype over environments ($\overline{x}$), linear regression of the genotypes over environment indices (bi) and deviation from this regression (S^2di).

According to Eberhart and Russell (1996) the stable genotype is one which has high mean, regression coefficient (bi) equal to unity and deviation from regression (S^2di), as small as possible or approaching zero. The results on these parameters for various characters are presented in Table 4.5.

4.4.1 Days to 50 *per cent* flowering (days)

The estimate of stability parameters for days to 50 *per cent* flowering revealed that the genotypes PBNS-129 and PBNS-138 were more stable across the environment and identified as early genotypes which had low mean value, the regression coefficient nearer to unity and non-significant deviation from regression (S^2di). The genotypes PBNS-137 and PBNS-150 having low mean value, regression coefficient nearer to unity and significant regression coefficient indicate their suitability to unfavorable environment and unpredictable regarding performance.

The genotypes PBNS-128 and PBNS-154 had high mean regression coefficient nearer to unity and non-significant (S^2di) but identified as late for flowering genotype.

The genotypes PBNS-130 and Sharda with high mean and significant S^2di with above average response (bi >1) revealing their adaptability to better environment and unpredictability about performance.

4.4.2 Days to maturity (days)

The genotypes PBNS-150 and PBNS-12 were identified as early genotypes with low mean and bi < 1 indicating that they are adapted to poor environments, whereas, PBNS-12 with significant S^2di indicates its unpredictability regarding performance.

PBNS-153, PBNS-151, Sharda and PBNS-129 were stable for days to maturity with high mean performance (Xi), bi >1 indicating their suitability for better environment and significant S^2di but identified late for days to maturity with unpredictability about performance.

The genotype PBNS-130 deviated non significantly from zero and regression coefficient near to unity (bi ≈1) is recommended for all environments.

4.4.3 Plant height (cm)

The genotypes PBNS-12, PBNS-137, PBNS-138 and PBNS-152 were stable and had regression coefficient more than unity (bi > 1) means below average stability with high mean and non significant deviation from regression coefficient (S^2di) indicates better adaptability to favorable environment. The genotypes PBNS-128, PBNS-129 and PBNS-130 had bi < 1 and significant S^2di indicating genotype may not be stable or adaptable over any type of environment.

The genotype Sharda deviated non significantly from zero and regression coefficient near to unity (bi ≈1) is recommended for all environments.

4.4.4 Number of primary branches per plant

The genotypes PBNS-153 and PBNS-154 are stable with high mean and bi > 1, as such require favorable environment. The genotypes PBNS-130, Sharda had high mean, bi < 1, indicates its suitability to unfavorable environment.

4.4.5 Number of secondary branches per plant

The genotypes PBNS-151, PBNS-138, PBNS-12 and PBNS-154 were stable with high mean and bi > 1 requires favorable environment. PBNS-15 and PBNS-138 with significant S^2di are unpredictable about performance. The genotypes PBNS-128, PBNS-153 and Sharda had high mean, bi < 1 indicates suitable to unfavorable environment.

The genotypes PBNS-151 and Sharda having non significant S^2di being unpredictable about performance.

4.4.6 Number of capitula per plant

The genotypes PBNS-138, PBNS-151 and PBNS-12 had high mean with bi >1 and significant S^2di indicates better adaptability to favorable environment with unpredictable performance. While, genotypes PBNS-128, PBNS-153 and Sharda had high mean with bi < 1 revealed their adaptability especially to poor environments.

4.4.7 Number of seed per capitula

The genotypes PBNS-128, PBNS-151 and PBNS-153 were stable having high mean with bi > 1 with non significant deviation from regression coefficient (S^2di) exhibited suitable over favorable environmental conditions. PBNS-138 and PBNS-154 showed significant S^2di with bi < 1 revealed it's unstable for this character and suitable to poor environment.

4.4.8 100-seed weight (g)

The genotypes PBNS-128, PBNS-129, PBNS-138 and PBNS-12 with higher mean performance, bi < 1 and non significant S^2di indicates suitable over unfavorable environmental conditions and considered as stable genotypes. Whereas, PBNS-130 and PBNS-137 had high mean, bi > 1 and non significant S^2di indicates they are recommended for favorable environment.

4.4.9 Chlorophyll content (Leaf spad readings)

Genotypes PBNS-151, PBNS-152 and PBNS-150 showed high mean performance bi < 1 with non significant S^2di indicates suitable over unfavorable environment. Genotypes PBNS-154 and PBNS-12 had high mean with bi > 1 showed suitability to favorable environment.

4.4.10 Oil content (%)

The genotypes PBNS-153 had high mean with stability bi < 1 with non significant deviation from regression coefficient (S^2di) showed its adaptability to poor environment, while the genotypes PBNS-137, PBNS-152, PBNS-150 and PBNS-12 observed with bi > 1 indicated their suitability to favorable conditions.

4.4.11 Harvest index (%)

The genotypes PBNS-12 and PBNS-128 had high mean with regression coefficient (bi) near to unity and non significant deviation from regression coefficient (S^2di) exhibited stable performance over all environmental condition.

PBNS-151 had above average mean, bi < 1 and significant S^2di indicates its suitability to poor environmental conditions and unpredictability of performance.

4.4.12 Seed yield per plant (g)

The genotypes PBNS-128, PBNS-151 and PBNS-12 had high mean with regression coefficient bi > 1 and non significant deviation from regression coefficient (S^2di) exhibited stable performance and indicates suitable to favorable conditions.

Whereas, PBNS-129, PBNS-152, PBNS-154, PBNS-150 and Sharda with low mean performance and bi < 1, suggesting their adaptability to unfavorable environments.

4.4.13 Seed yield per plot (g)

The genotypes PBNS-128, PBNS-151, PBNS-12 had high mean with regression coefficient bi > 1 and non significant deviation from regression coefficient (S^2di) exhibited stable performance and indicates suitable to favorable conditions.

Genotypes PBNS-129, PBNS-138, PBNS-152, PBNS-154, PBNS-150 and Sharda had low mean and bi < 1 indicating their adaptability to poor environmental conditions.

4.5 Correlation

Correlation coefficient is the most important statistical constant used as a measure for the degree of association between two characters worked at same time. Correlation studies help the breeder to compute the required genetic makeup of an ideal variety, in order to find out the association or correlation between the characters considered. In the present study, phenotypic and genotypic correlation coefficients was worked out for yield and yield contributing traits and are presented in Table 4.6 to 4.9.

4.5.1 Yield and yield contributing characters

Seed yield per plant with yield contributing characters.

In E_1 environment seed yield per plant exhibited significant and positive association with number of secondary branches per plant (G=0.649, P=0.435), number of capitula per plant (G=0.813, P=0.520) and harvest index (G=0.654 P=0.408), seed yield per plot (G=0.998, P=0.995) respectively at both the levels. The association was positive and significant with number of primary branches per plant (G=0.669), chlorophyll content (G=0.484) at genotypic level only. Seed yield per plant was also recorded positive but non significant association with plant height (G=0.296, P=0.234), number of seeds per capitulum (G=0.274 P=0.236) and 100-seed weight (G=0.328, P=0.204) at both the levels. The oil content had significant and negative association with yield per plant at genotypic level.

In E_2 environment, seed yield per plant recorded significant and positive association with number of primary branches per plant (G=0.746, P=0.425), number of secondary branches per plant (G=0.9859, P=0.624), number of capitula per plant (G=0.8912, P=0.591), harvest index (G=0.861, P=0.547) and seed yield per plot (G=0.999, P=0.999), at both the levels. Seed yield per plant recorded significant and positive association with days to 50 *per cent* flowering (G=0.511) and number of seeds per capitulum (0=0.571) at genotypic level.

In E_3 environment seed yield per plant recorded significant and positive association with number of primary branches per plant (G=0.803, P=0.609), number of secondary branches per plant (G=0.805, P=0.600), number of capitula per plant (G=0.7366, P=0.628), number of seeds per capitulum (G=0.707, P=0.563), harvest index (G=0.964, P=0.481) and seed yield per plot (G=0.999, P=0.957) at both the levels. The oil content (G=0.376, P=0.359) had significant and negative association with yield per plant at both levels. Plant height (G=0.378) showed significant and negative association with yield per plant at genotypic level.

In E_4 environment, seed yield per plant revealed significant and positive association with number of primary branches per plant (G=0.886, P=0.334), number of capitula per plant (G=0.428, P=0.339) and seed yield per plot (G=0.999, P=0.995) at both the levels and significant and positive association for days to maturity (G=0.726), number of secondary branches per plant (G=0.603) and harvest index (G=0.398) at genotypic level. Seed yield per plant recorded positive and non significant association with days to 50 *per cent* flowering. Seed yield per plant had significant but negative association with 100-seed weight at genotypic level.

4.5.1.1 Days to 50 *per cent* flowering with other characters (days)

In E_1 environment, the character days to 50 *per cent* flowering had positive and significant association with primary branches (G=0.340), number of capitula per plant (G=0.350), and oil content (G=0.362) at genotypic level only, but had negative and significant association with 100-seed weight (G= -0.399, P= -0.346) at both levels.

In E_2 environment, the character days to 50 *per cent* flowering had positive and significant association with number of capitula per plant (G=0.718, P=0.339) and oil content (G=0.616, P=0.450) at both the levels. Whereas, it showed positive and significant association with plant height (G=0.358), days to maturity (G=0.568), primary branches (G=0.869), secondary branches (G=0.452), number of seeds per capitulum (G=0.384) and seed yield per plot (G=0.518) at genotypic level only. However, there was significant but negative correlation with 100-seed weight (G= -0376) at genotypic level.

The character days to 50 *per cent* flowering had positive and significant correlation with harvest index (G=0.367) at genotypic level in E_3 environment.

In E_4 environment, the character days to 50 *per cent* flowering had positive and significant association with plant height (G=0.917, P=0.446). Whereas, it showed positive and significant association with number of seeds per capitulum (G=0.493), oil content (G=0.424) and negative significant association with days to maturity (G=0.385) and 100-seed weight (G=0.394) at genotypic level only.

4.5.1.2 Plant height with other characters (cm)

In E_1 environment, plant height had significant positive association with primary branches (G=0.771, P=0.478), secondary branches (G=0.560, P=0.512), number of capitula per plant (G=0.513, P=0.468), chlorophyll content (G=0964, P=0.849) and oil content (G=0.494, P=0.453) at both the levels. Plant height had significant and negative association with 100-seed weight.

In E_2 environment, the character plant height had significant positive association with days to maturity (G=0.922, P=0.469), secondary branches (G=0.4371, P=0.332), number of capitula per plant (G=0.452, P=0.409), chlorophyll content (G=05732, P=0.510) and oil content (G=0.649

P=0.529) at both levels. Number of seeds per capitulum had significant and negative association with plant height at genotypic level only.

The character plant height had significant positive association with chlorophyll content (G=0.813, P=0.802) and oil content (G=0.507, P=0.410) at both levels. Whereas, it had significant negative association with days to maturity (G= -0.479, P= -0.453) at both the levels in E_3 environment.

The character plant height had significant positive association with number of seeds per capitulum (G=0.863, P=0.402) at both levels. Whereas, it was positively and significantly associated with chlorophyll (G=0.383) and oil content (G=0.362) at genotypic level in E_4 environment. However, it showed significant but negative association with primary branches (G= -0.523, P= -0.419), secondary branches (G= -0.736, P= -0.345) and number of capitula per plant (G= -0.522, P= -0.343) at both the levels.

4.5.1.3 Days to maturity with other characters (days)

The character days to maturity had positive and significant association with number of seeds per capitulum (G=0.366) at genotypic level in E_1 environment but negative and significant association with chlorophyll content (G= -0.546, P= -0. 451) at both genotypic and phenotypic levels.

In E_2 environment, the character days to maturity had positive and significant association with primary branches (G=0.462) and oil content (G=0.681) at genotypic level only.

The character days to maturity was positively and significantly associated with primary branches (G=0.362) at genotypic level and showed negative and significant association with chlorophyll content (G= -0.356, P= -0.536) at both the levels in E_3 environment.

In E_4 environment, the character days to maturity had positive and significant association with primary branches (G=0396 P=0.337) at both the levels. However, it showed positive and significant association with seed yield per plot (G=0.729) at genotypic level only, whereas, there was negative significant association with 100-seed weight (G= -0.491) and oil content (G= -0.729 P= -0.366) at genotypic and both levels respectively.

4.5.1.4 Primary branches per plant with other characters

In E_1 environment, the character primary branches per plant had significant positive association with secondary branches (G=0.905, P=0.606), number of capitula per plant (G=0.785, P=0.522) and chlorophyll content (G=0.633, P=0.392) at both the levels. However number of seeds per capitulum (G=0.435) and seed yield per plot (G=0.669) had positive association at genotypic level.

In E_2 environment, the character primary branches per plant had significant positive association with secondary branches (G=0.908, P=0.727), number of capitula per plant (G=0.650, P=0.512) and seed yield per plot (G=0.738, P=0.431) at both levels. It also showed positive and significant association with seeds per capitulum (G=0.874) and harvest index (G=0.603) at genotypic level.

In E_3 environment, the character primary branches per plant had significant positive association with secondary branches (G=0.953, P=0.753), number of capitula per plant (G=0.885, P=0.667), harvest index (G=0.737, P=0.358) and seed yield per plot at (G=0.755, P=0.621) both levels. It also had negative and significant association with 100-seed weight (G= -0.391) and oil content (G= -0.437) at genotypic level.

In E_4 environment, the character primary branches per plant had significant positive association with secondary branches (G=0.961, P=0.487) and number of capitula per plant (G=0.766, P=0.475) at both the levels. The characters number of seeds per capitulum (G= -0.538) and chlorophyll content (G= -0.431) were significant but negatively associated with primary branches per plant at genotypic level.

4.5.1.5 Secondary branches per plant with other characters

In E_1 environment, the character secondary branches per plant had significant positive association with number of capitula per plant (G=0.918, P=0.752), chlorophyll content (G=0.514, P=0.468), harvest index (G=0.361, P=0.359) and seed yield per plot (G=0.647, P=0.410) at both the levels.

In E_2 environment, the character secondary branches per plant showed significant positive association with number of capitula per plant (G=0.786, P=0.662), harvest index (G=0.645, P=0.519) and seed yield per plot (G=0.989, P=0.624) at both the levels. It also showed positive and significant association with seeds per capitulum (G=0.874) at genotypic level.

In E_3 environment, the character secondary branches per plant had significant positive association with number of capitula per plant (G=0.964, P=0.842), harvest index (G=0.687, P=0.502) and seed yield per plot (G=0.815, P=0.585) at both the levels. There was also negative and significant association with 100-seed weight (G= -0.391) at genotypic level.

In E_4 environment, the character secondary branches per plant had significant positive association with number of capitula per plant (G=0.951, P=0.871) at both the levels. The characters oil content (G= -0.343) and chlorophyll content (G= -0.6878, P= -0.544) were significant but negatively associated at genotypic level and both the levels respectively.

4.5.1.6 Number of capitula per plant with other characters

In E_1 environment, the character number of capitula per plant had positive and significant association with chlorophyll content (G=0.627, P=0.757), harvest index (G=0.756, P=0.576), and seed yield per plot (G=0.810, P=0.507) at both the levels.

In E_2 environment, the character number of capitula per plant had positive and significant association with chlorophyll content (G=0.479, P=0.348), harvest index (G=0.864, P=0.482), seed yield per plot (G=0.885, P=0.592) at both the levels. Whereas, number of seeds per capitulum

(G=0.621), oil content (G=0.434) showed positive and significant association at genotypic level.

In E_3 environment, the number of capitula per plant was positively and significantly associated with harvest index (G=0.943, P=0.547) and seed yield per plot (G=0.770, P=0.647) at both the levels.

In E_4 environment, the character number of capitula per plant showed positive and significant association with seed yield per plot (G=0.438) and chlorophyll content (G=0.663, P=0.593) at genotypic level and both genotypic and phenotypic levels respectively.

4.5.1.7 Number of seeds per capitulum with other characters

In E_2 environment, the character number of seeds per capitulum had positive and significant association with harvest index (G=0.764, P=0.490) at both the levels. It also showed positive and significant association with seed yield per plot (G=0.578) and negatively significant association with oil content (G= -0.387) at genotypic level.

In E_3 environment, the character number of seeds per capitulum had positive and significant association with seed yield per plot (G=0.672, P=0.585) at both the levels.

In E_4 environment, the character number of seeds per capitulum had negative and significant association with 100-seed weight and oil content (G=0.836) at genotypic level.

4.5.1.8 100-seed weight with other characters (g)

In E_1 environment, the character 100-seed weight had positive and significant association with harvest index (G=0.384) and seed yield per plot (G=0.335) at genotypic level. Whereas, it showed negative and significant association with chlorophyll content (G= -0.336, P= -0.331) and oil content (G= -0.555, P= -0.497) at both the levels.

In E_2 environment, the character 100-seed weight had negative and significant association with chlorophyll content (G= -0.348, P= -0.341) and oil content (G= -0.472, P= -0.362) at both the levels.

In E_3 environment, the character 100-seed weight showed negative and significant association with chlorophyll content (G= -0.390, P= -0.369) at the both levels.

In E_4 environment, the character 100-seed weight had negative and significant association with chlorophyll content (G= -0.453) and seed yield per plot (G= -0.975) at genotypic level.

4.5.1.9 Chlorophyll content with other characters (Leaf spad readings)

In E_1 environment, chlorophyll content had positive and significant association with harvest index (G=0.374) and seed yield per plot (G=0.489) at genotypic level.

In E_2 environment, the character chlorophyll content had positive and significant association with harvest index (G=0.579, P=0.431) at both the levels.

In E_3 environment, the character chlorophyll content showed positive association with oil content (G=0.333) at genotypic level only.

In E_4 environment, a positive and significant association of chlorophyll content was observed with oil content (G=0.367, P=0.335) and harvest index (G=0.395, P=0.343) at both the levels.

4.5.1.10 Oil content with other characters (%)

In E_1 environment, character oil content had negative and significant association with harvest index (G= -0.380) and seed yield per plot (G= -0.382) at genotypic level.

In E_2 environment, the character oil content had negative and significant association with seed yield per plot (G= -0.388) at genotypic level**.**

In E_3 environment, the character oil content had negative and significant association with harvest index (G= -0.454) and seed yield per plot (G= -0.352) at genotypic level.

4.5.1.11 Harvest index with other characters (%)

In E_1 environment, the character harvest index had positive and significant association with seed yield per plot (G=0.653) at genotypic level.

In E_2 environment, the character harvest index had significant and positive association with seed yield per plot (G=0.859, P=0.548) at both the levels.

In E_3 environment, the character harvest index had significant and positive association with seed yield per plot (G= 0.929, P=0.490) at both the levels.

In E_4 environment, the character harvest index had significant and positive association with seed yield per plot (G= 0.418) at genotypic level.

4.6 Path analysis

The direct and indirect effect from given component character with seed yield per plant was analyzed in E_1, E_2, E_3 and E_4 environment separately for twelve different characters at genotypic level only. The results are presented in Table 4.10 to 4.13 and Fig. 1 to 4.

4.6.1. Direct and indirect effect

In E_1 environment the path coefficient analysis revealed that the seed yield per plot exhibited highest direct effect on seed yield per plant followed by, plant height, primary branches per plant, days to 50 *per cent* flowering and harvest index. However, negative highest direct effect was with chlorophyll content followed by, secondary branches per plant, number of capitula per plant number of seeds per capitulum, 100-seed weight, days to maturity and oil content.

The path coefficient analysis revealed that the seed yield per plot exhibited highest direct effect on seed yield per plant in E_2 environment followed by, number of capitula per plant, number of seeds per capitulum, chlorophyll content, secondary branches per plant, days to 50 *per cent* flowering and plant height. However, negative highest direct effect was harvest index followed by, primary branches, oil content, 100-seed weight and days to maturity.

In E_3 environment, the path coefficient analysis revealed that the seed yield per plot exhibited highest direct effect on seed yield per plant followed by, secondary branches per plant, oil content, days to 50 *per cent* flowering, days to maturity and chlorophyll content. However, negative highest direct effect was observed with number of seeds per capitulum followed by, number of capitula per plant, primary branches, harvest index, 100-seed weight and plant height.

The path coefficient analysis revealed that the seed yield per plot exhibited highest positive direct effect on seed yield per plant followed by, days to 50 *per cent* flowering, plant height, number of capitula per plant, primary branches per plant, harvest index and oil content. However, negative highest direct effect was with chlorophyll content, followed by, secondary branches per plant, days to maturity, 100-seed weight and number of seeds per capitulum per plant in E_4 environment.

4.6.1.1 Yield and yield contributing characters

4.6.1.1.1 Seed yield per plant versus days to 50 *per cent* flowering (days)

In E_1 environment, days to 50 *per cent* flowering positive direct effect (0.062) on seed yield per plant. It exerted its positive indirect effect via the characters *viz*., oil content (0.022), number of capitula per plant (0.21), primary branches per plant (0.021), days to maturity (0.014), secondary branches per plant (0.011), chlorophyll content (0.005) and harvest index

(0.004) on seed yield per plant. However, other character exhibited negative indirect effect.

In E_2 environment, days to 50 *per cent* flowering had positive direct effect on (0.013) on seed yield per plant. It exerted its indirect effect via primary branches (0.011), number of capitula per plant (0.0094), oil content (0.008), days to maturity (0.007), seed yield per plot (0.006), secondary branches (0.005), number of seeds per capitulum (0.005), plant height (0.004) and harvest index (0.004). However, negative indirect effect observed via, 100-seed weight (-0.004) and chlorophyll content (-0.002).

In E_3 environment days to 50 *per cent* flowering had positve direct effect (0.393) on seed yield per plant. It exerted its indirect effect via, the characters *viz*., harvest index (0.144), number of capitula per plant (0.080), secondary branches (0.074), number of seeds per capitulum (0.057), days to maturity (0.049), 100-seed weight (0.042), seed yield per plot (0.037), primary branches per plant (0.020). However, other characters observed negative indirect effect.

In E_4 environment, days to 50 *per cent* flowering had positive direct effect (0.0943) on seed yield per plant. It exerted its positive indirect effect via, the characters *viz*., 100-seed weight (0.037), days to maturity (0.036) and chlorophyll content (0.011). However, remaining characters observed negative indirect effect.

4.6.1.1.2 Seed yield per plant versus plant height (cm)

In E_1 environment plant height had positive direct effect (0.321) on seed yield per plant. It exerted positive indirect effect via the character *viz*., chlorophyll content (0.303), number of primary branches per plant (0.247), number of secondary branches per plant per plant (0.180), oil content (0.158) seed yield per plot (0.097), number of seeds per capitulum (0.052), harvest index (0.036) and days to 50 *per cent* flowering (0.032). However, other characters exhibited negative indirect effect.

The plant height had positive direct effect (0.0056) on seed yield per plant in E_2 environment. The characters *viz*. days to maturity (0.005), oil content (0.003), chlorophyll content (0.003), number of capitula per plant (0.002), days to 50 *per cent* flowering (0.002), number of secondary branches per plant (0.002), number of primary branches per plant (0.001), harvest index (0.001) and seed yield per plot (0.0009). However, negative indirect effect observed via, 100-seed weight (-0.0013) and number of seeds per capitulum (-0.002).

In E_3 environment, the plant height had direct negative effect (-0.206) on seed yield per plant. It exerted its indirect effect via the characters *viz*., 100-seed weight (0.121), days to maturity (0.099), number of seeds per capitulum (0.080), seed yield per plot (0.076), harvest index (0.024), days to 50 *per cent* flowering (0.020) and number of primary branches per plant (0.007). However, negative indirect effect observed via, oil content (-0.1049), chlorophyll content (-0.0168), number of secondary branches per plant (-0.027) and number of capitula per plant (-0.012).

In E_4 environment, the plant height had direct positive effect (0.052) on seed yield per plant. It exerted its indirect effect via the characters *viz*., days to 50 *per cent* flowering (0.048), number of seeds per capitulum (0.044), chlorophyll content (0.020) oil content (0.019) and harvest index (0.006). However, negative indirect effect observed via number of secondary branches per plant (-0.038), number of capitula per plant (-0.027), number of primary branches per plant (-0.0275), days to maturity (-0.0139) and seed yield per plot (-0.0061).

4.6.1.1.3 Seed yield per plant versus days to maturity (days)

In E_1 environment, the character days to maturity had negative direct effect (-0.0035) on seed yield per plant. However, the chlorophyll content (0.001), plant height (0.001), seed yield per plot (0.0009), harvest index

(0.0008), oil content (0.0007) and number of capitula per plant (0.0004). The negative indirect effects were observed in other characters.

In E_2 environment, the character days to maturity had negative direct effect (-0.001) on seed yield per plant. However, indirect effect via, number of seeds per capitulum (0.0009), 100-seed weight (0.0007), harvest index (0.0005) and seed yield per plot (0.0002). The negative indirect effects were observed for other characters.

In E_3 environment, the character days to maturity had positive direct effect (0.332) on seed yield per plant. However, the character number of primary branches per plant (0.120), number of secondary branches per plant (0.067), number of seeds per capitulum (0.041), days to 50 *per cent* flowering (0.041), number of capitula per plant (0.031) and seed yield per plot (0.024) had positive indirect effect on seed yield per plant. The negative indirect effects were observed through chlorophyll content (-0.186), plant height (-0.159), harvest index (-0.107), oil content (-0.059) and 100- seed weight (-0.044).

In E_4 environment, the character days to maturity had negative direct effect (-0.025) on seed yield per plant. However, indirect positive effect were exhibited for the character *viz*., 100-seed weight (0.012), days to 50 *per cent* flowering (0.0098), oil content (0.009), plant height (0.006) and harvest index (0.002) on seed yield per plant. The negative indirect effects were observed in remaining characters.

4.6.1.1.4 Seed yield per plant v/s primary branches per plant

In E_1 environment, the character primary branches per plant had positive direct effect (0.061) on seed yield per plant. Whereas, number of secondary branches per plant (0.064) number of capitula per plant (0.047), seed yield per plot (0.039), chlorophyll content (0.038), number of seeds per capitulum (0.026), days to 50 *per cent* flowering (0.027), days to maturity (0.018), harvest index (0.015), plant height (0.047) and oil content (0.015) had indirect positive effect on seed yield per plant. However, negative indirect effect was observed in 100-seed weight.

In E_2 environment, the character primary branches per plant had negative direct effect (-0.0586) on seed yield per plant. All other characters had negative indirect effect, except 100-seed weight (0.021) which had indirect positive effect on seed yield per plant

In E_3 environment, the character primary branches per plant had negative direct effect (-1.691) on seed yield per plant. Characters oil content (0.739), 100-seed weight (0.662) and plant height (0.061) had indirect positive effect on seed yield per plant, whereas, the remaining characters showed indirect negative effect.

In E_4 environment, the character primary branches per plant had positive direct effect (0.020) on seed yield per plant. Whereas, characters seed yield per plot (0.026), number of secondary branches per plant (0.019), number of capitula per plant (0.015) and harvest index (0.005) had indirect positive effect on seed yield per plant. However, remaining characters had negative indirect effect.

4.6.1.1.5 Seed yield per plant v/s secondary branches per plant

In E_1 environment, the character secondary branches per plant had negative direct effect (-0.131) on seed yield per plant. However, only 100-seed weight (0.030) showed indirect positive effect on seed yield per plant. Whereas, negative indirect effect was observed in all other characters.

In E_2 environment, the character secondary branches per plant had positive direct effect (0.013) on seed yield per plant. Whereas, positive indirect effect was exhibited by all other characters except oil content (-0.0017) which had indirect negative effect on seed yield per plant.

In E_3 environment, the character secondary branches per plant had positive direct effect (1.440) on seed yield per plant. Whereas, all other characters showed indirect positive effect except 100-seed weight (-0.640), which exhibited indirect negative effect on seed yield per plant.

In E_4 environment, the character secondary branches per plant had negative direct effect (-0.025) on seed yield per plant. However, characters plant height (0.019), chlorophyll content (0.017), oil content (0.008), number of seeds per capitulum (0.002), harvest index (0.002) and 100-seed weight (0.002) had indirect positive effect on seed yield per plant. However, remaining characters had negative indirect effect.

4.6.1.1.6 Seed yield per plant versus number of capitula per plant

In E_1 environment, the number of capitula per plant had negative direct effect (-0.074) on seed yield per plant. However, through days to maturity (0.008) there was positive indirect effect and all other characters had negative indirect effect on seed yield per plant.

In E_2 environment, the number of capitula per plant had positive direct effect (0.081) on seed yield per plant. Whereas, through 100-seed weight (-0.003), exerts negative indirect effect and all other characters exhibited positive indirect effect.

In E_3 environment, the number of capitula per plant had negative direct effect (-1.841) on seed yield per plant. However, 100-seed weight (0.279) had positive indirect effect and whereas, all other characters exhibited negative indirect effect.

In E_4 environment, the number of capitula per plant had positive direct effect (0.037) on seed yield per plant. However, through number of primary branches per plant (0.028), number of secondary branches per plant (0.038), seed yield per plot (0.016), days to 50 *per cent* flowering (0.007), days to maturity (0.008) and number of seeds per capitulum (0.003) exerts positive indirect effect on seed yield per plant. However, other characters had negative indirect effect on seed yield per plant.

4.6.1.1.7 Seed yield per plant versus number of seeds per capitulum

The character number of seeds per capitulum had negative direct effect (-0.017) on seed yield per plant in E_1 environment. The characters *viz*., days to 50 *per cent* flowering (0.002) and 100-seed weight (0.0009) had positive indirect effect on yield per plant. However, other character had negative indirect effects on seed yield per plant.

In E_2 environment, the character number of seed per capitulum had positive direct effect (0.046) on seed yield per plant. The characters *viz*., number of primary branches per plant (0.0402), harvest index (0.035), number of capitula per plant (0.028), seed yield per plot (0.026) number of secondary branches per plant (0.022) and days to 50 *per cent* flowering (0.017) had positive indirect effect on yield per plant. However, negative indirect effects were observed via days to maturity (-0.038), oil content (-0.017), plant height (-0.016) and 100-seedweight (-0.013).

In E_3 environment, the character number of seed per capitulum had negative direct effect (-2.154) on seed yield per plant. Through character plant height (0.840) and chlorophyll content (0.059) there was positive indirect effect on seed yield per plant.

In E_4 environment, the character number of seeds per capitulum had negative direct effect (-0.0006) on seed yield per plant. Through characters *viz*., 100- seed weight (0.0005), number of primary branches per plant (0.0003), number of secondary branches per plant (0.0001), harvest index (0.0001), seed yield per plot (0.0001) had positive direct effect on seed yield per plant. However, negative indirect effects were observed for other characters.

4.6.1.1.8 Seed yield per plant versus 100-seed weight (g)

In E_1 environment, the character 100-seed weight had negative direct effect (-0.015) on seed yield per plant. However, through rest of the characters *viz*., oil content (0.0084), plant height (0.0082), days to 50 *per cent* flowering (0.006), number of primary branches per plant (0.005), chlorophyll content (0.005), number of secondary branches per plant (0.003), days to maturity (0.002) and number of seeds per capitulum (0.0008) it exerted positive indirect effect on seed yield per plant. However, negative indirect effects were observed for other characters.

The character 100-seed weight had negative direct effect (-0.019) on seed yield per plant in E_2 environment. However, rest of the characters *viz*., days to maturity (0.012), oil content (0.009), days to 50 *per cent* flowering (0.007), number of primary branches per plant (0.007), chlorophyll content (0.006), number of seeds per capitulum (0.005), plant height (0.004), harvest index (0.001) and number of capitula per plant (0.0009) had positive indirect effect on seed yield per plant. However, other characters exhibited negative indirect effects. The character 100-seed weight had positive direct effect (-0.394) on seed yield per plant. However, through rest of the characters *viz*., plant height (0.232), number of secondary branches per plant (0.175), number of primary branches per plant (0.153), chlorophyll content (0.154), oil content (0.113), number of capitula per plant (0.059), days to maturity (0.053) had positive indirect effect on seed yield per plant. However, negative indirect effects were observed other characters in E_3 environment.

In E_4 environment, the character 100-seed weight had negative direct effect (-0.022) on seed yield per plant. However, except harvest index (-0.0021) rest of characters had positive indirect effect, whereas, harvest index showed negative indirect effect on seed yield per plant.

4.6.1.1.9 Seed yield per plant versus chlorophyll content (Leaf spad readings)

The character chlorophyll content had negative direct effect (-0.348) on seed yield per plant in E_1 environment. Through characters, days to maturity, 100-seed weight positive indirect effect was exerted on seed yield per plant. However, via other characters negative indirect effect was exhibited on seed yield per plant.

In E_2 environment, the character chlorophyll content had positive direct effect (0.032) on seed yield per plant. Through characters *viz*., harvest index (0.018), plant height (0.018), number of capitula per plant (0.015), number of secondary branches per plant (0.009), oil content (0.009), number of primary branches per plant (0.006), seed yield per plot (0.004), number of seeds per capitulum (0.003) and days to maturity (0.003) it had positive indirect effect on seed yield per plant. However, other characters had negative indirect effect on seed yield per plant.

In E_3 environment, the character chlorophyll content had positive direct effect (0.195) on seed yield per plant. Through characters *viz*., plant height (0.159), oil content (0.0652), number of secondary branches per plant (0.061), number of capitula per plant (0.056), harvest index (0.043), number of primary branches per plant (0.023), seed yield per plot (0.010) had positive indirect effect on seed yield per plant. However, other characters had negative indirect effect on seed yield per plant.

In E_4 environment, the character chlorophyll content had negative direct effect (-0.026) on seed yield per plant. Through characters *viz*., number of secondary branches per plant (0.018), number of capitula per plant (0.017), 100-seed weight (0.011), number of primary branches per plant (0.011) and days to 50 *per cent* flowering (0.003) it had positive indirect effect on seed yield per plant. However, other characters had negative indirect effect on seed yield per plant.

4.6.1.1.10 Seed yield per plant versus oil content (%)

In E_1 environment, the character oil content had negative direct effect (0.0001) on seed yield per plant. However, on 100-seed weight it exerted positive direct effect.

The character oil content has negative direct effect (-0.035) on seed yield per plant. Through the characters of, days to 50 *per cent* flowering (0.021), 100- seed weight (0.016), number of seeds per capitulum (0.013), seed yield per plot (0.013), number of secondary branches per plant (0.004) and harvest index (0.001) it had indirect positive effect on seed yield per plant. However, negative indirect effects were found via other characters in E_2 environment.

The character of oil content had positive direct effect (0.676) on seed yield per plant in E_3 environment. The plant height (0.343), chlorophyll content (0.225), number of capitula per plant (0.090), number of seeds per capitulum (0.067), number of secondary branches per plant (0.028) had indirect positive effect on seed yield per plant. However, negative indirect effects were found via other characters.

In E_4 environment, the character of oil content had positive direct effect (0.0013) on seed yield per plant. The chlorophyll content (0.0005), days to 50 *per cent* flowering (0.0005) and plant height (0.0005) had positive indirect effect. However, all other characters showed negative indirect effect on seed yield per plant.

4.6.1.1.11 Seed yield per plant versus harvest index (%)

In E_1 environment, the character of harvest index (0.089) had positive direct effect on seed yield per plant. The characters *viz*., number of capitula per plant (0.068), seed yield per plot (0.058), 100-seed weight (0.034), chlorophyll content (0.033), number of secondary branches per plant (0.032), number of primary branches per plant (0.023), days to 50 *per cent* flowering (0.006) and number of seeds per capitulum (0.006) had positive indirect effect on seed yield per plant, However, other characters had negative indirect, effect on seed yield per plant.

The character harvest index had negative direct effect (-0.106) on seed yield per plant in E_2 environment. However, through characters *viz*., days to maturity (0.054), 100-seed weight (0.007), and chlorophyll content (0.004) it had positive indirect effect on seed yield per plant. Whereas, through all other characters it had negative indirect effect on seed yield per plant.

In E_3 environment, the character of harvest index (-0.646) had positive direct effect on seed yield per plant. Through characters *viz*., oil content (0.293), days to maturity (0.208) and plant height (0.077) it had positive indirect effect on seed yield per plant. However, other characters had negative indirect effect on seed yield per plant.

The character of harvest index had positive direct effect (0.003) on seed yield per plant. The characters *viz*., seed yield per plot (0.0014), chlorophyll content (0.0013), plant height (0.0004), 100-seed weight (0.0003) and days to 50 *per cent* flowering (0.0001) had indirect effect on seed yield in E_4 environment. However, other characters exhibited negative indirect effect on seed yield per plant.

4.6.1.1.12 Seed yield per plant versus seed yield per plot (g)

In E_1 environment, the character of seed yield per plot had positive direct effect (1.144) on seed yield per plant. The characters number of capitula per plant, harvest index, number of secondary branches per plant, number of primary branches per plant, chlorophyll content, 100-seed weight, plant height and number of seeds per capitulum had positive indirect effect. However, oil content (-0.437), days to maturity (-0.307) and days to 50 *per cent* flowering (-0.243) exerted negative indirect effect on seed yield per plot.

The character of seed yield per plot had positive direct effect (1.002) on seed yield per plant in E_2 environment. Whereas, oil content (-0.38) and days to maturity (-0.205) had negative indirect effect and rest all characters exhibited positive indirect effect on seed yield per plot.

In E_3 environment, the character of seed yield per plot had positive direct effect (4.738) on seed yield per plant. However, plant height

(-1.761) and oil content (-1.668) had negative indirect effect, whereas, all other characters showed positive indirect effects seed yield per plot.

The character of seed yield per plot had positive direct effect (0.984) on seed yield per plant in E_4 environment via characters, number of primary branches per plant (1.296), days to maturity (0.718), number of secondary branches per plant (0.615), number of capitula per plant (0.432), harvest index (0.405), days 50 *per cent* flowering (0.066) and chlorophyll content (0.002) as indirect positve effect. However, other character had negative indirect effects on seed yield per plant.

Table 4.2 Mean performance of genotypes for stability analysis in safflower

Sr No.	Genotype	Days to 50% flowering (days)					Plant Height (cm)					Days to maturity (days)				
		E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean
1	**PBNS -128**	94.36	87	91.66	82.33	88.84	82.33	91.33	71.66	82.33	81.91	132.73	118.66	131.33	135	129.43
2	**PBNS -129**	93.2	86	88.33	81.66	87.3	79.66	89.66	70.66	82.66	80.66	137.66	119.33	132.66	130.66	130.08
3	**PBNS -130**	93.76	84	93.76	83.66	88.8	88	91	80.33	85.33	86.16	134.33	119.66	129.66	134	129.41
4	**PBNS -137**	93.13	83.66	89	84.33	87.53	101.73	97.66	91	86.66	94.26	132.4	120	128.66	133	128.51
5	**PBNS -138**	92.03	85.33	88.66	82.66	87.17	101.03	97.33	90.33	83.66	93.09	136.06	119	130.66	132.33	129.51
6	**PBNS -151**	93.93	86.66	87.66	80.33	87.15	108.66	101	87.66	82.33	94.91	135.66	120.33	130.33	136.66	130.75
7	**PBNS -152**	95.26	86	90	82	88.31	107.8	105	96	85.66	98.61	132.66	122	128.33	133	129
8	**PBNS -153**	96.73	89.66	91	85	90.6	99.66	99.66	89.66	85	93.5	137.06	121	135	132.66	131.43
9	**PBNS -154**	94.33	85.66	90.33	85.66	89	110.33	92.33	101	91	98.66	134.46	120.33	128.33	133.66	129.2
10	**PBNS -150**	90.76	84.33	86.66	85.33	86.77	104.73	90	95	87	94.18	129.66	116.66	127	129.66	125.75
11	**PBNS-12(ch.)**	96.1	85.33	93	82	89.10	105.33	97	95.66	86.66	96.16	130.9	118.33	125	131.66	126.47
12	**Sharda (ch.)**	95.2	85	92.66	84	89.21	100.33	96	90	83.66	92.5	134.56	119	134.56	134.66	130.7
	Mean	94.06	85.72	90.23	83.25	88.31	99.13	95.66	88.25	85.16	92.05	134.01	119.52	130.13	133.08	129.18
	S.E.±	0.65	0.73	1.10	1.19		3.09	1.45	0.82	1.68		1.16	1.29	0.71	1.50	
	C.D.at 5%	1.36	1.52	2.29	2.47		6.42	3.01	1.71	3.48		2.42	2.67	1.47	3.13	
	C.V.(%)	0.85	1.04	1.49	1.75		3.82	1.86	1.14	2.41		1.06	1.32	0.67	1.38	

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.2 Contd…

Sr No.	Genotype	Primary branches/plant					Secondary branches/plant					Number of capitula /plant				
		E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean
1	**PBNS -128**	8.66	8.33	9	9	8.75	16.33	20.66	19.33	20.33	19.16	24.33	19.33	26	21	22.66
2	**PBNS -129**	9.33	7.33	7.33	7.66	7.91	18.66	17	12.66	18	16.58	20	11.66	13.66	20.66	16.5
3	**PBNS -130**	10.33	8	9.66	8	9	20.66	18.33	18.66	18.33	19	21.33	12	21	21.33	18.91
4	**PBNS -137**	10.66	5.66	8.33	6.33	7.75	14.33	14.66	16.33	14.66	15	18.33	13	19.33	13.66	16.08
5	**PBNS -138**	12.33	7.33	7.66	6	8.33	26.66	19.333	13.33	19.33	19.66	29.33	15.33	16.33	22.33	20.83
6	**PBNS -151**	15.33	10	12.33	7.33	11.25	29.66	27	26.66	15.33	24.66	31.33	19.66	30.66	16	24.41
7	**PBNS -152**	10.66	7.66	6	6.33	7.66	20.66	18.33	13.66	14.33	16.75	25	15.33	13.66	15.33	17.33
8	**PBNS -153**	13.33	8.33	10.33	8.66	10.16	24.66	19	23.66	19.33	21.66	25.66	19	28.66	22.66	24
9	**PBNS -154**	11.66	8.33	9.66	6.33	9	24.33	17	19.66	15.33	19.08	26	14.66	20.33	17.66	19.66
10	**PBNS -150**	10.33	6.66	8.33	6.66	8	21.33	14.66	17	14.66	16.91	23.66	13.33	23.66	15.66	19.08
11	**PBNS -12(ch.)**	12.333	7.66	8	7.33	8.83	27.33	20.66	19.33	13.33	20.16	35.33	21	26.66	12	23.75
12	**Sharda (ch.)**	10.33	8	9.66	10.66	9.66	20.33	21	20	21.33	20.66	24.33	18.33	24.33	24.33	22.83
	Mean	11.27	7.77	8.86	7.52	8.86	22.08	18.97	18.36	17.02	19.11	25.38	16.05	22.02	18.55	20.50
	S.E.±	1.36	0.92	0.94	1.19		1.55	1.25	1.82	1.33		1.40	2.16	1.17	1.20	
	C.D.at 5%	2.83	1.90	1.96	2.48		3.22	2.61	3.78	2.77		2.90	4.48	2.43	2.49	
	C.V.(%)	14.83	14.49	13.09	19.47		8.62	8.12	12.17	9.62		6.76	16.51	6.53	7.92	

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.2 Contd…

Sr No.	Genotype	Number of seeds/capitulum					100 seed weight (g)				
		E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean
1	**PBNS -128**	29.66	29.66	30.66	20.33	27.58	6.7	6.7	6.92	6.56	6.66
2	**PBNS -129**	28.66	27.33	28.66	20.66	26.33	6.43	6.46	6.35	6.23	6.35
3	**PBNS -130**	23	26.33	28.33	21.33	24.75	6.3	6.21	6.21	6.33	6.25
4	**PBNS -137**	26.33	26.66	27.33	21.33	25.41	6.34	6.27	6.25	6.66	6.38
5	**PBNS -138**	31	29.66	26.33	23	27.5	6.85	6.78	6.69	6.33	6.66
6	**PBNS -151**	33.66	32.33	32	21.66	29.91	5.88	5.71	5.66	5.53	5.69
7	**PBNS -152**	30.33	22	30.33	22.33	26.25	5.67	5.2	5.64	5.86	5.59
8	**PBNS -153**	30	30.66	30	23.33	28.5	5.26	5.60	5.35	5.73	5.48
9	**PBNS -154**	26	31.33	26	25.66	27.25	5.09	4.88	4.98	5.23	5.02
10	**PBNS -150**	29.33	30.33	24.33	20.66	26.16	5.95	5.91	5.86	6.1	5.94
11	**PBNS -12(ch.)**	23.66	27.66	29.33	21.33	25.5	5.86	6.3	5.25	5.68	5.76
12	**Sharda (ch.)**	28.33	30	25.33	21	26.16	5.74	6.45	5.70	5.43	5.83
	Mean	28.33	28.66	28.22	21.88	26.77	6.01	6.01	5.90	5.97	5.96
	S.E.±	0.92	2.41	1.11	1.08		0.13	0.04	0.12	0.38	
	C.D.at 5%	1.91	5.01	2.31	2.25		0.26	0.09	0.25	0.79	
	C.V. (%)	3.99	10.32	4.83	6.07		2.65	0.88	2.52	7.87	

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.2 Contd…

Sr No.	Genotype	Chlorophyll content					Oil content (%)				
		E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean
1	**PBNS -128**	58.76	53.06	57.06	55.62	56.02	26.83	27.86	27.06	26.53	27.07
2	**PBNS -129**	52.9	51.3	50.86	49.06	51.03	26.73	26.73	26.8	26.81	26.55
3	**PBNS -130**	57.3	56.8	59.1	54.43	56.92	26.5	27.16	27.1	26.65	26.85
4	**PBNS -137**	64.66	60.8	62.13	60.2	61.98	28.5	28.16	29.6	28.81	28.77
5	**PBNS -138**	63.43	61.83	63.81	63.70	62.52	27.5	28.06	26.86	27.36	27.45
6	**PBNS -151**	72.4	69.2	70.9	71.1	70.91	26.8	27.43	26.23	26.9	26.98
7	**PBNS -152**	70.9	67.33	72.03	69.99	70.05	30.43	30.1	31.33	31.24	31.20
8	**PBNS -153**	59.73	58.16	61.33	50.6	59.45	31.43	30.83	30.96	30.80	30.57
9	**PBNS -154**	68.83	69.5	66.4	67.16	67.97	28.16	28.36	26.56	27.46	27.64
10	**PBNS -150**	68.2	69.4	69.9	68.60	69.36	29.36	28.2	30.13	29.62	29.33
11	**PBNS -12(ch.)**	71.46	70.1	71.28	70.76	70.90	28.33	28.96	29.3	28.75	28.83
12	**Sharda (ch.)**	65.76	67.03	66.4	65.76	66.24	27.7	27.13	27.66	27.95	27.61
	Mean	64.53	63.02	64.19	62.74	59.39	28.19	28.25	28.3	28.22	28.54
	S.E.±	1.04	0.65	0.87	8.89		0.60	0.59	1.07	0.53	
	C.D.at 5%	2.15	1.36	1.80	1.86		1.25	1.24	2.23	1.11	
	C.V.(%)	1.97	1.28	1.66	1.75		2.62	2.59	4.65	2.33	

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.2 Contd…

Sr No.	Genotype	Harvest index (%)					Seed yield /plot (g)					Seed yield /plant (g)				
		E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean	E_1	E_2	E_3	E_4	Pooled mean
1	PBNS - 128	29.96	28.86	29.16	29.7	29.42	1070	980.33	1295.66	820	1041.5	59.4	54.33	67.33	45.33	56.6
2	PBNS - 129	27.73	27.8	27.3	27.3	27.53	666	840	957.33	753.33	804.16	37.43	46.33	56.33	42	45.52
3	PBNS - 130	25.43	24.16	27.9	25.63	25.78	838	737	1034.33	693.33	825.66	46.66	40.66	57	38.66	45.75
4	PBNS - 137	27.16	26.63	27.5	28.6	27.47	793	780.66	1029.33	721.66	831.16	43.7	43	57	40	45.92
5	PBNS - 138	28.86	28.13	26.63	28.73	28.09	1121	779	936.66	680	879.16	61.6	43	52	37.66	48.56
6	PBNS - 151	29.83	31.5	29.86	28.16	29.84	1127.66	1057	1357.33	750	1073	63.8	58.66	75.33	42	59.95
7	PBNS - 152	25.86	26.76	24.2	26.53	25.84	796.66	749	841.33	750	784.25	44.33	41.33	46.66	41.33	43.41
8	PBNS - 153	26.56	27.8	27.4	27.7	27.36	763.33	837.33	1065.66	760	856.58	42.4	46.33	59	42.33	47.51
9	PBNS - 154	27.53	28.3	27.96	28.73	28.13	973.33	702.33	1015.66	800	872.83	53.66	38.66	56.33	44.33	48.25
10	PBNS - 150	28.26	29.03	28.06	29.23	28.65	891	758.33	904.33	710	815.91	49.5	42	50	39.33	45.20
11	PBNS - 12(ch.)	32.16	30.06	31.23	31.23	31.17	1015	907.66	1106	728.33	939.25	56.73	50.33	61.33	40.66	52.26
12	Sharda (ch.)	29.43	29.13	28.06	29.83	29.11	697.33	967.66	947.66	898.33	877.75	38.63	53.66	52.66	50	48.74
	Mean	28.23	28.18	27.94	28.45	28.20	896.02	841.36	1040.94	755.41	883.45	49.82	46.52	57.58	41.97	48.97

	S.E.+	0.91	0.96	1.47	0.54		113.68	86.12	71.11	50.68		5.99	4.74	3.75	2.62	
	C.D.at 5%	1.90	1.99	3.05	1.12		235.77	178.6	147.47	105.10		12.43	9.83	7.78	5.44	
	C.V.(%)	3.98	4.17	6.45	2.33		15.53	12.53	8.36	8.217		14.74	12.48	7.98	7.65	

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.1 Analysis of variance for thirteen characters in four environments

Enviro-nment	d.f.	MSS	Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches /plant	Secondary branches/ plant	Number of capitula/ plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorop-hyll content	Oil content (%)	Harvest index (%)	Seed yield/ plot (g)	Seed yield/ plant (g)
E1	**2**	**Replication**	0.63	41.45	5.86	1.19	6.08	0.52	2.58	0.04	4.87	0.12	2.91	18334.36	56.12
	11	**Treatment**	8.42**	315.94**	17.69**	10.11**	62.79**	68.41**	28.60**	0.828	117.03**	7.23**	11.17**	78694.3*	245.40*
	22	**Error**	0.65	14.38	2.042	2.80	3.62	2.95	1.28	0.02	1.62	0.54	1.26	19387.21	53.93
E2	**2**	**Replication**	7.68	10.08	1.86	0.02	1.19	0.36	21	0.002	0.18	0.25	2.75	5897.69	15.86
	11	**Treatment**	8.44	70.90*	5.66*	3.29*	32.75**	32.05*	23.93*	0.96**	143.89**	4.41**	10.22**	38017.6*	120.63*
	22	**Error**	0.80	3.17	2.49	1.27	2.37	7.02	8.75	0.002	0.65	0.53	1.38	11126.06	33.73
E3	**2**	**Replication**	0.56	0.08	0.15	0.19	0.36	4.52	0.52	0.002	0.77	0.29	0.27	3509.02	31
	11	**Treatment**	15.18**	269.28**	26.32**	8.02**	51.60**	94.75**	16.92**	1.04**	127.75**	10.11**	8.91*	69741.51**	180.55**
	22	**Error**	1.82	1.02	0.761	1.34	4.99	2.07	1.86	0.02	1.13	1.73	3.24	7585.33	21.12
E4	**2**	**Replication**	6.08	12.33	4.083	0.36	4.11	2.19	1.86	0.006	1.95	0.09	1.39	1158.33	2.11
	11	**Treatment**	8.31*	18.81*	11.03*	5.72*	21.96**	47.89**	6.80*	0.64*	160.16**	8.09**	6.97**	10948.67*	33.78*
	22	**Error**	2.14	4.24	3.41	2.14	2.68	2.16	1.77	0.22	1.20	0.43	0.44	3853.03	10.32

* and ** indicates significance at 5 and 1 percent level respectively

E1 = AICRP on Safflower Parbhani

E2 = Oilseeds Research Station, Latur

E3 = Pulses Research Station, Badnapur

E4 = ARS Somanathpur (Udgir)

Table 4.3 Analysis of variance for stability with four environments

Character	Genotype	Environment	G x E	Env + (G x E)	Env (L)	G x E (L)	Pooled deviation	Pooled error
Days to 50% flowering	5.205*	276.639**	2.665	25.496 **	829.916**	3.050	2.266**	0.453
Plant Height (cm)	142.47 **	500.454**	27.504	66.917*	1501.361**	22.003	27.734**	1.902
Days to maturity	11.075**	530.792 **	3.055	47.033**	1592.375**	1.742	3.403**	0.727
Primary branches/plant	4.613**	35.167**	1.480	4.287 **	105.500**	2.726 **	0.785	0.630
Secondary branches/plant	27.249 **	55.02**	9.708	13.485*	165.074**	15.692 *	6.15**	1.141
Number of capitula /plant	36.053*	199.076**	14.996	30.336	597.229**	9.556	16.239**	1.185
Number of seeds/capitulum	8.375	127.901**	5.684	15.86**	383.704**	3.976	5.993**	1.139
100 seed weight (g)	1.164 **	0.004	0.028	0.026	0.012	0.028	0.026	0.024
Chlorophyll content	153.108**	0.093	0.124 *	0.122 *	0.279*	0.258**	0.053	0.433
Oil content (%)	9.134 **	0.026	0.273	0.253	0.078	0.236	0.268	0.271
Harvest index (%)	9.880**	0.524	0.850	0.823	1.571	0.980	0.720	0.528
Seed yield /plot (g)	33333.710**	172506.800**	10822.330	24296.040 **	517520.500**	12459.180	9170.245**	3495.969
Seed yield /plant (g)	97.814**	519.396**	31.881	72.508 **	1558.188**	33.046	28.691 **	9.927

Table 4.5 Stability parameters for thirteen characters in safflower

Sr. No	Genotype	Days to 50% flowering (days)			Plant Height (cm)			Days to maturity (days)			Primary branches/plant			Secondary branches/plant		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	**PBNS -128**	88.842	1.08	1	81.917	0.58	73.5**	129.433	1.08	2.45*	8.75	-0.01*	-0.44	19.167	-0.81*	0.16
2.	**PBNS -129**	87.3	0.98	0.86	80.667	0.4	80.94**	130.083	1.09	9.88**	7.917	0.5	-0.31	16.583	0.44	8.44*
3.	**PBNS -130**	88.8	1.11	6.49**	86.167	0.47	14.92**	129.417	1.03	-0.31	9	0.64	-0.29	19	0.49	-0.86
4.	**PBNS -137**	87.533	0.89	1.69*	94.267	1.04	-1.79	128.517	0.89	0.09	7.75	1.27	-0.12	15	-0.16	-0.09
5.	**PBNS -138**	87.175	0.84	-0.43	93.092	1.17	0.24	129.517	1.09	1.11	8.333	1.58	-0.07	19.667	1.91	18.41**
6.	**PBNS -151**	87.15	1.1	4.42**	94.917	1.87**	-1.78	130.75	1.11	1.73*	11.25	1.87	1.41*	24.667	2.36	21.3**
7.	**PBNS -152**	88.317	1.17	-0.01	98.617	1.5	7.51*	129	0.76	0.8	7.667	1.03	1.55*	16.75	1.36	2.67*
8.	**PBNS -153**	90.6	0.97	2.18**	93.5	1.11	2.01	131.433	1.03	6.81**	10.16	1.32	-0.46	21.667	0.92	5.84**
9.	**PBNS -154**	89	0.85	0.73	98.667	0.83	75.08**	129.2	0.96	1.37	9	1.22	0.43	19.083	1.69	2.35
10.	**PBNS -150**	86.775	0.53	1.89*	94.183	0.85	43.47**	125.75	0.93	-0.47	8	1.01	-0.5	16.917	1.31	1.83
11.	**PBNS -12(ch.)**	89.108	1.35	0.7	96.167	1.08	12.31**	126.475	0.9	3.53**	8.833	1.33	-0.13	20.167	2.62	1.02
12.	**Sharda (ch.)**	89.217	1.13	1.39*	92.5	1.11	0.13	130.7	1.14	4.84**	9.667	0.24	1.27*	20.667	-0.14*	-0.71
	Mean	88.318			92.055			129.19			8.861			19.111		
	SE ±	0.8692			3.040			1.1			0.511			1.4326		
	SE (b)	0.181			0.470			0.2			0.298			0.669		

Table 4.5 Contd…

Sr. No	Genotype	Number of capitula/plant			Number of seeds/capitulum			100 seed weight (g)			Chlorophyll content		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	PBNS -128	22.667	0.63	2.91**	27.583	1.47	-0.5	6.723	-8.25**	-0.02	58.826	-0.57*	-0.46
2.	PBNS -129	16.5	0.53	22.48**	26.333	1.14	-0.16	6.368	-1.32	-0.01	52.79	0.86	-0.46
3.	PBNS -130	18.917	0.82	13.87**	24.75	0.69	6.15**	6.288	2.75**	-0.02	57.356	1.94	-0.46
4.	PBNS -137	16.083	0.69	2.48**	25.417	0.83	-0.85	6.403	8.25	-0.01	64.84	-0.26	-0.44
5.	PBNS -138	20.833	1.13	29.62**	27.5	0.93	4.12*	6.686	-5.29	0.06	63.465	-1.89**	-0.47
6.	PBNS -151	24.417	1.62	23.36**	29.917	1.68	-0.23	5.743	-0.68	0.02	72.39	-2.16*	-0.46
7.	PBNS -152	17.333	0.9	18.94**	26.25	0.73	23.61**	5.714	4.25	-0.02	70.796	-2.07	-0.44
8.	PBNS -153	24	0.81	8.38**	28.5	1.06	-1.2	5.438	8.64	0.07*	59.783	2.06	-0.46
9.	PBNS -154	19.667	1.17	-0.27	27.25	0.37	7.79**	4.998	3.74	0.01	68.163	8.96	-0.28
10.	PBNS -150	19.083	1.24	4.1*	26.167	1.16	7.83**	5.968	4.96	-0.02	68.327	-2.03*	-0.46
11.	PBNS -12(ch.)	23.75	1.93	50.13**	25.5	0.85	7.31**	6.507	-0.42	-0.02	71.154	2.57	-0.41
12.	Sharda (ch.)	22.833	0.54	5.19**	26.167	1.08	3.37*	5.655	-4.66	0	66.242	4.59	-0.16
	Mean	20.507			26.778			6.041			64.511		
	SE ±	2.3266			1.4134			0.0927			0.1327		
	SE (b)	0.5712			0.4329			5.1389			1.5077		

Table 4.5 Contd…

Sr. No.	Genotype	Oil content (%)			Harvest index (%)			Seed yield /plot (g)			Seed yield /plant (g)		
		Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di	Mean	bi	S²di
1.	PBNS -128	27.076	4.94	0.15	29.425	1.26	-0.26	1041.5	1.65*	-3273	56.6	1.38	-5.94
2.	PBNS -129	26.559	-3.89	-0.22	27.533	0.04	-0.42	804.167	0.63	11108.98*	45.525	0.84	42.2**
3.	PBNS -130	26.854	6.15	-0.21	25.783	-4.36	1.84*	825.667	1.25	-2296.64	45.75	1.23	-6.28
4.	PBNS -137	28.771	8.35	0.08	27.475	2.12	0.21	831.167	1.09	-1246.51	45.925	1.09	-1.95
5.	PBNS -138	27.45	-4.29	0.05	28.092	4.31	-0.18	879.167	0.97	32069.67**	48.567	1.01	90.27**
6.	PBNS -151	26.983	0.81	-0.12	29.842	-3.46	1.46*	1073	2.03	2046	59.95	2.04	8.38
7.	PBNS -152	30.576	3.03	-0.06	25.842	4.45	0.18	784.25	0.35*	-3105.08	43.417	0.37*	-8.82
8.	PBNS -153	31.202	-1.66	-0.16	27.367	0.29	-0.07	856.583	1.04	4242.68	47.517	1.03	14.48
9.	PBNS -154	27.64	-11.85	0.28	28.133	1.29	-0.26	872.833	0.93	10240.3**	48.25	0.96	30.88*
10.	PBNS -150	29.332	4.01	0.7*	28.65	2.11	-0.34	815.917	0.72	-447.62	45.208	0.72	-0.67
11.	PBNS -12(ch.)	28.838	8.54*	-0.24	31.175	0.41	0.56	939.25	1.29	333.91	52.267	1.29	1.98
12.	Sharda (ch.)	27.613	-2.13	-0.09	29.116	3.53*	-0.49	877.75	0.05	19505.74**	48.742	0.03	61.81**
	Mean	28.241			28.203			883.438			48.976		
	SE +	0.2987			0.4899			55.3			3.0925		
	SE (b)	6.4205			2.3452			0.5			0.4701		

Table 4.7 Estimation of phenotypic and genotypic correlation coefficient under E_2 environment in safflower (Latur)

Characters		Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches/ plant	Secondary branches/ plant	Number of capitula/ plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
Days to 50% flowering (days)	G	1	0.3587*	0.5681**	0.8693**	0.4528**	0.7183**	0.3840*	-0.3768*	-0.1781	0.6162**	0.3209	0.5187**	0.5113**
	P	1	0.2396	0.2784	0.2715	0.3025	0.3395*	0.2299	-0.2737	-0.1479	0.4507 **	0.2525	0.1407	0.1452
Plant Height (cm)	G		1	0.9226**	0.2822	0.4371**	0.4527**	-0.3529*	-0.2238	0.5732**	0.6493**	0.1952	0.1539	0.1528
	P		1	0.4649 **	0.1385	0.3323 *	0.4097 *	-0.2024	-0.2310	0.5109 **	0.5296**	0.0976	0.1881	0.1893
Days to maturity (days)	G			1	0.4625**	0.2862	0.0277	-0.8380**	-0.6433*	0.0919	0.6861**	-0.5127**	-0.2053	-0.208
	P			1	0.2066	0.0947	0.0304	-0.0353	-0.3106	0.0075	0.2504	-0.1132	-0.0654	-0.0714
Primary branches/ plant	G				1	0.908**	0.6506**	0.8749**	-0.3588*	0.1977	0.1140	0.6038**	0.7383**	0.746**
	P				1	0.7278 **	0.5128 **	0.1364	-0.2939	0.1399	-0.1583	0.2957	0.4312 **	0.4256 **
Secondary branches/ plant	G					1	0.7863**	0.4949**	0.0504	0.3018	-0.1250	0.6456**	0.9895**	0.9859**
	P					1	0.6629**	0.2309	0.0230	0.2835	-0.1189	0.5196 **	0.624 **	0.6247**
Number of capitula/ plant	G						1	0.6211**	-0.0479	0.4795**	0.4342**	0.8645**	0.8855**	0.8912**
	P						1	0.1532	-0.1051	0.3487*	0.2065	0.4821 **	0.5928**	0.5911**
Number of seeds/ capitulum	G							1	-0.2984	0.1001	-0.3878*	0.7642**	0.5784**	0.5771**
	P							1	-0.1412	0.0720	-0.0386	0.4909 **	0.2750	0.2778
100 seed weight (g)	G								1	-0.3481*	-0.472**	-0.0669	0.2865	0.279
	P								1	-0.3417 *	-0.3629 *	-0.0298	0.1318	0.1344
Chlorophyll content	G									1	0.2893	0.5793**	0.1459	0.1505
	P									1	0.2647	0.4317 **	0.1259	0.1311
Oil content (%)	G										1	-0.0436	-0.3880*	-0.3812
	P										1	-0.0606	-0.1113	-0.1084
Harvest index (%)	G											1	0.8596**	0.8616**
	P											1	0.5482**	0.5477**
Seed yield/ plot (g)	G												1	0.99**
	P												1	0.9993**
Seed yield/ plant (g)	G													1
	P													1

Table 4.6 Estimation of phenotypic and genotypic correlation coefficient under E_1 environment in safflower (Parbhani)

Characters		Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches/ plant	Secondary branches/ plant	Number of capitula/ plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
Days to 50% flowering (days)	G	1	0.1023	0.2359	0.3401*	0.1923	0.3509*	-0.1724	-0.3997*	0.0947	0.3623*	0.0729	-0.2129	0.1977
	P	1	0.0820	0.1344	0.1223	0.1705	0.2781	-0.1401	-0.3464*	0.0966	0.3151	0.1063	-0.1447	-0.1370
Plant Height (cm)	G		1	-0.3439*	0.7716**	0.5605**	0.5136**	0.1645	-0.5461**	0.946**	0.4949**	0.1149	0.3028	0.2966
	P		1	-0.2635	0.478**	0.5122**	0.4682**	0.1062	-0.5084**	0.8497**	0.4533**	0.0820	0.2371	0.2345
Days to maturity (days)	G			1	0.307	0.2504	-0.1196	0.3662*	-0.1311	-0.5466**	-0.2081	-0.2401	-0.2689	-0.2475
	P			1	0.2361	0.1469	-0.0686	0.2616	-0.1151	-0.4514**	-0.1275	-0.2800	-0.0676	-0.0753
Primary branches/plant	G				1	0.905**	0.7851**	0.435**	-0.3814*	0.633**	0.1724	0.2588	0.6438**	0.6697**
	P				1	0.6065 **	0.5228 **	0.2578	-0.2223	0.3920 *	0.2331	0.1254	0.2334	0.2354
Secondary branches/plant	G					1	0.9184	0.2384	-0.2304	0.5145**	0.0707	0.3613*	0.647**	0.649**
	P					1	0.7522 **	0.2531	-0.1980	0.4684 **	0.0510	0.3597 *	0.4105*	0.4352**
Number of capitulum/ plant	G						1	0.1703	0.0121	0.6271**	0.04	0.7566**	0.81**	0.8134
	P						1	0.1239	0.0106	0.575 **	0.0279	0.576 **	0.5073**	0.5207**
Number of seeds/ capitulum	G							1	-0.0536	0.1462	0.1454	0.0697	0.2724	0.2743
	P							1	-0.0583	0.1565	0.1268	0.0961	0.2129	0.2360
100 seed weight (g)	G								1	-0.3364*	-0.5555**	0.3849*	0.3357*	0.328
	P								1	-0.3315 *	-0.4970**	0.3226	0.2013	0.2024
Chlorophyll content	G									1	0.2978	0.3745*	0.4898**	0.4843**
	P									1	0.2575	0.3155	0.3090	0.3257
Oil content (%)	G										1	-0.3807*	-0.3824*	-0.3893*
	P										1	-0.2291	-0.2233	-0.2323
Harvest index (%)	G											1	0.6533**	0.6544**
	P											1	0.3928 *	0.4083 *
Seed yield /plot (g)	G												1	0.998**
	P												1	0.9957**
Seed yield /plant (g)	G													1
	P													1

Table 4.10. Direct and indirect effects of yield components on safflower seed yield per plant under E_1 environment (Parbhani)

Sr.No.	Characters	Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches/ plant	Secondary branches/ plant	Number of capitula/ plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Days to 50% flowering (days)**	**0.062**	0.0063	0.0146	0.0211	0.0119	0.0218	-0.0107	-0.0248	0.0059	0.0225	0.0045	-0.0132	-0.1977
2	**Plant Height (cm)**	0.0328	**0.3211**	-0.1104	0.2478	0.18	0.1649	0.0528	-0.1754	0.3038	0.1589	0.0369	0.0972	0.2966
3	**Days to maturity (days)**	-0.0008	0.0012	**-0.0035**	-0.0011	-0.0009	0.0004	-0.0013	0.0005	0.0019	0.0007	0.0008	0.0009	-0.2475
4	**Primary branches/plant**	0.0207	0.047	0.0187	**0.061**	0.0644	0.0478	0.0265	-0.0232	0.0386	0.0105	0.0158	0.0392	0.6697
5	**Secondary branches/plant**	-0.0252	-0.0734	-0.0328	-0.1383	**-0.131**	-0.1203	-0.0312	0.0302	-0.0674	-0.0093	-0.0473	-0.0848	0.649
6	**Number of capitula /plant**	-0.0262	-0.0383	0.0089	-0.0586	-0.0685	**-0.0746**	-0.0127	-0.0009	-0.0468	-0.003	-0.0564	-0.0604	0.8134
7	**Number of seeds/capitulum**	0.0029	-0.0028	-0.0062	-0.0074	-0.004	-0.0029	**-0.017**	0.0009	-0.0025	-0.0025	-0.0012	-0.0046	0.2743
8	**100 seed weight (g)**	0.006	0.0082	0.002	0.0058	0.0035	-0.0002	0.0008	**-0.0151**	0.0051	0.0084	-0.0058	-0.0051	0.328
9	**Chlorophyll content**	-0.033	-0.3295	0.1904	-0.2205	-0.1792	-0.2184	-0.0509	0.1172	**-0.3483**	-0.1037	-0.1304	-0.1706	0.4843
10	**Oil content (%)**	0	0	0	0	0	0	0	0.0001	0	**-0.0001**	0	0	-0.3893
11	**Harvest index (%)**	0.0066	0.0103	-0.0216	0.0233	0.0325	0.068	0.0063	0.0346	0.0337	-0.0342	**0.0899**	0.0587	0.6544
12	**Seed yield /plot (g)**	-0.2436	0.3464	-0.3076	0.7367	0.7403	0.9268	0.3117	0.3841	0.5604	-0.4376	0.7476	**1.1443**	1.0018

Residual effect = 1.0059

Table 4.11. Direct and indirect effects of yield components on safflower seed yield per plant under E_2 environment (Latur)

Sr.No.	Characters	Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches/ plant	Secondary branches/ plant	Number of capitula/ plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Days to 50% flowering (days)**	**0.0131**	0.0047	0.0074	0.0114	0.0059	0.0094	0.005	-0.0049	-0.0023	0.0081	0.0042	0.0068	0.5113
2	**Plant Height (cm)**	0.002	**0.0056**	0.0052	0.0016	0.0025	0.0026	-0.002	-0.0013	0.0032	0.0037	0.0011	0.0009	0.1528
3	**Days to maturity (days)**	-0.0006	-0.001	**-0.001**	-0.0005	-0.0003	0	0.0009	0.0007	-0.0001	-0.0007	0.0005	0.0002	-0.208
4	**Primary branches/plant**	-0.051	-0.0165	-0.0271	**-0.0586**	-0.0591	-0.0382	-0.0513	0.021	-0.0116	-0.0067	-0.0354	-0.0433	0.746
5	**Secondary branches/plant**	0.0062	0.006	0.0039	0.0137	**0.0136**	0.0107	0.0067	0.0007	0.0041	-0.0017	0.0088	0.0135	0.9859
6	**Number of capitula /plant**	0.0586	0.0369	0.0023	0.0531	0.0642	**0.0816**	0.0507	-0.0039	0.0391	0.0354	0.0706	0.0723	0.8912
7	**Number of seeds/capitulum**	0.0177	-0.0162	-0.0385	0.0402	0.0228	0.0286	**0.046**	-0.0137	0.0046	-0.0178	0.0352	0.0266	0.5771
8	**100 seed weight (g)**	0.0073	0.0043	0.0125	0.007	-0.001	0.0009	0.0058	**-0.0194**	0.0067	0.0092	0.0013	-0.0056	0.279
9	**Chlorophyll content**	-0.0058	0.0186	0.003	0.0064	0.0098	0.0156	0.0033	-0.0113	**0.0325**	0.0094	0.0188	0.0047	0.1505
10	**Oil content (%)**	0.0219	-0.0231	-0.0244	-0.0041	0.0045	-0.0155	0.0138	0.0168	-0.0103	**-0.0356**	0.0016	0.0138	-0.3812
11	**Harvest index (%)**	-0.0342	-0.0208	0.0547	-0.0644	-0.0689	-0.0923	-0.0816	0.0071	-0.0618	0.0047	**-0.1067**	-0.0917	0.8616
12	**Seed yield /plot (g)**	0.52	0.1543	-0.2059	0.7402	0.992	0.8878	0.5798	0.2872	0.1463	-0.389	0.8618	**1.0025**	1.0007

Residual effect = 1.0011

Table 4.12. Direct and indirect effects of yield components on safflower seed yield per plant under E_3 environment (Badnapur)

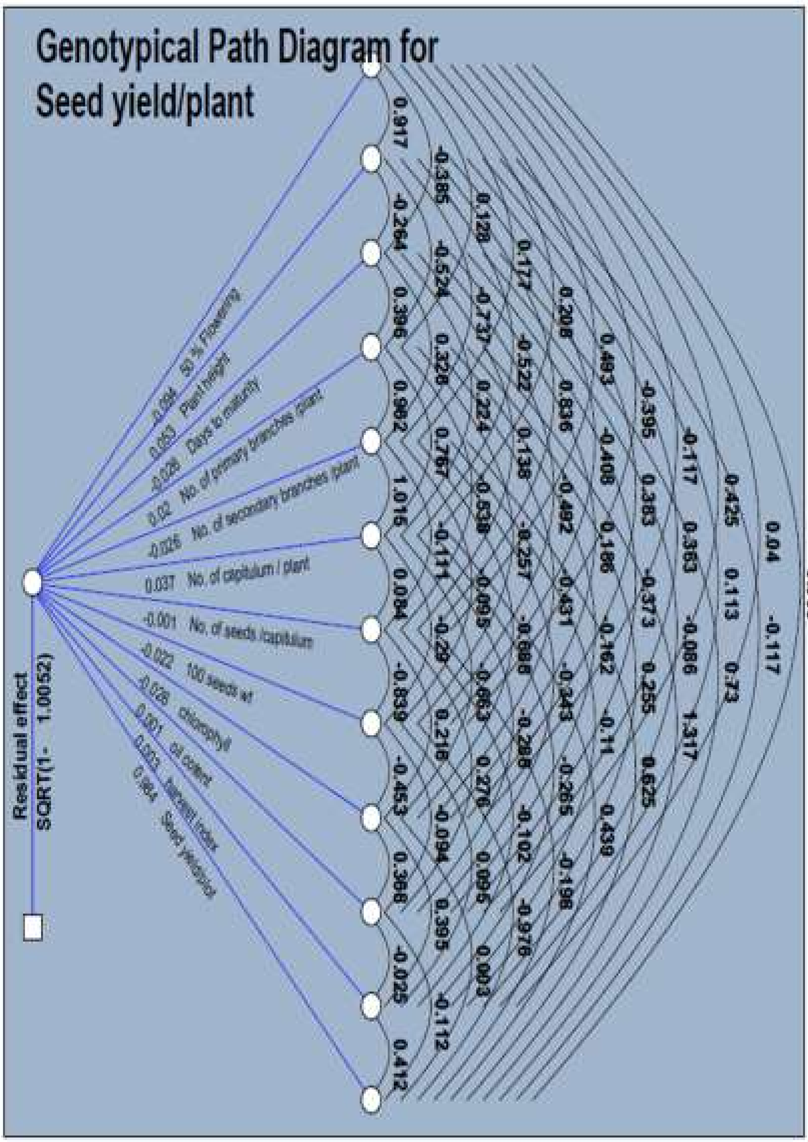
Sr. No.	Characters	Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches /plant	Secondary branches/ plant	Number of capitula / plant	Number of seeds/ capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Days to 50% flowering (days)**	**0.3932**	-0.0384	0.0493	0.02	0.0748	0.0804	0.0578	0.0423	-0.0688	-0.0318	0.1446	0.0374	0.0321
2	**Plant Height (cm)**	0.0202	**-0.2068**	0.0991	0.0075	-0.027	-0.0128	0.0806	0.1218	-0.1682	-0.1049	0.0247	0.0769	-0.3788
3	**Days to maturity (days)**	0.0416	-0.1592	**0.3322**	0.1203	0.0673	0.0313	0.0418	-0.0448	-0.1869	-0.0599	-0.1072	0.024	0.0864
4	**Primary branches/plant**	-0.086	0.0613	-0.6128	**-1.6917**	-1.7586	-1.4987	-0.3972	0.6623	-0.207	0.7393	-1.2481	-1.2786	0.8036
5	**Secondary branches/plant**	0.2741	0.1883	0.2918	1.4976	**1.4407**	1.3895	0.6027	-0.6405	0.4559	0.0598	0.9911	1.175	0.8052
6	**Number of capitula /plant**	-0.3765	-0.1142	-0.1736	-1.6311	-1.7758	**-1.8412**	-0.564	0.2792	-0.5295	-0.2464	-1.7364	-1.4187	0.7366
7	**Number of seeds/capitulum**	-0.3166	0.8401	-0.2714	-0.5059	-0.9013	-0.6599	**-2.1543**	-0.3451	0.0598	-0.2136	-0.4833	-1.4487	0.7071
8	**100 seed weight (g)**	-0.0424	0.2322	0.0531	0.1543	0.1753	0.0598	-0.0631	**-0.3942**	0.154	0.1133	-0.1167	-0.0771	0.1455
9	**Chlorophyll content**	-0.0342	0.1592	-0.11	0.0239	0.0619	0.0563	-0.0054	-0.0764	**0.1957**	0.0652	0.0434	0.0106	0.0431
10	**Oil content (%)**	-0.0547	0.3432	-0.122	-0.2957	0.0281	0.0906	0.0671	-0.1945	0.2255	**0.6767**	-0.3072	-0.2383	-0.3769
11	**Harvest index (%)**	-0.2376	0.0773	0.2086	-0.4768	-0.4446	-0.6095	-0.145	-0.1913	-0.1433	0.2934	**-0.6463**	-0.601	0.9646
12	**Seed yield /plot (g)**	0.4511	-1.7619	0.3421	3.581	3.8646	3.6509	3.1861	0.9268	0.2559	-1.6681	4.406	**4.7382**	0.9998

Residual effect = 0.8504

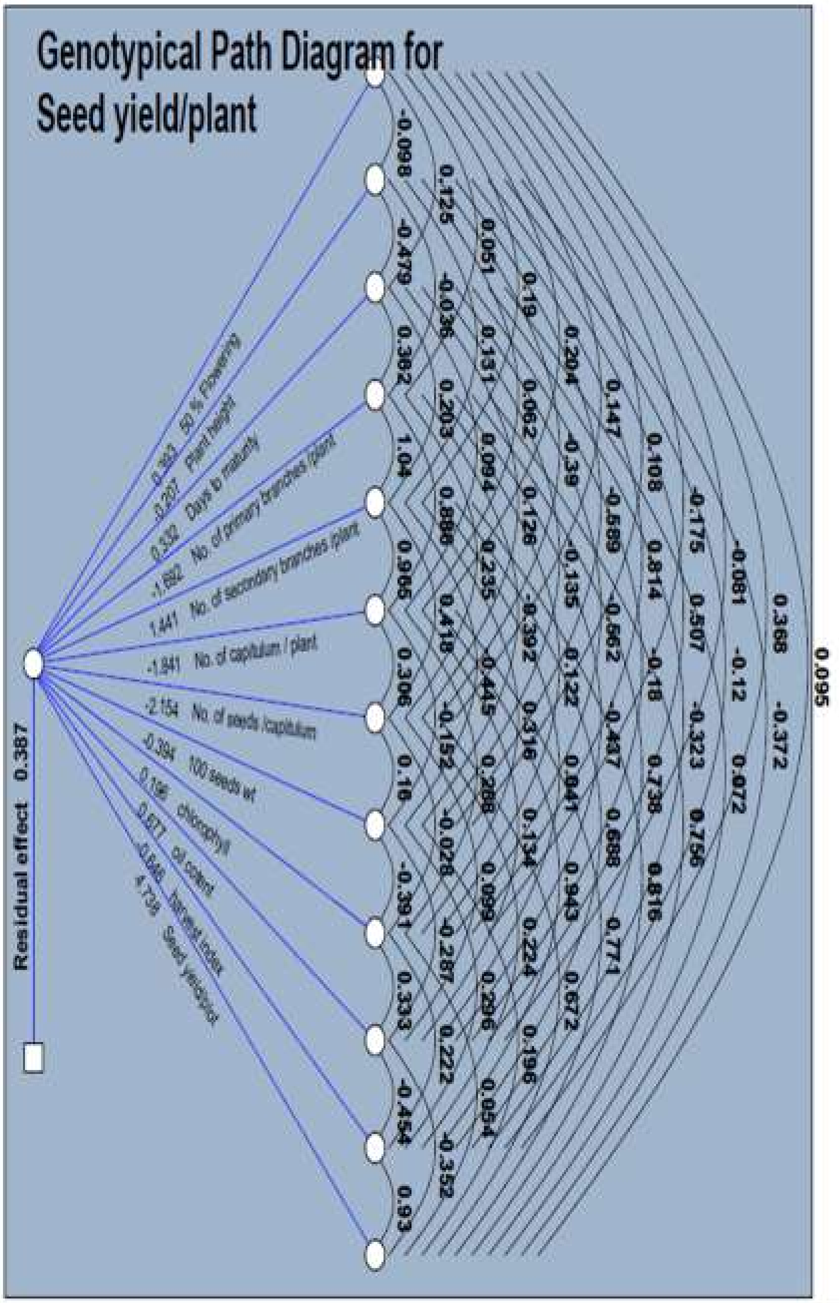
Table 4.13. Direct and indirect effects of yield components on safflower seed yield per plant under E_4 environment (Somanathpur)

Sr. No.	Characters	Days to 50% flowering (days)	Plant Height (cm)	Days to maturity (days)	Primary branches/plant	Secondary branches/plant	Number of capitula/plant	Number of seeds/capitulum	100 seed weight (g)	Chlorophyll content	Oil content (%)	Harvest index (%)	Seed yield/plot (g)	Seed yield/plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**Days to 50% flowering (days)**	**0.0943**	-0.0865	0.0363	-0.0121	-0.0167	-0.0196	-0.0465	0.0372	0.0111	-0.04	-0.0038	-0.0064	0.0485
2	**Plant Height (cm)**	0.0483	**0.0526**	-0.0139	-0.0275	-0.0387	-0.0275	0.044	-0.0215	0.0201	0.0191	0.006	-0.0061	-0.154
3	**Days to maturity (days)**	0.0098	0.0067	**-0.0256**	-0.0101	-0.0083	-0.0057	-0.0035	0.0126	-0.0047	0.0095	0.0022	-0.0187	0.7286
4	**Primary branches/plant**	0.0026	-0.0106	0.008	**0.0202**	0.0194	0.0155	-0.0109	-0.0052	-0.0087	-0.0033	0.0052	0.0266	1.2886
5	**Secondary branches/plant**	-0.0046	0.019	-0.0084	-0.0248	**-0.0258**	-0.0261	0.0029	0.0024	0.0177	0.0088	0.0028	-0.0161	0.603
6	**Number of capitula /plant**	0.0078	-0.0195	0.0084	0.0287	0.038	**0.0374**	0.0031	-0.0109	-0.0248	-0.0108	-0.0099	0.0164	0.4285
7	**Number of seeds/capitulum**	-0.0003	-0.0005	-0.0001	0.0003	0.0001	-0.0001	**-0.0006**	0.0005	-0.0001	-0.0002	0.0001	0.0001	-0.1937
8	**100 seed weight (g)**	0.0087	0.009	0.0109	0.0057	0.0021	0.0064	0.0186	**-0.0221**	0.01	0.0021	-0.0021	0.0216	-0.9555
9	**Chlorophyll content**	0.0031	-0.0101	-0.0049	0.0113	0.0181	0.0174	-0.0057	0.0119	**-0.0263**	-0.0097	-0.0104	-0.0001	-0.0015
10	**Oil content (%)**	0.0005	0.0005	-0.0005	-0.0002	-0.0004	-0.0004	0.0003	-0.0001	0.0005	**0.0013**	0	-0.0001	-0.1339
11	**Harvest index (%)**	0.0001	0.0004	-0.0003	0.0009	-0.0004	-0.0009	-0.0003	0.0003	0.0013	-0.0001	**0.0034**	0.0014	0.3987
12	**Seed yield /plot (g)**	0.0667	-0.115	0.7185	1.2962	0.6157	0.432	-0.1951	-0.9607	0.0025	-0.1106	0.4053	**0.9844**	1.0031

Residual effect = 1.0052


Genotypical Path Diagram for
Seed yield/plant
50 % Flowering
Plant height
Days to maturity
No. of primary branches /plant
No. of secondary branches /plant
No. of capitulum / plant
No. of seeds /capitulum
100 seeds wt
chlorophyll
oil content
harvest index
Seed yield/plot
Residual effect
SQRT(1 - 1.0052)

[redacted]


Genotypical Path Diagram for
Seed yield/plant
Residual effect 0.387

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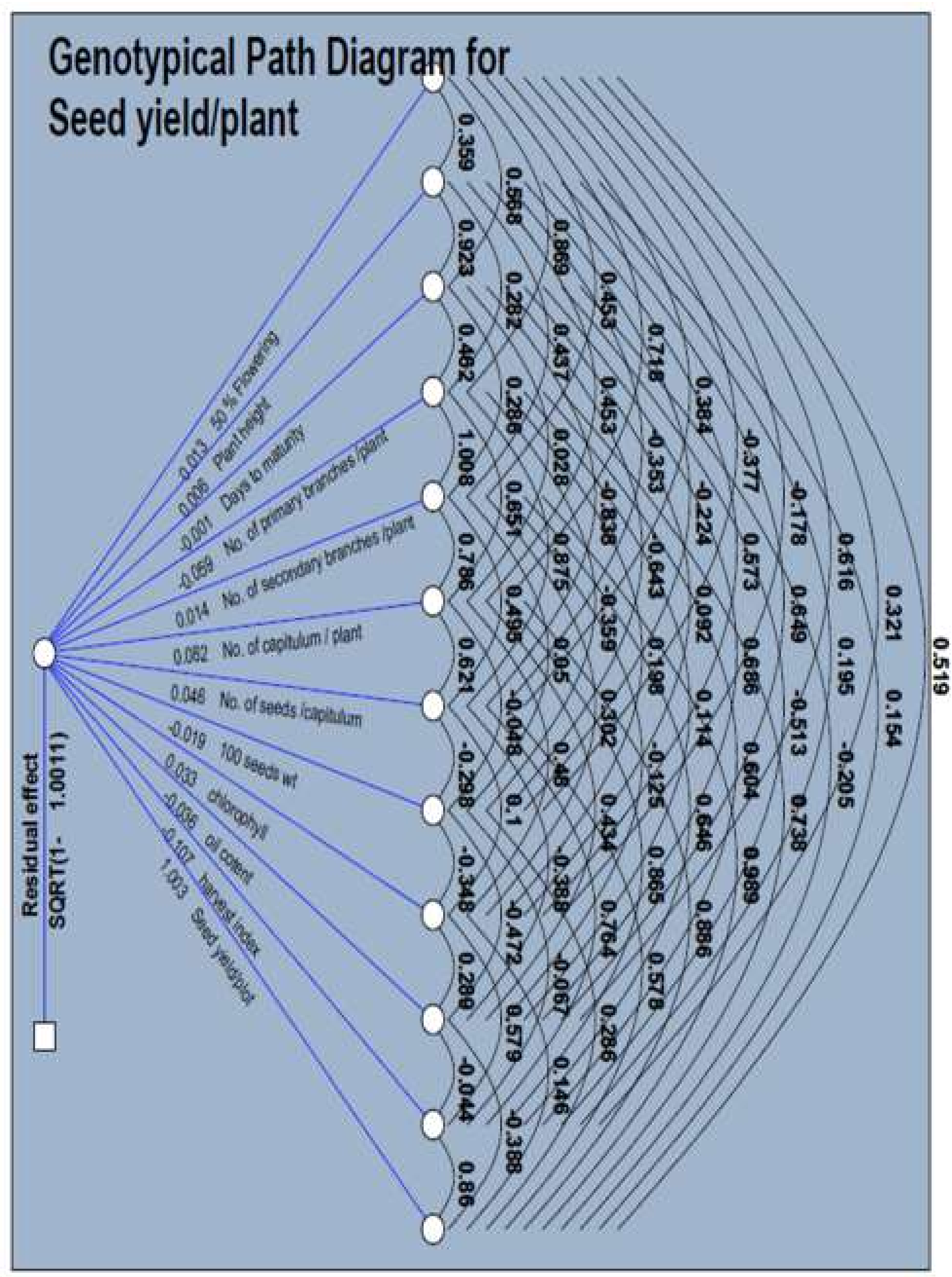
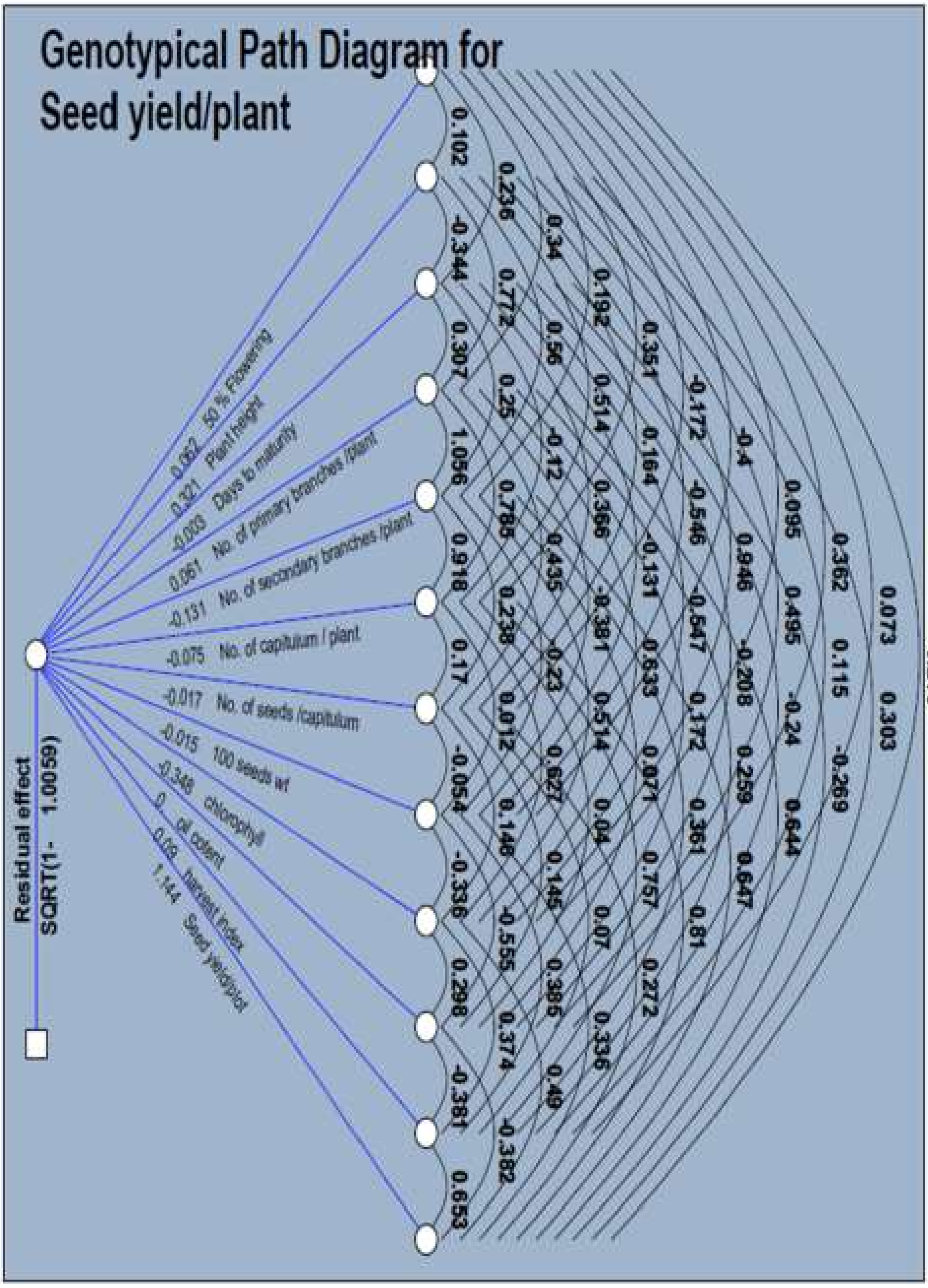

Genotypical Path Diagram for
Seed yield/plant
0.013 50 % Flowering
0.006 Plant height
0.001 Days to maturity
-0.069 No. of primary branches /plant
0.014 No. of secondary branches /plant
0.062 No. of capitulum / plant
0.046 No. of seeds /capitulum
-0.019 100 seeds wt
0.033 chlorophyll
-0.036 oil content
-0.107 harvest index
1.003 Seed yield/plot
Residual effect
SQRT(1- 1.0011)

[redacted]


Genotypical Path Diagram for
Seed yield/plant
0.062 50 % Flowering
0.321 Plant height
-0.003 Days to maturity
0.061 No. of primary branches /plant
-0.131 No. of secondary branches /plant
-0.075 No. of capitulum / plant
-0.017 No. of seeds /capitulum
-0.015 100 seeds wt
-0.348 chlorophyll
0 oil cotent
0.09 harvest index
1.144 Seed yield/plot
Residual effect
SQRT(1- 1.0059)

[redacted]

Discussion

CHAPTER V

DISCUSSION

Plant breeding played an important role in crop evolution. The breeder attempts to breed progressively better adopted genotypes to the existing conditions or to altered environments. Success or failure of such attempts depends upon the provision of recombinational variability.

The ability of crop varieties to perform well over a wide range of environmental conditions has long appreciated by plant breeders and agronomists. Methods have been developed which could be used to provide reliable estimates of genotype x environment interactions.

Safflower (*Carthamus tinctorius* L.) is an important oilseed crop of the country. Many improved varieties have been developed, but in spite of that there is no much difference in national average productivity of safflower and thus is facing deficits to meet the requirements of consumers and industries. Breeding for wider adaptability and better stability had been the major objectives in national oilseed improvement programme in India.

The present study was undertaken to collect the information on stability of yield and yield components in promising safflower genotypes and to study the genetic association of characters over environments. The phenotypic performance is an inter-play of the genotype with the environmental conditions in which it is grown. Such interactions are of major consequences. While association of various characters with yield and among themselves, would provide criteria for indirect selection through different components for improvement in safflower yield.

The results of the present investigation for variability, stability and correlation are briefly discussed in following heads.

5.1 Analysis of variance

5.2 Mean performance

5.3 Analysis of variance for stability

5.4 Stability analysis

5.5 Character association over environments

5.1 Analysis of variances

The analysis of variance showed significant differences among the treatments for all the characters. This indicates that there exists a wide range of variability among genotypes for yield and yield contributing characters.

5.2 Mean performance

Mean performance for twelve genotypes for thirteen quantitative characters were studied over four environments. A wide range of variability was noted for all the characters under study (Table 4.2).

The mean values for days to 50 *per cent* flowering varied from 86.77 (PBNS-150) to 90.6 days (PBNS-153) with a general mean of 88.31 days. The genotypes PBNS-151 (80.33) and PBNS-137 (83.66) were observed to flower earliest, while the genotype PBNS-12 (96.1) exhibited late flowering. Variability result for this trait were proposed by Fatemeh *et al*. (2007) and Pavithra *et al*. (2016).

The mean values for days to maturity varied from 125.75 (PBNS-150) to 131.43 days (PBNS-153) with a general mean of 139.18 days. The number of days to maturity was maximum for genotype PBNS-153 (131.43 days), followed by 130.75 days for PBNS-151, 130.70 days for Sharda and lower early in maturity were found in PBNS-137 (128.51 days), PBNS-12 (126.47 days) and PBNS-150 (125.75 days). Variability result for this trait were proposed by Fatemeh *et al*. (2007), Gopal *et al*. (2015) and Pavithra *et al*. (2016).

The mean values for plant height ranged from 80.66 ((PBNS-129) to 98.66 cm (PBN-154) with mean 92.95 cm. The genotype PBNS-129 (80.667 cm), and

PBNS-128 (81.91 cm) exhibited lowest plant height, while, PBNS-154 (98.66 cm) and PBNS-152 (98.61 cm) were found for highest plant height. Result of variability for this trait were in accordance with Fatemeh *et al*. (2007), Shivani *et al*. (2010) and Pavithra *et al*. (2016).

The pooled mean over environments for primary branches per plant ranged from 7.66 (PBNS-152) to 11.25 (PBNS-151) with general mean 8.86. The genotypes PBNS-151 (11.25), PBNS-153 (10.16) and Sharda exhibited highest number of primary branches per plant. Variability result for this trait were proposed by Reddy *et al*. (2004) and Fatemeh *et al*. (2007).

The mean values for secondary branches per plant ranged from 15 (PBNS-137) to 24.66 (PBNS-151) with general mean 19.11. The genotypes PBNS-151 (24.66), PBNS-153 (21.66) and Sharda exhibited highest number of secondary branches per plant. Variability result for this trait were given by Reddy *et al*. (2004), Fatemeh *et al*. (2007) and Gopal *et al*. (2015).

The mean values over environments for number of capitula ranged from 16.08 (PBNS-137) to 24.41 (PBNS-151) with mean 20.50. The genotypes PBNS-151 (24.41), PBNS-153 (24) and PBNS-12 (23.75) were observed for highest number of capitula per plant. Variability result for this trait were proposed by Khidir (1974), Fatemeh *et al*. (2007), Shivani *et al*. (2010), Gopal *et al*. (2015) and Pavithra *et al*. (2016).

The mean values for number of seeds per capitulum ranged from 24.75 (PBNS-130) to 29.91 (PBNS-151) with mean 26.77 number of seeds per capitulum. The genotypes PBNS-151 (29.91), PBNS-153 (28.5) and PBNS-128 (27.58) exhibited highest for number of seeds per capitulum. Variability result for this trait were given by Reddy *et al*. (2004), Fatemeh *et al*. (2007), Shivani *et al*. (2010) and Pavithra *et al*. (2016).

The mean values for 100-seed weight ranged from 5.02 (PBNS-154), to 6.66 g (PBNS-128) with general mean 5.96 g. The genotypes PBNS-128 and PBNS-138 (6.66 g), PBNS-129 (6.35 g) and PBNS-137 (6.38 g) observed for higher 100-

seed weight. Variability result for this trait were observed by Rudra Naik *et al*. (2005), Fatemeh *et al*. (2007), Shivani *et al*. (2010) and Pavithra *et al*. (2016).

The mean values for chlorophyll content ranged from 51.03 (PBNS-129) to 70.91 (PBNS-152) with mean 59.39. The genotypes PBNS-151 (70.91), PBNS-12 (70.90) and PBNS-152 (70.2) recorded higher chlorophyll content over all environments. Variability result for this trait was observed by Pavithra *et al*. (2016).

The mean values for oil content were ranged from 26.55 (PBNS-129) to 31.20 *per cent* (PBNS-152) with mean 28.24 *per cent*. The genotypes PBNS-152 (31.20), PBNS-153 (30.57) and PBNS-150 (29.33) recorded higher oil content over all environments. Variability result for this trait were recorded by Fatemeh *et al*. (2007) and Pavithra *et al*. (2016).

Pooled mean values for harvest index ranged from 25.78 (PBNS-130) to 31.17 *per cent* (PBNS- 12) with a mean of 28.20 *per cent*. The genotype PBNS-12 (31.17%) recorded higher harvest index, followed by PBNS-151 (29.84%) and PBNS-128 (29.42%). However, PBNS-130 (25.78%) recorded lower harvest index over all environments. Variability result for this trait was proposed by Pavithra *et al*. (2016).

The pooled mean over environments for seed yield per plot was ranged from 784.25 (PBNS-152) to 1073 g (PBNS-151) with a mean 883.45 g. The genotypes PBNS-151 (1073 g), PBNS-128 (1041 g) and PBNS-12 (939.25 g) recorded highest seed yield per plot over all environments. While, PBNS-129 (804.16 g) and PBNS-152 (784.25 g) recorded lowest seed yield per plot. Variability result for this trait was proposed by Khidir (1974), Gopal *et al*. (2015), Fatemeh *et al*. (2007), Shivani *et al*. (2010), Reddy *et al*. (2004) and Pavithra *et al*. (2016).

The pooled mean over environments for seed yield per plant ranged from 43.41 (PBNS-152) to 59.95 g (PBNS-151) with a mean of 48.97 g. The genotypes PBNS-151 (59.95 g), PBNS-128 (56.6 g) and PBNS-12 (52.26 g) observed for highest seed yield per plant over all environments. Whereas, PBNS-152 (43.41 g) and PBNS-150 (45.20 g) recorded lowest seed yield per plant. Variability result for this trait was proposed by Khidir (1974), Gopal *et al*. (2015), Fatemeh *et al*. (2007), Shivani *et al*. (2010), Reddy *et al*. (2004) and Pavithra *et al*. (2016).

5.3 Analysis of variance for stability

It is not expected that one genotype can perform equally well under different environments. Smaller differences have been observed in different environments conditions, and on the basis of these differences, micro and macro environments have been developed. Due to significant genotype x environmental interactions, it is very difficult to identify stable genotypes for a particular environment, because, some genotypes do well in poor environments or good environments, but few genotypes adopt in all the types of environments which is called as well adapted genotype or stable genotype. In order to identify stable genotype an experiment was conducted under different environments. In analysis of variance significance of linear and non linear components along with of G x E interactions are measured.

The occurrence of G X E interaction has long provided a major challenge for better understanding of genetic control of variability and thus to realization of procedures for breeding improved genotypes in crop plant (Breese, 1959). In the past, the principle analytical approach to estimate G X E interaction from pooled analysis of variance has helped to identify environmental factors which interact with genotypes and presence or absence of G X E interaction. However, the most widely used approach to estimate G X E interaction components of variability, interacts linear or non linear portions for assessing the stability of genotypes over range of environments is followed. In the present study same approach out lined by Eberhart and Russell (1966) has been used.

There are significant differences for genotypes, environments, Env + (G X E), Env (L) and pooled deviation for days to 50 *per cent* flowering, plant height, days to maturity, secondary branches per plant, seed yield per plot and seed yield per plant. Whereas, for primary branches per plant and number of capitula per plant there are significant differences for genotypes, environment and Env (L). However, chlorophyll content is significant for genotype, G X E, Env + (G X E), Env (L), and G X E (L). 100-seed weight, oil content and harvest index are significant only for genotype.

Narkhede *et al*. (1984b) observed significant G X E, which can help to predict performance across the environments, however, non linear components are non significant.

The significant genotype and G X E differences were also reported by Patil *et al*. (1992) Manjare (1993) Hedge *et al*. (1997) and Rao *et al*. (2007) in safflower.

Due to significant G X E interactions, measurement of stability parameters in order to identify the stable genotypes have been done and described as follows.

5.4 Stability parameters

In stability analysis two important indices are regression coefficient **(**bi) and the genotype mean over environments**.** Unit regression coefficient indicates average stabi1ity. When this is associated with high mean genotypes have general adaptability. When associated with low mean, genotypes are poorly adapted to all environments. Regression values increasing above 1.0 (bi > 1) reflect increasing sensitivity of the genotypes to environmental change (below average stability) and greater specificity of adaptability to high yielding (favorable) environments. Regression coefficients decreasing below unity (bi < 1) provides a measure of greater resistant to environmental change (above average stability) and therefore increasing specificity of adaptability to low yielding environments (Finley and Wilkinson, 1963). Further Eberhart and Russell (1966) extended the model by addition of another stability parameter namely the deviation from regression (S^2di) in judging the stability of a genotype, which will give predictability and unpredictability of genotypic performance. But Breese (1969), Samuel *et al*. 1970) and Paroda and Hays (1971) emphasized that linear regression could be regarded as a measure of a particular genotype while deviation around the regression line (S^2di) is most suitable measure of stability. Genotype with the least deviation value being most suitable and vice-versa**.**

The environment indices are given in Table 4.2, which indicate variable impact on environments. E_1 environment was favorable environment for all characters except oil content. E_2 environment was favorable for characters like, plant height, number of seeds per capitulum, 100-seed weight, chlorophyll and oil content. E_3 environment was favorable for days to 50 *per cent* flowering, days to maturity, number of primary branches per plant, number of capitula per plant, number of seeds per capitulum, chlorophyll content, oil content, seed yield per plot and seed yield per plant. Environment E_4 was found to be favorable only for days to maturity, 100-seed weight and harvest index. The various environmental indices indicate there is need to identify genotype according to environmental indices.

Days to 50 *per cent* flowering revealed that the genotypes PBNS-129 and PBNS-138 were more stable across the environments and identified as early genotypes. The genotypes PBNS-12, PBNS-151, PBNS-137, PBNS-138 and PBNS-152 were stable with high mean and non significant S^2di and bi > 1 and Sharda was observed to be stable genotype that deviated non significantly from zero and regression coefficient near to unity (bi ≈1) is recommended for all environments. Whereas, for days to maturity genotypes PBNS-150 and PBNS-12 were identified as early genotypes. However, for plant height the genotypes PBNS-12, PBNS-151, PBNS-137, PBNS-138 and PBNS-152 were stable and had regression coefficient more than unity (bi > 1) and high mean adaptable to favorable environment, whereas, Sharda is suitable for all environments. Genotype PBNS-12 with bi > 1 and high mean adaptable to favorable environment, whereas, Sharda was suitable for all environments. Genotypes PBNS-151, PBNS-154 and Sharda are stable for both number of primary branches per plant and secondary branches per plant. Genotypes PBNS-128, PBNS-151 and PBNS-153 were stable for both number of capitula per plant and seeds per capitulum. For 100-seed weight PBNS-128 and PBNS-130 were observed to be stable. Whereas, for chlorophyll content PBNS-151 was most stable. PBNS-153 and PBNS-137 were stable for oil content. For harvest index PBNS-151 was found to be more stable. For seed yield per plot and seed yield per plant genotypes PBNS-128, PBNS-151 and PBNS-12 were found to be more stable. Some of the genotypes have higher mean bi > 1 or bi < 1, some genotypes are with high mean, bi=l, but S^2di is high indicating instability regarding performance.

Patil *et al*. (1992), Manjare (1993), Nagaraj (1994), Rudra Naik *et al*. (2005) have considered the above three stability parameters and genotypes like A-l, Sharda, Bhima and NRS-209 were identified as most stable genotypes for yield and some of the yield contributing characters.

Akmal *et al*. (2008) tested nine elite genotypes of safflower, on the basis of bi and S^2di values they identified suitable genotypes for favorable and unfavorable environments. According to them SAF-30 and SAF-33 may perform under favorable environments, whereas, SAF-35 was found suitable for unfavorable environments.

5.5 Character association

5.5.1 Correlation studies

The expression of complex characters such as yield depends upon the interplay of a number of components. A better picture of the contribution of each component in building up the total genetic architecture of a complex character may be obtained through the study of correlation and causation which furnishes a realistic basis for the allocation of weight age to each of the component attributes. The phenotypic correlation indicates the extent of the observed relationship between two characters. This does not give a true genetic picture of relationship because it indicates the effect of both heredity as well as environmental influences. Genotypic correlation provides an estimate of an inherent association between genes controlling any two characters i.e., when two characters are invariably and linearly associated. The underlined genetic mechanism causing such association may be due to complete linkage between the two characters or pleiotrophy. Hence, genotypic correlation is of greater significance and can be effectively utilized in formulating an effective selection programme. Therefore, in the present discussion more stress is given on genotypic correlation coefficients only. They may help to identify the characters that are of major importance in crop improvement programme particularly improvement of major character of yield.

It is seen from Table 4.6 to 4.9 that seed yield per plant has significant and positive association with number of primary branches, number of secondary branches, number of capitula per plant, number of seeds per capitulum, harvest index and seed yield per plot in all the environments, these results in agreement with the finding of Makane *et al*. (1979), Singh *et al*. (1993), Ekshinge *et al*. (1994), Ahmadzaden *et al*. (2012).

In other correlations studies it is observed that, plant height had positive correlation with primary branches per plant, secondary branches per plant, number of capitulum per plant, chlorophyll, oil content in E_1 and E_2 environment, whereas, in E_3 and E_4 environments similar trends were not observed but had positive correlation with chlorophyll and oil content. Primary branches per plant had positive correlation with secondary branches per plant, number of capitula per plant, harvest index and seed yield per plot in E_1, E_2 and E_3 environments, whereas, E_4 was positively correlated with secondary branches per plant and number of capitula per plant.

Days to 50 *per cent* flowering had positive correlation with primary branches per plant, number of capitula per plant and oil content in E_1 and E_2 environments. Days to maturity was positively correlated with primary branches in E_1, E_2 and E_3 environments. Secondary branches per plant had positive correlation with number of capitula per plant and seed yield per plot in all the environments. There was positive correlation between number of capitula per plant with seed yield per plot in all the environments. Whereas, harvest index is positively correlated in E_1, E_2 and E_3 environments. Number of seeds per capitulum is positively correlated with seed yield per plot in E_2 and E_3 environment. Rest of the characters are positively correlated with each other in one or other environments.

Makne *et al*. (1979) Patil (1985), Dalvi *et al*. (2005) Naik *et al*. (2009) studied and genotypic and phenotypic correlation, but reported significant positive correlation between yield and yield contributing characters *viz*., days to maturity, plant height, primary branches per plant, number of capitulum per plant, number of seeds per capitula, harvest index and 100-seed weight.

5.5.2 Path coefficient analysis

The knowledge of inter-relationship between yield and its components and among the components of yield as themselves is necessary, if selections for simultaneous improvement in these characters are to be performed. As more variables are included in the correlation studies, the indirect associations become complex. In such situation the path coefficient analysis developed by Wright (1921) provides an effective means of finding out direct and indirect causes of association and permits, critical examination of specific force acting to produce a given correlation and measure the relative importance of each causal factor.

Highest Direct effect

Characters	**E_1**	**E_2**	**E_3**	**E_4**
Direct effect	1) seed yield per plot 2) plant height 3) primary branches per plant	1) seed yield per Plot 2) number of capitula per plant 3) number of seeds per capitulum	1) seed yield per plot 2) secondary branches per plant 3) oil content	1)seed yield per plot 2) days to 50*per cent* flowering 3) plant height

Above table indicates in all environments seed yield per plot had higher direct effect on yield followed by plant height, number of capitula per plant, secondary branches per plant and days to 50 *per cent* flowering in E_1, E_2, E_3 and E_4 environment respectively.

Primary branches per plant, harvest index and seed yield per plot in E_1, secondary branches per plant, secondary branches per plant, number of capitula per plant, number of seeds per capitulum in $E_{2,}$ secondary branches per plant in E_3, primary branches per plant, number of capitula per plant, harvest index showed significant positive correlation through direct effect on seed yield. Mathur *et al.* (1976), Mehrotra and Jain (1976), Patil and Deshmukh (1998), Chavan *et al.* (1999), Sarang *et al.* (2004a), Moghaddasi and Omidi (2010) and Ahmadzadeh *et al.* (2012) observed similar positive direct effect on seed yield per plant. Mehrotra and Jain (1976), Thombre and Joshi (1981), Ramachandram and Goud (1982), Malleshappa *et al.* (1989), Jadhav *et al.* (1992), Patil and Deshmukh (1998), Bagheri *et al.* (2001a), Lakshyadeep *et al.* (2005), Roopa and Ravikumar (2008), Behnam *et al.* (2012), Mohammadi *et al.* (2012) reported similar results. The above results indicated selection on above traits is highly desirable for improvement in seed yield.

In E_1 environment out of twelve characters, four characters *viz*., secondary branches per plant, number of seeds per capitulum, chlorophyll content and oil content via 100-seed weight, two characters *viz*., 100-seed weight and days to 50 *per cent* flowering via oil content, other two characters *viz*., plant height and days to maturity, via chlorophyll content, other two characters *viz*., seed yield per plot and harvest index via number of capitula per plant, remaining two characters *viz*., primary branches per plant and number of capitulum per plant via secondary branches and days to maturity had higher indirect effect.

In E_2 environment, three characters *viz*., plant height, 100-seed weight and harvest index via days to maturity, three characters *viz*., days to 50 *per cent* flowering, secondary branches per plant and number of seeds per capitulum via primary branches per plant, one character *viz*., primary branches per plant via 100-seed weight, chlorophyll content via harvest index, oil content via days to 50 *per cent* flowering, number of capitula per plant via seed yield per plot, days to maturity via number of capitula per plant and remaining characters *viz*., seed yield per pot via secondary branches per plant through days to 50 *per cent* flowering, harvest index and 100-seed weight had higher indirect effect.

In environment E_3, three characters *viz*., 100-seed weight, oil content and number of seeds per capitulum via plant height and other three characters *viz*., primary branches per plant, chlorophyll and harvest index via oil content, characters days to maturity and secondary branches per plant via primary branches per plant, two characters plant height and number of capitula per plant via 100-seed weight and the remaining characters days to 50 *per cent* flowering and seed yield per plot via harvest index reported higher indirect effect.

In E_4 environment three characters *viz*., days to maturity, number of seeds per capitulum and days to 50 *per cent* flowering via 100-seed weight, three characters *viz*., primary branches per plant, 100-seed weight and harvest index via seed yield per plot, two characters *viz*., secondary branches per plant and oil content via plant height, characters number of capitula per plant and chlorophyll via secondary branches per plant and remaining two characters *viz*., plant height and seed yield per plot via days to 50 *per cent* flowering and primary branches per plant respectively reported higher indirect effect.

Prakash (1993) and Malleshappa (1989) noticed 100-seed weight, Veena (1997) Patil and Deshmukh (1998), Pandya *et al*. (1996) observed number of capitula, 100-seed weight and number of seeds per capitula had highest direct effect on yield.

Baghari *et al*. (2001) Divakar *et* al. (2006) Ravikumar and Rupa (2010) reported number of capitulum per plant had highest direct effect on yield.

Golparvar *et al*. (2009) observed highest direct effect of 100-seed weight and seed number per plant.

5.5.3 Breeding implications and future line of work

The genotypes PBNS-151, PBNS-128 and PBNS-12 had average stability not only for seed yield but also for important yield components. They need to be involved in further breeding programme more extensively and these genotypes may be evaluated in multilocation trials. It is further suggested that number of primary and secondary branches per plant and harvest index could be most important components of seed yield in safflower. The safflower breeder engaged in selection for high yield should look for a place with large number of primary and secondary branches per plant, number of capitula per plant and high harvest index which could be fitted well in different environmental conditions.

Summary and Conclusion

CHAPTER VI

SUMMARY AND CONCLUSION

The present investigation entitled "Stability analysis for yield and yield contributing traits in safflower (*Carthamus tinctorius* L.)" was under taken with the following objectives.

1. To study the stability performance of different safflower genotypes for grain yield and its components under different environments.
2. To study the extent of genotypic and phenotypic association of grain yield with its components.

The field experiments comprising of twelve genotypes with observations were recorded on thirteen morphological characters was conducted in R.B.D. with three replication at AICRP on Safflower Parbhani, Oil Seeds Research Station, Latur, Pulses Research Station, Badnapur and ARS Somanathpur (Udgir) during *rabi* 2016.

The results are summarized as below

1. There were significant differences among all the thirteen characters, indicating much variability is available and is useful for further study.
2. The pooled mean performance indicated that for plant height, genotype PBNS-154 and for primary branches per plant PBNS-154 and for secondary branches PBNS-151 was promising. The genotype PBNS-150 was early to 50 *per cent* flowering and early in maturity.
3. Highest number of capitula per plant was recorded by PBNS-151, for highest number of seeds per capitulum PBNS-151 was found to be promising. For 100-seed weight genotype PBNS-128 and for chlorophyll, genotype PBNS-151 was promising.
4. Highest oil content was observed in PBNS-153 and highest harvest index was reported by PBNS-12.
5. Highest seed yield per plot was reported in PBNS-151 and for seed yield per plant the genotypes PBNS-151, PBNS-128 and PBNS-12 were promising.

6. The analysis of variance for stability indicated that there were significant differences, for genotypes, environments, G X E, and interaction for both linear and non linear components for all the characters.

7. The environmental indices indicated that E_1 (Parbhani) was favorable environment for all characters except oil content. Environment E_2 (Latur) environment was favorable for plant height, number of seeds per capitulum, 100-seed weight, chlorophyll and oil content. E_3 (Badnapur) environment was favorable for days to 50 *per cent* flowering, days to maturity, number of primary branches per plant, number of capitula per plant, number of seeds per capitulum, chlorophyll content, oil content, seed yield per plot and seed yield per plant. Environment E_4 (Somanathpur) was found to be favorable only for days to maturity, 100-seed weight and harvest index.

8. On the basis of stability parameters it has been indicated that for plant height, the genotype PBNS-12 and Sharda for primary and secondary branches, PBNS-151 and for days to 50 *per cent* flowering, genotype PBNS-129, for days to maturity PBNS-150, for number of capitula per plant and seeds per capitulum, genotype PBNS-128 was stable.

9. The genotype PBNS-151 for chlorophyll, PBNS-153 for oil content, PBNS-151 for harvest index and PBNS-128 for seed yield per plot and seed yield per plant was found to be most stable.

10. The significant and positive correlation was observed between yield and number of primary branches, number of secondary branches, number of capitula per plant, number of seeds per capitulum, harvest index and seed yield per plot.

11. Path analysis indicated that the highest direct effect on yield in E_1 environment, was observed via seed yield per plot followed by plant height, in E_2 environment, seed yield per plot followed by number of seeds per capitulum, in E_3 environment, seed yield per plot followed by secondary branches per plant and in E_4 environment, seed yield per plot followed by days to 50 *per cent* flowering.

CONCLUSION

On the basis of mean performance and stability parameters genotypes PBNS-151 and PBNS-128 found better for higher seed yield and exhibited wider adaptability.

The environmental indices indicated that E_1 (Parbhani) and E_2 (Latur) environments were favorable, whereas, E_3 (Badnapur) and E_4 (Somanathpur) were unfavorable. Genotypes PBNS-128 and PBNS-129 were found specially adapted to poor environments and the genotypes PBNS-151 and PBNS-12 were adapted to better environments. This could be attributed to their average stability for seed yield and high mean values for other yield components. These genotypes may be evaluated in multilocation trail. The important yield components of seed yield are primary branches, secondary branches, number of capitula per plant, number of seeds per capitulum and harvest index. These yield components may be used in any future breeding programme for yield improvement in safflower.

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Thesis Abstract

ABSTRACT

The present investigation entitled "Stability analysis for yield and yield contributing traits in safflower (C*arthamus tinctorius* L.)" was conducted to study, G X E interaction and nature of stability of different genotypes in safflower. The field experiments comprising of twelve genotypes were conducted in R.B.D. with four replications at AICRP on Safflower Parbhani, Oil seeds Research Station Latur, Pulses Research Station Badnapur and ARS Somanathpur (Udgir). The observations were recorded on thirteen morphological characters *viz*., days to 50 *per cent* flowering, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of capitula per plant, number of seeds per capitulum, chlorophyll content, oil content, 100-seed weight, harvest index, seed yield per plot and seed yield plant. Stability and character association analysis was carried out as per model of Eberhart and Russell (1966) and analysis of variance indicated significant genotypic differences existed among all the genotypes for all the characters studied.

Mean performance indicated that genotypes PBNS-151 was high yielding followed by PBNS-128 and PBNS-12. According to environmental indices, environment E_1 (Parbhani) was found to be most favorable, followed by E_3 (Badnapur), E_2 (Latur) and E_4 (Somanathpur). The stability parameters indicated PBNS-128 was most stable for seed yield per plant. There was positive correlation between yield and number of primary branches, number of secondary branches, number of capitula per plant, number of seeds per capitulum, harvest index and seed yield per plot. Path analysis indicated the highest direct effect in E_1 environment was of seed yield per plot followed by plant height, in E_2 environment, seed yield per plot followed by number of capitula per plant, in E_3 environment, seed yield per plot followed by secondary branches per plant and E_4 environment seed yield per plot had highest direct effect followed by days to 50 *per cent* flowering.