VARIABILITY AND STABILITY ANALYSIS OF NEWLY DERIVED S_6 LINES OF MAIZE (*Zea mays* L.)

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INTRODUCTION

Maize or corn (*Zea mays* L.) belonging to the family of grasses (Poaceae) is one of the most important cereal crops cultivated globally. The plant is native to South America. *Zea mays* is the only species of the genus Zea with chromosome number 2n=20. It has two close relatives, among the American Maydeae *viz*., genus Tripsacum (gamagrass) and Teosinte (Euchlena) which is regarded as the closest relative and five among Asiatic Maydeae *viz*., Chionachne, Sclerachne, Coix, Trilobachne and Polytoca.

Maize is a versatile crop grown over a range of agro climatic zones from 58^0N to 40^0S, from below sea level to altitudes higher than 3000 m and in areas with 250 mm to more than 5000 mm of rainfall per year (Shaw, 1988; Downsell *et al*., 1996). Most of the area under this crop is however in the warmer parts of temperate regions and in humid subtropical climate. Highest production is in areas having the warmest month isotherms from 21°C to 27°C and a frost free season of 120 to 180 days duration.

Maize is one of the staple food crop and widely cultivated crop throughout the world. The United States produces almost half of the world's production; other top producing countries are China, Brazil, France, Indonesia and South Africa. Globally, maize occupies an area of 163.94 mha with a production of 832 mt and productivity of 5080 kg/ha (Anon, 2013a). Maize is known as king of cereals because of its high production potential and wider adaptability. The United States, China, Brazil and Mexico account for 70 per cent of global production.

In India, maize is the third most important cereal crop next to rice and wheat. India ranks fifth in the world in maize production with 21.79 mt grown on an area of 8.79 mha with productivity of 2470 kg/ha (Anon., 2013b). India registered a growth rate of more than seven per cent in production and more than six per cent in productivity in last five years. About 26 per cent of maize production in India is consumed as food, 45 per cent goes to poultry, piggery and fish meal, 12 per cent goes to animal feed, 12 per cent in wet industry for making starch and oil, three per cent in dry milling for traditional requirements like Dalia, Sattu and other food products such as corn bread, corn chips and one per cent each for brewery and as seed.

Karnataka is a major maize producing state in India with an area of 1.36 mha with a production of 4.09 mt and a productivity of 3018 kg/ha (Anon., 2013a). In Karnataka, the area under maize is increasing rapidly because of suitable environment and relative ease in its cultivation. The average productivity of state is much higher than that of national average, but lags behind the states such as Andhra Pradesh, Haryana and Punjab in productivity. Hence, there is a need to significantly enhance maize productivity for improving the profitability of maize farmers through the development of stable cultivars. Maize is increasingly used as an animal feed and fodder crop as green forage and silage.

The development of effective plant breeding programme depends on the existence of genetic variability. The efficiency of selection depends on the magnitude of genetic variability present in the plant population thus success of genetic improvement in any character depends on nature of variability present in the gene pool for that character. Hence, assessment of existing variability for any character present in the gene pool of a crop species is utmost importance to a plant breeder for starting a judicious plant breeding programme. In early days the visual observations were used to measure of variability. Now several biometrical techniques are available for systematic assessment of variability. They are simple measure of variability (which includes range, mean, standard deviation, variance, standard error, coefficient of variation, covariance), components of variability (which includes phenotypic variation, genotypic variation, environmental variation, heritability, genetic advance), metroglyph analysis, D^2 statistics, principle component analysis and molecular diversity analysis.

Germplasm, which is a prerequisite for any breeding programme, serves as a valuable source material as it provides scope for building of genetic variability. Study of variability, heritability and genetic advance in the germplasm will help to ascertain the real potential value of the genotype. The direct selection is possible for characters with high heritability. However, polygenic characters like yield and economically important characters generally has low heritability and direct selection is not effective, hence, it is desirable to select indirectly for improved yield. Further, efficiency of selection in any breeding programme mainly depends upon the knowledge of association of the characters. Phenotypic correlation indicates the extent of the observation having relation between two characters while genotypic correlation provides an estimate of inherent association between the genes controlling any two characters. For formulating selection indices for genetic improvement of yield, the cause effect of the trait is very essential and can be done by path analysis.

In addition, there has been a wide fluctuation in maize productivity as the potential productivity of a region is largely dependent on the climate of that area. Several studies have indicated how yield of crops may be affected by environmental variation. Cropping system of a region not only relates to the distribution of area under different crops at a particular time, but it includes the sequence of crops and intensity of cropping in relation to climate, physiography, soil type, quantity and quality of irrigation water.

Stability of yield of a cultivar across a range of production environments is very important for variety recommendation. The cultivars must have the genetic potential for superior performance under ideal growing conditions and must also produce acceptable yields under less favourable environments. Therefore, a stable genotype can be referred to as the one that is capable of utilizing the resources available in high yielding environments and has a mean performance that is above average in all environments (Eberhart and Russell, 1966; Allard and Bradshaw, 1964).

Farmers prefer to purchase high yielding hybrids, which gives constant yield on their land in all the seasons. Therefore, breeders should attempt to develop such a hybrid, which gives stable performance across different environments. It is commonly observed that the relative performances of different genotypes alter in different environments due to genotype × environment interaction. It has been further observed by various workers that the relation between the performance of different genotypes in the various environments and some measure of these environments are linear. Hence, attention has to be paid to measure the response of genotypes to environment and to determine the difference between the responses for different genotypes.

The genotype × environment interaction is generally recognized when the same genotype is assessed in different environments, having a decisive influence in cultivar recommendation. Maize hybrids that are only adapted to particular environments can become a limiting factor to seed production in large scale. Hence one of the major objectives of breeders should be to obtain a hybrid with high mean yield and good adaptation to different environments.

Allard and Bradshaw (1964) suggested that the selection of genotypes should be based on least interactions with environments. They further opined that, heterozygous and heterogeneous populations offer the least opportunity to produce varieties which show small genotype × environment interactions. They used the term “individual buffer” for genotypes where the individual members of a population are well buffered such that each member of the population is well adapted to a wide range of environments. Three-way cross hybrids have both individual and population buffering, while single cross hybrid have only the individual buffering and inbred have no buffering capacity. In India, presently three-way cross hybrids, single cross hybrids and open-pollinated varieties are cultivated over a wide range of environments.

Maize being a cross-pollinated crop there is wide scope for the development of stable hybrids and varieties. In recent years, there has been a perceptible improvement in maize production in the state, but production and productivity of India is much less when compared to country like U.S.A. The varieties/hybrids, which are cultivated in the recent years, are not stable. Therefore, stable inbred lines are required, which can help in the development of stable hybrids/composites.

With this preamble, the present study was planned and executed with the following objectives.

1. To study the genetic variability and heritability for different parameters.
2. To study the nature and magnitude of association among yield traits and to study the direct and indirect effects on yield through path analysis.
3. To study the stability of S_6 lines for yield parameters over diverse environments.

REVIEW OF LITERATURE

Description of the nature and amount of variation and the contribution of the different yield and quality attributing characters of the breeding material to the final economic product is a road map for any successful crop improvement programme. Improvement of both quantitative and qualitative characters is the main interest of any plant breeder for which adequate knowledge on genetics of yield and its component characters is very much essential and also crop varieties show wide fluctuations in their yielding ability when grown over varied environments or agro-climatic zones. This causes difficulty in demonstrating the superiority of particular variety. Besides yield potential, yield stability over a range of environment is of major concern to the plant breeders and this has direct bearing on the spread of the variety, productivity and total production of the crop. Each genotype has a specific environment for its maximum performance and similarly in a specific environment, a specific genotype performs better.

Keeping in view the objectives of the present investigation, the literature on variability and stability analysis of maize has been reviewed and presented under following headings.

2.1 Genetic variability parameters

2.2 Correlation and path coefficient analysis

2.3 G × E interaction and stability analysis in maize (*Zea mays* L.)

2.4 Screening for turcicum leaf blight

2.1 Genetic variability parameters

Phenotypic variability expressed by a genotype or a group of genotypes in any species can be portioned into genotypic and phenotypic components. The genotypic components being the heritable part of the total variability, its magnitude on yield and its component character influences the selecting strategies to be adopted by the breeder.

Fisher (1918) partitioned the total genetic variance (σ^2A) (i) additive genetic variance (σ^2A), which is the sum of additive genetic variances contributed by individual loci (ii) Dominance variance (σ^2D) component which results from intra allelic interaction of genes at segregating loci (iii) Epistatic variance (σ^2I) results from inter allelic interaction of genes at segregating loci.

Lush (1940) defined heritability in both broad sense and narrow sense. In broad sense, heritability refers to the functioning of the whole genotype as a unit and is used in contrast with the environmental effects. In the narrow sense, heritability largely includes only the average effect of genes transmitted additively from parent to off spring. Warner (1952) has suggested different technique for estimating the degree of heritability in crop plant which is based on parent offspring regression variance component from an analysis of variance and approximation of non-heritable variance from genetically uniform population to estimate the total genetic variance.

Comstock (1955) reported that phenotype associated with a given genotype varies with the environment. This leads to complete inconsistency of genotypic value, a different value of a given genotype relative to every variance of environment major or minor. Longquist (1964) reported that phenotype of a quantitative character was mainly due to the joint action of genotype and environment.

Debnath and Azad Mak (1993) studied a total of 25 varieties which were grown in four environments during 1987-88 and evaluated for five yield components. Analysis of variance revealed significant genotype × environment interactions for all characters. Components of variance, genetic advance and broad sense heritability for each character were calculated for all environments and were shown to be higher than values obtained from a combined analysis after elimination of the genotype × environment interaction component. Heritability estimates were highest for ear height in all environments after the removal of the interactive effects.

Zahid *et al.* (2004) reported that highest heritability estimates were found in grain yield plant^{-1} (0.993) and by plant height (0.990).Values of genetic advance ranged between 43.80 for grain yield plant^{-1} to 1.33 for number of kernel rows ear^{-1}. Greater magnitude of broad sense heritability coupled with higher genetic advance in characters under study provided the evidence that these plant parameters were under the control of additive genetic effects, indicating that selection should lead to a fast genetic improvement of the material.

Abhirami *et al.* (2005) reported that genetic variance, heritability and genetic advance were studied in forty maize genotypes based on the data recorded on 20 quantitative traits and five biochemical characters. Investigations were conducted during *Rabi* 2003/04, at Coimbatore, Tamil Nadu, India. For all the characters studied, phenotypic variance was slightly higher than the genotypic variance. Genotypic and phenotypic coefficient of variance was higher for total sugar content, plant yield, weight of the cob, oil content and ear height. Heritability estimates were high for all the characters investigated. High heritability coupled with high genetic advance was observed for number of grains per cob.

Naushad *et al.* (2007) conducted a study to assess the magnitude of genetic variability in maize genotypes for yield and its components. Significant variability was observed for cob length, grains rows cob^{-1}, fresh cob weight, grain moisture content, grains weight and grain yield.

Ortiz *et al.* (2008) reported that the least number of environments and replications, which does not affect the precision of phenotypic, was selected for assessing each trait. The results suggest that fewer environments and replications are needed for reproductive than for plant traits because the former show higher heritability than vegetative traits.

Suvarna *et al.* (2008) indicated that there were significant differences among the genotypes evaluated for all the 12 characters. Seed yield exhibited moderate GCV and heritability, high PCV and moderately low GAM. Based on the results, the characters namely, number of leaves per plant, number of cobs per plant and plant height up to cob can be selected for improvement of yield in maize under dry land conditions.

Murugan *et al.* (2010) concluded that the crosses exhibited moderate PCV and GCV estimates for all the traits. Genotypic coefficient of variation (GCV) was less than its corresponding estimates of phenotypic coefficient of variation (PCV) for most of the quantitative characters indicating significant role of environment in the expression of these traits Low, medium and high estimates of broad sense heritability were found in different plant characters under study.

Jawaharlal *et al.* (2011) estimated the genetic variability in 40 inbred lines of maize. Number of seeds per cob and grain yield estimates combined with high genotypic coefficient of variation with high heritability indicating additive gene action controlling these traits.

Salman *et al.* (2011) Experiment conducted on normal irrigation and drought stress conditions. Results revealed that significant differences were found for number of days taken to 50 per cent tasseling, number of days taken to 50 per cent silking, number of ears per plant and 100 seed weight (g). The highest mean value of 37.05 was produced by inbred line USSR15 for 100-grain weight under irrigated condition while under drought condition W-64-TMS had maximum 100 seed weight of 30.55 g. Overall, the 100-grain weight, days to tasseling, and number of cobs decreased, whereas days to silking increased under drought conditions.

Zare *et al.* (2011) studied the heritability for some agronomic traits in maize and reported broad-sense heritability ranged between 47.4 per cent and 89.4 per cent for days to physiological maturity and number of rows per ear. However, narrow-sense heritability varied between 7.3 per cent and 50.6 per cent for days from anthesis to physiological maturity and ear leaf area, respectively.

Atif *et al.* (2012) studied genetic variability for yield and its component traits under irrigated farming and reported significant variability for plant height, stem diameter, number of rows per cob, ear length, days to 50 per cent flowering and 100-seed weight. Heritability estimates showed that days to 50 per cent flowering had maximum heritability while the minimum heritability was recorded for 100 seed weight.

Bello (2012) estimated genetic variability, heritability and genetic advance of grain yield and its component characters. High magnitude of phenotypic and genotypic coefficient of variations as well as high broad-sense heritability and genetic advance estimates were recorded for grain yield, ear weight, plant and ear heights. This provided evidence that these parameters were under the control of additive genetic effects.

Bharathi *et al.* (2012) evaluated 144 maize inbreds for different quantitative characters and reported variation for all the characters studied. The difference between PCV and GCV was very low for all the characters except anthesis-silking interval, cob yield/plant and grain yield/plant indicating very little environmental effect on these characters. Anthesis-silking interval recorded high PCV, GCV, heritability and genetic advance as per cent of mean. Characters such as grain yield/plant, cob yield/plant and ear height showed comparatively moderate PCV and GCV values and moderate to high heritability with moderate genetic gain. Days to 50 per cent tasseling, days to 50 per cent silking and number of leaves/plant showed low PCV, GCV and GA with very high heritability.

El-Badawy (2012) studied genetic parameters for grain yield and its components in six populations of maize. The result revealed over dominance towards the higher parent was detected for all traits under test. The additive gene effects were significant for No. of kernels row^{-1}, ear weight plant^{-1}, No. of rows ear^{-1}, grain yield plant^{-1}, 100-kernel weight, ear length and ear diameter. Dominance gene effect was significant for all traits except ear length. Additive x additive, additive x dominance and dominance x dominance epistatic types of gene action were significant for most traits. High genetic coefficient of variation for ear diameter, ear weight plant^{-1} and grain yield plant^{-1} was detected. High heritability values in broad sense were detected for most traits. High heritability in narrow sense was detected for ear diameter, ear weight plant^{-1}, No. of kernels row^{-1}, grain yield plant^{-1} and 100-kernel weight. Genetic advance expressed as the percentage of the mean was moderate to high for all the studied traits.

Sumalini *et al.* (2012) conducted a study on genetic variability. The results showed that high broad sense heritability estimates were detected for all the traits studied, indicating that the additive genetic variance was the major component.

Anshuman *et al.* (2013) reported significant mean sum of squares due to genotypes for all the characters except for number of cobs per plant. High to moderate estimates of GCV and PCV were recorded for anthesis-silking interval, grain yield per plant, ear height, harvest index, number of grains row per cob, number of grains per row and 100 seed weight. High estimates of heritability was observed for plant height, ear height and ear girth. Further, high to moderate heritability with moderate estimates of genetic advance was recorded for biological yield, grain yield per plant, plant height and ear height.

Dhairyashil *et al.* (2013) conducted an experiment on ten inbreds of maize and reported highest PCV and GCV for oil content preceded by days to 50 per cent tasseling and days to 50 per cent silking. High heritability was observed for days to 50 per cent tasseling, days to 50 per cent silking, protein content, starch content and number of kernels row^{-1}. High heritability with high genetic advance was observed for days to 50 per cent tasseling and days to 50 per cent silking.

From an investigation involving 70 diverse inbreds, Juliet *et al.* (2013) estimated the genetic diversity, variability, association of yield with other component traits and relative importance of direct and indirect effects of different components on yield was assessed. The results indicated that, among the traits evaluated, maximum genotypic and phenotypic coefficients of variation was observed for grain yield per plant followed by number of rows per cob and number of kernel per row. The estimate of heritability and genetic advance was high for grain yield per plant, number of kernels per row and number of rows per cob.

Kanagarasu *et al.* (2013) carried a study to estimate the various genetic parameters and nature of association among the traits influencing maize grain yield. Analysis of variance revealed the prevalence of substantial variability for all traits studied. The traits grain yield/plant, grains/row, plant height, ear height, cob length, 100 grain weight and leaf breadth had high GCV estimates with high heritability. Genetic advance was higher for grain yield/plant, ear height, grains/row, plant height, cob length and 100 grain weight. Genotypic correlation coefficients and path analysis revealed that grains/row, grain rows/cob, 100 grain weight and plant height had positive significant correlation and highest direct effect on grain yield.

Ozlem *et al.* (2013) determined the genetic variability, heritability, genetic advance, genotypic and phenotypic correlations of yield, yield components and kernel quality traits in seven sweet corn varieties. Sugar content, soluble solid concentration and number of leaves per plant revealed the highest genotypic and phenotypic coefficient of variation values. Then high heritability estimates coupled with high genetic advance for sugar content, soluble solid concentration and starch content was observed. Further positive correlations were revealed between yield and yield components except plant height and 1000 seed weight.

Rajesh *et al.* (2013) carried out a study to determine the genetic variability, broad sense heritability and genetic advance estimates among 65 maize genotypes. The analysis of variance revealed that the mean sum of squares due to genotypes showed significant differences for all the 11 characters studied. High to moderate estimates of GCV and PCV was recorded for grain yield, number of kernels per row, 100-kernel weight, ear length and plant height. The traits such as grain yield, number of kernels per row, 100-kernel weight, ear length and ear height had high GCV estimates with high heritability. Further, moderate estimates of genetic advance with high heritability were recorded for grain yield, number of kernels per row, 100-kernel weight, ear length, ear height and plant height.

Reddy *et al.* (2013) studied heritability analysis in 45 hybrids and ten parents. The results revealed that the phenotypic coefficients of variation (PCV) were higher than genotypic coefficient of variation for all the characters studied. The magnitude of PCV and GCV was high for grain yield per plant followed by ear height, number of kernels per row, 100-seed weight, ear length, plant height, ear girth and number of kernel rows per ear. High heritability coupled with high genetic advance as percentage of mean was observed for ear height, grain yield per plant, plant height, number of kernels per row and ear length.

A study on heritability, genetic advance and correlation was carried out using 24 hybrids with their parents including two checks by Bekele *et al.* (2014). The results revealed high heritability for characters like plant height, ear height, number of seeds per row, 100 seed weight, protein content and grain yield per plot. High genetic advance coupled with heritability was observed for plant height, grain yield per plot and protein content.

Hafiz *et al.* (2014) estimated the genetic variability parameters and characters association in 40 maize genotypes. The PCV was higher in magnitude than GCV for almost all the traits except for root density which showed greater value of GCV than PCV. Heritability estimates were also higher in all the traits and highest heritability was shown for chlorophyll content.

2.1.1 Character-wise review

The character-wise chronological report of review of literature on phenotypic coefficient of variability, genotypic coefficient of variability, heritability and genetic advance as per cent mean of maize is presented in the Table 1.

2.2 Correlation and path coefficient analysis

The inter relationship of quantitative characters with yield determine the efficiency of detection in breeding programs. It merely indicates the intensity of association. Phenotypic correlation reflects the observed relationship, while genotypic correlation underline the true relationship among characters. Selection procedures could be varied depending on the relative contribution of each. The following paragraphs give review of literature on correlation in maize.

Assuming yield is a contribution of several characters which are correlated among themselves and to the yield, path coefficient analysis was developed (Wright, 1921; Dewey and Lu, 1959). Unlike the correlation coefficient which measures the extent of relationship, path coefficient measures, the magnitude of direct and indirect contribution of a component character to a complex character and it has been defined as a standardized regression coefficient which splits the correlation coefficient into direct and indirect effects.

According to Appadurai and Nagarajan (1975), grain weight per ear and grain numbers per row had little effect on yield, while ear length and ear circumference had positive correlation with yield. Kim (1975) reported that 1000-grain weight was negatively correlated with days to silking and days to tasseling. Probecky (1976) reported that yield depends primarily on the number of grains per plant, which in turn depended mainly on the number of grains in the rows.

Sharma *et al.* (1982) reported that grain yield was positively correlated with grains per ear, 100-grain weight, plant height and ear height. Ei-Nagouly *et al.* (1983) concluded that phenotypic and genotypic correlation between yield and days to 50 per cent silking and ear height was positive and highly significant. Path analysis showed that yield was directly influenced by ear height and indirectly affected by days to 50 per cent silking via ear height.

Saha and Mukherjee (1985) observed that grain yield per plant was significantly correlated with ovules per ear, grains per ear and 100-grain weight. Malhotra and Khehra (1986) recorded positive correlation between grain yield and yield components like ear length, ear circumference, number of rows per ear, 100-grain weight, shelling percentage, days to silking, ear height and plant height.

Tyagi *et al.* (1988) opined that grain yield was influenced more by ear weight, ear length, plant height, kernels per row and 100-grain weight. They also reported that 50 per cent pollen shedding and silking had a direct correlation with yield and so, early maturing genotypes had relatively low yield. Maharajan *et al.* (1990) concluded that grain yield was positively correlated with ear length, number of kernels per row and plant height.

Table 1. Character–wise chronological report on variability, heritability and genetic advance (as % of mean) in maize

Sl. No.	Character	Experimental material	PCV (%)	GCV (%)	h^2 (bs)	Genetic advance (as % of mean)	References
1	Days to 50 % tasselling	36 genotypes	-----	----	83.8	-----	Gyanendra *et al.* (1995)
		45 F_1s	1.39	0.55	15.62	0.45	Satyanarayana and Saikumar (1996)
		24 hybrids	3.79	2.88	0.58	2.94	Pradeep and Satyanarayana *et al.* (2001)
		45 crosses	1034	7.78	72.28	2.97	Choudhary and Chaudhari (2002)
		47 genotypes	5.88	5.84	98.6	15.31	Sumathi *et al.*(2005)
		169 lines	6.83	6.37	86.9	12.91	Om prakash *et al.* (2006)
		20 genotypes	1.94	1.98	95.4	------	Mohammad *et al.* (2008)
2	Days to 50 % silking	10 set of lines	-----	----	40.32	-------	Reddy and Agarwal (1992)
		45 F_1s	1.61	1.12	48.65	1.62	Satyanarayana and Saikumar (1996)
		38 lines	14.26	14.05	97.12	28.53	Mani and Bisht (1996)
		66 genotypes	6.84	6.6	93.23	13.26	Jha and Ghosh (2001)
		24 hybrids	3.79	2.8	0.57	2.9	Pradeep and satyanarayana *et al.*(2001)
		20 genotypes	5.06	4.81	90.38	9.41	Satyanarayana *et al.* (2005)
		47 genotypes	5.74	5.69	98.5	14.92	Sumathi *et al.*(2005)
		169 lines	6.38	6.24	95.5	12.66	Om prakash *et al.* (2006)
		20 genotypes	2.34	2.43	92.6	-------	Mohammad *et al.* (2008)

Contd……

Sl. No.	Character	Experimental material	PCV (%)	GCV (%)	h^2 (bs)	Genetic advance (as % of mean)	References
3	Plant height	10 set of lines	----	----	67.02	-----	Reddy and Agarwal (1992)
		2 set of F_3 proginies	8.1	10.55	58.93	12.8	Robin and Subramanian (1994)
		36 genotypes	21.1	19.4	84.8	36.8	Gyanendra *et al.* (1995)
		38 lines	19.69	15.13	59.15	23.95	Mani and Bisht (1996)
		66 lines	18.86	18.34	94.55	36.73	Jha and Ghosh (2001)
		24 hybrids	10.1	8.08	0.84	12.27	Pradeep and satyanarayana *et al.*(2001)
		45 crosses	11	10.21	86.08	13.26	Choudhary and chaudhari (2002)
		20 genotypes	7.07	6.4	82.01	11.94	Satyanarayana *et al.* (2005)
		47 genotypes	11.71	11.38	94.5	29.21	Sumathi *et al.*(2005)
		169 lines	16.19	16.09	98.7	33.67	Om prakash *et al.* (2006)
		20 hybrids	4.78	6.64	52	-----	Mohammad *et al.* (2008)
4	Ear height	10 set of lines	--	---	71.28	---	Reddy and Agarwal (1992)
		38 lines	33.01	27.65	70.17	47.72	Mani and Bisht (1996)
		24 hybrids	14.51	13.45	0.86	11.1	Pradeep and satyanarayana *et al.*(2001)
		45 crosses	17.08	14.51	72.15	17.27	Choudhary and chaudhari (2002)
		20 genotypes	14.91	14.8	98.53	30.26	Satyanarayana *et al.* (2005)
		169 lines	19.65	29	93.4	40.71	Om prakash *et al.* (2006)
		20 genotypes	7.25	11.51	39.6	---	Mohammad *et al.* (2008)

Contd……

Sl. No.	Character	Experimental material	PCV (%)	GCV (%)	h^2 (bs)	Genetic advance (as % of mean)	References
5	Cob length	2 sets of F_3 progenies	9.23	11.01	69.25	15.82	Robin and Subramanian (1994)
		38 lines	17.42	10.62	37.14	13.33	Mani and Bisht (1996)
		45 crosses	10.53	7.28	47.84	7.05	Choudhary and chaudhari (2002)
		24 hybrids	12.5	9.93	0.63	10.6	Pradeep and Satyanarayana *et al.*(2001)
		169 lines	27.46	27.15	97.8	49.35	Om prakash *et al.* (2006)
6	Cob girth	38 lines	11.52	7.23	39.91	91.48	Mani and Bisht (1996)
		24 hybrids	6.27	5.13	0.66	5.19	Pradeep and Satyanarayana *et al.*(2001)
		169 lines	16.31	15.89	94.9	32.47	Om prakash *et al.* (2006)
7	Number of kernel rows per cob	38 lines	12.43	8.59	47.79	12.23	Mani and Bisht (1996)
		24 hybrids	8.12	4.55	0.35	4.55	Pradeep and Satyanarayana *et al.*(2001)
		45 crosses	8.3	5.39	42.13	4.91	Choudhary and chaudhari (2002)
		47 genotypes	8.83	8.35	89.38	20.84	Sumathi *et al.*(2005)
		169 lines	13.49	12.44	85	23.51	Om prakash *et al.* (2006)
8	Number of kernels per row	2 set of F_3 proginies	8.65	9.54	82.24	16.17	Robin and Subramanian (1994)
		36 genotypes	---	15.9	---	29.3	Gyanendra *et al.* (1995)
		38 lines	21.97	18.06	35.39	16.01	Mani and Bisht (1996)
		45 crosses	38.03	18.26	48.02	7	Choudhary and chaudhari (2002)
		47 genotypes	13.99	13.78	97.01	35.83	Sumathi *et al.*(2005)
		169 lines	27.42	27.19	98.3	46.65	Om prakash *et al.* (2006)

Contd……

Sl. No.	Character	Experimental material	PCV (%)	GCV (%)	h^2 (bs)	Genetic advance (as % of mean)	References
9	100-grain weight	41 S_1 families	---	---	52	13.6	Alika (1994)
		2 set of F_3 proginies	6.12	6.84	79.84	11.28	Robin and Subramanian (1994)
		36 genotypes	---	---	82.1	27.6	Gyanendra *et al.* (1995)
		38 lines	27.16	19.67	52.47	29.35	Mani and Bisht (1996)
		24 hybrids	15.16	14.17	0.87	10.9	Pradeep and Satyanarayana *et al.*(2001)
		45 crosses	16.02	14.45	81.31	18.24	Choudhary and chaudhari (2002)
		47 genotypes	14.84	13.92	88.08	34.49	Sumathi *et al.*(2005)
		169 lines	24.01	23.67	97.1	10.12	Om prakash *et al.* (2006)
10	Grain yield per plant	2 set of F_3 proginies	3.68	4.6	64.05	6.07	Robin and Subramanian (1994)
		36 genotypes	24.6	15.9	---	---	Gyanendra *et al.* (1995)
		38 lines	40.22	32.97	67.24	55.7	Mani and Bisht (1996)
		45 crosses	20.55	17.98	73.59	21.59	Choudhary and chaudhari (2002)
		47 genotypes	10.62	10.58	99.15	27.8	Sumathi *et al.*(2005)
		20 genotypes	10.85	11.92	82.8	----	Mohammad *et al.* (2008)
11	Grain yield per hectare	66 lines	20.43	20.11	96.88	40.78	Jha and Ghosh (2001)

Debnath and Khan (1991) revealed that days to silking, plant height, number of kernels per row and 1000-grain weight had strong positive contributions to grain yield. Dash *et al.* (1992) reported that maturity traits showed a negative correlation with yield per plant. Path coefficient analysis revealed that ear diameter, plant height, ear length and 100-seed weight were the major factors contributing to yield.

Boraneog and Duara (1993) observed that plant height and ear height were found to be significant and positively correlated with yield. Saha and Mukherjee (1993) reported positive significant correlations between grain yield per plant with 100-grain weight, ear length, ear circumference, number of grain rows per ear and number of grains per row. The ear circumference and number of grains per row had higher direct and indirect effects on grain yield.

Krishnan and Natarajan (1995) obtained highly positive association between grain yield on the one hand and plant height, ear length, ear weight, number of kernels per row, dry matter production and harvest index on the other. Path coefficient analysis revealed that selection on any trait in maize influence the grain yield only through dry matter production. Packiaraj (1995) observed direct positive correlation between grain yield and number of grains per row. Rahman *et al.* (1995) reported that grain yield was significantly and positively correlated with plant height, ear height, number of grains per ear and 1000-grain weight. Path analysis revealed that ear height, plant height and 1000-grain weight were the main contributors for grain yield.

The studies conducted by Sreekumar and Suma (1995) revealed that plant population recorded high coefficient of variation, heritability and genetic advance for plant height indicating that selection based on these characters will result in improving fodder yield. Highest genotypic correlations were observed between plant population and dry fodder yield.

According to Satyanarayana (1996) grain yield was positively correlated with kernel rows per ear, ear length, ear circumference and 100-grain weight. According to Kumar and Kumar (1997), values of genotypes correlation were slightly higher than the corresponding phenotypic values. Significant positive correlation was recorded for plant height, days to 50 per cent silking, ear length and ear height with yield per plant.

Annapurna *et al.* (1998) showed that seed yield was positively and significantly correlated with plant height, ear circumference, number of seeds per row, number of seed rows per ear, number of seeds per ear and test weight exercised maximum direct influence on yield. Datu (1998) reported correlations using the date of flowering, plant height and the number of leaves as indirect selection criteria may results in a positive correlated response in earliness, yield potential and superior stalk quality.

Khakim *et al.* (1998) noticed that grain yield was positively correlated with plant and ear insertion height, leaf area, ear number, ear length, row number, grain number per row and per cob, grain weight per cob, ear weight and 1000-grain weight. Manivannan (1998) reported that ear girth, number of kernels per row, 1000-grain weight, kernels per row and ear length had significant and positive correlation with grain yield. High and positive direct effects were observed for kernel rows and 1000-grain weight.

Alok *et al.* (1999) revealed that the number of grains per row, number of rows per ear, ear circumference, ear length, days to 50 per cent flowering and days to 50 per cent maturity had direct effect on grain yield. Gautam *et al.* (1999) suggested that maximum correlation of grain yield was obtained with number of kernels per row followed by leaf area, plant height, tassel length and ear length. Path analysis revealed that the number of kernels per row, plant height, ear width, leaf area and 1000-grain weight had positive direct effect on grain yield.

Mani *et al.* (1999) reported that grain yield per plant indicated the highly significant positive correlations with all the attributes and were highest with ear weight per plant. Path analysis also suggested that ear weight per plant followed by grains per row were the best direct contributors to grain yield per plant.

Nawar *et al.* (1999) observed that additive components were significant for row number. Highly significantly positive correlation coefficients were detected among yield per plant. Components of ear and plant height, number of kernels per row imparted positive direct effect towards grain yield followed by plant height.

Rather *et al.* (1999) observed that days to 50 per cent silking was positively correlated with ear height and grain yield. Singh *et al.* (1999) indicated that the highest positive direct effect on yield was exhibited by kernel rows per ear, followed by plant height and ear diameter. Geetha and Jayaraman (2000) observed number of grains per row exerted a maximum direct effect on grain yield. Kumar and Kumar (2000) suggested that selection based on plant height with greater ear weight, number of seeds rows per ear and number of seeds per ear was desirable for grain yield.

Netaji *et al.* (2000) reported that yield per plot was significantly and positively correlated with all the characters except days to 50 per cent tasseling, silking and dry husk. Maximum variability was observed for plant height, followed by ear height and test weight.

Umakanth *et al.* (2000) observed that yield per plot was positively correlated with plant height, 1000-grain weight and kernels per ear, but days to 50 per cent silking had negative correlation with yield.

Vaezi *et al.* (2000) noticed that grain yield was significantly and positively correlated to ear weight, ear circumference, kernel weight and number of kernels per row. Path analysis, for grain yield showed that kernel weight and kernel depth had the highest positive effect on grain yield. Path analysis showed that 100-kernel weight and kernel depth had the highest positive effect on grain yield whereas ear diameter had a negative indirect effect on grain yield through some traits.

Pradeep and Satyanarayana (2001) concluded that grain yield was positively associated with plant height, ear height, ear length, ear circumference, number of seed rows per ear and test weight.

Devi and Shaik (2001) indicated that the plant height, days to 75 per cent silking and maturity, ear length, number of seeds per row and 100-grain weight positively influenced the yield directly and also indirectly through several yield components.

Umakanth and Khan (2001) observed that grain yield per plot showed significant and positive correlations with ear circumference, ear length, plant height and 100-seed weight. Path analysis revealed that plant height followed by number of seeds per row, 100-seed weight, ear length and ear circumference showed maximum positive direct genotypic effects as well as indirect contribution through other characters on grain yield. Cheng *et al.* (2002) showed that importance of eight yield components to grain yield and suggested that more attention should be paid to cob length, cob diameter and kernel percentage.

Singh *et al.* (2003) observed that ear leaf area had the highest positive direct effect on green fodder yield per plant at genotypic and phenotypic levels followed by dry matter yield per plant, ear length and days to 50 per cent silking. Ear length had the maximum direct effect on grain yield followed by 500-kernel weight and ear leaf area. Number of leaves per plant, leaf: stem ratio and girth of basal internode had also highly positive direct effect on grain yield per plant.

Venugopal *et al.* (2003) indicated that number of seeds per row followed by 100-seed weight, days to 50 per cent tasseling, ear girth and plant height contributed directly towards grain yield per plant. Number of seed rows per ear had a direct positive contribution towards grain yield, ear length, 100-seed weight and number of seeds per row had a indirect negative influence on grain yield. Viola *et al.* (2003) revealed that early silking and harvesting of fresh cobs, greater plant height, cob length, cob weight, cob height and number of cobs per plant and lesser cob girth directly contributed to increased cob yield.

Arun and Singh (2004a) reported that days to 50 per cent silking and cob length had the maximum positive direct effect on grain yield. Whereas, days to 50 per cent tasseling and days to maturity had maximum negative effect on grain yield.

Heping *et al.* (2004) reported that maize yield was mainly influenced by ear length, followed by number of kernels per row, ear width, number of rows per ear, growth period and 1000-seed weight. Kernel per ear and number of pointless ears had minimum effect on maize yield.

Du mao *et al.* (2004) reported based on analyzing of correlation between yield per plant and the seven agronomic characters of 72 maize hybrids. The result shows that the most contribution to the yield is from ear diameter ($r = 0.788$, $p = 0.452$), the following is 100-grain weight ($r = 0.729$, $p = 0.370$), row-grain number ($r = 0.476$, $p = 0.348$) and ear length ($r = 0.528$, $p = 0.089$). The correlation value shows highly significant differences at 1 per cent level between 100-grain weight and ear diameter ($r = 0.657$), 100-grain weight and shelling percentage ($r = 0.392$), row number and bald tip length ($r = 0.369$), row grain number and ear length ($r = 0.703$).

Ei-Shouny *et al.* (2005) showed that grain yield per plant correlated positively and significantly with ear diameter, ear length, number of kernels per row, 100-kernel weight, number of rows per ear,

ear height, plant height and days to silking. Under normal planting date and with number of kernels per row, ear diameter, 100-kernel weight, ear length, number of rows per ear, ear height and days to silking under late planting date.

Shelake *et al.* (2005) noticed that grain yield was positively and highly correlated with number of grains per cob, biological yield per plant, harvest index, 100-grain weight, cob length, number of grain rows per cob and cob girth. Path analysis revealed high magnitude of direct effects for all characters at the genotypic level. The number of days to 50 per cent tasseling, number of days to 50 per cent silking and harvest index showed higher genotypic direct effect. Biological yield per plant had the highest negative genotypic direct effect on grain yield.

Sumathi *et al.* (2005) genotypic correlation studies indicated that ear weight, number of rows per ear, number of kernels/row, and total number of kernels/ ear were positively associated with grain yield. Oil per cent exhibited negatively non-significant correlation with grain yield, whereas it showed positive association with number of rows/ear only. Path coefficient analysis revealed that number of kernels per row showed high direct effect on grain yield followed by 100 seed weight, number of rows per ear and total number of kernels per plant.

Fan *et al.* (2005) indicated that correlation coefficient and path coefficient of ear length and other seven ear characters in grain yield except length of the ear without kernels showed positive value. Among them, directly path coefficient of ear rows with grain yield was 1.300, directly path coefficient of kernels per row with grain yield was 0.903. So, when selecting high grain yield hybrids of maize, we must pay more attention to select gene types of more ear rows and more kernels per row. At the same time, the relationship of the ear length, kernels length, 100 seeds weight and grain production rate, the relationship of the kernels per row, length of the ear without kernels and ear diameter were important.

Singh *et al.* (2006) reported significant positive correlations for grain yield with days to 75 per cent dry husk, plant height, ear height, and number of ears. Tan Heping *et al.* (2006) noticed that grain yield was significantly correlated with plant height, ear diameter, ear length, 100-kernel weight and grain production rate. Grain yield was most highly correlated with ear diameter, followed by 100-kernel weight, plant height, ear length and grain production rate.

Kumar *et al.* (2006) reported that Grain yield had positive and significant correlation with ear length, ear height, kernel rows per ear and 100-seed weight both at genotypic and phenotypic levels. Path analysis revealed that days to 50 per cent tasselling, anthesis-silking interval (ASI), ear height and 100-seed weight had highest direct effect on grain yield. The direct effects of ear length and kernel rows per ear were also considerable. The days to 50 per cent silking exhibited negative direct effect on grain yield, however, influenced the yield indirectly through days to 50 per cent tasselling. Therefore, ear length, kernel rows per ear and 100-seed weight were emphasized as primary yield determinants in maize and selection will be effective through these traits.

Wali *et al.* (2006) observed that yield was positively associated with plant height, ear length, ear circumference, number of kernels per row, fodder yield per plot and 100-grain weight, but was negatively correlated with number of days to 50 per cent silking at the phenotypic and genetic levels. The grain yield per plant was positively associated with plant height, ear length, ear circumference, number of kernels per row, fodder yield per plot and 100-grain weight at the phenotypic and genetic levels.

Yue *et al.* (2006) reported that the most contribution to the yield was from grains per row with value of (0.536), the following was ear length (0.498), 1000-grain weight (0.451). The correlation value showed highly significant differences at 1 per cent level between grains per row and rows per ear (0.599), grains per row and plant height (0.321) as well as ear length and 1000-grain weight (0.801). To enhance grains per row and 1000-grain weight, increase ear length and give dual attention to other agronomic characters was an effective way to enhance the corn yield.

Abirami *et al.* (2007) indicated that grain yield showed positive association with oil content and protein content. Path analysis showed that the weight of the cob contributed to the maximum direct effect to grain yield. It implied that selection for weight of the cob will be highly effective for the improvement of grain yield. Bhoite *et al.* (2007) reported that dry matter and crude protein yields showed positive and significant correlation with green forage yield and had positive direct influence on their correlation with green forage yield.

Sofi and Rather (2007) reported that the genotypic correlation coefficient revealed that ear diameter, 100-seed weight, ear length, number of kernel rows per ear and number of kernels per row showed the greatest correlation with grain yield. Path analysis indicated that 100-seed weight had greatest direct effect on grain yield, followed by number of kernels per row, number of kernel rows per ear, ear length and ear diameter.

Jiang *et al.* (2007) showed that kernels per plant was arranged for the top position among the many agronomic traits that contributed to the yield enhancement of a single plant and was followed by kernels per row, 1000-kernel weight and leaf orientation value.

Zhou *et al.* (2007) Reported that the sequence of genetic correlation coefficients of seven agronomic characters to yield was ear length, grains number per row, ear thickness, rows number per ear, ear height, plant height. Moreover, the relative importance order of agronomic characters to yield was ear length, ear thickness, grains number per row, rows number per ear, ear height and plant height.

Akbar *et al.* (2008) noticed that plant height had highly significant genotypic and phenotypic association with cob height and days to 50 per cent tasseling with days to 50 per cent silking. All traits had significant genotypic association but not significant phenotypic association with grain yield. Path analysis reported that all traits exerted positive direct effect on grain yield per plant except days to 50 per cent silking.

Brar *et al.* (2008) Studies conducted on 15 single cross hybrids (F1) of maize over two locations revealed that plant height, ear height, ear length, ear girth and number of ears per plot, had significant positive genotypic and phenotypic correlations with yield per plot. Highest direct effects (in descending order) with yield per plot were exhibited by ear girth, ear length, number of ears per plot, ear height and days to 50 per cent pollen shedding. Studies on estimation of selection indices suggest that ear length, ear girth and number of ears per plot are important yield component traits and indirect selection for yield based on these traits would be very effective because these characters exhibit high heritability estimates.

Li *et al.* (2008) Reported that Shelling percentage had the greatest effect on spike yield, followed by ear length and 100-grain weight. Path analysis showed that among the ear characteristics, the number of kernels per ear row had the greatest effect on spike yield, followed by 100-grain weight, number of ear rows, ear diameter and shelling percentage. Ear diameter, kernel length and 100-grain weight were the main traits contributing to dry yield.

Meng *et al.* (2008) reported that yield of spring-sowed maize positively correlated with ear length, grains per row and kernel production rate, but negatively correlated with bald length. For summer-sowed maize, its yield positively correlated with plant height, ear height, ear length, grains per row and 100-grain weight, negatively correlated with bald length. Path analysis suggested that ear length, ear width, bald length, grains per row and 100-grain weight determined the yield of spring-rowed maize while plant height, bald length, rows per ear, grains per row and 100-grain weight affected summer-sowed maize. It is critical to positively select grains per row and negatively select bald length in the breeding of inbred lines and cross combinations of maize.

Wang *et al.* (2008) Studies conducted on the correlation between yield and yield component factors were analyzed by method of grey correlative degree analysis for maize hybrids of Yunnan northern regional trial. The result showed that the values of correlation degree between yield and yield component factors among different hybrids were sequenced as follows: ear diameter > row numbers per ear > ear numbers per plant > plant height > thousand kernel weight > ear position > barren plant percentage > shelling percentage > ear length > kernel numbers per row > maturity period.

Shinde *et al.* (2009) studies on phenotypic correlation coefficients and path coefficients were computed among seven characters for maize grown in the *rabi* seasons of 2004-05 and 2005-06 in Parbhani, Maharashtra, India. The association analysis revealed high positive correlation of grain yield with cob weight, cob length, plant height, total dry matter, 1000-grain weight, leaf area per plant and shelling percentage. Path analysis also revealed the highest positive or indirect effects of cob weight followed by plant height and shelling percentage during the first year and shelling percentage and leaf area during the second year and negative direct effects of total dry matter during the first year and plant height during the second year.

Jawaharlal *et al.* (2011) estimated the correlations in 40 inbred lines of maize. Grain yield was found to be significantly and positively correlated with plant height, ear height, ear girth, number of seed rows per ear, number of seeds per row, number of seeds per ear and 100-seed weight. Number of seeds per ear exhibited highest positive correlation with grain yield followed by plant height, number of seeds per row, ear height, 100 seed weight, ear girth, and number of seed rows per ear. The character days to 50 per cent tasseling and days to 50 per cent silking exhibited significant negative genotypic correlation with grain yield.

Kanagarasu *et al.* (2012) assessed 72 maize hybrids along with their parental lines for genetic correlation among 14 quantitative traits. All the traits studied exhibited a positive and significant correlation with grain yield except days to tasseling, silking and days to maturity. Grains per row exhibited the highest positive and significant correlation with grain yield followed by cob diameter, cob length, plant height, leaf breadth, leaf length, cob height, and 100 grain weight, grain rows per cob and leaves per plant. A strong positive inter correlation was observed among the traits *viz.*, plant height, leaves per plant, leaf length, leaf breadth, cob length, cob diameter, grains per row and grain yield indicating that selection for these characters can help to improve the grain yield in maize indirectly.

Ravi *et al.* (2012) evaluated 70 Quality Protein Maize hybrids and assessed the relationship among total grain protein content, grain yield and its components were assessed. Total grain protein showed significant correlation with plant height and ear height. Character association analysis revealed strong positive association of grain yield per plant with plant height, ear height, ear length, ear diameter, kernel rows per cob, kernels per row, test weight and shelling per cent. Total grain protein showed strong negative association with days to 50 per cent flowering, days to anthesis and days to 50 per cent silking. Hence it was suggested that, simultaneous selection of plant height and ear height would contribute for the improvement of the grain yield per plant and total protein content in the grains.

Sumalini *et al.* (2012) conducted a study on correlations. The results showed that grain yield was significantly and positively correlated with all the characters studied except days to 50 per cent silk emergence. Plant height, ear height, ear length and ear girth had high moderate indirect positive effects on grain yield through kernels/row and 100 kernel weight. Ear girth had high significant positive genotypic correlation with grain yield followed by kernels/row and ear length.

Bupesh *et al.* (2013) reported that grain yield per plant had positive and significant correlation with days to 50 per cent pollen shed, days to 50 per cent silking and cobs per plant at genotypic level. All the traits exerted positive direct effects on grain yield per plant except days to 50 per cent pollen shed, ear height and stem girth.

Dhairyashil *et al.* (2013) conducted an experiment on ten inbreds of maize and reported highest significant and positive correlation was found between days to 50 per cent tasseling and days to 50 per cent silking followed by association of ear height and plant height, number of kernels row^{-1} and ear length, ear diameter and ear length. Significant and negative association were found between ear height and days to 50 per cent tasseling, ear height and days to 50 per cent silking, starch content and oil content. Oil content recorded maximum positive direct effect on yield. Direct effect of ear length, ear diameter, 100 kernel weight, oil content and starch content on yield was positive and high.

Juliet *et al.* (2013) reported that Grain yield per plant was positively and significantly correlated with cob weight, hundred kernel weight, number of kernel rows per cob and number of kernels per row. Path coefficient analysis further revealed that number of kernel rows per cob exhibited maximum positive direct effect followed by cob length. The significant association of grain yield per plant with hundred kernel weight and number of kernels per row is due to positive indirect effects through number of kernel rows per cob, days to 50 per cent silking, plant height and cob length.

Muneeb *et al.* (2013) investigated the genotypic and phenotypic association among grain yield components and their direct and indirect effects on yield. Correlation studies revealed significant positive genotypic and phenotypic relationship of grain yield with cob position, rows per cob and grains per row. The traits cob height, number of grains per row, stem diameter and cob girth had high positive direct effects on grain yield.

Ozlem *et al.* (2013) determined the genotypic and phenotypic correlations of yield, yield components and kernel quality traits in seven sweet corn varieties. Sugar content, soluble solid concentration and number of leaves per plant revealed the highest genotypic and phenotypic coefficient of variation values. Further positive correlations were revealed between yield and yield components except plant height and 1000 seed weight.

Reddy *et al.* (2013) studied correlation and path coefficient analysis in 45 hybrids and ten parents. The results indicated that grain yield was positively and significantly associated with 100-seed weight, ear girth, ear length, number of kernels per row, plant height, number of kernel row per ear and ear height. Days to 50 per cent tasseling had largest direct effect on grain yield per plant followed by 100-seed weight, ear length, days to maturity, ear height, number of kernels per row, ear height, number of kernel rows per and plant height.

Hafiz *et al.* (2014) estimated the characters association in 40 maize genotypes. Path coefficient analysis revealed that the fresh shoot length had maximum direct effect on fresh root length followed by root density, dry shoot weight, leaf temperature and dry root weight. They concluded that fresh root length, dry shoot weight, root density, leaf temperature and dry root weight are the characters which contribute largely to the fresh shoot length of maize seedlings.

Praveen *et al.* (2014) carried out an investigation on correlation and path analysis for 12 characters on 60 F_{1s} obtained by crossing 20 inbred lines with three testers using line × tester mating design in maize. The character association among the yield components revealed positive association of grain yield per plant with days to maturity, plant height, ear height, ear length, ear girth, number of kernel rows per plant, number of kernels per row, 100-kernel weight and shelling percentage. The path coefficient analysis at phenotypic level revealed that characters like 100-kernel weight exhibited the largest direct effect on grain yield per plant followed by number of kernels per row and ear girth.

2.3 G × E interaction and stability analysis in maize (*Zea mays* L.)

Genotypes x environment interaction are of considerable importance in breeding programme. A dynamic approach to the interpretation of varietal adaptation to varying environments was discovered by Finlay and Wilkinson (1963). This method was based on regression analysis which was demonstrated by estimating linear regression of yield of varieties on mean yield of all varieties in that environment. Eberhart and Russell (1966) further extended procedure by adding another parameter of stability *viz*., deviation from regression. According to them, a stable variety has unit regression co-efficient and least deviation from the regression. This method is being widely used for the evaluation of phenotypic stability in plant breeding. Knowledge of genotype x environment interaction is helpful in developing high yielding stable genotype. Stable genotypes are useful for successive cultivation over a range of environments and serve as base material for breeding programme. Later Breese (1969), Samuel *et al.* (1970), Paroda and Hayes (1971) and Jatsara and Paroda (1980) have emphasized the use of deviations from regression alone as a measure of stability.

When genotype x location interaction is large, the selection of genotypes on the basis of average performance over the entire area from which the locations were drawn may not be effective. However, sub grouping of locations on the basis of region, soil type, rainfall, maturity *etc.* may reduce genotype location interaction (Verma and Gill, 1975). Ron Parra (1985) studied the performance of 23 varieties of maize in 92 environments under rainfed and irrigated conditions at experimental stations and on farmer's land and the results showed variety x location and variety x location x year interactions were more important than the variety x year. Stability analysis indicated that stability of varieties was influenced by maturity and source of germplasm.

Jha *et al.* (1986) evaluated 36 experimental double cross hybrids and two commercial hybrids of maize for grain filling period, grain filling rate and grain yield at six locations. They found significant differences among genotypes for grain filling period and grain yield and G x E interaction in case of all three traits. Sain Dass *et al.* (1987) evaluated eight varieties of maize for stability performance over six environments and observed that mean squares due to G x E interactions were significant for all characters except ear weight and days to silking. Patel and Sanghi (1989) evaluated 64 genotypes of maize in four environments for their stability. The result showed that Syn Do X (CM 202 x CM 111) and lowa 2 early H0 gave good grain oil yields under favourable environments, but under poor to average conditions, lowa 2 early H0 x Vijay and Soan x Suwan 2 W were best for this trait. In general, H201-45 had good grain yield, oil content and earliness.

Mahajan *et al.* (1991) studied 28 hybrids obtained by crossing eight genetically diverse inbred lines of maize and tested in eight environments over two seasons. They reported heterogeneity in the genetic material for stem diameter, internodal length and ear leaf area was contributed by non-linear component while for number of leaves, plant and ear height was contributed by both linear and non-linear component. Prasad and Singh (1991) analyzed 64 maize genotypes under six different environments for their adaptability and noticed G x E interaction for all characters and they also observed that high yielding genotypes to be more sensitive to environmental changes than the low yielding genotypes. Information on stability was derived (Mahajan and Kherhra, 1992) from data on 6 yield components in 28 F1 hybrids from a diallel cross of 8 maize inbred lines grown at 2 locations in Punjab during winter. Deviation from regression appeared to be more important parameter than regression for measuring stability.

Vega and Vega (1992) evaluated 24 maize hybrids at 7 locations to obtain estimates of parameters describing yield stability over environments. The methods based on the effects or sum of squares of G x E interaction were useful and their stability parameters showed the highest coefficient of correlation, Satyanarayana and Kumar (1995) reported significant variation for eight promising genotypes of maize and G x E interaction for grain as well as fodder yields. Gharde *et al.* (1996) evaluated 14 genotypes of maize including eight hybrids and six composites for stability under eight artificially created environments. The result showed significant G x E interaction for all the characters under study. Gyanendra *et al.* (1996) assessed ten genotypes of maize under six environments for their stability. The results revealed significant genotype x environment interaction for all the traits except cob girth, rows per cob, seeds per row and 100-seed weight, but the linear component of G x E interaction was significant for all of the traits except seeds per row.

Chen Xuejun (1997) analyzed 11 maize hybrids for yield stability in seven Chinese provinces. Zhongdan had the highest average yield and good stability. Rastogi and Rastogi (1998) reported stability for yield and harvest index in H1681 (late) and H5 x H62 (early) genotypes over a wide range of environments. Dehganpour and Moghadam (1999) reported higher yield and stability in one early maturity hybrid and two very early maturity hybrids. Mani and Singh (1999) assessed the yield stability in 12 maize genotypes comprising of hybrids and components over three diverse environments. Composite ‘Navin’ followed by double top cross hybrid ‘EHF 1121’ were found to be most stable with greater yield than over all mean. Choukan (1999) studied nine medium maturity maize hybrids under ten locations for three years and classified hybrids (B73 x K1264) x M017/11-1 (K1264/1 × L17/12-1) × M017/11-1, K1259/3 × B73 and (K2509 × B73 × M017 as stable hybrids.

Carvalho *et al.* (2000) evaluated 21 maize cultivars at 26 environments and observed significant differences in yield due to environments, cultivars and cultivar x environment interactions. Choukan (2000) studied ten single cross hybrids of maize for their stability over 14 locations for two years. The result revealed significant heterogeneity of regression coefficients only for kernel depth and kernel rows, number per ear. The highest grain yield was produced by hybrid No. 6 and 10.

Gargi and Saikia (2000) studied the phenotypic stability of 21 baby corn genotypes over four environments for yield and yield attributing characters. The mean square due to genotype x environment (G x E) interaction was significant for all the characters except stem girth. For all the characters except stem girth, both linear and non-linear components were significant. While, for the stem girth only non-linear component contributed to G x E interaction variance. Gomes *et al.* (2000) studied 30 maize genotypes grown in 14 environments in Brazil and observed significant differences in yield stability were observed among the genotypes studied. Agarwal *et al.* (2000) observed significant genotype x environment interaction for grain yield, ear height, ear length and 100 kernel weight. The genotypes EH1, EH5, EH11, EH18 and EH19 were found to be stable for grain yield and other yield components.

Burak and Broccoli (2001) evaluated fourteen pop corn hybrids in 5 locations for their adaptability and observed significant differences in genotype x environment interaction, genotypes and environments. Ogunbodede *et al.* (2001) evaluated seven early maturity open pollinated and five yellow hybrid maize varieties over 22 locaitons. Stability analysis revealed that significant location effects for grain yield in two sets of maize varieties tested.

Pixley and Bjarnason (2002) evaluated 18 single cross, 18 three-way and 18 double cross hybrids and eight open pollinated cultivars grown at 13 tropical locations on four continents. Stability analysis showed largest genotype × environment interactions and sums of squares for deviations from linear regression for grain yield and protein concentration in grain were largest (indicating least stability) for single cross hybrids, followed by three way, double cross and open pollinated cultivars.

Tollenaar and Lee (2002) estimated the stability for maize hybrids along with three checks to examine the relationship between yield and yield stability. The results revealed that high yielding maize hybrids differed in yield stability, but the results did not support the contention that yield stability and high grain yield are mutually exclusive.

Aguiar *et al.* (2003) conducted an experiment to know the combining ability of five inbred lines and stability of their respective crosses. The single crosses were evaluated in seven environments along with two checks. Significant differences were detected for all the hybrids, environments and the Genotype × environment interaction was significant for all traits under study.

Dodiya and Joshi (2003) evaluated 86 genotypes for genotype × environment interaction and stability parameters with respect to yield and maturity over three locations. The results revealed significant G × E interaction for days to 50 per cent tasseling and grain yield. Singh *et al.* (2003) evaluated 15 single cross maize hybrids along with eight standard checks for genotype × environment interactions. The entry Vijay composite recorded the highest grain yield, over grand mean and regression value among the cultivars.

Lee *et al.* (2003) examined 12 maize breeding populations selected via reciprocal recurrent selection (RRS) and selfed progeny recurrent selection, to examine changes in the genetic structure of the phenotypic stability of three traits. Grain yield was further partitioned based on Gardner and Eberhart Analysis III model to examine the genetic components of stability. They found that recurrent selection (RS) improved grain yield stability, and that this trait was heritable, predictable, and mostly controlled through additive gene action. Their results indicated that grain yield stability can be improved through RS by selecting solely for mean performance across multiple environments.

Nirala and Jha (2003) conducted an experiment on 19 parents and 70 crosses to identify the high yielding and stable fodder maize genotypes. A highly significant mean sum of squares due to genotypes and environments for all the traits indicated the presence of significant differences among the genotypes and environment.

Oliveira *et al.* (2003) assessed the grain yield stability in 36 maize genotypes over ten environments. The analysis of variance detected significance for the genotype × environment interaction (G × E). The results indicated homogeneity of environments assessed and high correlation of the hybrid genetic constitution with the yield stability of the three types of the hybrids studied *viz.*, single, triple and double crosses. Some single crosses hybrids presented greater mean yield, while the double cross hybrids presented greater stability to the environments studied. Padam *et al.* (2003) evaluated 15 single cross maize hybrids and eight standard controls for genotype × environment interactions. Vijay composite showed the highest grain yield and overall mean and regression value among the cultivars.

Arun and Singh (2004b) evaluated seven parents and their 21 single crosses along with two standard checks for estimating the stability parameters by raising the crop at four different locations in maize. The stability analysis exhibited highly significant variation for genotypes, environments, G × E interactions and pooled deviation for most of the characters.

Reddy *et al.* (2004) carried out AMMI analysis to maize yield trials conducted with 45 hybrids over environments (years/location) to identify suitable and stable hybrids. Grain yield data subjected to AMMI analysis revealed significant G x E interaction which could be attributed to different rankings of the genotypes across environments.

Sallah *et al.* (2004) conducted a study to examine the effects of G × E interactions for grain yield in three different maturity groups of maize across 36 environments. Analysis of variance combined over locations and years within each maturity group indicated highly significant genotype × location × year interactions for yield in the three maturity groups. The genotype × year and genotype × location interactions were also significant in the intermediate and late maturity groups whereas, only genotype × location interaction was significant in the early groups.

Basu and Sharma (2005) evaluated five popular commercial maize hybrids to assess the effect of low temperatures on their vegetative growth, flowering behavior and seed yield. They found low temperatures had marginal effect on final plant height, leaves/plant, seed yield and 100 seed weight but greater effect on anthesis-silking interval (ASI), days to flowering and its duration. Nine genotypes of maize across 14 different locations of Pakistan were evaluated by Rasul *et al.* (2005). The pooled analysis of variance over the different locations was performed after observing that genotype mean sum of squares was significant at each location. The genotype × environment interaction was highly significant. The results indicated highly significant G × E interaction which demonstrated that genotypes responded differently to variation in environmental conditions.

Javed *et al.* (2006) evaluated six maize genotypes at six locations for their stability. Pooled analysis of variance for grain yield indicated significant differences for genotypes across the environment and their interactions which indicated uneven performance of the genotypes across the environment and year. The entries R-2302 and R-2210 showed highly stable performance across the environments. Kaundal and Sharma (2006) evaluated 21 elite genotype of maize in four environments to assess the genotype × environment interactions for grain yield and its attributes. The results showed that the combined environment and genotype × environment variance were highly significant for all the traits.

Soliman (2006) estimated the stability of 24 promising yellow maize single crosses along with two commercial check hybrids under different environmental conditions. The results showed that two single crosses, *viz.,* G14 and G23 significantly out yielded the commercial check hybrids. Further, highly significant genotype x environment interaction was detected for all studied traits. A larger portion of this interaction was accounted for the linear regression on the environmental means. In other words, these hybrids could be the most stable hybrids across all locations, since they had small and insignificant deviations from linearity.

Abdulai *et al.* (2007) evaluated nine maize genotypes for four years at eight locations in Ghana. Stability analysis identified seven genotypes as stable, when regression values (bi) alone were considered. However when the bi values and the deviations from regression (S^2d_i) were considered, two hybrids (GH24 × 1368) × 5012 and (GH22 × 1368) × 5012 were found stable. Amit and Joshi (2007) evaluated 74 genotypes of maize under four environments. Variance due to genotype, environment, genotype x environment interactions were significant for oil, starch and protein contents. Cardoso *et al.* (2007) assessed adaptability and yield stability of 15 maize cultivars and two triple maize hybrids under 41 environments and reported that the performance of the cultivars significantly varied among the environments.

Fan *et al.* (2007) evaluated 13 maize hybrids for grain yield stability across ten locations. They reported that cultivars and cultivar-location (C × L) interactions were significant and heterogeneity caused by environmental index did not contribute appreciably to C × L interactions. The only hybrid showing stable performance across locations was Tun-004.

Kumar *et al.* (2008) developed 10 single cross hybrids for semi-arid tropics. They were evaluated under *kharif, rabi* and normal irrigated conditions. The hybrids exhibited higher grain yield, plant height and ear height along with earliness and narrow anthesis-silking interval over parental lines under varying ecological situations.

Meseka *et al.* (2008) performed stability analysis for six hybrids and four checks under 12 environments. As per their report the combined analysis of variance for environments, genotypes, genotype × environment (GE) interaction effects were highly significant, suggesting that hybrids responded differently relative to each other to a change in environment. Out of six hybrids they evaluated, four hybrids were stable for grain yield. Min *et al.* (2008) reported that genotype x environment (G x E) interaction is associated with the differential performance of materials tested at different locations and in different years, and influences selection and recommendation of cultivars. Genotype and G x E interaction effects were highly significant indicating high variability among genotypes, and genotypes responded differently to the changing environments.

Sharma *et al.* (2008) conducted an experiment at five locations for three years to determine performance stability of 25 exotic maize genotypes including a local check and an improved check. The results revealed that several genotypes produced significantly higher grain yield than the local check. The findings from their study provided new information on the stability of the maize genotypes that are also adapted to other regions of the world.

Solomon *et al.* (2008) evaluated 15 maize genotypes at nine different locations under rainfed condition to identify stable maize genotypes for grain yield. Based on stability analysis five genotypes were found stable for grain yield across locations.

Twenty maize cultivars were evaluated for two years at nine locations by Worku and Zelleke (2008) to assess the nature and magnitude of genotype × environment (G × E) interaction. They reported variances due to genotypes, years, locations, genotype × year, genotype × location and genotype × year × location interaction were significant. Most of the cultivars had significant deviation from regression (S^2d_i), indicating these cultivars were unstable across environments. However, the top yielding cultivars at each maize agro-ecology were specifically adapted, indicating that, for high yield potential in each maize agro-ecology, a specific breeding program is necessary.

Balestre *et al.* (2009) evaluated two inter-varietal hybrids together with single, double and three-way cross hybrids to assess the stability and adaptability for grain yield of commercial inter-varietal maize hybrids. The performance of the inter-varietal hybrid BIO-4 was superior to all the double and three-way cross hybrids and out matched the single cross hybrids by 43 per cent. In terms of stability, BIO2 was more stable than BIO-4.

Singh *et al.* (2009) evaluated 66 single cross hybrids over nine environments both under irrigated and unirrigated conditions for their yield performance. Highly significant differences were detected among the genotypes and environments for each character. Significant G × E interaction indicated that evaluation of yield components must be taken for different environments. On partitioning these components into linear and non-linear components, both were responsible for expression of the traits. However, the linear component was found larger in magnitude than the non-linear component suggesting that variation in the performance of different cultivars could be predicted.

An investigation was undertaken by Arulselvi and Selvi (2010) to estimate the grain yield performance of 72 single cross maize hybrids, their nine parents and one commercial check across three seasons (*Summer, kharif* and *rabi*). The stability analysis indicated that grain yield performance of maize genotypes was mainly due to genotypes and environmental interaction. Among the parents, UMI 432 was found to be higher yielder and stable across environments. Nine hybrids were identified as stable yielder's across environments in addition to higher yield.

Banik *et al.* (2010) conducted experiments to analyze the genotype-environment (G × E) interaction for commonly cultivated 20 commercial maize hybrids over four locations over three years in Bangladesh. Analysis of variance revealed high significant effects of environments, genotypes and G × E for grain yield and plant height.

Bhushal and Jagdish (2010) did series of experiments to study the effect of climatic parameters on yield of maize. Results revealed that the temperature was more critical for yield potentiality of cultivars than any other climatic parameters. They suggested screening and adoption of new technology is required to combant changing climatic scenarios for attaining the potential yield of maize.

Brar *et al.* (2010) evaluated 20 populations of fodder maize in four environments for four traits. The results revealed that the mean squares due to genotypes, environments (linear) and pooled deviations were highly significant for all the traits. While Mean squares due to genotypes × environments were significant for green fodder yield and highly significant for days to pollen-shed, indicating the differential response of varieties under different environments only for these two traits.

Jai *et al.* (2010) tested thirteen maize hybrids along with two checks under six locations spreading over different agro-climatic zones of Himachal Pradesh. Pooled analysis of variance indicated the presence of considerable variability among the genotypes as well as environments with respect to the characters studied. Significant mean squares for hybrid x environment (H x E) interaction revealed the differential response of hybrids over environments for all the characters. The partitioning of environment + (hybrid x environment) mean squares further confirmed the existence of significant variation among the environments with regard to their effect on the performance of hybrids for all the traits. The hybrid X-717, having high mean yield and average stability exhibited general adaptability for seed yield whereas, three hybrids *viz*., DMH-829, X-789 and NMH-51 showed general adaptability for early silking and maturity across the environments in the state. It was concluded that plasticity of different components be taken into consideration while selecting for stability in yield and related traits.

With an objective to determine the genotype × environment interaction (G × E) in hybrid maize, Kandus *et al.* (2010) conducted experiments in three locations over a period of two years considering each year and location as a different environment. The results revealed significant differences for genotype × environment interaction.

Lata *et al.* (2010) conducted stability analysis for 15 maize genotypes at three locations. The results revealed that the variances due to genotypes, environments and G × E interaction were significant for yield and its related traits. G × E interaction (linear) component was non-significant indicating the equal importance of both linear and non-linear interaction. They concluded that yield and its related traits may be taken into account while evaluating genotypes for stability performance over environments.

Liu *et al.* (2010) applied nonparametric tests for estimating genotype × environment interaction for 14 maize genotypes grown at 25 locations in southwestern China. Results of nonparametric tests of GEI and a combined ANOVA across locations showed GEI was highly significant for yield. They recommended JY-686 and HX-168 as desirable and ND-108, CM-12, CN-36, and NK-6661 as undesirable genotypes.

Rahman *et al.* (2010) carried out stability analysis to assess stability in performance and genotype x environment interactions for 18 maize hybrids across three locations. They observed significant differences for all parameters except anthesis-silking interval and ear height, which were non-significant across the three locations. The hybrid × location interactions also revealed significant differences for days to 50 per cent silking, days to 50 per cent anthesis, ASI, grain moisture at harvest and grain yield per hectare while non-significant differences were observed for plant height and ear height.

Romay *et al.* (2010) conducted a study to determine the contribution of climatic and genetic factors contributing to genotype (G), environment (E), and genotype × environment (GE) variability for maize grain yield under stress conditions. A large sample of Spanish maize populations were evaluated along with checks at three diverse locations for three years and factorial regression was performed to obtain a biological explanation of the G, E, and GE interaction for yield. The results revealed that the commercial hybrids had more yield and stability than most populations. The main climatic covariates for yield were related to days with mean temperature over 15°C, but they were not consistent across locations. They concluded that if yield under stress conditions is a breeding goal, several climatic variables, especially those related to high temperatures, and genotypic traits such as kernel depth and ear length should be considered.

Saleh *et al.* (2010) investigated the performance and stability of maize at four locations, in two years. Spatial variability for grain yield was observed in the fields at all locations. In addition, soil and plant N, P and K analysis had provided some information on genotype × environment interaction effect.

Ibni *et al.* (2011) opined that stable performance of maize hybrids in multi-environment trials is critical to sustain food production. Hybrids main effect and hybrid × location interaction was significant. For stability of performance across locations, GGE biplot identified ICI-974 and Pioneer-3025 as the most stable hybrids across locations, while the rest of the hybrids were inferior. Among the three locations, Nowshera and Mansehra were identified as highly representative, whereas, Peshawar was the least representative one.

Mosa *et al.* (2011) cited that grain yield stability for the new maize hybrids is an important target in breeding programs. Highly significant differences among hybrids for grain yield were detected at each location and in the combined analysis across locations. Variances due to locations and hybrids x locations interaction were highly significant for grain yield. Linear and non-linear components were highly significant. Behera location had the highest environmental index and therefore it was considered as the most favourable environment for realizing the genotypes grain yield potential, while Minia was considered the poorest grain yielding location.

Tonk *et al.* (2011) tested 17 hybrid maize genotypes for stability at four different locations. The analysis of variance showed that mean squares of environments (E), genotypes (G) and GE interactions (GEI) were highly significant for grain yield. They proposed maize hybrid G-16 as reliably growing in test locations for high grain yield. They also suggested that grain yield per plant instead of grain yield per plot in hybrid maize breeding programs could be adopted.

Karadavut and Akilli (2012) conducted stability analysis in maize for two years at three different locations to determine the genotype-environment (G × E) interaction and also to determine stable corn cultivar for grain yield in Turkey. G × E interaction was analyzed by linear regression techniques and stability was estimated by the Eberhart and Russell methods. According to the stability analysis, the cultivar 3 was the most stable for grain yield as this genotype had regression coefficient (b_i =1) around unity and deviations from regression values (S^2d_i = 0) around zero.

An experiment, consisting of ten diverse inbreds of maize and their all-possible combinations (excluding reciprocals) was conducted by Lenka *et al.* (2012) to identify their stability performance across three diverse seasons *i.e.* rainy, winter and spring seasons. The results showed significant differences among the genotypes over environments for all the characters studied. The mean of genotypes were also highly variable under different seasons. The G x E interactions was also highly significant for all the traits except ear length, cob diameter and shelling percentage. They indicated that the performance of genotypes varied from season to season and it is imperative to select the genotypes as per environmental condition.

Ranjan and Phanindra (2012) examined the risk attached with weather variables in the rainfed agriculture of Odisha. The study examined the effects of climatic factors along with other non-climatic factors on the mean yield and variance of yield in case of three food crops, *viz.*, rice, maize and bajra. Estimation results were crop-specific and varied from one crop to the other. For maize and bajra, precipitation during the sowing period affected the crops negatively while during the growing period, it depicted a positive effect. The temperature also showed similar effects on yield variability. Results of climate change forecasting in two scenarios have revealed that rice would be more badly affected than other two crops.

An investigation was carried out by Vijay *et al.* (2012) in order to understand changes in the relative performance of 20 maize inbred lines across different environments. The pooled analysis revealed significant differences among the genotypes for most of the traits except for number of kernel rows per cob indicating the presence of large amount of variability in the material chosen for the study.

Nagabhushan *et al.* (2013) evaluated 15 hybrids of maize to assess the stability of hybrids for productivity traits. He reported significant differences among the genotypes and environments for most of the characters indicating the genotypes and environments tested were diverse in nature. He also concluded that G×E interaction was significant for most of the characters suggesting genotypes interacted significantly with the environments.

Wasala *et al.* (2013) tested 48 landrace accessions of maize under three locations for their stability. The study revealed considerable phenotypic diversity among the accessions for grain yield and its components, besides genotype × environment (G × E) interactions. The study was successful in identifying some highly promising accessions on the basis of their performance for various yield components and flowering behavior.

2.4 Screening for turcicum leaf blight

Gowda *et al.* (1989) evaluated 20 medium and 14 early maturity maize genotype against *Exerohilum turcicum* and found that one hybrid EH-40013 and a composite A-62 under medium maturity and three genotypes, EH-4010075, J-660 and R-2 showed moderately resistant reaction. The intensity of turcicum leaf blight was severe in field inoculation screening trials. Mahajan *et al.* (1991) evaluated maize cultivars for resistance to *E. turcicum* and reported that Deccan-103, Suwan-1, Ganga-11 and Hemant as resistant.

Gowda *et al.* (1994) evaluated several maize hybrids, pools and composites during rainy season of 1986-1991 against turcicum leaf blight. Three genotypes, Pool-28, Pool-32 and Across-8444 exhibited highly resistant reaction. Genotypes Poza-Rica 8149, Across-8445, Pool-17 and Suwan were rated as moderately resistant. Highly susceptible reaction was recorded in 25 genotypes. Maize varieties, such as Parbhat, BIO-9637, KH-581, HIM-129 and KH-510 have shown field resistance to turcicum leaf blight.

MATERIAL AND METHODS

The details of materials used and methods followed in carrying out the present investigation are presented in this chapter.

3.1 Experiment-I: Germplasm evaluation

3.1.1 Material

The experiment material consisted of 79 S_6 lines of maize along with three checks; CI-4, KDMI-16 and CM-111 (inbreds). The newly derived S_6 lines were isolated from yellow pool of maize, All India Co-ordinate Maize Improvement Project (AICMIP), Arabhavi. The details of the lines and checks used in present investigation are presented in Table 2.

3.1.2 Location

The first experiment was carried out at All India Co-ordinated Maize Improvement Project (AICMIP), Arabhavi, Gokak taluk (Karnataka) during *kharif* 2013.

3.1.3 Experimental layout

The experiment was laid out in replicated trial with row length of 4 m with inter and intra row spacing of 75 cm and 20 cm respectively. Each inbred line was sown with two rows.

3.1.4 Collection of data

Ten plants were tagged randomly for recording observations for each entry for all the quantitative characters except for days to 50 per cent tasseling and silking. Mean of ten plants for each entry in each replication was worked out for each character for using in statistical analysis.

3.1.5 Observations recorded

Observations on the following quantitative characters were recorded at appropriate stages of plant growth.

3.1.5.1 Days to 50 per cent tasseling

The number of days taken from the date of sowing to the day on which 50 per cent of plants in a genotype showed tassel emergence was recorded as days to 50 per cent tasseling.

3.1.5.2 Days to 50 per cent silking

The number of days taken from the date of sowing to the day on which 50 per cent of plants in a genotype showed silk emergence was recorded as days to 50 per cent silking.

3.1.5.3 Days to 75 per cent dry husk

The number of days taken from the date of sowing to the day on which 75 per cent of the plants in a genotype showed complete dry husk was recorded as days to 75 per cent dry husk.

3.1.5.4 Plant height (cm)

Height of the plant from ground level up to the base of fully opened flag leaf was recorded in centimeters as plant height, when plants were mature.

3.1.5.5 Ear height (cm)

Height from ground level up to the base of the upper most Cob bearing internode was recorded as ear height in centimeters.

3.1.5.6 Cob length (cm)

Length of the ear was measured and recorded in centimeters at the time of harvest as its total length (from the base to the tip of the ear).

Table 2. List of S_6 lines used under study with their pedigree and origin

Sl. No.	Code No.	Pedigree	Origin	Sl. No.	Code No.	Pedigree	Origin
1	ARYP-1	*YP* ⊗ 6 # 1	AICMIP, Arabhavi	26	ARYP-26	*YP* ⊗ 6 # 26	AICMIP, Arabhavi
2	ARYP-2	*YP* ⊗ 6 # 2	AICMIP, Arabhavi	27	ARYP-27	*YP* ⊗ 6 # 27	AICMIP, Arabhavi
3	ARYP-3	*YP* ⊗ 6 # 3	AICMIP, Arabhavi	28	ARYP-28	*YP* ⊗ 6 # 28	AICMIP, Arabhavi
4	ARYP-4	*YP* ⊗ 6 # 4	AICMIP, Arabhavi	29	ARYP-29	*YP* ⊗ 6 # 29	AICMIP, Arabhavi
5	ARYP-5	*YP* ⊗ 6 # 5	AICMIP, Arabhavi	30	ARYP-30	*YP* ⊗ 6 # 30	AICMIP, Arabhavi
6	ARYP-6	*YP* ⊗ 6 # 6	AICMIP, Arabhavi	31	ARYP-31	*YP* ⊗ 6 # 31	AICMIP, Arabhavi
7	ARYP-7	*YP* ⊗ 6 # 7	AICMIP, Arabhavi	32	ARYP-32	*YP* ⊗ 6 # 32	AICMIP, Arabhavi
8	ARYP-8	*YP* ⊗ 6 # 8	AICMIP, Arabhavi	33	ARYP-33	*YP* ⊗ 6 # 33	AICMIP, Arabhavi
9	ARYP-9	*YP* ⊗ 6 # 9	AICMIP, Arabhavi	34	ARYP-34	*YP* ⊗ 6 # 34	AICMIP, Arabhavi
10	ARYP-10	*YP* ⊗ 6 # 10	AICMIP, Arabhavi	35	ARYP-35	*YP* ⊗ 6 # 35	AICMIP, Arabhavi
11	ARYP-11	*YP* ⊗ 6 # 11	AICMIP, Arabhavi	36	ARYP-36	*YP* ⊗ 6 # 36	AICMIP, Arabhavi
12	ARYP-12	*YP* ⊗ 6 # 12	AICMIP, Arabhavi	37	ARYP-37	*YP* ⊗ 6 # 37	AICMIP, Arabhavi
13	ARYP-13	*YP* ⊗ 6 # 13	AICMIP, Arabhavi	38	ARYP-38	*YP* ⊗ 6 # 38	AICMIP, Arabhavi
14	ARYP-14	*YP* ⊗ 6 # 14	AICMIP, Arabhavi	39	ARYP-39	*YP* ⊗ 6 # 39	AICMIP, Arabhavi
15	ARYP-15	*YP* ⊗ 6 # 15	AICMIP, Arabhavi	40	ARYP-40	*YP* ⊗ 6 # 40	AICMIP, Arabhavi
16	ARYP-16	*YP* ⊗ 6 # 16	AICMIP, Arabhavi	41	ARYP-41	*YP* ⊗ 6 # 41	AICMIP, Arabhavi
17	ARYP-17	*YP* ⊗ 6 # 17	AICMIP, Arabhavi	42	ARYP-42	*YP* ⊗ 6 # 42	AICMIP, Arabhavi
18	ARYP-18	*YP* ⊗ 6 # 18	AICMIP, Arabhavi	43	ARYP-43	*YP* ⊗ 6 # 43	AICMIP, Arabhavi
19	ARYP-19	*YP* ⊗ 6 # 19	AICMIP, Arabhavi	44	ARYP-44	*YP* ⊗ 6 # 44	AICMIP, Arabhavi
20	ARYP-20	*YP* ⊗ 6 # 20	AICMIP, Arabhavi	45	ARYP-45	*YP* ⊗ 6 # 45	AICMIP, Arabhavi
21	ARYP-21	*YP* ⊗ 6 # 21	AICMIP, Arabhavi	46	ARYP-46	*YP* ⊗ 6 # 46	AICMIP, Arabhavi
22	ARYP-22	*YP* ⊗ 6 # 22	AICMIP, Arabhavi	47	ARYP-47	*YP* ⊗ 6 # 47	AICMIP, Arabhavi
23	ARYP-23	*YP* ⊗ 6 # 23	AICMIP, Arabhavi	48	ARYP-48	*YP* ⊗ 6 # 48	AICMIP, Arabhavi
24	ARYP-24	*YP* ⊗ 6 # 24	AICMIP, Arabhavi	49	ARYP-49	*YP* ⊗ 6 # 49	AICMIP, Arabhavi
25	ARYP-25	*YP* ⊗ 6 # 25	AICMIP, Arabhavi	50	ARYP-50	*YP* ⊗ 6 # 50	AICMIP, Arabhavi
51	ARYP-51	*YP* ⊗ 6 # 51	AICMIP, Arabhavi	68	ARYP-68	*YP* ⊗ 6 # 68	AICMIP, Arabhavi
52	ARYP-52	*YP* ⊗ 6 # 52	AICMIP, Arabhavi	69	ARYP-69	*YP* ⊗ 6 # 69	AICMIP, Arabhavi
53	ARYP-53	*YP* ⊗ 6 # 53	AICMIP, Arabhavi	70	ARYP-70	*YP* ⊗ 6 # 70	AICMIP, Arabhavi
54	ARYP-54	*YP* ⊗ 6 # 54	AICMIP, Arabhavi	71	ARYP-71	*YP* ⊗ 6 # 71	AICMIP, Arabhavi
55	ARYP-55	*YP* ⊗ 6 # 55	AICMIP, Arabhavi	72	ARYP-72	*YP* ⊗ 6 # 72	AICMIP, Arabhavi
56	ARYP-56	*YP* ⊗ 6 # 56	AICMIP, Arabhavi	73	ARYP-73	*YP* ⊗ 6 # 73	AICMIP, Arabhavi
57	ARYP-57	*YP* ⊗ 6 # 57	AICMIP, Arabhavi	74	ARYP-74	*YP* ⊗ 6 # 74	AICMIP, Arabhavi
58	ARYP-58	*YP* ⊗ 6 # 58	AICMIP, Arabhavi	75	ARYP-75	*YP* ⊗ 6 # 75	AICMIP, Arabhavi
59	ARYP-59	*YP* ⊗ 6 # 59	AICMIP, Arabhavi	76	ARYP-76	*YP* ⊗ 6 # 76	AICMIP, Arabhavi
60	ARYP-60	*YP* ⊗ 6 # 60	AICMIP, Arabhavi	77	ARYP-77	*YP* ⊗ 6 # 77	AICMIP, Arabhavi
61	ARYP-61	*YP* ⊗ 6 # 61	AICMIP, Arabhavi	78	ARYP-78	*YP* ⊗ 6 # 78	AICMIP, Arabhavi
62	ARYP-62	*YP* ⊗ 6 # 62	AICMIP, Arabhavi	79	ARYP-79	*YP* ⊗ 6 # 79	AICMIP, Arabhavi
63	ARYP-63	*YP* ⊗ 6 # 63	AICMIP, Arabhavi			**Checks**	
64	ARYP-64	*YP* ⊗ 6 # 64	AICMIP, Arabhavi	80	CI-4		CIMMYT, Mexico
65	ARYP-65	*YP* ⊗ 6 # 65	AICMIP, Arabhavi	81	CM-111		DMR, Delhi
66	ARYP-66	*YP* ⊗ 6 # 66	AICMIP, Arabhavi	82	KDMI-16		AICMIP, Arabhavi
67	ARYP-67	*YP* ⊗ 6 # 67	AICMIP, Arabhavi				

Arabhavi

Dharwad

Mandya

Plate 1: General view of experimental plot in different locations

3.1.5.7 Cob girth (cm)

Cob girth was measured and recorded in centimeters as the thickness of the cob.

3.1.5.8 Number of kernel rows per cob

Number of kernel rows per cob was counted and the average was recorded as number of kernel rows per cob.

3.1.5.9 Number of kernels per row

Number of kernels per row was counted and the average was recorded as number of kernels per row.

3.1.5.10 Shelling percentage

Average pith weight and average grain weight of the ten randomly selected plants per plot were used to compute the shelling percentage by using the following formula.

$$\text{Shelling percentage} = \frac{\text{Grain weight}}{\text{Total weight (grain weight + pith weight)}} \times 100$$

3.1.5.11 Hundred seed weight (g)

The weight of sun dried 100 seed samples drawn randomly from each entry was recorded in grams as 100 seed weight.

3.1.5.12 Grain yield per plant (g)

The average grain yield of ten plants was expressed in grams as grain yield per plant.

3.1.5.13 Grain yield per ha (q)

Fresh ear weight per plot was recorded at the time of harvest. Grain yield per ha was computed using the formula given below.

$$\text{Yield(t/ha)} = \frac{\text{Fresh ear weight} \times (100\text{-AVM})}{\text{Stand harvest} \times 1000} \times K$$

$$K = \frac{10000 \times 0.9412 \times (100\text{-AVM})}{100 \times \text{plot area}}$$

Where,

AVM = Average moisture content

3.1.6 Statistical analysis

The statistical analysis of the data on the individual character was carried out on the mean value of ten randomly selected plants on each genotype. The mean data was analyzed. Different statistical methods employed for analysis are as follows.

3.1.6.1 Mean

On the basis of individual plant observations, the population mean for each character was computed as follows.

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} Xi$$

Where,

$\bar{X}$ = population mean

X_i = individual value

n = number of observations

3.1.6.2 Range

The minimum and maximum values on the basis of individual plant observations were used to indicate the range of given character.

3.1.6.3 Estimation of genetic parameters

Genetic parameters were estimated for different traits on maize genotypes.

3.1.6.3.1 Genotypic and phenotypic coefficient of variation

The genotypic and phenotypic coefficient of variation was computed according to Burton and Devane (1953) and expressed as percentage.

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma_g}{\bar{X}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p}{\bar{X}} \times 100$$

Where,

σ_g = Genotypic standard deviation

σ_p = Phenotypic standard deviation

$\bar{X}$ = General mean of the character

PCV and GCV values were categorized as low, moderate and high values as indicated by Sivasubramanian and Menon (1973) as follows.

0 -10 per cent	: Low
10 – 20 per cent	: Moderate
> 20	: High

3.1.6.3.2 Heritability (h^2)

Heritability in broad sense was estimated as the ratio of genotypic variance to the phenotypic variance and expressed in percentage (Robinson *et al.,* 1949).

$$\text{Heritability } (h^2) = \frac{Vg}{Vp} \times 100$$

Where,

Vg = Genotypic variance

Vp = Phenotypic variance

The heritability percentage was categorized as low, moderate and high as followed by Robinson *et al.* (1949), as follows.

0 – 30 per cent	: Low
30 – 60 per cent	: Moderate
> 60 per cent	: High

3.1.6.3.3 Genetic advance

The extent of genetic advance to be expected by selecting five per cent of the superior progeny was calculated by using the following formula given by Robinson *et al.* (1949).

$$GA = i\sigma_p h^2$$

Where,

i = efficacy of selection which is 2.06 at 5 per cent selection intensity

σ_p = phenotypic standard deviation.

h^2 = heritability in broad sense.

3.1.6.3.4 Genetic advance as per cent of mean

$$\text{GA as per cent of mean} = \frac{GA}{\bar{X}} \times 100$$

Where,

GA = genetic advance

$\bar{X}$ = general mean of character

The GA as per cent of mean was categorized as low, moderate and high as following by Robinson *et al.* (1949) as follows.

0 - 10 per cent	: Low
10 – 20 per cent	: Moderate
20 and above	: High

3.1.6.4 Association analysis

The correlation coefficients were calculated to determine the degree of association of characters with yield and also among the yield components themselves. The analysis of covariance was conducted by following the method designed by Singh and Chaudhary (1979).

$$\textbf{Genotypic correlation} = V_{xy}(g) = \frac{\sqrt{COV_{xy}(g)}}{V_x(g) \times V_y(g)}$$

$$\textbf{Phenotypic correlation} = V_{xy}(P) = \frac{\sqrt{COV_{xy}(p)}}{V_x(p) \times V_y(p)}$$

Where,

COV_{xy} (p)	= Phenotypic covariance between characters x and y
Vx (p)	= Phenotypic variance of character x
Vy (p)	= Phenotypic variance of character y
COV_{xy} (g)	= Genotypic covariance between characters x and y
Vx (g)	= Genotypic variance of character x
Vy (g)	= Genotypic variance of character y

3.1.6.5 Path coefficient analysis

Path analysis was carried out using the genotypic correlation coefficients to know the direct and indirect effects of the components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959).

The following set of simultaneous equations were formed and solved for estimating the direct and indirect effects.

$r_1y = a + r_{12}b + r_{13}c + ... + r_{11i}$

$r_2y = r_{21}ab + r_{23}c + ... + r_{21i}$

$r_3y = r_{31}ab + r_{32}c + ... + r_{31i}$

$rny = rn_1ab + r_{12}c + ... + i$

Where,

r_1y to rny = coefficients of correlation between causal factors 1 to n and dependent character y.

r_{12}, r_{21}, r_{31}.... rn_1 = coefficients of correlation among the causal factors 1 to n.

a, b, c... i = direct effects of characters a toi on the dependent character y

Residual effect (R) = $1 – (a^2 + b^2 + c^2......... + i^2 + 2abr_{12} + 2acr_{13} +.......)$

The direct and indirect effects were suggested by Lenka and Misra (1973) as mentioned below.

> 1	Very high
0.3 - 0.9	High
0.2 – 0.29	Moderate
0.1 – 0.19	Low
< 0.1	Negligible

3.2 Experiment Ii: Evaluation of s_6 lines over locations

To assess the stability across locations, the experiment was conducted at three locations *viz.,* All India Co-ordinated Maize Improvement project (AICMIP), Arabhavi (Zone III), Zonal Agriculture Research Station (ZARS), Mandya (Zone VI) and Main Agriculture Research Station (MARS), Dharwad (Zone VIII). The details on the material and the methods used followed during the present investigation is given in the following headings.

3.2.1 Selection of material

The experimental material consisted of 12 S_6 lines and three checks (CI-4, KDMI-16 and CM-111), which are selected based on the *per se* performance and uniformity. List of 12 lines which are selected for the study ARYP- 68, ARYP-69, ARYP-70, ARYP-71, ARYP- 72, ARYP-73, ARYP-74, ARYP-75, ARYP-76, ARYP-77, ARYP-78 and ARYP-79.

3.2.2 Geographical location and weather conditions

3.2.2.1 Arabhavi

All India Co-ordinated Maize Improvement Project (AICMIP), Agricultural Research station (ARS), Arabhavi is located in Northern dry zone (Zone III) of Karnataka. Geographically it lies at 16°12' N latitude and 74°57' E longitude with an altitude of 640 m above sea level. The soils are sandy loam type with pH of 7.2. Source of irrigation water is from Ghataprabha Left Bank Canal [GLBC], which flows from first week of July to end of February month (8 months) and from March to June (4 months) open wells are the source of irrigation. Crop was raised under irrigated situation. The average rainfall of the Agricultural Research station, Arabhavi is 546 mm. The monthly maximum and minimum temperatures during hot months (March-April) was 18.67°C to 37.2°C and during cold months (December-January) was 12.5°C to 31.2°C respectively.

3.2.2.2 Mandya

Zonal Agriculture Research Station, V. C. farm, Mandya is located in southern dry zone (Zone VI) of Karnataka. Geographically it lies at 12°14' to 13°57' N latitude and 76°24' E longitude with an altitude of 695 m above sea level. The average annual rainfall is about 710 mm, which was distributed evenly during the cropping period.

3.2.2.3 Dharwad

Main Agriculture Research Station (MARS), Dharwad is located in Northern transition zone (Zone VIII) of Karnataka.Geographically, Dharwad is situated at 15°26'N latitude and 70°26'E longitude and at an altitude of 678 m above mean sea level. The average annual rainfall is about 770.95 mm, which was distributed evenly during the cropping period. The monthly maximum and minimum temperatures during hot months (March-April) was 27.20°C to 37.10°C and during cold months (December-January) was 13.14°C to 21.45°C respectively.

3.2.3 Experimental layout

The experiment under each environment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The plot size was 4.0 m × 1.5 m with inter and intra row spacing of 75 and 20 cm respectively. The recommended package of practices for respective environment at each location was followed in full to raise good crop.

3.2.4 Collection of data

Ten plants were tagged randomly for recording observations for each entry in each replication for all the quantitative characters except for days to 50 per cent tasseling and silking. Mean of ten plants for each entry in each replication was worked out for each character at each location and used for statistical analysis.

3.2.5 Observations recorded

Similar observations that are recorded in the first experiment are also recorded for this experiment in the same manner, in addition to those one more observation was recorded *i.e.*, reaction against turcicum leaf blight by following 1 – 5 scale given by Payak and Sharma (1985).

Grade	Infection type	Reaction
1.0	Very slight to slight infection, one or two to few scattered lesions on lower leaves	Highly resistant
2.0	Light infection, moderate number of lesions on lower leaves only	Resistant
3.0	Moderate infection, abundant lesions on lower leaves, few on middle leaves	Moderately Resistant
4.0	Heavy infection, lesions abundant on lower and middle leaves, extending to upper leaves	Susceptible
5.0	Very heavy infection, lesions abundant on almost all leaves, plants prematurely dry or killed by the disease	Highly Susceptible

3.2.7 Statistical analysis

3.2.7.1 Analysis of variance (ANOVA)

The data obtained for 13 quantitative characters from 12 S_6 lines and three inbreds over three locations (Arabhavi, Mandya and Dharwad), were subjected to two way analysis of variance as per Panse and Sukhatme (1964). The analysis of variance for different characters was carried out for each environment to partition the total variance (mean sum of squares) due to known and unknown causes. The structure of ANOVA is given below.

Sources of variation	d. f.	MSS	Expected value of MSS	Cal F.
Replication	(r-1)	M_1	--	
Inbreds	(g-1)	M_2	$\sigma^2 e + r\,\sigma^2 g$	M_2/M_3
Error	(r-1) (g-1)	M_3	$\sigma^2 e$	
Total	(rg-1)			

3.2.7.2 Tests of homogeneity of error variance

The data obtained from each of the three environments for all the characters was subjected to Bartlett's test to examine the homogeneity of error variance.

3.2.7.3 Two way analysis of variance

The data obtained for thirteen characters on 12 + 3 genotypes over three locations was subjected to two way analysis of variance using the method outlined by Sunderaraj *et al.* (1972). This was done for each character in order to find out the variation due to genotypes and environments to reveal the existence of genotype x environment interaction, if any. Only after ascertaining the genotypic x environment interaction was significant in the two way analysis of variance, the data was further subjected to stability analysis.

The structure of pooled analysis of variance

Source of variation	d. f.	MSS	Expected value of MSS	F-value
Genotypes	(g-1)		-	-
Environments	(e-1)	M_1	$\sigma^2_e + \sigma^2_{ge} + e\sigma^2_g$	-
Genotypes x Environments	(g-1) (e-1)	M_2	$\sigma^2_e + \sigma^2_{ge}$	-
Pooled error	M*	M_3	σ^2_e	-

* Degrees of freedom pooled over environments

3.2.7.4 Stability Analysis:

The stability model proposed by Eberhart and Russell (1966) was adapted to analyze the data over three environments by using WINDOWSTAT SOFTWARE. The model involves the estimation of three stability parameters; mean ($\bar{X}$), regression coefficient (b_i) and deviation from regression (S^2d_i), which are defined by the following mathematical formula.

$$Y_{ij} = \overline{\mu_i} + \beta_i I_j + \delta_{ij}$$

Where,

Y_{ij}	:	Mean of the i^{th} inbred at the j^{th} environment (i = 1, 2, 3, 4, 5, 6, 7. *j* = 1, 2, 3)
μ_i	:	The mean of i^{th} inbred over all the environments
β_i	:	The regression coefficient of i^{th} inbred on the environment index which measures the response of inbreds to to varying environment
δ_{ij}	:	The deviation from regression of the i^{th} inbred of j^{th} environment
I_j	:	The environmental index which is defined as the deviation of mean of all the inbreds at a given environment from the overall grand mean from the mean of all inbreds at j^{th} environment.

3.2.7.5 Stability parameters

The regression coefficient (b_i) and mean square deviation from linear regression (S^2d_i) are the two stability parameters proposed by Eberhart and Russell (1966) in their stability model. These parameters were computed by using the following formula.

b_i (regression coefficient) = $\frac{\Sigma_j Y_{ij} I_j}{\Sigma_j I_j^2}$

S^2d_i (deviation from the regression coefficient) = $\frac{\Sigma_j \delta^2_{ij}}{n-2} - \frac{\delta^2_e}{r}$

Where,

$\frac{\delta_e^2}{r}$	:	Mean square for (estimate of) pooled error
n	:	Number of environments
Y_{ij}	:	Performance of i^{th} inbred in j^{th} environment
$\Sigma_j \delta^2_{ij}$	:	Sum of squares of deviations from the regression line
I_j	:	Environmental index (*i.e.*, environmental mean – grand mean)

$$I_j = \frac{\Sigma_i Y_{ij}}{i} - \frac{\Sigma_i \Sigma_{ij} Y_{ij}}{nj}$$

Where,

$\Sigma_i Y_{ij}$	=	Total of all inbreds at j^{th} environment
$\Sigma_i \Sigma_{ij} Y_{ij}$	=	Grand total
N	=	Number of environments
I	=	Number of inbreds
$\Sigma_j I_j$	=	0

The total variation is partitioned into variation due inbreds, environment, environment (linear), inbred × environment (linear), pooled deviation and pooled error as given below.

ANOVA for stability

Source	d.f.	M.S.S.	F test
inbreds (I)	(i-1)	MS_1	MS_1/MS_3
Environment + (I × E)	i (n-1)		
Environment (E) (linear)	1		
inbreds× environment (linear)	(i-1)	MS_2	MS_2/MS_3
Pooled deviations	i (n-2)	MS_3	
Pooled error	n (r-1) (i-1)	Me	
Total	(nv-1)		

F test

To test the significance of differences among the inbreds, the 'F' test was performed as,

$$F = MS_1 / MS_3$$

Where,

MS_1 : Mean sum of squares of inbreds.

MS_3 : Mean sum of squares of pooled deviations

To test individual deviation from linear regression, the formula is as follows,

$$F = \left(\frac{\Sigma_i \delta^2_{ij}}{n-2}\right) ⊠ Me$$

Where,

n : Number of environments

$\Sigma_j \delta^2_{ij}$: Sum of squares of deviations from the regression

Me : Pooled error

To test the departure of regression coefficients of the inbreds on the environmental index, the appropriate test was,

$$t = \frac{\hat{b}i - 1}{SE\ (b)}$$

Standard error of b_i is got from the component of mean square for pooled deviations corresponding to the i^{th} inbred. Thus, for inbred *i*, the mean square for deviation corresponding to this inbred should be employed to calculate standard error of b_i. Thus,

$$SE\ (b) = [MS \text{ due to pooled deviation} / \Sigma_j\ I_j^2]^{1/2}$$

Inbred are said to be stable, based on following criteria:

1. The mean performance of the inbred over the environment $\bar{X}$
2. The regression coefficient (b_i) and
3. The deviation from linear regression (S^2d_i) is used to define stability of a inbred

The estimate of deviations from regression (S^2d_i) suggests the degree of reliance that should be put to linear regression in interpretation of the data. If these values are significantly deviating from zero, the expected phenotype cannot be predicted satisfactorily. When, deviations (S^2d_i) are not significant, the conclusion may be drawn by joint consideration of mean yield and regression coefficient (b_i) values (Finlay and Wilkinson, 1963 and Eberhart and Russell, 1966) as given below.

Regression coefficient	Stability	Mean yield	Remarks
$\hat{b}_i = 1$	Average	High	Well adapted to all environments
$\hat{b}_i = 0$	Average	Low	Poorly adapted to all environments
$\hat{b}_i \geq 1$	Below average	High	Specifically adapted to favourable environments
$\hat{b}_i \leq 1$	Above average	High	Specifically adapted to unfavourable environments

EXPERIMENTAL RESULTS

The present investigations were conducted during *Kharif* 2013 at All India Co-ordinated Maize Improvement Project (AICMIP), Arabhavi, Zonal Agricultural Research Station (ZARS), Mandya and Main Agriculture Research Station (MARS), Dharwad. The experiments were conducted to study the nature of genetic variability in newly derived S_6 lines and to study the association analysis and stability analysis of isolated lines derived from the Yellow pool population of maize. The results of the present investigation entitled "Variability and Stability Analysis of Newly Derived S_6 Lines of Maize (*Zea mays* L.) " are presented under following captions.

Experiment-I: Germplasm Evaluation

4.1 Analysis of variance

4.2 *Per se* performance of lines and checks

4.3 Genetic variability, heritability and genetic advance

4.4 Character association and path coefficient analysis

Experiment-II: Evaluation of S_6 Lines over Locations

4.5 Stability analysis

4.5.1 *Per se* performance of lines and checks at different locations

4.5.2 Analysis of variance in individual location

4.5.3 Pooled analysis of variance over locations

4.5.4 Analysis of variance for performance stability

4.5.5 Stability parameters

4.6 Genetic variability, heritability and genetic advance over locations

4.7 Screening of S_6 lines of maize against turcicum leaf blight at different locations.

4.1 Analysis of variance (ANOVA)

The analysis of variance was carried out for all thirteen characters of maize S_6 lines to partition total variation due to genotype and other sources. The variance (mean sum of squares) due to known and unknown causes is furnished in Table 3. The analysis of variance indicated significant differences among the genotypes for all the characters considered under investigation.

4.2 *Per se* performance of lines and checks

The observations recorded for the *per se* performance of 79 S_6 lines and 3 checks are presented in appendix-1.

4.2.1 Days to 50 per cent tasseling

There was a wide variation (55.5 to 60.00), among 79 S_6 lines for days to 50 per cent tasseling with mean of 57.60 days. 8 lines (ARYP-17, ARYP-20, ARYP-21, ARYP-34, ARYP-37, ARYP-52, ARYP-59 and ARYP-60) took very less (55.5) for days to 50 per cent tasseling.

4.2.2 Days to 50 per cent silking

Days to 50 per cent silking showed a wide variability with a range from 56.50 (ARYP-59 and ARYP-60) to 61.50 (ARYP-48) with a mean of 59.03.

4.2.3 Days to 75 per cent dry husk

There was a wide variation (92.00 to 102.00), among 79 S_6 lines for days to 75 per cent dry husk with mean of 99.00 days. The line ARYP-68 took very less (92.00) for days to 75 per cent dry husk.

4.2.4 Plant height (cm)

Plant height exhibited high variability among the genotypes studied, the mean value of which ranged from 131.50 (ARYP-13) to 202.00 (ARYP-76) with overall mean of 169.92 cm.

Table 3. Analysis of variance for 13 characters related to grain yield in maize

Traits	Source of variation		
	Replications (MSS)	**Genotypes (MSS)**	**Error (MSS)**
Days to 50 per cent tasseling	0.15	3.18**	0.62
Days to 50 per cent silking	0.49	3.10**	0.65
Days to 75 per cent dry husk	5.13	7.23**	1.51
Plant height (cm)	89.27	463.77**	61.89
Ear height (cm)	66.21	5160.04**	139.08
Cob length (cm)	0.39	5.12**	0.50
Cob girth (cm)	0.22	1.07**	0.17
Number of kernel rows per cob	0.83	1.81**	0.34
Number of kernels per row	2.51	16.57**	3.55
Shelling percentage	0.02	7.00**	3.05
100 seed weight (g)	7.05	30.82**	2.25
Grain yield per plant (g)	5.20	1390.61**	198.71
Grain yield per hectare (q)	0.03	47.88**	10.74

** Significant at 0.01 probability level

4.2.5 Ear length (cm)

The range of mean values for this trait was 48.00 (ARYP-9) to 113.00 (ARYP-65) with overall mean of 82.99 cm.

4.2.6 Cob length (cm)

The cob length among the genotypes studied was ranged from 11.05 cm to 18.84 cm. shortest and longest cob length was found in ARYP-9 and ARYP-68, respectively.

4.2.7 Cob girth (cm)

There was a wide variation (11.10 cm to 15.55 cm), among 79 S_6 lines for cob girth with mean of 14.13 cm. The line ARYP-68 had higher (15.55) for cob girth.

4.2.8 Number of kernel rows per cob

The number of kernel rows per cob varied between 11.00 (ARYP-26) to 16.00 (ARYP-33) rows with a mean of 14.00 rows per cob.

4.2.9 Number of kernels per row

There was a wide variation (24.00 to 38.00 kernels) for number of kernels per row, among 79 S_6 lines for number of kernels per row with mean of 33.00 kernels. The line ARYP-21 had higher kernels per row.

4.2.10 Shelling percentage

The range observed for 79 S_6 lines for this trait was 78.83 (ARYP-45) to 87.99 (ARYP-5) with mean value of 83.76, while the range for checks recorded was 81.66 (CM-111) to 85.85 (KDMI-16) with mean value 83.94.

4.2.11 Hundred seed weight (g)

It was observed that the trait had a general mean of 33.33 g with range of 25.00 g (ARYP-50) to 44.00 g (ARYP-69) revealing higher amount of variation exist among the lines under study.

4.2.12 Grain yield per plant (g)

The range observed for 79 S_6 lines for this trait was 58.60 to 212.0 with mean value of 137.27. The line ARYP-31 had highest grain yield per plant whereas, ARYP-13 was found be the low grain yield per plant.

4.2.13 Grain yield per hectare (q/ha)

Wide variability was noticed for grain yield with a range of 14.17 to 41.78 q/ha with mean of 28.69 q/ha. Among the 79 S_6 lines studied, the line ARYP-58 (41.78 q/ha) was the highest grain yield whereas, the lowest grain yield was recorded by ARYP-13 (14.17 q/ha).

4.3 Genetic variability, heritability and genetic advance as per cent mean

In the present investigation, an attempt was made to study the various genetic parameters such as genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance as per cent over mean for 79 + 3 genotypes for 13 parameters, which will help in formulating breeding strategies for maize improvement for various characters. These genetic parameters give an idea about variations present in the genotypes and extent of improvement that can be achieved. The results of these components for different characters are presented in Table 4 and Fig. 1.

4.3.1 Genotypic (GCV) and phenotypic (PCV) coefficients of variation

The present results revealed that phenotypic coefficient of variation were comparatively higher than that of the genotypic coefficient of variation. It is apparent from Table 4, that none of character manifested higher magnitude of both GCV and PCV.

The characters *viz.,* days to 50 per cent tasseling (1.96% and 2.39%), days to 50 per cent silking (1.87% and 2.32%), days to 75 per cent dry husk (1.70% and 2.11%), Plant height (8.34% and 9.54%), cob girth (4.74% and 5.58%), number of kernel rows per cob (6.25% and 7.56%), number of kernels per row (7.80% and 9.70%) and shelling percentage (1.67% and 2.67%) showed lower magnitude of both GCV and PCV, respectively. whereas, ear height (11.83% and 17.25%), 100-grain weight (11.33% and 12.19%) and grain yield per hectare (15.01% and 18.86%) showed moderate magnitude of both GCV and PCV respectively. Grain yield per plant showed moderate magnitude (17.79%) of GCV and higher magnitude (20.54%) of PCV, whereas, cob length expressed 9.83 per cent and 10.84 per cent which were low GCV and moderate PCV respectively.

4.3.2 Heritability

In the present study, days to 50 per cent tasseling (67.30%), days to 50 per cent silking (65.30%), days to 75 per cent dry husk (65.40%), plant height (76.50%), cob length (82.20%), cob girth (72.00%), number of kernel rows per cob (68.40%), number of kernels per row (64.70%), 100 seed weight (86.40%), grain yield per plant (75.00%) and grain yield per hectare (63.40%) showed higher heritability, whereas, ear height (47.00%) and shelling percentage (39.30%) showed moderate heritability. Broad sense heritability ranged from 39.30 per cent (shelling percentage) to 86.40 per cent (100 seed weight).

4.3.3 Genetic advance as per cent of mean (GAM)

The genetic advance expressed as percentage of mean values ranged from 2.16 to 31.73 per cent (Table 3). The days to 50 per cent tasseling (3.31%), days to 50 per cent silking (3.11%), days to 75 per cent dry husk (2.84%), cob girth (8.28%) and shelling percentage (2.16%) showed low magnitude of GAM. While, the characters plant height (15.02%), ear height (16.71%), cob length (18.36%), number of kernel rows per cob (10.65%) and number of kernels per row (12.93%) showed moderate magnitude of GAM. High magnitude of GAM recorded for the characters 100 seed weight (21.71%), grain yield per plant (31.73%) and grain yield per hectare (24.62%).

4.4 Character association and path coefficient analysis

4.4.1 Correlation Analysis

Among all traits, selection for seed yield is a complex phenomenon that involved interaction among different growth and yield contributing character of a genotype. In the present investigation an attempt was made to understand association of different traits at population level contributing towards yield improvement. The phenotypic and genotypic correlation of grain yield per plant with 12 other yield components among S_6 lines worked out and same is presented in Table 5 and Fig. 2.

The different characters under study revealed that seed yield exhibited significant positive correlation with few yield traits, but also exhibited significant negative association with few other traits. The results obtained on the basis of association of individual trait with grain yield are presented below.

4.4.1.1 Days to 50 per cent tasseling

The data revealed highly significant positive phenotypic and genotypic association with days to 50 per cent silking (0.92 and 0.91) and days to 75 per cent dry husk (0.50 and 0.51). Number of rows per cob (0.07 and 0.03), shelling percentage (0.01 and 0.06) and 100 seed weight (0.01 and 0.01) recorded non-significant positive phenotypic and genotypic association.

Negative significant genotypic association with plant height (-0.17), ear height (-0.24) and number of kernels per row (-0.17), while, cob length (-0.07) and cob girth (-0.01) were negatively non-significant association. Phenotypic coefficient of correlation had positive non-significant for plant height (0.10), cob length (0.04), cob girth (0.03) and number of kernels per row (0.03) whereas, ear height (0.18) exhibited positive significant association at 0.05 per cent of probability level.

4.4.1.2 Days to 50 per cent silking

A highly significant positive phenotypic and genotypic association with days to 50 per cent tasseling (0.50 and 0.51), days to 75 per cent dry husk (0.51 and 0.51). While number of kernel rows per cob (0.09 and 0.09) was recorded positive non-significant phenotypic and genotypic association respectively. A non-significant negative phenotypic and genotypic association with grain yield per plant (-0.06 and -0.14) whereas, ear height (0.22 and -0.30) was recorded significant positive phenotypic and negative genotypic association respectively. Negative significant genotypic association with plant height (-0.16) and number of kernels per row (-0.23) but plant height (0.09) and number of kernels per row (0.07) was found positive phenotypic association.

Table 4. Mean, range, genetic variability, heritability and genetic advance parameters for grain yield and its component traits in maize

Traits	Mean	Range	PCV (%)	GCV (%)	h^2bs (%)	GAM (%)
Days to 50 per cent tasseling	57.62	55.50 – 60.00	2.39	1.96	67.30	3.31
Days to 50 per cent silking	59.03	56.50 – 61.50	2.32	1.87	65.20	3.11
Days to 75 per cent dry husk	99.01	92.00 – 102.50	2.11	1.70	65.40	2.84
Plant height (cm)	169.92	131.50 – 202.00	9.54	8.34	76.50	15.02
Ear height (cm)	82.99	48.00 – 113.00	17.25	11.83	47.00	16.71
Cob length (cm)	15.45	11.05 – 18.84	10.84	9.83	82.20	18.36
Cob girth (cm)	14.13	11.10 – 15.55	5.58	4.74	72.00	8.28
Number of kernel rows per cob	13.68	11.20 – 16.40	7.56	6.25	68.40	10.65
Number of kernels per row	32.69	24.40 – 38.20	9.70	7.80	64.70	12.93
Shelling percentage	83.76	78.80 – 87.99	2.67	1.68	39.30	2.16
100 seed weight (g)	33.33	25.00 – 44.00	12.19	11.33	86.40	21.71
Grain yield per plant (g)	137.27	58.60 – 212.20	20.54	17.79	75.00	31.73
Grain yield per hectare (q)	28.69	14.17 – 41.78	18.86	15.01	63.40	24.62

PCV – Phenotypic coefficient of variation
GCV – Genotypic coefficient of variation
h^2bs – Heritability in broad sense
GAM – Genetic advance as per cent over mean

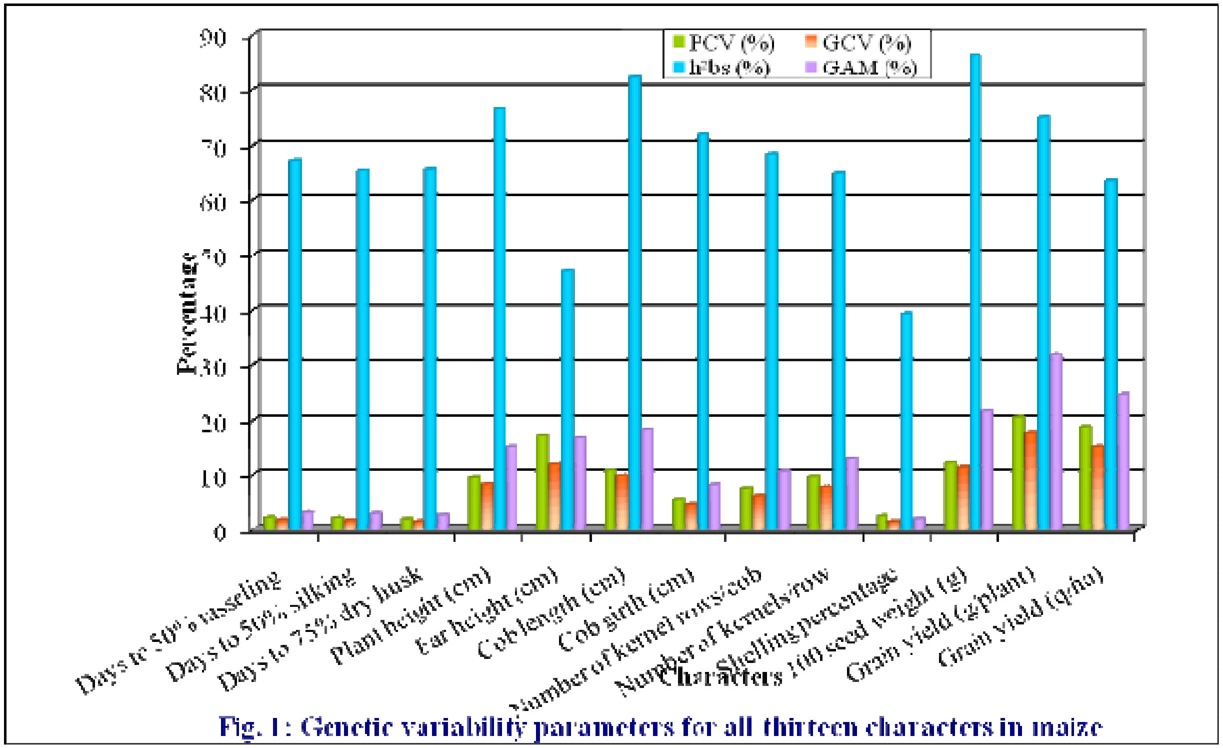


Fig. 1: Genetic variability parameters for all thirteen characters in maize

Table 5. Phenotypic and genotypic correlations among different quantitative traits in maize at Arabhavi

Characters		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1: Days to 50% tasselling	P	1.00	0.92**	0.50**	0.10	0.18*	0.04	0.03	0.07	0.03	0.01	0.01	0.02
	G	1.00	0.91**	0.51**	-0.17*	-0.24**	-0.07	-0.01	0.03	-0.17*	0.06	0.01	-0.09
X2: Days to 50% silking	P		1.00	0.51**	0.09	0.22**	0.05	0.03	0.09	0.07	0.06	0.02	-0.06
	G		1.00	0.51**	-0.16*	-0.30*	-0.08	-0.02	0.09	-0.23*	-0.04	-0.02	-0.14
X3: Days to 75% dry husk	P			1.00	0.13	0.03	0.05	0.15*	0.13	0.09	0.09	0.20**	0.12
	G			1.00	0.16*	-0.05	0.06	0.17*	-0.14	0.10	0.18*	0.31**	0.21**
X4: Plant height (cm)	P				1.00	0.61*	0.48**	0.45**	0.11	0.44**	0.04	0.40**	0.60**
	G				1.00	0.64*	0.60**	0.53**	0.17*	0.56**	0.01	0.47**	0.71**
X5: Ear height (cm)	P					1.00	0.33**	0.48**	0.10	0.40**	0.07	0.36**	0.50**
	G					1.00	0.36**	0.55**	0.13	0.46**	0.08	0.40**	0.55**
X6: Cob length (cm)	P						1.00	0.26**	0.11	0.67**	0.01	0.42**	0.60**
	G						1.00	0.33**	-0.10	0.78**	-0.07	0.49**	0.69**
X7: Cob girth (cm)	P							1.00	0.14	0.27**	0.06	0.43**	0.50**
	G							1.00	0.19*	0.31**	-0.07	0.54**	0.60**
X8: No. of rows per cob	P								1.00	0.13	0.03	0.13	0.16*
	G								1.00	-0.12	0.01	-0.17*	0.22**
X9: No. of kernels per row	P									1.00	0.21**	0.27**	0.58**
	G									1.00	0.13	0.32**	0.64**
X10: Shelling percentage	P										1.00	0.01	0.19*
	G										1.00	-0.01	0.28**
X11:100 seed weight (g)	P											1.00	0.65**
	G											1.00	0.72**
X12: Grain yield per plant (g)	P												1.00
	G												1.00

* Significant at 0.05 probability level   ** Significant at 0.01 probability level   P: phenotypic correlation   G: genotypic correlation

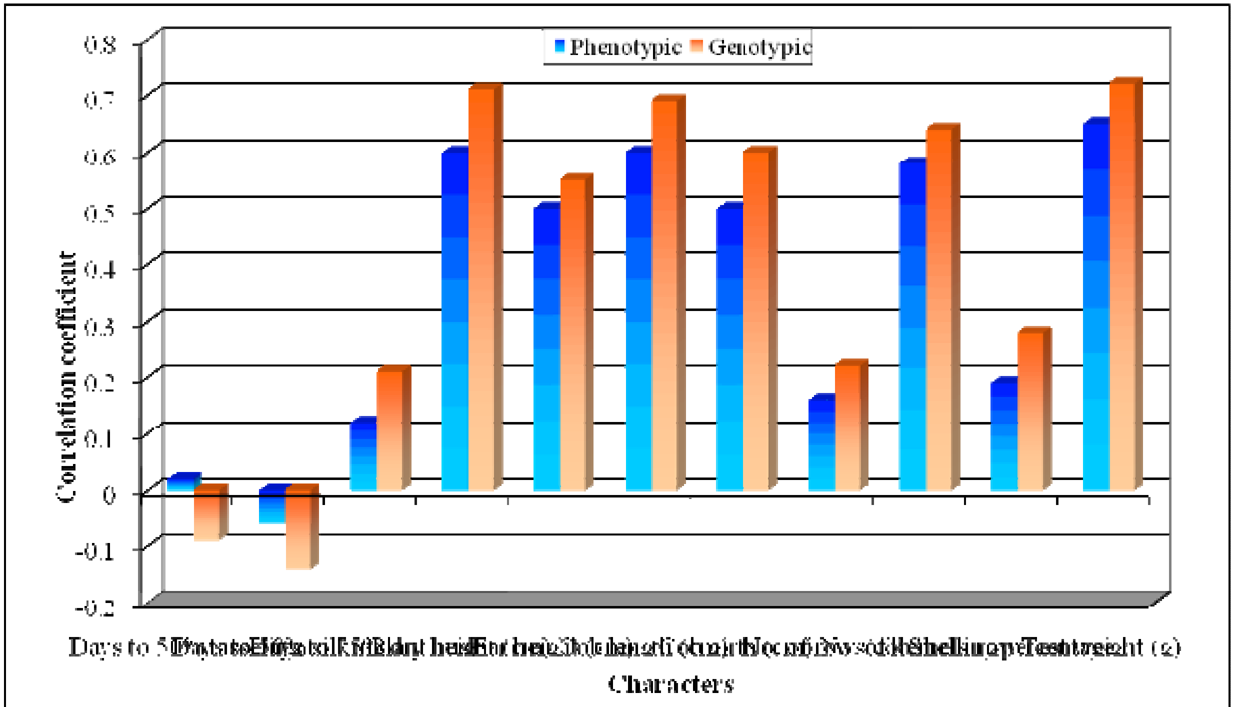


Fig. 2: Phenotypic and genotypic correlation coefficient of grain yield per plant

Fig. 2: Phenotypic and genotypic correlation coefficient of grain yield per plant with other twelve characters

4.4.1.3 Days to 75 per cent dry husk

Cob girth (0.15 and 0.17) and 100 seed weight (0.20 and 0.31) had positive significant phenotypic and genotypic association with days to 75 per cent dry husk. Positive non-significant phenotypic coefficient of correlation association with plant height (0.13), ear height (0.03), number of rows per cob (0.13), cob length (0.05), number of kernels per row (0.09), shelling percentage (0.09) and grain yield per plant (0.12). Grain yield per plant (0.21), shelling percentage (0.18) and plant height were observed positive significant genotypic association while, cob length (0.06), number of kernels per row (0.10), days to 50 per cent tasseling (0.10) and days to 50 per cent silking (0.09) exhibited positive non-significant. Days to 50 per cent tasseling (-0.17) and days to 50 per cent silking (-0.16) was found negative significant genotypic association whereas, ear height (-0.05) and number of rows per cob (-0.04) exhibited negative non-significant genotypic association.

4.4.1.4 Plant height (cm)

The result revealed positive highly significant phenotypic and genotypic association with ear height (0.61 and 0.64), cob length (0.48 and 0.60), cob girth (0.45 and 0.53), number of kernels per row (0.44 and 0.56), 100 seed weight (0.40 and 0.47) and grain yield per plant (0.60 and 0.71) Whereas, shelling percentage (0.04 and 0.01) recorded positive non-significant phenotypic and genotypic association. Days 50 per cent tasseling (-0.17) and days to 50 per cent silking (-0.16) was found negative significant whereas, days to 75 per cent dry husk (0.16) and number of rows per cob (0.17) exhibited positive significant genotypic association as five per cent significant level. Phenotypic coefficient of correlation had positive non-significant association with days to 50 per cent tasseling (0.10), days to 50 per cent silking (0.09), days to 75 per cent dry husk (0.13) and number of rows per cob (0.11).

4.4.1.5 Ear height (cm)

A significant phenotypic and genotypic association with plant height (0.61 and 0.64), cob length (0.33 and 0.36), cob girth (0.58 and 0.55), number of kernels per row (0.40 and 0.46), 100 seed weight (0.36 and 0.40) and grain yield per plant (0.50 and 0.55). While number of rows per cob (0.10 and 0.13) and shelling percentage (0.07 and 0.08) recorded positive non-significant phenotypic and genotypic association. A negatively significant genotypic association with days to 50 per cent silking (-0.30) and days to 50 per cent tasseling (-0.24) while, same traits exhibited positive significant phenotypic association of 0.22 and 0.18, respectively. Days to 75 per cent dry husk was found non-significant positive phenotypic (0.03) and negative genotypic association (-0.05).

4.4.1.6 Cob length (cm)

The result revealed positive highly significant genotypic and phenotypic association with ear height (0.36 and 0.33), plant height (0.60 and 0.48), cob girth (0.33 and 0.26), number of kernels per row (0.78 and 0.67), 100 seed weight (0.49 and 0.42) and grain yield per plant (0.69 and 0.60) Whereas, Days to 75 per cent dry husk (0.06 and 0.05) was recorded positive non-significant genotypic and phenotypic association. Number of rows per cob (-0.10 and 0.11), shelling percentage (-0.07 and 0.01), days to 50 per cent silking (-0.08 and 0.05) and days to 50 per cent tasseling (-0.07 and 0.04) were recorded negatively genotypic non-significant and positive phenotypic association.

4.4.1.7 Cob girth (cm)

Majority of the traits exhibited positive significant phenotypic and genotypic association with cob girth While, days to 50 per cent silking (-0.01 and 0.03) and days to 50 per cent tasseling (-0.01 and 0.03) was recorded negatively non-significant genotypic and positively phenotypic association. A significant positive phenotypic association was recorded with number of rows per cob (0.19) and also recorded positive non-significant genotypic (0.14) association.

4.4.1.8 Number of kernel rows per cob

The result revealed most of the traits were recorded positive and negative non-significant phenotypic and genotypic association except grain yield per plant (0.22 and 0.16) was recorded positive significant phenotypic and genotypic association.

4.4.1.9 Number of kernels per row

The characters *viz.,* 100 seed weight (0.32 and 0.27), grain yield per plant (0.64 and 0.58), cob girth (0.31 and 0.27), cob length (0.78 and 0.67), ear height (0.46 and 0.40) and plant height (0.56 and 0.44) was recorded positive highly significant genotypic and phenotypic association, but days to 75 per cent dry husk (0.10 and 0.09) exhibited positive non-significant association. Days to 50 per cent tasseling (-0.17 and 0.03) and days to 50 per cent silking (-0.23 and 0.07) had negative significant genotypic association and positive phenotypic non-significant association. Positive significant phenotypic coefficient (0.21) and non-significant genotypic coefficient (0.13) had associated with shelling percentage.

4.4.1.10 Shelling percentage

From the results of the present study, it is clear that characters *viz*., days to 50 per cent tasseling (0.06 and 0.01), plant height (0.01 and 0.04), ear height (0.08 and 0.07) and number of rows per cob (0.03 and 0.01) was recorded positive non-significant genotypic and phenotypic association with shelling percentage. But grain yield per plant (0.27 and 0.17) exhibited positive significant association. Days to 50 per cent silking (-0.04 and 0.06), cob length (-0.07 and 0.01) and 100-seed weight (-0.01 and 0.01) was recorded negatively non-significant genotypic and phenotypic association. Days to 75 per cent dry husk (0.18) and number of kernels per row (0.21) was recorded positive significant genotypic and phenotypic association respectively.

4.4.1.11 100 seed weight (g)

Majority of traits exhibited positive significant phenotypic and genotypic association with 100 grain weight except days to 50 per cent tasseling (0.01 and 0.01) was recorded positive non-significant association of both phenotypic and as well as genotypic direction. Shelling percentage (-0.01 and 0.01) and days to 50 per cent silking (-0.01 and 0.01) was recorded negative genotypic and positive phenotypic non-significant association. Number of rows per cob was recorded positive phenotypic non-significant (0.13) and negative genotypic significant association (-0.17).

4.4.1.12 Grain yield per plant (g)

Grain yield per plant was recorded positive significant genotypic and phenotypic association with 100 seed weight (0.72 and 0.65), plant height (0.71 and 0.60), cob length (0.69 and 0.60), number of kernels per row (0.64 and 0.58), cob girth (0.60 and 0.50), ear height (0.55 and 0.50), shelling percentage (0.28 and 0.19), number of kernel rows per cob (0.22 and 0.16) and days to 75 per cent dry husk (0.21 and 0.12). Days to 50 per cent silking (-0.06 and -0.14) was recorded negative non-significant phenotypic and genotypic association while, days to 75 per cent dry husk had positive phenotypic (0.02) and negative (-0.09) non-significant genotypic coefficient of correlation.

4.4.2 Path coefficient analysis

To get the idea about the actual effects of a character on the yield, path analysis was employed. When a dependent character like yield is to be improved, which were governed by many independent characters through direct or indirect effects of other characters. Hence, sometimes even character showing significant correlation with the yield may not be considered for improvement as its correlation with yield may be due to the indirect effects of this trait through other characters. Under these circumstances, it is always more appropriate to split the correlation value into direct and indirect effects through path coefficient analysis. This would facilitate the results weightage to be given while considering a character for selection to improve economic yield. Path coefficient values showing direct and indirect effects of components traits on grain yield per plants are presented in the Table 6.

4.4.2.1 Direct effects of different component characters on grain yield per plant

The result revealed that, among the characters studied, the 100 seed weight had highest positive direct effect of 0.44 and 0.47 both phenotypic and as well as genotypic correlation on grain yield per plant respectively followed by number of kernel rows per cob (0.24, 0.33), cob length (0.17, 0.29), shelling percentage (0.12, 0.28), plant height (0.15, 0.12), cob girth (0.09, 0.12), days to 50 per cent silking (0.02, 0.01) and days to 75 per cent dry husk (0.01, 0.04), while the direct contribution to grain yield per plant by days to 50 per cent tasseling (-0.03, -0.11) was negative. The direct contribution of ear height to grain yield per plant was positive in phenotypic correlation (0.01) and negative in genotypic correlation (-0.05).

4.4.2.2 Indirect effects of different characters on grain yield per plant

4.4.2.2.1 Days to 50 per cent tasseling

Positive indirect effect of this character through ear height (0.01, 0.03), plant height (0.01, 0.02), number of kernels per row (0.01, 0.02), cob length (0.01, 0.01), cob girth (0.01, 0.01), number of rows per cob (0.01, 0.01) and 100-seed weight (0.01, 0.01) in negligible magnitude, while it had negative indirect effect via days to 50 per cent silking (-0.03, -0.10) and days to 75 per cent dry husk (-0.02, -0.05) which is negligible in both phenotypic and genotypic correlation.

Table 6. Direct (diagonal) and indirect effects of grain yield component traits on grain yield per plant at phenotypic and genotypic level in maize at Arabhavi

Characters		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
X1: Days to 50 per cent tasselling	P	-0.03	-0.03	-0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.02
	G	-0.11	-0.10	-0.05	0.02	0.03	0.01	0.01	0.01	0.02	-0.01	0.01	-0.09
X2: Days to 50 per cent silking	P	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.06
	G	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-0.14
X3: Days to 75 per cent dry husk	P	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.12
	G	0.02	0.02	0.04	0.01	0.01	0.01	0.01	-0.01	0.01	0.01	0.01	0.21
X4: Plant height (cm)	P	-0.02	-0.01	0.02	0.15	0.09	0.07	0.07	0.02	0.07	0.01	0.06	0.60
	G	-0.02	-0.02	0.02	0.12	0.08	0.07	0.06	0.02	0.07	0.01	0.06	0.71
X5: Ear height (cm)	P	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50
	G	0.01	0.02	0.01	-0.03	-0.05	-0.02	-0.03	-0.01	-0.02	0.01	-0.02	0.55
X6: Cob length (cm)	P	-0.01	-0.01	0.01	0.08	0.06	0.17	0.04	-0.02	0.11	0.01	0.07	0.60
	G	-0.02	-0.02	0.02	0.17	0.10	0.29	0.09	-0.03	0.22	-0.02	0.14	0.69
X7: Cob girth (cm)	P	0.01	0.01	0.01	0.04	0.04	0.02	0.09	0.01	0.02	0.01	0.04	0.50
	G	0.01	0.01	0.02	0.06	0.07	0.04	0.12	0.02	0.04	-0.01	0.07	0.60
X8: No. of rows per cob	P	0.02	0.02	-0.03	0.03	0.03	-0.03	0.03	0.24	-0.03	0.01	-0.03	0.16
	G	0.01	0.03	-0.04	0.06	0.04	-0.03	0.06	0.33	-0.04	0.01	-0.06	0.22
X9: No. of kernels per row	P	-0.01	-0.02	0.02	0.11	0.10	0.16	0.07	-0.03	0.24	0.05	0.07	0.58
	G	-0.03	-0.04	0.02	0.09	0.07	0.12	0.05	-0.02	0.16	0.02	0.05	0.64
X10: Shelling percentage	P	0.01	-0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.12	0.01	0.19
	G	0.02	-0.01	0.05	0.01	0.02	-0.02	-0.02	0.01	0.04	0.28	0.01	0.28
X11: 100 seed weight (g)	P	0.01	-0.01	0.09	0.18	0.16	0.18	0.19	-0.06	0.12	0.01	0.44	0.65
	G	0.01	-0.01	0.14	0.22	0.19	0.23	0.25	-0.08	0.15	-0.01	0.47	0.72

Note: P: phenotypic correlation G: genotypic correlation P residual effect= 0.5133 G residual effect= 0.2488
X12: grain yield per plant

4.4.2.2.2 Days to 50 per cent silking

Indirect contribution of this character on grain yield was positive through all traits in both phenotypic and as well as in genotypic correlation in negligible magnitude.

4.4.2.2.3. Days to 75 per cent dry husk

This trait contributed positively to grain yield through all characters in lower magnitude except number of rows per cob (-0.01) was found negative genotypic correlation.

4.4.2.2.4 Plant height (cm)

This trait also contribute positively negligible magnitude in most of traits except days to 50 per cent tasseling (-0.02, -0.02) and days to 50 per cent silking (-0.01, -0.02) had negative indirect effects on grain yield in phenotypic and genotypic level.

4.4.2.2.5 Ear height (cm)

This trait contributed negatively to the grain yield through plant height (-0.03), cob length (-0.02), cob girth (-0.03), number of rows per cob (-0.01), number of kernels per row (-0.02) and 100 seed weight (-0.02) while, it contributed positively via days to 50 per cent tasseling (0.01), days to 50 per cent silking (0.02), days to 75 per cent dry husk (0.01) and shelling percentage (0.01) was negligible in genotypic correlation. Phenotypic correlation all traits had positive indirect effects on grain yield in negligible magnitude.

4.4.2.2.6 Cob length (cm)

Majority of characters contributed positively to the grain yield in lower magnitude in both phenotypic and genotypic correlation except days to 50 per cent tasseling (-0.01, -0.02), days to 50 per cent silking (-0.01, -0.02) and number of kernel rows per cob (-0.02, -0.03).

4.4.2.2.7 Cob girth (cm)

All traits contributed positively to the grain yield in lower magnitude both phenotypic and genotypic correlation while it contributed positively via shelling percentage (0.01) in phenotypic correlation but it had negative contribution in genotypic correlation (-0.01) in negligible magnitude.

4.4.2.2.8 Number of kernel rows per cob

Indirect contribution of this character to a grain yield was positive through days to 50 per cent tasseling (0.02, 0.01), days 50 per cent silking (0.02, 0.03), plant height (0.03, 0.06), ear height (0.03, 0.04), cob girth (0.03, 0.06) and shelling percentage (0.01, 0.01). It had negative indirect phenotypic and genotypic effect on grain yield through days to 75 per cent dry husk (-0.03, -0.04), cob length (-0.03, -0.03), number of kernels per row (-0.03, -0.04) and 100 seed weight (-0.03, -0.06).

4.4.2.2.9 Number of kernels per cob

Highest positive indirect contribution of this character was through cob length (0.16, 0.12) followed by plant height (0.11, 0.09), ear height (0.10, 0.07), cob girth (0.07, 0.05), 100 seed weight (0.07, 0.05), shelling percentage (0.05, 0.02) and days to 75 per cent dry husk (0.02, 0.02). It had negative indirect phenotypic and genotypic effects through days to 50 per cent tasseling (-0.01, -0.03), days to 50 per cent silking (-0.02, -0.04) and number of kernel rows per cob (-0.03, -0.02).

4.4.2.2.10 Shelling percentage

The Phenotypic correlation of this trait had negative contribution to grain yield in most of the traits except days to 50 per cent silking (-0.01) and it was negligible. Genotypic correlation exhibited positive indirect effects in majority of the traits except days to 50 per cent silking (-0.01), cob length (-0.02) and cob girth (-0.02).

4.4.2.2.11 Hundred seed weight (g)

Though it had a highest direct effect on grain yield (0.44, 0.47), positive indirect contribution was made through other characters *viz.*, cob girth (0.19, 0.25), cob length (0.18, 0.23), plant height (0.18, 0.22), ear height (0.16, 0.19), number of kernels per row (0.12, 0.15), days to 75 per cent dry husk (0.09, 0.14) and days to 50 per cent tasseling (0.01, 0.01). 100-seed weight also exhibited negative indirect effect on grain yield through days to 50 per cent silking of -0.01 and -0.01 both as genotypic and phenotypic coefficients but it was negligible.

4.5 Stability analysis

4.5.1 Influence of different environments on different phenotypic characters (Mean Performance)

The data collected on different character in each of the 12 lines and three checks of maize lines were analyze location wise to find out performance of each genotypes across location. The mean values, range and environmental indices for different traits across different location are presented in Table 7, Fig. 3 and Plate 1-2b.

4.5.1.1 Days to 50 per cent tasseling

Out of three locations, the mean was maximum at Arabhavi (57.13) followed by Dharwad (55.64), while minimum was at Mandya (53.24). The maximum range was observed in Arabhavi (56.33 to 59.00) and minimum range was observed in Mandya (50.00 to 55.00). The environmental indices ranged from -2.10 at Mandya to 1.79 at Arabhavi.

4.5.1.2 Days to 50 per cent silking

Number of days taken by the plant to bear 50 per cent silking was maximum at Arabhavi (58.27) and minimum at Mandya (54.84). The range for this character was maximum at Arabhavi (57.33 to 61.00) whereas, minimum was observed at Mandya (52.00 to 57.00) and environmental indices ranged from -1.92 at Mandya to 1.50 at Arabhavi.

4.5.1.3 Days to 75 per cent dry husk

Out of three locations, the mean was maximum at Dharwad (100.58) followed by Arabhavi (99.40), while minimum was at Mandya (92.40). The maximum range was observed in Dharwad (97.00 to 103.67) and minimum range was observed in Mandya (90.00 to 94.00). The environmental indices ranged from -5.06 at Mandya to 3.12 at Dharwad.

4.5.1.4 Plant height (cm)

Overall mean of genotypes for plant height was maximum at Mandya (199.62) followed by Arabhavi (183.96), whereas, in Dharwad it was minimum (178.80). The maximum range was observed in Mandya location (193.00 to 211.00) and minimum range was observed in Dharwad (165.00 to 190.00). The environmental indices ranged from -8.66 at Dharwad to 12.16 at Mandya.

4.5.1.5 Ear height (cm)

Mean ear height was maximum at Mandya (110.20) while minimum was observed at Arabhavi (96.00). The range for this character was maximum at Mandya (98.00 to 120.33). While minimum was at Arabhavi (85.00 to 105.00). The environmental indices ranged from -4.93 at Arabhavi to 9.27 at Mandya.

4.5.1.6 Cob length (cm)

Average length of the cob was maximum at Arabhavi (17.12), while minimum at Dharwad (15.44). The maximum range was recorded at Mandya (13.50 to 19.00) whereas, minimum range was observed at Dharwad (13.43 to 17.30). The environmental indices ranged from -1.09 at Dharwad to 0.59 at Arabhavi.

4.5.1.7 Cob girth (cm)

Overall mean of genotypes for cob girth was maximum at Mandya (15.27), while minimum was observed at Dharwad (13.93). Maximum range for this character was observed in Mandya (14.00 to 16.15) and minimum range was at Dharwad (12.97 to 15.00). The environmental indices ranged from -0.68 at Dharwad to 0.02 at Arabhavi.

4.5.1.8 Number of kernel rows per cob

Average number of kernel rows per cob was maximum at Mandya (14.37) and minimum was recorded at Arabhavi (13.67). The maximum range was recorded at Dharwad (12.67 to 15.80) and minimum range was observed at Arabhavi (12.33 to 15.00) and the environment indices range of -0.36 and 0.34 at Arabhavi and Mandya respectively.

Table 7. Mean, Range and Environmental index for traits in maize at different locations

Traits	Mean			Range			Environmental Index		
	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD
Days to 50 per cent tasseling	57.13	53.24	55.64	56.33 – 59.00	50.00 – 55.00	52.33 - 58.67	1.79	-2.10	0.30
Days to 50 per cent silking	58.27	54.84	57.18	57.33 – 61.00	52.00 – 57.00	53.33 - 60.67	1.50	-1.92	0.42
Days to 75 per cent dry husk	99.40	92.40	100.58	92.67 – 102.00	90.00 – 94.00	97.00 - 103.67	1.94	-5.06	3.12
Plant height (cm)	183.96	199.62	178.80	166.3 – 201.00	193.00 – 211.00	165.00 – 190.00	-3.50	12.16	-8.66
Ear height (cm)	96.00	110.20	96.60	85.00 – 105.00	98.00 - 120.33	90.00 – 108.00	-4.93	9.27	-4.33
Cob length (cm)	17.12	17.03	15.44	14.86 - 18.67	13.50 – 19.00	13.43 - 17.30	0.59	0.50	-1.09
Cob girth (cm)	14.64	15.27	13.93	13.86 - 15.64	14.00 - 16.50	12.97 – 15.00	0.02	0.66	-0.68
Number of kernel rows per cob	13.67	14.37	14.06	12.33 – 15.00	12.93 - 15.73	12.67 - 15.80	-0.36	0.34	0.02
Number of kernels per row	36.18	36.33	32.11	32.90 - 38.27	32.67 - 39.27	29.93 – 37.00	1.30	1.46	-2.76
Shelling percentage	83.60	85.24	82.41	80.96 - 85.86	82.72 - 86.98	78.74 - 85.90	-0.15	1.49	-1.34
100 seed weight (g)	37.12	39.34	28.86	30.00 – 44.00	34.33 - 43.67	20.83 - 34.67	2.02	4.24	-6.25
Grain yield per plant (g)	168.92	178.56	103.76	134.00 – 196.00	149.00 - 206.33	76.20 – 128.00	18.51	28.15	-46.65
Grain yield per hectare (q)	34.64	35.74	29.05	26.33 – 37.62	29.96 – 41.96	18.83 – 38.51	1.49	2.59	-4.09

ARB: Arabhavi MAN: Mandya DWD: Dharwad

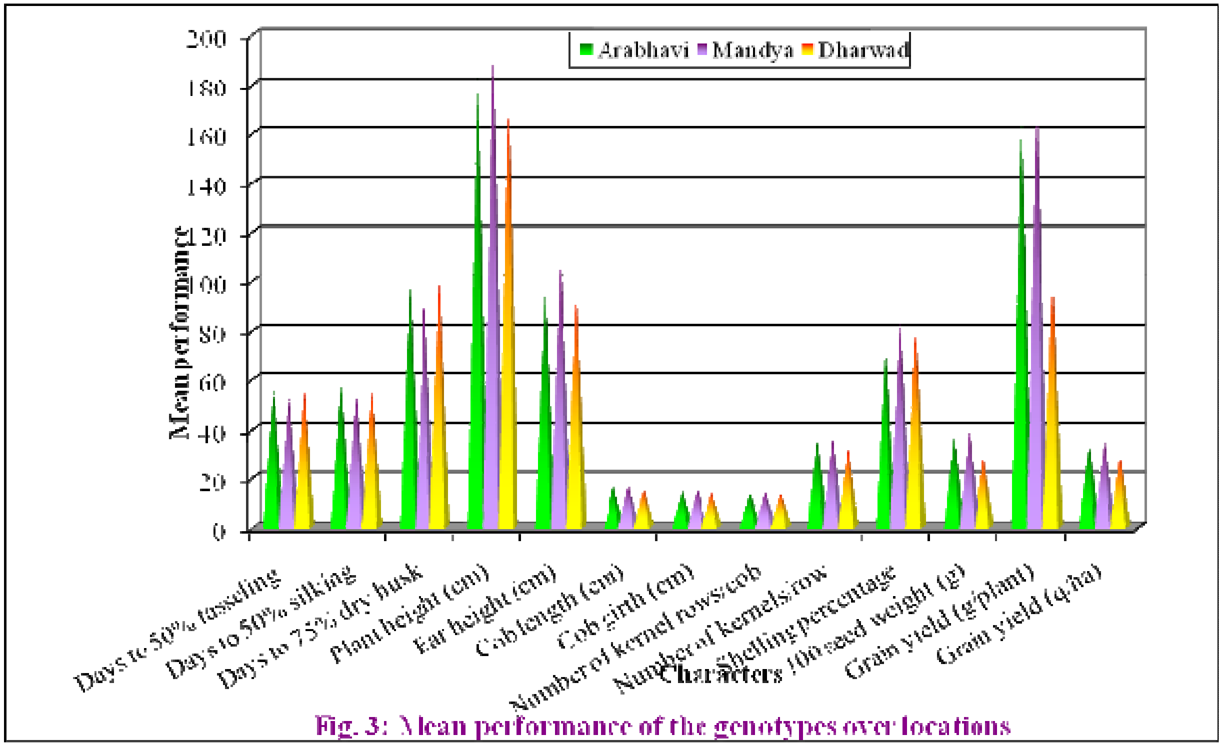


Fig. 3: Mean performance of the genotypes over locations

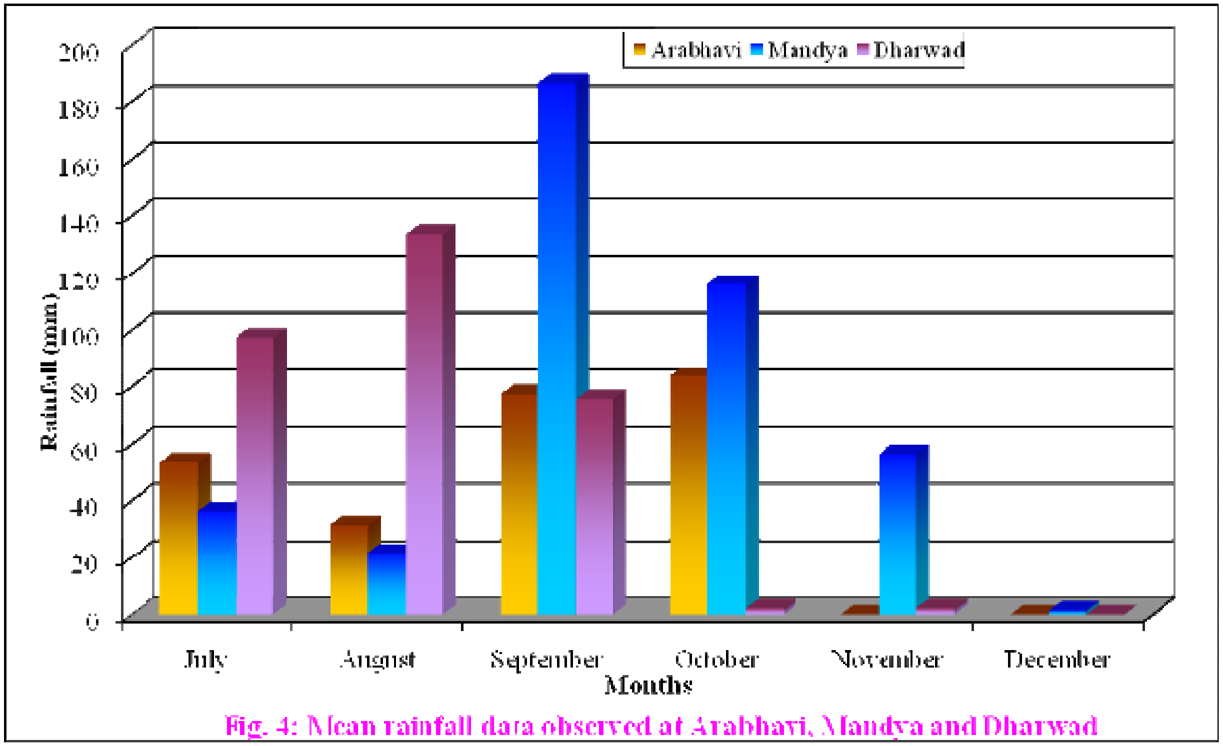


Fig. 4: Mean rainfall data observed at Arabhavi, Mandya and Dharwad

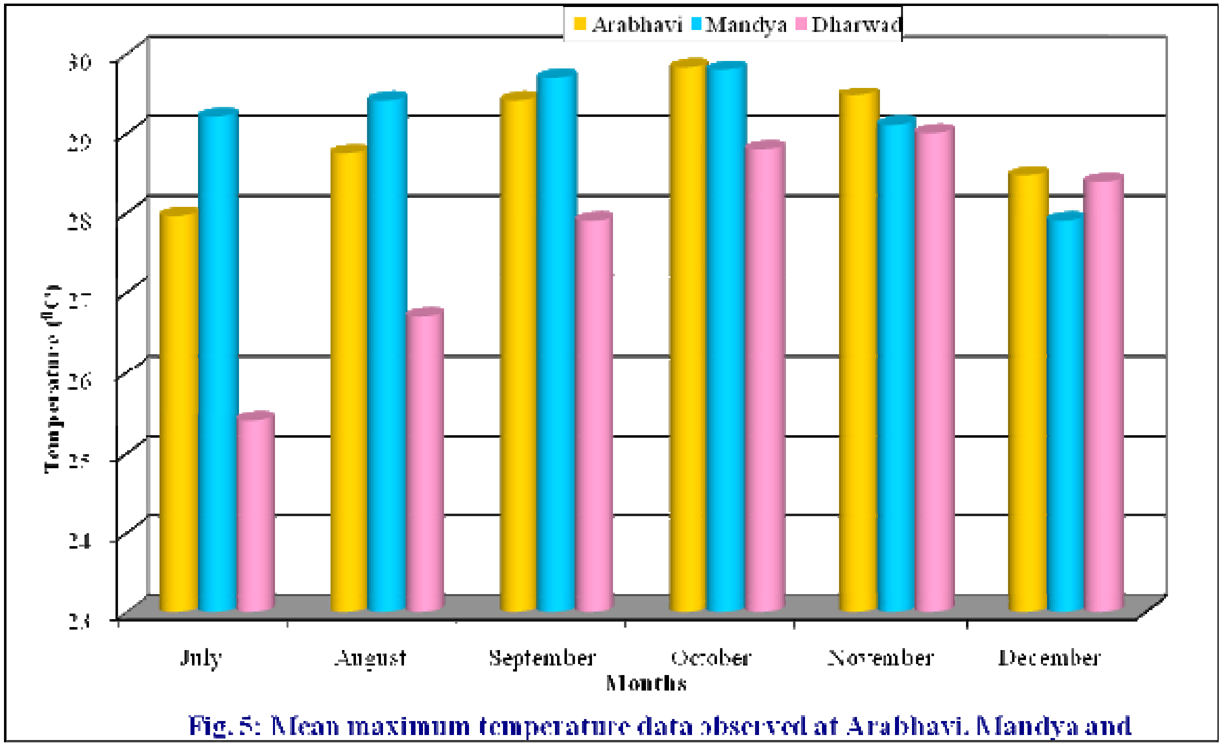
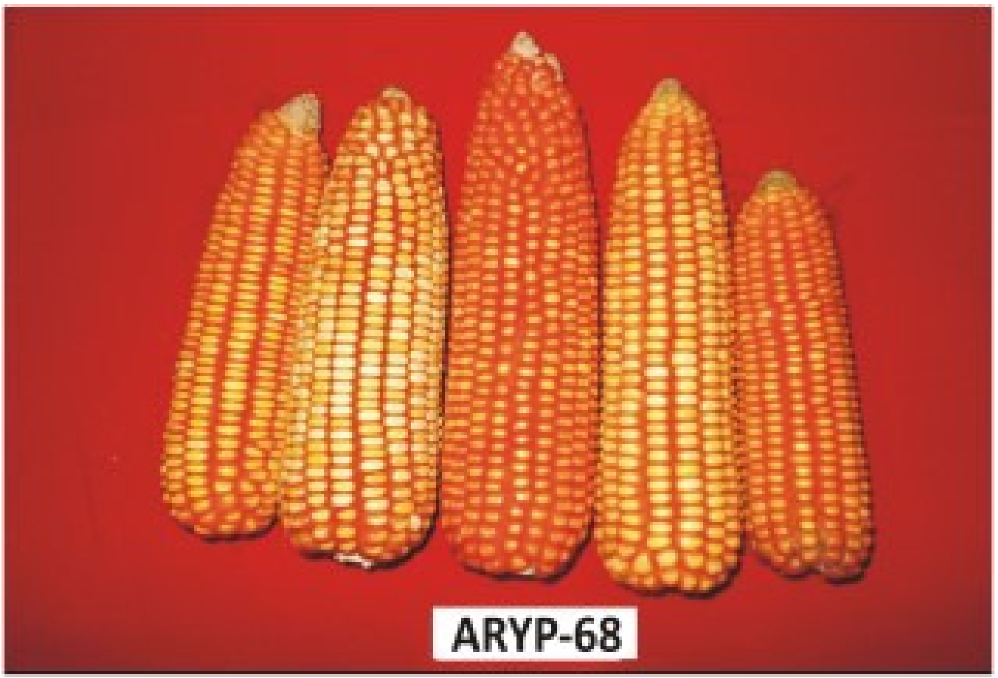


Fig. 5: Mean maximum temperature data observed at Arabhavi, Mandya and Dharwad

Plate2a: Best performance over locations



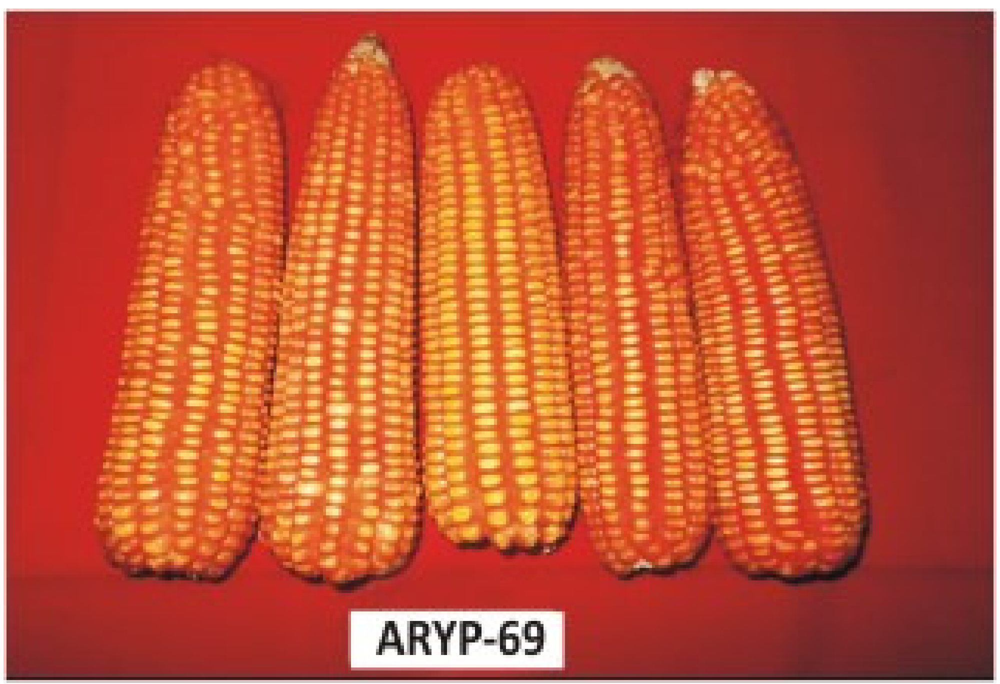


Plate 2b: Best performance over locations

4.5.1.9 Number of kernels per row

Maximum mean values for number of kernels per row was recorded in plant at Mandya (36.33) followed by Arabhavi (36.18) and Dharwad (32.11). The range for this character was highest at Mandya (32.67 to 39.27) while, lowest range was recorded at Dharwad (29.93 to 37.00). The environmental indices ranged from -2.76 at Dharwad to 1.46 at Mandya.

4.5.1.10 Shelling percentage

Overall mean of genotypes for shelling percentage was maximum at Mandya (85.24), while minimum was observed at Dharwad (82.41). Maximum range for this character was observed in Mandya (82.72 to 86.98) and minimum range was at Arabhavi (80.96 to 85.86). The environmental indices ranged of -1.34 and 1.49 at Dharwad and Mandya respetively.

4.5.1.11 100 seed weight (g)

The average 100-seed weight was maximum at Mandya (39.34), while, minimum was recorded at Dharwad (28.86). The maximum range was observed at Mandya (34.33 to 43.67) while, the range was minimum at Dharwad (20.83 to 34.67). The environmental indices ranged from -6.25 at Dharwad to 4.24 at Mandya.

4.5.1.12 Grain yield per plant (g)

Out of three locations, maximum average value for grain yield per plant was recorded at Mandya (178.56) whereas, minimum was at Dharwad (103.76). The range of this character was maximum at Mandya (149.00 to 206.33) while, minimum was recorded at Dharwad (76.20 to 128.00). The environmental indices ranged from -46.65 at Dharwad to 28.15 at Mandya.

4.5.1.13 Grain yield (q/ha)

Mean grain yield per hectare was maximum at Mandya (35.74) while, minimum was observed at Dharwad (29.05). The maximum range was recorded at Mandya (29.96 to 41.96) whereas, minimum range was observed at Arabhavi (26.33 to 37.51). The environmental indices ranged from -4.09 at Dharwad to 2.59 at Mandya.

4.5.2 Analysis of Variance

Location wise analysis of variance was carried out for 13 quantitative characters to partition the total variance (mean sum of squares) due to known and unknown causes were worked out using the method suggested by Panse and Sukhatme (1961). The analysis of variance for grain yield and its component characters under study indicated highly significant variation among the S_6 lines for all the characters across three locations (Table 8).

4.5.3 Pooled Analysis of Variance

Pooled analysis of variance was carried out for 13 quantitative characters to partition the total variance (mean sum of squares) due to known and unknown causes were worked out using the method suggested by Sundararaj *et al.* (1972). The analysis of variance for grain yield and its component characters under study indicated highly significant variation among the genotypes, environments and genotype x environment for all the characters across three locations (Table 9) permits for stability analysis.

4.5.4 Analysis of variance for performance stability

Eberhart and Russell (1996) model of stability analysis was used for the assessment of environment influence and genotype × environment interaction on genotype for each character. When the genotype × environment interaction were significant for the characters, then partitioning of total sum of squares due to genotype × environment interactions into predictable and unpredictable source of variations was done using the procedure given by Eberhart and Russell (1966).

Analysis of variance for stability of 13 different characters over three locations are given in Table 10. Genotypic pooled differences over environments were significant for all the characters. Variance due to environments and environments (linear) was significant for all the characters. G × E was significant for all the characters except cob length and cob girth whereas, G x E (linear) were found to be significant at both five and one per cent level of significance for number of kernels per row, shelling percentage and grain yield per hectare. As regard to pooled deviation was significant for all the characters, which indicated the non-linear unpredictable portion of G x E interaction when tested against pooled error.

Table 8. Analysis of variance for grain yield and other quantitative characters at three locations in maize

Traits	Sources of variation								
	Replications (MSS)			Genotypes (MSS)			Error (MSS)		
	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD
Days to 50 per cent tasseling	0.46	0.15	0.15	1.84**	5.4**	9.06**	0.22	0.15	0.46
Days to 50 per cent silking	0.466	0.15	0.42	3.67**	6.42**	10.61**	0.228	0.13	0.54
Days to 75 per cent dry husk	0.46	0.06	0.15	14.24**	5.05**	9.68**	0.37	0.49	0.60
Plant height (cm)	1.07	29.62	2.51	295.27**	73.61**	147.41**	1.15	16.81	2.45
Ear height (cm)	0.06	5.60	0.2	119.38**	93.51**	61.58**	0.69	4.10	1.50
Cob length (cm)	0.16	9.59	0.05	4.66**	7.11**	3.27**	0.12	7.19	0.16
Cob girth (cm)	0.03	0.04	0.44	0.68**	1.01**	1.51**	0.08	0.11	0.15
Number of kernel rows per cob	0.001	0.14	0.05	1.21**	1.98**	2.38**	0.02	0.06	0.07
Number of kernels per row	0.01	0.10	0.01	10.20**	10.40**	10.55**	0.02	0.07	0.18
Shelling percentage	0.13	0.41	0.38	8.80**	3.88**	14.57**	0.25	0.19	0.46
100 seed weight (g)	0.62	1.37	0.27	50.91**	23.82**	46.08**	0.34	0.71	0.36
Grain yield per plant (g)	21.95	0.95	20.14	1160.7**	1115.60**	878.62**	17.68	0.38	29.24
Grain yield per hectare (q)	0.09	1.37	2.88	30.26**	42.39**	105.12**	0.98	1.66	2.01

ARB: Arabhavi MAN: Mandya DAR: Dharwad

* Significant at 0.05 probability level ** Significant at 0.01 probability level

Table 9. Analysis of variance for pooled data for thirteen quantitative traits in maize over three locations

Source	d.f.	Mean sum of squares												
		Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Percent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
Environments	2	173.25**	137.56**	879.47**	5291.92**	2902.20**	40.22**	20.22**	5.57**	257.92**	90.57**	1374.70**	74498.80**	578.34**
Replications in Environments	4	0.30	0.43	0.24	8.24	2.39	2.60	0.16	0.08	0.04	0.07	0.90	5.34	0.65
Genotype	14	10.06**	14.68**	13.51**	350.14**	146.98**	5.57**	2.00**	3.83**	12.71**	20.58**	67.82**	2249.83**	134.89**
Genotype x Environments	28	3.13**	3.02**	7.74**	83.09**	63.75**	4.74**	0.60**	0.88**	9.23**	3.34**	26.50**	452.56**	21.44**
Error	84	0.28	0.30	0.49	6.81	2.10	2.49	0.12	0.06	0.09	0.30	0.47	15.77	1.55

* Significant at 0.05 probability level ** Significant at 0.01 probability level

Table 10. Analysis of variance for performance stability in S_6 lines of maize for thirteen quantitative traits over three locations

Sources	d.f.	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Percent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
Inbreds	14	3.35**	4.89**	4.50**	116.71**	48.99**	1.85**	0.66**	1.27**	4.23**	6.86**	22.60**	749.94**	44.96**
Env.+ (Inbred × Env.)	30	4.82	3.99	21.95	143.447	84.32	2.37	0.63	0.39	8.60	3.05	38.79	1796.32	19.52
Environments	2	57.75**	45.85**	293.15**	1763.97**	967.40**	13.40*	6.73**	1.85**	85.97**	30.18**	458.23**	24832.93**	192.77**
Inbred × Env.	28	1.37**	1.18*	2.58**	30.70**	21.24*	1.58	0.20	0.29**	3.07**	1.11**	8.99**	198.35**	7.14**
Environments (Linear)	1	115.50**	91.70**	586.31**	3527.94**	1934.7**	26.81**	13.47**	3.71**	171.94**	60.37**	916.46**	49665.87**	385.54**
Inbred × Env. (Linear)	14	0.62	0.74	2.54	22.49	18.70	0.90	0.13	0.38	3.81**	1.56**	8.03	89.19	8.40**
Pooled Deviation	15	1.04**	1.01**	2.44**	27.69*	22.20 **	2.11**	0.25**	0.18**	2.17**	0.61**	8.83**	150.85**	5.50**
Pooled Error	84	0.09	0.10	0.16	2.26	0.70	0.83	0.03	0.01	0.03	0.10	0.15	5.25	0.51
Total	**44**	**4.35**	**4.28**	**16.40**	**134.94**	**73.08**	**2.20**	**0.64**	**0.67**	**7.21**	**4.26**	**33.64**	**1463.38**	**27.61**

* Significant at 0.05 probability level ** Significant at 0.01 probability level

Table 11a. Stability parameters for days to 50 per cent tasseling, days to 50 per cent silking and days to 75 per cent dry husk

Lines	Days to 50 per cent tasseling				Days to 50 per cent silking				Days to 75 per cent dry husk			
	μ	S²di	bi	rank	μ	S²di	bi	rank	μ	S²di	bi	Rank
ARYP-68	54.33	7.09**	0.56	13	55.33	7.65**	0.54	13	94.22	11.23**	0.51	15
ARYP-69	54.77	4.32**	0.84	9	56.22	3.51**	0.72	9	96.55	0.22	1.02	2
ARYP-70	55.77	0.64**	0.82	10	57.44	0.12	0.64	11	97.88	1.11**	1.34	12
ARYP-71	54.88	0.33*	1.00	2	56.44	0.22	0.83	7	97.44	4.36**	0.83	10
ARYP-72	54.33	0.05	1.01	3	55.33	0.24	1.12	3	97.55	0.35	0.85	9
ARYP-73	55.11	2.00**	1.27	11	56.11	1.31**	1.46	14	98.33	-0.03	1.00	1
ARYP-74	53.77	-0.04	1.36	12	55.44	-0.10	1.27*	8	96.22	2.71**	0.60	13
ARYP-75	55.11	0.01	0.96	4	56.77	0.36*	0.84	6	98.55	0.64*	0.92	6
ARYP-76	56.22	0.03	0.53	14	57.55	0.38*	0.55	12	99.22	2.79**	1.07	5
ARYP-77	55.00	-0.09	1.11	6	56.55	-0.10	0.98	2	98.22	-0.06	1.04	3
ARYP-78	55.44	0.49*	0.89	5	56.77	0.36*	0.84	5	97.33	1.79**	0.89	7
ARYP-79	54.55	2.43**	1.62	15	55.66	1.28**	1.76	15	96.55	0.16	1.31	11
Checks												
CI-4	56.00	0.15	0.88	7	57.00	0.02	1.00	1	97.44	0.11	1.46	14
CM-111	57.33	0.55*	1.15	8	59.33	0.22	1.31	10	97.66	9.00**	1.05	4
KDMI-16	57.44	1.20**	1.00	1	59.44	0.77**	1.15	4	98.66	-0.11	1.12	8
Population Mean	**55.34**				**56.76**				**97.45**			

* Significant at 0.05 probability level ** Significant at 0.01 probability level **μ-** Overall mean **bi** – Regression coefficient
S²di – Deviation from regression

Plate 3a: Stable S_6 lines over locations

Plate 3b: Stable S_6 lines over locations

4.5.5 Stability parameters

The three stability parameters *viz.,* mean ($\bar{X}$), regression coefficient (b_i) and deviation from linear regression line (S^2_{di}) were estimated for all the 13 traits and the same has been present in the Table 11a – 11d and Plate 3a-3b.

4.5.5.1 Days to 50 per cent tasseling

The data on location wise mean days to 50 per cent tasseling for 12 S_6 lines and three checks studied is presented in Table 11a. Out of 12 S_6 lines, the line ARYP-76 required maximum number of days to 50 per cent tasseling (56.22 days) while, the line ARYP-74 exhibited minimum number of days to 50 per cent tasseling (53.77 days). In check CI- 4 (56.00 days) required minimum number of days to 50 per cent tasseling while, KDMI-16 (57.44 days) required maximum number of days 50 per cent tasseling and mean over three environments was 55.34 days.

All the lines had regression values were not significantly deviating from unity. The mean deviations from regression values were significantly different from zero for the lines ARYP-68, ARYP-69, ARYP-70, ARYP-71, ARYP-73, ARYP-78, ARYP-79 and the checks CM-111 and KDMI-16 (inbreds). The lines ARYP-72, ARYP-75, ARYP-74 and ARYP-77 were found to have lower mean days to 50 per cent tasseling than population mean with bi and S^2_{di} values not significantly different from unity but lineARYP-76 and checks CI-4, CM-111 and KDMI-16 were found higher mean days to 50 per cent tasseling than population mean.

4.5.5.2 Days to 50 per cent silking

Mean values and stability parameters for this trait were presented in Table 11a. The mean value of the this character indicated that line ARYP-76 required maximum number of days to 50 per cent silking (58.00 days) and minimum number of days to 50 per cent silking was recorded by lines ARYP-68 and ARYP-72 (55.33 days) while, in checks, CI-4 recorded minimum number of days to 50 per cent silking (57.00 days) and KDMI-16 required maximum number of days to 50 per cent silking (59.00 days) and mean across lines was 57.00 days. All the S_6 lines had regression value not significantly deviating from unity except genotype ARYP-74. The mean deviations from regression values were significantly different from zero for the lines ARYP-68, ARYP-69, ARYP-73, ARYP-75, ARYP-76, ARYP-78, ARYP-79 and the check KDMI-16. The lines ARYP-71, ARYP-72, ARYP-74 and ARYP-77 were found to have lower mean value than population mean with bi and S^2_{di} values not significantly different from unity while, ARYP-70 and the checks CI-4 and KDMI-16 were found higher mean days to 50 per cent silking than population mean.

4.5.5.3 Days to 75 per cent dry husk

The data on location wise mean days to 75 per cent dry husk for 12 S_6 lines studied is presented in Table 11a. Out of 12 S_6 lines, the line ARYP-76 required maximum number of days to 75 per cent dry husk (99.22 days) while, the line ARYP-68 exhibited minimum number of days to 75 per cent dry husk (94.22 days). In checks, KDMI-16 required maximum number of days to 75 per cent dry husk (98.66 days) while, CI-4 exhibited minimum number of days to 75 per cent dry husk was 97.44 days and mean over three environments was 97.00 days.

All the S_6 lines had regression value not significantly deviating from unity. The lines ARYP-68, ARYP-70, ARYP-71, ARYP-74, ARYP-75, ARYP-76, ARPY-78 and CM-111 (check) had mean deviations from regression values were significantly different from zero. The test S_6 lines ARYP-69, ARYP-79 and the check CI-4 were found to have lower mean days to 75 per cent dry husk than population mean with bi and S^2di values not significantly different from unity. Whereas, the lines ARYP-72, ARYP-73, ARYP-77 and the check KDMI-16 were found higher mean value than population mean with bi and S^2di values not significantly different from unity.

4.5.5.4 Plant height (cm)

The stability parameters bi and S^2di for plant height for the S_6 lines across locations along with mean values are presented in Table 11b. The S_6 line ARYP-77 with mean plant height of 201.11 cm was the tallest and the line ARYP-78 with a mean plant height of 184.11 cm was the shortest among genotype tested. In checks, CM-111 (182.77 cm) recorded maximum plant height and KDMI-16 (176.44 cm) recorded minimum plant height while, the average plant height over genotypes was 187.45cm. None of the S_6 lines had the significant regression values either lower or higher than unity while, all the lines except ARYP-70, ARYP-71, ARYP-75, ARYP-79 and the checks CI-4 and CM-111 had significant deviation from regression. The lines ARYP-68, ARYP-69, ARYP-74, ARYP-76 and ARYP-77 were found higher mean plant height than population mean with S^2d_i values significantly different from zero.

Table 11b. Stability parameters for plant height, ear height and cob length

Lines	Plant height (cm)				Ear height (cm)				Cob length (cm)			
	μ	S²di	bi	rank	μ	S²di	bi	rank	μ	S²di	bi	rank
ARYP-68	188.22	11.41*	1.27	11	101.88	16.31**	0.83	5	17.74	-0.81	1.33	8
ARYP-69	190.66	15.01**	0.40	15	101.44	22.4**	0.90	3	16.49	12.84**	-0.61	15
ARYP-70	187.33	0.82	0.49	14	96.33	18.65**	0.19	15	17.38	-0.17	1.15	6
ARYP-71	193.00	0.93	1.26	10	101.44	46.31**	1.63	14	17.45	-0.79	0.73	7
ARYP-72	186.00	37.44**	0.84	7	97.66	13.92**	0.67	10	16.80	-0.80	2.18	13
ARYP-73	186.44	61.72**	0.90	4	98.44	24.26**	1.01	1	16.33	-0.79	1.53	10
ARYP-74	190.11	69.40**	0.98	2	102.55	36.52**	1.04	2	16.53	-0.60	-0.23	14
ARYP-75	192.44	4.30	0.80	9	111.00	1.61	0.87	4	16.28	-0.77	0.98	2
ARYP-76	190.66	32.69**	0.94	3	100.11	81.67**	0.82	6	16.10	-0.84	1.66	12
ARYP-77	201.11	19.50**	0.89	6	107.00	32.85**	1.42	12	17.34	-0.79	1.50	9
ARYP-78	184.11	128.95**	1.18	8	101.22	0.26	1.20	7	16.34	4.19*	1.12	4
ARYP-79	185.77	-2.24	1.00	1	100.66	-0.10	0.72	9	14.60	-0.84	1.08	3
Checks												
CI-4	176.77	2.04	1.46	12	95.11	12.18**	1.55	13	15.64	-0.85	0.44*	11
CM-111	182.77	6.04	1.10	5	101.77	-0.56	0.78	8	16.33	0.38	1.14	5
KDMI-16	176.44	37.11**	1.48	13	97.33	16.37**	1.38	11	16.48	9.58**	1.01	1
Population Mean	**187.45**				**100.93**				**16.53**			

* Significant at 0.05 probability level ** Significant at 0.01 probability level **μ-** Overall mean **bi** – Regression coefficient
S²di – Deviation from regression

Table 11c. Stability parameters for cob girth, no. of kernels row per cob and no. of kernels per row

Lines	Cob girth (cm)				No. of kernels row per cob				No. of kernels per row			
	μ	S^2di	bi	rank	μ	S^2di	bi	rank	μ	S^2di	bi	rank
ARYP-68	14.80	0.22*	0.54	11	13.13	0.26**	1.68	8	36.82	0.46**	1.34	10
ARYP-69	15.06	0.13*	0.66	8	13.28	-0.02	0.57	4	34.86	0.02	1.31	7
ARYP-70	15.02	0.6**	0.48	13	14.62	-0.02	2.09*	12	35.46	1.13**	1.20	6
ARYP-71	15.23	-0.04	0.65	10	14.35	-0.02	2.09*	11	34.62	3.82**	0.69	9
ARYP-72	14.05	0.00	1.12	4	13.75	0.13**	1.19	2	35.33	0.28**	1.64	14
ARYP-73	14.65	-0.03	1.03	1	13.73	-0.02	1.51	6	35.88	2.43**	0.96	2
ARYP-74	14.29	0.21*	0.38	15	13.22	0.38**	-1.69	15	34.88	2.42**	-0.78	15
ARYP-75	14.24	0.13*	0.88	3	14.51	0.04	-1.59	14	36.53	0.18*	1.02	1
ARYP-76	15.57	-0.04	1.34	9	15.28	0.09*	1.75	9	35.06	0.99**	1.49	13
ARYP-77	14.22	0.19*	1.21	5	13.91	0.05	0.6	3	35.53	0.19**	0.86	4
ARYP-78	14.96	1.25**	1.03	2	15.08	0.62**	2.56	13	33.84	4.02**	1.43	12
ARYP-79	14.13	-0.04	1.56*	14	13.77	1.06**	0.07	10	32.28	-0.01	0.83	5
Checks												
CI-4	14.28	-0.01	1.28	6	13.51	-0.01	1.13	1	33.31	0.76**	0.92	3
CM-111	14.15	0.50**	1.31	7	14.08	0.00	1.5	5	34.71	-0.02	0.69	8
KDMI-16	14.47	0.13*	1.51	12	14.22	0.01	1.54	7	33.93	15.56**	1.41	11
Population Mean	**14.61**				**14.03**				**34.87**			

* Significant at 0.05 probability level ** Significant at 0.01 probability level **μ-** Overall mean **bi** – Regression coefficient
S^2di – Deviation from regression

Table 11d. Stability parameters for shelling percentage, 100-seed weight, grain yield per plant and grain yield per hectare

Lines	Shelling percentage				100 seed weight (g)				Grain yield per plant (g)				Grain yield per hectare (q)			
	μ	S^2di	bi	rank	μ	S^2di	Bi	rank	μ	S^2di	bi	rank	μ	S^2di	bi	rank
ARYP-68	82.07	0.91**	2.14	15	36.33	0.07	1.35	10	152.90	39.80**	1.10	9	35.79	-0.11	1.54	10
ARYP-69	81.36	-0.03	0.85	2	40.72	3.52**	0.97	1	171.93	81.87**	0.97	2	38.84	16.03**	0.21	13
ARYP-70	82.73	0.20	1.38	7	34.72	6.92**	0.67	9	167.38	-5.17	0.94	6	34.23	21.92**	0.69	3
ARYP-71	81.73	0.56*	0.73	6	37.88	5.64**	0.45	15	167.15	36.83**	0.82	11	37.67	-0.04	0.17	14
ARYP-72	83.99	0.10	0.74	5	35.72	24.35**	1.21	3	142.08	51.05**	1.19	12	33.24	3.96**	1.34	5
ARYP-73	85.40	0.07	0.01	13	36.33	0.32	0.76	4	156.87	71.09**	0.91	8	35.86	0.69	0.70	2
ARYP-74	82.73	0.92**	1.62	10	37.27	17.35**	0.73	6	147.05	231.47**	0.62	15	33.60	6.76**	0.52	8
ARYP-75	84.91	0.00	0.81	4	30.22	4.01**	0.68	8	139.90	-2.25	0.91	7	31.32	0.74	1.75	12
ARYP-76	86.17	0.01	0.32	12	34.88	2.83**	1.55	14	167.65	7.39	1.24	14	34.80	0.51	0.48	9
ARYP-77	84.36	2.41**	1.16	3	35.05	10.35**	1.05	2	144.99	132.05**	1.15	10	31.16	5.26**	1.84	15
ARYP-78	84.80	0.00	0.50	9	36.11	1.82**	0.73	7	168.94	138.03**	1.05	5	37.55	1.10	0.53	7
ARYP-79	85.50	0.14	0.88	1	33.33	12.75**	1.27	5	130.58	-5.22	0.95	4	30.77	-0.50	0.90	1
Checks																
CI-4	84.35	-0.10	0.37*	11	34.83	3.32**	0.64	11	132.22	236.37**	0.96	3	29.20	16.61**	1.31	4
CM-111	82.19	-0.09	2.04*	14	30.00	0.11	1.45	12	122.17	75.96**	1.00	1	25.17	2.13*	1.60	11
KDMI-16	83.93	2.60**	1.47	8	33.16	39.03**	1.50	13	144.26	1807.64**	1.20	13	27.95	-0.26	1.44	6
Population Mean	**83.75**				**35.10**				**150.41**				**33.14**			

* Significant at 0.05 probability level ** Significant at 0.01 probability level **μ-** Overall mean **bi** – Regression coefficient **S^2di** – Deviation from regression

4.5.5.5 Ear height (cm)

Mean across locations along with corresponding bi and S^2di value for each S_6 lines in respect of ear height are presented in Table 11b. The mean ear height across S_6 lines was 100.93 cm. The maximum (111.00 cm) and minimum (96.33 cm) ear height were recorded in the lines ARYP-75 and ARYP-70, respectively and in checks, maximum (101.77 cm) and minimum (95.11 cm) ear height were recorded CM-111 and CI-4, respectively.

All the lines had the non-significant regression values either lower or higher than unity. The lines ARYP-75, ARYP-79 and the check CM-111 had significantly deviation from regression. The lines ARYP-70, ARYP-72, ARYP-73, ARYP-76 and the checks CI-4 and KDMI-16 was shown lowest mean value than population mean with S^2di values significantly different from zero.

4.5.5.6 Cob length (cm)

Mean across genotypes and stability parameters for cob length are presented in Table 11b. Among 12 S_6 lines tested over three environments, the lines ARYP-68 and ARYP-79 exhibited maximum (17.74 cm) and minimum (14.60 cm) cob length, respectively and among checks, maximum (16.48 cm) and minimum (15.64 cm) cob length were recorded by KDMI-16 and CI-4, respectively. The mean cob length over lines was 16.53 cm. The check CI-4 showed significant regression coefficient (bi) value from unity and deviation from regression was significant from zero for the lines ARYP-69, ARYP-78 and the check KDMI-16. The lines ARYP-68, ARYP-70, ARYP-71, ARYP-72, ARYP-74 and ARYP-77 were found to have higher mean value than population mean with bi and S^2di values not significantly different from unity and zero, respectively (Fig. 6).

4.5.5.7 Cob girth (cm)

Mean cob girth across the locations and stability parameters for each lines are presented in Table 11c. The maximum (15.57 cm) and minimum (14.05 cm) cob girth were shown by line ARYP-76 and ARYP-72, respectively. The mean cob girth over three environments was 14.61 cm. All S_6 lines had differed non-significant for regression coefficient values from unity except line ARYP-79. While, the lines ARYP-68, ARYP-69, ARYP-70, ARYP-74, ARYP-75, ARYP-77, ARYP-78 and the checks CM-111 and KDMI-16 showed significant deviation from regression. The lines ARYP-71 and ARYP-73 were found to have higher mean value than population mean with bi and S^2di values not significantly different from unity and zero, respectively.

4.5.5.8 Number of Kernel rows per cob

The stability parameters for number of kernel rows per cob are presented in Table 13. Among the 12 S_6 lines tested over three environments, line ARYP-76 and ARYP-68 exhibited maximum (15.28) and minimum (13.13) number of kernel rows per cob, respectively and in checks, KDMI-16 and CI-4 exhibited maximum (14.22) and minimum (13.51) number of kernel rows per cob, respectively. The mean number of kernel rows per cob over lines was 14.03 cm.

The line ARYP-70 and ARYP-71 had higher mean value than population mean and regression value significantly deviating from unity. The deviations from regression values were significantly from zero for the lines ARYP-68, ARYP-72, ARYP-74, ARYP-76, ARYP-78 and ARYP-79. The lines ARYP-69, ARYP-73, ARYP-77 and CI-4 (check) were found to have lower mean than population mean with bi and S^2di values not significantly different from unity and zero, respectively.

4.5.5.9 Number kernels per row

The stability parameters for number of kernels per row are presented in table 11c. Among the 12 S_6 lines tested over three environments, ARYP-68 and ARYP-79 exhibited maximum (36.82) and minimum (32.28) number of kernels per row, respectively and in checks, CM-11and CI-4 exhibited maximum (34.71) and minimum (33.31) number of kernels per row, respectively. The mean number of kernels per row over lines was 34.87 cm. None of the lines had the significant regression coefficient value either lower or higher than unity. While, all the S_6 lines had S^2di values significantly different from zero except ARYP-69, ARYP-79 and CM-111. The lines ARYP-68, ARYP-70, ARYP-72, ARYP-73, ARYP-74, ARYP-75, ARYP-76 and ARYP-77 were found higher mean than population mean with S^2di values significantly different from zero.

4.5.5.10 Shelling percentage

The stability parameters for shelling percentage are presented in table 11d. Among the 12 S_6 lines tested over three environments, the lines ARYP-76 and ARYP-69 exhibited maximum (86.17%)

and minimum (81.36%) shelling percentage, respectively and in checks, CI-4 and CM-111 exhibited maximum (84.35%) and minimum (82.19%) shelling percentage, respectively. The mean shelling percentage over lines was 83.75per cent. The checks CI-4 and CM-111 had regression value significantly deviating from unity. The deviations from regression values were significantly from zero for the lines ARYP-68, ARYP-71, ARYP-74, ARYP-77 and KDMI-16 (check). The lines ARYP-72, ARYP-73, ARYP-74, ARYP-75, ARYP-78 and ARYP-79 were found to have higher mean than population mean with bi and S^2di values not significantly different from unity and zero.

4.5.5.11 100 seed weight (g)

Stability parameters in respect of 100 seed weight are presented in table 11d. Maximum (40.72 g) and minimum (30.22 g) 100 grain weight was recorded by lines ARYP-69 and ARYP-75, respectively and in check inbreds, maximum (34.83 g) and minimum (30.00 g) 100 seed weight was recorded by CI-4 and CM-111 respectively. While, population mean for 100 seed weight was 35.10 g.

Among twelve S_6 lines, none of the lines showed significant difference for unity. While, most of the S_6 lines showed S^2di values significantly different from zero except lines ARYP-68, ARYP-73 and CM-111. The lines ARYP-68, ARYP-69, ARYP-71, ARYP-72, ARYP-73, ARYP-74 and ARYP-78 were found to have higher mean value than population mean (Fig. 7).

4.5.5.12 Grain yield per plant (g)

Stability parameters for grain yield per plant are presented in Table 14. The S_6 line ARYP-69 recorded the highest (171.93 g) while, the line ARYP-12 recorded the lowest (130.58 g) mean value for grain yield per plant and in checks, KDMI-16 recorded the highest (144.26 g) while, CM-111 recorded the lowest (122.17 g) mean value for grain yield per plant. The average grain yield per plant over three environments was 150.41 g. None of the lines had the significant regression coefficient values either lower or higher than unity. While all the S_6 lines had S^2di values significantly different from zero except ARYP-70, ARYP-75, ARYP-76 and ARYP-79. The lines ARYP-68, ARYP-69, ARYP-71, ARYP-73 and ARYP-78 were found to have higher mean value than population mean with bi values not significantly different from unity, while, the lines ARYP-70 and ARYP-76 exhibited higher mean value than population mean grain yield per plant with bi and S^2di values not significantly different from unity and zero (Fig. 8).

4.5.5.13 Grain yield per hectare (q)

Stability parameters for grain yield per hectare are presented in Table 11d. The S_6 line ARYP-69 recorded the highest (38.84 q) while, the line ARYP-79 recorded the lowest (30.77 q) mean value for grain yield per hectare and in check inbreds, CI-4 recorded the highest (29.20 q) while, CM-111 recorded the lowest (25.17 q) mean value for grain yield per hectare. The average grain yield per hectare over three environments was 33.14 (q).

None of S_6 lines had the significant regression coefficient values either lower or higher than unity. The lines ARYP-69, ARYP-70, ARYP-72, ARYP-74, ARYP-77 and the checks CI-4 and CM-111 exhibited significant deviation from regression for zero. The lines ARYP-68, ARYP-69, ARYP-70, ARYP-71, ARYP-72, ARYP-73, ARYP-74, ARYP-76 and ARYP-78 were found higher mean than population mean but the lines ARYP-69, ARYP-70, ARYP-72 and ARYP-74 showed significant deviation from regression (S^2d_i).

4.6 Genetic variability, heritability and genetic advance over locations

To understand the extent to which the observed variations are due to genetic factors, genetic variability estimates including genotypic and phenotypic coefficient of variation, heritability in broad sense and genetic advance as per cent mean in respect of these characters were computed over a locations and are presented in Table 12.

4.6.1 Days to 50 per cent tasseling

The GCV and PCV were low in all three location *viz.,* Arabhavi (1.29, 1.53), Mandya (2.48, 2.59) and Dharwad (3.04, 3.28). The heritability estimate was highest in Mandya (91.80%) followed by Dharwad (86.00%) and Arabhavi (70.20%). The genetic advance as per cent mean had lower of 2.22, 4.90 and 5.82 at Arabhavi, Mandya and Dharwad respectively.

Table 12. Genetic variability, heritability and genetic advance parameters for grain yield and its component traits in S_6 lines of maize at different locations

Traits	PCV (%)			GCV (%)			h^2bs (%)			GAM (%)		
	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD
Days to 50 per cent tasseling	1.53	2.59	3.28	1.29	2.48	3.04	70.20	91.80	86.00	2.22	4.90	5.82
Days to 50 per cent silking	2.02	2.72	3.45	1.84	2.64	3.20	83.40	94.10	86.10	3.46	5.28	6.13
Days to 75 per cent dry husk	2.25	1.54	1.90	2.16	1.34	1.73	92.60	75.40	83.30	4.29	2.39	3.25
Plant height (cm)	5.41	3.00	3.99	5.38	2.18	3.89	98.80	53.00	95.20	11.02	3.27	7.81
Ear height (cm)	6.61	5.28	4.80	6.55	4.95	4.63	98.30	87.90	93.00	13.38	9.57	9.20
Cob length (cm)	7.48	4.85	7.09	7.19	3.99	6.60	92.40	82.13	86.50	14.24	2.82	12.64
Cob girth (cm)	3.62	4.20	5.60	3.06	3.58	4.83	71.30	72.70	74.40	5.32	6.29	8.58
Number of kernel rows per cob	4.75	5.85	6.55	4.62	5.56	6.24	94.60	90.20	90.60	9.25	10.88	12.23
Number of kernels per row	5.11	5.16	5.94	5.09	5.11	5.79	99.40	97.80	94.90	10.46	10.41	11.62
Shelling percentage	2.11	1.40	2.76	2.02	1.30	2.63	91.70	86.40	91.00	3.98	2.49	5.17
100 seed weight (g)	11.17	7.38	13.69	11.06	7.05	13.53	98.00	91.50	97.70	22.56	13.90	27.55
Grain yield per plant (g)	11.82	10.80	17.03	11.56	10.80	16.22	95.60	99.90	90.60	23.27	22.23	31.81

ARB: Arabhavi MAN: Mandya DWD: Dharwad
PCV – Phenotypic coefficient of variation GCV – Genotypic coefficient of variation,
h^2_{bs} – Heritability in broad sense GAM – Genetic advance as per cent over mean.

4.6.2 Days 50 per cent silking

The GCV (1.84, 2.64 and 3.20) and PCV (2.02, 2.72 and 3.45) were in lower magnitude. It showed highest heritability of 83.40 per cent, 94.10 per cent and 86.10 per cent and lowest genetic advance as per cent mean such as 3.46, 5.28 and 6.13 in Arabhavi, Mandya and Dharwad respectively.

4.6.3 Days to 75 per cent dry husk

The GCV (2.16, 1.34 and 1.73) and PCV (2.25, 1.54 and 1.90) were exhibited lower value coupled with high heritability (92.60%, 75.40% and 83.30%). The GAM was observed lower in all three locations (4.29, 2.39 and 3.25).

4.6.4 Plant height (cm)

The variability parameters, genotypes recorded lower value for both GCV (5.38, 2.18 and 3.89) and PCV (5.41, 3.00 and 3.99). The heritability estimates higher in Arabhavi (98.80%) and Dharwad (95.20%) while moderate in Mandya (53.00%). The GAM was observed moderate in Arabhavi (11.02) whereas lower in Mandya (3.27) and Dharwad (7.81).

4.6.5 Ear height (cm)

Lower GCV (6.55, 4.95 and 4.63) and PCV (6.61, 5.28 and 4.80) and highest heritability (98.30%, 87.90% and 93.00%) values were observed on this character. The GAM was lower in Mandya (9.57) and Dharwad (9.20) while moderate in Arabhavi (13.38).

4.6.6 Cob length (cm)

The cob length exhibited lower GCV (7.19, 3.99 and 6.60) and PCV (7.48, 4.85 and 7.09) and coupled with higher heritability (92.40%, 82.13% and 86.50%) in all three locations. Moderate genetic advance as per cent mean were recorded in Arabhavi (14.24) and Dharwad (12.64) whereas, low in Mandya (2.82).

4.6.7 Cob girth (cm)

The genetic parameters *viz.,* GCV (3.06, 3.58 and 4.83), PCV (3.62, 4.20 and 5.60) and GAM (5.32, 6.29 and 8.58) exhibited lower values coupled with higher (71.30%, 72.70% and 74.40%) heritability estimates over a location.

4.6.8 Number of kernel rows per cob

The genotypes recorded lowest GCV (4.62, 5.56 and 6.24) and PCV (4.75, 5.85 and 6.55) and coupled with higher heritability (94.60%, 90.20% and 90.60%). Lower GAM was recorded in Arabhavi (9.25) while moderately exhibited in Mandya (10.88) and Dharwad (12.23).

4.6.9 Number of kernels per row

GCV (5.09, 5.11 and 5.79) and PCV (5.11, 5.16 and 5.94) were found to be low. Further heritability estimate (99.40%, 97.80% and 94.90%) for this trait was high coupled with moderate (10.46, 10.41 and 11.62) GAM in all three locations.

4.6.10 Shelling percentage

Lowest GCV (2.02, 1.30 and 2.63), PCV (2.11, 1.40 and 2.76) and GAM (3.98, 2.49 and 5.17) coupled with high heritability (91.70%, 86.40% and 91.00%) were recorded for this character over a location.

4.6.11 Hundred seed weight (g)

In Arabhavi moderate GCV (11.06), PCV (11.17) coupled with high heritability (98.00%) and GAM (22.56) was recorded for this trait. Low phenotypic (7.38) and genotypic (7.05) coefficients of variation were recorded and high heritability (91.50%) with moderate genetic advance as per cent mean (13.90) was also noticed for this trait in Mandya. Moderate PCV (13.69), GCV (13.53) coupled with high heritability (97.70%) and GAM (27.55) was observed in Mandya.

Table 13. Reaction of newly derived S_6 lines of maize against turcicum leaf blight

Genotype	Disease reaction (1-5 scale)		
	ARB	MAN	DWD
ARYP-68	3	2	3
ARYP-69	3	2	3
ARYP-70	2	2	3
ARYP-71	3	2	3
ARYP-72	3	2	3
ARYP-73	3	2	3
ARYP-74	3	2	3
ARYP-75	2	2	3
ARYP-76	3	2	3
ARYP-77	3	3	4
ARYP-78	3	3	4
ARYP-79	3	2	4
Checks			
CI-4	3	2	3
CM-111	3	3	4
KDMI-16	3	2	3

ARB: Arabhavi MAN: Mandya DWD: Dharwad
1= Highly Resistant
2= Resistant
3= Moderately Resistant
4= Susceptible
5= Highly Susceptible

4.6.12 Grain yield per plant (g)

The genetic parameters like GCV (11.56, 10.80 and 16.22) and PCV (11.82, 10.80 and 17.03) values were moderate for this trait. However, highest heritability estimates (95.60%, 99.90% and 90.60%) and genetic advance as per cent mean (23.27, 22.23 and 31.81) were recorded over a location.

4.7 Screening of newly derived S_6 lines of maize against turcicum leaf blight at different locations

Totally 15 maize genotypes were screened against *Exserohilum turcicum* under natural epiphytotic condition during *kharif* 2013 at All India Co-ordinated Maize Improvement Project (AICMIP), Arabhavi, Zonal Agricultural Research Station (ZARS), Mandya and Main Agriculture Research Station (MARS), Dharwad as described in “Material and Methods” and results are presented in Table 13.

The data revealed that, among the 15 lines screened, none of the line showed highly resistant reaction over the location. At AICMIP, Arabhavi all the lines except ARYP-75 showed moderately resistant reaction (3 grade) whereas line ARYP-75 (2 grade) exhibited resistant reaction.

At ZARS, Mandya, 12 out of 15 lines exhibited resistant reaction (2 grade) and remaining three genotype *viz.,* ARYP-77, ARYP-78 and CM-111 (check) have shown moderately resistant (3 grade) reaction. At MARS, Dharwad, the disease pressure was more compared to other two locations, 11 out of 15 genotypes have sown moderately resistant reaction and remaining four lines *viz.,* ARYP-77, ARYP-78, ARYP-79 and CM-111 showed susceptible (4 grade) reaction.

DISCUSSION

Crop improvement largely depends on the extent of variability and its proper exploitation by the plant breeder. The plant breeder has to identify sources of favourable genes, incorporate them into breeding populations/lines and select for a combination of desirable traits that might result in the isolation of productive accessions/cultivars. To achieve these goals, plant breeders need to know the extent of variability present in a population. Evaluation of germplasm lines along with popular accessions is the first step towards the goal. This improvement in any crop is based on the extent of genetic variation and magnitude of available beneficial genetic variability. The proportion of genotypic, environmental variance and their interaction (G × E) can be determined by employing useful biometrical and genetical methods. Some of these parameters include genotypic (GCV) and phenotypic (PCV) coefficients of variation. High value of these coefficients indicates wider diversity. Similarly, narrow difference between GCV and PCV reveals low sensitivity to the environmental effects. Another indicator of variability is heritability, which is the ratio of genetic variance to total variance. This is broad sense heritability and gives an idea about that portion of observed variability which is attributable to genetic differences.

The estimates of heritability, however do not give indication of the amount of progress expected from the selection process. These estimates will be highly meaningful when accompanied by genetic advance (GA). GA is the measure of improvement that can be achieved by practicing selection. High genetic advance coupled with high heritability estimates is an indicator of high additive gene action.

The potential progress expected in accomplishing the objectives demands knowledge of interrelationships among various traits and component characters contributing to yield, which helps the breeder in the simultaneous improvement of several characters in the selection programme. Character associations may vary with environmental conditions. Association of economically important yield components of quantitative nature, which is statistically determined by correlation coefficient, is quite useful as a basis of selection. Path coefficient analysis is used to partition the association among characters into direct and indirect effects and measures the relative importance of the causal factors involved. It is simply a standardized partial regression coefficient and as such measures the direct influence of one variable upon another. The characters associated can be considered together as criteria for selection by plant breeders to identify traits that are useful as selection criteria to improve the crop yield.

The knowledge about the extent of fluctuations of yield and yield attributes over environments is very important to identify genotypes which are widely adapted. Grain yield is quantitatively inherited character and there is considerable interaction between genotypes and environments. Some of the crop varieties are widely adapted, whereas others do not. Multilocation testing of genotypes provides an opportunity to the plant breeders to study the adaptability of genotypes to a particular environment and the stability of the genotype over different environments. The information on genotype × environment interaction is of major importance to the plant breeder in developing improved stable varieties/hybrids. The ability of a genotype to produce a narrow range of phenotype in different environments can be called as stable. The genotypes will be stable in the absence of the environmental influence as well as genotype × environment interaction.

Eberhart and Russell (1966) model of stability analysis was used for the assessment of environmental influence and genotype × environmental interaction on genotypes for each character. When the genotype × environment interaction was significant for the characters, then partitioning of total sum of squares due to genotype × environment interactions into predictable and unpredictable source of variations was done using the procedure given by Eberhart and Russell (1966).

In the present investigation, 79 newly developed S_6 lines of maize were evaluated for various characters under fairly uniform and congenial environment. During this study, to assess the genotypic and phenotypic variability and to estimate heritability in broad sense along with genetic advance as per cent mean in respect of thirteen different characters. An attempt was also made to understand the association among various characters related to grain yield and to investigate the direct and indirect effects of certain yield attributes. Out of this based on morphological and yield traits, twelve S_6 generation lines are selected for stability analysis. The results obtained are discussed under the following heads.

5.1 Analysis of variance

5.2 *Per se* performance

5.3 Genetic parameters

5.4 Character association

5.5 Path coefficient analysis

5.6 Mean performance of lines in different locations

5.7 Stability analysis

5.8 Genetic variability, heritability and genetic advance as per cent mean at different location

5.9 Screening of newly derived S_6 lines of maize against turcicum leaf blight

5.1 Analysis of variance

The analysis of variance for all the 13 characters revealed the significant differences among the genotypes studied. This information indicates that sizable variability exists for all the characters studied and considerable improvement can be achieved in these characters by selection. However the analysis of variance by itself is in conclusive in explaining all the inherent genetic variability in the collection. This is evident by partitioning the total variability inherent in the genotypes from the phenotypic variance. Thus it is necessary to work out the phenotypic and genotypic coefficients of variation which indicate the extent of variability existing for various traits. Earlier workers like Suvarna *et al.* (2008), Abhirami *et al.* (2005) and Rajesh *et al.* (2013) have reported the significant differences among the genotypes for all the characters the considered.

5.2 *Per se* performance

The performance of 79 S_6 lines was studied for 13 different characters. The scope for improvement through selection is enhanced by the range of variability in the population. The comparison of results revealed higher range values for number of 50 per cent tasseling, number of 50 per cent silking, number of days to maturity, plant height, ear height, cob length, cob girth, number of rows per cob, number of kernels per cob, shelling percentage, 100 grain weight, grain yield per plant and grain yield per hectare. These results are in conformity with the observations of Vijay *et al.* (2012). The data indicated that the lines such as ARYP-31 (212.20g), ARYP-76 (195.20g), ARYP-59 (185.60g), ARYP-71 (181.00g), ARYP-68 (178.00g), ARYP-30 (177.40g), ARYP-5 (174.60g), ARYP-67 (174.20g), ARYP-66 (172.00g), ARYP-72 (170.40g), ARYP-78 (169.00g), ARYP-74 (167.00g), ARYP-73 (167.00g), ARYP-42 (165.60g), ARYP-61 (159.40g), ARYP-75 (156.00g), ARYP-35 (154.80g), ARYP-69 (153.00g), ARYP-51 (153.00g), ARYP-33 (152.20g), ARYP-77 (151.00g), ARYP-70 (151.00g), ARYP-63 (150.40g), ARYP-60 (148.60g), ARYP-4 (146.40g) and ARYP-34 (145.40g) were found to be superior compare to checks for grain yield per plant. In checks, grain yield per plant had higher in CI-4 (163.00g) followed by KDMI-16 (152.00g) and CM-111 (145.00 g).

5.3 Genetic parameters (Variability, heritability and genetic advance)

Effectiveness of selection and identification of superior genotypes depends on the magnitude of inherent variability for a particular character. Hence it is prerequisite to study the estimates of genetic parameters such as coefficients of genotypic and phenotypic variability, heritability and genetic advance. Improvement of any characters in a crop depends upon the amount of variability present in the base population, in absence of which there shall be no response to selection. In the present study, the parameters like phenotypic and genotypic coefficients of variation (PCV and GCV), heritability in broad sense and genetic advance as per cent mean were estimated to know the nature and magnitude of variation existing among genotypes under study (Table 14).

The scope for improvement through selection is enhanced by the range of variability in the germplasm. The comparison of results revealed higher range values for yield and yield components among the genotypes studied. Therefore, there is lot of scope for selection for majority of the traits in the progenies. Absolute variability of different characters does not reveal which of the particular characters are showing the highest variability. This could be assessed through standardizing the genotypic and phenotypic variance by obtaining coefficients of variability. Thus, components of variation, such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed.

Table 14. Comparison of different variability parameters in respect of 13 characters in maize

Traits	PCV (%)	GCV (%)	h^2_{bs} (%)	GAM (%)
Days to 50 per cent tasseling	Low	Low	High	Low
Days to 50 per cent silking	Low	Low	High	Low
Days to 75 per cent dry husk	Low	Low	High	Low
Plant height (cm)	Low	Low	High	Moderate
Ear height (cm)	Moderate	Moderate	Moderate	Moderate
Cob length (cm)	Moderate	Low	High	Moderate
Cob girth (cm)	Low	Low	High	Low
Number of kernel rows per cob	Low	Low	High	Moderate
Number of kernels per row	Low	Low	High	Moderate
Shelling percentage	Low	Low	Moderate	Low
100 seed weight (g)	Moderate	Moderate	High	High
Grain yield per plant (g)	High	Moderate	High	High
Grain yield per hectare (q/ha)	Moderate	Moderate	High	High

PCV – Phenotypic coefficient of variation
GCV – Genotypic coefficient of variation
GAM – Genetic advance as per cent over mean
h^2_{bs} – Heritabilityin broad sense

A wide range of variation for grain yield per plant was noticed in the present investigation. A narrow difference between GCV and PCV indicate that they are less influenced by environment. The character also showed moderate GCV and PCV values with high heritability and GAM, indicating that it is controlled by additive gene action and less influenced by environment. In addition, this trait can be improved through selection. But, yield is a complex character and is function of several component characters and their interaction with environment. Direct selection based on yield alone will not be very effective in crop improvement programmes. Grafius (1959) pointed out that structure of yield probed through its components rather than directly would be more efficient. Study of yield components and their inter relationship along with yield and their direct and indirect contribution towards yield is of immense importance. Falconer (1981) obtained that this helps to base selection procedure to strike a balance when two opposite desirable characters affecting the principal characters are being selected. Also, it helps to improve different characters simultaneously. The magnitude of genotypic coefficient of variation was low as compared to that of phenotypic coefficients of variation in all the traits studied.

Lower values of genotypic coefficient of variation and phenotypic coefficient of variation were noticed for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, cob girth, number of kernel rows per cob, number of kernels per row and shelling percentage. Similar results of low GCV and PCV were reported by Satyanarayana *et al.* (2005) for days to 50 per cent silking and plant height, Satyanarayana and Saikumar (1996) and Pradeepkumar and Satyanarayana (2001) for days to 50 per cent tasseling, days to 50 per cent silking and plant height and Choudhary and Chaudhari (2002) for cob length. For ear height, 100-seed weight and grain yield per hectare the GCV and PCV was moderate. Cob length had moderate PCV and low GCV. Whereas, grain yield per plant exhibited high PCV and moderate GCV was recorded.

The amount of genetic variation alone may not be of more relevance unless it is supplemented with the information on estimates of heritability of a character which provides a measure of effectiveness of selection for that character as it indicates the heritable portion of the total variation. It has been suggested by Burton and De Vane (1953) that the GCV along with heritability estimate could provide a better picture of degree and magnitude of improvement that can be expected by phenotypic selection. Since genetic advance is dependent on phenotypic variability and heritability in addition to selection intensity, the heritability estimates in conjunction with genetic advance values will be more effective and reliable in predicting the response to selection by providing more genetic information on the character. Knowledge on the heritability of characters is important to the breeders, since it indicates the possibility and extent of improvement that can be achieved through selection for a particular trait.

Heritability values for all the characters were found to be high except ear height and shelling percentage. 100-seed weight recorded higher heritability value (86.40%) and shelling percentage recorded the lowest heritability value (39.30%). Gyanendra *et al.* (1995) and Om prakash *et al.* (2006) were reported similar results. Genetic advance as per cent mean was high for 100-seed weight, grain yield per plant and grain yield per hectare and it was moderate for plant height, ear height, cob length, number of kernel rows per cob and number of kernels per row. Days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, cob girth and shelling percentage exhibited lowest genetic advance as per cent mean. Similar results of high GAM for 100 seed weight, grain yield per plant and grain yield per hectare and moderate GAM for plant height and ear height were noticed by Sumathi *et al.* (2005) and Mani and Bisht (1996). Pradeep and Satyanarayana *et al.* (2001) and Choudhary and Chaudhari (2002) were reported moderate GAM for plant height and ear height.

The results of the present study clearly indicated the importance of grain yield per plant, grain yield per hectare and 100 seed weight they exerted high heritability and genetic advance. High heritability coupled with high genetic advance indicated that these traits were controlled by additive gene action; hence, phenotypic selection could be effective in improvement of such traits. High heritability with moderate GCV, PCV and GA registered by cob length suggested selection will also effective for these traits. High heritability with low GCV and PCV coupled with moderate GMA was exhibited by plant height, number of kernel rows per cob and number kernel per row indicating the suitability of selection. Days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk cob girth and shelling percentage registered high heritability estimates coupled with Low GCV, PCV and GAM suggesting selection will be less effective for these traits.

Table 15. Correlation of grain yield per plant with its attributing characters at phenotypic and genotypic level in maize

Traits	Phenotypic correlation		Genotypic correlation	
	Significant	non-significant	Significant	non-significant
Days to 50 per cent tasseling		+		-
Days to 50 per cent silking		-		-
Days to 75 per cent dry husk		+	+	
Plant height (cm)	+		+	
Ear height (cm)	+		+	
Cob length (cm)	+		+	
Cob girth (cm)	+		+	
Number of kernel rows per cob	+		+	
Number of kernels per row	+		+	
Shelling percentage	+		+	
100 seed weight (g)	+		+	
Grain yield per plant (g)	+		+	

5.4 Character association studies

For a rationale approach towards the improvement of yield, selection will be more rewarding when it is based on the component traits of yield. Association of yield components with yield thus, assumes special importance as the basis of indirect selection. Simple phenotypic correlation indicates broadly the type of correlation that exists between various traits but it by itself does not provide any reliable basis for selection. Hence, the genotypic correlation which is based on the heritable part of the observed variation enables the assessment of pattern of inherent relationship that exists between various traits.

Generally, genotypic correlations will be higher than that of phenotypic level. This may be due to the relative stability of genotypes as majority of them were subjected to certain amount of selection (Johnson *et al.*, 1981). The relationship between phenotypic, genotypic and environmental correlations as discussed by Falconer (1981) emphasized that for the characters having high heritability, the environmental correlations are generally expected to be lower than genotypic correlations. Since, the phenotypic correlation includes a part of genotypic correlation and a portion of environmental correlation corresponding to the heritable portion of variation in two characters, it is expected that for highly heritable characters, genotypic correlations would be higher than phenotypic correlation, when the correlations are in the same direction. Phenotypic correlation can exceed genotypic correlation only if heritability of the two characters is low and there is a higher environmental correlation (Falconer, 1981). In maize, understanding the nature of association of characters may not be of direct help in selection of breeding material in segregating population. However, it is very much useful in selection of parents for yield based on the information available on the nature of association of characters. It also focuses on the degree of importance to be given, while selecting a genotype as a parent in hybridization. Therefore, correlations were worked out in the present study on grain yield.

In the present investigation, genotypic and phenotypic correlation coefficients (Tables 15) indicated that grain yield per plant had significant and positive correlation with 100 seed weight, shelling percentage, number of kernels per row, number of kernel rows per cob, cob length, cob girth, ear height and plant height. Thus, these traits play a greater role as an important contributing character for higher grain yield. Days 50 per cent silking had negative non-significant with grain yield both at genotypic and phenotypic level. While, days to 50 per cent tasseling exhibited positive phenotypic and negative genotypic non-significant association with grain yield per plant. Netaji *et al.* (2000), Wali *et al.* (2006), Kanagarasu *et al.* (2012) and Jawaharlal *et al.* (2011) were reported similar results.

From the results of this investigation, it can be concluded that for improvement of grain yield, breeder should give weightage on characters like 100 grain weight, cob length, cob girth, number of rows per cob and number of kernels per row which had significant positive phenotypic and genotypic correlation, indicating that selection for these characters can help to improve the grain yield in maize.

5.5 Path coefficient analysis

The correlation values decide only the nature and degree of association existing between pairs of characters. The economic character like yield is dependent on several mutually associated component characters and hence change in any one of the components is likely to affect the whole network of cause and effect. This in turn might affect the true association of component characters both in magnitude and direction and tend to vitiate the association of yield with its attributes. Hence, it has to be analysed through path analysis, where the two types of action namely direct effect of component characters on the yield and the indirect effects through other component characters on the yield are obtained which cannot be ascertained correlation studies.

Path co-efficient is the standardized partial regression coefficient of correlation, which splits correlation co-efficient into direct and indirect effects of component characters on complex dependent character like yield. The concept of path co-efficient analysis was developed by Wright (1921), but the technique was first used in plant breeding by Dewey and Lu (1959).

If the correlation between dependent variable and the independent variables is due to the direct effects of the character, it reflects a true relationship between them and selection has to be invariably practiced for such a character in order to improve dependent variable. The correlation co-efficient measures the sum total effects (direct and indirect) of all the characters to which it is correlated either positively or negatively and hence selection based on this value alone will be sometimes misleading unless the direct effect is very high and operates in the same direction. Hence, the study of direct and indirect effects through path analysis enables the breeders to judge the important component characters during selection (Singh *et al.*, 1999).

As a guideline for interpretation of results of path analysis, the following broad points may be kept in view.

If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect, then correlation explains the true relationship and direct selection though this trait will be effective.

If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.

Further, correlation coefficient may be negative but the direct effect is positive and high. Under these circumstances, a restricted simultaneous selection model is to be followed that is, restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effect is also negative, then we have to drop the selection based on that character.

The residual effect determines how best the causal factors account for the variability of the dependent factor. If the residual effect is high, some other factors which have not been considered here need to be included in this analysis to account fully for the variation in yield.

In the present investigation, 12 grain yield associated characters were subjected separately to path analysis for partitioning the correlation values into direct and indirect effects through alternative path ways and results are discussed below. Path analysis was carried out taking grain yield per plant as dependent character and the characters having positive association with grain yield *viz*., days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, ear height, cob length, cob girth, number of rows per cob, number of kernels per row, shelling percentage and 100 seed weight as independent characters (Table 16).

Hundred seed weight, number of kernel rows per cob, number of kernels per row, cob length, plant height, shelling percentage*,* cob girth, ear height, days to 75 per cent dry husk and days to 50 per cent silking affected grain yield directly. Days to 50 per cent tasseling had negative direct effects on grain yield both as phenotypic and genotypic level. The direct effect on yield by plant height, 100-seed weight (Packiaraj, 1995), kernel rows, kernels per row (Manivannan, 1998), ear girth (Goutam, 1999) and (Krishna and Natrajan, 1995) was also reported by several workers. The negative direct effects were observed by Umakath *et al.* (2001).

In the light of results obtained in the present study, it can be suggested that traits such as 100 seed weight, number of kernel rows per cob, number of kernels per row, cob length, plant height, shelling percentage*,* cob girth, ear height, days to 75 per cent dry husk should be used as target traits to improve maize grain yield. Besides, weightage may be given for these traits while effecting selection in the breeding material.

5.6 Mean performance of newly derived S_6 lines of maize in different locations

Among the environments, Mandya location has taken minimum days to 50 per cent tasseling and days to 50 per cent silking followed by Dharwad and Arabhavi. For days to 75 per cent dry husk, Mandya location has recorded minimum days followed by Arabhavi and Dharwad. For better expression of plant height, ear height, cob girth, number of kernels per row, shelling percentage, 100 seed weight and grain yield per plant Mandya location was more favourable followed by Arabhavi and Dharwad.

In respect of, cob length genotypic expression was better at Arabhavi followed by Mandya and Dharwad. For number of kernel rows per cob genotype expression was better at Mandya compared to other two locations. Among three environments, Mandya is better for all traits expression followed by Arbhavi and Dharwad.

Table 16. Direct effects of grain yield component traits on grain yield per plant at phenotypic and genotypic level in maize at Arabhavi

Traits	Direct effects	
	Phenotypic	Genotypic
Days to 50 per cent tasseling	-	-
Days to 50 per cent silking	+	+
Days to 75 per cent dry husk	+	+
Plant height (cm)	+	+
Ear height (cm)	+	-
Cob length (cm)	+	+
Cob girth (cm)	+	+
Number of kernel rows per cob	+	+
Number of kernels per row	+	+
Shelling percentage	+	+
100 seed weight (g)	+	+
Grain yield per plant (g)	+	+

5.7 Stability analysis

5.7.1 Pooled analysis of variance for stability analysis

The pooled analysis of variance revealed that mean sum of squares (MSS) due to genotype and environment was highly significant indicating the presence of variation among the genotypes and environments for most of the characters. The genotype x environment interaction was significant for all the traits indicating differential response of genotypes to varying environments.

Significance of BARTLEET's test for most traits suggested non homogeneity of non genetic sources of variances of ANOVA of S_6 lines evaluated at different locations. Although these results invalidate the pooled analysis of variance, large genotypes × location interaction variance warrants such pooled analysis to identify genotypes adapted across locations.

5.7.2 Analysis of variance for stability performance

The analysis of variance for stability performance revealed genotype x environment interaction for all the traits indicating differential response of the genotypes to varying environments. The MSS due to environment + (genotype x environment) was non-significant for all the characters. MSS due to environment (liner) was significant for all the character indicating that environment effects are additive. The linear component of G x E interaction was also significant for character *viz.,* number of kernels per row, shelling percentage and grain yield per hectare indicating significant rate of linear response of the genotypes to environmental changes. The pooled deviation was also significant for all the characters indicating that non-linear component of G x E interaction were predominant. Similar results were reported by Sain *et al.* (1987), Arun and Singh (2004b), Kaundal and Sharma (2006) and Brar *et al.* (2010) indicating the differential response of varieties under different environments.

5.7.3 Stability parameters

Stability analysis was carried out by employing the linear regression model proposed by Eberhart and Russell (1966). Although there are number of models available to characterize the genotypes for their G x E interactions, this model is widely used for its simplicity and reliability. Many workers have employed this model in maize like Jha *et al.* (1986), Satyanarayana *et al.* (1995), Mani *et al.* (1999), Arun and Singh (2004b) and Kaundal and sharma (2006).

An ideal stable genotype is defined as the one possessing high mean performance, with regression coefficient around unity (bi=1) and deviation from regression (S^2_{di}) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environment. If the regression coefficient (bi) is greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If regression coefficient (bi) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (bi) is less than unity, it indicates less sensitivity to environmental changes and if accomplished by a high mean value, then the genotype is said to be better adapted for unfavourable environment (17-18).

In the present study, stability parameters such as mean ($\bar{X}$), regression coefficient (bi) and deviation from regression (S^2_{di}), as suggested by Eberhart and Russell (1966) were considered to explain and discuss the stability of different genotypes for various characters under consideration.

5.7.3.1 Days to 50 per cent tasseling

Environmental index was lower in Mandya indicated early flowering followed by Dharwad and Arabhavi. Among these lines were studied ARYP-72 was the earliest to 50 per cent tasseling while, KDMI-16 was late to 50 per cent tasseling. The lines which require minimum number of days to 50 per cent tasseling are more desirable. The lines ARYP-68, ARYP-69, ARYP-70, ARYP-71, ARYP-73, ARYP-78, ARYP-79, CM-111 and KDMI-16 had significant deviation from regression value more than zero, the genotypes performance are cannot be predicted. Whereas, the lines ARYP-72, ARYP-75, ARYP-77 and CI-4 exhibited low mean value, b_i value is closer than unity and mean deviation from regression nearer to zero, then the genotypes said to be average stability and adopted to all environments. The line ARYP-74 had lower mean and regression coefficient higher than unity indicates adopted to favourable environments. Similar kind of results was reported by Rahman *et al.* (2010) and Liu *et al.* (2010).

5.7.3.2 Days to 50 per cent silking

The lines CI-4, ARYP-77, ARYP-72 and ARYP-78 are lower mean value, near to unity for regression coefficient and no much deviation from regression, hence they considered as stable. Whereas, the lines ARYP-68, ARYP-69, ARYP-73, ARYP-75, ARYP-76, ARYP-78, ARYP-79 and KDMI-16 are significantly deviations from regression value more than zero, the genotype performance cannot be predicted. Environmental index was lower in Mandya indicated early flowering followed by Dharwad and Arabhavi. Similar kind of results was reported by Rahman *et al.* (2010) and Liu *et al.* (2010).

5.7.3.3 Days to 75 per cent dry husk

The stability parameters for days to 50 per cent dry husk showed that the lines ARYP-73, ARYP-69, ARYP-77 and ARYP-75 are near to unity for regression coefficient, hence they consider as stable. The lines ARYP-68, ARYP-70, ARYP-71, ARYP-74, ARYP-76, ARYP-78 and CM-111 had significant deviation from regression value more than zero, then the genotypes performance cannot be predicted. The lines ARYP-79, KDMI-16 and CI-4 had the high mean value, regression value more than unity and regression from deviation nearer to zero, which indicated their suitability to favourable environments. Similar kind of results was reported by Arun and Singh (2004b) and Kaundal and Sharma (2006). The Environmental index was lower in Mandya indicated early maturity followed by Arabhavi and Dharwad.

5.7.3.4 Plant height (cm)

The present study revealed that Mandya location is the most favorable environment for plant height as indicated by environmental index (12.16), whereas Dharwad locations resulted in dwarf (environmental index -8.66). Considering stability parameters of twelve S_6 lines tested over environments, none of the lines had stable performance. While, the lines ARYP-68, ARYP-69, ARYP-72, ARYP-74, ARYP-76, ARYP-73, ARYP-77 and ARYP-78 had bi value near to unity and significant deviation from regression indicating their suitability for all environments under study with unpredictable performance. The line ARYP-70 had high mean and lower regression coefficient indicates above average stability and specifically adapted to unfavourable environment. The present findings are in agreement with Sain *et al.* (1987), Mahajan *et al.* (1991), Gargi *et al.* (2001), Arun and Singh (2004b) and Kaundal and Sharma (2006).

5.7.3.5 Ear height (cm)

Highest ear height was observed in Mandya location as indicated by higher environmental index (9.27) and lowest ear height was observed in Arabhavi location as environmental index is low (-4.93). The line ARYP-73, ARYP-74, ARYP-69, ARYP-71, ARYP-68 and ARYP-76 had regression coefficient near to unity and high mean value indicating their stability in performance across the tested environments and the genotypes which are significantly deviating from regression value indicating unpredictable performance for this trait under tested environments. Similar findings were also reported by Sain *et al.* (1987), Mahajan *et al.* (1991) and Arun and Singh *et al.* (2004b).

5.7.3.6 Cob length (cm)

High environmental index of 0.59 in Arabhavi location represents favourable condition for expression of this character, while Dharwad location showed low environment index of -1.09 indicating unsuitability of this environment for expression of this character. The genotype KDMI-16 showed high mean value, non-significant regression coefficient near to unity and significantly deviating from regression value indicated their stability under tested environments with unpredictable performance. The lines ARYP-75, ARYP-79, ARYP-78, CM-111, ARYP-70, ARYP-71, ARYP-68, ARYP-77 and ARYP-73 showed high mean value, non-significant regression value and non-significant deviation from regression indicating wider adaptability to tested environments. While, the lines ARYP-69 and ARYP-74 had negative regression value and non-significant deviation from regression indicated unadapt to tested locations as concerned with cob length. Similar findings were also reported by Karadavut and Akilli (2012), Vijay *et al.* (2012) and Nagabhushan *et al.* (2013).

5.7.3.7 Cob girth (cm)

The lines ARYP-68, ARYP-69, ARYP-70, ARYP-74, ARYP-75, ARYP-77, ARYP-78, CM-111 and KDMI-16 had mean around the population mean, significant deviation from linear regression and non-significant regression coefficient. These genotypes are classified as average sensitive genotypes indicating their suitability to all the environments with unpredictable performance. The lines ARYP-72, ARYP-73 and CI-4 had regression value near to unity and deviation from regression value nearer to zero indicated stable across location for this trait. Significant observations were also made by Arun and Singh (2004b) and Kaundal and Sharma (2006) confirming the present investigation. High environmental index of 0.66 in Mandya location represents favourable condition for expression of this character, while Dharwad location showed low environment index of -0.68 indicating unsuitability of this environment for expression of this character. Similar findings were also reported by Karadavut and Akilli (2012), Vijay *et al.* (2012) and Nagabhushan *et al.* (2013).

5.7.3.8 Kernel rows per cob

The study revealed that Mandya location is the most ideal for expression of this trait as maximum environmental index (0.34) was recorded. Lowest environmental index (-0.36) in Arabhavi location indicated that, this environment had suppressed the expression of this trait. Stability parameters for this character revealed that CM-111 had higher mean performance, non-significant regression coefficient (bi>1) from unity and deviation from regression (S^2_{di}) close to zero, which revealed their adaptation to all the environments. While the lines ARYP-70 and ARYP-71 had higher mean and significant deviation of regression from unity indicating their unpredictable performance over locations. Similar findings were also made by Karadavut and Akilli (2012), Vijay *et al.* (2012), Nagabhushan *et al.* (2013), Arun and Singh (2004b) and Kaundal and Sharma (2006) also made similar observations thus confirmed the present results.

5.7.3.9 Number of kernels per row

The study revealed that Mandya location is the most ideal for expression of this trait as maximum environmental index (1.46) was recorded. Lowest environmental index (-2.76) in Dharwad location indicated that, this environment had suppressed the expression of the trait. The lines *viz.,* ARYP-75, ARYP-73 and ARYP-77 had high mean value with regression coefficient around unity indicating their adaptability of tested environments. The lines ARYP-68, ARYP-70, ARYP-71, ARYP-72, ARYP-74, ARYP-76, ARYP-78, CI-4 and KDMI-16 had significant deviation from the regression value indicating unpredictably performance to tested environment. The line ARYP-74 had negative regression coefficient and significant deviation from regression indicates unstable over environments. These are in accordance with observations made by Arun and Singh (2004b), Kaundal and Sharma (2006), Vijay *et al.* (2012) and Nagabhushan *et al.* (2013).

5.7.3.10 Shelling percentage

The lines ARYP-79, ARYP-69 and ARYP-75 had high mean value, regression coefficient nearer to unity and regression from deviation closer to zero indicates average sensitive to environment fluctuations and adapted to all environments. Whereas, the lines ARYP-73, ARYP-76 and ARYP-78 had higher mean value with lower regression coefficient indicate adapted to unfavourable environment.

5.7.3.11 100 seed weight (g)

The lines ARYP-69, ARYP-70, ARYP-71, ARYP-72, ARYP-73, ARYP-74 and CM-111 showed significant deviation from regression value more than zero indicates that the genotypic performance cannot be predicted. However, the lines *viz.*, ARYP-68 and ARYP-73 had high mean, deviation from regression nearer to zero and regression coefficient closer to unity indicating their average sensitivity to all environments were studied with predicted performance. Arun and Singh (2004b), Vijay *et al.* (2012) and Nagabhushan *et al.* (2013) also reported same results in their studies, which endorsed the present investigation.

5.7.3.12 Grain yield per plant (g)

The lines ARYP-68, ARYP-69, ARYP-71, ARYP-72, ARYP-73, ARYP-74, ARYP-77, ARYP-78, CI-4, CM-111 and KDMI-16 had a significant deviation from regression and regression coefficient around unity indicating their average sensitivity to environment with unpredictable performance. Whereas, the lines ARYP-70 and ARYP-76 had high mean value and regression coefficient closer to unity indicated average stability and adapted to all environments. These findings are in line with Jha *et al.* (1986), Sain *et al.* (1987), Arun and Singh (2004b) and Kaundal and Sharma (2006), which enlightened the present outcome on grain yield per plant. High environmental index of 28.15 in Mandya location represents favourable condition for expression of this character, while Dharwad location showed low environment index of -46.65 indicating unsuitability of this environment for expression of this character. Similar kind of results had reported by vijay *et al.* (2012).

5.7.3.13 Grain yield (q/ha)

In Mandya location plants exhibit maximum grain yield per hectare as indicated by highest environmental index of 2.59 and Dhawad location offered restriction to have more grain yield per hectare as it had minimum environmental index (-4.09). The lines *viz.,* ARYP-69, ARYP-70, ARYP-72, ARYP-74, ARYP-77, CI-4 and CM-111 were recorded significant deviation from regression value higher than zero indicates performance of the genotypes cannot predicted. The genotypes ARYP-68 and ARYP-75 had high mean value and regression coefficient higher than unity indicated below average stability and specifically adopted to favourable environment. Whereas, the lines ARYP-71, ARYP-76 and ARYP-73 had high mean yield and lower regression coefficient from unity indicated specifically adopted to unfavourable environments. Satayanarayana *et al.* (1995) and Vijay *et al.* (2012) were reported similar results.

5.8 Genetic variability, heritability and genetic advance as per cent mean in different location

To know the amount of variability for yield and yield contributing characters, 15 genotypes were evaluated over three locations. The results clearly indicated presence of higher amount of variability for yield and yield components among the genotypes studied. Therefore, there is lot of scope for selection for majority of the traits in the progenies. Absolute variability of different characters does not reveal which of the particular characters are showing the highest variability. This could be assessed through standardizing the genotypic and phenotypic variance and by obtaining coefficients of variability. Thus, components of variation, such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were computed. The estimates of heritability alone fail to indicate the response to selection (Johnson *et al*., 1981). Therefore, the heritability estimates appears to be more meaningful when accompanied by estimates of genetic advance. The genetic advance as per cent over mean was also estimated (Table 19).

The GCV and PCV were moderate and high heritability coupled with high GAM for grain yield per plant and 100 grain weight. These traits were under the control of additive genetic effect indicating that selection should lead to a fast genetic improvement of the material. Zahid *et al.* (2004), Mani *et al.* (1996), Choudhary and Chaudhari (2002) and Om Prakash *et al.* (2006) noticed similar results. The high variability values for grain yield per plant among the genotypes suggest that there is lot of scope for selection of high yielding superior genotypes.

Low values of genotypic coefficient of variation and phenotypic coefficient of variation were noticed for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, ear height, cob length, cob girth, number of kernel rows per cob, number of kernels per row and shelling percentage. Similar results of Low GCV and PCV were noticed for days to 50 per cent tasseling and days to 50 per cent silking by Satyanarayana and Saikumar (1996), Pradeep and Satyanarayana *et al.* (2001) and Sumathi *et al.* (2005). Mohammad *et al.* (2008) noticed low GCV and PCV for Plant height and ear height. Robin and Subramanian (1994) reported same results for cob length and number of kernels per row. Pradeep and Satyanarayana *et al.* (2001) noticed low GCV and PCV for cob girth and number of kernel rows per cob.

Heritability values for all the characters were found to be high except plant height in Mandya had moderate heritability. The values ranged from 53.00 per cent to 99.90 per cent. Grain yield per plant recorded the highest heritability value over a location. The results suggest that the yield components in maize are less influenced by environmental conditions. High heritability values for these traits indicate that the variation observed was mainly under genetic control and less influenced by environment. Similar results of high heritability by Murugan *et al.* (2010), Sumathi *et al.* (2005), Choudhary and Chaudhari (2002) and Jha and Ghosh (2001). Moderate genetic advance as per cent over mean and high heritability was recorded for number of kernel rows per cob and number of kernels per row. These traits consider for selection. Robin and Subramanian (1994) were noticed same results. Whereas, Low values of GAM were noticed for days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, ear height, cob length, cob girth and shelling percentage. Pradeep and Satyanarayana *et al.* (2001) had noticed similar results for days to 50 per cent tasseling, days to 50 per cent silking, cob length and cob girth. Mohammad *et al.* (2008) was reported similar results for plant height and ear height had low GAM.

Table 17. Stable genotypes identified for each characters over locations

Sl. No	Traits	Stable genotypes
1	Days to 50 per cent tasseling	KDMI-16, ARYP-71, ARYP-72, ARYP-75, ARYP-78 and ARYP-79
2	Days to 50 per cent silking	CI-4, ARYP-77, ARYP-72, KDMI-16, ARYP-78 and ARYP-75
3	Days to 75 per cent dry husk	ARYP-73, ARYP-69, ARYP-77, CM-111, ARYP-76 and ARYP-75
4	Plant height (cm)	ARYP-79, ARYP-74, ARYP-76, ARYP-73, CM-111 and ARYP-77
5	Ear height (cm)	ARYP-73, ARYP-74, ARYP-69, ARYP-75, ARYP-68 and ARYP-76
6	Cob length (cm)	KDMI-16, ARYP-75, ARYP-79, ARYP-78, CM-111 and ARYP-70
7	Cob girth (cm)	ARYP-73, ARYP-78, ARYP-75, ARYP-72, ARYP-77 and CI-4
8	Number of kernel rows per cob	CI-4, ARYP-72, ARYP-77, ARYP-69, CM-111 and ARYP-73
9	Number of kernels per row	ARYP-75, ARYP-73, CI-4, ARYP-77, ARYP-79 and ARYP-70
10	Shelling percentage	ARYP-79, ARYP-69, ARYP-77, ARYP-75, ARYP-72 and ARYP-71
11	100 seed weight (g)	ARYP-69, ARYP-77, ARYP-72, ARYP-73, ARYP-79 and ARYP-74
12	Grain yield per plant (g)	CM-111, ARYP-69, CI-4, ARYP-79, ARYP-78 and ARYP-70
13	Grain yield per hectare (q)	ARYP-79, ARYP-73, ARYP-70, CI-4, ARYP-72 and KDMI-16

Table 18. Stability of genotypes for different characters based on stability parameters

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per Cob	No. of kernels per row	Shelling percent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)	Total score
ARYP-68	-	-	-	-	1	-	-	-	-	-	-	-	-	1
ARYP-69	-	-	1	-	1	-	-	1	-	1	1	1	-	6
ARYP-70	-	-	-	-	-	1	-	-	1	-	-	1	1	4
ARYP-71	1	-	-	-	-	-	-	-	-	1	-	-	-	2
ARYP-72	1	1	-	-	-	-	1	1	-	1	1	-	1	7
ARYP-73	-	-	1	1	1	-	1	1	1	-	1	-	1	8
ARYP-74	-	-	-	1	1	-	-	-	-	-	1	-	-	3
ARYP-75	1	1	1	-	1	1	1	-	1	1	-	-	-	8
ARYP-76	-	-	1	1	1	-	-	-	-	-	-	-	-	3
ARYP-77	-	1	1	1	-	-	1	1	1	1	1	-	-	8
ARYP-78	1	1	-	-	-	1	1	-	-	-	-	1	-	5
ARYP-79	1	-	-	1	-	1	-	-	1	1	1	1	1	8
CI-4	-	1	-	-	-	-	1	1	1	-	-	1	1	6
CM-111	-	-	1	1	-	1	-	1	-	-	-	1	-	5
KDMI-16	1	1	-	-	-	1	-	-	-	-	-	-	1	4

Table 19. Comparison of different variability parameters in respect of 13 characters in newly derived S_6 lines of maize at different location

Traits	PCV (%)			GCV (%)			h^2bs (%)			GAM (%)		
	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD	ARB	MAN	DWD
Days to 50 per cent tasseling	L	L	L	L	L	L	H	H	H	L	L	L
Days to 50 per cent silking	L	L	L	L	L	L	H	H	H	L	L	L
Days to 75 per cent dry husk	L	L	L	L	L	L	H	H	H	L	L	L
Plant height (cm)	L	L	L	L	L	L	H	M	H	M	L	L
Ear height (cm)	L	L	L	L	L	L	H	H	H	M	L	L
Cob length (cm)	L	L	L	L	L	L	H	H	H	M	L	M
Cob girth (cm)	L	L	L	L	L	L	H	H	H	L	L	L
Number of kernel rows per cob	L	L	L	L	L	L	H	H	H	L	M	M
Number of kernels per row	L	L	L	L	L	L	H	H	H	M	M	M
Shelling percentage	L	L	L	L	L	L	H	H	H	L	L	L
100 seed weight (g)	M	L	M	M	L	M	H	H	H	H	M	H
Grain yield per plant (g)	M	M	M	M	M	M	H	H	H	H	H	H

ARB: Arabhavi MAN: Mandya DWD: Dharwad L: Low M: Moderate H: High
PCV – Phenotypic coefficient of variation GCV – Genotypic coefficient of variation h^2_{bs} – Heritability in broad sense
GAM – Genetic advance as per cent over mean.

5.9 Screening of newly derived S_6 lines of maize against turcicum leaf blight at different locations

Attempts have been made in the past in India by various workers (Gowda *et al.*, 1889, Mahajan *et al.*, 1991 and Gowda *et al.*, 1994) to locate the sources of resistance against the *E. turcicum*.

In the present investigation, 15 genotypes were screened over three locations against *E. turcicum*. 11 out of 15 genotypes have shown moderately resistant reaction and four genotypes exhibited susceptible reaction at MARS, Dharwad where the severity of turcicum leaf blight was high.

Future line of work

1. Genetic variability studies indicated that there is ample quantum of variability for grain yield per hectare, grain yield per plant, 100 seed weight, number of rows per cob and number of kernels per row on account of their moderate phenotypic and genotypic coefficients of variance coupled with high heritability and genetic advance as per cent over mean indicating more additive gene action hence the selection for this traits could be effective. Variability present for these traits can be exploited either by selection for their further improvement.
2. The grain yield attributing characters such as 100 seed weight, number of kernel rows per cob, number of kernels per row, cob length and cob girth exhibited significant positive association and direct effects with grain yield. Hence, these characters can be targeted in future breeding programmes to achieve the higher yield.
3. The S_6 lines such as ARYP-73, ARYP-75, ARYP-77, ARYP-79, ARYP-71 and ARYP-69 are exhibited excellent stability parameters, hence these lines may be included in developing better hybrid combinations for wider adoptability.

SUMMARY AND CONCLUSIONS

The present investigation was taken up to elucidate the information on the amount of variability present in the component traits of yield and the amount to which it is heritable, nature of association and their direct and indirect effect of their component character on grain yield per plant and genotype × environment interaction in order to assess the relative stability of maize genotypes for productivity traits.

In the first experiment, 79 genotypes along with 3 checks were evaluated at Arabhavi. The observations were recorded for 13 quantitative traits *viz.,* days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, ear weight, cob length, cob girth, number of kernel rows per cob, number of kernels per row, shelling percentage, 100 seed weight, grain yield per plant and grain yield per hectare. The results obtained in the first experiment are summarized below.

The performance of 79 S_6 lines along with three checks was studied for 13 different characters. The data indicated that the lines such as ARYP-31, ARYP-76, ARYP-59, ARYP-71, ARYP-68, ARYP-30, ARYP-5, ARYP-67, ARYP-66, ARYP-72, ARYP-78, ARYP-74, ARYP-73, ARYP-42, ARYP-61, ARYP-75, ARYP-35, ARYP-69, ARYP-51, ARYP-33, ARYP-77, ARYP-70, ARYP-63, ARYP-60, ARYP-4 and ARYP-34 were found to be superior compare to checks for grain yield per plant. In checks, grain yield per plant had higher in CI-4 followed by KDMI-16 and CM-111.

Wide range of variation was observed for all the characters studied. Genotypes differed significantly for all the characters as evidenced by 'F' test of ANOVA. Genetic variability analysis revealed that, moderate GCV and PCV were obtained for ear height, 100 seed weight, grain yield per plant and grain yield per hectare. Whereas days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, plant height, cob length, cob girth and shelling percentage exhibited low GCV and PCV.

Heritability in broad sense was high for all the characters studied except for ear height. Genetic advance as per cent mean was highest for 100 seed weight, grain yield per plant and grain yield per hectare. Plant height, ear height, cob length, number of kernel rows per cob and number of kernels per row had moderate GAM. Whereas, days to 50 per cent tasseling, days to 50 per cent silking, days to 75 per cent dry husk, cob girth and shelling percentage exhibited low GAM.

Grain yield per plant was found correlated significantly and positively at both phenotypic and genotypic level with 100 seed weight, shelling percentage, number of kernel rows per cob, number of kernels per row, cob girth, cob length, ear height, plant height and days to 75 per cent dry husk. While, days to 50 per cent tasseling and days to 50 per cent silking exhibited negative non-significant association with grain yield at both genotypic and phenotypic level.

Path analysis revealed that 100 seed weight, number of kernel rows per cob, number of kernels per row, cob length, plant height, shelling percentage, cob girth, ear height, days to 75 per cent dry husk and days to 50 per cent silking affected grain yield directly while, days to 50 per cent tasseling had negative direct effects on grain yield both as phenotypic and genotypic level.

In the second experiment, 12 genotypes along with three checks were evaluated for stability and tested in randomized complete block design with three replications in three different locations *viz.,* Arabhavi, Mandya and Dharwad. Similar observations that are recorded in the first experiment are also recorded for this experiment in same manner, in addition to those one more observation was recorded *i.e.*, reaction against turcicum leaf blight. The results obtained in the present study aresummarized below.

Mean performance of hybrids in three different locations indicated that Mandya was the most favourable environment for the better expression of most of the characters than Arabhavi and Dharwad.

Analysis of variance revealed significant differences among the genotypes at all the locations suggesting a high degree of variability among the genotypes tested. The analysis of variance for performance stability revealed genotype x environment interaction for all the traits indicating differential response of the genotypes to varying environments. The MSS due to environment + (genotype x environment) was non-significant for all the characters. MSS due to environment (liner) was significant for all the character indicating that environment effects are additive. The linear component of G x E interaction was also significant for character *viz.,* number of kernels per row, shelling percentage and grain yield per hectare indicating significant rate of linear response of the genotypes to environmental changes. The pooled deviation was also significant for all the characters indicating that non-linear component of G x E interaction were predominant. On the basis of stability parameters, ARYP-73, ARYP-75, ARYP-77, ARYP-79, ARYP-72, ARYP-69 and CI-4 were promising stable genotypes for majority of characters with higher mean performance across the environments.

Genetic variability analysis revealed that, low to moderate PCV and GCV were observed majority of the traits except 100 seed weight and grain yield per plant. Heritability estimates high for all the characters was studied in all three location. GAM were found high for 100 seed weight and grain yield per plant whereas, other characters had low to moderate genetic advance as per cent mean.

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Appendix I: *per se* performance of 79 S_6 lines and three checks

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Percent-age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
ARYP-1	58.50	60.50	99.00	169.00	85.00	16.45	13.87	14.00	29.50	85.19	34.0	142.00	28.62
ARYP-2	57.50	59.50	99.50	164.00	74.00	15.50	13.35	12.80	31.00	81.26	34.0	130.00	27.46
ARYP-3	59.50	60.50	102.50	170.50	97.00	15.50	13.43	12.50	34.60	86.43	35.0	152.40	31.22
ARYP-4	58.00	59.00	98.00	156.50	71.00	14.80	13.54	14.60	32.90	86.06	34.0	146.40	30.62
ARYP-5	58.50	59.50	102.00	175.00	86.00	15.10	14.79	12.90	37.90	87.99	39.0	174.60	33.40
ARYP-6	59.50	60.50	101.50	149.50	72.50	15.10	13.02	12.80	29.80	83.12	33.0	108.20	19.84
ARYP-7	59.50	60.50	96.50	137.00	54.00	14.95	12.56	14.10	30.60	79.81	29.0	100.20	23.22
ARYP-8	57.00	60.00	97.00	154.00	66.00	13.85	14.23	15.60	28.70	82.04	30.0	119.60	22.75
ARYP-9	58.50	60.50	100.00	135.50	48.00	11.05	13.14	14.20	24.40	86.16	33.0	96.80	18.39
ARYP-10	58.00	59.00	99.00	146.00	64.00	15.85	13.17	12.60	33.20	83.58	31.0	114.00	22.77
ARYP-11	56.50	57.50	97.00	165.50	79.00	14.60	13.80	14.00	31.90	82.70	30.0	137.40	29.55
ARYP-12	57.00	58.00	95.50	163.00	81.00	16.40	12.32	14.55	33.80	82.89	30.0	138.00	27.42
ARYP-13	56.50	57.50	97.00	131.50	64.00	12.05	13.53	11.60	27.00	79.59	29.0	58.60	14.17
ARYP-14	57.50	58.50	97.00	170.00	73.50	14.50	11.10	14.00	33.20	86.40	30.0	124.20	29.42
ARYP-15	56.50	58.50	97.00	172.50	80.00	16.05	12.17	14.20	31.10	81.12	28.0	110.00	23.72
ARYP-16	58.50	60.00	100.50	169.50	75.50	13.95	13.72	13.50	30.40	81.92	32.0	124.40	29.05
ARYP-17	55.50	56.50	97.00	145.50	73.00	14.45	13.42	12.00	33.10	86.36	28.0	78.40	22.75
ARYP-18	58.50	60.50	100.50	181.00	89.00	15.65	13.36	12.80	32.60	82.35	35.0	136.80	29.81
ARYP-19	59.50	60.50	100.00	147.00	76.50	15.68	12.80	13.20	32.80	83.89	29.0	99.40	20.55

Contd….

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Percent-age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
ARYP-20	55.50	57.00	97.50	141.00	67.00	12.10	13.05	13.60	28.80	84.71	29.0	110.20	22.35
ARYP-21	55.50	57.50	99.00	179.00	88.50	17.10	13.38	12.30	38.20	83.69	31.0	137.00	30.36
ARYP-22	57.50	58.50	98.00	155.50	79.50	13.20	13.27	13.40	28.70	84.36	32.0	102.00	28.30
ARYP-23	56.50	58.50	97.50	159.00	68.50	16.15	14.28	14.80	32.30	82.77	30.0	115.20	23.15
ARYP-24	58.50	59.50	101.00	160.50	75.50	15.65	14.15	13.10	33.90	83.62	31.0	128.00	28.00
ARYP-25	58.50	60.50	102.00	179.00	78.50	16.15	14.24	12.50	34.60	85.73	32.0	115.40	25.25
ARYP-26	58.50	59.50	101.00	145.00	69.00	13.70	14.11	11.20	28.65	83.33	39.0	114.80	25.48
ARYP-27	56.00	58.00	100.00	146.50	66.50	15.00	14.01	13.40	30.00	82.75	32.0	122.00	23.93
ARYP-28	59.50	60.50	98.00	174.50	88.00	18.25	14.59	12.60	31.20	81.44	32.0	143.40	28.75
ARYP-29	57.50	59.50	97.00	171.50	77.00	18.65	14.12	14.70	36.30	82.33	31.0	136.80	24.05
ARYP-30	59.50	60.50	100.00	174.00	86.50	18.05	14.66	12.80	37.90	85.58	40.0	177.40	31.66
ARYP-31	58.50	59.50	99.50	165.00	83.50	17.10	14.28	13.60	33.50	86.77	36.0	212.20	32.73
ARYP-32	59.50	60.50	100.50	162.50	77.00	13.50	14.49	15.80	33.80	84.71	29.0	139.00	23.83
ARYP-33	59.00	60.00	100.00	177.00	88.50	15.50	14.69	16.40	32.70	84.27	31.0	152.20	29.93
ARYP-34	55.50	57.50	97.50	179.00	89.50	14.25	14.58	14.60	29.50	83.83	39.0	145.40	38.84
ARYP-35	57.50	58.50	98.00	187.00	97.50	15.20	14.73	14.80	34.50	84.71	35.0	154.80	28.41
ARYP-36	59.00	60.00	99.00	164.00	80.50	15.90	14.34	13.50	33.80	82.64	28.0	129.20	23.69
ARYP-37	55.50	57.50	97.00	190.00	94.50	15.85	14.13	12.80	31.60	83.32	33.0	134.80	26.18
ARYP-38	59.00	60.00	99.00	177.50	86.00	14.45	14.02	13.60	32.70	82.58	25.5	115.00	29.32
ARYP-39	56.50	58.50	97.50	175.50	80.50	14.35	14.45	15.00	28.75	83.79	34.0	130.40	25.53
ARYP-40	59.00	60.00	97.50	171.50	85.50	14.90	14.45	15.00	28.80	82.95	33.0	115.40	26.52

Contd….

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Per-cent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
ARYP-41	57.50	59.50	99.00	175.00	79.50	16.15	14.42	12.60	29.90	80.85	38.0	131.80	29.99
ARYP-42	58.50	59.50	102.00	178.00	83.00	16.00	14.81	15.20	29.20	84.06	39.0	165.60	29.55
ARYP-43	57.50	59.50	102.00	165.50	69.10	13.71	14.28	14.00	28.20	84.99	33.0	127.40	31.47
ARYP-44	56.00	57.00	99.50	167.00	75.00	16.39	14.41	12.80	34.85	84.09	33.0	130.40	28.79
ARYP-45	59.50	60.50	101.50	176.50	81.50	14.40	14.70	14.40	32.40	78.83	34.0	135.80	30.74
ARYP-46	60.00	61.00	102.50	178.50	81.50	13.17	14.25	12.60	29.30	85.96	32.0	107.00	26.43
ARYP-47	56.00	58.00	97.50	163.50	80.00	14.75	14.22	12.40	35.60	81.87	31.0	133.80	30.34
ARYP-48	59.50	61.50	102.50	167.50	80.00	15.81	14.61	13.40	32.65	82.82	37.0	138.20	24.89
ARYP-49	57.00	59.00	99.50	159.50	70.50	16.17	13.95	12.20	34.10	86.24	30.0	115.80	26.94
ARYP-50	57.50	59.50	98.00	148.50	68.50	14.11	13.95	14.70	29.65	84.11	25.0	107.00	29.30
ARYP-51	58.50	59.50	100.50	172.50	88.00	15.15	14.55	14.00	33.20	85.97	36.0	153.00	33.77
ARYP-52	55.50	57.50	99.00	177.50	87.50	15.00	14.40	13.60	35.30	83.84	30.0	129.40	31.09
ARYP-53	58.00	59.00	98.00	145.00	69.00	15.07	14.26	13.80	32.00	84.17	32.0	119.60	23.63
ARYP-54	59.00	60.00	97.00	171.00	84.00	13.80	14.35	13.60	31.50	87.17	29.0	122.40	26.31
ARYP-55	57.00	58.00	96.00	155.50	65.50	12.20	14.24	14.80	28.60	82.03	28.0	98.60	25.03
ARYP-56	57.00	58.00	98.00	186.50	102.50	14.32	14.30	13.60	28.40	83.12	33.0	118.60	28.89
ARYP-57	57.50	59.50	98.00	176.50	90.50	14.67	14.45	13.30	34.00	84.80	31.0	134.60	34.22
ARYP-58	59.50	60.50	100.50	163.50	84.00	14.85	14.63	14.60	33.80	84.90	33.0	142.00	24.63
ARYP-59	55.50	56.50	98.00	172.00	82.50	16.90	14.87	14.00	35.20	84.84	39.0	185.60	41.78
ARYP-60	55.50	56.50	97.50	188.00	95.00	15.11	14.81	14.20	36.40	84.13	34.0	148.60	33.71
ARYP-61	57.00	58.00	97.00	158.00	77.00	16.24	14.54	13.60	36.90	87.36	34.0	159.40	29.26

Contd.…

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Per-cent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
ARYP-62	58.50	60.50	99.00	170.50	85.50	15.29	14.44	14.20	34.20	82.47	31.0	123.40	23.82
ARYP-63	59.00	61.00	98.00	158.50	73.00	14.25	14.69	14.30	32.00	82.56	39.0	150.40	25.35
ARYP-64	56.50	57.50	97.50	168.50	78.50	13.00	14.58	14.00	28.30	84.46	28.0	120.80	28.07
ARYP-65	57.50	59.50	100.00	199.50	113.00	14.85	14.50	14.20	33.60	82.10	33.0	141.40	36.05
ARYP-66	57.50	59.50	99.00	192.50	98.50	16.61	14.24	14.00	35.20	82.95	36.0	172.00	33.11
ARYP-67	56.50	58.50	98.00	175.50	83.00	15.00	14.99	13.80	34.20	82.67	39.0	174.20	32.65
ARYP-68	56.50	57.50	92.00	186.50	102.00	18.84	15.55	12.80	36.50	84.65	39.0	178.00	37.86
ARYP-69	57.50	58.50	99.00	182.00	97.00	18.11	14.80	13.20	34.70	80.84	44.0	153.00	33.67
ARYP-70	58.50	59.50	102.00	183.50	93.50	17.15	14.40	13.60	37.50	83.49	32.0	151.00	24.51
ARYP-71	57.00	58.50	101.00	185.00	91.50	18.03	15.17	13.40	36.00	80.88	41.0	181.00	34.89
ARYP-72	56.50	58.00	99.00	189.50	96.00	18.79	14.31	13.60	36.80	84.11	41.0	170.40	35.19
ARYP-73	57.00	58.00	101.00	174.50	87.50	17.80	14.59	13.20	35.60	84.39	37.0	167.00	36.43
ARYP-74	56.50	57.50	99.00	195.00	106.50	17.11	14.70	13.20	34.40	80.76	40.0	167.00	35.18
ARYP-75	56.50	58.00	99.00	184.00	98.50	17.13	14.71	15.40	33.90	84.96	29.0	156.00	27.99
ARYP-76	57.00	58.00	100.50	202.00	104.50	17.45	15.51	14.60	35.70	85.08	37.0	195.20	37.00
ARYP-77	57.00	58.50	99.50	192.00	100.50	18.15	13.90	13.60	36.10	85.79	34.0	151.00	34.76
ARYP-78	56.50	57.50	98.00	179.00	94.00	15.14	13.85	13.60	32.20	84.18	35.0	169.00	33.08
ARYP-79	57.00	58.00	98.00	187.50	100.00	15.74	14.06	13.40	33.00	85.59	36.0	144.00	31.20
Mean	57.60	58.99	98.94	169.47	82.45	15.43	14.12	13.68	32.66	83.76	33.3	136.60	28.64
Maximum	60.00	61.50	102.50	202.00	113.00	18.84	15.55	16.40	38.20	87.99	44.0	212.20	41.78
Minimum	55.50	56.50	92.00	131.50	48.00	11.05	11.10	11.20	24.40	78.83	25.0	58.60	14.17

Contd….

Lines	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Ear height (cm)	Cob length (cm)	Cob girth (cm)	No. of rows per cob	No. of kernels per row	Shelling Per-cent age	100 seed weight (g)	Grain yield per plant (g)	Grain yield per hectare (q)
Checks													
CI-4	57.50	58.50	101.00	186.50	95.50	16.00	14.35	13.80	32.30	84.31	35.0	163.00	30.37
CM-111	59.00	61.00	101.50	182.50	101.00	16.95	14.77	13.20	35.90	81.66	38.0	145.00	28.40
KDMI-16	58.50	60.50	101.00	176.50	95.50	15.83	14.38	14.60	32.90	85.85	33.0	152.00	31.88
Mean	**58.33**	**60.00**	**101.17**	**181.83**	**97.33**	**16.26**	**14.50**	**13.87**	**33.70**	**83.94**	**35.3**	**153.33**	**30.21**
Maximum	59.00	61.00	101.50	186.50	101.00	16.95	14.77	14.60	35.90	85.85	38.0	163.00	31.88
Minimum	57.50	58.50	101.00	176.50	95.50	15.83	14.35	13.20	32.3	81.66	33.0	145.00	28.40
S.E	0.55	0.57	0.86	5.56	8.33	0.50	0.29	0.41	1.33	1.23	1.05	9.96	2.31
C.D. 5%	1.56	1.60	2.44	15.65	23.46	1.40	0.83	1.15	3.74	3.42	2.98	28.04	6.52
C.D. 1%	2.07	2.13	3.24	20.75	31.10	1.86	1.10	1.53	4.96	4.60	3.95	37.18	8.64

Appendix II: *per se* performance of twelve S_6 lines and three checks in Maize at three location

Lines	Days to 50 per cent tasseling			Days to 50 per cent silking			Days to 75 per cent dry husk			Plant height (cm)		
	ARB	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**
ARYP-68	56.67	54.00	52.33	57.67	55.00	53.33	92.67	92.00	98.00	186.67	203.00	175.00
ARYP-69	57.33	53.67	53.33	58.33	55.33	55.00	99.00	91.33	99.33	186.00	196.33	189.67
ARYP-70	57.67	54.33	55.33	58.67	56.33	57.33	101.33	91.00	101.33	187.00	193.00	182.00
ARYP-71	57.00	53.00	54.67	58.00	55.00	56.33	100.67	93.00	98.67	190.00	208.00	181.00
ARYP-72	56.33	52.33	54.33	57.33	53.33	55.33	98.67	93.33	100.67	188.00	195.00	175.00
ARYP-73	56.67	52.00	56.67	57.67	53.00	57.67	100.00	93.33	101.67	177.00	199.00	183.33
ARYP-74	56.33	51.00	54.00	57.33	53.00	56.00	98.67	93.00	97.00	193.33	200.33	176.67
ARYP-75	56.67	53.00	55.67	57.67	55.00	57.67	99.67	94.00	102.00	191.67	201.67	184.00
ARYP-76	57.00	55.00	56.67	58.00	56.33	58.33	100.00	94.00	103.67	192.00	201.00	179.00
ARYP-77	57.00	52.67	55.33	58.00	54.67	57.00	100.00	93.00	101.67	201.67	211.00	190.67
ARYP-78	56.67	53.33	56.33	57.67	55.00	57.67	98.00	93.00	101.00	171.00	200.67	180.67
ARYP-79	56.67	50.67	56.33	57.67	52.00	57.33	98.67	90.00	101.00	182.00	198.00	177.33
Checks												
CI-4	57.33	54.00	56.67	58.33	55.00	57.67	100.67	90.00	101.67	170.00	195.00	165.33
CM-111	59.00	54.67	58.33	61.00	56.67	60.33	102.00	92.00	99.00	176.67	196.67	175.00
KDMI-16	58.67	55.00	58.67	60.67	57.00	60.67	101.00	93.00	102.00	166.33	195.67	167.33
Mean	**57.13**	**53.24**	**55.64**	**58.27**	**54.84**	**57.18**	**99.40**	**92.40**	**100.58**	**183.96**	**199.62**	**178.80**
S.E.	0.28	0.23	0.39	0.28	0.21	0.42	0.35	0.41	0.45	0.62	2.37	0.91
C.D. 5%	0.80	0.66	1.14	0.80	0.61	1.23	1.02	1.18	1.30	1.80	6.86	2.62

ARB: Arabhavi MAN: Mandya DWD: Dharwad

Contd…

Lines	Ear height (cm)			Cob length (cm)			Cob girth (cm)			No. of kernels row per cob		
	ARB	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**
ARYP-68	100.67	109.67	95.33	18.66	18.27	16.30	15.24	14.95	14.24	12.33	13.47	13.60
ARYP-69	93.67	109.67	101.00	18.67	13.50	17.30	14.74	15.67	14.77	13.07	13.47	13.33
ARYP-70	92.33	98.00	98.67	17.50	18.57	16.10	14.38	15.69	15.01	13.87	15.33	14.67
ARYP-71	88.67	116.33	99.33	18.05	17.63	16.67	15.19	15.69	14.81	13.60	15.07	14.40
ARYP-72	97.00	104.00	92.00	18.29	17.80	14.49	14.24	14.71	13.21	13.47	14.33	13.47
ARYP-73	90.00	107.67	97.67	17.40	16.93	14.68	14.62	15.37	13.99	13.20	14.27	13.73
ARYP-74	101.67	112.33	93.67	16.74	16.05	16.80	14.71	14.33	13.84	14.07	12.93	12.67
ARYP-75	105.67	119.00	108.33	17.05	16.57	15.23	14.60	14.65	13.49	15.00	13.87	14.67
ARYP-76	102.33	108.00	90.00	17.17	16.86	14.30	15.64	16.45	14.65	14.53	15.73	15.60
ARYP-77	104.00	120.33	96.67	18.07	18.27	15.70	13.86	15.23	13.59	13.60	14.00	14.13
ARYP-78	96.00	112.33	95.33	15.46	18.53	15.03	14.06	16.13	14.70	13.87	15.60	15.80
ARYP-79	97.67	107.33	97.00	15.19	15.20	13.43	14.16	15.17	13.08	14.13	14.27	12.93
Checks												
CI-4	85.00	109.33	91.00	15.90	15.86	15.17	14.45	15.05	13.34	13.13	13.93	13.47
CM-111	97.67	109.00	98.67	17.77	16.10	15.13	14.78	14.70	12.97	13.60	14.67	14.00
KDMI-16	87.67	110.00	94.33	14.86	19.33	15.27	14.85	15.29	13.29	13.60	14.67	14.40
Mean	**96.00**	**110.20**	**96.60**	**17.12**	**17.03**	**15.44**	**14.64**	**15.27**	**13.93**	**13.67**	**14.37**	**14.06**
S.E.	0.48	1.17	0.71	0.20	1.55	0.23	0.16	0.19	0.23	0.09	0.15	0.16
C.D. 5%	1.40	3.39	2.05	0.59	3.69	0.67	0.47	0.56	0.66	0.25	0.44	0.47

ARB: Arabhavi MAN: Mandya DWD: Dharwad

Contd…

Lines	No. of kernels per row			Shelling percentage			100 seed weight(g)		
	ARB	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**
ARYP-68	38.07	39.27	33.13	82.58	84.91	78.74	38.67	42.33	28.00
ARYP-69	36.40	36.93	31.27	81.02	82.72	80.36	44.17	43.67	34.33
ARYP-70	37.80	36.47	32.13	82.09	84.97	81.15	34.00	39.17	31.00
ARYP-71	36.93	34.27	32.67	80.96	83.10	81.13	40.67	38.33	34.67
ARYP-72	37.87	37.33	30.80	84.25	84.94	82.80	42.00	37.83	27.33
ARYP-73	38.27	36.20	33.20	85.07	85.55	85.58	37.33	40.00	31.67
ARYP-74	35.00	32.67	37.00	81.67	85.48	81.04	42.00	37.83	32.00
ARYP-75	37.53	38.33	33.73	84.53	86.23	83.99	30.00	34.33	26.33
ARYP-76	37.73	36.53	30.93	85.86	86.75	85.90	36.67	42.50	25.50
ARYP-77	37.00	36.47	33.13	85.48	85.55	82.06	34.67	41.50	29.00
ARYP-78	34.27	37.33	29.93	84.47	85.66	84.28	38.67	38.33	31.33
ARYP-79	33.47	33.40	30.00	84.98	86.98	84.56	38.67	36.50	24.83
Checks									
CI-4	33.87	35.27	30.80	84.24	84.93	83.90	34.67	38.67	31.17
CM-111	35.53	35.80	32.80	81.81	85.26	79.51	33.33	35.83	20.83
KDMI-16	32.93	38.73	30.13	85.05	85.55	81.19	31.33	43.33	24.83
Mean	**36.18**	**36.33**	**32.11**	**83.60**	**85.24**	**82.41**	**37.12**	**39.34**	**28.86**
S.E.	0.08	0.16	0.25	0.29	0.25	0.39	0.34	0.49	0.35
C.D. 5%	0.25	0.46	0.72	0.85	0.74	1.14	0.98	1.42	1.01

ARB: Arabhavi MAN: Mandya DWD: Dharwad

Contd…

Lines	Grain yield per plant (g)			Grain yield per hectare (q)		
	ARB	**MAN**	**DWD**	**ARB**	**MAN**	**DWD**
ARYP-68	178.20	179.33	101.17	37.63	40.21	29.56
ARYP-69	196.80	193.00	126.00	36.06	41.97	38.51
ARYP-70	184.93	193.67	123.57	31.67	39.04	31.99
ARYP-71	187.20	186.00	128.27	37.40	38.55	37.08
ARYP-72	169.73	170.67	85.87	36.86	35.37	27.52
ARYP-73	180.20	176.67	113.77	36.07	38.37	33.16
ARYP-74	170.00	154.33	116.83	36.44	33.25	31.13
ARYP-75	158.00	164.33	97.37	34.80	35.15	24.03
ARYP-76	193.33	200.33	109.30	36.29	35.40	32.72
ARYP-77	157.47	185.00	92.50	35.75	34.41	23.32
ARYP-78	179.40	206.33	121.10	37.37	39.72	35.56
ARYP-79	148.27	157.33	86.17	32.22	33.01	27.09
Checks						
CI-4	161.60	149.00	86.07	34.32	29.97	23.33
CM-111	134.00	156.33	76.20	26.34	30.36	18.84
KDMI-16	134.60	206.00	92.20	30.49	31.36	22.02
Mean	**168.92**	**178.56**	**103.76**	**34.65**	**35.74**	**29.06**
S.E.	2.43	0.36	3.12	0.57	0.74	0.82
C.D. 5%	7.03	1.04	9.04	2.24	2.90	3.20

ARB: Arabhavi MAN: Mandya DWD: Dharwad

Appendix III: Monthly meteorological data during crop growth period (2013) at ARS, Arabhavi (Gokak)

Months	Rainfall (mm)	Temperature (^{0}c)		Relative humidity (%)
		Mean maximum	Mean minimum	
July	53.5	27.96	21.17	86.2
August	31.3	28.75	20.37	81
September	77.2	29.4	20.28	78.6
October	83.8	29.83	19.77	76
November	0	29.47	13.74	70.3
December	0	28.48	11.62	66.4

Appendix IV: Monthly meteorological data during crop growth period (2013) at MARS, University of Agricultural Sciences, Dharwad

Months	Rainfall (mm)	Temperature (^{0}c)		Relative humidity (%)
		Mean maximum	Mean minimum	
July	97.2	25.4	20.3	89
August	133.6	26.7	19.9	85
September	75.4	27.9	20.2	81
October	2.2	28.8	19.4	76
November	2.2	29	15.8	64
December	0	28.4	12.7	53

Appendix V: Monthly meteorological data during crop growth period (2013) at ZARS, College of Agriculture, V. C. Farm, Mandya

Months	Rainfall (mm)	Temperature (^{0}c)		Relative humidity (%)
		Mean maximum	Mean minimum	
July	36.20	29.20	19.20	87.50
August	21.70	29.40	19.30	90.10
September	186.80	29.70	19.00	88.90
October	116.00	29.80	18.50	90.10
November	56.40	29.10	16.60	89.40
December	1.40	27.90	12.50	88.40

VARIABILITY AND STABILITY ANALYSIS OF NEWLY DERIVED S_6 LINES OF MAIZE (*Zea mays* L.)

VISHWE GOWDA **2014** **Dr. M. C. WALI**
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ABSTRACT

The present investigation was carried out to study genetic variability, character association and to assess the stability of newly derived S_6 lines of maize.The variability study comprising of 79 S_6 lines and 3 checks of maize was conducted in RCBD with two replications during 2013 at AICMIP, ARS, Arabhavi.

The ANOVA revealed significant variability among the lines for all traits. Hundred seed weight and grain yield per hectare (q/ha) exhibited high GCV, PCV and heritability coupled with high GAM indicating the role of additive genes for the expression of these traits, hence, selection of these traits could be effective. Hundred seed weight, plant height, cob length, cob girth, number of rows per cob, number of kernels per row and shelling percentage had significant positive phenotypic and genotypic association and direct effects with grain yield.

The stability analysis comprising of 12 S_6 lines and 3 checks of maize was conducted in RCBD with three replications during 2013 at AICMIP, Arabhavi, MARS, Dharwad and ZARS, Mandya.

The pooled ANOVA revealed significant differences among the lines and environments for all traits studied indicating the lines and environments tested are diverse in nature. G × E interaction was significant for all the traits suggesting genotype interacted significantly with the environments. The non-linear component was significant for all the traits indicating variance in terms of lines is unpredictable. On the basis of stability parameters, ARYP-69, ARYP-79 and ARYP-78were promising S_6 lines for grain yield. ARYP-72, ARYP-75, ARYP-77, ARYP-73 and ARYP-79 were promising S_6 lines for cob length, cob girth, days to 50% tasseling, days to 50% silking, plant height, shelling percentage and test weight.