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Association studies of grain yield and its related traits in diverse S_2 populations developed through reciprocal recurrent selection in maize (*Zea mays* L.)

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Abstract
The experiment was conducted at College of Agriculture, University of Agricultural Sciences, Dharwad during *kharif*, 2017 to determine the inter-character association in newly developed S_2 progenies through reciprocal recurrent selection. Association studies in Population A revealed that, grain yield per hectare was positively and significantly associated with cob length (0.642), hundred seed weight (0.591), plant height (0.569), number of kernels per row (0.397), days to 50 per cent tasseling, ear height, cob girth and number of kernel rows per cob. But days to 50 per cent silking (-0.08) was negatively associated with grain yield per hectare. In case population B Grain yield per hectare was positively and significantly associated with cob girth (0.46), cob length (0.40), number of kernel rows per cob (0.45), hundred seed weight (0.36), days to 50 per cent tasseling, days to 50 per cent silking, plant height, ear height, number of kernels per row and shelling percentage. The brown husk maturity was negatively associated with Grain yield per hectare. The information on correlations among traits remains crucial in improving the efficiency of breeding programs by employing the appropriate selection indices in cultivar or varietal improvement.

Keywords: Maize, grain yield, correlation, reciprocal recurrent selection

Introduction
Maize is the second most important cereal crop in the world in terms of acreage and is called the 'Queen of Cereals'. According to the USDA world agricultural supply and demand estimates reported that maize production was forecasted 1068.30 million tonnes in 2018-19. Among the countries United States of America was stood first in maize production with 371.52 million tonnes followed by China (256 mt), Brazil (94.50 mt), European Union (59.50 mt), Argentina (42.50 mt) and India (26.50 mt) (Anon., 2018) [2]. The crop is less water demanding than other similar cereals and being a 'C4' as well as 'day-neutral plant', it gives higher yield per hectare in a shorter period and can be grown in any season. By growing Maize farmers save 90% of water, 70% of power compared to paddy. The multiple utilities of maize as a 'food, 'fodder' and 'feed' makes it further more demand friendly and insulates it against low demand situations. These unique characteristics of maize make the crop a suitable crop candidate for enhancing farmer's income and livelihoods in India.

The grain yield is influenced by several genes which also interact with various environmental conditions. Thus, the yield has a multiplicative effect on the end product of many factors otherwise referred to as yield components (Zeeshan *et al*. 2013) [21]. These yield component traits are simply inherited with minimal environmental deviations, and hence selection based on them is more appropriate than direct selection for yield (Nagabhushan *et al*. 2011) [13]. The inter-character correlation helps to measure the level of relationship between the traits. Selection for specific character is known to result in correlated response in certain other characters. Generally plant breeders make selection for one or two attributes at a time then it becomes important to know the effect on other characters. Improvement in yield is the most important target character in most of the crops. It is a complex quantitative trait governed many genes and can be achieved by direct selection through other easily observed characters. But this needs a good understanding of association of different traits with yield and their possible association among themselves. This study aimed at understanding the different traits influencing the maize yield.

Materials and Methods

Plant Materials

The experiment consisting of 48 S_2 progenies each from populations A and B with commercial checks CP-818, NK-6240, GH-0727 and an inbred tester CI-4 for evaluation were laid out by Augmented RCBD (Federer 1975) [5].

Data on days to 50% tasseling (X_1), days to 50% silking (X_2),plant height(X_3),ear height (X_4), days to maturity (X_5), cob length (X_6), cob girth (X_7), number of kernel rows per cob (X_8), number kernels per cob (X_9), 100 grain weight (X_{10}), shelling percentage (X_{11}) and yield (q/ha) (X_{12}) were recorded.

Experimental site location

The experiment were laid at College of Agriculture, University of Agricultural science, Dharwad during *kharif 2017*. In Karnataka, dharwad is situated in Northern transition zone-VIII. Geographically, Dharwad lies between 15°26' N latitude and 70°26' E longitude and at an altitude of 678 m above mean sea level.

Statistical analysis

Five plants were selected randomly and data on individual mean for each trait was subjected to statistical analysis. The data was analysed using INDOSTAT software Programme version 9.1). For the analysis of the data the following statistical methods were employed. Analysis of variance (ANOVA) for augmented design-II as per Federer (1975) [5] was carried out for each character.

Character association

The correlation coefficients were worked out to determine the degree of association of a character with yield and also among the yield components. The mean values were used to calculate the phenotypic correlations by using the formula given by Weber and Moorthy (1952) [20].

$$r = \frac{\text{Cov}(x, y)}{sp_x \times sp_y} \times 100$$

Where,
r = Correlation coefficient
Cov (x, y) = Covariance between the characters 'x' and 'y'
spx and spy = Phenotypic variance of the character 'x' and 'y' respectively

Correlation coefficients were compared against 'r' values given in Fisher and Yates (1963) [6] tables at (n-2) degrees of freedom at the probability levels of 0.05 and 0.01 to test for their significance.

Results

Analysis of variance was performed to test the significance of difference among the genotypes for the characters studied. Partitioning the variance and co-variance into genotypic, phenotypic and environmental components. The results obtained from analysis of variance for all entries, including checks for 12 characters revealed that the treatment variances were highly significant for all the characters. This indicates the presence of substantial variability among the S_2 progenies (Table 1 & 2).

Table 1: Analysis of variance for twelve quantitative characters in S_2 progenies of pop A

Source of variation	D.F	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Block (Eliminating Check +Var.)	5	5.941	4.291	49.081	31.1	17.009	0.721	0.025	0.645	4.031	4.556	2.898	0.659
Entries (Ignoring Blocks)	51	74.3 **	83.2**	530.8**	237.5**	65.5**	8.7**	0.31**	6.1**	47.5 **	43.8**	28.21**	7.31**
Checks	3	91.58**	106.13**	1703**	388 **	700.73**	23.9**	0.72**	2.926 *	53.56 *	53.18**	170.31**	29.63**
Varieties	47	10.08 *	12.7 **	455 **	229.9*	25.06 *	3.13 **	0.16 **	4.11**	28.8*	39.8**	19.38**	0.992 **
Checks vs. Varieties	1	3043.3**	3325**	570.9**	147.2*	65.3 *	227.2**	6.40 **	109.2 **	909**	201.6**	16.9 *	237.6 **
ERROR	15	3.425	2.764	65.635	31.345	11.033	0.953	0.034	0.768	12.409	5.656	3.288	0.301

*- significant at 5% level, **-significant at 1% level

days to 50% tasseling (X_1), days to 50% silking (X_2),plant height(X_3),ear height (X_4), days to maturity (X_5), cob length (X_6), cob girth (X_7), number of kernel rows per cob (X_8), number kernels per cob (X_9), 100 grain weight (X_{10}), shelling percentage (X_{11}) and yield (q/ha) (X_{12}) were recorded.

Table 2: Analysis of variance for twelve quantitative characters in S_2 progenies of pop B

Characters	D.F	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Block (eliminating Check+Var.)	5	5.941	4.29	49.081	15.275	9.599	0.721	0.025	0.645	4.031	4.555	3.64	0.659
Entries (ignoring Blocks)	51	84.6 **	77.4**	643**	334.7**	64.0**	7.0**	0.34**	4.46**	48.26**	46.3**	29.02**	7.3**
Checks	3	91.5**	106.1**	1703**	2405**	609.6**	23.9**	0.72**	2.92 *	53.05 *	53.18**	245.9**	29.63**
Varieties	47	22.0**	8.16*	571.6**	197.8**	29.0 *	2.96 *	0.17**	3.12 **	37.38 *	43.31 **	15.27**	0.74*
Checks vs. Varieties	1	3006**	3249**	812**	558.5**	69.44*	148.8**	6.83**	71.9**	545.6**	168.7**	24.6**	248.9**
ERROR	15	3.425	2.764	65.635	15.72	12.684	0.953	0.034	0.768	12.409	5.657	2.501	0.301

*- significant at 5% level, **-significant at 1% level

days to 50% tasseling (X_1), days to 50% silking (X_2),plant height(X_3),ear height (X_4), days to maturity (X_5), cob length (X_6), cob girth (X_7), number of kernel rows per cob (X_8), number kernels per cob (X_9), 100 grain weight (X_{10}), shelling percentage (X_{11}) and yield (q/ha) (X_{12}) were recorded.

Days to 50 per cent tasseling

In respect of Pop A, days to 50 per cent tasseling showed positively significant association with grain yield per hectare (0.380), whereas days to 50 per cent silking (0.903) cob girth (0.235) and number kernel rows per cob (0.233) showed significant positive association. (Table- 3)

Table 3: Correlation coefficients for grain yield and its components in maize (pop A)

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Days to 50% tasseling	1.000	0.903**	-0.109	-0.128	-0.025	0.090	0.235*	0.233*	-0.026	-0.009	0.097	0.380**
Days to 50% silking		1.000	-0.173	-0.273*	-0.045	0.083	0.210*	0.177	-0.049	-0.042	0.012	-0.08
Plant height (cm)			1.000	0.351**	0.221*	0.311**	0.256*	0.147	0.202*	0.518**	-0.028	0.569**
Ear height (cm)				1.000	0.054	0.137	0.197	0.026	0.157	0.273*	0.01	0.300**
Brown husk maturity					1.000	0.157	-0.085	0.022	0.158	0.086	0.028	0.098
Cob length (cm)						1.000	-0.073	-0.070	0.704**	0.274*	0.285**	0.642**
Cob girth (cm)							1.000	0.659**	-0.143	0.433**	-0.129	0.290**
Number of kernel rows /cob								1.000	0.030	-0.104	0.088	0.218*
Number of kernels/ row									1.000	-0.122	0.476**	0.397**
100 seed weight										1.000	-0.092	0.591**
Shelling percentage (%)											1.000	0.172
Grain yield (q/ha)												1.000

*- significant at 5% level, **-significant at 1% level

days to 50% tasseling (X_1), days to 50% silking (X_2),plant height(X_3),ear height (X_4), days to maturity (X_5), cob length (X_6), cob girth (X_7), number of kernel rows per cob (X_8), number kernels per cob (X_9), 100 grain weight (X_{10}), shelling percentage (X_{11}) and yield (q/ha) (X_{12}) were recorded.

In case of Pop B, days to 50 per cent tasseling showed positive significant correlation with grain yield per hectare (0.306). The characters like days to 50 per cent silking (0.656), hundred seed weight (0.311) showed significant positive association with days to 50 per cent tasseling. (Table-4).

Table 4: Correlation coefficients for grain yield and its components in maize (pop B)

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
Days to 50% tasseling	1.0	0.65**	-0.05	0.086	-0.044	0.196	0.100	-0.034	-0.137	0.311**	-0.104	0.306**
Days to 50% silking		1.0	0.02	0.172	-0.014	0.360**	0.193	0.052	0.127	0.167	0.104	0.280*
Plant height (cm)			1.0	0.851**	0.247*	0.142	0.305**	0.257*	0.078	0.411**	-0.080	0.396**
Ear height (cm)				1.0	0.129	0.241*	0.267*	0.226*	0.079	0.424**	-0.083	0.425**
Brown husk maturity					1.0	-0.173	0.121	0.105	-0.166	0.104	0.054	-0.05
Cob length (cm)						1.0	-0.044	-0.010	0.560**	0.130	0.219*	0.406**
Cob girth (cm)							1.0	0.690**	-0.269*	0.447**	-0.030	0.468**
Number of kernel rows /cob								1.0	0.044	-0.045	0.253*	0.454**
Number of kernels/ row									1.0	-0.39**	0.464**	0.329**
100 seed weight										1.0	-0.205*	0.367**
Shelling percentage (%)											1.0	0.297*
Grain yield (q/ha)												1.0

*- significant at 5% level, **-significant at 1% level

days to 50% tasseling (X_1), days to 50% silking (X_2),plant height(X_3),ear height (X_4), days to maturity (X_5), cob length (X_6), cob girth (X_7), number of kernel rows per cob (X_8), number kernels per cob (X_9), 100 grain weight (X_{10}), shelling percentage (X_{11}) and yield (q/ha) (X_{12}) were recorded.

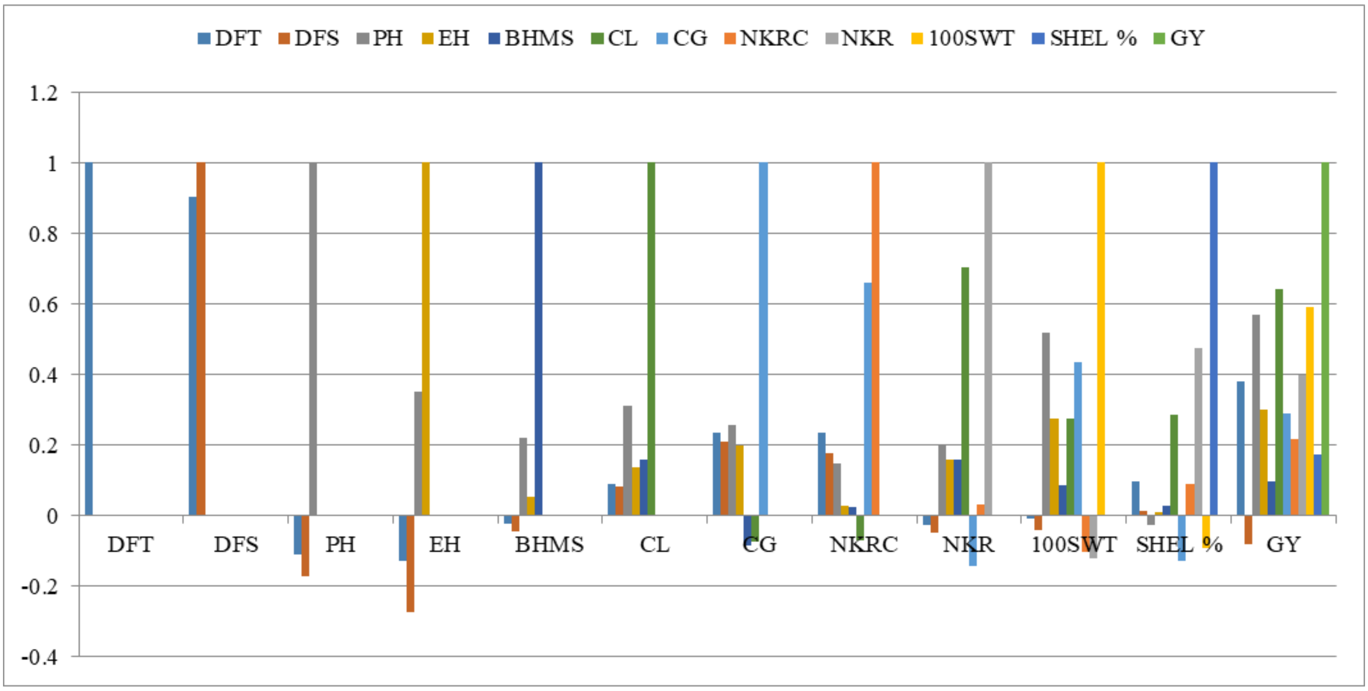

Fig 1: Correlation coefficients for grain yield and its components in maize for pop A

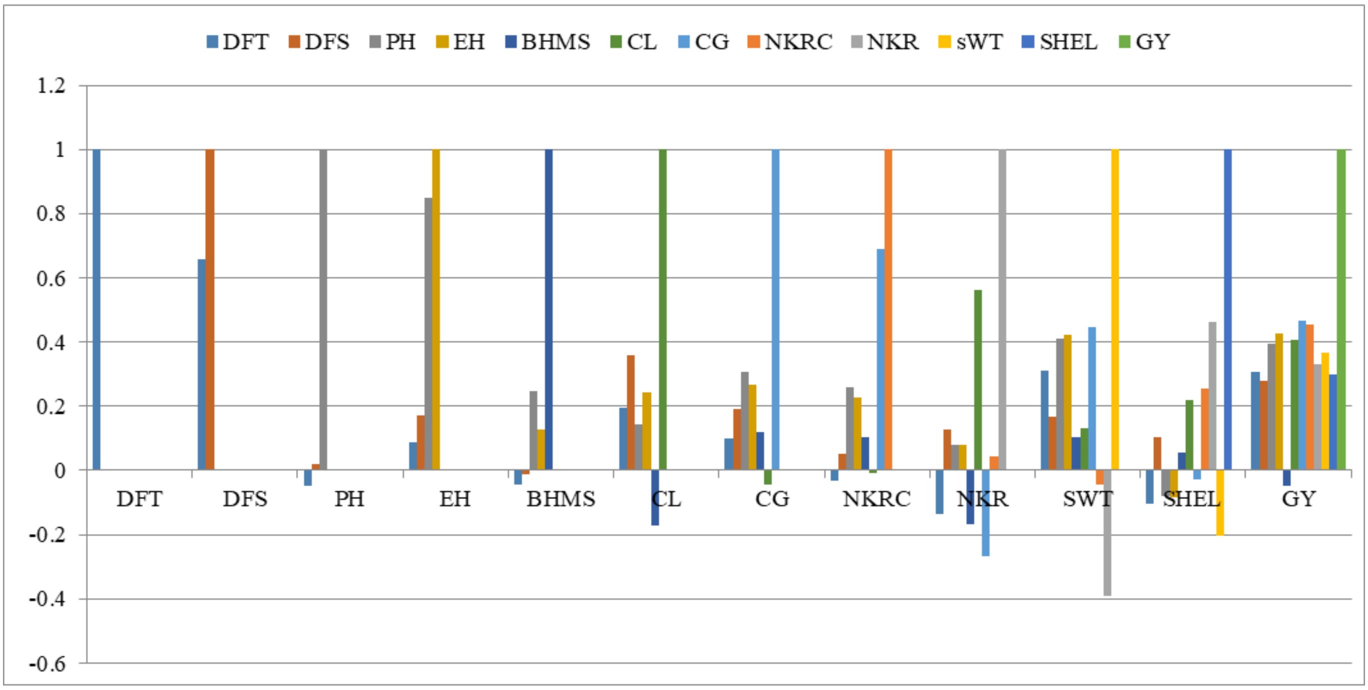

Fig 2: Correlation coefficients for grain yield and its components in maize for pop B

Days to 50 per cent silking

In case of Pop A, days to 50 per cent silking showed negatively association with grain yield per hectare (-0.08) and ear height showed (-0.273), whereas cob girth (0.210) showed significant positive association.

As regards to Pop B, days to 50 per cent silking showed positive significant association with grain yield per hectare (0.280) and cob length (0.360), whereas negatively associated with brown husk maturity (-0.014).

Plant height (cm)

With respect pop A, plant height showed highly significant positive correlation with grain yield per hectare (0.569), hundred seed weight (0.518), number of kernels per row (0.202), cob girth (0.256), cob length (0.311), brown husk maturity (0.221), and ear height (0.351), whereas shelling percentage (-0.02) showed negative significance.

In case of Pop B, plant height showed significant positive association with grain yield per hectare (0.396), hundred grain weight (0.411), number of kernels row per cob (0.257), cob girth (0.305), brown husk maturity (0.247), and ear height (0.851), while shelling percentage (-0.08) showed negative significance.

Ear height (cm)

In regard to estimation of inter character correlation in Pop A, ear height showed significant positive association grain yield per hectare (0.300) and also with hundred seed weight (0.273)

In case of Pop B, ear height showed significant positive association grain yield per hectare (0.425), hundred seed weight (0.424), number of kernels row per cob (0.226), cob girth (0.267), and cob length (0.241), whereas shelling percentage (-0.083) showed negative association.

Brown husk maturity

In regard to estimation of inter character correlation in Pop A, Brown husk maturity showed positive correlation with plant height (0.221) and number kernels per cob (0.158), whereas grain yield per hectare (0.098), cob girth (-0.085) negatively associated.

With respect pop B, Brown husk maturity showed positive correlation with plant height (0.247) and whereas negatively associated with grain yield (-0.05).

Cob length (cm)

In case of Pop A, cob length showed highly significant positive correlation with plant height (0.311), grain yield per hectare (0.642), hundred seed weight (0.274), shelling percentage (0.285), number of kernels per row (0.704), whereas cob girth (-0.073), and number of kernels row per cob (-0.070) showed negative association.

In respect of Pop B, cob length showed highly positive significant correlation with grain yield per hectare (0.406), shelling percentage (0.219), number of kernels per row (0.560), 50 per cent silking (0.306), and ear height (0.241) while number of kernels row per cob (-0.010), cob girth (-0.044) showed negative correlation.

Cob girth (cm)

In correlation study of Pop A, con girth showed highly significant positive correlation with days to 50 per cent tasselling (0.235), 50 per cent silking (0.210), plant height (0.256),grain yield per hectare (0.290), hundred seed weight (0.433), number of kernels row per cob (-0.010), whereas, shelling percentage (-0.129), number of kernels per row (-0.143) showed negative significance.

In case of Pop B, cob girth showed positive significant correlation with plant height (0.305), ear height (0.267), grain yield per hectare (0.468), hundred seed weight (0.447), number of kernels row per cob (0.690), whereas number of kernels per row (-0.269) showed negative significance.

Number of kernel rows per cob

The correlation study in Pop A exhibited, number of kernel rows per ear showed highly significant positive correlation with grain yield per hectare (0.218), cob girth (0.659), 50 per cent tasselling (0.233),while hundred seed weight (-0.104), cob length (-0.070), showed negative association.

In respect of Pop B, number of kernel rows per cob showed significant positive correlation with grain yield per hectare

(0.454), shelling percentage (0.253), cob girth (0.690), plant height (0.257), and ear height (0.226). Then hundred seed weight (-0.045), cob length (-0.010), showed negative association.

Number of kernels per row

The estimates of inter character association in Pop A exhibited number of kernels per row showed highly significant positive correlation with grain yield per hectare (0.397), shelling percentage (0.476), plant height (0.202), and cob length (0.704), whereas hundred seed weight (-0.122), cob girth (-0.143) showed negative association.

In case of Pop B, number of kernels per row showed significant positive correlation with grain yield per hectare (0.329), shelling percentage (0.464), and cob length (0.560). Then hundred seed weight (-0.39) cob girth (-0.269), showed negative significance.

Hundred seed weight (gm.)

In case of Pop A, hundred grain weight showed highly significant positive correlation with grain yield per hectare (0.591), cob length (0.274), cob girth (0.433), plant height (0.518), ear height (0.273) whereas, shelling percentage (-0.092), number of kernels per row (-0.122) and number of kernels row cob (-0.104) showed negative association.

In respect of Pop B, hundred grain weight showed significant positive correlation with grain yield per hectare (0.367), cob girth (0.447), plant height (0.411), ear height (0.424), and days to 50 per cent tasselling (0.311). Then number of kernels per row (-0.39) shows negative significance.

Shelling percentage (%)

Shelling percentage showed highly significant positive correlation with number of kernels per row (0.476) and cob length (0.285), whereas negative association with cob girth (-0.129), hundred seed weight (-0.092) with respect to Pop A.

In **c**ase of Pop B, shelling percentage showed significant positive correlation with grain yield per hectare (0.297), number of kernels row per cob (0.253),number of kernels per row (0.464) and cob length (0.219).then cob girth (-0.030), hundred seed weight (-0.205), and plant height (-0.08) showed negative association

Grain yield per hectare (q/ha)

A significant positive correlation was recorded between grain yield per hectare with plant height, ear height, days to 50 per cent tasseling, cob length, cob girth, number of kernels per row, number of kernel rows per ear and 100-seed weight with respect to pop A. The magnitude of correlation with grain yield per hectare was highest in case of cob length with correlation value of (0.642). Characters viz., days to 50% tasselling (0.38), plant height (0.569), cob girth (0.290), ear height (0.300), 100-grain weight (0.591), and number of kernels per row (0.397), were found highly correlated while, number of kernel rows per cob (0.218) were moderately correlated. Other characters like shelling percentage, brown husk maturity were recorded as positive, and days to 50% silking recorded as negative but non-significant correlation with grain yield per hectare.

In case of Pop B, grain yield per hectare showed significant positive correlation with plant height, ear height, days to 50 per cent tasseling, days to 50% silking, cob length, cob girth, number of kernels per row, number of kernel rows per ear and 100-grain weight and shelling percentage. The magnitude of correlation with grain yield per hectare was highest in case of cob girth with correlation value of (0.468). Characters viz., plant height (0.396), ear height (0.425), days to 50 per cent tasseling (0.306), cob length (0.406), number of kernels per row (0.329), number of kernel rows per cob (0.454) and 100-grain weight (0.367) were found highly correlated while, shelling percentage (0.297) and days to 50% silking (0.280) were moderately correlated. Brown husk maturity (-0.05) negatively correlated but not significant.

Discussion

Yield is the ultimate product in which breeder is interested. It is a highly complex quantitative character, which is governed by polygenes; its expression depends largely on the environment, as polygenes are highly sensitive to the environment. Hence, selection of superior genotypes based on yield may not be effective. For rational approach towards the improvement of yield, selection has to be operated through associated characters.

The strong positive correlation of grain yield with plant height was reported by Malik *et al*. (2005) [11], and Raghu *et al*. (2011) [15] and Baretta *et al*. (2016) [3] also showed positive association of yield with ear height. Bello *et al*. (2010) [4] showed similar results for days to 50 per cent tasselling and days to 50% silking. Mohammadia *et al*. (2003) [10] and Mohan *et al*. (2002) [12] reported similar results with respect to cob length, cob girth and 100 grain weight. High correlation of grain yield with number of kernel rows per ear and number of kernels per row was reported by Khayatnezhad *et al*. (2010) [8] and Mohammadia *et al*. (2003) [10]. The negative association was observed between grain yield and maturity characters by Netaji *et al.* (2000) [14], Reddy *et al.* (2012) [16]. The negative association was observed between grain yield and days to 50% silking Kumar *et al.* (2014) [9], Sadek *et al.* (2006) [17], Hossain *et al.* (2007). The positive relationships observed in this study also indicate that favourable genes controlling these traits present in the population could be utilized for the improvement of the population sources in maize breeding programs.

Conclusion

Correlation studies indicated that plant height, ear height, days to 50 per cent tasselling, number of kernel rows per ear, number of kernels per row and 100-grain weight had strong association and directly affected grain yield both the populations. Compare to direct selection for yield, by selecting yield related traits gave better results. Thus, the information on correlations among traits remains crucial in improving the efficiency of breeding programs by employing the appropriate selection indices in cultivar or varietal improvement.

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