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Association Analysis over Seasons among Morphological, Physiological and Yield Components with Kernel Yield in Maize (*Zea mays* L.)

N Sabitha [a*], D Mohan Reddy [a], D Lokanatha Reddy [a], P Sudhakar [a] and B Ravindra Reddy [a]

[a] *S V Agricultural College, Acharya N G Ranga Agriculture University, Tirupati -517502, A.P., India.*

Authors' contributions

This work was carried out in collaboration among all authors. Author NS designed the study, performed the statistical analysis, wrote the first draft of the manuscript and did literature searches. Authors DMR and BRR verified the review of literature and results of the experiment. Fourth author managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Forty five single cross hybrids made from 10 inbred lines of maize through diallel mating design were evaluated for three seasons *viz*. *rabi*, *summer* and kharif from 2016-17 to 2017-18.Kernel yield had consistent significant and positive associations with SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1},number of kernels row^{-1},100 kernel weight and harvest index in *rabi*, *summer* and *kharif* seasons. Similar trend of positive and significant association of kernel yield with all the above characters were recorded at genotypic level indicating existence a close relationship among these characters. Days to 50% tasseling, days to 50% silking, days to maturity and specific leaf weight showed consistent negative and significant correlations with kernel yield both at phenotypic and genotypic level indicating yield penalty with increase in

**Corresponding author: E-mail: nsabitha84@gmail.com;*

days to 50% tasselling, days to 50% silking and specific leaf weight because more of vegetative growth and less time for reproductive growth which consequently lead to less kernel yield. The associations of anthesis-silking interval with kernel yield were consistently negative and non-significant in all the three seasons at phenotypic level revealing that narrow interval of anthesis silking interval facilates good seed setting. Plant height showed either negative and significant or negative but non-significant association with kernel yield across seasons suggesting that any increase in plant height may lead to reduction in kernel yield and thus medium plant height is desirable for recording higher kernel yields in Maize. Based on the results of character association analysis it was concluded that SPAD chlorophyll meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index might be given due importance, while formulating selection indices aimed at kernel yield improvement as these characters had showed consistently positive and significant associations with kernel yield. A plant with medium plant height and duration coupled with higher SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1},number of kernels row^{-1},100 kernel weight and harvest index is desirable for getting higher kernel yield in maize.

Keywords: Maize; association analysis; kernel yield; yield components; cereal crop; maize breeding; breeding programs.

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most important productive potential cereal crop after wheat and rice and is considered one of the most versatile crops with greater adaptability in various agro-ecological regions [1]. It is a multipurpose crop used as food, feed, and industrial raw materials for diverse products [2]. Grain yield of maize is expected to increase due to combined effects of increased genetic potential of the hybrids and improved cultural practices and management .It is reported that half of the yield increase was contributed by improvements in genetic gain [3]. Therefore the principal goal of maize breeding programs is to develop new hybrids/ varieties that outperform existing hybrids/ varieties with respect to many characters. Maize yield had increased greatly with the extension of single cross hybrids throughout the world [4]. The kernel yield is a complex quantitative character influenced by several yield-contributing characters and controlled by multiple factors [5]. Hence, selection for kernel yield alone may not be much effective [6]. Knowledge of interrelationships between kernel yield and its contributing components significantly improves the efficiency of breeding programs through the use of appropriate selection indices [7], (Dan Singh *et al*.,2017).Correlation measures the degree of association: genetic or non-genetic between two or more characters and is measured by a correlation coefficient [8]. Phenotypic correlation involves both genetic and environmental effects, whereas genotypic correlation is the association of breeding values of the two characters [9,10,11]. Both measure the extent to which degree the same genes or closely linked genes cause co-variation in two different characters [12]. Character association studies will help to assess the relationship between the yield and its contributing traits for enhancing efficiency selection [13]. The present study was conducted to determine the extent and nature of morpho-physiological and yield components relationship with kernel yield in maize through a simple coefficient correlation analysis.

2. MATERIALS AND METHODS

Forty five single cross hybrids developed from 10 inbred lines of maize through diallel mating design (Method II and Model II) were evaluated for their performance over three seasons *viz*., *rabi*, *summer* and *kharif* from 2016-17 to 2017-18 at Agricultural Research Station, Perumallapalli, A.P. The experiment was laid out in a randomized block design with three replications with five meters row length with 75 × 20 cm in *kharif* and 60× 20 cm in both *rabi* and *summer* between rows and between plant to plant spacing was adopted respectively. The two seeds per hill were dibbled and one week after germination thinning operation was carried out to maintain single plant per hill. All the recommended package of practices was followed in raising a healthy crop. Data were recorded for 15 morpho-physiological and yield contributing characters on five randomly selected plants in each replication. The mean values for different characters were analysed using online software “OPSTAT” developed by Chaudhary Charan Singh

Agricultural University, Hissar. Correlation coefficients for different characters were estimated by the method suggested by Panse and Sukhatme [14].

3. RESULTS AND DISCUSSION

Phenotypic and genotypic correlation coefficients worked out for all the 15 characters over three seasons *i.e rabi*, *summer* and *kharif* are presented in Table 1. Genotype correlations were in general greater in magnitude than the phenotypic correlations indicating the lesser influence of environments on the expression of the characters.

Kernel yield had consistent significant and positive associations with SPAD meter reading (0.39**, 0.50** and 0.26**), specific leaf area (0.44**, 0.27** and 0.22**), cob length (0.53**, 0.49** and 0.45**), cob girth (0.62**, 0.59** and 0.52**), number of kernel rows cob^{-1} (0.59**, 0.69** and 0.56**), number of kernels row^{-1} (0.58**, 0.57** and 0.57**), 100 kernel weight (0.65**, 0.57** and 0.52**) and harvest index (0.26**, 0.29** and 0.32**) in *rabi*, *summer* and *kharif* seasons, respectively at phenotypic level. Similar trend of positive and significant association of kernel yield with all the above characters was recorded at genotype level. The significant and positive associations of SPAD meter readings [15], cob length [16,17] (Ghirmire and Timsina 2015) [18-25], cob girth [15,18,19,20,22,21,23,24,26], number of kernel rows cob^{-1} [18] number of kernels row^{-1} [15,18,20,22,21,27,24,23,28,25], 100 kernel weight [15,18,20,22,21,24,27,29,25] were reported by several research workers in maize.

Days to 50% tasseling (-0.45**, -0.27** and -0.48**), days to 50% silking (-0.40**, -0.26** and -0.47**), days to maturity (-0.48**, -0.36** and -0.31**) and specific leaf weight (-0.42**, -0.30** and -0.29**) showed consistent negative and significant correlations with kernel yield at phenotypic level. Ghimire and Timsina [15] reported that more number of days to 50% tasseling and days to 50% silking will result in more vegetative growth and less time for reproductive growth and leads to less yield. Negative associations of days to tasseling, days to silking with days to maturity with kernel yield as recorded in the present study are desirable in maize breeding aimed at the development of high yielding hybrids/ varieties with earliness. These results are in agreement with the findings of Ghimire and Timsina [15] Vijay Kumar et al. [18] and Woldu Mogesse [29] in maize.

The associations of anthesis-silking interval with kernel yield were consistently negative but non-significant (-0.03, -0.10 and -0.09) and significantly negative at genotypic level with kernel yield in all the three seasons. Plant height showed either negative and significant or negative but non-significant (-0.03, -0.24** and -0.32**) association with kernel yield across seasons. Contrary to the present study results, Ghilmire and Timsina [15], Hailegebrial and Yemane [19] and Jemal et al. [9] reported positive and significant associations of plant height with kernel yield in maize. This may be due to variation in the study environment, experimental material and number of genotypes handled in the study.

Associations among the characters revealed that days to 50% tasseling had significant positive correlations with days to 50% silking, days to maturity, specific leaf weight and negative significant association with SPAD meter reading, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight, harvest index at both phenotypic and genotypic level. Days to 50% silking showed positive and significant associations with anthesis-silking interval. Days to maturity showed negative and significant associations with SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index.

Association of days to maturity with SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index were consistently significant and negative, while these same characters had positive and significant association with specific leaf weight in all the three seasons.Anthesis-silking interval showed inconsistent negative or positive associations with plant height, SPAD meter readings, specific leaf area, specific leaf weight, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index except with days to maturity.

In the present study plant height had consistent significant and negative associations with SPAD meter readings, specific leaf area and positive and significant associations with specific leaf weight.Contrary to these findings Woldu Mogesse [29] observed significant and positive correlations of plant height with ear height, days to maturity, ear length, ear diameter, number of kernels row^{-1} and number of kernel row cob^{-1} at

Table 1. Estimates of phenotypic and genotypic correlation coefficients among morpho-physiological and yield components and with kernel yield in maize over seasons

Character(s)	Season(s)	DT	DS	ASI	DM	PH	SPAD	SLA	SLW	CL	CG	NKRC	NKPR	KW	HI	KY
DT	*Rabi*	**1.00**	0.86**	0.10	0.46**	0.03	-0.24*	-0.23**	0.20*	-0.30**	-0.49**	-0.36**	-0.32**	-0.34**	-0.24**	-0.45**
	Summer	**1.00**	0.96**	0.33**	0.40**	0.11	-0.40**	-0.32**	0.32**	-0.26**	-0.32**	-0.24**	-0.28**	-0.24**	-0.30**	-0.27**
	Kharif	**1.00**	0.93**	0.09	0.46**	0.35**	-0.34**	-0.34**	0.34**	-0.37**	-0.46**	-0.37**	-0.52**	-0.42**	-0.40**	-0.48**
DS	*Rabi*	0.94**	**1.00**	0.56**	0.50**	-0.02	-0.19*	-0.16	0.11	-0.30**	-0.39**	-0.26**	-0.25**	-0.30**	-0.22*	-0.40**
	Summer	1.00**	**1.00**	0.59**	0.39**	0.13	-0.38**	-0.33**	0.33**	-0.27**	-0.32**	-0.26**	-0.30**	-0.25**	-0.29**	-0.26**
	Kharif	1.00**	**1.00**	0.45**	0.46**	0.38**	-0.34**	-0.38**	0.37**	-0.39**	-0.46**	-0.42**	-0.54**	-0.45**	-0.38**	-0.47**
ASI	*Rabi*	0.28**	0.61**	**1.00**	0.24**	-0.09	0.03	0.09	-0.13	-0.06	0.02	0.06	0.05	-0.01	0.02	-0.03
	Summer	0.92**	0.94**	**1.00**	0.14	0.13	-0.14	-0.19*	0.18*	-0.15	-0.16	-0.17*	-0.19*	-0.16	-0.11	-0.10
	Kharif	1.62**	1.54**	**1.00**	0.19*	0.16	-0.11	-0.19*	0.17*	-0.15	-0.15	-0.23**	-0.20*	-0.20*	-0.08	-0.09
DM	*Rabi*	0.61**	0.65**	0.36**	**1.00**	-0.11	-0.23**	-0.27**	0.23**	-0.35**	-0.44**	-0.41**	-0.42**	-0.38**	-0.31**	-0.48**
	Summer	0.52**	0.53**	0.60**	**1.00**	0.19*	-0.47**	-0.26**	0.28**	-0.40**	-0.42**	-0.40**	-0.53**	-0.39**	-0.34**	-0.36**
	Kharif	0.56**	0.59**	1.54**	**1.00**	0.27**	-0.23**	-0.31**	0.26**	-0.37**	-0.47**	-0.41**	-0.33**	-0.25**	-0.23**	-0.31**
PH	*Rabi*	0.01	-0.04	-0.12	-0.15	**1.00**	0.16	-0.16	0.16	-0.02	-0.01	0.16	-0.07	-0.01	0.05	-0.03
	Summer	0.14	0.16	0.35**	0.26**	**1.00**	-0.26**	-0.30**	0.32**	-0.19*	-0.15	-0.16	-0.35**	-0.21*	-0.10	-0.24**
	Kharif	0.49**	0.52**	1.42**	0.38**	**1.00**	-0.16	-0.29**	0.24**	-0.23**	-0.22*	-0.36**	-0.36**	-0.32**	-0.24**	-0.32**
SPAD	*Rabi*	-0.30**	-0.23**	0.06	-0.27**	0.19*	**1.00**	0.31**	-0.23**	0.50**	0.48**	0.51**	0.36**	0.49**	0.37**	0.39**
	Summer	-0.50**	-0.51**	-0.60**	-0.66**	-0.36**	**1.00**	0.44**	-0.45**	0.47**	0.60**	0.54**	0.65**	0.49**	0.32**	0.50**
	Kharif	-0.58**	-0.65**	-2.21**	-0.58**	-0.31**	**1.00**	0.36**	-0.32**	0.41**	0.39**	0.34**	0.44**	0.34**	0.26**	0.26**
SLA	*Rabi*	-0.38**	-0.24**	0.21*	-0.58**	-0.43**	0.69**	**1.00**	-0.90**	0.48**	0.44**	0.43**	0.39**	0.53**	0.29**	0.44**
	Summer	-0.55**	-0.56**	-0.60**	-0.54**	-0.59**	0.77**	**1.00**	-0.98**	0.35**	0.30**	0.24**	0.50**	0.22*	0.24**	0.27**
	Kharif	-0.66**	-0.62**	-0.10	-0.62**	-0.67**	0.95**	**1.00**	-0.91**	0.25**	0.35**	0.34**	0.26**	0.23**	0.30**	0.22**
SLW	*Rabi*	0.33**	0.17*	-0.26**	0.54**	0.38**	-0.56**	-0.97**	**1.00**	-0.43**	-0.36**	-0.40**	-0.34**	-0.50**	-0.27**	-0.42**
	Summer	0.53**	0.54**	0.59**	0.54**	0.61**	-0.76**	-1.00**	**1.00**	-0.36**	-0.31**	-0.25**	-0.52**	-0.23**	-0.24**	-0.30**
	Kharif	0.65**	0.61**	0.13	0.57**	0.59**	-0.94**	-0.83**	**1.00**	-0.25**	-0.37**	-0.35**	-0.25**	-0.24**	-0.23**	-0.29**
CL	*Rabi*	-0.44**	-0.34**	0.07	-0.47**	-0.07	0.79**	0.86**	-0.80**	**1.00**	0.64**	0.60**	0.50**	0.62**	0.46**	0.53**
	Summer	-0.55**	-0.55**	-0.53**	-0.76**	-0.32**	0.91**	0.73**	-0.74**	**1.00**	0.50**	0.37**	0.41**	0.43**	0.28*	0.49**
	Kharif	-0.55**	-0.60**	-1.85**	-0.52**	-0.41**	0.91**	0.62**	-0.71**	**1.00**	0.63**	0.53**	0.42**	0.49**	0.29**	0.45**
CG	*Rabi*	-0.68**	-0.51**	0.09	-0.54**	-0.03	0.65**	0.92**	-0.88**	0.96**	**1.00**	0.67**	0.53**	0.66**	0.32**	0.62**
	Summer	-0.40**	-0.39**	-0.29**	-0.52**	-0.22**	0.77**	0.50**	-0.50**	0.86**	**1.00**	0.58**	0.59**	0.60**	0.33**	0.59**
	Kharif	-0.62**	-0.62**	-1.01**	-0.59**	-0.33**	0.77**	0.69**	-0.74**	0.89**	**1.00**	0.62**	0.49**	0.56**	0.37**	0.52**
NKRC	*Rabi*	-0.53**	-0.41**	0.07	-0.62**	0.15	0.76**	0.90**	-0.87**	0.98**	1.00**	**1.00**	0.52**	0.69**	0.40**	0.59**
	Summer	-0.33**	-0.35**	-0.44**	-0.69**	-0.28**	0.79**	0.57**	-0.57**	1.01**	0.85**	**1.00**	0.56**	0.67**	0.29**	0.69**
	Kharif	-0.68**	-0.68**	-1.04**	-0.68**	-0.50**	0.94**	0.79**	-0.85**	1.03**	0.95**	**1.00**	0.53**	0.45**	0.19*	0.56**
NKPR	*Rabi*	-0.62**	-0.52**	0.03	-0.62**	-0.07	0.60**	1.01**	-0.91**	0.99**	0.87**	0.92**	**1.00**	0.56**	0.30**	0.58**
	Summer	-0.39**	-0.42**	-0.55**	-0.72**	-0.53**	0.92**	0.84**	-0.84**	0.98**	0.80**	0.93**	**1.00**	0.57**	0.36**	0.57**
	Kharif	-0.75**	-0.76**	-1.29**	-0.59**	-0.51**	0.85**	0.64**	-0.67**	0.80**	0.76**	0.92**	**1.00**	0.47**	0.34**	0.57**
KW	*Rabi*	-0.47**	-0.41**	-0.05	-0.52**	-0.01	0.66**	0.91**	-0.93**	0.91**	0.83**	0.93**	0.89**	**1.00**	0.37**	0.65**
	Summer	-0.25**	-0.28**	-0.41**	-0.53**	-0.34**	0.64**	0.45**	-0.46**	0.81**	0.81**	1.05**	0.91**	**1.00**	0.26**	0.57**
	Kharif	-0.56**	-0.63**	-2.38**	-0.32**	-0.41**	0.56**	0.45**	-0.46**	0.73**	0.73**	0.72**	0.70**	**1.00**	0.46**	0.52**
HI	*Rabi*	-0.31**	-0.27**	0.03	-0.47**	0.15	0.51**	0.67**	-0.56**	0.65**	0.46**	0.71**	0.57**	0.55**	**1.00**	0.26**
	Summer	-0.49**	-0.52**	-0.66**	-0.47**	-0.25**	0.50**	0.46**	-0.44**	0.67**	0.55**	0.63**	0.55**	0.61**	**1.00**	0.29**
	Kharif	-0.53**	-0.56**	-1.39**	-0.30**	-0.43**	0.69**	0.77**	-0.61**	0.49**	0.54**	0.45**	0.63**	0.58**	**1.00**	0.32**
KY	*Rabi*	-0.56**	-0.50**	-0.07	-0.66**	0.01	0.47**	0.84**	-0.81**	0.78**	0.84**	0.83**	1.00**	0.81**	0.41**	**1.00**
	Summer	-0.34**	-0.34**	-0.26**	-0.59**	-0.25**	0.76**	0.68**	-0.70**	0.93**	0.79**	0.87**	0.87**	0.86**	0.55**	**1.00**
	Kharif	-0.64**	-0.71**	-2.31**	-0.44**	-0.49**	0.48**	0.54**	-0.67**	0.80**	0.69**	0.83**	0.87**	0.70**	0.39**	**1.00**

**Significant at 5% level of significance; **Significant at 1% level of significance; Values upper diagonal indicates phenotypic correlations; Values lower diagonal indicates genotypic correlations*

DT=Days to tasseling; DS=Days to silking; ASI=Anthesis-silking interval; DM=Days to maturity; PH=Plant height; SPAD=SPAD meter readings; SLA=Specific leaf area; SLW=Specific leaf weight; CL=Cob length; CG=Cob girth; NKRC=Number of kernel rows cob^{-1}; NKPR=Number of kernels row^{-1}; KW=100 kernel weight; HI=Harvest index; KY=Kernel yield plant^{-1}

phenotypic and genotypic level. This could be due to variation in the experimental material, sample size and environment.

SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index showed consistent significant and positive associations among the characters at phenotypic and genotypic level across three seasons. However, specific leaf weight had consistently showed significant and negative associations over three seasons both at phenotype and genotype level with SCMR, specific leaf area, specific leaf weight, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index.

4. CONCLUSION

From the present investigation it is evident that SPAD meter readings, specific leaf area, cob length, cob girth, number of kernel rows cob^{-1}, number of kernels row^{-1}, 100 kernel weight and harvest index had consistent positive and significant associations with kernel yield. Selection for any one of these characters would bring in simultaneous improvement of other characters and also finally improvement in kernel yield. Hence, simultaneous selection of these characters might be given due importance, while formulating selection indices or making selections for high yielding hybrids in maize. Negative associations of anthesis- silking interval with kernel yield suggests that narrow interval of anthesis- silking interval is desirable for good seed setting.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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