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Estimation of character associations, direct and indirect effects among yield, yield component and water use efficiency traits in blackgram

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Abstract
An investigation was carried out using 30 blackgram genotypes to study the correlations and various direct and indirect effects among yield, yield components and water use efficiency traits on seed yield in order to identify high yielding lines with more water use efficiency. Character association studies revealed that number of clusters per plant (r_p = 0.470**, r_g = 0.584**), followed by pods per plant (r_p = 0.424**, r_g = 0.604**), pod length (r_p = 0.235*, r_g = 0.384**) and number of seeds per pod (r_p = 0.414**, r_g = 0.673**) exhibited significant positive correlation, whereas days to 50% flowering (r_p = -0.267*, r_g = -0.400**) recorded significant negative association with seed yield. Path analysis revealed that number of seeds per pod had high positive direct effect, while number of pods per plant exhibited moderate positive direct effect on seed yield. Hence, selection based on these traits would aid in simultaneous improvement of seed yield and water use efficiency.

Keywords: Correlation, path analysis, seed yield, water use efficiency, blackgram

Introduction
Pulses have gained much importance in the present context of major shift in preference towards vegetarian diet and plant based proteins. Pulses being short duration crops offer other advantages like soil structure maintenance and cropping pattern intensification Blackgram (*Vigna mungo* (L.) Hepper) is one of the important pulses grown in India. It is an important source of proteins, carbohydrates, vitamins and minerals that occupies a prime position in addressing nutritional security. Although India contributes a lion share to world pulse production, it is not yet self sufficient.

Despite a number of varieties available to the farming community there is no much improvement in yield levels. This signifies the need to re examine the germplasm resources and identify potential parents. Screening of germplasm is a much needed research criterion the present context as it acts as a powerful tool to the plant breeder in more precise selection of parents that exactly meets his objectives. To meet the protein requirement demands of the ever rising population the country needs to produce about more than 39 MT by 2050. This highlights the exigency to push up the yield plateau in pulses. As yield being a complex polygenic trait, direct selection cannot be imposed. The study on inter-relationships among the yield component traits and seed yield will be an effective selection strategy. Hence knowledge regarding the association of yield with other component traits is of research interest to enhance yield levels Majority of blackgram cultivation in India is restricted to rainfed marginal lands because of which crop often faces terminal moisture stress that results in yield loss. Hence an insight into surrogate traits of water use efficiency traits and their association with yield is of research significance to develop high yielding blackgram genotypes with improved water use efficiency. Correlation studies provide better understandings of yield components that help the plant breeder during selection (Johnson *et al.* 1955) [7].

Path analysis permits the understanding of the cause and effect of related traits (Wright, 1921) [18]. Studies on correlation of the yield components and their contribution to the yield in path analysis would help towards crop improvement towards higher yields. In view of these in the present investigation, thirty blackgram genotypes were studied for yield, yield component and water use efficiency traits to determine the degree of correlation and their direct and indirect effect on yield.

Material and Methods

The present investigation was carried out among 30 blackgram genotypes during *Kharif,* 2017 at dry land farm of Sri Venkateswara Agricultural College, Tirupati using a Randomized Block Design with three replications. The recommended agronomic and plant protection practices were followed. Observations were recorded on five randomly selected plants in each genotype for plant height, number of primary branches per plant, number of clusters per plant, number of pods per cluster, number of pods per plant, pod length, number of seeds per pod, 100 seed weight, harvest index, SCMR (SPAD Chlorophyll Meter Reading) at 35 DAS, SCMR (SPAD Chlorophyll Meter Reading) at 50 DAS, SLA (Specific Leaf Area) at 35 DAS, SLA (Specific Leaf Area) at 50 DAS, RWC (relative water content) and seed yield per plant, whereas for days to 50% flowering and days to maturity observations were recorded on plot basis. SLA, SCMR and RWC were considered as surrogate traits for evaluation of water use efficiency. Genotypic and phenotypic correlation coefficients were calculated using the method given by Johnson *et al.* (1955) [7]. Path coefficient analysis suggested by Wright (1921) [18] and elaborated by Dewey and Lu (1959) [3] was used to calculate the direct and indirect contribution of various traits to yield.

Results and Discussion

The analysis of variance revealed the existence of significant differences among the genotypes for all the traits except days to maturity. Phenotypic and genotypic correlation coefficients of seed yield per plant with yield component and water use efficiency traits are presented in Table 1. Seed yield per plant showed highly significant and positive correlation with number of clusters per plant (r_p = 0.470**, r_g = 0.584**), followed by pods per plant (r_p = 0.424**, r_g = 0.604**), pod length (r_p = 0.235*, r_g = 0.384**) and number of seeds per pod (r_p = 0.414**, r_g = 0.673**). It exhibited significant negative correlation with days to 50% flowering (r_p = -0.267*, r_g = -0.400**). Selection for early flowering genotypes with more number of clusters per plant, pods per plant, number of seeds per pod and longer pods would result in early flowering better yielding lines which can be further utilised in hybridization programs. Results of significant and positive correlation of seed yield per plant with number of clusters per plant was earlier reported by Bharti *et al.* (2014) [2], Vijay *et al.* (2015) [17], Kanimoli *et al.* (2015) [8], Patel and Bala (2020) [12].

Significant positive association of seed yield per plant with number of pods yield per plant observed in the present investigation was similar to the reports of Parveen *et al.* (2011) [11], Singh *et al.* (2014) [15], Sharma (2015) [14], Vijay *et al.* (2015) [17], Kanimoli *et al.* (2015) [8], Mehra *et al.* (2016) [9], Sohel *et al.* (2016) [16], Rasel *et al.* (2016) [13], Monika *et al.* (2016) [10], Hemalatha *et al.* (2017) and Patel and Bala (2020) [12]. Significant and positive association of seed yield per plant with number of seeds per pod was in accordance with the results obtained by Singh *et al.* (2014) [15], Bharti *et al.* (2014) [2], Vijay *et al.* (2015) [17], Kanimoli *et al.* (2015) [8], Monika *et al.* (2016) [10] and Patel and Bala (2020) [12].

The results of Vijay *et al.* (2015) [17], Sohel *et al.* (2016) [16], Rasel *et al.* (2016) [13] and Patel and Bala (2020) [12]. Were similar to the present report of significant and positive association of seed yield per plant with pod length.

Significant and negative association of seed yield per plant with days to 50% flowering was in accordance with the results obtained by Singh *et al.* (2014) [15], Kanimoli *et al.* (2015) [8], Vijay *et al.* (2015) [17], Hemalatha *et al.* (2017) [6] and Patel and Bala (2020) [12].

Path coefficient analysis was conducted using seed yield per plant as dependent variable and five independent variables, days to 50% flowering, number of clusters per plant, number of pods per plant, pod length and number of seeds per pod that exhibited significant phenotypic correlation with seed yield and the results were presented in the Table 2 and phenotypic path diagram was furnished in Fig. 1.

Number of seeds per pod exhibited high positive direct effect, while number of pods per plant exhibited moderate positive direct effect on seed yield per plant. Hence, number of seeds per pod and number of pods per plant should be given importance during selection. The traits *viz.*, days to 50% flowering, number of clusters per plant, number of pods per plant and pod length registered negligible positive indirect effects on seed yield per plant through number of seeds per pod. The results of high and positive direct effect for number of seeds per pod on seed yield per plant were similar with the reports of Bandi *et al.* (2018) [1]. Moderate positive direct effect of number of pods per plant on seed yield per plant was reported by Hassan *et al.* (2003) [5] and Gill *et al.* (2017) [4].

Based on overall analysis of character association and path analysis, it can be concluded that more selection pressure number of seeds per pod and number of pods per plant, moderate specific leaf area and high SPAD chlorophyll meter readings at flowering stage would aid simultaneous improvement of yield and water use efficiency in blackgram.

Table 1: Phenotypic (r_p) and genotypic (r_g) correlation coefficients among yield, yield components and water use efficiency traits in blackgram

		DF	DM	PH (cm)	PB	CP	PC	PP	PL(cm)	SP	100 SW(g)	HI (%)	SCMR 35	SCMR 50	SLA 35	SLA 50	RWC (%)	SYP (g)
DF	r_p	1	0.241*	0.099	-0.206	-0.210*	-0.182	-0.221*	-0.113	-0.046	-0.054	-0.093	-0.036	-0.065	-0.024	-0.043	-0.263*	-0.267*
	r_g	1	0.354**	0.172	-0.437**	-0.326**	-0.373**	-0.367**	-0.243*	-0.178	-0.105	-0.132	0.207	-0.257*	-0.156	-0.042	-0.296**	-0.400**
DM	r_p		1	-0.030	0.001	-0.043	-0.018	-0.056	0.093	0.046	-0.117	-0.030	-0.138	0.030	-0.001	-0.297**	-0.023	-0.122
	r_g		1	0.090	-0.197	-0.039	-0.255*	-0.029	0.040	0.096	-0.170	0.011	-0.178	-0.130	0.191	-0.422**	-0.020	-0.100
PH(cm)	r_p			1	0.078	0.349**	-0.121	0.100	0.223*	0.239*	0.138	-0.140	-0.087	-0.167	-0.126	0.440**	-0.193	0.021
	r_g			1	-0.007	0.339**	-0.293**	0.157	0.406**	0.239*	0.267*	-0.357**	-0.205	-0.331**	-0.111	0.561**	-0.243*	-0.022
PB	r_p				1	0.298**	-0.063	0.103	-0.073	0.270**	-0.250*	-0.098	-0.035	0.095	-0.092	-0.017	0.061	0.126
	r_g				1	0.354**	0.009	0.419**	-0.189	-0.005	-0.652**	-0.328**	-0.066	0.272**	0.148	0.029	0.085	0.191
CP	r_p					1	0.079	0.630**	0.110	0.284**	-0.038	0.118	0.048	0.111	-0.181	0.125	-0.343**	0.470**

	r_g					1	-0.030	0.940**	0.227*	0.406**	0.003	0.112	0.159	0.113	-0.167	0.170	-0.405**	0.584**
PC	r_p						1	0.248*	0.058	-0.119	-0.066	-0.064	0.086	0.100	0.061	-0.028	0.111	0.110
	r_g						1	0.554**	-0.197	-0.369**	0.081	-0.354**	0.084	0.083	0.243*	-0.035	0.191	0.211*
PP	r_p							1	0.059	0.094	-0.034	0.024	-0.003	0.192	-0.084	0.025	-0.208*	0.424**
	r_g							1	0.080	0.339**	-0.097	0.075	0.134	0.252*	-0.249*	0.020	-0.224*	0.604**
PL(cm)	r_p								1	0.342**	0.406**	0.081	0.018	-0.089	0.087	0.174	-0.258*	0.235*
	r_g								1	0.886**	0.447**	0.177	-0.243*	-0.007	0.333**	0.223*	-0.390**	0.384**
SP	r_p									1	0.233*	0.097	-0.169	0.141	-0.040	-0.000	-0.362**	0.414**
	r_g									1	0.539**	0.011	-0.715**	0.183	0.613**	0.046	-0.696**	0.673**

Table 1: Cont…

100SW(g)	**r_p**	**1**	**-0.040**	**0.094**	**-0.191**	**0.035**	**0.248***	**-0.282****	**-0.008**
	r_g	**1**	**-0.043**	**-0.394****	**0.102**	**0.372****	**0.321****	**-0.398****	**0.011**
HI (%)	r_p		1	0.004	0.025	-0.097	-0.153	-0.073	0.157
	r_g		1	-0.319**	-0.086	0.088	-0.323**	-0.091	0.095
SCMR35	r_p			1	0.169	-0.386**	0.140	0.125	0.081
	r_g			1	0.581**	-0.687**	0.144	0.272**	0.093
SCMR50	r_p				1	-0.049	-0.329**	0.075	0.056
	r_g				1	-0.292**	-0.537**	0.136	0.150
SLAat35	r_p					1	-0.252*	-0.049	-0.083
	r_g					1	-0.290**	-0.109	-0.032
SLA50DAS	r_p						1	-0.023	0.116
	r_g						1	-0.026	0.137
RWC (%)	r_p							1	-0.186
	r_g							1	-0.219*
SYP(g)	r_p								1
	r_g								1

*Significant at 5% level;**Significant at 1% level

DF: Days to 50% flowering; DM: Days to maturity; PH: Plant height (cm); PB: Primary branches per plant; CP: Clusters per plant; PC: Pods per cluster; PP: Pods per plant: PL: Pod length (cm); SP: Seeds per pod; 100 SW: 100 seed weight (g); HI: Harvest index (%); SCMR 35: SPAD chlorophyll meter reading at 35 DAS: SCMR 50: SPAD chlorophyll meter reading at 50 DAS; SLA 35: Specific leaf area at 35 DAS; SLA 50: Specific leaf area at 50 DAS; RWC: Relative water content (%); SYP: Seed yield per plant (g).

Table 2: Phenotypic path coefficient analysis for yield, yield components and water use efficiency traits in blackgram

	Days to 50% flowering	No. of clusters per plant	No. of pods per plant	Pod length (cm)	No. of seeds per pod	Seed yield per plant(g)
Days to 50% flowering	-0.1508	-0.0414	-0.0516	-0.0090	-0.0139	-0.267*
No. of clusters per plant	0.0317	0.1965	0.1474	0.0088	0.0857	0.470**
No. of pods per plant	0.0332	0.1237	0.2341	0.0047	0.0285	0.424**
Pod length(cm)	0.0170	0.0217	0.0138	0.0794	0.1032	0.235*
No. of seeds per pod	0.0069	0.0558	0.0221	0.0271	0.3019	0.414**

Residual Effect (Phenotypic): 0.790
Bold: Direct effects; Normal: Indirect effects
* Significant at 5% level; ** Significant at 1% level

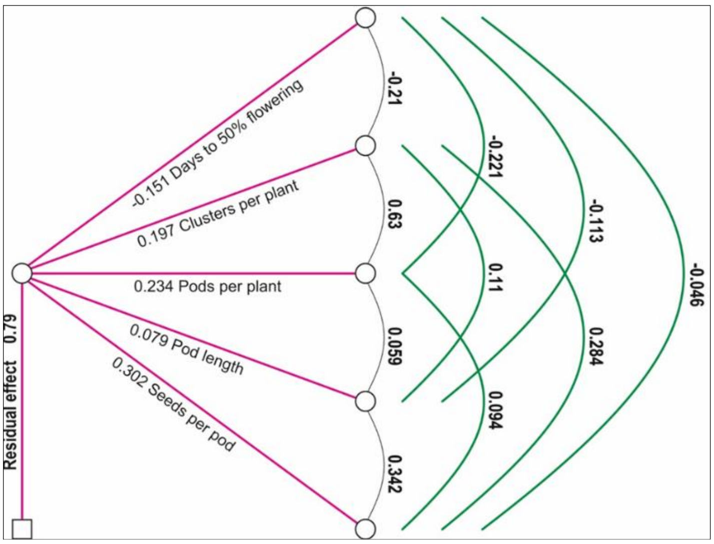

Fig 1: Phenotypic path diagram for yield, yield components and water use efficiency traits

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