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Genetic Association among Yield and Drought Tolerance Related Physiological Traits in Clusterbean [*Cyamopsis tetragonoloba* (L.)]

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ABSTRACT: Clusterbean (*Cyamopsis tetragonoloba* (L.) Taub.) commonly known as guar is an important self pollinated crop. Clusterbean in current years has achieved status of an industrial crop due to its water soluble natural polymers galactomannan content which has several diversified uses in the industries like mining, petroleum drilling, textiles, paints, explosives, paper oil, pharmaceuticals, foods, cosmetics and photography. Average productivity of clusterbean is very low as the crop is confined to rainfed farming in arid and semi arid areas, having poor fertility soils and erratic rainfall leading to frequent droughts. However, clusterbean is an important drought tolerant crop but very meagre information is available on the physiology of this crop. Therefore, this experiment was conducted to elicit information on correlation and path analysis among 11 morphological and 6 drought tolerance related physiological traits in different plant types of clusterbean. Association studies revealed that chlorophyll content, number of pods per plant, leaf area per plant, biological yield per plant, relative water content, germination stress index, seeds per pod and seedling vigour index exhibited positive and significantly high correlation with grain yield and can be used as selection criteria in improving grain yield with drought tolerance in clusterbean. Path analysis showed that traits having high direct effect in favourable direction and positive significant correlation at genotypic level with grain yield can be considered as direct yield contributing characters. Therefore, biological yield per plant, harvest index, number of pods per plant, seeds per pod, number of branches per plant, 100-seed weight, relative water content and germination stress index can be exploited for breeding high yielding and drought tolerant clusterbean genotypes.

Key words: Clusterbean, *Cyamopsis tetragonoloba* (L.), correlation, path analysis, drought tolerance

INTRODUCTION

Clusterbean is grown in arid and semi-arid area, having poor fertility soils and scanty and erratic rainfall leading to frequent droughts. Very limited knowledge on genetic improvement for yield and drought tolerance has been achieved through modification of plant type in clusterbean. Therefore, it is of paramount importance to identify and develop drought tolerant genotypes based on sound physiological mechanisms that influence the performance of clusterbean under water deficits. There is massive variation in clusterbean for spread and growth of plant characters. On the basis of this, three striking plant types can be conceptualized *viz*; single stemmed, branched and dwarf that could be expected to be situation specifically suitable for intensive and traditional growing situations. Knowledge of association between various characters is essential before starting breeding programme, because it helps in combining of various characters. Path coefficient (Wright, 1921) is an important tool for partitioning the correlation coefficient into direct and indirect effects of independent variables on dependent variable. Keeping above facts in consideration the present investigation was framed to ascertain association among yield and drought tolerance related physiological traits in different plant types of clusterbean (single stem, branched and dwarf). On considering the findings of correlation coefficients and path analysis it is revealed that the traits having high direct effect in favourable direction and positive significant correlation at genotypic level with grain yield can be considered as direct yield contributing characters in clusterbean. Therefore, it may be concluded that characters biological yield per plant, harvest index, number of pods per plant, seeds per pod, number of branches per plant, 100-seed weight, relative water content and germination stress index can be exploited for breeding high yielding and drought tolerant clusterbean genotypes.

MATERIALS AND METHODS

The present experiment on clusterbean was conducted at Centre of Excellence for Research on Pulses, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat to elicit information on 11 morphological and 6 drought tolerance related physiological traits of clusterbean *viz*., days to 50% flowering, days to maturity, plant height (cm), number of branches per plant, number of pods per plant, pod length (cm), seeds per pod, 100-seed weight (g), biological yield per plant (g), grain yield per plant (g), harvest index (%), relative water content, leaf area per plant (cm^2), chlorophyll content, leaf thickness (mm), seedling vigour index and germination stress index. The experimental material consisted of 26 genotypes selected on the basis of spread and growth habit of clusterbean (8 single stem, 8 branched, 8 dwarf + 2 check *i.e.* GG-1 and GG-2) of clusterbean grown in randomised block design (RBD) with 3 replications. Each genotype was accommodated in 6 rows plot of 4 m length with 45 cm inter row and 10 cm plant to plant distance.. The collected data from five randomly selected competitive plants from each plot in each replication were subjected to analysis of variance (Panse and Sukhatme, 1985), genotypic and phenotypic correlation coefficient (Al-Jibouri *et al.,* 1958) and path coefficient (Dewey and Lu, 1959).

RESULT AND DISCUSSION

In the present experiment mean squares due to genotypes revealed a wide range of variability and significant differences among all genotypes for all the characters under study. In correlation studies among yield and drought related physiological traits of different types of clusterbean genotypes generally a close agreement existed between genotypic and phenotypic correlation coefficients. Although genotypic correlations were generally higher than their corresponding phenotypic correlations for most of the traits, this may be due to the masking effect of environment in modifying the total expression of the genotypes. Therefore, henceforth reference will be made to genotypic correlation only (Table 1).

Highest positive and significant correlation with grain yield per plant was observed in chlorophyll content, number of pods per plant, leaf area per plant, biological yield per plant, relative water content, germination stress index, seeds per pod, seedling vigour index, 100-seed weight, leaf thickness, harvest index, days to 50% flowering, number of branches per plant and plant height at both genotypic and phenotypic levels. However, the characters, days to maturity and pod length showed positive but non-significant association at both genotypic and phenotypic levels with grain yield per plant. Similar associations for one or other aforesaid component characters with grain yield per plant in clusterbean and other crops were also reported for seedling vigour index (Shah and Deora, 2002), days to maturity and 100- seed weight (Kumawat and Khangarot, 2003), leaf area per plant in Urdbean (Kadam *et al*., 2008), chlorophyll content (Singh *et al*., 2008), relative water content (Kumar and Sharma, 2010) and for plant height, number of pods per plant, number of branches per plant, pod length and seeds per pod (Sultan *et al*., 2012). Variable results were obtained with regard to mutual association between component traits. Most of the characters having positive association with grain yield per plant were positively correlated among themselves in present study. In the light of the above results, it may be concluded that chlorophyll content, number of pods per plant, leaf area per plant, biological yield per plant, relative water content, germination stress index, seeds per pod and seedling vigour index exhibited positive correlation of considerable magnitude with grain yield per plant and can be used as selection criteria in improving grain yield with drought tolerance in clusterbean. Mutual correlation among these traits suggests that simultaneous selection for these traits will have a better efficiency for improving the grain yield. However, when more variables are there which influence the yield, techniques of path coefficient analysis which partition the genotypic correlation into direct and indirect effects is more efficient.

In present study path coefficient analysed at genotypic level for grain yield. Residual effects were negligible which indicates that variability of grain yield per plant was completely governed by the characters included in the analysis (Table 2). Highest direct effect on grain yield in favourable direction was exhibited by biological yield per plant (0.745) followed by harvest index (0.452), number of pods per plant (0.285), days to maturity (0.151), seeds per pod (0.132), number of branches per plant (0.094), 100-seed weight (0.089), relative water content (0.088), germination stress index (0.023) and days to 50% flowering (0.014). Whereas, contributions of plant height (-0.169), leaf thickness (0.140), leaf area per plant (-0.109), seedling vigour index (-0.043) and chlorophyll content (-0.014) were in unfavourable direction. Biological yield per plant exhibited highest direct effect and considerable significant positive correlation with grain yield. The indirect effects of biological yield on grain yield were through other contributing characters, *viz*., number of pods per plant, days to maturity, relative water content, 100-seed weight and number of branches per plant. Significant and positive correlation of harvest index with grain yield was mainly due to its direct effect and indirect effects via number of pods per plant, relative water content, plant height, 100-seed weight, number of branches per plant as also reported by different researchers (Shah and Deora, 2002 and Kalia *et al*., 2007). Number of pods per plant showed positive significant correlation and positive direct effect on seed yield, which was supported by indirect effect through biological yield per plant, harvest index, relative water content, number of branches per plant, 100-seed weight. The results are in accordance with the earlier reports (Ibrahim *et al*., 2012 and Udensi *et al*., 2012). The correlation between days to maturity and grain yield per plant was positive but non-significant, although it was mainly due to direct effect on grain yield. Seeds per pod exhibited positive significant correlation with grain yield which was mainly due to its direct effect and indirect effect of biological yield per plant, number of pods per plant, days to maturity, leaf area per plant and plant height. Similar results were for one or more characters were also reported by different workers (Hingane and Navale, 2008, Ibrahim *et al*., 2012 and Udensi *et al*., 2012) in clusterbean and other crops.

Number of branches per plant exhibited positive significant correlation and its direct effect was also positive but having low magnitude. The positive association was mainly due to its indirect effects through biological yield per plant followed by harvest index, number of pods per plant, relative water content and leaf thickness (Henry *et al*., 1986) in clusterbean.

Table 1: Genotypic and phenotypic correlation coefficients for different characters in cluster bean.

Characters		Days to maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Seeds per pod	100-seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Leaf area per plant (cm^2)	Chlorophyll content	Leaf thickness (mm)	Seedling vigour index	Germination stress index	Grain yield per plant (g)
Days to 50% flowering	rg	0.166	0.168	0.694**	0.341**	-0.145	-0.904**	0.296**	0.514**	0.218	0.678**	0.370**	0.053	0.210	0.452**	0.055	0.532**
	rp	-0.007	0.164	0.415**	0.179	-0.031	-0.138	0.290*	0.316**	-0.066	0.154	0.212	-0.012	0.045	0.279*	0.051	0.223*
Days to maturity	rg		0.833**	-0.168	0.153	0.464**	0.485 **	0.278*	0.434**	-0.355**	0.043	0.387**	0.011	0.446**	0.085	0.270*	0.196
	rp		0.206	-0.087	0.011	0.179	0.002	0.030	0.217	-0.172	-0.014	0.196	0.167	0.113	-0.016	0.107	0.054
Plant height (cm)	rg			0.041	0.281*	0.489**	-0.263*	0.681**	0.604**	-0.243*	0.333**	0.275*	0.418**	0.305**	0.105	0.256*	0.364**
	rp			0.051	0.239*	0.290*	0.037	0.479**	0.393**	-0.013	-0.005	0.234*	0.190	-0.027	0.082	0.172	0.306**
Number of branches per plant	rg				0.451**	-0.531**	-0.854**	0.036	0.271*	0.306**	0.329**	0.360**	-0.017	-0.118	0.323**	0.245*	0.426**
	rp				0.380**	-0.299**	-0.362**	0.041	0.245*	0.139	0.116	0.332**	-0.015	-0.110	0.303**	0.231*	0.389**
Number of pods per plant	rg					-0.068	-0.931**	0.453**	0.741**	0.655**	0.776**	0.719**	0.870**	0.512**	0.724**	0.669**	0.896**
	rp					0.032	-0.240*	0.292**	0.593**	0.256*	0.476**	0.611**	0.527**	0.353**	0.572**	0.488**	0.776**
Pod length (cm)	rg						0.889 **	0.670**	0.074	-0.081	-0.406**	0.054	0.394**	0.428**	-0.194	0.224*	0.022
	rp						0.147	0.329**	0.071	0.094	0.236*	0.035	0.348**	0.263*	-0.081	0.200	0.124
Seeds per pod	rg							-0.235*	0.675**	0.540**	-0.946**	-0.512**	-0.175	0.139	-0.765**	-0.136	0.751**
	rp							-0.018	0.104	0.165	-0.245*	-0.115	-0.096	0.042	-0.307**	-0.075	0.231*
100-seed weight	rg								0.563**	0.341**	0.522**	0.632**	0.634**	0.374**	0.218	0.423**	0.614**
	rp								0.401**	0.124	0.154	0.442**	0.436**	0.191	0.193	0.335**	0.452**
Biological yield per plant	rg									-0.051	0.632**	0.706**	0.524**	0.391**	0.428**	0.566**	0.802**
	rp									-0.358**	0.221	0.503**	0.317**	0.235*	0.316**	0.384**	0.622**
Harvest index (%)	rg										0.760**	0.436**	0.713**	0.575**	0.681**	0.504**	0.571**
	rp										0.297**	0.239*	0.261*	0.115	0.316**	0.297**	0.489**
Relative water content (%)	rg											0.704**	0.838**	0.478**	0.775**	0.646**	0.795**
	rp											0.287*	0.500**	0.261*	0.520**	0.357**	0.455**
Leaf area per plant (cm^2)	rg												0.831**	0.455**	0.614**	0.637**	0.834**
	rp												0.532**	0.234*	0.532**	0.569**	0.665**
Chlorophyll content	rg													0.695**	0.679**	0.727**	0.962**
	rp													0.381**	0.426**	0.547**	0.514**
Leaf thickness (mm)	rg														0.375**	0.624**	0.599**
	rp														0.229*	0.323**	0.312**
Seedling vigour index	rg															0.434**	0.718**
	rp															0.392**	0.591**
Germination stress index	rg																0.777**
	rp																0.634**

*, ** Significant at 0.05 and 0.01 levels, respectively.

Table 2: Path coefficient analysis showing direct and indirect effects of different characters on grain yield in clusterbean.

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of pods per plant	Pod length (cm)	Seeds per pod	100-seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Relative water content (%)	Leaf area per plant (cm^2)	Chlorophyll content	Leaf thickness (mm)	Seedling vigour index	Germination stress index	Grain yield per plant (g)
Days to 50% flowering	**0.014**	0.025	-0.028	0.065	0.097	-0.001	-0.119	0.026	0.383	0.099	0.060	-0.040	-0.001	-0.029	-0.019	0.001	0.532**
Days to maturity	0.002	**0.151**	-0.141	-0.016	0.044	0.002	0.064	0.025	0.323	-0.160	0.004	-0.043	0.001	-0.062	-0.004	0.006	0.196
Plant height (cm)	0.002	0.125	**-0.169**	0.004	0.080	0.003	-0.035	0.061	0.450	-0.110	0.029	-0.030	-0.006	-0.043	-0.005	0.006	0.364**
Number of branches per plant	0.010	-0.025	-0.007	**0.094**	0.129	-0.003	-0.112	0.003	0.202	0.138	0.029	-0.039	0.001	0.015	-0.014	0.006	0.426**
Number of pods per plant	0.005	0.023	-0.047	0.042	**0.285**	0.001	-0.122	0.040	0.456	0.296	0.096	-0.078	-0.013	-0.072	-0.031	0.016	0.896**
Pod length (cm)	-0.002	0.070	-0.083	-0.050	-0.019	**0.005**	0.117	0.060	0.055	-0.037	-0.036	-0.006	-0.006	-0.060	0.008	0.005	0.022
Seeds per pod	-0.013	0.073	0.044	-0.080	0.229	0.005	**0.132**	-0.021	0.503	-0.109	-0.083	0.056	0.003	-0.019	0.033	-0.003	0.751**
100-seed weight (g)	0.004	0.042	-0.115	0.003	0.129	0.004	-0.031	**0.089**	0.419	0.154	0.046	-0.069	-0.009	-0.052	-0.009	0.010	0.614**
Biological yield per plant (g)	0.007	0.065	-0.102	0.026	0.211	0.001	-0.089	0.050	**0.745**	-0.023	0.055	-0.077	-0.008	-0.055	-0.018	0.013	0.802**
Harvest index (%)	0.003	-0.053	0.041	0.029	0.187	0.001	-0.032	0.030	-0.038	**0.452**	0.114	-0.047	-0.016	-0.081	-0.029	0.012	0.571**
Relative water content (%)	0.009	0.006	-0.056	0.031	-0.07	-0.002	-0.124	0.046	0.470	0.586	**0.088**	-0.076	-0.012	-0.067	-0.048	0.015	0.795**
Leaf area per plant (cm^2)	0.005	0.058	-0.046	0.034	0.205	0.001	-0.067	0.056	0.526	0.197	0.062	**-0.109**	-0.012	-0.064	-0.026	0.015	0.834**
Chlorophyll content	0.001	0.002	-0.071	-0.002	0.248	0.002	-0.023	0.056	0.390	0.499	0.074	-0.090	**-0.014**	-0.097	-0.029	0.017	0.962**
Leaf thickness (mm)	0.003	0.067	-0.051	-0.011	0.146	0.002	0.018	0.033	0.291	0.260	0.042	-0.049	-0.010	**-0.140**	-0.016	0.015	0.599**
Seedling vigour index	0.006	0.013	-0.018	0.030	0.206	-0.001	-0.101	0.019	0.319	0.308	0.097	-0.067	-0.010	-0.053	**-0.043**	0.010	0.718**
Germination stress index	0.001	0.041	-0.043	0.023	0.191	0.001	-0.018	0.038	0.422	0.228	0.057	-0.069	-0.011	-0.087	-0.019	**0.023**	0.777**

Residual effect: Genotypic: -0.0112 and **Phenotypic:** 0.0220

100-seed weight had significant association with grain yield mainly due to indirect effects via biological yield per plant, harvest index, number of pods per plant, relative water content, days to maturity (Ibrahim *et al*., 2012 and Udensi *et al*., 2012). Positive and significant correlation of relative water content with grain yield was mainly due to indirect effects via harvest index, biological yield per plant, number of pods per plant, 100-seed weight and number of branches per plant although it's direct effect was in low magnitude.

Germination stress index showed positive and significant correlation with grain yield per plant though its direct effect was low. The positive association was mainly due to indirect effect of biological yield per plant, harvest index and number of pods per plant, relative water content and days to maturity. Days to 50% flowering exhibited positive significant correlation via indirect effects of biological yield per plant, harvest index, number of pods per plant, number of branches per plant and relative water content because its direct effect was low in magnitude. On the other hand, chlorophyll content exhibited highest positive significant correlation with grain yield although its direct effect was low and negative. However, chlorophyll content contributed to the grain yield mainly via indirect effect of harvest index, biological yield per plant, number of pods per plant, relative water content and 100-seed weight. Similarly, some other characters *viz*., seedling vigour index, leaf area per plant, leaf thickness and plant height exhibited positive and significant correlation with grain yield per plant though their direct effects on grain yield were negative with low magnitude. The contribution of these characters to the grain yield per plant was mainly via indirect effects of other characters *viz*., biological yield per plant, harvest index, number of pods per plant, relative water content, days to maturity, 100-seed weight and number of branches per plant. Similar results for one or more characters were also reported (Das *et al*., 2004 and Kalia *et al*., 2007) in clusterbean.

On considering the findings of correlation coefficients and direct and indirect effects of different yield components on grain yield discussed here, it is revealed that the traits having high direct effect in favourable direction and positive significant correlation at genotypic level with grain yield can be considered as direct yield contributing characters. Therefore, it may be concluded that the characters *viz*., biological yield per plant, harvest index, number of pods per plant, seeds per pod, number of branches per plant, 100-seed weight, relative water content and germination stress index can be exploited for breeding high yielding and drought tolerant clusterbean genotypes. Further, with the support of above findings it may be suggested that clusterbean ideotype should have early type with high biological yield per plant, harvest index, number of pods per plant, seeds per pod and 100-seed weight. Hence, it would be rewarding to lay more stress on these components of yield in selection programme for simultaneous improvement of grain yield and drought tolerance in clusterbean.

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