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Research Article

Land race as a source for improving photosynthetic rate and productivity in cowpea (*Vigna unguiculata* W.)

Suma Biradar, P.M. Salimath and B.C.Patil

Abstract

Cowpea is an important grain legume of arid and semiarid regions of Asia and Africa. Productivity of cowpea is low and stagnant. Conventional breeding approaches aimed at improvement of yield per se have not been successful so far in breaking the yield barrier. Manipulation of physiological processes such as photosynthesis is expected to yield positive results. A land race 'Goa local' with a very high photosynthetic rate was used to improve this trait in selected cultivars, C-152, KM-1 and V-118 with different growth habits. KM-1 x Goa local and C-152 x Goa local F_1 hybrids yielded better than the best parent, a land race itself. This improved productivity was mainly associated with the increase in number of pods per plant and seeds per pod as well as test weight. Physiologically, the improved productivity of hybrids could be associated with higher chlorophyll content, photosynthetic rate as well as conductance. Association analysis among biophysical traits and productivity traits indicated significant positive association of photosynthetic rate and chlorophyll content with seed yield per plant. Interestingly, the four biophysical traits showed significant and positive correlation with seeds per pod and hundred seed weight as well as with pod length (except transpiration rate) but, failed to show any association with number of pods per plant. The results indicated the scope of using a land race in improving the productivity in cowpea through manipulation of biophysical traits like chlorophyll content and photosynthesis.

Key words:
Cowpea, Land race, physiological traits, Heterosis, IRGA

INTRODUCTION

A break through in the productivity of major crops particularly cereals like wheat and rice was achieved in the mid 60's following restructuring on plant type resulting in the improved harvest index. It is now fast becoming evident that yield platue has been reached in these crops and it is doubtful whether the harvest index of these crops can be raised further. Investigations in other crops revealed that, one of the key avenues towards enhancing the biological efficiency of crop plants is through improving leaf and canopy photosynthetic rate. The future increase in crop yield must accrue through improving the photosynthetic efficiency by which the intercepted radiation is converted to biomass.

Lot of information on these aspects is generated in major cereal crops (Khanna-Chopra, 1982, Peng *et al*., 1991, Mehta *et al*., 1992). Even though selection for high and low photosynthetic rates was successful in maize (Crosbie and Pearce, 1982), yield potential remained unchanged through such alterations in some crops (Nelson, 1988). Nonetheless, positive correlation was recorded between photosynthetic rate and grain yield (Dwyer *et al*., 1991). Peng *et al*. (1991) have also observed a positive correlation of leaf photosynthetic rate with biomass and grain production in grain sorghum lines. Jainchnge *et al*. (1997) have observed correlated response of greater yield potential with greater stomatal conductance, higher photosynthetic rate and chlorophyll content. Genetic improvement of photosynthetic efficiency will be a new step towards another green revolution. As far as legumes are concerned, there has been no major breakthrough in breaking their yield barrier except perhaps in soybean. Major changes in the plant architecture with associated changes in

Department of Genetics and plant breeding,
UAS, Dharwad

physiological processes are yet to be achieved. Cowpea (*Vigna unguiculata* L.), a multipurpose grain legume, extensively cultivated in arid and semiarid regions of Asia and Africa, fits well in a variety of cropping systems and is grown as catch crop, intercrop, cover crop and mixed crop. Naturally it would be of interest to understand the relationship of important photosynthetic parameters with productivity in legumes including cowpea.Land races adapted to a variety of agro-ecological niches constitute a rich source of genetic diversity (Zhenshan *et a*l., 1996; Sudha *et al*., 2004). Though undomesticated, unadopted germplasm and land races are phenotypically less desirable; breeders have long recognized their intrinsic value for improvement of simply inherited traits including disease, pest resistance (Malik *et al*., 1992) and other useful traits.Keeping these ideas in view, an investigation was carried out to ascertain the importance of land race in broadening genetic base and the association of different photosynthetic parameters with productivity in cowpea. A local land race 'Goa local' characterized by high chlorophyll content and photosynthetic rate and three other agronomically superior but with variable lower photosynthetic rate (Suma, 2001) were chosen to represent diverse parental lines for the traits of interest to generate experimental material to study the nature of variation and association of photosynthetic rate and its related parameters with productivity. The results of this study conducted at University of Agricultural Sciences, Dharwad, India are presented in this paper.

MATERIAL AND METHODS

Considering rate of photosynthesis per unit area and the total chlorophyll content as important traits for improving productivity, the local cultivars like C-152, KM-1 and V-118 with lower but variable photosynthetic rate and Goa local, a local land race of Goa in India having high total chlorophyll content and photosynthetic rate were selected for the study C-152, KM-1 and V-118 are determinate in their growth habit while Goa local is semi-determinate in nature. Seed size of V-118 is small while, that of KM-1 and C-152 is medium. The land race Goa local is characterized by bold seeds. Goa local was crossed with KM-1, C-152 and V-118 to generate F_1 hybrids KM-1 x Goa local, C-152 x Goa local and V-118 x Goa local.

Experimental design: The three 'F_1' hybrids along with parents were planted in a randomized block design with three replications during rainy season. Each entry was sown in three rows of 3m length each with a row spacing of 60cm and was spaced 20cm apart within the row. Standard cultural practices were followed to raise a healthy crop.

Characters and observational procedures: Data were recorded on the biophysical, biochemical and quantitative traits as indicated below.

Biophysical parameters:
Photosynthetic rate, conductance and transpiration were recorded on the abaxial surface of the 4^{th} fully expanded leaf from the top at pod formation stage on a cloudless day between 9.30-11.30A.M. with the help of the battery operated LCA-2 model of Infra Red Gas Analyzer (IRGA). Three plants per replication were selected at random from each entry for recording observations. The fields were irrigated two days before taking observations to avoid any moisture stress.

Biochemical parameters: The total chlorophyll content (mg/g) was determined at the pod formation stage following the standard procedure (Arnon, 1949).

Quantitative traits: Number of pods per cluster, total number of pods per plant, pod length, seeds per pod, hundred seed weight (g) and seed yield per plant (g) were recorded on the same three tagged plants per replication for each entry and standardized at 15% grain moisture immediately after harvesting.

Statistical analysis: Heterosis (%) over mid parent, better parent and commercial check (C-152) for each character were computed by the methods of Turner (1953) and *Hays et al.* (1955). Simple correlations among all the traits were computed following standard statistical procedures.

RESULTS AND DISCUSSION

Narrow genetic base has been implicated as one of the reasons for low productivity in a number of crop species particularly in legumes (Esquinas-Akazar, 1993). The pedigree of released cultivars very much supports this view with parentage tracing back to just a few genotypes. Obviously it calls for a fresh look on our breeding approaches. Of the several ways suggested to broaden the genetic base, use of land races in hybridization programmes is one. Land races in most of the cases are rich reservoirs of useful genes. A land race of cowpea obtained from Goa in India referred to as Goa local is characterized by high seed weight and moderate resistance to rust (Suma, 2001). Its evaluation in the present study (Table 1) also indicated clearly that it had distinctly higher pod length, seed weight and consequently higher seed yield per plant. It thus provided an opportunity to study and understand the morpho-physiological basis of yield variation in cowpea.

The results indicated that Goa local had higher chlorophyll content, photosynthetic rate and also transpiration rate compared to the other three evolved genotypes used in the study, two of them being released cultivars (C-152 and V-118) and the other (KM-1) one an advanced generation mutant derivative. Though the land race is a high yielder compared to other three genotypes, some of the undesirable characters usually associated with such varieties like late maturity and indeterminate growth habit prevent it to be exploited commercially although some farmers in and around Goa grow it because of its higher seed size (Persn. Commun.). The material generated in the present study by crossing Goa local with KM-1, C-152 and V-118 provide an opportunity to recombine the desirable features so that selection in such material is likely to result in identification of high yielding genotype with acceptable other features. KM-1 and C-152 are semi-determinate in their growth habit while V-118 is determinate. Among these three, KM-1 and C-152 were relatively high yielding. KM-1 was further characterized by the higher chlorophyll content, photosynthetic rate, conductance and transpiration rate compared to other two genotypes. It had higher mean pod length as well as seeds per pod. Goa local appeared to combine well with KM-1 and C-152 as evident by higher mean seed yield of the respective F_1 hybrids as compared to its cross with V-118 (Table-1). The higher productivity of KM-1 x Goa Local and C-152 x Goa local may probably to be due to higher number of pods per plant, pod length and seeds per pod. KM-1 x Goa local is characterized by higher chlorophyll content, photosynthetic rate, conductance and transpiration rate (Table 1). Higher mean performance in respect of these physiological parameters is in turn reflected by high positive heterosis for seed yield per plant particularly over commercial check (Table 2). Cross KM-1 x Goa local also showed significant positive heterosis for three of its important morphological component traits like pods per plant, pod length, seeds per pod and hundred seed weight. It may be noted here that this cross also showed high mean and significant positive heterosis for the physiological parameters. Cross C-152 x Goa local which also showed significant positive heterosis for seed yield was compared with higher seed weight besides higher pod length and seeds per pod as reflected by significant heterotic values at least in one season. It was only photosynthetic rate for which significant positive heterosis was observed in C-152 x Goa local cross. The study thus clearly brings out the importance of photosynthetic rate in deciding productivity. Yap and Harve (1972) have reported in barley that certain morpho-physiological traits other than yield components are highly heritable and strongly correlated with yield. The present study has been successful in identifying such morpho-physiological traits. The correlation analysis indicates that yield is positively associated with rate of photosynthesis and chlorophyll content (Table 3). However, their correlation with pods per plant was non significant. The two important components of yield viz., number of pods and seed weight, however showed significant positive correlation with productivity in each of the three crosses. The two yield components were, further positively associated with each other in KM-1 x Goa local and C-152 x Goa local. The four physiological parameters showed significantly positive correlations with seeds per pod and hundred seed weight (Table 4).

Kumar *et al.* (2000) reported positive association of photosynthetic rate with grain yield. Reynolds *et al.* (1994) have reported significant positive correlation of flag leaf photosynthesis with grain yield in wheat. They also observed that photosynthesis recorded during reproductive stage had stronger positive correlation with grain yield than when recorded at vegetative stage. It indicates that reproductive phase is a critical phase when higher rate of photosynthesis is required to realize high yield and this suggests that reproductive phase is the most critical period for observing the photosynthetic rate recorded as selection criterion to select photosynthetically efficient cowpea genotypes for higher yield.

From the data on stomatal conductance and transpiration rate, which showed positive association with grain yield, it may be presumed that these parameters have helped indirectly in translocation of photo assimilates. The stomatal conductance, which is a component of photosynthesis, exhibited significant positive correlation with photosynthesis rate. It also had a positive association with transpiration rate. The present study reveals importance of higher leaf photosynthesis rate, stomatal conductance during reproductive phase under rainfed condition as indicated by their positive association with grain yield.

Data from the present study also supports the view that the medium diversity of the parents' results in higher heterosis than the cross derived from more diverse parents as demonstrated by Arunachalam *et al.* (1984) in ground nut. KM-1 x Goa local and C-152 x Goa local which represent crosses involving medium diversity parents are highly heterotic for yield than V-118 x Goa local that represent cross involving parents with high diversity. The study is thus successful in identifying the morpho-physiological traits, which could be of use for improving productivity in cowpea. It has also helped in identifying a land race 'Goa local' which can be used in improving the productivity of cowpea with acceptable features of the established agronomic backgrounds. As discussed earlier, even with higher length of pod, the number of seeds per pod is less in Goa local. Poor seed filling is thus one of the constraints, with the improvement of which still higher yield can be realized. Incidentally C-152 x Goa local and KM-1 x Goa local have both shown higher number of seeds per pod than the parental genotypes. This suggests the possibility of improving productivity in these cross derivatives through improved seed filling also. Based on the results of the present study, it is proposed to plan for further introgression of the desired genes from this land race in the agronomic backgrounds.

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Table 1: Mean performance of parental genotypes and their F_1 hybrids in respect of productivity and other bio-physical traits in cowpea

Characters	KM-1	C-152	V-118	Goa local	KM-1 x Goa local	C-152 x Goa local	V-118 x Goa local
Photosynthetic rate	26.03	23.22	20.80	29.7	32.79	31.65	21.88
Conductance	0.38	0.26	0.21	0.19	0.38	0.25	0.40
Transpiration rate	8.00	6.23	7.41	9.14	8.19	6.49	7.01
T.chlorophyll content	1.78	1.71	1.61	1.79	1.94	1.82	1.88
No. of pods/plant	24.11	25.68	26.92	26.39	33.3	31.26	22.54
Pod length (cm)	16.69	13.71	13.64	20.68	18.50	19.42	17.95
Seeds/ pod	14.81	11.98	11.66	12.37	14.7	14.9	13.97
Hundred seed weight (g)	13.38	10.12	12.54	24.04	21.98	12.01	25.63
Seed yield/plant (g)	26.93	25.73	20.05	33.31	37.25	34.02	20.18

Table 2: Estimate of heterosis for productivity and other bio-physical traits in three hybrid populations of cowpea

Cross	KM-1 x Goa local			C-152 x Goa local			V-118 x Goa local		
	MP	BP	CC	MP	BP	CC	MP	BP	CC
Photosynthetic rate	16.6	11.37	38.3	12.19	1.49	25.50	4.05	26.33	5.74
Conductance	33.95	0.5	18.3	16.8	-9.3	-9.3	113.4	105.1	65.5
Transpiration rate	4.5	9.96	42.65	16.18	29.1	5.9	-15.25	23.34	16.46
T. Chlorophyll content	7.02	5.83	11.77	5.22	1.35	6.4	10.61	4.74	8.99
No. of pods/plant	18.85	9.98	14.57	1.30	15.07	7.39	-12.1	-20.6	-7.03
Pod length	0.92	10.53	35.25	12.63	6.11	21.61	4.7	-13.22	31.12
Seeds/pod	9.03	0.99	23.26	36.7	11.7	26.76			
Hundred seed weight	6.42	-8.67	116.9	-8.17	34.9	55.33	3.90	7.18	117.70
Seed yield per plant	23.79	12.25	45.96	15.45	2.10	34.50	-6.17	30.80	7.10

(MP- Mid parent; BP-Better parent; CC: Commercial check)

Table 3: Phenotypic correlation coefficients among productivity and biophysical traits in cowpea

Character	*Conductance*	Transpiration rate	T.Chlorophyll content	Plant height (cm)	No. of pods per plant	Pod length (cm)	Seeds per pod	Hundred seed weight(g)	Seed yield per plant
Photosynthetic rate	0.658**	0.344*	0.833**	0.704**	-0.057	0.622**	0.766**	0522**	0.481**
Conductance		0.484**	0.628**	0.189	0.250	0.483**	0.637**	0.761**	0.082
Transpiration rate			0.421**	-0.094	-0.078	0.253	0.385**	0.475**	0.169
T. Chlorophyll content				0.760**	0.038	0.787**	0.831**	0.708**	0.600**

** significant at 1 per cent level.

Table 4: Phenotypic correlation coefficients among number of pods, hundred seed weight and seed yield in cowpea

Character	Hundred seed weight (g)			Seed yield per plant (g)		
	C_1	C_2	C_3	C_1	C_2	C_3
Number of pods per plant	0.22**	0.13**	0.01	0.76**	0.70**	0.77**
Hundred seed weight (g)				0.13*	0.30**	0.23**

Where, *Indicates significance at 5% probability

** Indicates significance at 1% probability

C_1 – KM-1 x Goa local

C_2 – C-152 x Goa local

C_3– V-118 x Goa local