Progressive Research – An International Journal
Print ISSN : 0973-6417, Online ISSN : 2454-6003
Volume 10 (Special-VI) : 3323-3327 (2015)

Society for Scientific Development
in Agriculture and Technology
Meerut (U.P.) INDIA

EVALUATION OF COWPEA GENOTYPES FOR PHYSIOLOGICAL EFFICIENCY AND PRODUCTIVITY UNDER AGROCLIMATIC CONDITIONS OF KYMORE PLATEAU ZONE, MADHYA PRADESH

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ABSTRACT

The present research experiment was conducted during Kharif season of 2014-15 at the Horticultural Research Farm, Department of Horticulture, JNKVV, Jabalpur (MP). The treatments comprised of ten cowpea genotypes. The objective of the experiment was to evaluate cowpea genotypes for physiological efficiency and productivity under agro climatic conditions of kymore plateau zone, Madhya Pradesh. The investigations revealed that the genotype 2014/COPBVAR-6 out yielded other genotypes (232.74 g plant per plant) owing to its highest dry matter production (47.65 g) followed by the genotypes 2014/COPBVAR-5 and Gomti. Gomti had the highest chlorophyll index (53.9), carboxylation efficiency (0.2070 ìmolm^{-2}s^{-1}(molmmol^{-1})$^{-1}$ and Quantum efficiency (0.0412) reflected ultimately the highest pod yield per plant. Gomti recorded the maximum quantum efficiency (0.0412), photosynthetic rate (49.66 molm^{-2}s^{-1}) and carboxylation efficiency (0.207 molm^{-2}s^{-1}(mol m mol^{-1})$^{-1}$). The highest water use efficiency was found in the genotype 2012/COPBVAR-2 (62.8 mol m/mol) and mesophyll efficiency in the genotype 2012/COPBVAR-5 (1897.14 molmol-1(mol m^{-2}s^{-1})$^{-1}$) with the lowest stomatal conductance (0.14 mol m^{-2}s^{-1}) and transpiration rate (0.59 mmol m^{-2}s^{-1}) suggesting their suitability for drought resistance may also be utilized in a breeding programme.

Key words : *Cowpea, Transpiration rate, Stomatal conductance, Photosynthetic rate, Mesophyll efficiency, Water use efficiency, Carboxylation efficiency, Quantum efficiency*

The cowpea [*Vigna unguiculata* (L.)] Walp. the crop of round utilization is an important legume crop and forms an important component of farming systems throughout the tropics and warm sub-topics. Cowpea cultivars grown for the immature green pods which are used as vegetable are variously known as yard-long bean, asparagus bean and snake bean. Cowpea belongs to the family leguminosae; sub family fabaceae and genus *Vigna* with chromosome number, 2n = 22 (Steele, 1976). Vavilov (1939) considered India as the main *Centre of Origin*. In India, it has been known since the Vedic times. Cowpea is well adapted to stress and has excellent nutritive qualities. It supplies high quality, inexpensive protein 3.5 g, calcium 72.0 mg, phosphorus 59.0 mg, iron 2.5 mg, carotene 564.0 mg, thiamine 0.07 mg, riboflavin 0.09 mg and vitamin 'C' 24.0 mg per 100 g in edible pods (Gopalan *et al*., 1982). Amino acid profile reveals that lysine, leucine and phenylalanine content were relatively higher in cowpea (Bressani and Elias, 1980). Among legumes, cowpea is one of the most important vegetable crops grown during rainy and summer seasons. Tender pods as well as green-shelled seeds are used as vegetable and as a pulse when dried. It is also suitable for green manuring, fodder cover and catch crop. The annual area cropped under cowpea and its total production in India is difficult to estimate, since it is rarely grown as single crop. However, the total production and yield per unit area has increased over the past decades. The area under cowpea is about 1.5 million hectare.

There is a direct correlation between variety and growth parameters. Pod yield is highly correlated with leaf area index, plant height, photosynthetic rate, chloroplast, photochemical activity, specific leaf weight and nitrate reductase activity. Gering and Mitcenkova (1961) suggested that genetic difference in physiological traits should be considered in breeding programme based on yield components in cowpea. It is also stated that selection of genotypes based on the physiological traits should be an effective method for improving pod yield in cowpea (Camussi and Ottaviano 1987). In order to screen out the cowpea genotypes having physiological superiority a physiological approach is needed. Efforts are also being made to identify constraints of productivity and ways to ameliorate them. Though few studies have been conducted on growth analysis in cowpea crop, scanty information is available with regards to influence of various physiological mechanisms viz., photosynthetic rate, transpiration rate, stomatal conductance, water use efficiency, carboxylation efficiency and quantum efficiency etc. on economic productivity in cowpea. Physiological characteristics contributing to yield are not clearly understood. Therefore, the present investigations were undertaken to evaluate cowpea genotypes for physiological efficiency and growth traits influencing productivity.

Table-1 : Analysis of variance for eleven physiological traits in 10 genotypes of cowpea.

Character	Mean sum of squares		
	Replications (df = 2)	Treatments (df = 9)	Error (df = 18)
Photosynthesis rate	11.033	333.384*	0.033
Stomatal conductance	0.001	0.05*	0.00
Intercellular Co_2	6.4	3351.794*	0.4
Transpiration rate	0.002	1.13*	0.005
PARi	40	3.299*	0.007
Chlorophyll content index	10	145.208*	0.003
Dry matter production	0.003	113.25*	0.008
Water use efficiency	10	970.371*	0.005
Carboxylation efficiency	0.004	0.008*	0.006
Quantum efficiency	0.005	0.007*	0.009
Mesophyll efficiency	14.4	498791*.5	0.178
Pod Yield per plant (g)	32.4	4849.493*	0.178

* = significant at 5% level of significance

MATERIALS AND METHODS

A field experiment was conducted at the Horticultural Research Farm, Department of Horticulture, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (M.P.) during Kharif season of 2014-15 in a randomized block design replicated thrice and treatments comprised of ten cowpea genotypes viz; 2014/COPBVAR-4, 2014/COPBVAR-5, 2014/COPBVAR-6, 2012/COPBVAR-2, 2012/COP-BVAR-3 and 2012/COPBVAR-5, Pusa Komal, Arka Garima, Gomti and Kashi Kanchan which were sown in the field adopting recommended cultural practices. These were planted in a two row plot. The plot size and spacing were 3.0×2.4 m^2 and 60×30 cm, respectively. Five plants were taken for recording observations on various physiological parameters. The chlorophyll index was worked out by using chlorophyll meter (Model CCM 200), whereas, dry matter production was recorded by drying the plants in an electric oven at 80 ^{0}C temperature for 36 hrs. till constant weight. The physiological mechanisms *viz;* photosynthetic rate, stomatal conductance, transpiration rate, PAR (photosynthetically active radiation) absorption, intercellular CO_2 concentration etc. were quantified by using Infra – red gas analyser (IRGA) Li-Cor-6400 (LiCor Instruments USA). The quantum efficiency was determined as per specifications of Pandey *et al.* (2001), whereas, water use, carboxylation and mesophyll efficiencies were calculated as per methods suggested by Kannan and Vankataraman (2010), respectively.

RESULTS AND DISCUSSION

Chlorophyll content index : Highly significant differences among the genotypes were observed for all the characters studied indicating presence of sufficient amount of variability in all the characters studied (Table 1). The maximum chlorophyll content index was achieved in young fully expended leaf and gradually started to decline with the advancement of age and senescence (Nair et al. 2006). Higher SCMR means greater nitrogen and chlorophyll and thus these values can be considered as an index for evaluation of genotypes for drought tolerance. The chlorophyll content reduces with abiotic stresses and more with drought stress. The results revealed (Table-2) that genotypes Gomti (53.9), 2012/COPBVAR-5 (51.87) and 2012/ COPBVAR-5 (52.93) recorded significantly higher chlorophyll index over rest of the genotypes. Trait can be utilized in a breeding program for enhancing photo- synthetic efficiency of crop as the photosynthetic capability of plant increased with chlorophyll concentration (Bonner 1952 and Ziyad, 2014).

Photosynthetic Active Radiation : The varieties Arka Garima, 2014/COPBVAR-5 and Pusa Komal intercepted significantly the highest PAR compared with the rest of the other varieties The highly positive correlation of fodder yield per hectare with the percentage transmitted photosynthetically active radiation are in tune with the findings of Gallagher and Biscoe (1978) who reported that under non-stressed environmental conditions, the amount of dry matter produced by a crop is linearly related to the amount of solar radiation (SR), especially photo-synthetically active radiation (PAR), intercepted by the crop. Also fodder yield per hectare and PAR are highly negatively correlated with soil moisture suction measurements. Therefore, species that intercept a large fraction of PAR are important in the dry environments like the Sudan savanna of North East Nigeria, where sunshine is abundant (Kamai *et al.* 2014).

Photosynthetic rate : The crop yields depend upon both the rate and duration of photosynthesis and increased photosynthesis potential is considered to be a possible approach in improving yield (Ojma et al. 1969). The rate of photosynthesis assessed as carbon exchange rate was the important component which has direct relevance with yield components (Camussi and Attaviano 1987). The net photosynthesis rate (pn) per plant is the important factor that determines the biomass production and water use efficiency of a species. Variation in Pn has been reported as determinant of plant productivity (Natraja and Jacob 1999). The present study revealed the varietal difference in photosynthetic rate in cowpea genotypes (Table-2). The genotypes Gomti (49.66), 2012/COPBVAR-2 (47.32) and 2012/COPBVAR-5 (40.53) indicated higher photo-synthetic rate as compared to other genotypes. These genotypes may be used in a breeding programme for increasing photosynthetic productivity. On the other hand genotypes Arka Garima (12.91) and 2014/COPBVAR-4

Table-2 : Estimate of physiological parameters in various genotypes of Cowpea.

Genotype	Pn (µ mol/m_2)/ sec	gs (mol/ m^2)/sec	Ci	€ (mmol/ m^2)/sec	PARi	CCI	WUE (Pn/ E) µ mol/ mmol	CE (Pn/Ci) µmol/m^2)/ sec	QE(Pn/PARi) $molm^{-2}s^{-1}$ $(molmol^{-1})^{-1}$)	ME(Ci/g) mol mol^{-1}(mol $m^{-2}s^{-1})^{-1}$)	DMP (g)	PYPP (g)
2014/ COPBVAR-4	28.24	0.41	290.2	1.59	1201	39.57	17.7610	0.09731	0.02351	707.8049	41.58	181.38
2014/ COPBVAR-5	38.71	0.25	210.4	0.99	1204.333	43.67	39.1010	0.18398	0.03214	841.6	49.69	225.67
2014/ COPBVAR-6	29.25	0.33	310.7	1.41	1202.667	40.56	20.7446	0.09414	0.02432	941.515	51.66	232.74
2012/ COPBVAR-2	47.32	0.19	234.6	0.65	1202.667	52.93	62.8	0.20170	0.03934	1234.73	37.63	141.31
2012/ COPBVAR-3	34.33	0.36	278.4	1.75	1203.222	43.33	19.6171	0.12331	0.02853	773.333	42.73	198.53
2012/ COPBVAR-5	40.53	0.14	265.6	0.59	1202.852	51.87	58.6949	0.15259	0.03369	1897.14	32.56	129.72
Arka Garima	12.91	0.26	295.8	1.13	1204.66	31.37	11.4247	0.04364	0.01071	1137.69	36.47	126.77
Kashi Kanchan	31.33	0.21	223.5	0.88	1203.578	42.13	35.6022	0.14017	0.02603	1064.28	39.83	152.91
Gomti	49.66	0.58	239.8	2.59	1203.697	53.9	19.1737	0.20708	0.04125	413.448	47.65	214.57
Pusa Komal	35.66	0.38	251.3	1.76	1203.978	42.83	20.2613	0.14190	0.02961	661.31	45.72	203.53
CD at 5%	0.313	0.003	1.085	0.009	0.007	0.008	0.087	0.00	0.005	0.723	0.009	0.723

Where, Pn=Net photosynthesis rate, gs=Stomatal conductance, Ci=Intercullular CO_2,€=Transpiration rate, PARi=Photosynthetic active radiation, CCI=Chlorophyll content index, WUE=Water use efficiency, CE=Carboxylation efficiency, ME=Mesophyll efficiency, DM=Dry matter production, PYPP= Pod yield per plant

(28.24) were found to be associated with the lowest photosynthetic rate. In most of the species photosynthesis rate increases when stomatal conductance increased (Heber *et al.* 1986 and Hossain *et al.* 2009).

Stomatal conductance : The photosynthesis is largely depends upon stomatal regulation (Hsiao 1973). The stomatal conductance is of utmost importance when photosynthesis is concerned. Stomata play a pivotal role in controlling the balance between assimilation and transpiration (Beadle *et al.* 1981). The stomatal conductance of genotypes declined with decrease in soil water availability. Stomatal closure is the immediate response to avoid excessive water loss through transpiration. The variation in rate of photosynthesis was observed with reference to stomatal conductance (Balsimha *et al.* 1993). The results indicated that (Table-2) genotypes Gomti (0.58), 2014/COPBVAR-4 (0.41) and Pusa Komal (0.38) possessed higher magnitudes for stomatal conductance. The higher stomatal conductance is associated with the higher transpiration rate. The minimum was registered in 2012/COPBVAR-5 (0.14) at par with 2012/COPBVAR-2 (0.19) Similar results have been reported by Hossain et al. (2009) and Anitha et al. (2015).

Transpiration rate : It is necessary to have higher plant conductance to achieve higher canopy photosynthesis which not only enhance the CO_2 exchange rate but also results in higher transpiration rate (Farquhar and Sharkey 1982). The transpiration is one of the major gas exchange parameters related/ associated with plant growth and productivity (Taiz and Zeiger 2002). The present study indicated that genotypes Gomti (2.59), Pusa Komal (1.76) and 2012/COPBVAR-3 (1.75) recorded the higher transpiration rates, respectively indicating their unsuitability for drought sensitive areas (Table-2). However, the higher transpiration rate is a beneficial trait as long as water availability is in abundance. It causes stomatal opening which facilitates CO_2 entry in the plants required for production of photoassimilates. On the other hand if transpiration rate exceeds absorption rate which is common in soils having water scarcity this will cause stomatal closure retarding CO_2 uptake in plants subsequently reducing photosynthesis. The lowest transpiration rate was recorded in 2012/COPBVAR-5 (0.59) and 2012/COPBVAR-2 (0.65) indicating suitability of these genotypes for cultivation in drought sensitive areas. The rate of transpiration decreased with the advancement of maturity. It might have occurred on account of the cumulative effect of decreased soil moisture content (Gupta et al. 2012 and Anitha et al. (2009).

Quantum efficiency : The quantum efficiency represents the efficiency of crop plants in converting solar energy absorbed by the plant to the chemical energy. The genotypes Gomti (0.0412), 2012/COPBVAR-2 (0.0393) and 2012/COPBVAR-5 (0.0336) possessed significantly more quantum efficiencies over rest of the genotypes (Table-2). The genotypes may be used for this trait in a breeding program. On the other hand genotype Arka Garima (0.0107) was associated with the lowest magnitude for this character.

Carboxylation efficiency : The ratio of net photosynthesis rate to intercellular CO_2 concentration is termed as intrinsic carboxylation efficiency, higher ratio better the efficiency for carboxylation (Hamerlynck et al. 2000). The present study showed (Table-2) that genotypes Gomti (0.2070) and 2012/COPBVAR-2 (0.2017) indicated higher carboxylation efficiencies indicating better utilization of intercellular CO_2 for converting it in to photoassimilates. The higher CE may be attributed to the higher magnitudes and efficiency of Phosphoenol pyruvate carboxylase enzyme in these genotypes. The lowest value was found in Arka Garima (0.0436) and 2014/COPBVAR-2 (0.0941). The present result corroborated the findings of Hossain et al (2009) and Hayatu *et al* (2010).

Water use efficiency : The water use efficiency has been defined as the amount of dry matter (DM) produced/ unit of water lost from the plant. The water use efficiency for irrigation after 70, 100 and 130 mm evaporation from evaporation pan was 1.30%, 1.16% and 1.03%, respectively. The present investigations revealed (Table 2) that the genotype 2012/COPBVAR-2 (62.8) possessed the maximum water use efficiency followed by 2012/COPBVAR-5 (58.69) suggesting their suitability for drought prone areas as it could maintain net photosynthesis rate and lowered its Transpiration rate. On the other hand genotypes Arka Garima (11.42) and 2014/COPBVAR-4 (17.76) were found to be associated with the lowest magnitude for this character. Similar findings were noticed by Ackerson *et al.* (1990) and Anitha *et al.* (2015).

Mesophyll efficiency : At a given stomatal conductance, lower Ci indicated better mesophyll efficiency and better draw down rate of the substrate CO_2 (Ramanjulu et al. 1968). The present study revealed (Table 2) that genotypes 2012/COPBVAR-5 (1897.14) and 2012/COPBVAR-2 (1234.73) were found to be associated with higher mesophyll efficiencies, a beneficial trait for breeding purposes. The minimum was recorded in Gomti (413.44) and Pusa Komal (661.31).

Total dry matter production : The maximum rate of dry matter production occurs during the period when the plants are at flowering and fruiting stages. The significant differences observed with the dry matter showed that attainment of reproductive phase was a varietal characteristic related to the genetic constitution of the varieties. The present study (Table-2) indicated that the genotypes 2014/COPBVAR-6 (51.66 g) and 2014/ COPBVAR-5 (49.69 g) recorded higher dry matter production over the remaining genotypes whereas, the lowest value was recorded in the 2012/COPBVAR-5 (32.56). High vigor genotypes attained higher growth rate and accumulated more dry matter than low vigor ones. Hossain et al. (2009) hypothesized that the genotypes having lower dry mass accumulation in the vegetative stage are lower yielder.

Pod yield per plant (g) : The present study revealed (Table 2) that the genotype 2014/COPBVAR-6 out yielded other genotypes (232.74 g/plant) followed by the genotypes 2014/COPBVAR-5 and Gomti owing to its highest dry matter production (47.65 g) which had reflected in its highest yield. Genotype 2014/COPBVAR-5 (225.67 g/plant) was ranked second in yield performance due to its comparatively higher water use and carboxylation efficiency. Genotype Arka Garima produced the lowest pod yield which was attributed to a low performance of all the yield and physiological components. Similar findings were noticed by Abdou et al. (2103) and Kamai *et al.* (2014).

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