PHENOLOGICAL CHANGES IN PHOTOSYNTHETIC RATE, TRANSPIRATION RATE AND STOMATAL CONDUCTANCE AND THEIR RELATIONSHIP WITH SEED YIELD IN COWPEA (*VIGNA UNGUICULATA* (L.) WALP)

M. KALPANA, M.B. CHETTI AND B.P. RATNAM

Department of Crop Physiology, University of Agricultural Sciences, Dharwad-580 005, Karnataka

Received on 27 June, 2002, Revised on 1 April, 2003

SUMMARY

Results of field experiment conducted during *kharif* seasons of 1999 and 2000 under rainfed condition with cowpea genotypes belonging to different growth habit indicated that the determinate genotypes had higher values of photosynthetic rate (Pn), transpiration rate (TR), stomatal conductance (SC), as compared to indeterminate genotypes. It was also observed that all these parameters were maximum at flowering stage and declined at pod development stage. The genotypes KM-5 and KM-4 among the determinate and C-44 and C-22 among indeterminate had higher seed yield and also showed higher values for Pn and SC.

***Key words*: Cowpea, photosynthesis, seed yield, stomatal conductance, transpiration.**

INTRODUCTION

Crop yield is mainly dependent on the interplay of various bio-physical and biochemical functions of the plants in addition to the impact of growing environment. The stomates are important for the diffusion of gases and water vapour which in turn determine the metabolism of crop plants. The arrangement and the frequency of the stomata vary widely among the species and within species. Hsiao (1973) reported that photosynthesis is largely dependent on stomatal regulation. Plant productivity is to a large extent determined by the efficiency of photosynthesis under a given environmental condition and available resources. Cowpea cultivars were found to have a high mean stomatal frequency on lower surface of leaf than on the upper surface of leaf and no significant differences in stomatal size, guard cell size and pore size were recorded (Anonymous 1996). Sivakumar *et al.* (1996) studied the response of four cowpea cultivars to semiarid environment and found that they did not differ significantly in stomatal conductance or in net photosynthetic rates and the photosynthetic rates increased with an increase in photon flux density. Attempts to relate photosynthesis and stomatal frequency with yield have met with only limited success in a variety of plant species. With this background, the present investigation was aimed to analyse the phenological changes in various biophysical parameters and their relationship with productivity in cowpea genotypes belonging to different growth habit.

MATERIALS AND METHODS

Field experiments were conducted during *kharif* seasons of 1999 and 2000 with 12 cowpea genotypes belonging to different growth habit (determinate and indeterminate) under rainfed condition on vertisols at University of Agricultural Sciences, Dharwad, Karnataka. The experiment was laid out in a randomized block design with three replications. The crop was fertilized with nitrogen and phosphorus @ 25 and 50 kg ha^{-1} in the form of urea and single super phosphate. Seeds were treated with captan and thiram @ 3 g kg^{-1} seed and planted at a spacing of 45 cm between the rows and 15 cm between the plants within rows, to maintain required plant population of 1.4 lakhs ha^{-1}. Interculture operations were carried out twice at 20 and 35 days after sowing. The crop was sprayed with endosulfon @ 1.5 ml l^{-1} and monocrotophos @ 1.0 ml l^{-1} at 40 and 65 DAS, respectively to control leaf eating caterpillar and pod borer. The canopy spread per plant was calculated by multiplying the maximum spread of the plant in two directions perpendicular to each other *i.e.* N-S and E-W directions. Stomatal frequency was examined by using clear polystyrene replicas (Quarrie and Jones 1977) on both adaxial and abaxial surfaces. The photosynthetic rate, stomatal conductance and transpiration rate were measured in the third trifoliate leaf from the top using portable photosynthetic system (LI 6200) of LICOR, USA. The leaves were inserted in chamber such that, their normal position was not disturbed. These measurements were made between 1000 to 1200 hrs. Seed yield was recorded from five tagged plants used for recording various biophysical parameters. The data of two seasons were pooled and analysed statistically.

RESULTS AND DISCUSSION

In the present study, genotypic variations were observed with respect to stomatal frequency (Table 1). In general, not much difference was observed in the stomatal frequency between determinate and indeterminate genotypes. The mean stomatal frequency on lower surface was higher at both the stages as compared to upper surface in all the genotypes. Among determinate types, KM-5 showed significantly higher stomatal frequency at flowering stage and KM-6 had higher stomatal frequency on the abaxial surface at both the stages (Table 1). C-70 belonging to indeterminate type registered higher stomatal frequency. Significantly lower stomatal frequency was observed in KM-1 among determinate type and C-152 among indeterminate type at flowering stage. The canopy photosynthesis depends on the leaf conductance, which in turn depends on stomatal frequency and leaf area per plant. Hence, it is necessary to have higher plant conductance to achieve higher canopy photosynthesis which would lead to higher biological yield. It should be borne in mind that high plant conductance rate not only enhances the CO_2 exchange rate but also results in higher transpiration rate (Farquhar and Sharkey 1982).

Table 1. Genotypic differences in stomatal frequency (mm^2 leaf area) at different growth stages in cowpea.

Genotypes	Adaxial (Upper)		Abaxial (Lower)	
	Flowering stage	Pod development stage	Flowering stage	Pod development stage
Determinate				
KM-1	19	23	30	30
KM-2	21	28	30	33
KM-3	21	29	29	36
KM-4	21	25	28	29
KM-5	30	32	33	29
KM-6	28	29	41	36
TVX-944	25	25	32	37
Mean	23.6	27.3	31.9	32.9
Indeterminate				
C-11	22	26	35	26
C-22	25	27	35	28
C-44	21	27	30	32
C-70	25	29	28	27
C-152 (Check)	19	26	27	30
Mean	22.4	27.0	31.0	28.6
CD (5%)	2.1	3.5	6.9	5.4

The data on canopy spread indicated that it was higher in indeterminate genotypes compared to determinate types at all the stages (Table 2) and the canopy spread increased from vegetative stage to flowering stage and decreased thereafter at pod development stage, irrespective of the growth habit of the genotypes. However, the decline in the canopy spread was less in indeterminate types as compared to determinate type. Canopy development is one of the important pre-requisites for better light interception (Yoshida 1972), but in broad leaved crops like cowpea, canopies are more planophile and require a lower leaf area for complete light interception than cereals. In the present investigation, it was observed that in general, the genotypes possessing higher seed yield irrespective of growth habit had lower canopy spread as compared to those of low yielding genotypes. For example, KM-5 and KM-6 which are high yielder under determinate group and C-44 and C-22 under indeterminate group had significantly lower canopy spread over all other genotypes. This clearly indicates that higher canopy spread is not a desirable trait in cowpea.

The Pn, SC and TR were maximum at flowering stage and declined at pod development stage in all the genotypes, irrespective of the growth habit and a wide variation existed among the genotypes (Table 3). The relatively high Pn, TR and SC at flowering stage indicate that the crop had the capacity to maintain high assimilation rate. The decline in Pn at pod development stage could be due to the mobilization of leaf N for the development of protein rich seeds (Pate *et al.* 1983). Similar observations have been made in other grain legumes (Sinha and Ghildiyal 1971, Ghildiyal and Sirohi 1986, Venkateshwarlu and Balasubramanian 1993). Pandey *et al.* (2001) showed that Rubisco is mobilized during pod development in chickpea. TR, Pn and SC were lower at pod development stage than at flowering stage. These physiological processes were higher in determinate genotypes compared to indeterminate types and the differences became narrower at later

Table 2. Genotypic differences in canopy spread (cm^2 $plant^{-1}$) at different growth stages in cowpea.

Genotypes	Vegetative stage	Pre flowering stage	Flowering stage	Pod development stage
Determinate				
KM-1	916	1306	1906	1329
KM-2	1044	1292	2034	1533
KM-3	1176	1343	1890	1255
KM-4	1158	1394	1845	1248
KM-5	1205	1331	1791	1143
KM-6	1080	1283	1811	1068
TVX-944	1260	1384	1840	1260
Mean	1119	1333	1874	1262
Indeterminate				
C-11	1081	1441	2098	1635
C-22	1110	1364	1913	1566
C-44	1284	1344	1888	1341
C-70	1053	1300	2158	1705
C-152 (Check)	1103	1462	2208	1785
Mean	1126	1382	2053	1606
CD (5%)	NS	34.1	49.9	22.6

Table 3. Genotypic differences in photosynthetic rate, stomatal conductance, transpiration rate and seed yield in cowpea.

Genotypes	Photosynthetic rate (µmol m^{-2} s^{-1})		Stomatal conductance (µmol m^{-2} s^{-1})		Transpiration rate (µmol m^{-2} s^{-1})		Seed yield (g/plant)
	Flowering stage	Pod development stage	Flowering stage	Pod development stage	Flowering stage	Pod development stage	
Determinate							
KM-1	22.0	15.3	4.6	3.5	40.1	31.9	11.08
KM-2	20.5	14.4	4.1	3.3	38.1	30.1	10.41
KM-3	23.3	15.6,	4.8	3.6	41.1	32.2	13.82
KM-4	25.6	17.7	5.1	3.8	43.2	33.1	14.56
KM-5	28.3	19.8	5.7	4.2	47.8	38.2	16.94
KM-6	27.2	18.5	5.6	4.1	45.3	37.2	15.61
TVX-944	25.1	17.3	4.9	3.6	44.2	36.8	14.44
Mean	24.6	16.9	4.9	3.7	42.8	34.2	-
Indeterminate							
C-11	18.3	14.3	3.8	2.9	41.8	32.2	12.66
C-22	20.1	15.6	4.0	3.1	44.2	34.6	13.01
C-44	22.7	16.5	4.3	3.2	46.3	38.9	14.55
C-70	15.3	13.5	3.5	2.8	36.7	29.8	9.68
C-152 (Check)	14.5	12.7	3.1	2.4	35.1	28.2	9.11
Mean	18.2	14.5	3.7	2.9	40.8	32.7	12.83
CD (5%)	1.7	1.4	0.6	0.5	5.2	4.1	0.22

stages, indicating that the growth habit has significant influence on these processes. Field (1987) also reported that the stomatal conductance varies with the leaf age and genotypes belonging to determinate type in general possessed higher values as compared to indeterminate genotypes. Among the determinate genotypes, KM-5 followed by KM-6 and among indeterminate genotypes, C-44 followed by C-22 had higher Pn, SC and TR (Table 3).

It is interesting to note that these genotypes also had lower canopy spread and higher seed yield. It is expected that if the stomatal frequency is more, there is better exchange of gases and water vapour and may lead to higher productivity. In the present study, however, higher stomatal frequency was not necessarily associated with higher productivity. Farquhar and Sharkey (1982) reported that leaf photosynthesis could be limited by decreased stomatal conductance. In senescing leaves, non-stomatal factors were found preponderant in limiting photosynthesis (Field 1987) possibly mainly through decreased Rubisco activity (Jiang *et al.* 1993). Hsiao (1973) reported that photosynthesis is largely dependent on stomatal regulation. However, stomatal size, guard cell size and pore size did not differ significantly among the cowpea cultivars studied (Anonymous 1996). In the present study, genotypes having higher Pn and SC were found to be high yielders. Based on this, the thrust may, therefore, be given to select the genotypes having higher Pn and SC in future breeding programmes.

REFERENCES

Anonymous (1996). Stomatal characters and diurnal variation in two cowpea cultivars. Asian Vegetable Res. Dev. Centre Reports, AVRDC, pp. 41-56. Taiwan.

Farquhar, G.D. and Sharkey, T.D. (1982). Stomatal conductance and photosynthesis. *Ann. Rev. Plant Physiol.* **33:** 317-345.

Field, C.B. (1987). Leaf age effects on stomatal conductance. In : E. Zeiger, G.D. Farquhar and I.R. Cowan (eds), Stomatal Function, pp. 367-384. Stanford University Press, Stanford.

Ghildiyal, M.C. and Sirohi, G.S. (1986). Nitrogen utilization during growth and development in mungbean. *Indian J. Exp. Biol.* **24:** 124-126.

Hsiao, T.C. (1973). Plant response to water stress. *Annu. Rev. Plant Physiol.* **24:** 519-570.

Jiang C.Z., Rodermel, S.R. and Shibles, R.M. (1993). Photosythesis, rubisco activity and amount and their regulation by transcription in senescing soybean leaves. *Plant Physiol.* **101:** 105-112.

Pandey, R., Sharma-Natu, P. and Ghildiyal, M.C. (2001). Irrigation decreases loss of leaf nitrogen and rubisco during pod development in chickpea. *J. Agron. Crop Sci.* **187:** 177-183.

Pate, J.S. Peoples, M.B. and Atkins, C.A. (1983). Post-anthesis economy of carbon in cultivar of cowpea. *J. Exp. Biol.* **34:** 544-562.

Quarrie, S.A. and Jones, H.G. (1977). Effect of ABA and water stress on development and morphology of wheat. *J. Expt. Bot.* **28:** 192-203.

Sinha, S.K. and Ghildiyal, M.C. (1971). Variability in photosynthesis and nitrogen fixation in mungbean and cowpea cultivars. In: G.S. Sirohi (ed.), Physiological Studies on Pulses, pp. 38-42. Division of Plant Physiology, IARI, New Delhi.

Sivakumar, M.V.K., Nfare, B.R. and Roberts, J. M. (1996). Growth, yield and plant water relations of four cowpea (*Vigna unguiculata)* cultivars in the Sahel. *J. Agril. Sci.* **126:** 183-190.

Venkateshwarlu, S. and Balasubramanian, V. (1993). Photosynthesis during reproductive phase of rainfed greengram. *Indian J. Plant Physiol.* **36:** 174-177.

Yoshida, S. (1972). Physiological aspects of grain yield. *Annu. Rev. Plant Physiol.* **23:** 437-464.