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INTERCEPTION OF PHOTOSYNTHETICALLY ACTIVE RADIATION AND ITS UTILIZATION BY CHICKPEA VARIETIES UNDER IRRIGATED AND WATER STRESS CONDITIONS

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SUMMARY

Field experiments were conducted at IARI, New Delhi to study the interception of photosynthetically active radiation and utilization in six varieties of chickpea *viz.*, Amethyst, Annegiri, BG-362, ICC-4958, K-850 and Tyson. Among the varieties, BG-362, K-850 and Annegiri intercepted higher percentage of photosynthetically active radiation (PAR) as compared to the other three varieties under both irrigated and unirrigated conditions at the maximum leaf area index (LAI) stage. The intercepted photosynthetically active radiation (IPAR) was closely related to the biomass production. The R^2 values for the regression equations between IPAR and biomass revealed that IPAR accounted for 90 to 93 per cent of the variation in biomass production in chickpea. Both IPAR and radiation use efficiency (RUE) were reduced under unirrigated conditions. However, the reduction in RUE was relatively less in Annegiri, K-850 and ICC-4958 suggesting that it has a role to play for increasing the productivity of chickpea in rainfed areas.

Key words: **Biomass production, chickpea, radiation interception, radiation utilization efficiency, water stress.**

INTRODUCTION

Solar radiation is a natural resource, which essentially controls plant growth, development and production of dry matter. The ultimate capacity of a plant community to produce dry matter depends on the degree of exploitation of solar radiation (Pearce *et al.* 1963). Radiation interception and utilization assume great importance because its utilization efficiency can be improved through appropriate crop management practices such as canopy architecture, plant population and variety (Raghunatha and Jaganath 1976). Though radiation interception and its utilization play a major role in contributing to seed yield, much attention has not been directed on this aspect in chickpea. This very fact substantiates the necessity of undertaking this work in this important pulse crop.

MATERIALS AND METHODS

The experiment was conducted during two *rabi* seasons of 2000-01 and 2001-02 in the research farm of the Indian Agricultural Research Institute, New Delhi. Six varieties of chickpea, *viz.*, Amethyst, Annegiri, BG-362, ICC-4958, K-850 and Tyson were grown (sowing date. 15th November in both the years) under irrigated and unirrigated conditions, following the recommended agronomic practices in a randomized block design (RBD) with three replications each and the plot size was 3 m × 4 m. Under irrigated conditions during the first season, beacuse of 12 mm of rainfall received during the pod development stage, only two irrigations (at pre-sowing and vegetative stages of the crop) were given while in the second season, three irrigations were given (at pre-

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sowing, vegetative and pod development stages of the crop). Under unirrigated condition only pre-sowing irrigation was given in both the seasons.

For measuring the leaf area index (LAI) plants were harvested at random from a square meter ground level, the green leaves were separated, their area was measured using a leaf area meter (Model LICOR-3100) and the LAI was computed. The samples collected for the estimation of leaf area index were utilized for assessing the biomass production. These samples were oven dried at 65°C until constant weight.

A Line Quantum Sensor (LICOR LQA-0968) was used to measure the PAR (400 to 700 nm) at canopy level and at the bottom of the canopy, at regular intervals on clear days between 1100 and 1200 hours. The intercepted PAR (IPAR) expressed as percentages of the incident PAR was determined using the following relationship :

$$\text{IPAR}\ (\%) = (\text{IPAR}/\text{Incident PAR}) \times 100)$$

Where, IPAR = Incident radiation on the canopy - Reflected radiation by the canopy - Transmitted radiation + Reflected radiation from the ground.

Since it was not possible to measure the daily incident radiation, the mean daily values of solar radiation received above the crop canopy were estimated using Penman (1948) formula and the PAR was calculated by multiplying it with 0.48 (Monteith 1972, Kailasnathan and Sinha 1984). The calculations are as follows :

$$Ri = Ra\ (1 - r)\ (a + b\ n/N)\ \text{cal/cm}^2\text{/day}$$

where, Ri = incoming solar radiation, cal/cm^2

Ra = radiation received at the top of the atmosphere, cal/cm^2

r = reflection coefficient (0.25 has been used for the green crops)

N = Maximum possible sunshine (hours/day)

n = actual bright sunshine hours (hours/day)

a&b = constants. For Delhi, 0.32 and 0.46 have been used for a and b respectively following Gangopadhyaya *et al.* (1970).

The PAR values were converted into MJ/m^2 and used to calculate the radiation utilization efficiency. The data of actual sunshine hours (n) collected from IARI meterological observatory located in the adjoining field were used. Data on radiation received at the top of the atmosphere (Ra) and maximum possible sunshine hours (N) were taken from Smithsonian meteorological tables (List 1964). The values of radiation utilization efficiency (RUE) were computed as follows :

$$\text{RUE (g/MJ)} = \frac{\text{Maximum biomass (g/m}^2)}{\text{Cumulative IPAR Corresponding to the day of maximum biomass accumulation}}$$

RESULTS AND DISCUSSION

The intercepted photosynthetically active radiation (IPAR, %) was generally lower during the initial stages of crop growth due to slow canopy development (Fig. 1). Thereafter the interception increased reaching a maximum when canopy cover was greatest and then declined when the crop started to senesce. During the *rabi* season of 2000-01, the peak values of IPAR under irrigated conditions in BG-362, K-850 and Annegiri (70 to 77%) were higher as compared to Amethyst, Tyson and ICC-4958 (64 to 67%). In the second season also, the former three varieties intercepted higher PAR (68 to 72%) as compared to the latter where the interception varied from 60 to 63 per cent. These could be attributed to the differences in the leaf area index-varieties BG-362, K-850 and Annegiri having higher

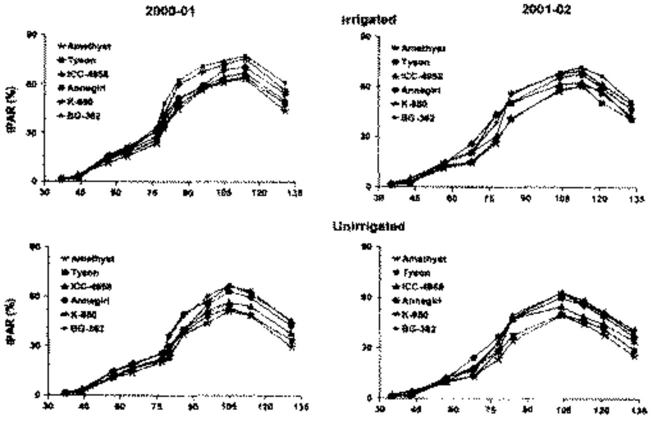

Fig. 1. Variation in intercepted photosynthetically active radiation (IPAR, %) in chickpea varieties under irrigated and unirrigated conditions during 2000-01 and 2001-02

LAI intercepted more amount of radiation as compared to the other three varieties. Under unirrigated conditions also, similar trend was observed. These results are in agreement with those reported by Nanda and Saini (1990) and McKenzie *et al.* (1992) who observed that solar radiation interception was closely related to the leaf area index. Under unirrigated conditions, the peak PAR interception was reduced in all the varieties, by 9 to 19 per cent. Huges and Keatinge (1983), Muchow (1985) and Thomas and Fukai (1995) also observed reductions in intercepted PAR under unirrigated or water stress conditions due to the decrease in leaf area. In the present study, LAI in all the varieities was reduced under unirrigated conditions hence leading to lower PAR interception. The differences were greater during the later part of the crop growth (after about 80 to 90 days after sowing) suggesting that the effects of water stress became evident during this period or the differences could be due to genetic differences.

The biomas accumulated during the growth period and the corresponding intercepted photosynthetically active radiation was closely correlated under irrigated (r=0.87) and unirrigated (r=0.82) conditions. The best fitting regression equations obtained from the pooled data for all the varieties in the two seasons under irrigated and unirrigated conditions (Table 1) indicated that the biomass production was closely associated with IPAR. The R^2 values indicated that IPAR could explain 90 to 93 per cent of the variation in biomass production in chickpea. Singh and Sri Rama (1989) reported that the biomass production in chickpea was closely related to PAR interception.

Table 1. Relationship between IPAR and biomass production.

Irrigated			
Biomass = 12.191*	Exp (0.051*IPAR)	N = 120	$R^2 = 0.93$
Unirrigated			
Biomass = 8.6923*	Exp (0.0615*IPAR)	N = 120	$R^2 = 0.90$

Though the amount of PAR received above the canopy was same, different varieties intercepted radiation differently due to differences in their canopy structure, leaf area and biomass production. Thus, the radiation utilization efficiency would differ. The varieties BG-362 and K-850 recorded the highest RUE values followed by Annegiri and ICC-4958 under both irrigated and unirrigated conditions (Table 2). The lowest RUE values were found in Amethyst and Tyson singifying the poor conversion of energy into dry matter in these varieties. Under unirrigated conditions there was a reduction in the RUE in all the varieties due to lower biomass production under moistrue stress. The reduction was more in Amethyst, Tyson and BG-362 as compared to the Annegiri, K-850 and ICC-4958, suggesting that latter varieties are better converters of energy even under water stress conditions. The effect of reduced LAI and biomass production due to moisture stress can be seen on RUE because it is the leaf, which intercepts light where it is converted into chemical energy. Jamieson *et al.* (1995), Thomas and Fukai (1995) and Kumar (2000) observed reduction in RUE due to water stress.

The study concludes that the chickpea varieties BG-362, K-850 and Annegiri intercepted higher amount of

Table 2. Radiation utilization efficiency (RUE) in different chickpea varieties under irrigated and unirrigated conditions during *rabi* seasons of 2000-01 and 2001-02.

Varieties	PAR at maximum biomass level (MJ/m^2)	Maximum biomass (g/m^2)		RUE (g/MJ)	
		Irrigated	Unirrigated	Irrigated	Unirrigated
Amethyst	835 (799)	408 (319)	319 (235)	0.49 (0.40)	0.38 (0.29)
Tyson	835 (799)	406 (312)	299 (240)	0.49 (0.39)	0.36 (0.30)
ICC-4958	835 (799)	430 (349)	338 (294)	0.51 (0.44)	0.40 (0.37)
Annegiri	835 (799)	454 (365)	374 (306)	0.54 (0.46)	0.45 (0.38)
K-850	835 (799)	525 (435)	423 (366)	0.63 (0.54)	0.51 (0.46)
BG-362	835 (799)	537 (444)	421 (349)	0.64 (0.56)	0.50 (0.44)

(Values for the year 2001-02 are given in parenthesis).

photosynthetically active radiation under both irrigated and unirrigated conditions. However, under water stress conditions, the reduction in radiation utilization was lower in Annegiri, K-850 and ICC-4958. This suggests that such chickpea varieties have a key role to play in increasing the productivity in rainfed areas.

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