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Assessing the leaf area index in chickpea crop using spectral indices

T. D. LAMA* and N. V. K. CHAKRAVARTY
Division of Agricultural Physics, I.A.R.I., New Delhi - 110012

ABSTRACT

A study was carried out to develop useful quantitative relationships between spectral indices (IR/R and NDVI) and leaf area index (LAI) in chickpea crop under irrigated and unirrigated conditions under field conditions. Six varieties differing in their growth habits and plant types were grown on sandy clay loam soils of Indian Agricultural Research Institute research farm during two *rabi* seasons of 2000-01 and 2001-02 under irrigated and unirrigated conditions following the recommended agronomic practices. The coefficients of determination (r^2) values were obtained for the relations between LAI and spectral indices (IR/R and NDVI). Various types of regressions were tried and finally it was inferred that LAI can be best estimated by both IR/R and NDVI derived from the spectral reflectance data using linear or polynomial equations.

Key words : Spectral indices, LAI estimation, chickpea.

Chickpea is one of the major pulse crops throughout the world. Because of its diversified uses and its ability to grow better as compared to other pulse crops with low inputs under harsh edaphic and arid environments, it has been an important component of the cropping system of subsistence farmers in the Indian subcontinent. In India chickpea is grown as a winter crop and consequently, its production is limited by climatic factors and water availability. Crop monitoring has become more easy and non-destructive with the advent of the satellite imageries being obtained through remote sensing satellites. The development of functional relations between crop characteristics and remote spectral observations has gained more importance in recent years. Though several attempts have been made to relate the plant parameters like the leaf area index and biomass production with the derived spectral indices in different crops (Wiegand and Richardson, 1984, 1990; Ajai *et al.*, 1983; Asrar *et al.*, 1984; Hatfield *et al.*, 1985; Sastri and SubbaRao, 1992), quantitative information relating the leaf area index with the spectral indices is lacking in the chickpea crop. Hence an attempt has been made in the present study to develop useful quantitative relations between spectral indices (IR/R and NDVI) and LAI for

*Present Address : ICAR Research Complex for NEH Region, Umiam 793103, Meghalaya

chickpea crop under irrigated and unirrigated conditions to assess the leaf area index under field conditions without destructing the plants.

MATERIALS AND METHODS

Six varieties of chickpea namely Amethyst, Annegiri, BG-362, ICC-4958, K-850 and Tyson were grown during the *rabi* seasons of 2000-2001 and 2001-2002 on the sandy clay loam soils of Indian Agricultural Research Institute research farm, New Delhi (28° 35' N, 77° 1' E), following the recommended agronomic practices. In both the years, the crops were sown on 15th November in a RBD with three replications, the plot size was 3m × 4m and the crops were grown both under irrigated and unirrigated conditions. Under irrigated conditions, during the first season, because of 12 mm rainfall received during the pod development stage, only two irrigations (pre-sowing and vegetative stages of the crop) were given while in the second season, three irrigations (pre-sowing, vegetative and pod development stages of the crop) were given. Under unirrigated condition only pre-sowing irrigation was given in both the seasons.

For measuring the leaf area index (LAI) three plants were cut at random at the ground level, the green leaves were separated and their area was measured using a leaf area meter (Model LICOR-3100). From the leaf area measured the LAI was computed.

Spectral reflectance was measured with the help of a hand held spectroradiometer (Model LICOR-1800) at different wavelengths between 330 nm to 1100nm. The measurements were taken between 1100 to 1300 hours on clear days by keeping the sensor inverted at 50 cm above the canopy. The standards were taken by keeping the sensor upwards. From the spectroradiometer readings the two spectral indices derived were: IR/R = MSS7/MSS5 (Tucker 1979) and Normalised Difference Vegetation Index (NDVI) = (MSS7 –MSS5)/(MSS7+MSS5) (Deering *et. al.*, 1975) where, MSS 5 = 600-700 nm and MSS7 = 800-1100 nm.

Linear and polynomial regression equations were then fitted between LAI and spectral indices (IR/R and NDVI) following standard statistical methods.

RESULTS AND DISCUSSION

Since in the literature though several findings were reported relating the spectral indices with the plant parameters, there is no report in the direction of assessing the leaf area index using the spectral indices, more so in chickpea. With an idea to do away the destructive plant sampling to determine the leaf area index, in the present study the LAI was taken as the dependent variable while both the spectral indices were taken as the independent variables. Regressions were worked out between LAI and the spectral indices for various combinations viz., individual varieties and varieties put together year wise. But for clarity sake, regression lines for the pooled data for all the six varieties, in both the seasons and under irrigated as well as

Table 1: Values of r^2 between LAI and spectral indices in chickpea for the pooled data of two seasons (2001-01 & 2001-02)

Cultivars	Irrigated				Unirrigated			
	Linear		Polynomial		Linear		Polynomial	
	IR/R	NDVI	IR/R	NDVI	IR/R	NDVI	IR/R	NDVI
Amethyst	0.91	0.85	0.92	0.90	0.81	0.83	0.83	0.83
Annegiri	0.90	0.79	0.93	0.88	0.83	0.83	0.85	0.84
BG-362	0.89	0.82	0.89	0.87	0.90	0.83	0.90	0.90
ICC-4948	0.83	0.71	0.87	0.79	0.92	0.88	0.92	0.91
K-850	0.82	0.76	0.83	0.80	0.91	0.89	0.93	0.91
Tyson	0.89	0.81	0.91	0.88	0.82	0.82	0.83	0.84

Table 2 : Regression equations between LAI and spectral indices in chickpea for the pooled data of two seasons (2000-01 & 2001-02).

	Regression equation	r^2
	Linear	
Irrigated	LAI = 0.57 IR/R – 0.90	0.86
	LAI = 5.18 NDVI – 1.53	0.77
Unirrigated	LAI = 0.56 IR/R – 0.90	0.88
	LAI = 4.80 NDVI – 1.43	0.84
	Polynomial	
Irrigated	LAI = 0.01 $(IR/R)^2$ + 0.48 IR/R – 0.74	0.86
	LAI = 12.27 $(NDVI)^2$ – 6.89 NDVI + 1.18	0.84
Unirrigated	LAI = - 0.04 $(IR/R)^2$ + 0.82 IR/R – 1.28	0.88
	LAI = 8.19 $(NDVI)^2$ – 2.99 NDVI + 0.30	0.88

unirrigated conditions are presented in Fig.1 and Fig.2. Though linear and polynomial regressions were worked out, for clarity sake, only polynomial equations are presented in the graphs. It can be seen that with increase of LAI, both IR/R and NDVI

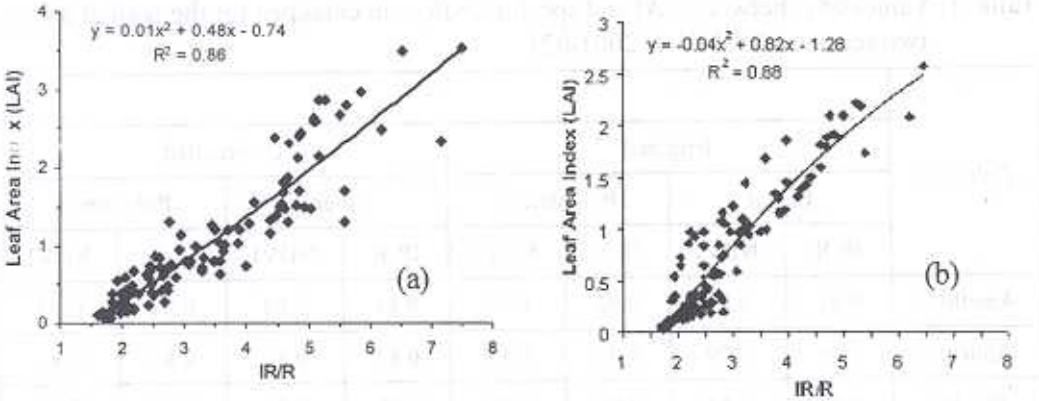

Fig. 1: Relation between IR/R and leaf area index (LAI) in chickpea under (a) irrigated and (b) unirrigated conditions

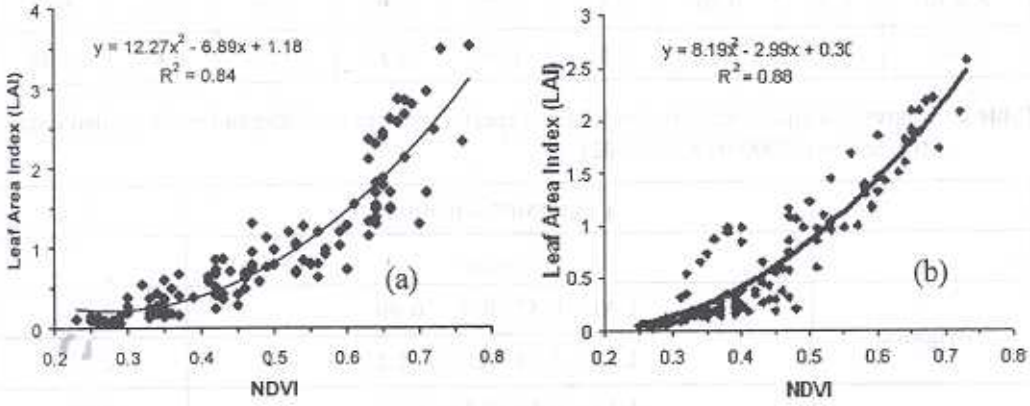

Fig. 2: Relation between NDVI and leaf area index (LAI) in chickpea under (a) irrigated and (b) unirrigated conditions

increased steadily, however the increase was slower during the early growth stages of the crop. Under irrigated condition maximum values of both IR/R and NDVI were observed at LAI » 3.5 while under unirrigated condition the maximum values were observed at LAI » 2.5. This may be attributed to differences in vegetative growth under the two conditions. After reaching the maximum value (about 114 days in irrigated and 105 days in case of unirrigated crop), the values of both LAI and spectral indices (IR/R and NDVI) decreased reaching a minimum around 130 days. At this stage, the magnitude of both LAI and spectral indices were higher in irrigated crop than in unirrigated crop due to differences in vegetative growth.

The r^2 values for the linear and polynomial relations between LAI and spectral indices for the different chickpea varieties under both irrigated and unirrigated conditions are shown in Table 1. For the linear relationship, under irrigated conditions, the r^2 values between LAI and IR/R in different varieties varied from 0.84 to 0.91 showing superiority over the NDVI whose values varied from 0.71 to 0.85 while under unirrigated conditions, the r^2 values were found to be more or less the same for both IR/R and NDVI (0.81 to 0.92). On the other hand, the r^2 values in case of the polynomial relation of LAI with IR/R were between 0.83 to 0.93 both under irrigated and unirrigated conditions. As far as the NDVI is concerned, the r^2 values under irrigated conditions, varied from 0.79 to 0.90 while in the unirrigated they ranged from 0.83 to 0.91.

For the pooled data (Table 2) considering all the varieties together, the r^2 values under irrigated and unirrigated conditions were respectively 0.86 and 0.88 for the linear relation between LAI and IR/R while the corresponding values were 0.77 and 0.84 in case of NDVI. However, the r^2 values for the polynomial relation between LAI and IR/R were 0.86 and 0.88 while for NDVI the values were 0.84 and 0.88 under irrigated and unirrigated conditions respectively showing only marginal differences.

The above results suggest that both the spectral indices, IR/R and NDVI can be used to predict LAI in chickpea crop both under irrigated and unirrigated conditions with 80 per cent confidence level as is evident from the r^2 values.

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