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Spectral Characteristics and Growth of Rainfed Chickpea (*Cicer arietinum* L) in Relation to Agronomic Practices

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ABSTRACT

An experiment was conducted in sandy loam soil (Typic Ustrocrept) at Indian Agricultural Research Institute in 1998-99 to study the spectral response of chickpea (*Cicer arietinum* L) under the influence of different *in situ* water conservation practices like bunding, bunding with farm yard manure and green manuring with three levels of phosphorus. *In situ* moisture conservation practices in conjunction with phosphorus produced higher leaf area index (LAI), biomass and yield and bunding with farmyard manure with 60 kg P_2O_5/ha were found to be the better treatment in terms of LAI, biomass and final yield. The study emphasized potential application of spectral indices to monitor different management practices and prediction of LAI, biomass and yield of the crop.

Key words: Moisture conservation practices, Crop yield prediction, Remote sensing, Spectral reflectance monitoring

Introduction

Crop condition under various agronomic management practices can be monitored on a large scale by remote sensing techniques. The basis of evaluation of any management practices is the radiance measured in the red and infrared regions and their ratio (IR/R) and normalized difference (ND) defined as spectral vegetation as indicators of crop vigor. These indices are widely used to predict plant growth parameters like leaf area index (LAI), biomass and yield (Verma *et al.*, 2002).

Several workers studied the effect of agronomic practices on spectral signatures in various crops (LaRuffa *et al.*, 2001; Lukina *et al.*, 2001; Sembiring *et al.*, 2000). Information on spectral responses on chickpea, a major pulse crop of India under different management practices, is meager. The objectives of this study are to monitor different moisture conservation practices (bunding, farmyard manuring and green manuring) and phosphorous levels on spectral response, and to establish relationship between spectral indices with plant growth parameters of chickpea.

Materials and methods

Study area

A field experiment was carried out during November-April of 1998-99 on chickpea crop (variety BG 256) at Indian Agricultural Research Institute Farm (slope < 1 %). The farm is situated between latitude 28°37' to 28°39' N and longitude 77°9' to 77°11' E at an altitude of 228.7 m above mean sea level. The climate is semiarid and subtropical with extreme weather conditions. Monthly average weather condition is given in the Fig 1. Soil is sandy loam of Typic Ustochrepts with medium to angular blocky structure, non-calcareous and slightly alkaline in reaction. The major physico-chemical properties of the soil (0-30 cm depth) are given in Table 1.

Experimental design

The experiment was laid out in split plot design with three replications. The main plot (10.5 x 13.5 m^2) consisted of control, bunding (ridging), bunding with farm yard manure @ 10 tonnes ha^{-1} (bunding with FYM) and green manuring with daincha (*Sesbania aculeata*) (GM) without bunding. Bunded fields were prepared to check surface runoff by simply raising ridges of height of 20 cm around the plots. These bunds were prepared before monsoon to permit *in situ* conservation of water. Farmyard manure (with 0.43 N, 0.25 P and 0.44 K per dry weight basis) was incorporated in the soil during the field preparation. In case of green manuring, daincha was grown *in situ* as per treatment with a seed rate of 60 kg ha^{-1}. About 40 days old green manure crop (2.19 N, 0.24 P and 2.08 K on dry weight basis) was incorporated and allowed to decompose for two weeks before sowing chickpea. The sub-plots (3 x 6 m^2) treatments consisted of three levels of phosphorus applied during crop season @ 0, 30 and 60 kg P_2O_5 ha^{-1}, respectively. Phosphorus was applied at the time of planting as single super phosphate. Seeds were sown on 28

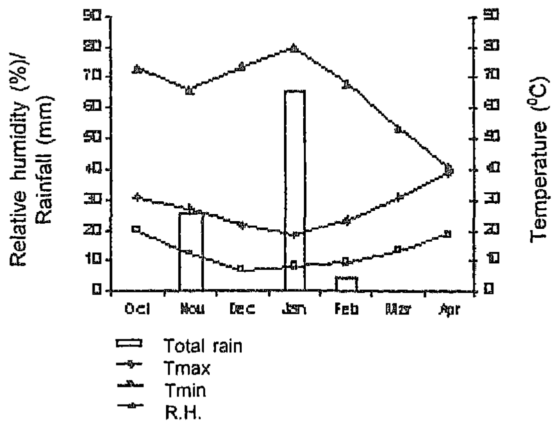

Fig. 1. Monthly averages of different weather parameters during the crop growth period.

October 1998 with a seed rate of 80 kg ha^{-1} using a seed drill with a spacing of 30 x 15 cm. All the crop management practices were adopted timely.

Data collection

Spectral reflectance in the range of 330-1100 nm with 1 nm wavelength (with 180° fully cosine corrected receptor) interval was measured using portable spectroradiometer (Model-Licor PC1800). Three random measurements were taken per plot keeping the sensor one meter above the canopy (relative height) on clear sunny days before noon. The observations were taken periodically to cover entire crop duration starting from spectral emergence (about 30 days after sowing) to final maturity. IR/R and NDVI were calculated corresponding to MSS (Multi Spectral Scanner) bands.

IR/R = MSS 7/MSS 5 ---(1)

NDVI = (MSS 7-MSS 5) / (MSS 7+ MSS 5) --- (2)

Where MSS 5 corresponds to red (600-700 nm) and MSS 7 corresponds to infrared (800-1100 nm) part of the spectrum, which are the standard bandwidths for study of vegetation.

Other growth parameters like leaf area index (LAI) and dry biomass were recorded periodically on the same day of spectral response measurement. The area occupied by single plant is 15 x 30 cm^2 and the LAI values were calculated accordingly using 3 randomly selected plants from each plot and green leaf portions were separated and their area was measured with leaf area meter (model: Licor 3100). The total harvested green biomass was oven-dried at 65°C for 72 hours or till constant weight is attained and expressed at dry biomass (DBM) per unit area. Final yield was recorded after harvest at the end of experiment (158 days).

Results and Discussion

Leaf area index (LAI), dry biomass (DBM) and yield

LAI increased gradually with the advance in days after sowing (Fig. 2). It reached maximum and there after decreased due to drying of leaves at maturity. At different phosphorus levels, moisture conservation practices showed higher LAI than control. Among different moisture conservation practices, Bunding with FYM tended to show higher LAI. Bunding and GM treatments showed same pattern under 30 and 60 kg P supply.

The dry biomass (DBM) also increased in a sigmoid growth pattern (Fig.3). The effect of phosphorus in combination with moisture conservation practices was clearly visible on total dry biomass production of the chickpea. Within different P levels, the treatments did not show much difference up to 120 DAS and after that substantial addition of biomass was observable.

Table 1. Soil Properties of Experimental Site (0-30 cm depth)

Parameters	CONTENT		
Mechanical composition	Sand (%) = 71.7	Silt (%) = 12.0	Clay (%) = 16.3
Physico-chemical Properties	pH (1:2.5) = 7.4	EC (ds/m) = 0.34	
Fertility status	Total N (%) = 0.031	Available P = 6.9 (Kg/ha)	Available K = 279.1 (Kg/ha)

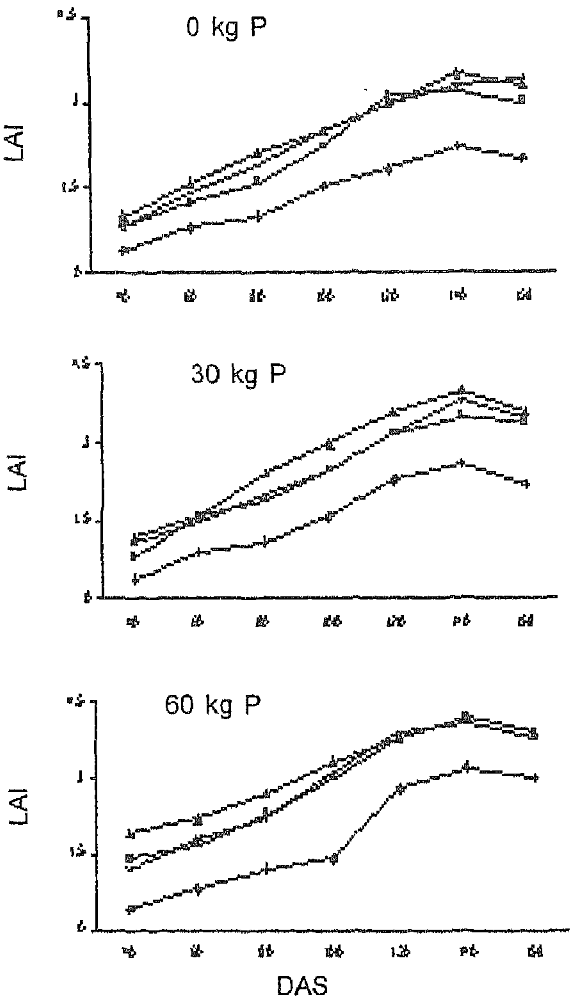

Fig. 2. Leaf area index of chickpea during the crop growth

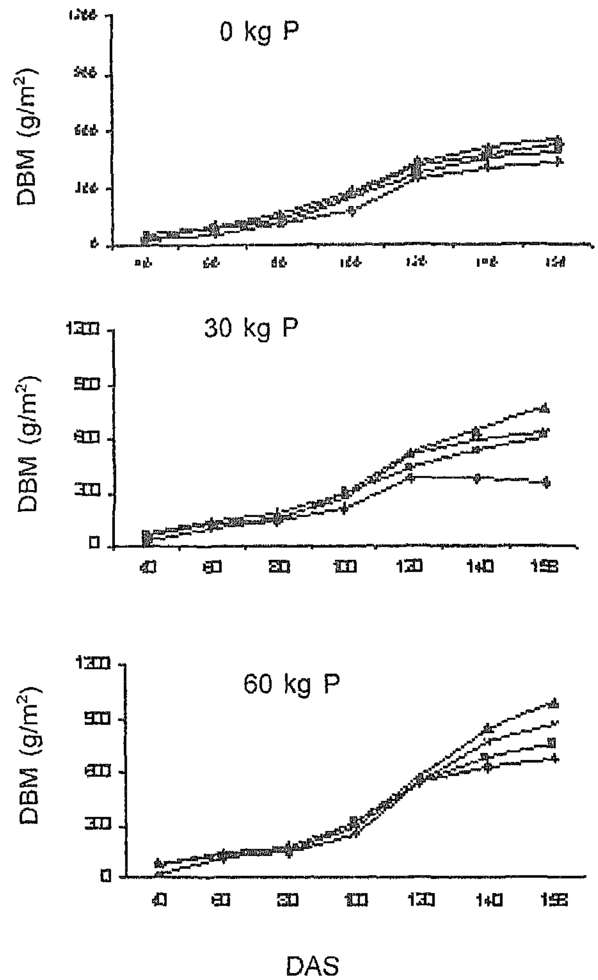

Fig. 3. Development of dry biomass (DBM) of chickpea during the crop growth

Table 2. *Grain yield of chickpea under different moisture conservation practices (M) and phosphorus levels (P)*

Treatments	Control	Bunding	Bunding with FYM	Gm	Mean
0 kg P	11.20	12.74	13.97	13.90	**12.95**
30 kg P	14.91	17.21	15.57	18.60	**16.57**
60 kg P	18.13	24.98	25.69	24.40	**23.30**
Mean	**14.75**	**18.31**	**18.41**	**18.97**	

Treatments	SE m ±	CD at 5 %
M	0.45	1.75
P	0.39	1.52
M*P	0.77	3.03

Among all the moisture conservation practices, bunding with FYM had higher final dry biomass than other treatments. The average grain yield of the crop under different moisture conservation practices and phosphorus levels are given in Table 2. The grain yields under different treatments were significantly higher than the control.

Soil moisture conservation practice and applied phosphorus levels increased growth in terms of higher LAI, biomass and final yield. Rainfall events occurred during the month of January (65.1 mm) nullified the effect of moisture conservation practices and substantial addition of LAI and dry biomass was observed afterwards. Moisture conservation practices were helpful to increase the moisture use efficiency and productivity of chickpea under dry conditions (Lal *et al.* 1996). In this study, moisture conservation practices with 60 kg P/ha increased the yield (Sanoboir and Sarawgi, 1998; Singh, 1995; Gautam and Kumar, 1992). P treatment alone also increased yield significantly (Saraf *et al.* 1997; Singh, 1995).

Spectral indices (IR/R and NDVI) and their relationship with plant growth parameters

The temporal variation of the IR/R and NDVI for all treatments are given in Fig. 4 and 5, respectively. Irrespective of treatments, IR/R and NDVI increased with advance in crop growth except a decrease of the index around 90 days after sowing (DAS) due to severe lodging of the crop after a severe rain (70 DAS). The observations were taken a few days after a heavy rain, on partially recovered crop. The maximum IR/R and NDVI were observed around 120 DAS. Bunding with FYM tended to show higher values of IR/R than in other treatments in 0 kg and 30 kg P application. However, the differences between main treatments were less with 60 kg P application. NDVI showed the same trends.

The increase in spectral indices was due to increase in green vegetation and difference in indices was due to leaf area development (Tucker *et al.*, 1981; Mahey *et al.*, 1991), which is determined by the water and nutrient supply. The red reflectance decreased more rapidly with advance in growth due to increase in LAI, which implied more photosynthesis, biomass production and yield. During the crop growth period, high rainfall occurred (70 DAS) which completely lodged crop and spectral indices dropped to very low values due to more soil exposure. After 120 DAS of crop growth, the red reflectance increased due to senescence of the crop.

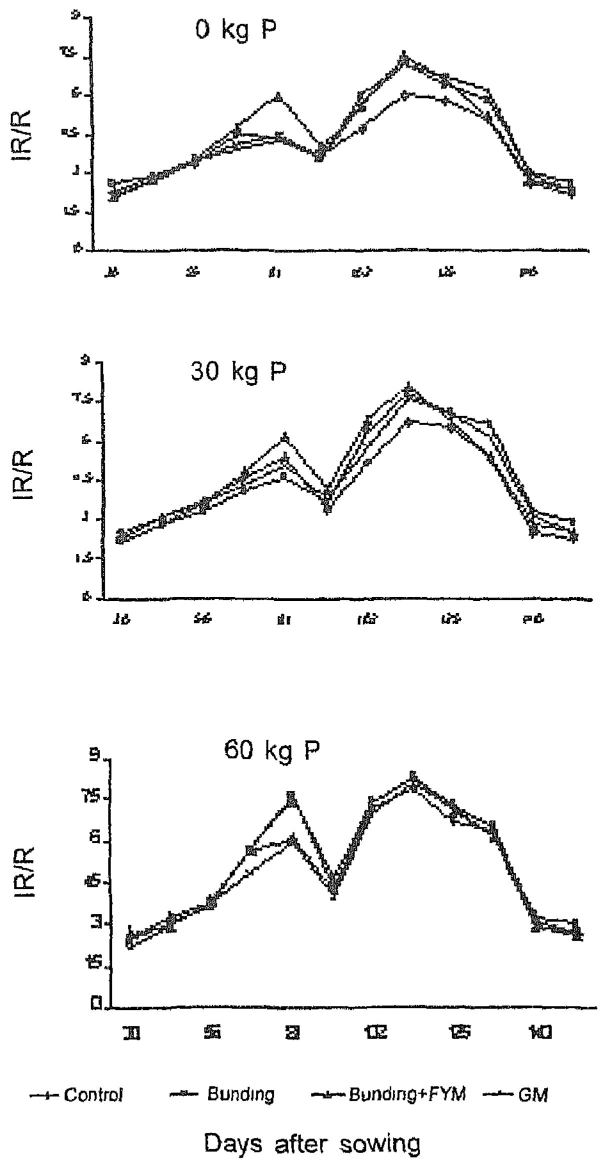

Fig. 4. IR/R of chickpea under different moisture conservation practices and phosphorus levels

The maximum values of LAI and final dry biomass gave good correlation with maximum values of IR/R and NDVI as shown in Fig. 6 and 7. It can be seen that IR/R ($r^2 = 0.88$) is better index to predict LAI ($r^2 = 0.73$). However, the maximum value of NDVI ($r^2 = 0.82$) found better to predict final dry biomass. For final yield prediction, average values of IR/R and NDVI during the crop growth period was found to be better than the maximum values (Fig. 8) of these indices.

Many authors in various crops reported the possibility of predicting LAI, biomass and final yield using spectral indices. In this study, we tried to use

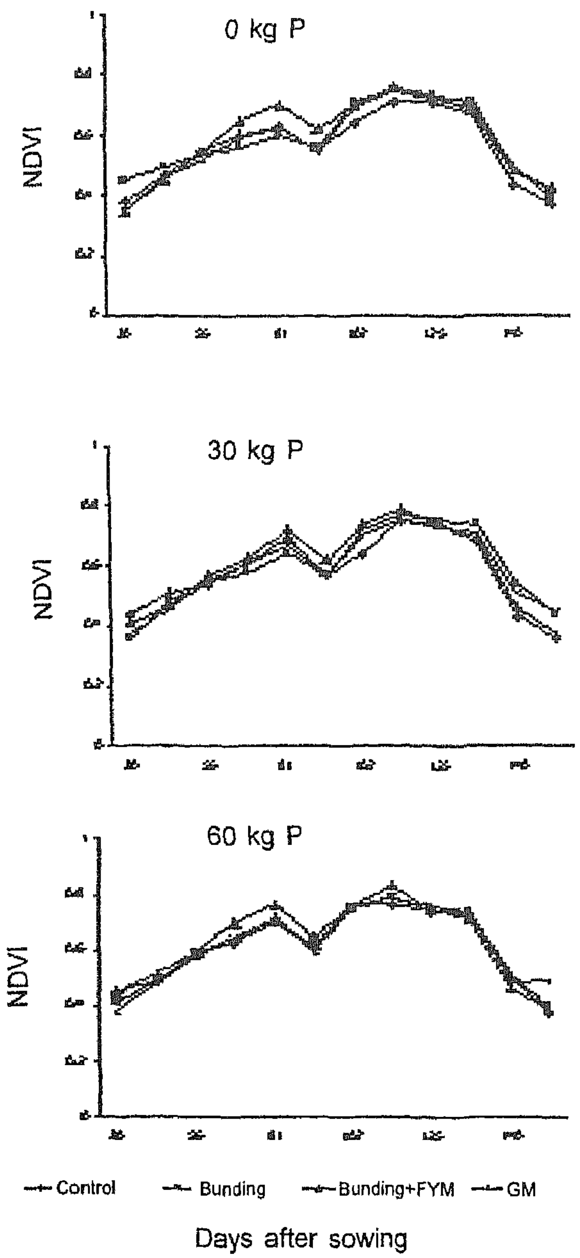

Fig. 5. MDVI of chickpea under different moisture conservation practices and phosphorus levels

average values of temporal measurements and maximum values of IR/R and NDVI to predict the biomass. Maximum value of IR/R was well correlated with maximum LAI. Brakke and Kanemasu (1979) and Ajai *et al.* (1983) reported that both indices were equally useful in prediction of LAI and final biomass. Similarly maximum value of NDVI gave good correlation with final dry biomass produced (Sashikumar *et al.*, 1984). For the prediction of yield, average value of the indices

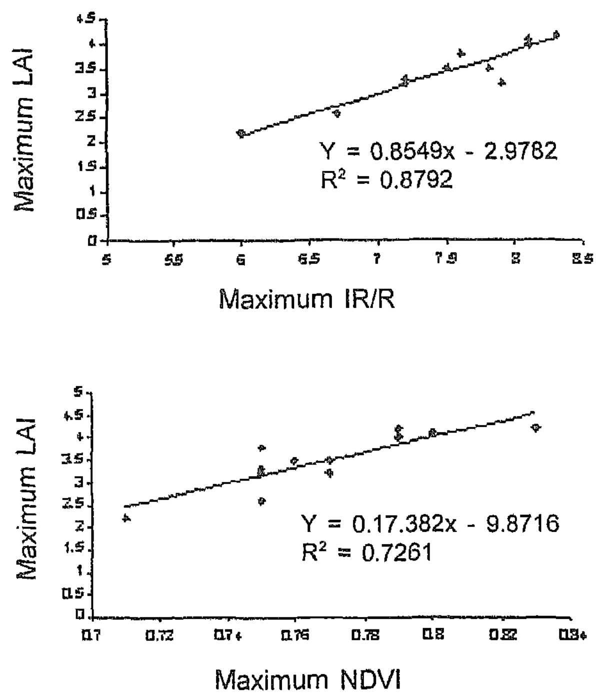

Fig. 6. Relationship between maximum leaf area index (LAI) attained with maximum values of IR/R and NDVI

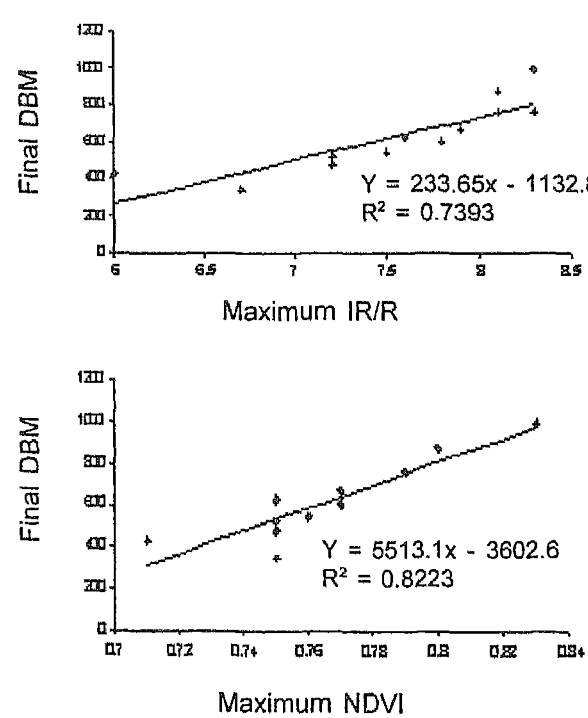

Fig. 7. Relationship between final dry biomass (DBM) with maximum values of IR/R and NDVI

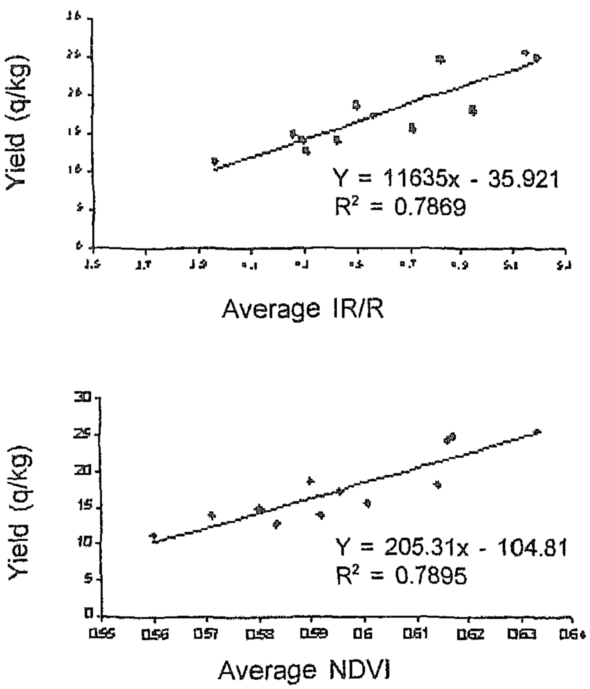

Fig. 8. Relationship between final yield with average values of IR/R and NDVI

during the crop growth period was found to be better than maximum values of these indices (Fig. 7). Possibility of prediction of yield from spectral indices will be very useful to predict yield over large area using satellite images.

Conclusions

This study has shown that all moisture conservation practices with phosphorus produced higher LAI, biomass and yield. IR/R and NDVI gave good prediction of maximum leaf area index and final dry biomass by taking the maximum values of these indices. For the final yield prediction, average value of spectral indices gave better correlation with yield. This study yielded only basic information about spectral signatures under various agronomic practices in field and further studies under controlled conditions are necessary in future.

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