Spectral response of nitrogen fertilization in cotton (*Gossypium* species)

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Abstract

Remote sensing is an effective tool to monitor and assess nutrient stressed crop growth and conditions. A field experiment was conducted on American (*Gossypium hirsutum*) and *Desi* (*G. arboreum*) cotton at Ludhiana, India during *Kharif* 1997-98 to study spectral response and understand relationships between agronomic and spectral parameters of nitrogen fertilized crops. Five nitrogen (N) levels were applied to a Trans-Gangetic alluvial sandy loam soils. Reflectance's data were collected fortnightly interval throughout growth period in red (R) (625 - 689 nm) and near infrared (NIR) (760-897 nm) wave band from a hand held multiband ground truth radiometer (GTR 12-0.4). In no N fertilization, highest and lowest reflectance percentages were observed in R and NIR, respectively and vise versa in highest N fertilized crop. Both spectral indices i.e., radiance ratio (RR) and normalized difference vegetation index (NDVI) were lowest under no N and highest in 160 Kg N. The maximum differences and peak in spectral reflectances and indices of different N level crop were observed during 95-125 days after sowing for both cotton species. This stage coincided with the initiation to 25% of boll opening in *G. hirsutum* and 50% boll formation to initiation of boll opening in *G. arboreum*. The plant height, total and partitioned dry biomass were highly correlated with NDVI than RR, and leaf area index (LAI) and chlorophyll content with RR than NDVI. Hence crop N conditions can be assessed from the percent reflectance and spectral indices (RR and NDVI) and the agronomic parameters can be estimated by the spectral indices.

Key words

reflectance, vegetation indices, nitrogen, cotton

Introduction

Detection of nutrient especially N of crops are basic pre-requisites for timely remedial measures to improve crop productivity. N deficiency in plant leads to reduction of LAI (Van Delden, 2001), chlorophyll content (Moorby and Besford 1983), dry mass and ultimately reduction in yield (Reeves *et al* 1993). The researchers reported the spectral discrimination of N treatments at different crops in many countries (Stanhill *et al* 1972 in Israel, Walburg *et al* 1982 and Hinzman *et al* 1986 in USA, Clevers 1986 in Netherlands, Kleman and Fagerlund 1987 in Sweden, Patel *et al* 1985, Mahey *et al* 1989 and Mahey *et al* 1990 in India, Boese 1994 in Germany, Fernandez *et al* 1994 in Spain, Shen *et al* 2001 in China, etc). As cotton is recognized a 'white gold' plays a dominant role in world agriculture and industrial economy. Few researches were investigated in cotton in respect of nitrogen assessment with remote sensing (Hattey *et al* 1994, Saranga *et al* 1998, Tarpley *et al* 2000 and Read *et al* 2002) and there were lack of studies to relate to spectral indices with agronomic parameters. Thus, there was a need to investigate the spectral response and understand the relationships between agronomic and spectral parameters in different levels of nitrogen fertilized cotton crops during crop growth period.

Methods

Site and treatments

A field experiment was conducted on cotton (*Gossypium species)* during *Kharif* season of 1997-98 at Punjab Agricultural University, Ludhiana, India situated at latitude of 30? 54' N and longitude of 75? 49' E at a height of 247 meters above the mean sea level. Crop was grown in sixty 10.0 m x 4.5 m test plots laid out in a split-plot design with two sowing dates (normal and late sowing) and two cotton species {American cotton; *G. hirsutum* (cv. F 846) and *Desi* cotton; *G. arboreum* (cv LD 327)} as the main treatments and five nitrogen fertilizer application rate (0, 40, 80, 120 and 160 Kg N /ha) as the sub-treatment. These treatments were applied to a Trans-Gangetic alluvial sandy loam soils having a neutral pH, low available N (140.8 Kg N/ha), medium phosphorus and high potassium content.

Spectral and biometrical data

The reflectance data were taken between 0930 and 1300 hours from red (R) (625 - 689 nm) and near infrared (NIR) (760-897 nm) band from a hand held multiband ground truth radiometer (GTR 12-0.4) manufactured by Optomech Engineers Private Limited, Hyderabad, India. Six to eight measurements were made on each plot measuring 10.0 m x 4.5 m with radiometer elevated 1 m vertically above the top of crop canopy surface, throughout the growth cycle of the crop at fortnightly interval. Immediately after each spectral measurement on a given plot - a solar intensity calibration reading was taken from a white standard with $BaSO_4$ coated reference panel board. The data were collected in direct sunlight in cloudless sky. The per cent reflectances (% R and % NIR) and spectral indices (radiance ratio, RR and normalized difference vegetation index, NDVI) were calculated from the canopy reflectance and $BaSO_4$ board data. The per cent R reflectance (% R) values were calculated by dividing the canopy reflectance values at R band with that of the corresponding standard values taken from a $BaSO_4$ board. Similarly, the per cent NIR reflectance (% NIR) values were calculated by dividing the canopy reflectance values at NIR band with that of corresponding standard values taken from a $BaSO_4$ board. The RR was calculated by dividing the canopy reflectance of NIR band with that of R band i.e., NIR/R. The NDVI was calculated as the difference between reflectance of NIR band and R band divided by the sum of these two bands viz., (NIR-R)/(NIR+R). The biometrical observations were recorded concurrently (except with chlorophyll content) with all dates spectral data.

Results and discussions

The highest and lowest reflectance percentages are observed in R and NIR band, respectively in no N fertilization and vice- versa in highest N fertilized crop (Fig.1). These results were supported by the work of Stanhill *et al* (1972). RR and NDVI are lowest under no N and highest at 160 Kg N fertilizations (Fig.2). Rao *et al* (1997) also reported similar results. The maximum differences and peak in spectral indices are observed during 95-125 days after sowing (Fig 2). This stage coincided with the initiation to 25% of boll opening in *G. hirsutum* and 50% boll formation to initiation of boll opening in *G. arboreum* (Ansari 1999).

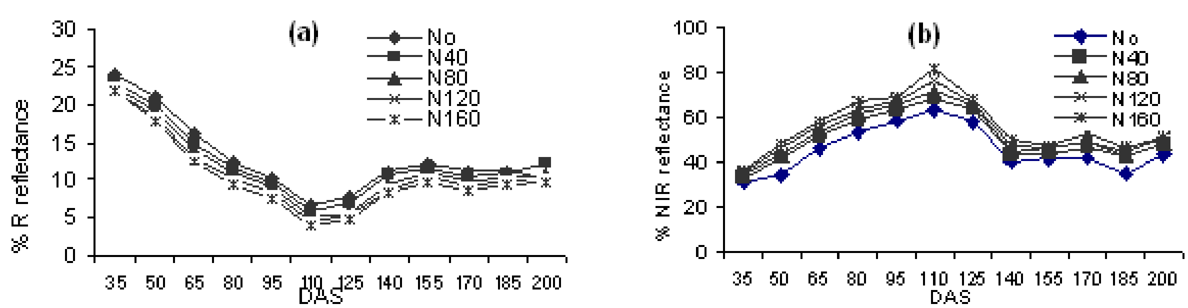

Fig.1. Effect of nitrogen levels on (a) red and (b) near infrared reflectance

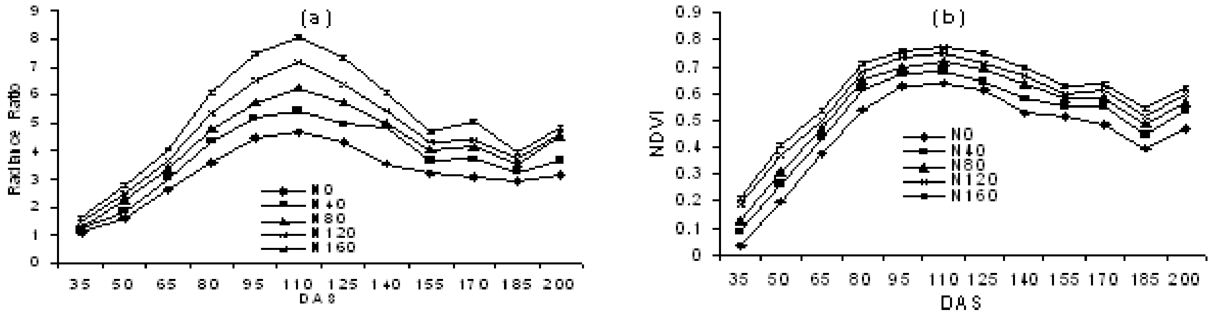

Fig.2. Effect of nitrogen levels on (a) radiance ratio and (b) NDVI

The LAI, plant height, total, stem and leaf dry biomasses are found highly significantly correlated with both RR and NDVI to all N levels for both cotton species (Table 1). Reproductive dry biomass and chlorophyll are not highly correlated with all N levels. N availabilities were an important determinant of crop productivity (Van Keulen *et al* 1989). Moreover, N stress can also cause qualitative depreciation of crops (Akiyama *et al* 1996). The regression analysis showed that in general, NDVI was more correlated than RR with agronomic parameters like plant height; total, stem, leaf and reproductive dry matter in both cotton species and N fertilization levels whereas RR was more correlated than NDVI with LAI and chlorophyll content. The chlorophyll content is highly significantly negatively correlated with RR than NDVI at 0 and 40 kg N/ha treatments in *G. hirsutum* but not with *G. arboreum* cotton. That implies that chlorophyll concentration can be estimated in N deficient crop.

Table 1. The correlation (r) between crop parameters and spectral indices affected by nitrogen fertilization (significant at α = 0.01)

N levels (kg/ha)	LAI		Plant height		Total dry wt.		Stem dry wt.		Leaf dry wt.		Reproductive dry wt.		Chlorophyll content?	
	RR	NDVI	RR	NDVI	RR	NDVI	RR	NDVI	RR	NDVI	RR	NDVI	RR	NDVI
							American cotton (*G. hirsutum*)							
0	.73	.77	.40*	.68	.47*	.63	.40*	.59	.68	.66	.15a	.38*	-.66	-.64*
40	.83	.76	.51	.66	.49*	.64	.44*	.59	.62	.74	.23a	.36a	-.69	-.67
80	.82	.74	.51	.65	.48*	.62	.48*	.60	.57	.69	.26a	.39*	-.47*	-.38a
120	.83	.74	.53	.66	.54	.68	.50	.62	.64	.76	.23a	.35a	-.60*	-.59*
160	.81	.72	.51	.68	.58	.73	.51	.65	.64	.76	.18a	.34a	-.40a	-.47*
mean	.82	.75	.50	.67	.54	.64	.51	.63	.64	.73	.18a	.34a	.20ab	.20ab

						***Desi* cotton (*G. arboreum*)**								
0	.68	.63	.77	.81	.72	.79	.64	.71	.73	.75	.42*	.46*	-.33a	-.28a
40	.69	.66	.75	.83	.67	.78	.64	.74	.58	.76	.51	.50	-.11a	-.04a
80	.76	.68	.81	.84	.75	.81	.69	.76	.68	.72	.26a	.27a	-.01a	-.05a
120	.78	.68	.74	.81	.74	.83	.65	.77	.66	.73	.52	.52	-.18a	.01a
160	.78	.69	.67	.76	.74	.83	.66	.77	.69	.74	.46*	.46*	-.21a	-.14a
mean	.77	.68	.72	.80	.73	.81	.68	.76	.68	.74	.25a	.27a	.16ab	.24ab
						American+*Desi* cotton								
mean	.69	.66	.66	.75	.61	.73	.59	.69	.57	.68	.22a	.27a	.30ac	.34ac

* denotes significant at α = 0.05
a denotes not significant at either α = 0.05 or α = 0.01
n = 22 (n for mean is 110 for American and *desi* cotton, 220 for both as together)
? n = 12
n at b = 60 and n at c = 120

Conclusions

Thus, the crop N conditions can be assessed from the per cent reflectance (%R and %NIR) and spectral indices (RR and NDVI) during the crop growth periods. The strong relationship between agronomic parameters and vegetation indices shows that the agronomic parameters can be estimated by the spectral indices with respect of nitrogen treatment.

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