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RELATIONSHIP OF WHEAT GRAIN YIELD WITH SPECTRAL INDICES

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ABSTRACT

The field experiments were carried out during *rabi* seasons of 2013-14 and 2014-15 at the Research Farm, School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana to study the relationship of various spectral vegetation indices with grain yield of wheat. The various spectral indices such as NDVI, DVI, RVI, GI and GNDVI were studied and their relationship with grain yield was evaluated. The stepwise regression analysis revealed a strong linear and positive one to one relationship of grain yield with spectral vegetation indices. NDVI was found to be the best index to explain the yield variability. It was observed that model fitted with NDVI, GI and yield reflected the highest predictability in grain yield. The NDVI was the best index for yield estimation in 2013-14 (R_2 = 0.73) and 2014-15 (R_2 = 0.79). The best fitted model with NDVI, GI and yield reflected the predictability up to 83 per cent in 2013-14 and 84 per cent in 2014-15.

INTRODUCTION

Crop performance and yield largely depend on environmental interaction. So, the knowledge of how environment influences crop growth, development and yield, is of great importance (Fitter and Hay, 2002). Growth and development of wheat is adversely affected by environmental stresses like high temperature (Kasana *et al.,* 2015 and Nishio *et al.,* 2013), soil moisture deficit, nutrient stress (Li *et al.,* 2013), low light intensity, *etc.* It becomes imperative to develop suitable production practices for obtaining higher yield under stress conditions. In the effort of developing sustainable production strategies, remote sensing has been commonly considered as an effective technique for comparing the yield of wheat under stress conditions where these are detected on the basis of variations in the plant canopy spectral response (Daughtry *et al.*, 2000). Since reflectance of crops and soils differs in the visual and near infrared wavelengths under stressed as well as unstressed conditions. Jones (2009) also showed that the use of thermal remote sensing, especially when combined with spectral reflectance or even fluorescence measurement, is becoming a powerful and increasingly-used tool to diagnose and monitor the effects of heat and moisture stress on plants.

Crop identification and prediction of yield are the major concerns of remote sensing application in agriculture. Crop canopies are dynamic entities influenced by many management practices including cuitivars, seeding rate, soil moisture, fertilizers and disease, *etc.* in addition to architecture of the crop (Rao *et al* .,1997). The knowledge of these factors is required for monitoring crop growth and evaluating productivity. There is potential for using reflection measurements in different wavelengths to distinguish yield differences in wheat crop under different stresses. In the view of this, the present study is an attempt to evaluate the relationship of grain yield of wheat with spectral vegetation indices and choose best model which explain the yield variability.

MATERIALS METHODS

A factorial experiment was laid out in split- split plot design at the Research farm of School of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana having three temperature regimes (D_1 = October 30, D_2 = November 15 and D_3 = November 30) in main plot, three nitrogen levels N_1 = RDF (Recommended dose of N), N_2 = 125% RDF (25% more than recommended N), N_3 = 150% RDF (50% more than recommended N) in sub plot and four post- anthesis strategies (P_0 = Control, P_1 = Water sprayed, P_2 = Foliar spray of $ZnSO_4.7H_2O$ (0.5%), P_3 = Thiourea (10 mM) at anthesis and 20 days after anthesis in sub-sub plot during both years.

Multiband spectral data was recorded with the help of multiband ground truth radiometer (Model-41) developed by Space Application Centre (SAC) Ahmedabad. The spectral reflectance were measured in four spectral bands viz., MSS_4 (0.44 to 0.50 m); MSS_5 (0.52 to 0.58 m), MSS_6 (0.62 to 0.69 m) and MSS_7 (0.77 to 0.81 m). The spectral reflectance were recorded at one meter height above the canopy. Standard readings (100 percent reflectance) were taken keeping the sensor over Barium Sulphate plate. Percent reflectance values were computed by dividing canopy reflectance with that of standard one. These observations were taken at 30 days intervals on cloud free days between 1000-1200 hrs. throughout the growing season. Various vegetation indices have been developed to reduce the multiband observations to a single number with combination of reflectance parameters (Kauth and Thomas 1976) (Table 1).

RESULTS AND DISCUSSION

Spectral vegetation indices

A critical examination of the spectral vegetation indices viz. NDVI, DVI, RVI, GNDVI and GI under different temperature regimes, nitrogen levels and post anthesis strategies at maximum leaf area stage indicates that mean values of these indices varied significantly under different levels of stresses (Table 2). The October 30 sowing depicted higher value of these vegetation indices followed by November 15 and November 30 sowing during both the years, because with delay in sowing of the crop, duration of different phenophases decreased and late sown crop also experienced high temperature during later stages, due to which, crop experienced stress which lowered the value of spectral vegetation indices. Among the nitrogen levels, 150% RDF have higher values of these indices as compared to 125% RDF and RDF during both the years due to the availability of better nutrition to crop Among the post anthesis strategies, the crop sprayed with $ZnSO_4.7H_20$ (0.5%), Thiourea and water at anthesis and at regular intervals had higher value of these indices because these stress alleviating chemicals helped the crop to avoid the impact of high temperature during both years and resulted in better crop health.

Grain yield

The highest grain yield was recorded in October 30 sowing,

Table 1: Different spectral indices computed using spectral reflectance of wheat

Sr No.	Vegetation Indices	Abbreviations	Formula	References
1	Normalized difference vegetation index	NDVI	NIR-R/NIR+R	Rouse *et al.* (1974)
2	Difference vegetation index	DVI	NIR-R	Tucker (1979)
3	Ratio vegetation index or Simple ratio	RVI	NIR/R	Jordan (1969)
4	Green normalized difference vegetation index	GNDVI	NIR-G/NIR+G	Gitelson *et al.* (1996)
5	Greenness index	GI	G/R	Zarco-Tejada *et al.* (1999)

Table 2: Spectral Indices at maximum LAI (90 DAS) and grain yield of wheat under different temperature regimes, nitrogen levels and post anthesis strategies during 2013-14 and 2014-15

Treatment	NDVI		GNDVI		RVI		DVI		GI		Grain yield (q/ha)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Temperature regimes												
30-Oct	0.59	0.76	0.40	0.58	6.10	6.90	62.0	65.5	7.60	8.57	47.33	50.12
15-Nov	0.52	0.68	0.32	0.51	5.40	6.40	54.9	55.0	7.32	8.29	43.77	45.55
30-Nov	0.47	0.63	0.27	0.46	4.80	5.70	49.6	48.0	7.11	8.07	39.61	42.39
CD (p=0.05)	0.03	0.01	0.03	0.01	0.30	0.10	3.20	0.9	0.24	0.21	4.06	4.12
Nitrogen levels												
RDF	0.45	0.63	0.28	0.46	4.90	5.80	49.1	50.3	7.12	8.08	41.4	43.62
125% RDF	0.53	0.69	0.33	0.52	5.50	6.50	55.3	57.8	7.33	8.31	43.58	46.81
150% RDF	0.61	0.78	0.41	0.60	6.20	7.00	64.1	68.2	7.63	8.60	45.73	47.63
CD (p=0.05)	0.02	0.03	0.02	0.02	0.10	0.20	1.50	1.6	0.13	0.16	2.11	2.69
Post- anthesis strategies												
Control	0.52	0.71	0.32	0.52	5.50	6.40	55.4	55.6	7.34	8.34	42.12	45.31
Water sprayed	0.52	0.70	0.33	0.50	5.40	6.40	55.0	55.2	7.32	8.32	42.25	45.44
$ZnSO_4.7H_2O$ (0.5%)	0.53	0.69	0.32	0.52	5.40	6.30	55.1	57.1	7.37	8.37	44.13	47.46
Thiourea (10mM)	0.53	0.69	0.34	0.51	5.50	6.30	56.6	56.7	7.35	8.35	43.78	46.77
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 3: Stepwise regression models between spectral vegetation indices and grain yield of wheat during *rabi* 2013-14

Spectral vegetation indices	Equation	R^2
NDVI, GI	Y= 22.87+26.09 NDVI+ 2.54 GI	0.83
NDVI, GNDVI	Y=26.30+55.21NDVI-8.91GNDVI	0.80
NDVI, GI, GNDVI	Y=23.39+45.23 NDVI+2.79 GI-12.53 GNDVI	0.80
NDVI,RVI, GI	Y=22.68+52.71 NDVI- 2.11 RVI+2.95 GI	0.79
NDVI,DVI, GNDVI	Y=26.61+58.24 NDVI-0.08 DVI- 4.36 GNDVI	0.78
NDVI, RVI, GI, GNDVI	Y=22.61+54.39 NDVI-1.81 RVI+3.03 GI- 7.34 GNDVI	0.75
NDVI, RVI	Y= 25.88+61.64 NDVI-1.59 RVI	0.72

Where Y= Grain yield (q/ha)

Table 4: Stepwise regression models between different spectral vegetation indices and grain yield of wheat during *rabi* 2014-15

Spectral vegetation indices	Equation	R^2
NDVI, GI	Y=22.40+27.92 NDVI+5.01 GI	0.84
NDVI, GNDVI	Y=29.69+67.48 NDVI-25.03 GNDVI	0.83
NDVI, RVI, GI	Y=28.16+89.11 NDVI-8.29 RVI+4.66 GI	0.83
NDVI, RVI, GI, GNDVI	Y=27.36+89.77 NDVI-7.64 RVI+ 4.76 GI-7.07 GNDVI	0.83
NDVI, GI, GNDVI	Y=20.59+55.40 NDVI+5.40 GI-35.78 GNDVI	0.82
NDVI, RVI	Y=36.24+113.27 NDVI-9.15 RVI	0.81
NDVI, DVI, GNDVI	Y=30.33+71.79 NDVI- 0.10 DVI- 20.60 GNDVI	0.80

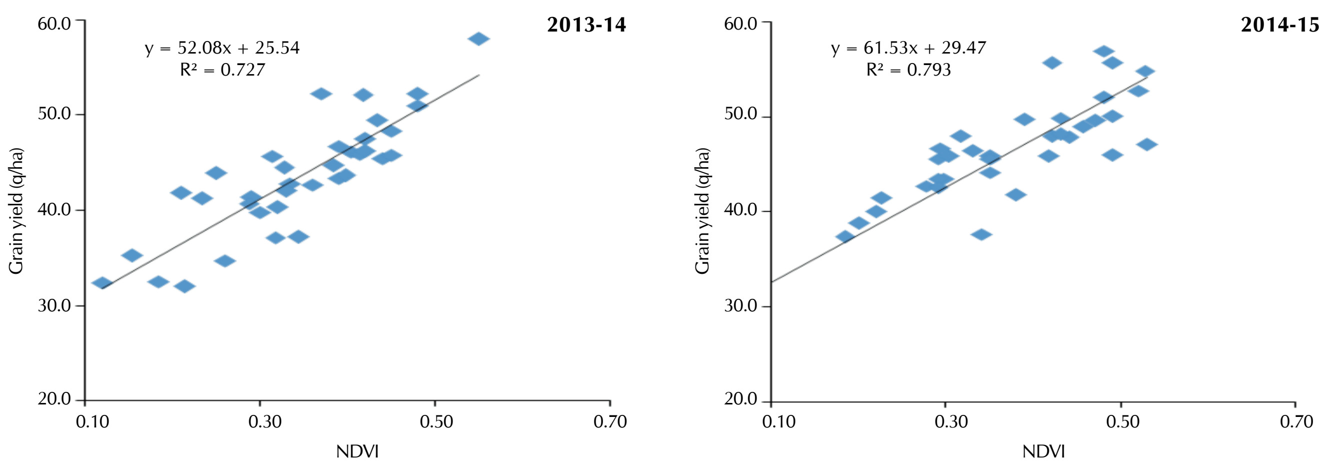

Figure 1. Relationship between grain yield and NDVI of wheat during *rabi* 2013-14 and 2014-15

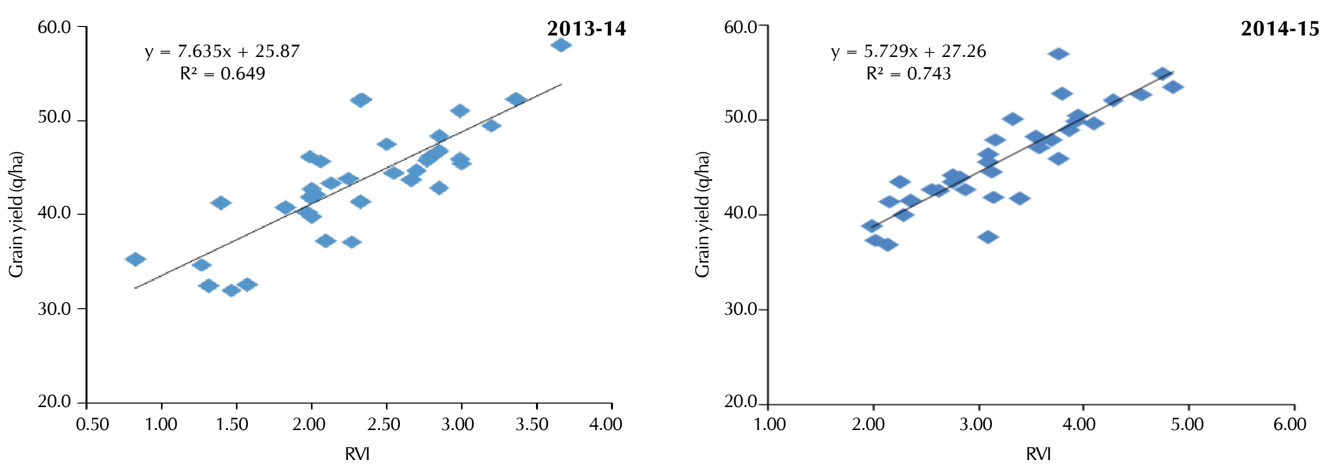

Figure 2: Relationship between grain yield and RVI of wheat during *rabi* 2013-14 and 2014-15

which was significantly better than November 15 and November 30 sowing date during both the years (Table 2) The highest grain yield in October 30 might be due to higher dry matter accumulation, highest tillers production, highest effective tillers, ear length, number of grains per ear and 1000 grain weight. The higher grain yield in early sowing (October 30) was also due to longer duration of different phenophases as compared to November 15 and November 30 sowing dates. Pankaj *et al.* (2015) also revealed that the crop sown on 16th October took more number of days from sowing to heading than other dates of sowing, thus it availed longest vegetative phase. Similar results were also reported by Hedge and Bhatia (1993), Kaur and Pannu (2008) and Meena *et al.* (2015).

Among nitrogen levels, 150% RDF recorded significantly higher grain yield (45.73 q/ha) than 125% RDF (43.58 q/ha) and RDF (41.40 q/ha) during 2013-14, whereas during 2014-15, the grain yield recorded in 150% RDF (47.63 q/ha) was statistically at par with 125% RDF (46.81 q/ha) but it was significantly higher than RDF (43.62 q/ha). Sharma (2015) also revealed that application of 50% NPK + 50% FYM registered higher crop yield (32.61 q ha^{-1}) relative to control. Similar results were also reported by Ali *et al.* (2003) and Meena *et al.* (2013).

Among post anthesis strategies, although yield differences was non-significant, however $ZnSO_4.7H_2O$ (0.5%) and Thiourea (10 mM) recorded higher grain yield as compared to that in

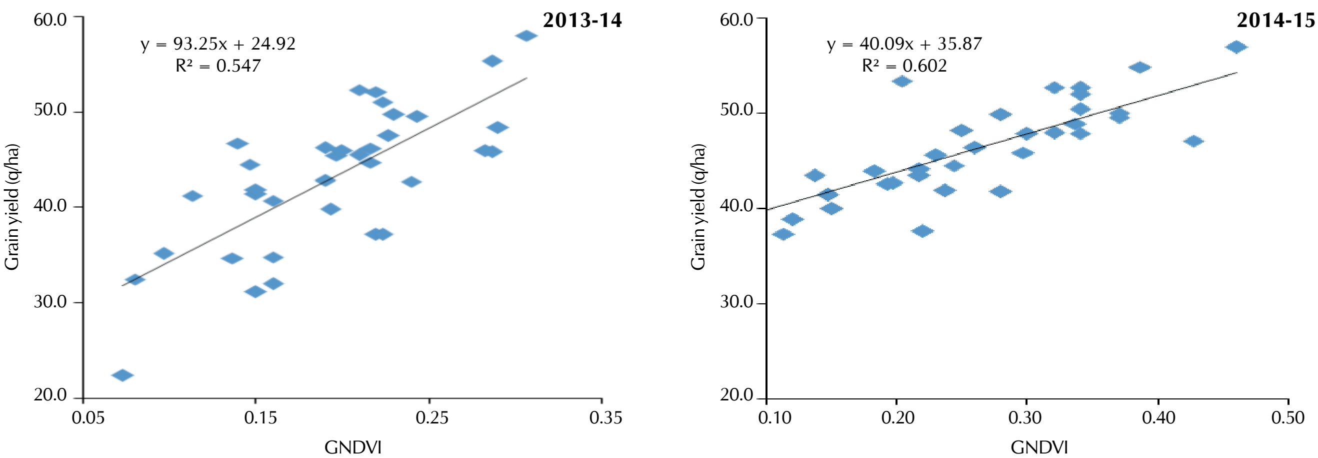

Figure 3: Relationship between grain yield and GNDVI of wheat during *rabi* 2013-14 and 2014-15

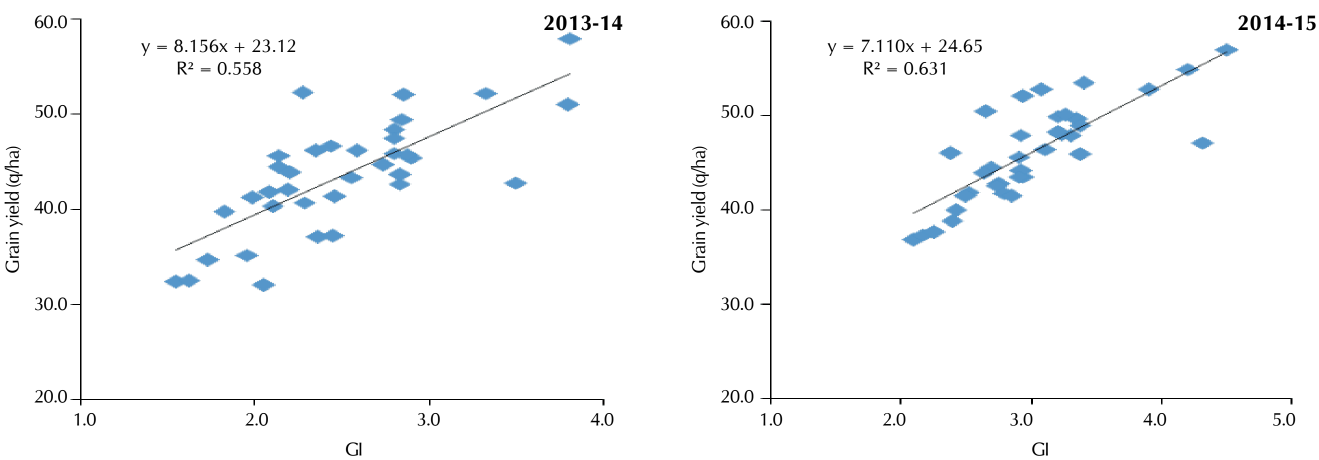

Figure 4: Relationship between grain yield and GI of wheat during *rabi* 2013-14 and 2014-15

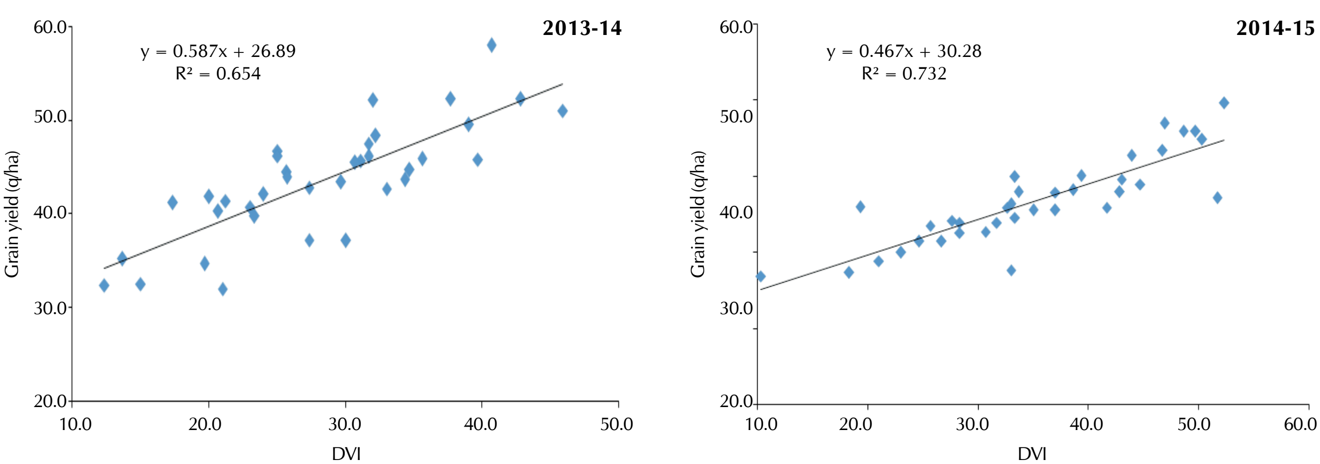

Figure 5: Relationship between grain yield and DVI of wheat during *rabi* 2013-14 and 2014-15

control plots, which might be due to higher 1000 grain weight and longer duration of reproductive growth period. Similar results were also reported by Das and Sarkar (1981).

Relationship of spectral vegetation indices with grain yield

Significant linear relationship was observed between grain yield and vegetation indices. Linear regression relationship between grain yield and NDVI explained about 72.7% and 79.3% yield variability (Fig. 1), RVI of 64.9% and 74.3% (Fig. 2), GNDVI about 54.7% and 60.2% (Fig. 3), GI about 55.8% and 63.1% (Fig. 4) and DVI explained 65.4% and 73.2% (Fig.

5) variability in grain yield during *rabi* 2013-14 and 2014-15 respectively.

Among different vegetation indices, NDVI and RVI depicted a strong relationship with yield, so prediction of grain yield of wheat was found to be more accurate by using NDVI and RVI during both the years. Singh *et al*. (2001) also revealed the relationship of spectral indices with grain yield of wheat. Spectral indices were correlated with crop parameters and they observed GI as the best index for yield estimation. Similar results have also been found by Das *et al*. (1990) and Mahey *et al*. (1991) for wheat crop.

Stepwise regression analysis

Stepwise regression analysis is a procedure wherein the predictors are entered and removed in a stepwise manner until there is no justifiable reason to enter or remove variable further. It is attempted when there is a large set of predictor variables. Goal is to choose a small subset from the larger set so that the resulting regression model is simple and yet have good predictive ability. The stepwise regression analysis attempted between grain yield and spectral vegetation indices has been presented in the Table 3 for *rabi* 2013-14 and Table 4 for *rabi* 2014-15. The attempt has been made to find out the potential predictor for wheat grain yield by using the spectral reflectance. It was observed that model fitted with NDVI, GI and yield reflected the predictability up to 83 per cent for *rabi* 2013-14 and 84 per cent for 2014-15. The significant values of coefficient of determination indicate that such models can be used effectively for estimating wheat grain yield from spectral vegetation indices.

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