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CORRELATING SPECTRAL REFLECTANCE INDICES WITH LEAF AREA INDEX IN PEARL MILLET (*PENNISETUM GLAUCUM* L.) CROP UNDER ROW ORIENTATIONS

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SUMMARY

Pearl millet (*Pennisetum glaucum* L.) is a crucial cereal crop, particularly in arid and semi-arid regions, serving as a staple food source and livestock forage. This study investigates the quantitative relationship between spectral reflectance indices and LAI under NS and EW row orientations. The field experiment was carried out at the Research Farm of CCS Haryana Agricultural University, Hisar, Haryana during *kharif* season, 2022 with three cultivars, namely HHB 299, HC 20 Composite, and HHB 67 Improved sown in NS and EW row orientations. The results suggested that all three spectral reflectance indices, SR, NDVI and TVI can be used to predict LAI in pearl millet crop both under NS as well as EW row orientations with 95 percent confidence level as is evident from the r^2 values; highlighting the potential of remote sensing for crop health assessment.

Key words: Pearl millet, spectral reflectance indices, LAI, row orientations

Pearl millet (*Pennisetum glaucum* L.) stands as a resilient and vital cereal crop, deeply ingrained in the agricultural landscapes of arid and semi-arid regions across the globe. As a staple food source for millions and a valuable forage crop for livestock, its significance in ensuring food security and sustainable agriculture cannot be overstated. In this context, the ability to comprehensively assess the health and growth dynamics of pearl millet emerges as a critical imperative for crop management, resource allocation, and informed decision-making among farmers and agricultural stakeholders.

Conventional assessments of agronomic parameters like biomass and LAI are labour-intensive and expensive, whereas the evaluation of spectral reflectance indices is rapid, non-invasive, and conducive to large-scale implementation. (Eitel *et al.*, 2008). These indices were developed to assess vegetation health, canopy cover, phenological stages, and related processes, as well as to support applications such as land cover classification, climate and land use monitoring, drought assessment, and tracking habitat loss (Padilla *et al.*, 2011). More recently, these have been defined as mathematical formulas that utilize reflectance values from different regions of the electromagnetic spectrum, designed to enhance information retrieval and standardize measurements across diverse environmental conditions (Mirik *et al.*, 2012). Specifically, these have found application in assessing various physiological characteristics such as leaf area index, measurements of chlorophyll levels, absorbed radiation, biomass production and photosynthetic capability. (Wiegand and Richardson, 1984, 1990; Ajai *et al.*, 1983; Asrar *et al.*, 1984; Hatfield *et al.*, 1985; Gutierrez *et al.*, 2005) Reflectance is often decreased in the NIR and increased in the red (due to chlorophyll degradation) as a result of LAI reduction, which indicates decreased photosynthetic activity. Commonly employed spectral reflectance indices for studying the morpho-physiology of crop plants typically include the SR and NDVI. (Araus *et al.*, 2002).

This research endeavours to explore the intricate relationship between spectral reflectance indices and LAI in pearl millet crops under two row orientation. By correlating these spectral reflectance indices with LAI across various growth stages, we aim to elucidate their potential in enabling precise and timely assessments of crop health.

MATERIALS AND METHODS

Location and climatic conditions

The study was conducted during *Kharif* season of 2022 at the CCS Haryana Agricultural

University's Research Farm in Hisar. The test site is located in the subtropics at longitude 75° 46' E and latitude 29° 10' N, and it is 215.2 meters above mean sea level. During the summer in Hisar, daytime temperatures typically range from 40 to 46 °C. The Southwest Monsoon season, spanning from June to September, contributes significantly to the city's annual precipitation, accounting for about 75 to 80% of the total rainfall. Hisar receives an average annual rainfall of approximately 450 mm.

Experimental details

Field experiment was laid out during *kharif* 2022 at Hisar with three cultivars; HHB 299, HC 20 Composite and HHB 67 improved in two row orientations i.e., North-South (NS) and East-West (EW). The design of the experiment was Factorial Randomized Block Design having four replications with a plot size of 4.5 m X 4.5 m. According to Panse and Sukhatme (1985) description of a factorial randomised block design, the data were statistically analyzed using analysis of variance (ANOVA). The "F-test" was used to determine the significance of treatment effects at a 5% level of significance.

LAI Measurement

The leaf area of each plot was determined at 10-day intervals, starting 20 days after planting. A leaf area meter (specifically, the CI-203 Handheld Laser Leaf Area Meter from Biosciences) was employed to measure the green leaf area in cm^2. The leaf area data obtained with the leaf area meter was then utilized to calculate the leaf area index, employing the formula below.

$$\text{LAI} = \frac{\text{Leaf area (cm}^2\text{)}}{\text{Land area covered by plant (cm}^2\text{)}}$$

Spectral Reflectance Indices

Spectral reflectance indices were recorded at 10-day intervals starting 20 days after sowing using a spectro-radiometer (PSR-1100f field-portable spectro-radiometer, developed by Spectral Evolution, USA). The spectral readings were taken on clear, cloud-free days between 10:00 AM and 12:00 PM. To gather the simple ratio (SR) and normalized difference vegetation index (NDVI), the DARWin SP application software was employed. Additionally, the transformed vegetation index (TVI) was computed using formula mentioned below.

Simple ratio: $\text{SR} = \frac{\text{IR}}{\text{R}}$ (Rouse *et al.*, 1973)

Normalized difference vegetation index:

$\text{NDVI} = \frac{(\text{IR} - \text{R})}{(\text{IR} + \text{R})}$ (Rouse *et al.*, 1973)

Transformed vegetation index:

$\text{TVI} = \sqrt{(\text{NDVI} + 0.5)}$ (Deering *et al.*, 1975)

RESULTS AND DISCUSSION

To explore the influence of crop row orientation on vegetative growth and spectral reflectance in pearl millet, three key figures are presented. Fig. 1 illustrates the variation in LAI under NS and EW row orientations, providing insight into how different planting arrangements affect canopy development. Fig. 2 and Fig. 3 represent pooled spectral reflectance curves for all the three cultivars sown in NS as well as EW row orientations at milking stage.

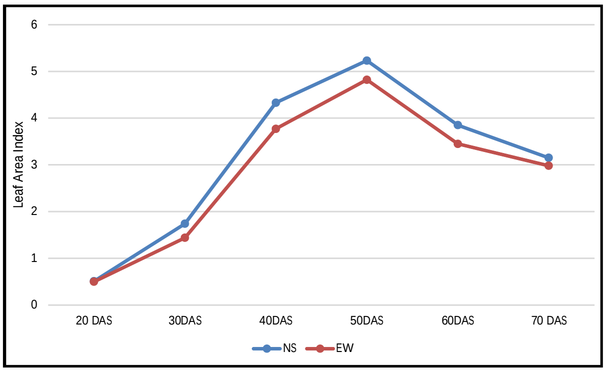

Fig. 1. LAI of pearl millet crop under NS and EW row orientations.

The highest values for SR, NDVI and TVI occurred when LAI was approximately 4.33 in crops planted in the NS row orientation, while in the EW row orientation, the maximum values were observed at an LAI of around 3.77. This difference can be attributed to variations in vegetative growth between the two conditions. Subsequently, following their peak values at around milking stage (50 DAS), both LAI

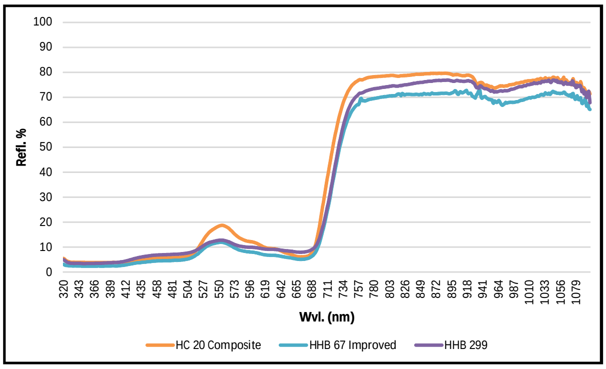

Fig. 2. Spectral reflectance curves of pearl millet cultivars in EW row orientation at milking stage.

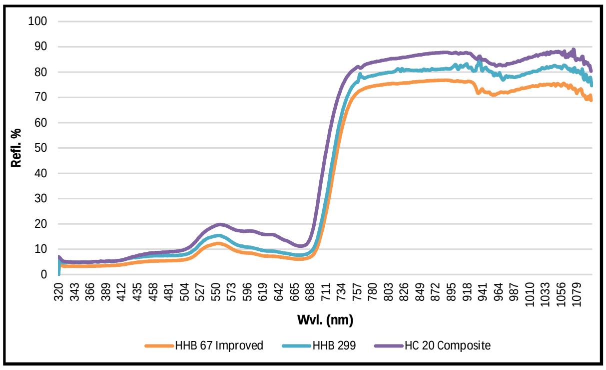

Fig. 3. Spectral reflectance curves of pearl millet cultivars in NS row orientation at milking stage.

and spectral reflectance indices decreased, reaching a minimum at the maturity stage. At this stage, the magnitude of both LAI and spectral reflectance indices was greater in crops with the NS row orientation due to differences in vegetative growth.

While the literature contains numerous findings regarding the correlation between spectral reflectance indices and plant parameters, there is a noticeable absence of research addressing the assessment of leaf area index (LAI) for pearl millet crops planted in a two-row orientation using spectral reflectance indices. To eliminate the need for destructive plant sampling to determine LAI, this study

TABLE 1

Values of r^2 between LAI and spectral reflectance indices in pearl millet crop sown in different row orientations

Cultivars	NS row orientation			EW row orientation		
	SR	NDVI	TVI	SR	NDVI	TVI
HHB 299	0.87	0.77	0.77	0.72	0.79	0.78
HC 20 Composite	0.85	0.92	0.93	0.81	0.90	0.91
HHB 67 Improved	0.83	0.91	0.89	0.87	0.86	0.87

conducts regressions to establish relationships between LAI and spectral reflectance indices for various cultivars planted in different row orientations, as shown in Table 1.

R-squared (r^2) values represents the strength of the linear relationships between LAI and spectral reflectance indices for various pearl millet cultivars grown in both NS and EW row orientations. Specifically, under NS row orientation, the r^2 values for LAI's linear relationship with the spectral indices SR ranged from 0.83 to 0.87 across different cultivars. In the case of NDVI and TVI, the r^2 values varied from 0.77 to 0.93. Conversely, under EW row orientation, the r^2 values were generally lower for all three indices.

But for clarity's sake, regression lines for the pooled data for all the three cultivars sown in NS as well as EW row orientations is presented in Fig. 4, Fig. 5 and Fig. 6.

For the pooled data (Table 2) considering all the cultivars together, the r^2 values under NS as well as EW row orientations were respectively 0.84 and 0.77 for the linear relation between LAI and SR while the corresponding values were 0.86 and 0.76 in case of NDVI as well as TVI.

CONCLUSION

The above results suggest that all three spectral reflectance indices, SR, NDVI and TVI can

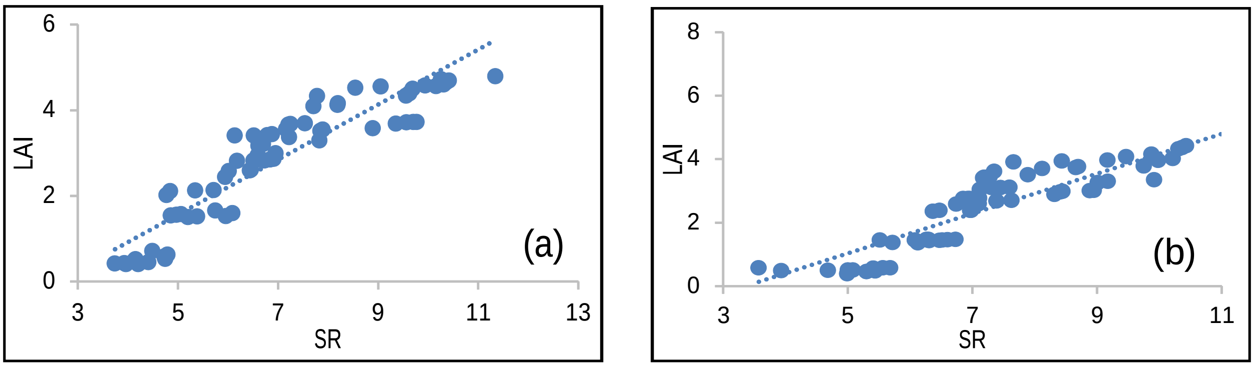

Fig. 4. Relationship between Simple Ratio and Leaf Area Index in pearl millet crop under (a) NS and (b) EW row orientations.

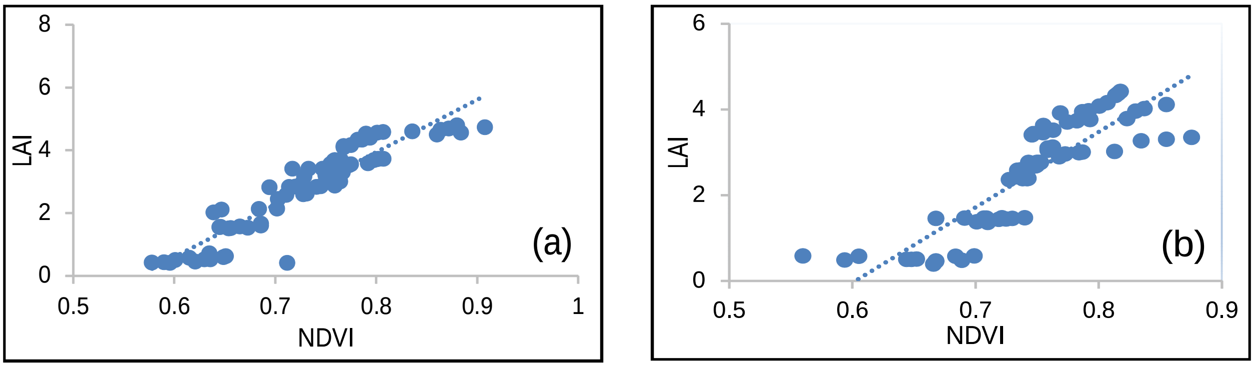

Fig. 5. Relationship between NDVI and Leaf Area Index in pearl millet crop under (a) NS and (b) EW row orientations.

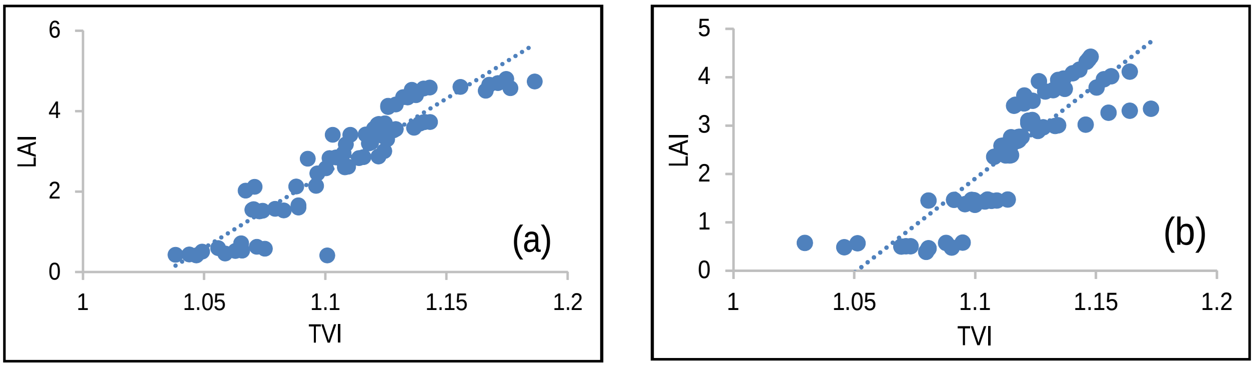

Fig. 6. Relationship between TVI and Leaf Area Index in pearl millet crop under (a) NS and (b) EW row orientations.

TABLE 2

Regression equation between LAI and spectral reflectance indices for the pooled data for all three cultivars of pearl millet crop sown in different row orientations

Row Orientation	Spectral Indices	Regression equation	r^2
North-South	SR	0.64SR - 1.64	0.84
	NDVI	16.70NDVI - 9.42	0.86
	TVI	37.11TVI - 38.37	0.86
East-West	SR	0.62SR - 2.10	0.77
	NDVI	17.58NDVI - 10.59	0.76
	TVI	38.92 TVI - 40.91	0.76

be used to predict LAI in pearl millet crop both under NS as well as EW row orientations with 95 per cent confidence level as is evident from the r^2 values.

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