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Validation of spectral tools to guide need-based nitrogen management strategies in potato

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Abstract

A handheld SPAD meter has demonstrated significant potential as a tool for evaluating nitrogen status in crops; however, its prohibitive cost restricts widespread adoption among farmers. To overcome this financial limitation while preserving the tool's efficacy, the PAU-LCC tool was validated against the SPAD meter, as both instruments operate on analogous principles. This study was conducted in Ludhiana and Naraingarh to examine the applicability of the LCC tool in potato cultivation and to evaluate the strength of its correlation with the SPAD meter, determining whether their relationship exhibited a positive trend or a different pattern. Upon completion of the experiment, the PAU-LCC scores displayed a strong positive correlation with the SPAD meter readings, with correlation coefficients of 0.96 and 0.98, respectively. These findings suggest that the PAU-LCC tool can serve as an effective alternative for nitrogen management in potatoes, enabling the identification and correction of nitrogen deficiencies in the field. In addition, the assessment of superior varieties revealed that PP102 exhibited higher NUE efficiency and accumulated a higher nitrogen concentration at harvest. Data analysis was conducted using Statistical Product and Service Solutions (SPSS), with graphical representation was done using Python programming.

Keywords: PAU-LCC, SPAD meter, precision nutrient management

1. Introduction

Potato (*Solanum tuberosum*) is an important perennial tuber crop of the solanaceae family. India ranks second in potato production (after China). Globally it ranks fourth in terms of area of production after rice, wheat and maize (Muleta and Aga 2019)^[16]. The ability to produce high - quality potential yield per unit input in a shorter crop cycle makes it one of the most useful crops in the areas facing malnutrition due to heavy reliance on cereal crops. Potato being a rich source of starch, carbohydrates, vitamins, potassium etc. has good market value and is getting global importance among the farmers (Nagel *et al.* 2022)^[17]. These quality factors are produced by nitrogen which is the most crucial element to provide to a specific crop due its to huge losses in the environment.

Nitrogen (N) maintains the crop canopy for continuing tuber growth throughout the growing stages. However, nitrogen use efficiency (NUE) in potato rarely exceeds 50% and is of serious concern for the researchers to reduce the footprints of excessive use of N fertilizer in potato which has led to issues such as groundwater contamination (Follet and Walker 1989)^[10] and soil degradation (Jie *et al.* 2002)^[12], prompting a shift towards more balanced and efficient nitrogen management strategies. Blanket N management practice in potato comprises of applying 187.5 kg ha⁻¹ fertilizer N in equal splits at sowing and earthing up (Anonymous 2022)^[2], but it cannot examine fields and temporal variations in N supply from soil throughout the growth period (Varinderpal-Singh *et al.* 2010)^[24]. Potatoes have distinct growth stages with varying nitrogen demands, from initial planting to tuber initiation and bulking stages (Alwa 2004). To minimize the nitrogen losses and increase the NUE at each stage, the farmers usually apply the nitrogen in split doses. This technique of splitting the dose helps for the availability of nitrogen according to the peak demand of the crop throughout its life cycle, promoting optimum growth and tuber development while avoiding the risk of nitrogen leaching into groundwater or runoff into water bodies to much extent. This blanket recommendation holds good for soils containing soil organic carbon (SOC) in a medium range of 0.40 to 0.75% in the surface 0 - 0.15 m soil layer. It is advised to apply more nitrogen fertilizers in soils testing low in SOC.

Managing nitrogen fertilizer application efficiently is crucial for optimizing potato yield and quality while minimizing environmental impacts. One effective method increasingly adopted by farmers is the use of LCC (Leaf Colour Chart) or SPAD (Soil Plant Analysis Development) meters to monitor and guide nitrogen application throughout the crop's growth stages (Duttarganvi *et al.* 2014) [8]. However, the site - specific guidelines are not yet defined for precision N management in potato. In a quest to achieve high tuber production, the farmers generally keep the canopy dark green and finally apply high total N fertilizer to the soil. Excessively applied fertilizer N increase leaching losses (Varinderpal-Singh *et al.* 2021) [26] and greenhouse gases (GHG) emission in the atmosphere (Sapkota *et al.* 2020) [20]. Majumdar *et al.* (2015) [15] estimated emissions equivalent to 100 million tons CO₂ year⁻¹ during production and transport of fertilizers in India that constitutes 17.6% of the total GHG emissions in India.

The researchers widely employed the gadgets like chlorophyll meters, leaf colour charts and canopy sensors for developing real - time N management strategies in field crops (Bijay-Singh *et al.* 2020; Varinderpal-Singh *et al.* 2010, 2012, 2017) [6, 25]. Small holder farmers in developing nations cannot afford chlorophyll meters and canopy reflectance sensors. Thus, the artificial intelligence and farmers' friendly LCC provides a potential solution to mitigate the harmful effects of excessive fertilizer N topdressings at on-farm locations (Bijay-Singh *et al.* 2002; Shukla *et al.* 2004; Varinderpal-Singh *et al.* 2007, 2011; Swarbreck *et al.* 2019) [5, 21, 24, 23]. Thus, this the LCC is widely used in other field crops as an artificial intelligence to provide guidelines for N application and mitigate on-site crop deficiencies (Varinderpal-Singh *et al.* 2011) [24]. Defining threshold leaf greenness is the prerequisite for applying LCC for need-based N topdressings. Threshold leaf greenness for making real - time N topdressing decisions is not yet established for different varieties of potato in India. Hence this study mainly focuses on establishing relation between SPAD meter and LCC to set some recommendations for N management in potato.

2. Material and Methods

2.1 Site and location

The Field experiment was carried out at two different locations firstly at Department of soil science, Punjab Agricultural University (PAU), Ludhiana (30.91°N and 75.85°E) and secondly at University Seed Farm, Naraingarh (30.35°N and 76.15°E) in October 2023. Soil in these locations is well drained sandy loam with mean annual rainfall of 733mm and 757mm respectively. The climate of both the location is sub-tropical and mean monthly temperature varied from 17°C to 32°C, which is ideal for potato cultivation.

2.2 Experiment

The experiment was conducted in split plot design with three replications. Different levels of Nitrogen (T₁-N₀ = control, T₂-N₁ = 62.5kg/ha⁻¹, T₃-N₂ = 125kg/ha⁻¹, T₄-N₃ = 187.5kg/ha⁻¹, T₅-N₄ = 250kg/ha⁻¹, T₆-N₅ = 312.5kg/ha⁻¹, T₇-N₆ = 375kg/ha⁻¹) were assigned in the main plot and corresponding varieties (Punjab Potato 102 and Kufri Pukhraj) were assigned in the sub plot. The total number of treatments in the current investigation was 14 different combinations. The dosage of nitrogen was applied in the form of neem coated urea at 3 and 6 weeks after planting in equal splits after managing the application of DAP in all plots other than control (Single super phosphate in control) as a source of nitrogen at sowing. The required amount of Phosphorus and potash (P₂O₅ - 62.5 kg ha⁻¹, K₂O - 62.5 kg ha⁻¹) and Farmyard manure (50 t ha⁻¹) were applied according to the PAU (Punjab Agricultural University) guidelines.

2.3 Soil sampling and Analysis

The soil samples were taken 10-days prior to sowing of the crop and field operations. Samples were tested for different physical (Sand%, Silt% and Clay%) and chemical properties (pH, EC, OC, N, P, K, Fe, Mn, Cu, Zn). The particle size distribution was calculated using Piper method (1966) and soil nutrient status were estimated using different protocols for each nutrient such as N by Subbiah and Asija's method, P by Olsen's method, K by Jackson's method and micronutrients (Fe, Cu, Mn, Zn) by Lindsey and Norwell's method previously described by Rayment and Lyons (2011) [19], shown in Table 1.

Table 1: Soil Analysis of experimental sites at Ludhiana and Naraingarh

Component	Ludhiana	Naraingarh
Physical properties		
Sand%	74.1	76.3
Silt%	16.6	14.8
Clay%	9.3	8.9
Soil texture	Sandy loam	Sandy loam
Chemical properties		
Electrical conductivity (dSm ⁻¹)(1:2)	0.16	0.15
pH (1:2)	7.12	7.40
Organic Carbon (%)	0.38	0.34
Available N (kg/ha ⁻¹)	69.0	43.9
Available P (kg/ha ⁻¹)	15.3	23.5
Available K (kg/ha ⁻¹)	90.5	82.6
Available Fe (kg/ha ⁻¹)	32.6	29.2
Available Mn (kg/ha ⁻¹)	26.8	35.6
Available Zn (kg/ha ⁻¹)	9.6	7.25
Available Cu (kg/ha ⁻¹)	3.5	2.88

2.4 The Spectral tools

The instruments such as LCC, SPAD meter and GreenSeeker Optical Sensor were used to take readings at every 7-day interval after 28 days of sowing up to 63 days of sowing. These tools help to measure the greenness of the leaves.

2.4.1 LCC

The leaf colour chart uses six shades of green colour and the intensity of colour is proportional to the number. For measurement, the colour of ten diseased free fully-expanded leaves were observed in shade by placing it over the LCC and matching its colour with the specific stripes. That leaves are then used for the N estimation to calculate the accurate N concentration of the leaves.

2.4.2 SPAD

The SPAD meter is a lightweight handheld meter for measuring the chlorophyll content of leaves without causing damage to plants. It is a non-invasive measurement that includes clamping the meter over leafy tissue, and receive an indexed chlorophyll content reading (0-99.9) in less than 2 seconds which uses the principle of transmittance of light rays by the leaf surface as it uses two LED which emit red light with peak wavelength of 650nm and infrared radiation with 940nm. These radiations are made to pass through the leaf surface. A portion of this is absorbed and remaining is transmitted through the leaf which is received by the silicon photodiode detector converted into electrical signal. Which further produces a magnitude over the screen. For measurement, the same ten diseased free fully-expanded leaves which were used for LCC were used.

2.4.3 GreenSeeker Optical Sensor

This sensor is used to measure the NDVI (Normalized Difference Vegetation Index) as it works on the principle of reflectance of light rays by the chlorophyll. The instrument is pressed while

walking along the row of crop and the trigger is released just before when the row ends. The magnitude (0-0.99) displayed will depict the reflectance of rays as well as the biomass of the crop.

2.4.4 Sampling and Analysis

The leaves which are used for LCC, SPAD are plucked and dried in shade for some time and then put it in an oven at 70°C for 3-4 hours. The fresh tubers are also cleaned and chopped and dried in the same manner. The dried matter is then crushed and digested using sulphuric acid. After digestion, the aliquot was used for N estimation using Kelplus, and boric acid as an absorbing agent.

Results

3.1 Relation between PAU-LCC scores and Days after sowing

The colour of the uppermost fully expanded leaf of potato plants, assessed using Leaf Color Chart scores, was recorded for both cultivars—PP102 and Kufri Pukraj. The average LCC scores, shown in Figure 1, varied with time and the amount of nitrogen fertilizer applied in 2023-24. The leaf greenness is increased from the vegetative stage up to tuber initiation stage, regardless of nitrogen levels. After that, LCC scores typically decreased from tuber initiation to tuber bulking.

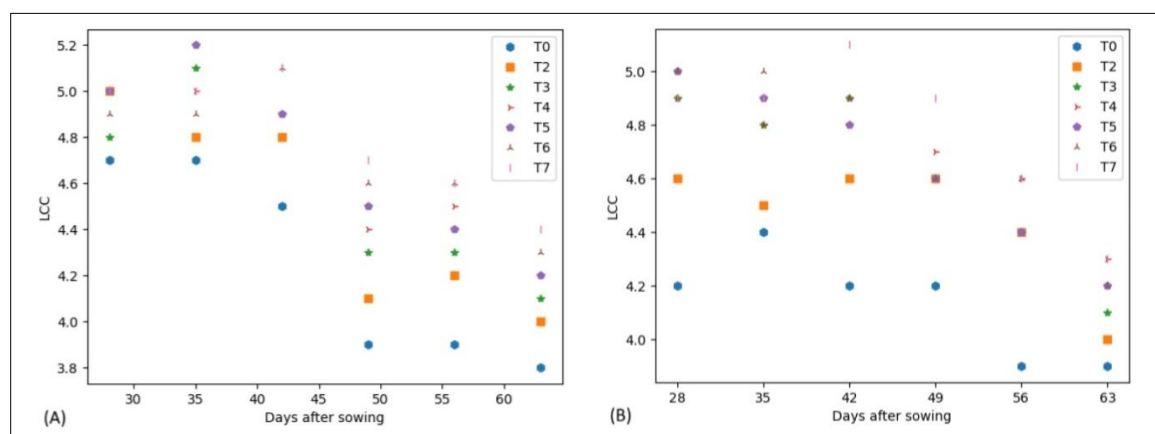
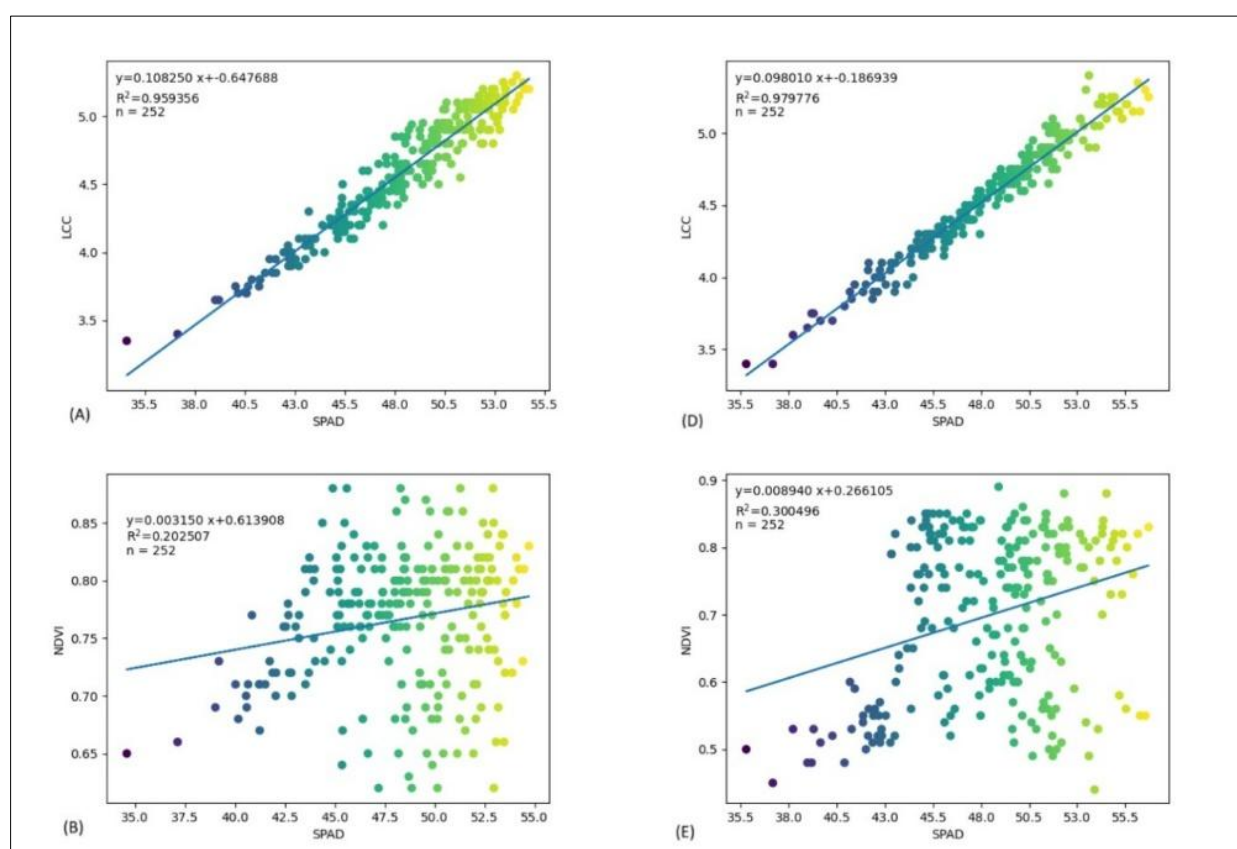


Fig 1: Relationship of PAU-LCC scores with days after sowing as affected by different levels of Nitrogen.

3.2 Relationship between PAU-LCC and SPAD meter

Figure 2 presents a strong positive correlation between PAU-LCC scores and SPAD meter readings in the potato varieties PP102 and Kufri Pukhraj, with high R^2 values of 0.959 and 0.979, respectively ($n=252$). Both the PAU-LCC and SPAD meter

measure leaf greenness as an indicator of nitrogen concentration in the leaves. In addition, significant positive correlations ($P<0.01$) were observed between PAU-LCC scores and leaf nitrogen levels, further reinforcing the reliability of PAU-LCC as a tool for assessing nitrogen content in potato leaves.



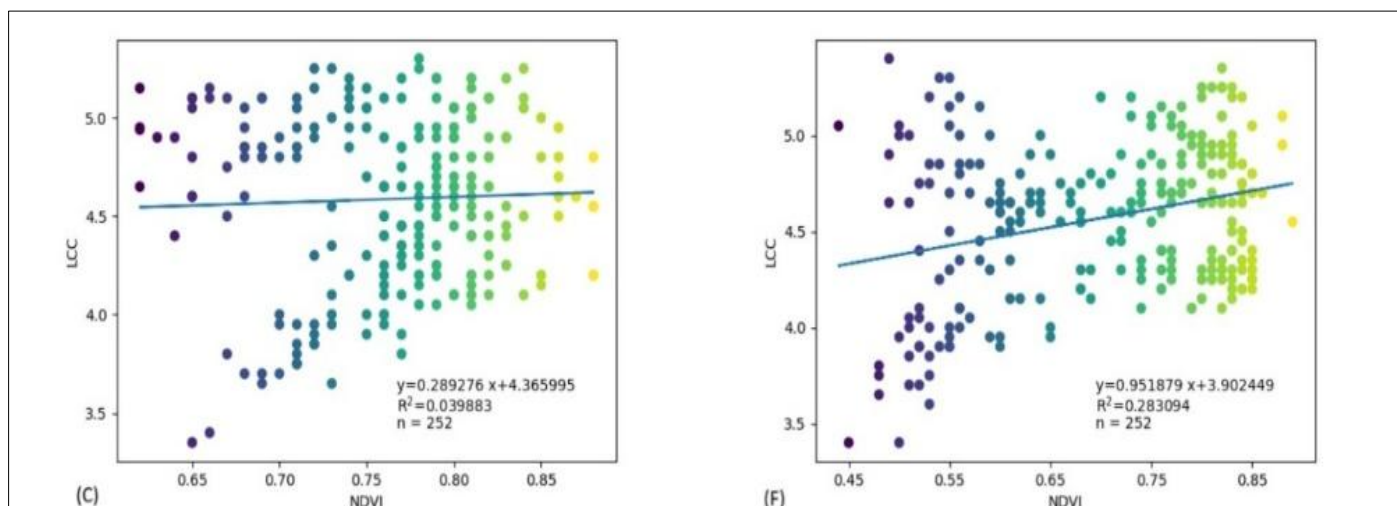


Fig 2: Relationship of PAU-LCC scores and SPAD meter readings, NDVI values and SPAD meter readings and PAU-LCC scores and NDVI values at Ludhiana (A, B, C) and Naraingarh (D, E, F).

3.3 Relationship between NDVI index and SPAD meter readings

Figure 2 illustrates the NDVI meter and SPAD readings for potatoes at various growth stages. The data reveals a weak linear correlation between the NDVI values and SPAD readings, with R^2 values of 0.3 and 0.2 ($n=216$). This weak correlation highlights the distinct functions of the two devices used for measurements.

3.4 Relationship between PAU-LCC and NDVI index

Figure 2 displays the relationship between PAU-LCC scores and NDVI values in spring maize. The weak correlation ($R^2 = 0.04$

and 0.28, $n = 216$) suggests a limited connection between the two parameters, similar to the relationship observed between SPAD readings and NDVI values.

3.5 Correlation of PAU-LCC with Leaf N

The nitrogen concentration at various weekly intervals was calculated and correlated with the corresponding Leaf Color Chart (LCC) scores, as shown in Figure 3. A strong positive correlation was observed between LCC scores and leaf nitrogen concentrations at weekly intervals with potato varieties.

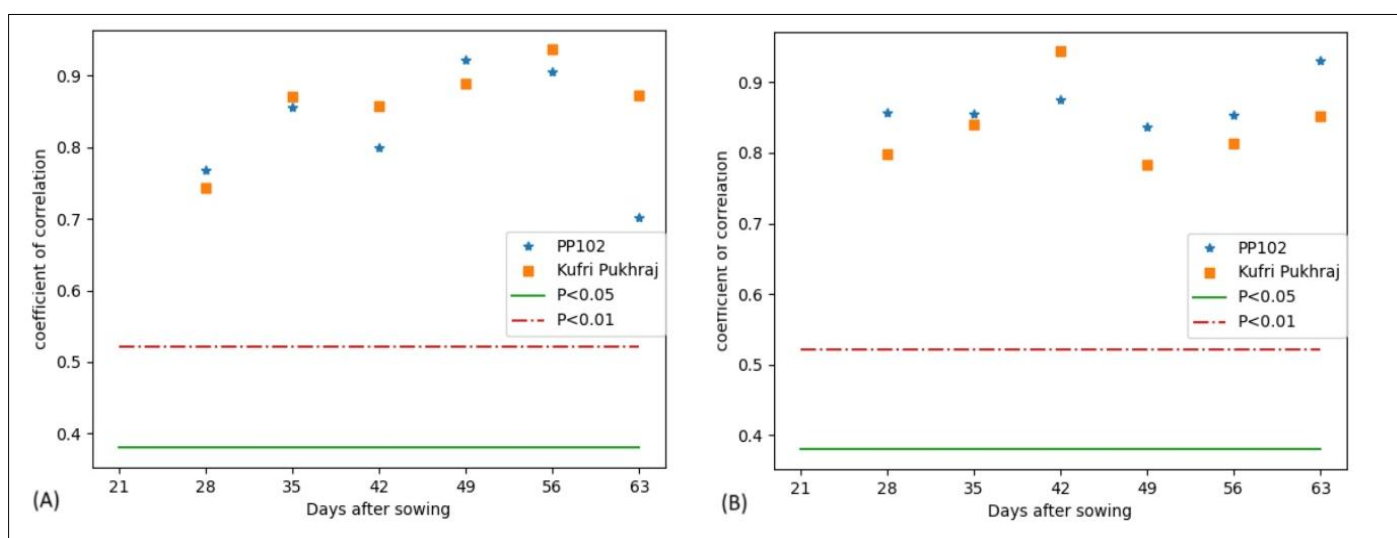


Fig 3: Coefficients of correlation of LCC score with leaf nitrogen concentration at different growth stages in different potato cultivars at Ludhiana (A) and Naraingarh (B).

3.6 Nitrogen Use efficiency

The study revealed significant differences in nitrogen use efficiencies (NUEs) for the two potato varieties. Agronomic efficiency (AE) for PP102 was 86.2 kg and 83.3 kg of tuber per kg of nitrogen, while Kufri Pukhraj had AE values of 76.2 and 74.0 kg of tuber per kg of nitrogen, also shown in table 2. Nitrogen recovery efficiency (RE) for PP102 was 27.9% and 28.5%, and

for Kufri Pukhraj, it was 25.1% and 26.0%. Nitrogen application increased AE and RE for both varieties, with RE peaking at 43.2 and 43.5% for PP102 and 39.0 and 40.4% for Kufri Pukhraj. However, NUE showed an initial increase with nitrogen application, but beyond a specific threshold, further nitrogen additions resulted in a decrease in NUE, indicating diminishing returns from higher nitrogen inputs.

Table 2: Effect of different levels of nitrogen on Tuber yield, Agronomic efficiency (AE_N) and Recovery Efficiency (RE_N) at Ludhiana.

Treatments	Ludhiana				Naraingarh			
	AE _N (kg tuber kg ⁻¹ N applied)		RE _N (%)		AE _N (kg tuber kg ⁻¹ N applied)		RE _N (%)	
	V1*	V2 [#]	V1	V2	V1	V2	V1	V2
T ₁	-	-	-	-	-	-	-	-
T ₂	83.2 ^a	77.8 ^a	27.8 ^a	22.6 ^a	89.8 ^{ab}	59.5 ^a	28.3 ^a	22.2 ^a
T ₃	104.0 ^{ab}	83.8 ^{ab}	31.4 ^a	27.6 ^a	97.1 ^{ab}	101.5 ^{bc}	33.8 ^a	29.3 ^a
T ₄	141.8 ^b	129.4 ^b	43.2 ^a	39.0 ^a	136.7 ^c	122.7 ^c	43.5 ^a	40.4 ^a
T ₅	112.7 ^{ab}	99.4 ^{ab}	34.1 ^a	37.4 ^a	108.3 ^{bc}	100.1 ^{bc}	32.6 ^a	39.0 ^a
T ₆	88.6 ^a	78.6 ^a	32.3 ^a	27.7 ^a	83.7 ^{ab}	75.5 ^{ab}	31.5 ^a	28.4 ^a
T ₇	72.8 ^a	64.4 ^a	26.8 ^a	21.2 ^a	67.2 ^a	58.8 ^a	29.6 ^a	23.0 ^a
Mean	86.2	76.2	27.9	25.1	83.3	74.0	28.5	26.0

*PP102

[#]Kufri Pukhraj

Same letter represents no significance difference

3.7 N content in tuber and shoot biomass at harvesting

The study evaluated the impact of potato varieties and nitrogen fertilization on nitrogen content in tubers and shoots at harvest. Significant variation was observed between the two varieties for tuber nitrogen content, with PP102 showing the highest values of 1.94% and 1.92%, while Kufri Pukhraj exhibited 1.77% and 1.73%, represented in table 3. The highest overall nitrogen

content in PP102 was recorded in T₇, which was comparable to T₃ at both L1 (Ludhiana) and L2 (Naraingarh). For Kufri Pukhraj, the highest nitrogen content was observed in T₇, which was similar to T₃ at L1 and T₄ at L2. Overall, nitrogen fertilization had a significant effect on both tuber and shoot nitrogen content at harvest.

Table 3: Effect of different levels of nitrogen on Tuber N%, Shoot N% and Total N% at Ludhiana and Naraingarh

Treatments	Ludhiana						Naraingarh					
	Tuber N%		Shoot N%		Total N%		Tuber N%		Shoot N%		Total N%	
	V1*	V2 [#]	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
T ₁	0.92 ^a	0.80 ^a	0.61 ^a	0.67 ^a	1.53 ^a	1.47 ^a	0.89 ^a	0.72 ^a	0.68 ^a	0.57 ^a	1.57 ^a	1.29 ^a
T ₂	1.72 ^{ab}	1.17 ^{ab}	0.75 ^{ab}	0.72 ^a	2.47 ^{ab}	1.89 ^{ab}	1.63 ^{ab}	1.37 ^{ab}	0.97 ^{ab}	0.73 ^{ab}	2.60 ^{ab}	2.11 ^{ab}
T ₃	1.91 ^b	1.36 ^{abc}	1.11 ^{abc}	0.83 ^{ab}	3.01 ^{bc}	2.19 ^{abc}	1.95 ^{ab}	1.51 ^{ab}	1.06 ^{ab}	0.76 ^{abc}	3.01 ^{abc}	2.27 ^{ab}
T ₄	1.93 ^b	1.68 ^{bcd}	1.28 ^{abc}	1.24 ^{abc}	3.21 ^{bc}	2.92 ^{bc}	1.99 ^{ab}	1.83 ^{ab}	1.21 ^{abc}	1.33 ^{bc}	3.20 ^{bc}	3.16 ^{bc}
T ₅	2.32 ^b	2.17 ^{cd}	1.37 ^{abc}	1.28 ^{abc}	3.69 ^c	3.45 ^c	2.19 ^b	1.97 ^{ab}	1.44 ^{bc}	1.45 ^c	3.63 ^{bc}	3.43 ^{bc}
T ₆	2.37 ^b	2.52 ^{de}	1.45 ^{bc}	1.47 ^{bc}	3.83 ^c	3.99 ^c	2.28 ^b	2.28 ^b	1.67 ^{bc}	1.60 ^c	3.95 ^{bc}	3.88 ^c
T ₇	2.44 ^b	2.68 ^e	1.51 ^c	1.57 ^c	3.95 ^c	4.25 ^c	2.53 ^b	2.43 ^b	1.81 ^c	1.79 ^c	4.34 ^c	4.21 ^c
Mean	1.94	1.77	1.15	1.11	3.10	2.88	1.92	1.73	1.26	1.18	3.18	2.91

*PP102

[#]Kufri Pukhraj

Same letter represents no significance difference

4. Discussion

4.1 Relation between PAU-LCC scores and Days after sowing

This decline after the tuber initiation was due to the high nitrogen demand from the developing tubers and the movement of nutrients to the reproductive parts. The only exception was the no-nitrogen control, where the leaf color dropped sharply from tuber initiation to tuber bulking, indicating that the soil nitrogen was insufficient to maintain the greenness of leaves. Varinderpal-Singh *et al.* (2011)^[24] also demonstrated a decline in LCC as maize development progressed.

4.2 Relationship between PAU-LCC and SPAD meter

The high correlation observed between PAU-LCC scores and SPAD meter readings indicates that PAU-LCC could serve as an effective and affordable alternative to the more expensive SPAD meter for nitrogen assessment in potatoes. The simplicity and affordability of the PAU-LCC make it an accessible tool, even for smallholder farmers or those with limited literacy skills, enabling them to assess their nitrogen fertilizer needs efficiently. These findings align with previous research by Varinderpal-Singh *et al.* (2011)^[24] in maize and Shukla *et al.* (2004)^[21] in rice and wheat, where strong correlations between PAU-LCC and SPAD meter readings were also reported. While PAU-LCC has not been widely adopted in potato farming due to the absence of a threshold limit, the present study's results suggest that it can now be

recommended for use in nitrogen management in potatoes. The significant correlation between PAU-LCC and leaf nitrogen levels supports the potential of PAU-LCC to replace the SPAD meter, thereby making nitrogen management more cost-effective and accessible to a wider range of potato farmers.

4.3 Relationship between NDVI index and SPAD meter readings

The weak correlation between NDVI values and SPAD readings can be attributed to the differing roles of the two tools. The SPAD meter specifically measures chlorophyll content, which is directly related to the nitrogen concentration in the leaves. On the other hand, the NDVI meter assesses both leaf greenness and biomass, capturing a broader range of plant characteristics. As such, the NDVI meter and SPAD readings cannot be used interchangeably for determining nitrogen fertilizer requirements in potatoes. This distinction emphasizes the need for careful selection of tools based on the specific nitrogen management objectives when working with potato crops.

4.4 Relationship between PAU-LCC and NDVI index

The weak correlation between PAU-LCC scores and NDVI values arises from the different functions of the two measurement tools. PAU-LCC measures only leaf greenness, providing a direct estimate of nitrogen status based on visual indicators. In contrast,

NDVI reflects both photosynthetic activity and overall plant greenness, capturing a broader range of plant growth characteristics. While PAU-LCC can be effective for making in-season nitrogen fertilizer decisions (Varinderpal-Singh *et al.* 2011)^[24], the NDVI meter, like GreenSeeker, is typically used to determine a fixed nitrogen dose after initial application. This difference in purpose and capability underscores that the two devices cannot be used interchangeably for scheduling nitrogen topdressings in potatoes.

4.5 Correlation of PAU-LCC with Leaf N

The close relationship between LCC scores and leaf N concentrations indicates that LCC can be used as an effective tool to estimate nitrogen status in potato plants. Since LCC scores are highly correlated with both leaf N levels and SPAD meter readings, it serves as a reliable indicator of the indigenous nitrogen supply (INS) in the soil. Indigenous nitrogen supply refers to the total nitrogen accumulated in the plant and tubers by the time of maturity, which includes nitrogen contributions from various sources such as the soil, organic materials, crop residues, rhizosphere nitrogen fixation, and natural inputs from irrigation and rainfall throughout the growing season. The ability to assess INS using LCC helps optimize nitrogen management and improve crop productivity.

4.6 Nitrogen Use Efficiency

Strategic scheduling of additional nitrogen inputs, considering the soil's intrinsic nitrogen supply and other endogenous sources, has been shown to improve nitrogen use efficiency (NUE) in field crops (Bijay-Singh *et al.* 2003)^[4]. Notable gains in NUE were observed with need-based nitrogen fertigation, where nitrogen application was aligned with crop demand. Both AE and RE metrics were influenced by increased tuber yield and nitrogen uptake relative to a no-fertilizer control, with higher efficiencies observed at lower fertilizer doses. Optimizing NUE depends on factors like crop nitrogen demand, available indigenous nitrogen, fertilizer quantity, and timing of application (Varinderpal-Singh *et al.* 2017)^[25]. Dobermann (2007)^[7] highlighted the importance of managing nitrogen inputs from soil and natural nitrogen pools, particularly in enhancing nitrogen recovery in the early crop stages, when nitrogen losses tend to be most significant. The pattern of initial increase followed by a sharp decline aligns with the observations of Kleinkopf *et al.* (1981)^[13] and Zebarth *et al.* (2004)^[31], who reported similar trends in their studies. R. J. López-Bellido and L. López-Bellido (2001)^[14] similarly noted a reduction in wheat grain yield when nitrogen application exceeded a certain threshold, attributing this decline to the phenomenon wherein the increase in grain yield becomes progressively less than the amount of nitrogen supplied by both the soil and applied fertilizers.

4.7 N content in tuber and shoot biomass at harvesting

Tuber nitrogen content varies significantly across various treatments and potato varieties, which may be attributed to increased nitrogen application that enhances overall growth parameters and assimilation rates. Zedan (2011) concluded that increased nutrient application leads to enhanced assimilation in the reproductive parts of plants, and Ahmed *et al.* similarly noted that nitrogen content increases with higher nitrogen applications. Biemond and Vos (1992) also reported similar results, observing elevated shoot nitrogen content under higher nitrogen application, though it gradually declined as plant growth advanced. The data revealed that PP102 demonstrated higher nitrogen content in both shoots and tubers compared to Kufri Pukhraj at the same interval.

This difference may be attributed to more efficient nitrogen assimilation and enhanced growth factors in PP102, a finding consistent with Wulansari *et al.* (2024), who observed varying net assimilation rates among different amaranth varieties.

5. Conclusion

High amount of N is required by the potato crop for the production of tubers which also increases its over exploitation of nitrogenous fertilizers by the farmers. This tool (LCC) helps to maintain leaf greenness in leaves by matching with the color strips of high to low intensity. Many experiments were performed to calibrate the LCC by the SPAD meter to set need-based guidelines for N application in field crops. Also, LCC lead to minimize the N losses and also to increase the profit margins by the farmer. So, this experiment was performed in order to verify that whether this technology can be used in vegetable crops or not. But, as the correlation between SPAD meter and LCC is highly positive (0.96 and 0.98), this provides enough evidence that LCC can be used to guide N recommendation in potato also.

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Statements and Declaration

The author declares no conflict of interest.

Data Availability Statement

Data will be made available on request.

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None

Authors contribution

CRedit: Abhishek Grover: Data curation, Formal analysis, Investigation, Visualization, Writing - original draft; A.A.S. Gill: Conceptualization, Methodology; Shaminder Singh Chahal: Writing - review & editing.

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