Project ID -769

Competitive Research Grant

Sub-Project Completion Report

on

Development of mobile phone applications for phenotyping and assessment of nitrogen fertilizer requirement by digital image analysis in cereal crops

Project Duration

May 2017 to September 2018

Seed Technology Division
Bangladesh Agricultural Research Institute

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
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Acronyms

Abbreviation	Full Name
B	Blue
BARI	Bangladesh Agricultural Research Institute
BRAVI	Blue-Red Adjusted Vegetation Index
Car	Carotenoid
CC	Canopy cover
Chl	Chlorophyll
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
DGCI	dark green color index
DNA	Deoxyribonucleic acid
EVIgreen	Enhanced Vegetation Index-Green
G	Green
GMR	Green Minus Red
HSB	Hue, Saturation, and Brightness
LAI	Leaf area index
LSD	Least Significant Difference
EGI	Excessive Greenness Index (EGI)
MEGI	Modified Excessive Greenness Index
NDI	Normalized Different Index
NDVI	Normalized Difference Vegetation Index
NDVIrgb	Normalized Difference Vegetation Index R-GB
PC	Principal component
PCA	Principal component analysis
PGRC	Plant Genetic Resources Centre
pH	Potential of hydrogen
R	Red
SAT	Hue and saturation
SDW	Shoot Dry Weight
SPAD	Soil-Plant Analyses Development
STAR	Statistical Tool for Agricultural Research
VARI	Visible Atmospherically Resistant Index

SI Units

English Abbr.	English Full Name
℃	Degree Celsius
cm	Centimeter
g	Gram (s)
ha	Hectare
m	Meter
M	Molar
mM	Millimolar
mol/L	Molar concentration/Liter
mg	Milligram
ml	Milliliter
Min	Minute (s)
MT	Million ton (s)
ng	Nano gram(s)
t	Ton (s)
μ	Micron
μg	Microgram (s)
μL	Microliter (s)
v/v	Volume per volume
w/v	Weight per volume

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Executive Summary

Digital image analysis is used to quantify the "greenness" of foliage as indirect measurements of crop N status and phenotyping. Digital images record information as amounts of red, green, and blue (RGB) light emitted; however, the intensity of red and blue often alters how green an image appears. To simplify the interpretation of digital color data and converting RGB values to the more intuitive hue, saturation, and brightness (HSB) color spectrum, which is based on human perception of color. Plant color has potential to indicate N status of rice, corn and wheat accurately.

Canopy cover of crops has often been used as a predictor of crop yield and growth parameters such as leaf area index (LAI), above-ground biomass, etc. As an alternative method for destructive monitoring of crop growth and nutrition status that is time and resource consuming, digital images have increasingly been employed in recent agronomic studies on the characterization of crop growth and nutrition status due to its simplicity and cost-effectiveness. The objectives of this CRG project were (i) to use digital camera image and software for assessment of leaf nitrogen of rice, wheat and maize at different growth stages.(ii) to establish a relationship between morpho-physiological parameters with image parameters of rice, wheat and maize and (iii) to develop a mobile phone application for phenotyping and assessment of nitrogen requirement by image analyses.

To fulfill the above-mentioned objectives three experiments were conducted at three locations of BARI, head quarter, Gazipur, Bangladesh Wheat and Maize Research Institute (BWMRI), Nashipur, Dinajpur and Regional Agricultural Research Station, Hathazari, Chattrogram from July 2017-August 2018with wheat, maize and rice. The experiments were laid out in split plot (randomized block) design with three replications. Initial soil samples were collected for lab analysis. Data on Leaf area (LA), Leaf Area Index (LAI), Canopy cover (CC) at different stages, SPAD value of leaf, Plant height (cm), Leaf nitrate content, Leaf chlorophyll content, NDVI, Number of tillers, Total dry matter, images at different growth stage, Length of panicle (cm) etc. were recorded. Canopy cover (CC) is an important phenotypic trait which indicate overall plant growth and helpful to predict advanced traits like biomass and yield. Manual measurement of CC is laborious and bottleneck for maize research. The goal of this research was to develop and evaluate a high throughput phenotyping (HTP) system using images analysis Apps for measuring CC of maize under field conditions. The image was taken from 50cm above the plant canopy by using modified selfie stick. Developed three software (BARI_WCC for wheat, BARI_MCC for maize and BARI_RCC for rice) for digital HTP in JAVA and Interface design in JFrame(http://bariprecisionagriculture.org/). A five-step algorithm was developed to measure the CC of individual plots by RGB (red, green, and blue). The output gave 27 digital trails value after analyzing an image including CC and NDVI. Leaf area. The values of canopy cover were closely correlated with the NDVI and the ratio vegetation index. Models were calibrated to describe the relationship between canopy cover and five traits of wheat. There were close, linear relationships between canopy cover and four traits. The relationships for estimating aboveground total dry matter were most precise, the coefficients of determination ($R2$) values ranged from 0.82 for wheat, 0.86 for maize and 89 for rice. In conclusion, digital image has good potential for HTP of wheat, maize and rice.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. **Title of the CRG sub-project**:
   Development of mobile phone applications for phenotyping and assessment of nitrogen fertilizer requirement by digital image analysis in cereal crops
2. **Implementing organization**:
   Bangladesh Agricultural Research Institute
3. **Name and full address with phone, cell and E-mail of PI/Co-PI (s)**:

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4. **Sub-project budget (Tk)**:
   4.1 Total: 4000000.00(Forty lakh taka only)
   4.2 Revised (if any): N/A
5. **Duration of the sub-project**:
   5.1 Start date (based on LoA signed): From 15th May 2017
   5.2 End date: 30 September 2018
6. **Justification of undertaking the sub-project**:

In recent years, digital cameras and image analysis programs have been used to quantify the "greenness" of foliage as indirect measurements of crop N status and phenotyping. Digital images record information as amounts of red, green, and blue (RGB) light emitted; however, the intensity of red and blue often alter how green an image appears. To simplify the interpretation of digital color data and converting RGB values to the more intuitive hue, saturation, and brightness (HSB) color spectrum, which is based on human perception of color.

Karcher and Richardson (2003), working with quality of turfgrass in response to N fertilizer, processed HSB values into a single measurement of dark green color, the dark green color index (DGCI). Dark green color index values were a more consistent measure of green color than were individual RGB values across all turf varieties and N treatments.

Plant color has potential to indicate N status of corn and other non-leguminous row crops accurately when the correct methods are applied. Differences in lighting conditions, camera quality, and available camera settings could affect DGCI values and limit their utility in diagnosing N deficiencies; furthermore, factors such as disease, water status, nutritional deficiencies other than N, or differences in hybrid may affect greenness regardless of N status.

Canopy cover (CC) is defined as the fractional or percent area of plant canopies projected vertically onto the horizontal ground surface beneath (Guevara-Escobar et al. 2005). Canopy cover of crops has often been used as a predictor of crop yield and growth parameters such as leaf area index (LAI), above-ground biomass, etc. (Behrens and Diepenbrock 2006; Li et al. 2010; Pan et al. 2007; Richardson et al. 2001). As an alternative method for destructive monitoring of crop growth and nutrition status that is time and resource consuming, digital cameras have increasingly been employed in recent agronomic studies on the characterization of crop growth and nutrition status due to its simplicity and cost-effectiveness. Color digital image analysis using digital camera have been proposed to evaluate the plant color and nutrition status (Jia et al. 2004, 2007; Li et al. 2010;

Sims et al. 2002; Yoshioka et al. 2004), canopy cover (Guevara-Escobar et al. 2005; Laliberte et al. 2007; Li et al. 2010; Pan et al. 2007), growth characteristics (Reiko and Hiroyuki 2010), and weed research (Vrindts et al. 2002). Though digital image analysis may provide researchers with improved methods, it is required to develop reliable image analysis techniques to segment plants from a variety of soil backgrounds (Mao et al. 2003). Many studies have been con-ducted on the plant segmentation performance of several color indices that use color components defined in RGB space in single or in combination. Normalized color indices such as excessive greenness index (EGI) and modified EGI (MEGI) have been successful in several case-studies of plant segmentation from bare upland soil background (Gonzalez et al., 1987; Li et al. 2010; Tang et al. 2003). However, few studies have been done on the segmentation of rice, maize and wheat plant from soil backgrounds.

7. **Sub-project goal**:

   To enhance cereal production by assessment of N-fertilizer requirement of cereal crops

8. **Sub-project objective (s)**:

   i. To use digital camera image and software for assessmeant of leaf nitrogen of rice, wheat and maize at different growth stage.
   ii. To establish a relationship between morpho-physiological parameters with image parameters of rice, wheat and maize.
   iii. To develop a mobile phone application for phenotyping and assessment of nitrogen requirement by image analyses

9. **Implementing location (s)**: Gazipur, Chittagong and Dinajpur

10. **Methodology in brief:**

To fulfill the above-mentioned objectives threefield experiments and one modeling experiment were conduct title 1. Effect of nitrogen on morpho-physiological traits of wheat;2 Effect of nitrogen on morpho-physiological traits of maize; 3. Effect of nitrogen on morpho-physiological traits of T. *Aman* rice; 4. Computer based Modeling and simulation experiment was done at dry Lab, Gazipur.

The first experiment was conducted at Seed Technology Division, Gazipur under Bangladesh Agricultural Research Institute during November, 2017 to March, 2018. Three wheat varieties (BARI Gom 26, BARI Gom 28 and BARI Gom 30) with five levels of nitrogen (B1 (N=0kg/ha), B2 (N=80kg/ha), B3 (N=100kg/ha), B4 (N=120kg/ha) and B5 (N=160kg/ha). The experiment was laid out in split plot design with three replications. Each plot was $5\times3m^2$, row to row distancewas 20 cm with continuous seeding. Seeds were sown on 24 November, 2017 at Gazipur and 14 December, 2017 at WRC, Dinajpur. Three irrigations were applied at crown root initiation, maximum tillering and initial grain filling stages of the crop. Blanket dose of fertilizerswere applied at the rate of P_{60} K_{40}, S_{20} Zn_5 and B_1 kg/ha in the form of TSP, MoP, gypsum, zincsulphate and boric acid, respectively. In case of irrigated plots, two third urea and whole amount of all fertilizers were applied as basal and one third urea was top dress at CRI stage. Initial soil analysis was done.

The second experiment was conducted at Plant Genetic Resources Centre (PGRC), Gazipur under Bangladesh Agricultural Research Institute during November, 2017 to March, 2018. Three hybrid maize varieties BARI Hybrid maize-9, Hybrid 981 and Hybrid P3396with three levels of nitrogen (N_1=100kg/ha, N_2=200kg/ha, N_3=300kg/ha. The experiment was laid out in split plot design with three replications. Each plot was $5\times3m^2$, row to row distance was 60 cm and plant to plant distance 20cm. Seeds were sown on 11 December, 2017. Three irrigations were applied at knee height stage, tasseling stage and grain filling stage stages during the crop season. Blanket dose of fertilizers was applied at the rate of P_{55} K110, S_{40} Zn_5 and B_1 kg/ha in the form of TSP, MoP, gypsum, zinc sulphate and boric acid, respectively. Intercultural operations like thinning and weeding were done as and when necessary. Physiological parameters like leaf area index (LAI) (Leaf area meter-LICOR-3300, USA), The normalized difference vegetation index (NDVI) was measured by hand green seeker (Trimble) and green seeker RT100 (Agri Optics), SPAD value by (Model-SPAD-502, Minolta, Japan),leaf nitrogen was measured by ion meter (Kodel-B-743, NO_3^-), dry matter etc. Middle two rows were harvested for yield and yield contributing characters were recorded from ten plants from each plot in the field and Chlorophyll a, Chlorophyll b, and Carotenoid, were measured in the laboratory.

The third was conducted three locations at BARI, head quarter, Gazipur, Wheat Research Center (WRC), Nashipur, Dinajpur and Regional Agricultural Research Station, Hathazari, Chittagong from July 2017. The experiment was laid out in split plot randomized block design with three replications. Rice varieties considered of(BRRI dhan 62, BRRI dhan 75 and BRRI dhan 76) were placed in the main plots and nitrogen doses (0,50,100 and 150 kg N ha^{-1})were placed in sub-plots. Twenty-four to thirty-five day old seedling were transplanting during 29 July 2017 at Gazipur, 3rd August 2017 at Dinajpur and 10th August 2017 at Chittagong with spacing of 20×15 cm. Two to three seedlings were transplanted in each hill. Fertilizer application was made with 20 and 60 kg ha^{-1} of P and K, respectively. Initial soil samples were collected for analysis.

Chlorophyll and carotenoid determination

Extraction and determination of chlorophyll (Chl) and carotenoid (Car) was performed according to the method of Arnon (1949). Five hundred milligram of fresh leaf material was homogenized in 10 ml of 80% acetone at 4°C and centrifuged at 2500 rpm for 10 minutes at 4°C. This procedure was repeated until the residue became colorless. The extract was transferred to a graduated tube and made up to 10 ml with 80% acetone and assayed immediately. Three milliliters aliquots of the extract were transferred to a cuvette and the absorbance was read at 645, 663 and 480 nm with a spectrophotometer (UV-1800, Shimadzu, Japan) against 80% acetone as blank. Chlorophyll content was calculated using the formula of Arnon (1949) and expressed in mg g^{-1} fresh weight (FW).

Total Chl (mg g^{-1}FW^{-1})= (0.0202) × (A_{645}) + (0.00802) × (A_{663})

Chl*a* (mg g^{-1}FW^{-1})= (0.0127) × (A_{663}) – (0.00269) × (A_{645})

Chl*b* (mg g^{-1}FW^{-1})= (0.0229) × ($A_{.645}$) – (0.00468) × (A_{663})

Car content was estimated using the formula of Kirk and Allen (1965) and also expressed in mg g^{-1} FW.

Car (mg g^{-1}FW^{-1}) = A_{470} + (0.114 × A_{663} – 0.638 × A_{645}).

Wheat leaf tissue (0.5g) was homogenized in 1 ml of 50 mM ice-cold K–P buffer (pH 7.0) by mortar and pestle containing 100 mM KCl, 1 mM ascorbate, 5 mM β-mercaptoethanol and 10 % (w/v) glycerol. The homogenates were centrifuged at 11,500×*g* for 10 min and the supernatants were used for determination of enzyme activity. All procedures were performed below 4 °C.

The normalized difference vegetation index (NDVI) was measured by hand green seeker (Trimble) and green seeker RT100 (Agri Optics).

The formula for NDVI is:NDVI = (NIR — VIS)/(NIR + VIS)

Where, Near Infrared (NIR),

Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green.

Image Processing and Modeling

Image acquisition

Canon camera and Android mobile phone were utilized for image acquisition. Images were stored in the JPG format. Substantial effort was made develop a standard imaging protocol to ensure imaging consistency and quality. Tefash function was kept of and an umbrella was always used to shade the area under the camera view in order to minimize illumination discrepancies between images. A light/color calibration protocol was also followed. An image of a color calibration chart (X-Rite Color Checker Color Rendition Chart) was taken at the beginning of imaging operations, and every 20 min thereafter or whenever light condition changes (cloud cover, etc.). White taking pictures, the whole canopy was in the field of view of the camera. Weed control was practiced consistent with research plots and commercial farms; however, due to the small size of the field weed removal was done manually. Weeds in the view of camera were removed for enhanced efficiency of subsequent image processing. Images were taken across several days (at several times of the day) under various illumination conditions. Finally, the imaging protocol was chosen so that the imaging window and the camera resolution resulted in images with at least 6 pixels/mm, ensuring that the approach is transferable to other cameras that use an appropriate imaging window to get this resolution.

Image analysis

MCCBARI description

MCCBARI is automatic color threshold (ACT) image analysis software developed in the JAVA programming language using color values in the red, green, blue (RGB) system. MCCBARI analyzes and classifies all pixels in the image. The analysis is based on the selection of pixels according to ratios of R/G, B/G and the excess green index. The result of the analysis is a binary image where white pixels correspond to the pixels that satisfied the selection criteria (green canopy) and black pixels correspond to the pixels that did not meet the selection criteria (not green canopy). Fractional green canopy cover ranges from 0 (no green canopy cover) to 1 (100% green canopy cover). The classification of green canopy is based on the following criteria:

$$R/G < X1 \text{ and } B/G < X2 \text{ and } 2G–R–B > X3$$

where X1 and X2 are parameters that typically have a value near 1 to classify pixels that are predominantly in the green band (~500–570 nm), and X3 is a parameter that sets the minimum excess green index, which typically has a value around 20 to select green vegetation (Meyer and Neto, 2008; Richardson et al., 2007). The default parameter values for MCCBARI are X1 = 0.89, X2 = 0.89, and X3 = 25.

The threshold value for the excess green index was set constant at a value of 20. The excess green index effectively classifies dark or gray pixels that cannot be adequately discriminated using the R/G and B/G ratios alone. MCCBARI also has the capability to reduce noise by removing isolated green pixels. Isolated pixels that meet the color ratio specifications can sometimes occur in other objects and are not exclusively part of green canopy. For instance, some isolated pixels in residue shadows may have R/G and B/G ratios similar to those found in green canopies. MCCBARI can remove these pixels or small clusters of pixels (e.g., small weeds in a row crop) by analyzing connected neighboring pixels. MCCBARI saves a text file which canbe opened in spreadsheet (Microsoft Excel format). MCC_BARI saves the image file name, picture taken date and time, total plant pixel, plant pixel percentage values, intensity, saturation, NDVI value etc. The supported image formats are .jpeg (Joint Photographic Experts Group), .png (Portable Network Graphic).

Digital photo provides spectral information in the red, green, and blue wave lengths (Reiko and Hiroyuki 2010). RGB color component has 256 levels, numbered 0 to 255, and in total, 256, 3 colors can be represented, with black shown as 0, 0, 0 and white shown as 255, 255, 255 (Gonzalez et al. 1987). Digital images were analyzed with a computer program (Image Analysis of Fertilizer) written in Microsoft visual basic 6.0 for the present study. The program extracts red, green, and blue (RGB) features from the digital camera image files and computes color indices.

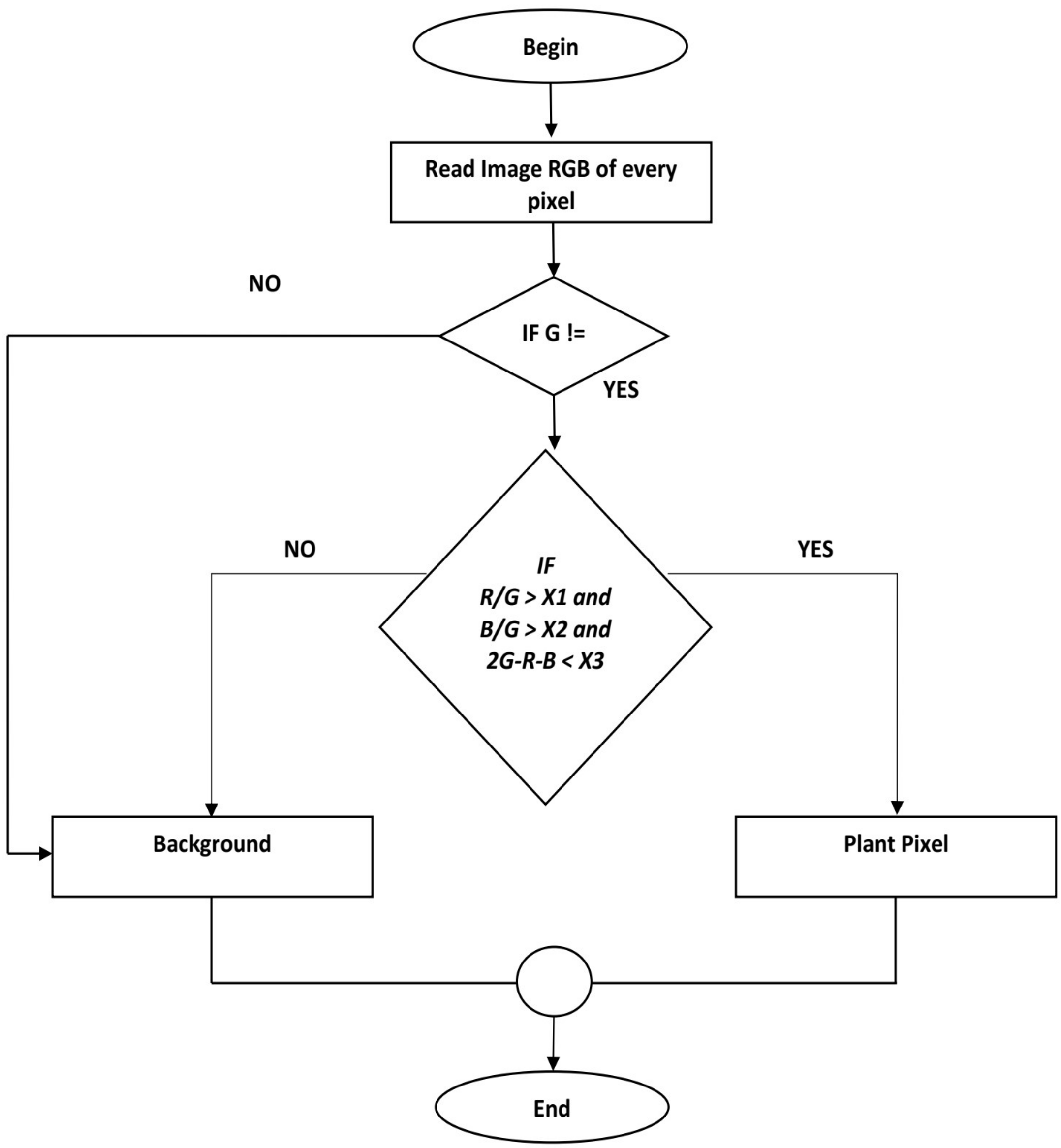


Fig.1. Flowchart algorithm of the overall methodology and modeling

Calculation of color indices

Canopy Cover

CC = (1+) × (($G-R$)/(G+R+L))

The detail software algorithm of the computer programmer as follows:

If R< 2.6 and R<G−5and G>G+5
    Then canopy pixel
if R + G + B< 200
    then sunlit canopy(SC) pixel
elseshaded canopy (ShC) pixel
end if else soil backgrounds
if R + G + B> 250
    then sunlit soil (SS) pixel
else
    shaded soil (ShS) pixel------------------------------------- KukandB.Uzun (2013)

HUE

Hue = 120+ { 60(B-R) / max(R;G;B) – min(R;G;B) } ----------Karcher and Richardson (2003)

EGI

EGI = 3 x g-1

MEGI

If g < r or g < b
Then MEGI = 0
else
MEGI = EGI

Normalized Different Index (NDI)

NDI = (g – r) / g + r +0.01 --------------------------- Mao et al. (2003)

Normalized Difference Vegetation Index R-GB

NDVIrgb = (g + b) – r / (g – b) + r -------------------------- BayuTaruna (2017)

Normalized Difference Vegetation Index-Green

NDVIgreen = (g + b) / (g + b) ------------------------ Gitelson et al. (2002)

Soil Adjusted Vegetation Index-Green

SAVIgreen= (1 + L) x (g – r) / (g + r) + L) -------------------- Li et al. (2010)

L = correction factor

Green Minus Red (GMR)

GMR = g – r --- Wang et al. (2013)

Simple Ratio (SR)

SR = g / r ------------------------------------ Wang et al. (2013)

Visible Atmospherically Resistant Index (VARI)

VARI = (g – r) / (g + r – b) -------------------------- Gitelson et al. (2002)

Blue-Red Adjusted Vegetation Index (BRAVI)

BRAVI = N (g – r) / g + r + N , where noise intensity ‘N’ ------------ BayuTaruna (2017)

BRAVI-Simple Ratio

BRAVIsr = N x g / r + N, noise intensity ‘N’ --------------- BayuTaruna (2017)
Enhanced Vegetation Index-Green
EVIgreen = 2.5 x (g – r) / (g + 6 x r - 7.5 x b + 1) ------- A. Huete et al. (2002)
Enhanced Vegetation Index 2-Green
EVIgreen2= 2.5 x (g – r) / (g + 2.4 x r + 1) ------------------ Jiang et al. (2008)
Optimized Soil Adjusted Vegetation Index-Green
OSVIgreen = 1.5 x (g – r) / (g + r) + 0.16 ------------------- Rondeaux et al. (1996)
Simple Ratio Intensity R-GB
SRrgb = r / (g + b) -- BayuTaruna (2017)
R, G, B

R = RED
G = GREEN
B = BLUE

Normalized ‘r’ ‘g’ ‘b’
"r", (Normalized r)
r = R / R+G+B
"g", (Normalized g)
g = G / R+G+B
"b", (Normalized b)
b = B / R+G+B

Sum of R, G, B
SumRGB = Total (R + G + B)

Intensity
Total (R + G + B) / 3
Saturation
SAT = 1 – 3 x min (r , g , b)
or
{[max(RGB) – min(RGB)]/max(RGB)} ------ C. Andy King, MatthewC (2011)
HUE
If max(RGB) = R, 60*{(G – B)/[(max(RGB) – min(RGB)]}
If max(RGB) = G, 60*{2+{(B – R)/ [max(RGB) – min(RGB)]}}
If max(RGB) = B, 60*{4+{(R – G)/ [max(RGB) – min(RGB)]}} Matthew(2011)

Twelve indices based on the RGB and normalized RGB values were computed for each of the three mosaic digital camera images. Normalization reduces the effect of illumination (Cheng et al. 2001).
Excessive green index (EGI) is a linear function of normalized green (g) and modified EGI (MEGI) is a variation of EGI (Mao et al. 2003). Hue and saturation (SAT) were calculated according to Tang et al. (2003). Hue can be visualized as a circular variable measured as an angle between 0 and 2π radians. Hue value is 0 for red, $2/3\pi$for green, and $4/3\pi$for blue. Saturation or chroma is purity of color. A saturation value of 1 is indicative of pure color that is absent of white light, and a saturation value of 0 means white or grey that has no hue (Ahmad and Reid 1996).

Statistical analysis

We used Microsoft Excel 2010 and R-package (2018, version) to analyze the data. The analysis of variance and mean comparison were based on the least significant difference (LSD) test at the 0.05 probability level.

11. Results and discussion:

Wheat

Correlation of Canopy Cover (CC) and color indices with growth and physiological parameters of Wheat

For wheat, As a prior step to model development for estimating crop growth and N nutrition parameters by CCW_BARI image analysis, correlation analysis was carried out between color indices and crop parameters (Table 2). NDVI, NDVIg, and SRrgbshowed significant correlations with CC and more than 6 color indices values in the segmented dataset and 7 color indices except NDVIrgbvalue in the non-segmented dataset. CC derived from digital image analysis revealed very high positive correlations of r = 0.89**, 0.63**, and 0.45** with NDVI, NDVIg, and SRrgb, respectively. g and NDI values among color indices showed relatively high correlation with NDVI, NDVIg, and SRrgbin both background segmented and non-segmented dataset. LA was highly correlated with saturation value of color indices in background segmented and non-segmented dataset. Overall, color indices of the non-segmented dataset showed higher correlations than those of the segmented dataset because color indices in the non-segmented dataset reflected the reflection variation by the change of CC.

Relationship of CC with plant physiological parameters

As presented in Fig. 2 to Fig. 9, CC was found to have curve-linear relationship generally with LA and SDW, being well fitted to a negative exponential function with asymptote of unity. However, this relationship would not be used for diagnosing those crop parameters before it is tested whether the non-linear relationship varies significantly.

Initial soil status

Both the soils are acidic in nature containing low organic matter. Ca, Mg, K, P, S, Cu, Fe, Mn and Zn content of the soil are high. N content of both the soils are low. B content of Gazipur soil is low while it was at per at Dinajpur. However, N content was very low in both the locations as shown in Table 1.

Table 1: Analytical data of soil sample

Sample no.	pH	O.M.%	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			Meq/100 gm				μg/gm						
							Bray						
BARI, Gazipur	6.40	1.47	6.9	2.4	.16	.078	27.3	25.3	.12	2.1	34	6.1	3.65
WRC, Dinajpur	5.6	0.78	5.2	1.8	0.46	0.041	7.8	39.7	0.20	1.8	21	2.1	2.61
Critical Level			2.0	0.5	0.12	-(B)	7.0	10	0.2	0.2	4.0	1.0	0.6

Table 2. Correlation of growth parameters with color indices during 2017-18 in wheat

	CC	*NDVI*	*SPAD*	*PH*	*LA*	*LN*	*Chl a*	*C hl b*	*Chl (ab)*	*SPMS*	*SPS*	*GPS*	*SI*	*GYPMS*	*HI%*	*YTPH*	*TDM*	*CCover*	*NDVIrgb*	*NDVIg*	*SR*
CC	1.00																				
NDVI	0.98	1.00																			
SPAD	0.89	0.81	1.00																		
PH	0.95	0.91	0.92	1.00																	
LA	0.06	0.12	0.06	0.08	1.00																
LN	0.95	0.90	0.96	0.93	0.03	1.00															
Chl a	0.81	0.71	0.94	0.90	- 0.04	0.90	1.00														
C hl b	0.68	0.58	0.89	0.80	0.04	0.81	0.94	1.00													
Chl (ab)	0.12	0.23	-0.07	0.05	- 0.10	0.00	-0.08	-0.05	1.00												
SPMS	0.93	0.87	0.95	0.91	0.03	0.99	0.91	0.79	- 0.06	1.00											
SPS	0.87	0.79	0.97	0.90	0.02	0.96	0.96	0.92	- 0.08	0.96	1.00										
GPS	0.84	0.77	0.89	0.76	- 0.12	0.93	0.81	0.71	- 0.06	0.92	0.89	1.00									
SI	0.87	0.78	0.96	0.92	- 0.05	0.96	0.98	0.92	- 0.04	0.96	0.98	0.87	1.00								
GYPMS	0.82	0.75	0.92	0.84	- 0.17	0.90	0.88	0.82	- 0.08	0.90	0.93	0.86	0.93	1.00							
HI%	0.85	0.82	0.90	0.83	- 0.04	0.92	0.84	0.80	0.06	0.92	0.93	0.87	0.90	0.95	1.00						
YTPH	0.46	0.55	0.18	0.33	0.33	0.28	0.04	-0.14	0.24	0.24	0.06	0.17	0.10	0.00	0.06	1.00					
TDM	0.79*	0.70*	0.93**	0.84**	- 0.19	0.89**	0.90**	0.85**	- 0.15	0.89**	0.93**	0.86**	0.94**	0.99**	0.90**	- 0.02	1.00				
CCover	0.80**	0.85	0.59	0.63	0.23	0.72	0.50	0.34	0.33	0.71	0.58	0.67	0.57	0.50	0.65	0.59	0.43	1.00			
NDVIrgb	0.14	0.15	0.19	0.35	- 0.12	0.18	0.34	0.33	0.11	0.20	0.24	-0.11	0.32	0.25	0.21	- 0.04	0.25	- 0.08	1.00		
NDVIg	0.63**	0.71	0.35	0.43	0.38	0.51	0.20	0.09	0.34	0.48	0.34	0.50	0.31	0.30	0.47	0.55	0.20	0.85	-0.30	1.00	
SR	-0.70*	-0.77	-0.45	-0.51	- 0.36	-0.60	-0.29	-0.17	- 0.29	-0.58	-0.44	-0.59	-0.40	-0.39	-0.55	- 0.54	- 0.30	-0.89	0.29	- 0.99	1.00
BRAVIsr	-0.73*	-0.82	-0.47	-0.58	- 0.36	-0.63	-0.35	-0.23	- 0.35	-0.61	-0.48	-0.56	-0.45	-0.43	-0.59	- 0.56	- 0.33	-0.89	0.09	- 0.97	0.98
SRrgb	0.45*	0.50	0.22	0.21	0.32	0.35	0.04	-0.04	0.20	0.31	0.19	0.48	0.13	0.15	0.29	0.44	0.09	0.70	-0.69	0.89	- 0.89
HUEp	-0.76*	-0.82	-0.54	-0.56	- 0.30	-0.67	-0.35	-0.24	- 0.19	-0.65	-0.52	-0.66	-0.46	-0.50	-0.65	- 0.51	- 0.41	-0.90	0.28	- 0.93	0.96

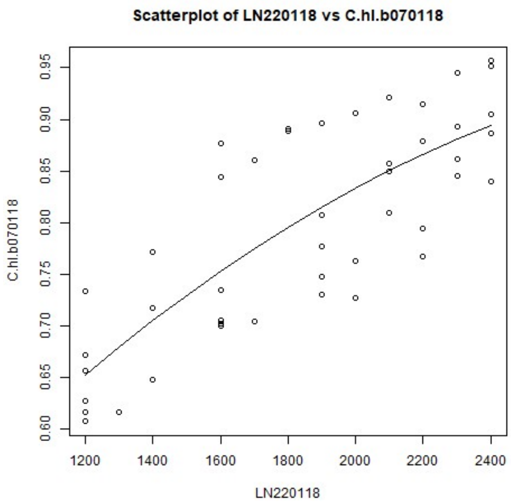


Fig.2 The relationship between Chlorophyll and leaf nitrogen contentof wheat

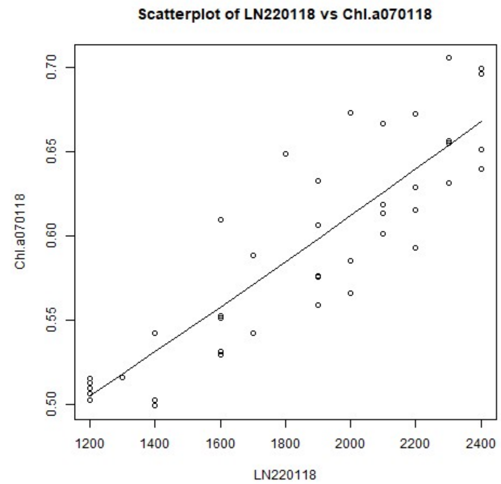


Fig.3 The relationship between Chlorophyll band leaf nitrogen contentof wheat

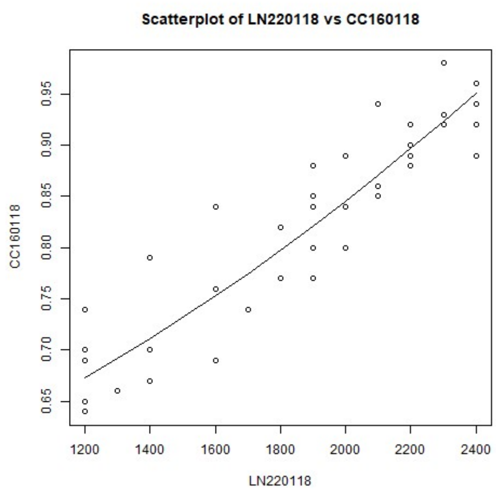


Fig.4 The relationship between canopy coverand leaf nitrogen contentof wheat

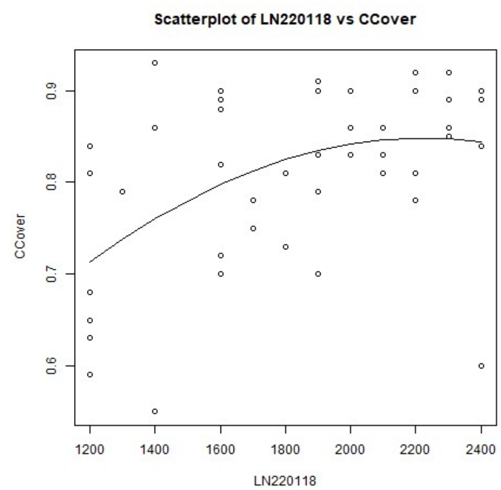


Fig. 5The relationship between digital canopy cover and leaf nitrogen content of wheat

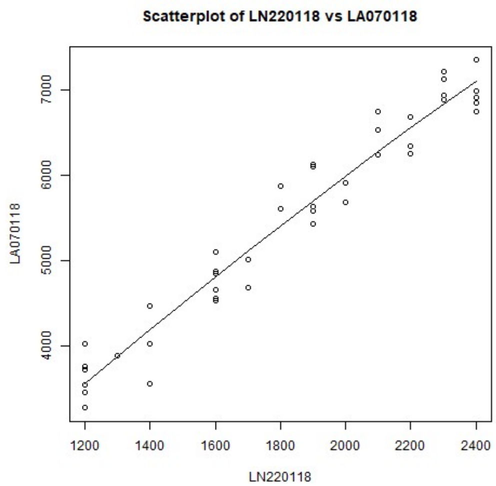


Fig.6 The relationship between leaf areaand leaf nitrogen content of wheat

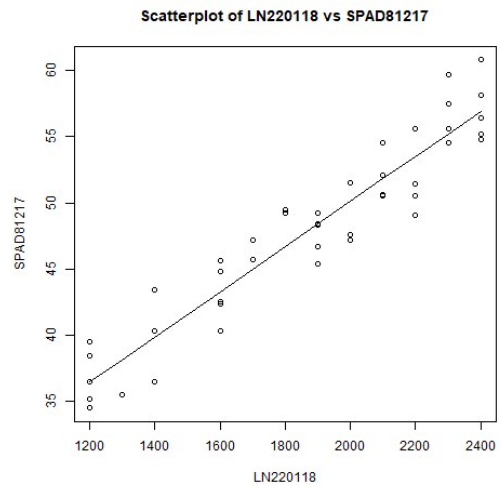


Fig.7 The relationship between SPAD valueand leaf nitrogen content of wheat

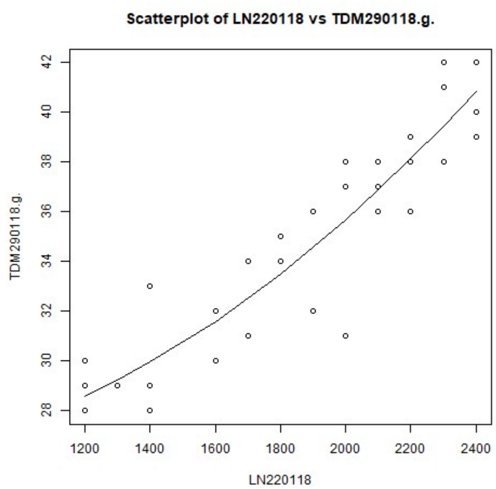


Fig. Fig. 8 The relationship between TDMand leaf nitrogen content of wheat

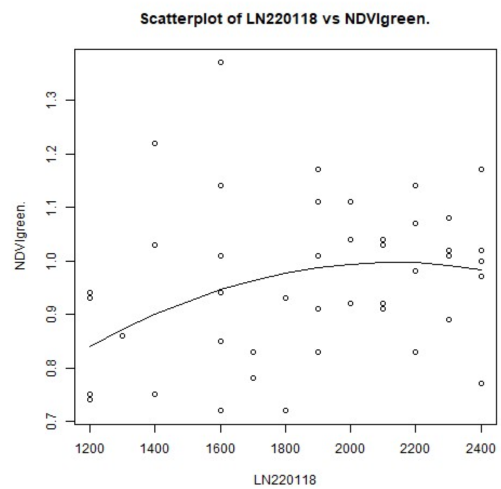


Fig.9 The relationship between digital NDVIand leaf nitrogen content of wheat

Conclusion

It could be concluded that under the conditions of the current experiment, application of nitrogen fertilizer has positive effects on Physiological parameter of wheat cultivar. Potential use of digital camera as a tool combined with software to make nitrogen fertilizer recommendation for large fields of wheat.

Correlation of Canopy Cover (CC) and color indices with growth and physiological parameters of Maize

For maize crop to model development for estimating crop growth and N nutrition parameters by using color image analysis, correlation analysis was carried out between color indices and crop parameters (Table 4). NDVI, SDWand leaf area (LA) showed significant correlations with CC and more than 6 color indices except G and INT values in the segmented dataset and 9 color indices except G value in the non-segmented dataset. CC derived from digital image analysis revealed very high positive correlations of r = 0.70**, 0.65**, and 0.83** with NDVI, SDW, and LA, respectively. g and NDI values among color indices showed relatively high correlation with NDVI, SDW, and LA in both background segmented and non-segmented dataset. LA was highly correlated with saturation value of color indices in background segmented (r = −0.68**) and non-segmented dataset (r = −0.52**). Overall, color indices of the non-segmented dataset showed higher correlations than those of the segmented dataset because color indices in the non-segmented dataset reflected the reflection variation by the change of CC.

Relationship of CC with plant physiological parameters

As presented in Fig. 1, CC was found to have curve-linear relationship generally with LA and SDW, being well fitted to a negative exponential function (Eq. (8)) with asymptote of unity. However, this relationship would not be used for diagnosing those crop parameters before it is tested whether the non-linear relationship varies significantly.

Initial soil status

Both the soils are acidic in nature containing low organic matter. Ca, Mg, K, P, S, Cu, Fe, Mn and Zn content of the soil are high. N content of soil are low shown in Table

Table 3: Analytical data of soil sample

Sample no.	pH	O.M.%	Ca	Mg	K	Total N%	P	S	B	Cu	Fe	Mn	Zn
			Meq/100 gm				µg/gm						
							Bray						
BARI, Gazipur	6.11	1.06	7.0	2.4	0.17	.056	45.5	27.9	0.30	1.9	40	7.1	3.18
Critical Level			2.0	0.5	0.12		7.0	10	0.2	0.2	4.0	1.0	0.6

Table4 . Correlation of growth parameters with color indices during 2017-18 of maize

	NDVI	*SPAD*	*DW*	*BY*	*GY*	*Yield*	*LA*	*Chl a*	*CC*	*R*	*G*	*B*	*R*	*g*	*b*	*NDI*	*SAT*	*hue*	*inten*	*dis*
NDVI	1.00																			
SPAD	0.25	1.00																		
SDW	0.49	0.06	1.00																	
BY	0.44	0.27	0.16	1.00																
GY	0.25	0.37	-0.04	0.55	1.00															
Yield	0.36	0.08	0.22	0.83	-0.01	1.00														
LA	0.53	0.16	0.50	0.25	0.20	0.16	1.00													
Chl a	0.48	0.34	0.42	0.48	0.44	0.27	0.58	1.00												
CC	0.70**	0.37*	0.65**	0.23	0.20	0.14	0.83**	0.46*	1.00											
R	0.48	-0.39	-0.48	0.09	-0.02	0.12	-0.42	-0.22	0.78	1.00										
G	0.53	-0.43	-0.48	0.03	-0.06	0.08	-0.45	-0.28	0.85	0.98	1.00									
B	0.45	0.25	0.12	0.46	0.31	0.34	0.18	0.30	0.42	0.11	-0.05	1.00								
R	0.68	-0.46	-0.55	-0.15	-0.16	-0.06	-0.46	-0.35	0.91	0.89	0.94	-0.33	1.00							
G	0.57	-0.16	0.02	-0.39	-0.25	-0.30	-0.14	-0.28	0.28	-0.27	-0.09	-0.93	0.12	1.00						
B	0.65	0.43	0.38	0.34	0.27	0.23	0.41	0.42	0.83	-0.49	-0.63	0.80	-0.80	-0.69	1.00					
NDI	0.47	-0.34	-0.51	0.08	-0.01	0.10	-0.34	-0.17	0.69	0.97	0.91	0.19	0.85	-0.42	-0.37	1.00				
SAT	-0.61	-0.36	-0.35	-0.38	-0.25	-0.29	-0.33	-0.40	0.71	0.32	0.48	-0.87	0.68	0.77	-0.96	0.21	1.00			
Hue	0.71	0.46	0.54	0.23	0.20	0.14	0.46	0.37	0.91	-0.79	-0.86	0.50	-0.98	-0.29	0.89	-0.74	-0.81	1.00		
Inten	-0.27	-0.25	-0.40	0.24	0.10	0.21	-0.29	-0.09	-0.54	0.92	0.87	0.44	0.68	-0.55	-0.16	0.92	0.03	-0.54	1.00	
Dis	-0.31	-0.21	-0.05	-0.34	-0.21	-0.26	-0.18	-0.30	-0.38	-0.09	0.11	-0.86	0.26	0.92	-0.74	-0.25	0.86**	-0.44	-0.31	1.00

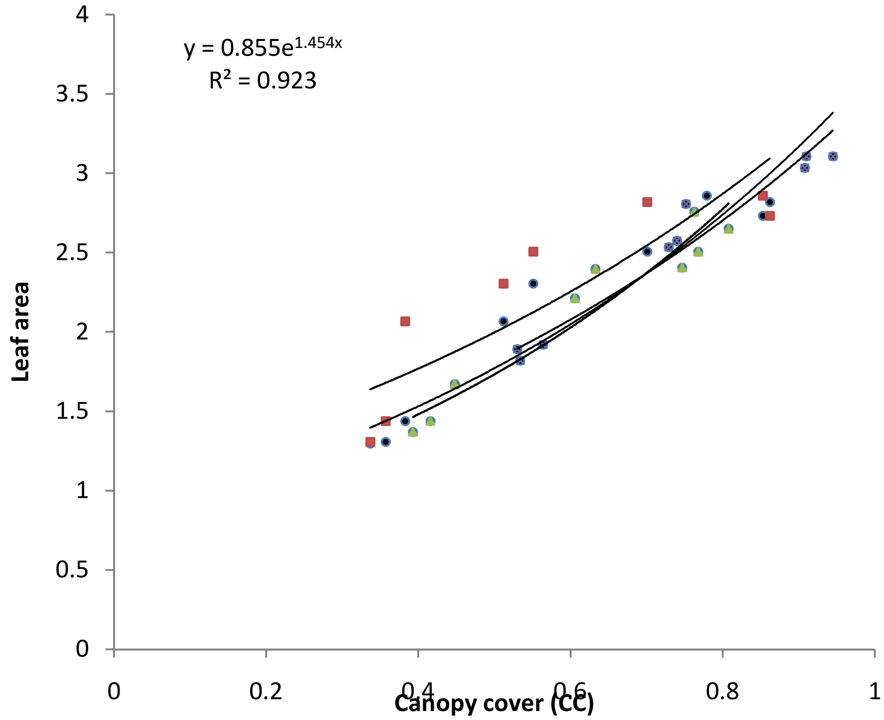


Fig. 10 The exponential relationship between canopy cover calculated from digital images and LA of maize

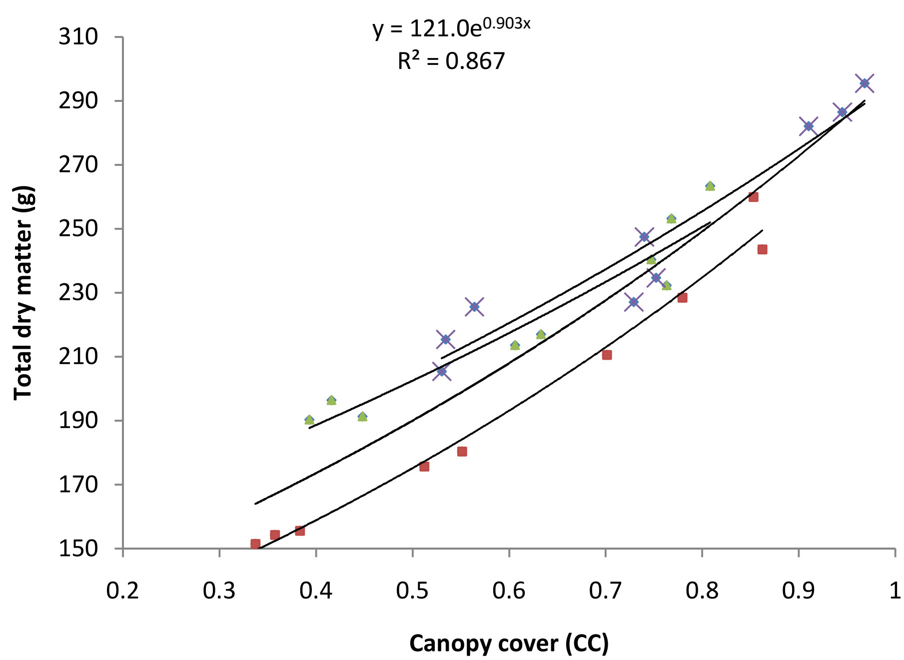


Fig 11. The exponential relationship between canopy cover calculated from digital images and TDM of maize

Calibration and validation of Stepwise multiple linear regression (SMLR) models for estimating plant growth and N nutrition parameters

As analyzed in the previous section, the nonlinear relationships of CC with all the parameters were statistically different among N fertilization levels and with LAI and shoot N accumulation among cultivars. The only exception was that the relationship of CC with SDW was not significantly different among cultivars. These results imply that not only cultivar but also color indices other than CC be included to compensate the effects of N fertilization levels in constructing the model for estimating crop growth and N nutrition parameters using color digital camera image analysis of maize canopy. Stepwise multiple linear regression (SMLR) analysis was carried out to formulate models to estimate LAI, SDW, and shoot N accumulation with CC and color indices derived from the analysis of digital camera images of maize canopy. The SMLR analysis extracted two to three variables at the significant level of $P = 0.05$ to enter and stay in the models for estimating LAI, SDW, and shoot N accumulation in calibration. Based on the results of previous analysis on nonlinear relationships of CC with all three parameters, ten models using CC and color indices were derived from SMLR analysis The statistics for evaluating the performance of SMLR models were presented in Table 3. The models for LAI had R^2 s ranging from 0.81 to 0.83 and REPs ranging from 16.1% to 21.0% in calibration datasets. R^2 s of the models for SDW were 0.81 and 0.83 and REPs were 30.0% and 32.6% in background segmented and background non-segmented datasets, respectively, And the models for shoot N accumulation had R^2 s ranging from 0.85 to 0.87 and REPs ranging from 18.7% to 22.5% in calibration datasets. The models derived from background segmented datasets showed better performance, when evaluated by R^2, RMSEP, and REP, than those from background non-segmented datasets in both calibration and validation. The model equations showing the best performance to estimate LAI, SDW, and shoot N accumulation were determined by the criteria of high R^2 values, low RMSEP, and REP, and the minimum variations of these statistics between calibration and validation. In this regard the five models were selected respectively for estimating LAI, SDW, and shoot N accumulation since the five models achieved relatively good precision and accuracy. Compared to the calibration, the R^2 values in validation were somewhat lower but RMSEP and REP were rather decreased in validation. However, the errors of models for LAI, SDW, and shoot N accumulation became greater as they increased. This indicates that the precision of the models decreased at the advanced growth stage of maize especially like the stem elongation stage.

Rice

Different morpho-physiological and digital parameters were significantly influenced by different varieties (Fig.12) of rice and level of nitrogen application (Fig. 12). Nitrogen rate and rice varieties both had had significant effects on rice morpho-physiological traits and yield. Among all treatments,grain yield was highest in the N3V2 treatment with 5.3MT ha^{-1}, while yield was the lowest in N0V3 treatment 2.80 MT ha^{-1}.

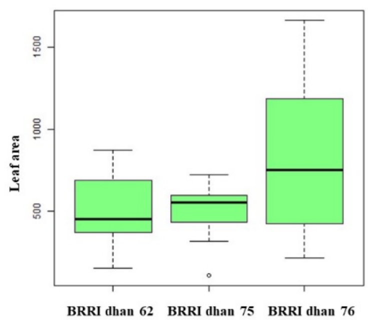


Fig.: Leaf area of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles

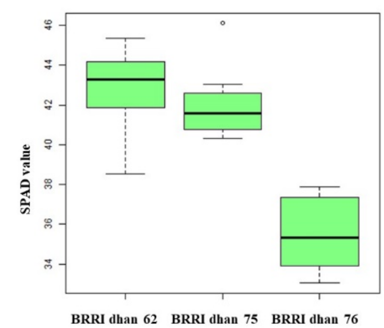


Fig.: SPAD value of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box.

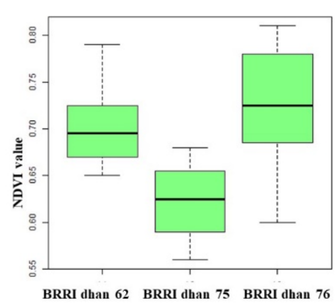


Fig.: NDVI value of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box.

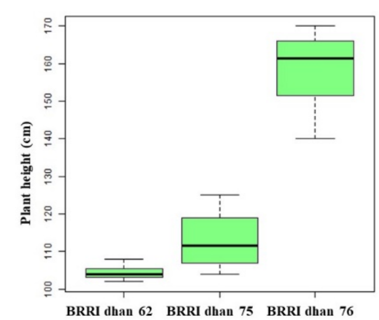
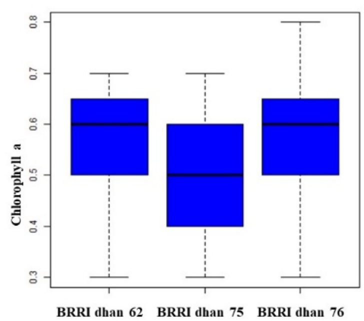
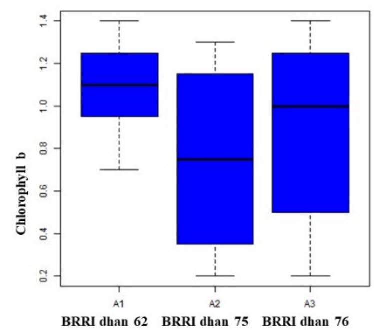


Fig.: Plant height of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box.

 Fig.: Chlorophyll a of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles	 Fig.: Chlorophyll b of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles
Fig. 12. Varital effect of rice on different morpho-physiological traits of rice	

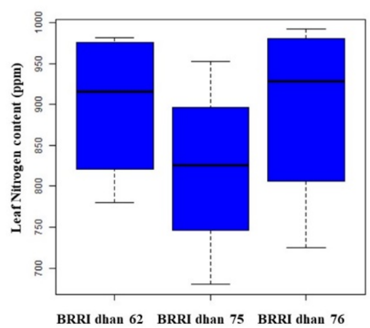


Fig.: Leaf nitrogen content of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles

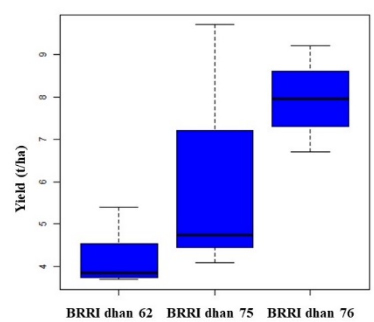


Fig.: Yield of different rice varieties. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles

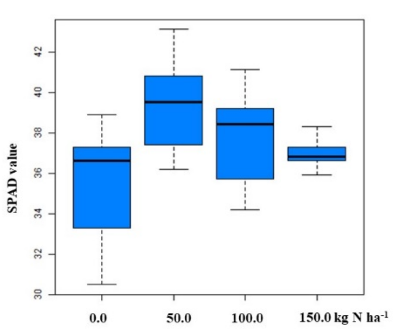


Fig.: Effect of nitrogen on SPAD value rice. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles

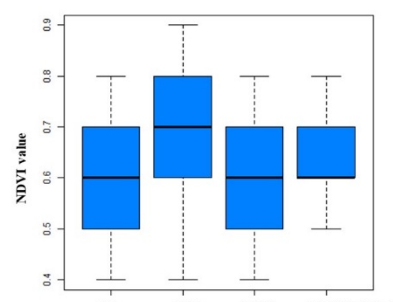


Fig.: Effect of nitrogen on NDVI value rice. Box edges show upper and lower quantile and the median as shown in the middle of the box. Individuals falling outside of the rank of whisker are shown as circles

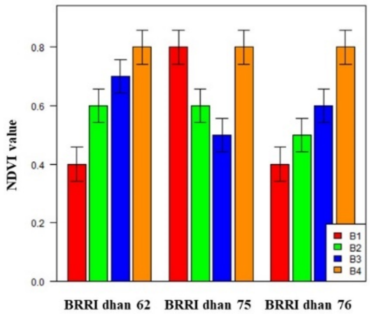


Fig.: Interaction effect of different varieties and different nitrogen doses on NDVI value of rice

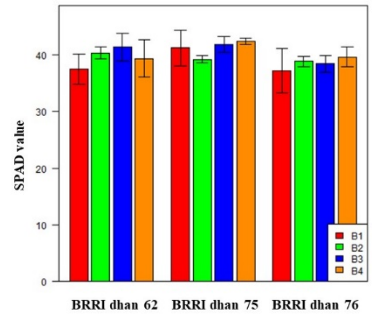


Fig.: Interaction effect of different varieties and different nitrogen doses on SPAD value of rice

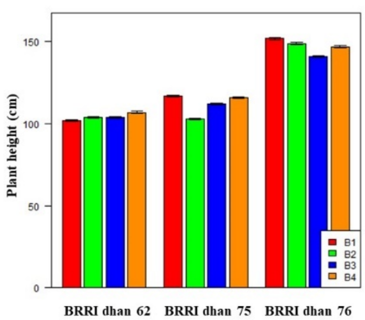


Fig.: Interaction effect of different varieties and different nitrogen doses on plant height of rice

Fig. 13. Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Table 5 . Correlation of growth parameters with color indices during 2017-18 of Rice

	CC	NDVI	SPAD	PH	LA	LN	Chl a	C hl b	Chl ab	SPMS	SPS	GPS	SI	GYPMS	HI%	YTPH	TDM	CCover	NDVIrgb	NDVIgreen	SR	BRAVIsr	SRrgb	HUEp
CC	1.00																							
NDVI	0.98	1.00																						
SPAD	0.89	0.81	1.00																					
PH	0.95	0.91	0.92	1.00																				
LA	0.06	0.12	0.06	0.08	1.00																			
LN	0.95	0.90	0.96	0.93	0.03	1.00																		
Chl a	0.81	0.71	0.94	0.90	-0.04	0.90	1.00																	
C hl b	0.68	0.58	0.89	0.80	0.04	0.81	0.94	1.00																
Chl ab	0.12	0.23	-0.07	0.05	-0.10	0.00	-0.08	-0.05	1.00															
SPMS	0.93	0.87	0.95	0.91	0.03	0.99	0.91	0.79	-0.06	1.00														
SPS	0.87	0.79	0.97	0.90	0.02	0.96	0.96	0.92	-0.08	0.96	1.00													
GPS	0.84	0.77	0.89	0.76	-0.12	0.93	0.81	0.71	-0.06	0.92	0.89	1.00												
SI	0.87	0.78	0.96	0.92	-0.05	0.96	0.98	0.92	-0.04	0.96	0.98	0.87	1.00											
GYPMS	0.82	0.75	0.92	0.84	-0.17	0.90	0.88	0.82	-0.08	0.90	0.93	0.86	0.93	1.00										
HI%	0.85	0.82	0.90	0.83	-0.04	0.92	0.84	0.80	0.06	0.92	0.93	0.87	0.90	0.95	1.00									
YTPH	0.46	0.55	0.18	0.33	0.33	0.28	0.04	-0.14	0.24	0.24	0.06	0.17	0.10	0.00	0.06	1.00								
TDM	0.79	0.70	0.93	0.84	-0.19	0.89	0.90	0.85	-0.15	0.89	0.93	0.86	0.94	0.99	0.90	-0.02	1.00							
CCover	0.80	0.85	0.59	0.63	0.23	0.72	0.50	0.34	0.33	0.71	0.58	0.67	0.57	0.50	0.65	0.59	0.43	1.00						
NDVIrgb	0.14	0.15	0.19	0.35	-0.12	0.18	0.34	0.33	0.11	0.20	0.24	-0.11	0.32	0.25	0.21	-0.04	0.25	-0.08	1.00					
NDVIgreen	0.63	0.71	0.35	0.43	0.38	0.51	0.20	0.09	0.34	0.48	0.34	0.50	0.31	0.30	0.47	0.55	0.20	0.85	-0.30	1.00				
SR	-0.70	-0.77	-0.45	-0.51	-0.36	-0.60	-0.29	-0.17	-0.29	-0.58	-0.44	-0.59	-0.40	-0.39	-0.55	-0.54	-0.30	-0.89	0.29	-0.99	1.00			
BRAVIsr	-0.73	-0.82	-0.47	-0.58	-0.36	-0.63	-0.35	-0.23	-0.35	-0.61	-0.48	-0.56	-0.45	-0.43	-0.59	-0.56	-0.33	-0.89	0.09	-0.97	0.98	1.00		
SRrgb	0.45	0.50	0.22	0.21	0.32	0.35	0.04	-0.04	0.20	0.31	0.19	0.48	0.13	0.15	0.29	0.44	0.09	0.70	-0.69	0.89	-0.89	-0.78	1.00	
HUEp	-0.76	-0.82	-0.54	-0.56	-0.30	-0.67	-0.35	-0.24	-0.19	-0.65	-0.52	-0.66	-0.46	-0.50	-0.65	-0.51	-0.41	-0.90	0.28	-0.93	0.96	0.93	-0.84	1

12. Research highlight/findings (Bullet point – max 10 nos.):

-Three software were developed for digital phenotyping of rice, maize and wheat (RCC_BARI for rice, MCC_BARI for Maize and WCC_BARI for Wheat)

-Developed algorithms for relationship between manual phenotyping and digital phenotyping

- Developed algorithms for relationship between leaf nitrogen and digital field image.

-Developing three mobile Apps for real time estimation of nitrogen fertilizer requirement for Rice, Maize and Wheat.

B. Implementation Position

1. **Procurement:**

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment					
i. High regulation DSLR camera	01	150000	01	150000	
ii. High configuration mobile	01	70000	01	70000	
iii. Ordinary android mobile	03	20000	03	18000	
iv. Android tab	01	20000	01	20000	
v. Brand Laptop with Genuine OS and Genuine Office 2016	01	100000	01	100000	
vi. High configuration All in one Brand Desktop with Genuine OS and Genuine Office 2016	01	80000	01	80000	
Total		**440000**		**438000**	
(b) Lab &field equipment					
i. Hand Green Seeker	01	180000	01	180000	
ii. Ion meter	03	150000	03	148500	
iii. IR gun	03	30000	03	28500	
Total		**360000**		**357000**	
G. Total		**800000**		**795000**	
(c) Other capital items					

2. **Establishment/renovation facilities:**

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. **Training/study tour/ seminar/workshop/conference organized:**

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	679360	682739	682739	0	100%	
B. Field research/lab expenses and supplies	1535000	1716478	1716478	0	100%	
C. Operating expenses	385640	198997	198997	0	100%	
D. Vehicle hire and fuel, oil & maintenance	200000	186800	186800	0	100%	
E. Training/workshop/seminar etc.	250000	0	0	0		
F. Publications and printing	110000	0	0	0	100%	
G. Miscellaneous	40000	20200	20200	0	80%	
H. Capital expenses	800000	795000	795000	0	100%	
	4000000	**3600214**	**3600214**	**0**	**97%**	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
To use digital camera image and software for assessment leaf nitrogen of rice, wheat and maize at different growth stage.	-Set three field experiments on rice, maize and wheat to estimate effect of nitrogen on growth and yield at three locations viz. Gazipur, Chittagong and Dinajpur - Collect image data by using camera, tab and mobile phone at different growth stages -Estimate leaf nitrogen content by using ion meter (Kodel-B-743, NO_3^-) at different growth stage - Measuring NDVI through hand green seeker at different growth stages. - Measure leaf chlorophyll content in laboratory	-Developed algorithms for relationship between manual phenotyping and digital phenotyping - Developed algorithms for relationship between leaf nitrogen and digital field image.	Digital phenotyping of rice, maize and wheat is possible through image processing(http://bariprecisionagriculture.org/).
To establish a relationship between morpho-	-Collect different morpho-physiological	-Established relationship between	

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
physiology parameters with image parameters of rice, wheat and maize.	data of rice, maize and wheat	morpho-physiology parameters with image parameters of rice, wheat and maize.	
To develop a mobile phone application for phenotyping and assessment of nitrogen requirement by image analyses	-Estimate leaf nitrogen content by using ion meter (Kodel-B-743, NO_3^-) at different growth stage - Measuring NDVI through hand green seeker at different growth stages. - Measure leaf chlorophyll content in laboratory	- Developed algorithms for relationship between leaf nitrogen and digital field image.	

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.	3-leaflet		
Journal publication	3 Journal paper		
Information development			
Other publications, if any		2 Abstract in conference	

F. Technology/Knowledge generation/Policy Support (as applied):

i. **Generation of technology (Commodity & Non-commodity):**

Three software's (RCC_BARI, MCC_BARI and WCC_BARI) were developed for digital phenotyping of rice, maize and wheat

ii. **Generation of new knowledge that help in developing more technology in future:**

The software's will be used for High throughput phenotyping (HTP) which is pre-requisite for precision agriculture

iii. **Technology transferred that help increased agricultural productivity and farmers' income:**

After fine-tuning and large-scale validation of the software's and mobile apps farmers can use the mobile application for real time estimation nitrogen requirement f

iv. **Policy Support:**

Policy support needed for precision agriculture

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring:

Report type	**Date of submission as per Plan/ schedule**	**Actual date of submission**	**Remarks**
a. Inception report	June, 2017	12/06/2017	
b. Statement of expenditure. (SoE)*	14/12/2017	10/09/2017, 10/10/17, 05/11/2017 10/12/2017	
c. Quarterly report(s)*	August, 2017	11/10/2017	
d. Six monthly report	14/12/2017	18/03/2018	
e. Procurement plan	August, 2017	08/11/2018	
f. Field Monitoring Report(s)**			

ii) Field Monitoring (time& No. of visit, Team visit and output):

Monitoring team	Date(s) of visit	Total visit till date (No.)	Remarks
Technical Division/ Unit, BARC	22.02.2018	01	
PIU-BARC, NATP-2	14.03.2018	01	
Internal Monitoring	05.09.2017, 16.10.2017 and 19.02.2018	03	
Others Visitors (WBeam, HDSTU)	23.03.2018	02	

I. Lesson Learned/Challenges (if any)

i) Digital image has good potential for phenotyping of cereals like wheat, maize and Rice.

ii) Digital image has good potential for assessment of nitrogen fertilizer requirement for wheat, maize and Rice.

J. Challenges (if any)

The project work is a hybrid between two basic sciences like biological science and computational science. So, big challenge is understanding and coordination between biological science and computational science.

06.08.2019

Signature of the Principal Investigator

Seal

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06.8.2019

Counter signature of the Head of the organization/authorized representative

Seal

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PROJECT: DEVELOPMENT OF MOBILE APPS FOR ASSESSMENT OF NITROGEN FERTILIZER IN CEREAL CROPS (CRG, NATP-2)

Appendices (Maize)

Appendix -1(I). ANOVA for NDVI of different growth stage of Maize during 2017-18

Source	df	NDVI						
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	0.000048	0.000070	0.000033	0.000004	0.000059	0.000470371	0.00023
Variety	2	0.000181	0.001270	0.000144	0.002359	0.000093	0.0028037	0.00014
Error(a)	4	0.000181	0.000115	0.000078	0.000015	0.000015	0.000103704	0.00001
Nitrogen	2	0.007337	0.009348	0.008411	0.008426	0.015737	0.0169593	0.00781
Variety: Nitrogen	4	0.000220	0.000109	0.000022	0.001120	0.000093	0.000225926	0.00016
Error(b)	12	0.000231	0.000028	0.000057	0.000061	0.000069	0.000103704	0.00009

Appendix -1(II). ANOVA for SPAD of different growth stage of Maize during 2017-18

Source	df	SPAD						
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	10.0845	5.13001	4.88481	4.20259	1.0237	0.36148	4.47147
Variety	2	42.4878	2.94334	1.22259	24.3615	2.9337	1.46926	9.82704
Error(a)	4	4.04889	0.893333	1.63093	0.687038	3.04759	1.60148	1.32815
Nitrogen	2	632.434	432.335	384.274	313.467	261.083	320.863	231.083
Variety: Nitrogen	4	22.3472	1.75111	3.44315	2.23315	1.28815	8.3926	3.42093
Error(b)	12	3.12408	1.51444	1.66611	2.35667	1.49408	1.79759	1.85648

Appendix -1(III). ANOVA for plant height of different growth stage of Maize during 2017-18

Source	Df	PH							
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS
Replication	2	1.5137	1.44444	2.48148	3.81481	1.92593	5.61445	6.37408	0.482592
Variety	2	0.979259	17.3333	72.7037	32.1481	45.8148	25.5345	37.9486	19.6104
Error(a)	4	0.432593	1.77778	5.92593	0.648148	1.09259	1.49722	1.40358	1.50704
Nitrogen	2	187.405	257.333	387.704	354.926	539.371	376.981	600.68	355.427
Variety: Nitrogen	4	0.25037	1.33333	13.3148	1.09259	9.7037	2.89722	10.7141	11.8598
Error(b)	12	0.737404	0.666661	5.94443	0.703686	1.98146	0.919073	2.51789	2.64611

Appendix -1(IV). ANOVA for leaf nitrogen (N2) content of different growth stage of Maize during 2017-18

Source	df	Leaf N_2 Content (ppm)					
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS
Replication	2	5833.33	1481.48	3233.33	2311.11	4159.26	2803.7
Variety	2	110833	104815	107878	183244	142781	148181
Error(a)	4	4166.67	3703.7	277.778	88.8889	1325.93	498.148
Nitrogen	2	360833	444815	60033.3	67733.3	106804	127159
Variety: Nitrogen	4	416.667	2037.04	1777.78	1044.44	1870.37	11087
Error(b)	12	4444.44	3518.52	396.291	229.629	659.255	1755.55

Appendix -1(V). ANOVA for leaf area of different growth stage of Maize during 2017-18

Source	Df	Leaf area						
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	1058.65	2562.13	3352.84	3255.36	9080.03	8858.56	22979
Variety	2	10054.9	2017.04	1925.88	1859.19	21012.2	77935.9	3070.31
Error(a)	4	63.374	112.243	1096.33	1208.25	3686.68	716.913	6154.59
Nitrogen	2	235880	137305	73590.9	118991	388663	646458	472175
Variety: Nitrogen	4	4882.88	1019.28	189.439	531.372	1516.75	9102.17	1046.49
Error(b)	12	552.873	302.769	613.717	392.96	1761.3	2466.66	1428.43

Appendix -1(VI). ANOVA for TDM of different growth stage of Maize during 2017-18

Source	Df	TDM							
		20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS
Replication	2	0.690476	0.777778	1.92593	1.59259	4.92593	4.03704	7.7037	0.690476
Variety	2	5.14153	0.111111	2.92593	30.8148	4.92593	4.14815	1.59259	5.14153
Error(a)	4	3.163	0.888889	0.537037	0.925926	0.87037	1.2037	1.92593	3.163
Nitrogen	2	102.275	269.778	743.815	606.037	326.926	621.593	878.37	102.275
Variety: Nitrogen	4	1.73803	4.22222	3.25926	10.8704	1.7037	3.09259	4.92593	1.73803
Error(b)	12	1.57214	0.740741	2.77773	1.48149	0.944435	2.37037	3.85186	1.57214

Appendix -1(VIII). ANOVA for different traits of Maize during 2017-18

Source	Df	EH	DFT	MP	TEM	NPPM	NCPM	CL	NRPC
Replication	2	9.14815	1.81481	2.52	0	1.14815	1.14815	1.59259	0.14815
Variety	2	8.03704	279.37	1.42333	0	3.37037	3.37037	3.59259	0.14815
Error(a)	4	1.42593	3.59259	1.375	0	1.59259	1.59259	2.25926	1.03704
Nitrogen	2	991.815	1160.48	5.47	0	78.2592	78.2592	152.259	64.1482
Variety: Nitrogen	4	12.0926	5.09259	0.565	0	0.703704	0.70370	1.42593	0.37037
Error(b)	12	5.88888	4.55557	0.913333	0	1.05556	1.05556	0.648154	0.74074

Appendix -1(IX). ANOVA for different traits of Maize during 2017-18

Source	df	NSPR	NSPC	FW	TSW	YTPH
Replication	2	3.44444	645.481	0.0415815	186.333	186.333
Variety	2	3.44445	16387.7	0.22517	443.444	443.444
Error(a)	4	0.888889	668.315	0.0175148	54.7778	54.7778
Nitrogen	2	274.333	126662	8.05016	38650.1	38650.1
Variety: Nitrogen	4	2.44444	1506.04	0.0905426	29.8889	29.8889
Error(b)	12	1.85186	1026.2	0.0774759	563.852	563.852

Appendix -1(X). ANOVA for different digital traits of Maize during 2017-18

Source	Df	PPixel	CCover	R	G	B	SumRGB	r	G
Replication	2	56.2593	584713000000.00	0.0014393	9.92593	15.4444	36.7778	111.259	0.000039
Variety (V)	2	121.593	5346370000000.00	0.0131606	7.37037	3.44444	4.11111	14.7037	0.000046
Error(a)	4	2.53704	21766700000000.00	0.0535808	5.7037	15.5556	17.0556	47.5926	0.000146
Nitrogen (N)	2	2997.82	1910070000000.00	0.0047018	2.25926	4.11111	7	15.8148	0.000003
Variety: Nitrogen	4	49.2593	2130360000000.00	0.0052441	1.37037	3.55556	1.11111	8.14815	0.000004
Error(b)	12	36.611	949029000000.00	0.0023361	2.83333	4.01852	3.96296	20.8704	0.000009

Appendix -1(XI). ANOVA for different digital traits of Maize during 2017-18

Source	Df	b	INT	SAT	HUE	EIG	MEGI	NDI	NDVIrgb
Replication	2	0.0001026	0.00027	12.3621	0.002392	0.00257228	0.000924	0.000923546	0.0000069
Variety (V)	2	0.0000014	0.00006	1.63375	0.000558	0.00228102	0.000012	1.24851E-05	0.0000781
Error(a)	4	0.0000144	0.00012	5.28807	0.001079	0.00736368	0.000129	0.000129158	0.0003982
Nitrogen (N)	2	0.0000440	0.00007	1.7572	0.000585	0.00029082	0.000396	0.000396419	0.0000258
Variety: Nitrogen	4	0.0000127	0.00002	0.90535	0.000140	0.00016766	0.000114	0.000114449	0.0000228
Error(b)	12	0.0000128	0.00003	2.31893	0.000253	0.00053231	0.000115	0.00011541	0.0000249

Appendix -1(XII). ANOVA for different digital traits of Maize during 2017-18

Source	df	NDVIgree n	SAVIgreen	GMR	SR	VARI	BRAVI
Replication	2	0.0031747	0.000013	0.000010	0.000018	0.000071	0.000061
Variety (V)	2	0.0016360	0.000159	0.000058	0.000032	0.000761	0.000274
Error(a)	4	0.0043347	0.000830	0.000315	0.000201	0.003722	0.001115
Nitrogen (N)	2	0.0005462	0.000053	0.000028	0.000029	0.000240	0.000013
Variety: Nitrogen	4	0.0001640	0.000048	0.000021	0.000017	0.000209	0.000034
Error(b)	12	0.0004474	0.000052	0.000021	0.000016	0.000228	0.000061

Appendix -1(XIII). ANOVA for different digital traits of Maize during 2017-18

Source	Df	BRAVIsr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb
Replication	2	0.0000013	0.000025	0.00017	0.000011	0.000014
Variety (V)	2	0.0000016	0.000000	0.00037	0.000058	0.000117
Error(a)	4	0.0000114	0.000004	0.00133	0.000314	0.000612
Nitrogen (N)	2	0.0000019	0.000011	0.00001	0.000029	0.000045
Variety: Nitrogen	4	0.0000011	0.000003	0.00003	0.000021	0.000037
Error(b)	12	0.0000010	0.000003	0.00008	0.000021	0.000039

Appendix -2 (I). Mean effect of Maize varieties on NDVI

	NDVI						
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981	0.450	0.501	0.542	0.596	0.630	0.697	0.734
BHM9	0.442	0.478	0.544	0.566	0.624	0.667	0.727
P3396	0.450	0.486	0.550	0.591	0.624	0.666	0.732
SE	0.004	0.004	0.003	0.001	0.001	0.003	0.001
LSD (0.05)	0.018	0.014	0.012	0.005	0.005	0.013	0.004

Appendix -2 (II). Mean effect of Maize varieties on SPAD value

	SPAD						
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981	42.322	43.189	45.878	50.022	55.456	61.678	65.756
BHM9	37.978	43.622	45.156	51.578	55.456	60.933	65.900
P3396	40.233	44.322	45.389	48.289	54.467	61.033	67.633
SE	0.671	0.315	0.426	0.276	0.582	0.422	0.384
LSD (0.05)	2.629	1.235	1.669	1.083	2.281	1.653	1.506

Appendix -2 (III).Mean effect of Maize varieties on PH

	PH							
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	20DAS
981	51.111	57.667	71.111	74.889	79.667	87.733	103.901	114.711
BHM9	51.311	55.000	71.778	76.667	83.333	84.778	99.811	114.622
P3396	50.667	57.000	66.556	78.667	83.778	84.856	102.178	117.222
SE	0.219	0.444	0.811	0.268	0.348	0.408	0.395	0.409
LSD (0.05)	0.859	1.742	3.181	1.052	1.366	1.599	1.548	1.604

Appendix -2 (IV). Mean effect of wheat varieties on leaf area

	Leaf area						
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981	706.353	789.52	862.7	962.949	1291.88	1721.77	1806.74
BHM9	773.141	799.598	840.579	986.971	1382.88	1667.23	1839.00
P3396	737.259	818.976	868.221	988.632	1309.2	1540.4	1838.46
SE	2.65359	3.5315	11.0369	11.5866	20.2394	8.92508	26.15
LSD (0.05)	10.4015	13.8427	43.2624	45.417	79.3339	34.9844	102.50

Appendix -2 (V).Mean effect of Maize varieties on leaf nitrogen content

	Leaf nitrogen content (ppm)					
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS
981	1422.22	1566.67	1543.33	1588.89	1690	1581.11
BHM9	1222.22	1422.22	1428.89	1311.11	1713.33	1625.56
P3396	1238.89	1355.56	1324.44	1393.33	1484.44	1384.44
SE	21.5166	20.286	5.55556	3.1427	12.1378	7.43974
LSD (0.05)	84.3403	79.5168	21.7766	12.3187	47.5774	29.1622

Appendix -2 (VI).Mean effect of Maize varieties on total dry matter

	TDM						
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981	28.67	50.56	61.000	76.111	89.889	100.444	123.78
BHM9	28.56	50.22	58.333	76.222	90.333	99.667	122.22
P3396	28.44	49.44	57.444	74.889	89.000	99.778	129.22
SE	0.31	0.24	0.321	0.311	0.366	0.463	0.53
LSD (0.05)	1.23	0.96	1.257	1.219	1.434	1.813	2.08

Appendix -2 (VIII). Meaneffect of Maize varieties on yield and yield contributing characters of Maize

Variety	EH	DFT	MP	TEM	NPPM	NCPM
981	80.89	76.11	18.70	33	12.4444	12.4444
BHM9	81.22	86.44	18.60	33	12.5556	12.5556
P3396	79.44	84.89	19.33	33	13.5556	13.5556
SE	0.40	0.63	0.39	0	0.42066	0.42066
LSD (0.05)	1.56	2.48	1.53	0	1.6489	1.6489

Appendix -2 (IX). Meaneffect of Maize varieties on yield and yield contributing characters of Maize

Variety	CL	NRPC	NSPR	NSPC	FW	TSW
981	17.6667	16.000	36.222	614.333	2.730	348.00
BHM9	17.3333	15.778	35.000	662.333	2.503	357.22
P3396	18.5556	15.778	35.778	577.222	2.426	343.44
SE	0.501028	0.339	0.314	8.617	0.044	2.47
LSD (0.05)	1.96392	1.331	1.232	33.778	0.173	9.67

Appendix -2 (X). Meaneffect of Maize varieties on yield and yield contributing characters of Maize

Variety	PPixel	CCover	R	G	B	SumRGB
981	10769500.00	0.53	91.56	132.44	61.33	285.33
BHM9	9911330.00	0.49	91.78	132.00	60.22	284.00
P3396	11449400.00	0.57	90.11	131.22	61.44	282.78
SE	1555160.00	0.08	0.80	1.31	1.38	2.30
LSD (0.05)	6095890.00	0.30	3.12	5.15	5.40	9.01

Appendix -2 (XI). Meaneffect of Maize varieties on digital characters of Maize

Variety	R	G	b	INT	SAT	HUE
981	0.32	0.464	0.215	95.111	0.355	1.659
BHM9	0.32	0.465	0.212	94.667	0.364	1.641
P3396	0.32	0.464	0.217	94.259	0.348	1.673
SE	0.00	0.001	0.004	0.767	0.011	0.029
LSD (0.05)	0.02	0.005	0.014	3.005	0.043	0.112

Appendix -2 (XII). Meaneffect of Maize varieties on digital contributing characters of Maize

Variety	EIG	MEGI	NDI	NDVIrgb	NDVIgreen\	SAVIgreen
981	0.393	0.393	0.180	0.630	0.691	0.167
BHM9	0.394	0.394	0.177	0.615	0.695	0.165
P3396	0.392	0.392	0.183	0.642	0.687	0.170
SE	0.004	0.004	0.007	0.022	0.010	0.006
LSD (0.05)	0.015	0.015	0.026	0.086	0.038	0.023

Appendix -2 (XIII). Meaneffect of Maize varieties on digital characters of Maize

Variety	GMR	SR	VARI	BRAVI	BRAVIsr	EVIgreen
981	0.143	1.447	0.252	0.042	0.232	0.203
BHM9	0.142	1.438	0.246	0.041	0.233	0.196
P3396	0.145	1.457	0.257	0.042	0.232	0.208
SE	0.005	0.020	0.011	0.001	0.001	0.012
LSD (0.05)	0.019	0.080	0.044	0.004	0.002	0.048

Appendix -2 (XIV). Meaneffect of Maize varieties on digital characters of Maize

Variety	EVIgreen2	OSVIgreen	SRrgb	HUEp
981	0.160	0.227	0.473	94.6127
BHM9	0.158	0.224	0.478	93.6673
P3396	0.163	0.231	0.468	95.3328
SE	0.006	0.008	0.009	1.50083

LSD (0.05)	0.023	0.032	0.034	5.88293

Appendix -3 (I). Meaneffect of nitrogen on yield and yield contributing characters of Maizeduring 2017-18

	NDVI						
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N1 (100.0 kg/ha N_2)	0.421	0.456	0.514	0.554	0.587	0.634	0.702
N2 (200.0 kg/ha N_2)	0.478	0.520	0.576	0.616	0.670	0.721	0.761
N3 (300.0 kg/ha N_2)	0.443	0.489	0.547	0.582	0.622	0.673	0.730
SE	0.005	0.002	0.003	0.003	0.003	0.003	0.003
LSD (0.05)	0.016	0.005	0.008	0.008	0.009	0.010	0.009

Appendix -3 (II). Meaneffect of nitrogen on SPAD value of Maizeduring 2017-18

	SPAD						
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N1 (100.0 kg/ha N_2)	31.967	36.989	38.778	43.90	49.64	55.97	61.51
N2 (200.0 kg/ha N_2)	39.844	43.311	45.811	50.30	55.32	59.97	66.14
N3 (300.0 kg/ha N_2)	48.722	50.833	51.833	55.69	60.41	67.71	71.63
SE	0.589	0.410	0.430	0.51	0.41	0.45	0.45
LSD (0.05)	1.815	1.264	1.326	1.58	1.26	1.38	1.40

Appendix -3 (III). Meaneffect of nitrogen on plant height of Maizeduring 2017-18

	PH							
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS
N1 (100.0 kg/ha N_2)	46.39	51.44	63.44	70.56	74.22	79.11	94.65	108.84
N2 (200.0 kg/ha N_2)	51.19	56.11	69.44	76.56	82.89	86.22	100.47	116.39
N3 (300.0 kg/ha N_2)	55.51	62.11	76.56	83.11	89.67	92.03	110.78	121.32
SE	0.29	0.27	0.81	0.28	0.47	0.32	0.53	0.54
LSD (0.05)	0.88	0.84	2.50	0.86	1.45	0.98	1.63	1.67

Appendix -3 (IV). Meaneffect of nitrogen on leaf nitrogen of Maizeduring 2017-18

	LN (ppm)					
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS
N1 (100.0 kg/ha N_2)	1100.00	1222.22	1351.11	1346.67	1522.22	1405.56
N2 (200.0 kg/ha N_2)	1283.33	1455.56	1431.11	1426.67	1625.56	1543.33
N3 (300.0 kg/ha N_2)	1500.00	1666.67	1514.44	1520.00	1740	1642.22
SE	22.22	19.77	6.64	5.05	8.55865	13.9664
LSD (0.05)	68.47	60.93	20.45	15.56	26.3721	43.0354

Appendix -3 (V). Meaneffect of nitrogen on leaf area of Maizeduring 2017-18

	LA						
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N1 (100.0 kg/ha N_2)	561.366	677.799	765.553	872.32	1112.08	1356.2	1595.61
N2 (200.0 kg/ha N_2)	777.046	805.512	859.591	965.272	1345.27	1686.19	1835.06
N3 (300.0 kg/ha N_2)	878.342	924.782	946.355	1100.96	1526.62	1887.01	2053.55
SE	7.83775	5.80009	8.25777	6.60774	13.9893	16.5552	12.60
LSD (0.05)	24.1508	17.872	25.445	20.3607	43.1057	51.0121	38.82

Appendix -3 (VII). Meaneffect of nitrogen on yield and yield contributing characters of Maizeduring 2017-18

Nitrogen dose	EH	DFT	MP	TEM	NPPM	NCPM	CL
N0 (100.0 kg/ha N_2)	71.00	71.56	17.98	33.00	10.00	10.00	13.67
N2 (200.0 kg/ha N_2)	78.78	81.67	19.31	33.00	12.67	12.67	18.00
N3 (300.0 kg/ha N_2)	91.78	94.22	19.34	33.00	15.89	15.89	21.89
SE	0.81	0.71	0.32	0.00	0.34	0.34	0.27
LSD (0.05)	2.49	2.19	0.98	0.00	1.06	1.06	0.83

Appendix -3 (VIII). Meaneffect of nitrogen on yield and yield contributing characters of Maizeduring 2017-18

Nitrogen dose	NRPC	NSPR	NSPC	FW	TSW	YTPH
N1 (100.0 kg/ha N_2)	13.11	29.89	495.67	1.56	279.56	9.76
N2 (200.0 kg/ha N_2)	16.00	36.22	625.67	2.66	359.67	13.84
N3 (300.0 kg/ha N_2)	18.44	40.89	732.56	3.44	409.44	16.45
SE	0.29	0.45	10.68	0.09	7.92	0.42
LSD (0.05)	0.88	1.40	32.90	0.29	24.39	1.29

Appendix -3 (IX). Meaneffect of nitrogen on total dry matter of Maizeduring 2017-18

		TDM					
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N1 (100.0 kg/ha N_2)	23.44	40.56	51.22	69.22	81.89	91.00	108.56
N2 (200.0 kg/ha N_2)	27.89	51.00	58.00	76.89	88.89	98.33	122.00
N3 (300.0 kg/ha N_2)	34.33	58.67	67.56	81.11	98.44	110.56	144.67
SE	0.29	0.56	0.41	0.32	0.51	0.65	2.02
LSD (0.05)	0.88	1.71	1.25	1.00	1.58	2.02	6.21

Appendix -3 (X). Meaneffect of nitrogen on digital characters of Maizeduring 2017-18

Nitrogen dose	PPixel	CCover	R	G	B	SumRGB	r
N1 (100.0 kg/ha N_2)	10446900.00	0.52	91.67	132.22	61.67	285.56	0.32
N2 (200.0 kg/ha N_2)	10441300.00	0.52	90.67	131.11	61.33	283.11	0.32
N3 (300.0 kg/ha N_2)	11242000.00	0.56	91.11	132.33	60.00	283.44	0.32
SE	324727	0.02	0.56	0.67	0.66	1.52	0.00
LSD (0.05)	1000590	0.05	1.73	2.06	2.04	4.69	0.00

Appendix -3 (XI). Meaneffect of nitrogen on digital characters of Maizeduring 2017-18

Nitrogen dose	G	b	INT	SAT	HUE	EIG	MEGI
N1 (100.0 kg/ha N_2)	0.463	0.216	95.185	0.352	1.658	0.389	0.389
N2 (200.0 kg/ha N_2)	0.463	0.217	94.370	0.350	1.663	0.389	0.389
N3 (300.0 kg/ha N_2)	0.467	0.212	94.482	0.365	1.652	0.401	0.401
SE	0.001	0.002	0.508	0.005	0.008	0.004	0.004
LSD (0.05)	0.004	0.005	1.564	0.016	0.024	0.011	0.011

Appendix -3 (XII). Meaneffect of nitrogen on digital characters of Maizeduring 2017-18

Nitrogen dose	NDI	NDVIrgb	NDVIgreen	SAVIgreen	GMR	SR	VARI
N1 (100.0 kg/ha N_2)	0.179	0.631	0.693	0.166	0.142	1.443	0.250
N2 (200.0 kg/ha N_2)	0.180	0.635	0.692	0.167	0.143	1.446	0.252
N3 (300.0 kg/ha N_2)	0.182	0.620	0.689	0.169	0.145	1.453	0.252
SE	0.002	0.007	0.002	0.002	0.001	0.005	0.003
LSD (0.05)	0.005	0.022	0.007	0.005	0.004	0.016	0.008

Appendix -3 (XIII). Meaneffect of nitrogen on yield and yield contributing characters of Maizeduring 2017-18

Nitrogen dose	BRAVI	BRAVIsr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb	HUEp
N1 (100.0 kg/ha N_2)	0.041	0.232	0.201	0.159	0.226	0.473	94.548
N2 (200.0 kg/ha N_2)	0.042	0.232	0.203	0.160	0.227	0.471	94.8304
N3 (300.0 kg/ha N_2)	0.042	0.234	0.202	0.162	0.230	0.474	94.2345
SE	0.000	0.001	0.003	0.002	0.002	0.002	0.403735
LSD (0.05)	0.001	0.002	0.009	0.005	0.006	0.007	1.24404

Appendix -4 (I). Interaction effect of nitrogen doses and varieties on NDVI of Maize during 2017-18

	NDVI						
Inter-action	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981×100	0.423	0.473	0.510	0.567	0.593	0.647	0.700
981×200	0.443	0.497	0.543	0.593	0.623	0.700	0.730
981×300	0.483	0.533	0.573	0.627	0.673	0.743	0.773
BHM9×100	0.407	0.447	0.517	0.553	0.583	0.623	0.703
BHM9×200	0.443	0.477	0.543	0.567	0.617	0.660	0.727
BHM9×300	0.477	0.510	0.573	0.577	0.673	0.717	0.750
P3396×100	0.433	0.447	0.517	0.543	0.583	0.633	0.703
P3396×200	0.443	0.493	0.553	0.587	0.627	0.660	0.733
P3396×300	0.473	0.517	0.580	0.643	0.663	0.703	0.760
SE	0.009	0.003	0.004	0.005	0.005	0.006	0.005
LSD (0.05)	0.027	0.009	0.013	0.014	0.015	0.018	0.016

Appendix -4 (II). Interaction effect of nitrogen doses and varieties on SPAD value of Maize during 2017-18

	SPAD						
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981×100	33.50	36.53	39.60	44.200	49.767	56.267	61.83
981×200	42.70	42.37	46.43	50.767	56.367	61.400	65.57
981×300	50.77	50.67	51.60	55.100	60.233	67.367	69.87
BHM9×100	30.50	37.53	39.30	45.433	50.367	55.067	60.57
BHM9×200	34.43	42.73	44.57	52.400	55.400	58.200	64.97
BHM9×300	49.00	50.60	51.60	56.900	60.600	69.533	72.17
P3396×100	31.90	36.90	37.43	42.067	48.800	56.567	62.13
P3396×200	42.40	44.83	46.43	47.733	54.200	60.300	67.90
P3396×300	46.40	51.23	52.30	55.067	60.400	66.233	72.87
SE	1.02	0.71	0.75	0.886	0.706	0.774	0.79
LSD (0.05)	3.14	2.19	2.30	2.731	2.175	2.385	2.42

Appendix -4 (III). Interaction effect of nitrogen doses and varieties on plant height characters of Maize during 2017-18

	PH							
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS
981×100	46.57	51.67	62.67	68.67	73.33	80.33	97.10	110.17
981×200	50.90	57.67	73.00	75.33	78.67	88.43	104.03	115.00
981×300	55.87	63.67	77.67	80.67	87.00	94.43	110.57	118.97
BHM9×100	46.60	50.33	65.67	70.33	75.67	79.33	93.00	107.87
BHM9×200	51.67	54.33	71.33	76.00	84.33	84.33	97.67	116.00
BHM9×300	55.67	60.33	78.33	83.67	90.00	90.67	108.77	120.00
P3396×100	46.00	52.33	62.00	72.67	73.67	77.67	93.83	108.50
P3396×200	51.00	56.33	64.00	78.33	85.67	85.90	99.70	118.17
P3396×300	55.00	62.33	73.67	85.00	92.00	91.00	113.00	125.00
SE	0.50	0.47	1.41	0.48	0.81	0.55	0.92	0.94
LSD (0.05)	1.53	1.45	4.34	1.49	2.50	1.71	2.82	2.89

Appendix -4 (IV). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of Maize during 2017-18

	LN					
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS
981×100	1233.33	1366.67	1486.67	1513.33	1606.67	1483.33
981×200	1416.67	1566.67	1546.67	1586.67	1670	1580
981×300	1616.67	1766.67	1596.67	1666.67	1793.33	1680
BHM9×100	1033.33	1166.67	1333.33	1233.33	1613.33	1553.33
BHM9×200	1200.00	1433.33	1433.33	1286.67	1713.33	1610
BHM9×300	1433.33	1666.67	1520.00	1413.33	1813.33	1713.33
P3396×100	1033.33	1133.33	1233.33	1293.33	1346.67	1180
P3396×200	1233.33	1366.67	1313.33	1406.67	1493.33	1440
P3396×300	1450.00	1566.67	1426.67	1480	1613.33	1533.33
SE	38.49	34.25	11.49	8.74888	14.824	24.1906
LSD (0.05)	118.60	105.53	35.41	26.9583	45.6779	74.5394

Appendix -4 (V). Interaction effect of nitrogen doses and varieties on leaf area characters of Maize during 2017-18

	LA						
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981×100	548.697	672.403	771.247	864.183	1078.25	1463.66	1582.01
981×200	770.993	804.797	856.373	953.037	1303.93	1775.47	1807.23
981×300	799.37	891.36	960.48	1071.63	1493.47	1926.19	2030.99
BHM9×100	580.657	677.993	750.487	880.707	1142.79	1397.04	1622.66
BHM9×200	780.773	784.44	848.773	975.887	1423.88	1726.4	1842.46
BHM9×300	957.993	936.36	922.477	1104.32	1581.96	1878.26	2051.88
P3396×100	554.743	683	774.927	872.07	1115.2	1207.91	1582.14
P3396×200	779.37	827.3	873.627	966.893	1307.98	1556.71	1855.48
P3396×300	877.663	946.627	956.11	1126.93	1504.43	1856.57	2077.76
SE	13.5754	10.046	14.3029	11.4449	24.2302	28.6744	21.82
LSD (0.05)	41.8304	30.9553	44.072	35.2658	74.6613	88.3555	67.24

Appendix -4 (VII). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of Maize during 2017-18

Nitrogen dose	EH	DFT	MP	TEM	NPPM	NCPM	CL
981×100	70.00	66.33	17.53	33.00	9.33	9.33	13.67
981×200	81.00	74.33	18.90	33.00	12.00	12.00	17.67
981×300	91.67	87.67	19.67	33.00	16.00	16.00	21.67
BHM9×100	71.67	75.00	17.93	33.00	9.67	9.67	12.67
BHM9×200	77.67	87.00	19.30	33.00	12.33	12.33	18.33
BHM9×300	94.33	97.33	18.57	33.00	15.67	15.67	21.00
P3396×100	71.33	73.33	18.47	33.00	11.00	11.00	14.67
P3396×200	77.67	83.67	19.73	33.00	13.67	13.67	18.00
P3396×300	89.33	97.67	19.80	33.00	16.00	16.00	23.00
SE	1.40	1.23	0.55	0.00	0.59	0.59	0.46
LSD (0.05)	4.32	3.80	1.70	0.00	1.83	1.83	1.43

Appendix -4 (VIII). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of Maize during 2017-18

Nitrogen dose	NRPC	NSPR	NSPC	FW	TSW	YTPH
981×100	13.33	31.00	468.00	1.66	279.67	10.68
981×200	16.00	36.33	631.00	2.86	357.33	13.73
981×300	18.67	41.33	744.00	3.66	407.00	17.00
BHM9×100	13.33	28.67	559.67	1.47	285.33	7.95
BHM9×200	16.00	36.67	673.00	2.49	371.00	13.59
BHM9×300	18.00	39.67	754.33	3.56	415.33	15.88
P3396×100	12.67	30.00	459.33	1.54	273.67	10.65
P3396×200	16.00	35.67	573.00	2.63	350.67	14.19
P3396×300	18.67	41.67	699.33	3.10	406.00	16.45
SE	0.50	0.79	18.50	0.16	13.71	0.72
LSD (0.05)	1.53	2.42	56.99	0.50	42.24	2.23

Appendix -4 (IX). Interaction effect of nitrogen doses and varieties on TDM of Maize during 2017-18

		TDM					
Nitrogen dose	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
981×100	23.67	40.33	53.67	69.67	82.67	93.00	108.33
981×200	28.67	52.33	61.67	78.00	89.33	98.67	121.67
981×300	33.67	59.00	67.67	80.67	97.67	109.67	141.33
BHM9×100	24.33	41.67	49.33	70.00	83.00	90.00	105.00
BHM9×200	27.67	51.00	56.67	77.00	89.00	98.33	115.00
BHM9×300	33.67	58.00	69.00	81.67	99.00	110.67	146.67
P3396×100	22.33	39.67	50.67	68.00	80.00	90.00	112.33
P3396×200	27.33	49.67	55.67	75.67	88.33	98.00	129.33
P3396×300	35.67	59.00	66.00	81.00	98.67	111.33	146.00
SE	0.50	0.96	0.70	0.56	0.89	1.13	3.49
LSD (0.05)	1.53	2.97	2.17	1.73	2.74	3.49	10.76

Appendix -4 (X). Interaction effect of nitrogen doses and varieties on digital characters of Maize during 2017-18

Nitrogen dose	PPixel	CCover	R	G	B	SumRGB	R
981×100	11194200.00	0.56	91.33	132.33	61.67	285.33	0.32
981×200	10345100.00	0.51	91.67	132.33	62.00	286.00	0.32
981×300	10769100.00	0.53	91.67	132.67	60.33	284.67	0.32
BHM9×100	10034800.00	0.50	93.00	133.67	60.67	287.33	0.32
BHM9×200	9485900	0.47	90.67	130.33	61.00	282.00	0.32
BHM9×300	10213300.00	0.51	91.67	132.00	59.00	282.67	0.32
P3396×100	10111800.00	0.50	90.67	130.67	62.67	284.00	0.32
P3396×200	11492800.00	0.57	89.67	130.67	61.00	281.33	0.32
P3396×300	12743500.00	0.63	90.00	132.33	60.67	283.00	0.32
SE	562444	0.03	0.97	1.16	1.15	2.64	0.0018
LSD (0.05)	1733080	0.09	2.99	3.57	3.54	8.13	0.0054

Appendix -4 (XI). Interaction effect of nitrogen doses and varieties on digital characters of Maize during 2017-18

Nitrogen dose	g	b	INT	SAT	HUE	EIG	MEGI
981×100	0.46	0.22	95.11	0.35	1.66	0.39	0.39
981×200	0.46	0.22	95.33	0.35	1.66	0.39	0.39
981×300	0.47	0.21	94.89	0.36	1.65	0.40	0.40
BHM9×100	0.47	0.21	95.78	0.37	1.64	0.40	0.40
BHM9×200	0.46	0.22	94.00	0.35	1.65	0.39	0.39
BHM9×300	0.47	0.21	94.22	0.37	1.63	0.40	0.40
P3396×100	0.46	0.22	94.67	0.34	1.67	0.38	0.38
P3396×200	0.46	0.22	93.78	0.35	1.67	0.39	0.39
P3396×300	0.47	0.21	94.33	0.36	1.67	0.40	0.40
SE	0.0021	0.0031	0.88	0.01	0.01	0.01	0.01

LSD (0.05)	0.0064	0.0094	2.71	0.03	0.04	0.02	0.02

Appendix -4 (XII). Interaction effect of nitrogen doses and varieties on digital characters of Maize during 2017-18

Nitrogen dose	NDI	NDVIrgb	NDVIgreen	SAVIgreen	GMR	SR	VARI
981×100	0.18	0.63	0.69	0.17	0.14	1.45	0.25
981×200	0.18	0.64	0.69	0.17	0.14	1.44	0.25
981×300	0.18	0.62	0.69	0.17	0.14	1.45	0.25
BHM9×100	0.18	0.61	0.70	0.16	0.14	1.44	0.25
BHM9×200	0.18	0.63	0.70	0.16	0.14	1.44	0.25
BHM9×300	0.18	0.60	0.69	0.17	0.14	1.44	0.25
P3396×100	0.18	0.65	0.69	0.17	0.14	1.44	0.25
P3396×200	0.18	0.64	0.69	0.17	0.15	1.46	0.26
P3396×300	0.19	0.64	0.68	0.17	0.15	1.47	0.26
SE	0.00	0.01	0.00	0.00	0.00	0.01	0.00
LSD (0.05)	0.01	0.04	0.01	0.01	0.01	0.03	0.01

Appendix -4 (XIII). Interaction effect of nitrogen doses and varieties on digital characters of Maize during 2017-18

Nitrogen dose	BRAVI	BRAVIsr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb	HUEp
981×100	0.042	0.232	0.205	0.16	0.23	0.47	94.91
981×200	0.041	0.232	0.203	0.16	0.23	0.47	94.86
981×300	0.042	0.233	0.200	0.16	0.23	0.48	94.07
BHM9×100	0.041	0.233	0.194	0.16	0.22	0.48	93.44
BHM9×200	0.041	0.231	0.199	0.16	0.22	0.47	94.33
BHM9×300	0.042	0.234	0.194	0.16	0.23	0.48	93.23
P3396×100	0.041	0.230	0.205	0.16	0.22	0.47	95.30
P3396×200	0.042	0.233	0.208	0.16	0.23	0.47	95.30
P3396×300	0.043	0.234	0.211	0.17	0.24	0.47	95.40
SE	0.001	0.001	0.005	0.00	0.00	0.00	0.70
LSD (0.05)	0.002	0.003	0.016	0.01	0.01	0.01	2.15

Appendices (Wheat)

Appendix -1(I). ANOVA for NDVI of different growth stage of wheat during 2017-18

Source	df	NDVI							
		10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	0.0017	0.0093	0.0060	0.0082	0.0049	0.0299	0.0013	0.0014
Variety	2	0.0312	0.0225	0.0158	0.0126	0.0153	0.0004	0.0139	0.0195
Error(a)	4	0.0002	0.0008	0.0006	0.0002	0.0007	0.0155	0.0008	0.0007
Nitrogen	4	0.0889	0.0830	0.0846	0.0844	0.0968	0.0591	0.0837	0.0774
Variety: Nitrogen	8	0.0040	0.0023	0.0014	0.0003	0.0003	0.0213	0.0006	0.0006
Error(b)	24	0.0003	0.0004	0.0006	0.0006	0.0005	0.0175	0.0007	0.0015

Appendix -1(II). ANOVA for SPAD of different growth stage of wheat during 2017-18

Source	df	SPAD							
		10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	8.19	10.47	5.18	5.67	2.82	2.42	3.89	8.20
Variety	2	26.38	70.45	59.28	54.88	34.91	29.40	35.43	30.14
Error(a)	4	1.12	0.97	1.56	1.58	0.83	0.89	1.81	2.49
Nitrogen	4	526.57	651.71	724.77	739.75	775.23	771.65	737.09	742.34
Variety: Nitrogen	8	7.61	11.90	8.74	9.52	14.25	11.60	14.38	14.48
Error(b)	24	1.19	1.79	1.86	1.99	1.58	1.38	1.88	2.36

Appendix -1(III). ANOVA for plant height of different growth stage of wheat during 2017-18

Source	df	PH							
		10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
Replication	2	5.36	6.67	12.29	4.27	16.16	4.69	9.49	21.49
Variety	2	37.42	0.80	31.49	76.07	134.29	178.42	77.62	35.62
Error(a)	4	1.72	0.77	1.56	0.83	2.56	0.62	2.16	0.22
Nitrogen	4	320.59	523.26	574.09	548.52	733.20	923.08	659.83	678.83
Variety: Nitrogen	8	6.17	2.02	1.49	5.04	5.57	4.06	2.82	2.07
Error(b)	24	1.21	1.82	2.19	1.95	1.64	4.78	2.57	2.76

Appendix -1(IV). ANOVA for leaf area of different growth stage of wheat during 2017-18

Source	Df	Leaf area				
		20DAS	40DAS	50DAS	60DAS	70DAS
Replication	2	281465	675640	1649540	4152780	445182
Variety	2	120435	2456440	1837750	13534900	28788000
Error(a)	4	4279	1707390	4277740	6255400	1490170
Nitrogen	4	15560900	9990260	15418500	10008100	19774900
Variety: Nitrogen	8	69475	1684630	7875540	24491700	24759200
Error(b)	24	34678	1710550	3396260	3926730	1426400

Appendix -1(V). ANOVA for leaf nitrogen (N_2) content of different growth stage of wheat during 2017-18

Source	df	Leaf N_2 Content (ppm)				
		20DAS	40DAS	50DAS	60DAS	70DAS
Replication	2	12666.70	20222.20	6222.22	23228.90	8926.66
Variety	2	4666.67	2888.89	6888.89	5282.22	148447.00
Error(a)	4	7333.33	4888.89	9555.55	17568.90	5523.34
Nitrogen	4	1054780.00	1196330.00	1697000.00	1979610.00	1705270.00
Variety: Nitrogen	8	3277.78	11500.00	6333.33	22037.80	15285.60
Error(b)	24	1611.10	6111.13	4555.60	23927.90	5841.15

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ndix -1(VI). ANOVA for TDM of different growth stage of wheat during 2017-18

		TDM				
Source	df	20DAS	40DAS	50DAS	60DAS	70DAS
Replication	2	32.67	11.56	4.67	16.67	2370.47
Variety	2	788.67	646.22	220.67	240.67	20014.50
Error(a)	4	5.33	1.56	2.33	5.33	932.93
Nitrogen	4	1918.33	2234.78	2016.33	1923.00	148369.00
Variety: Nitrogen	8	27.00	6.78	6.50	19.00	3778.58
Error(b)	24	5.28	2.94	3.94	4.67	757.39

Appendix -1(VII). ANOVA for TDM of different growth stage of wheat during 2017-18

		NDVI		
Source	df	NDVI070118	NDVI260118	NDVI050318
Replication	2	0.0055	0.0077	0.0040
Variety	2	0.0901	0.0539	0.0337
Error(a)	4	0.0019	0.0010	0.0004
Nitrogen	4	0.1674	0.1101	0.0905
Variety: Nitrogen	8	0.0011	0.0007	0.0010
Error(b)	24	0.0019	0.0004	0.0004

Appendix -1(VIII). ANOVA for different traits of wheat during 2017-18

Source	df	Chl a070118	C hl b070118	Chl (ab)070 118	Car0701 18	SPMS	SPS	GPS	Sl
Replication	2	0.0002	0.0004	0.0000	0.0000	381.27	0.60	1.40	0.10
Variety	2	0.0098	0.0654	0.0026	0.0001	394.87	8.87	145.87	5.22
Error(a)	4	0.0000	0.0005	0.0026	0.0001	186.33	0.47	2.47	0.09
Nitrogen	4	0.0343	0.0755	0.0051	0.0000	39631.40	67.31	475.61	39.96
Variety: Nitrogen	8	0.0008	0.0014	0.0009	0.0000	386.98	0.39	6.31	0.18
Error(b)	24	0.0001	0.0003	0.0027	0.0001	161.51	0.48	3.86	0.34

Appendix -1(IX). ANOVA for different traits of wheat during 2017-18

Source	df	SPMS	SPS	GPS	Sl	GYPMS	HI%	YTPH
Replication	2	381.27	0.60	1.40	0.10	2029.16	6.56	8.70
Variety	2	394.87	8.87	145.87	5.22	11561.40	32.61	3.60
Error(a)	4	186.33	0.47	2.47	0.09	500.29	3.79	0.49
Nitrogen	4	39631.40	67.31	475.61	39.96	148376.0	719.73	0.41
Variety: Nitrogen	8	386.98	0.39	6.31	0.18	2650.11	37.37	0.34
Error(b)	24	161.51	0.48	3.86	0.34	321.36	7.34	0.25

Appendix -1(X). ANOVA for different digital traits of wheat during 2017-18

Source	df	**CCover**	**R**	**G**	**B**	**SumRGB**	**r**	**g**	**b**
Replication	2	0.003	9.87	170	52.42	15	0.000	0.002	0.0008
Variety (V)	2	0.020	18.60	1131	70.82	1259	0.002	0.005	0.0016
Error(a)	4	0.002	13.57	195	7.29	206	0.000	0.001	0.0003
Nitrogen (N)	4	0.026	79.13	1264	36.61	1756	0.001	0.004	0.0019
Variety: Nitrogen	8	0.004	44.68	234	39.21	290	0.000	0.001	0.0008
Error(b)	24	0.010	56.33	585	15.86	892	0.000	0.002	0.0008

Appendix -1(XI). ANOVA for different digital traits of wheat during 2017-18

Source	df	**INT**	**SAT**	**HUE**	**EIG**	**MEGI**	**NDI**	**NDVIrgb**	**NDVIgreen**
Replication	2	1.71	0.01	0.15	0.01	0.02	0.00	0.00	0.02
Variety (V)	2	139.87	0.01	0.38	0.04	0.06	0.00	0.02	0.07
Error(a)	4	22.88	0.00	0.09	0.01	0.01	0.00	0.00	0.02
Nitrogen (N)	4	195.10	0.02	0.11	0.04	0.06	0.01	0.01	0.03
Variety: Nitrogen	8	32.27	0.01	0.08	0.01	0.01	0.00	0.00	0.01
Error(b)	24	99.15	0.01	0.08	0.01	0.02	0.00	0.00	0.02

Appendix -1(XII). ANOVA for different digital traits of wheat during 2017-18

Source	df	**SAVIgreen**	**GMR**	**SR**	**VARI**	**BRAVI**	**BRAVIsr**	**EVIgreen**	**EVIgreen2**
Replication	2	0.0034	0.0026	0.0262	0.0072	0.0003	0.0004	0.0034	0.0030
Variety (V)	2	0.0016	0.0013	0.0903	0.0026	0.0001	0.0012	0.0020	0.0016
Error(a)	4	0.0009	0.0006	0.0161	0.0028	0.0001	0.0003	0.0013	0.0007
Nitrogen (N)	4	0.0065	0.0051	0.0541	0.0123	0.0005	0.0009	0.0062	0.0059
Variety: Nitrogen	8	0.0005	0.0004	0.0153	0.0016	0.0000	0.0003	0.0008	0.0004
Error(b)	24	0.0023	0.0018	0.0269	0.0047	0.0002	0.0004	0.0025	0.0021

Appendix -1(XIII). ANOVA for different digital traits of wheat during 2017-18

Source	df	**OSVIgreen**	**SRrgb**	**HUEp**
Replication	2	0.0062	0.0016	70.7971
Variety (V)	2	0.0029	0.0119	386.2490
Error(a)	4	0.0017	0.0025	20.2352
Nitrogen (N)	4	0.0119	0.0035	252.9630
Variety: Nitrogen	8	0.0010	0.0012	40.4533
Error(b)	24	0.0042	0.0024	106.8800

Appendix -2 (I). Mean effect of wheat varieties on NDVI during 2017-18

	NDVI							
Variety	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
BARI Gom 26	0.561	0.648	0.687	0.739	0.793	0.843	0.821	0.799
BARI Gom 28	0.649	0.710	0.746	0.791	0.852	0.835	0.876	0.859
BARI Gom 30	0.587	0.639	0.693	0.743	0.801	0.845	0.825	0.795
SE	0.004	0.007	0.006	0.004	0.007	0.032	0.007	0.007
LSD (0.05)	0.014	0.029	0.024	0.016	0.027	0.126	0.028	0.027

Appendix -2 (II). Mean effect of wheat varieties on SPAD value during 2017-18

	SPAD							
Variety	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
BARI Gom 26	48.3	53.5	58.2	61.7	63.8	65.3	64.1	62.4
BARI Gom 28	46.0	49.5	54.2	57.9	60.7	62.5	61.0	59.6
BARI Gom 30	48.3	53.0	56.5	59.6	62.4	63.9	62.6	61.1
SE	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.4
LSD (0.05)	1.1	1.0	1.3	1.3	0.9	1.0	1.4	1.6

Appendix -2 (III). Mean effect of wheat varieties on PH during 2017-18

	PH							
Variety	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS
BARI Gom 26	43.5	53.1	57.9	64.4	69.7	80.1	88.3	91.0
BARI Gom 28	46.1	53.1	56.1	64.5	74.6	80.4	85.7	89.7
BARI Gom 30	46.3	53.5	58.9	60.5	69.2	74.3	83.7	87.9
SE	0.3	0.2	0.3	0.2	0.4	0.2	0.4	0.1
LSD (0.05)	1.3	0.9	1.3	0.9	1.6	0.8	1.5	0.5

Appendix -2 (IV). Mean effect of wheat varieties on leaf area during 2017-18

	Leaf area				
Variety	20DAS	40DAS	50DAS	60DAS	70DAS
BARI Gom 26	5435	7014	7037	6958	6866
BARI Gom 28	5503	7246	7505	5632	4726
BARI Gom 30	5613	6459	6820	7474	7320
SE	17	337	534	646	315
LSD (0.05)	66	1322	2093	2531	1235

Appendix -2 (V). Mean effect of wheat varieties on leaf nitrogen content during 2017-18

	Leaf nitrogen content				
Variety	20DAS	40DAS	50DAS	60DAS	70DAS
BARI Gom 26	1420	1673	1840	1660	1202
BARI Gom 28	1453	1647	1833	1638	1125
BARI Gom 30	1447	1653	1873	1623	1323
SE	22	18	25	34	19
LSD (0.05)	87	71	99	134	75

Appendix -2 (VI). Mean effect of wheat varieties on total dry matter during 2017-18

	TDM				
Variety	20DAS	40DAS	50DAS	60DAS	70DAS
BARI Gom 26	247.3	283.3	304.7	348.7	475.6
BARI Gom 28	238.7	266.0	305.3	356.0	406.9
BARI Gom 30	204.0	242.0	284.0	331.3	462.9
SE	1.9	1.0	1.2	1.9	7.9
LSD (0.05)	7.4	4.0	4.9	7.4	30.9

Appendix -2 (VII). Mean effect of wheat varieties on yield and yield contributing characters of wheat during 2017-18

Variety	Chl a070118	C hl b070118	Chl (ab)070118	Car070118	SPMS	SPS
BARI Gom 26	0.621	0.869	1.303	0.016	242.9	17.0
BARI Gom 28	0.572	0.740	1.316	0.018	239.3	15.5
BARI Gom 30	0.583	0.778	1.290	0.013	249.4	16.3
SE	0.002	0.006	0.013	0.003	3.5	0.2
LSD (0.05)	0.007	0.022	0.052	0.010	13.8	0.7

Appendix -2 (IX). Mean effect of wheat varieties on yield and yield contributing characters of wheat during 2017-18

Variety	GYPMS	HI%	YTPH
BARI Gom 26	318.5	66.0	2.78
BARI Gom 28	271.8	64.1	3.72
BARI Gom 30	321.1	67.0	3.03
SE	5.8	0.5	0.18
LSD (0.05)	22.6	2.0	0.70

Appendix -3 (I). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	NDVI							
Nitrogen dose	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N0 (0.0 kg/ha N_2)	0.453	0.527	0.571	0.622	0.678	0.721	0.707	0.690
N1 (80.0 kg/ha N_2)	0.559	0.630	0.663	0.709	0.752	0.804	0.782	0.761
N2 (100.0 kg/ha N_2)	0.609	0.673	0.717	0.764	0.824	0.873	0.862	0.834
N3 (120.0 kg/ha N_2)	0.662	0.714	0.771	0.820	0.882	0.933	0.910	0.886
N4(160.0 kg/ha N_2)	0.711	0.783	0.821	0.871	0.940	0.872	0.943	0.918
SE	0.005	0.007	0.008	0.008	0.007	0.044	0.009	0.013
LSD (0.05)	0.016	0.020	0.023	0.024	0.021	0.129	0.025	0.037

Appendix -3 (II). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	SPAD							
Nitrogen dose	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N0 (0.0 kg/ha N_2)	36.767	40.31	43.52	47.28	49.12	50.54	49.48	47.93
N1 (80.0 kg/ha N_2)	44.167	47.47	52.12	54.37	57.77	59.77	58.67	57.17
N2 (100.0 kg/ha N_2)	47.944	52.70	57.03	60.89	63.61	65.09	63.77	62.10
N3 (120.0 kg/ha N_2)	51.756	57.56	61.98	66.12	67.96	69.50	67.90	66.04
N4(160.0 kg/ha N_2)	56.956	62.06	66.72	69.87	73.10	74.61	73.11	71.86
SE	0.364	0.45	0.45	0.47	0.42	0.39	0.46	0.51
LSD (0.05)	1.063	1.30	1.33	1.37	1.22	1.14	1.33	1.50

Appendix -3 (III). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	PH							
Nitrogen dose	20DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS
N0 (0.0 kg/ha N_2)	37.22	42.56	46.22	52.33	58.22	65.00	73.78	77.11
N1 (80.0 kg/ha N_2)	41.78	49.56	53.78	59.22	67.33	71.67	81.44	85.11
N2 (100.0 kg/ha N_2)	46.22	53.89	58.56	63.78	72.00	79.22	86.89	91.22
N3 (120.0 kg/ha N_2)	48.67	58.11	62.89	67.67	76.22	85.11	92.11	95.11
N4(160.0 kg/ha N_2)	52.56	62.22	66.67	72.67	82.00	90.22	95.22	99.22
SE	0.37	0.45	0.49	0.47	0.43	0.73	0.53	0.55
LSD (0.05)	1.07	1.31	1.44	1.36	1.25	2.13	1.56	1.62

Appendix -3 (IV). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	LA				
Nitrogen dose	20DAS	40DAS	50DAS	60DAS	70DAS
N0 (0.0 kg/ha N_2)	3698.16	5439.04	6349.43	7167.66	7040.07
N1 (80.0 kg/ha N_2)	4748.34	6300.37	7103.7	7580.59	7525.21
N2 (100.0 kg/ha N_2)	5744.88	7044.24	7902.96	7416.1	7050.41
N3 (120.0 kg/ha N_2)	6395.16	7992.12	8803.46	6224.62	6079.71
N4(160.0 kg/ha N_2)	6998.17	7756.06	5443.22	5052.02	3824.43
SE	62.0738	435.96	614.298	660.533	398.106
LSD (0.05)	181.176	1272.44	1792.96	1927.91	1161.96

Appendix -3 (VI). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	LNC				
Nitrogen dose	20DAS	40DAS	50DAS	60DAS	70DAS
N0 (0.0 kg/ha N_2)	1044.44	1166.67	1255.56	1023.33	660.00
N1 (80.0 kg/ha N_2)	1233.33	1466.67	1600	1311.11	923.33
N2 (100.0 kg/ha N_2)	1377.78	1666.67	1900	1727.78	1253.33
N3 (120.0 kg/ha N_2)	1622.22	1877.78	2133.33	1983.33	1501.11
N4(160.0 kg/ha N_2)	1922.22	2111.11	2355.56	2155.56	1745.56
SE	13.3795	26.0579	22.4984	51.56	25.48
LSD (0.05)	39.051	76.0557	65.6665	150.50	74.36

Appendix -3 (VII). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

Nitrogen dose	Chl a070118	C hl b070118	Chl (ab)070118	Car070118	SPMS	SPS
N0 (0.0 kg/ha N_2)	0.51	0.66	1.284	0.015	156.889	12.556
N1 (80.0 kg/ha N_2)	0.56	0.76	1.341	0.019	199.222	14.667
N2 (100.0 kg/ha N_2)	0.60	0.80	1.294	0.015	251.778	16.556
N3 (120.0 kg/ha N_2)	0.63	0.86	1.285	0.013	292.667	18.111
N4(160.0 kg/ha N_2)	0.67	0.90	1.310	0.016	318.778	19.444
SE	0.00	0.01	0.017	0.003	4.236	0.232
LSD (0.05)	0.01	0.02	0.050	0.009	12.364	0.676

Appendix -3 (VIII). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

Nitrogen dose	GPS	Sl	TDM	GYPMS	HI%	YTPH
N0 (0.0 kg/ha N_2)	38.89	6.18	313.44	170.00	54.36	2.85
N1 (80.0 kg/ha N_2)	46.22	7.66	370.67	228.78	61.45	3.18
N2 (100.0 kg/ha N_2)	50.11	8.89	408.11	267.89	65.49	3.23
N3 (120.0 kg/ha N_2)	53.44	10.22	511.89	351.56	68.79	3.45
N4(160.0 kg/ha N_2)	58.00	11.56	638.22	500.89	78.49	3.19
SE	0.65	0.19	9.17	5.98	0.90	0.17
LSD (0.05)	1.91	0.57	26.78	17.44	2.64	0.48

Appendix -3 (IX). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

	TDM			
Nitrogen dose	20DAS	40DAS	50DAS	60DAS
N0 (0.0 kg/ha N_2)	165.56	198.89	240.00	286.67
N1 (80.0 kg/ha N_2)	206.67	236.67	267.78	317.78
N2 (100.0 kg/ha N_2)	235.56	263.33	296.67	343.33
N3 (120.0 kg/ha N_2)	256.67	291.11	324.44	374.44
N4(160.0 kg/ha N_2)	285.56	328.89	361.11	404.44
SE	2.42	1.81	2.09	2.28
LSD (0.05)	7.07	5.28	6.11	6.65

Appendix -3 (X). Mean effect of nitrogen on yield and yield contributing characters of wheat during 2017-18

Nitrogen dose	CCover	R	G	B	SumRGB
N0 (0.0 kg/ha N_2)	0.72	110.67	134.11	64.11	308.89
N1 (80.0 kg/ha N_2)	0.81	105.89	114.00	62.44	282.33
N2 (100.0 kg/ha N_2)	0.82	105.89	113.00	64.89	283.78
N3 (120.0 kg/ha N_2)	0.85	103.89	104.56	65.00	273.44
N4(160.0 kg/ha N_2)	0.85	103.00	105.78	68.00	276.78
SE	0.03	2.50	8.06	1.33	9.96
LSD (0.05)	0.09	7.30	23.54	3.87	29.06

Appendix -3 (XI). Mean effect of nitrogen on digital of wheat during 2017-18

Nitrogen dose	r	G	b	INT	SAT	HUE	EIG	MEGI
N0 (0.0 kg/ha N_2)	0.36	0.43	0.21	102.96	0.369	1.285	0.293	0.291
N1 (80.0 kg/ha N_2)	0.38	0.40	0.22	94.11	0.333	1.114	0.211	0.175
N2 (100.0 kg/ha N_2)	0.37	0.40	0.23	94.59	0.309	1.086	0.187	0.155
N3 (120.0 kg/ha N_2)	0.38	0.38	0.24	91.15	0.285	1.003	0.144	0.100
N4(160.0 kg/ha N_2)	0.37	0.38	0.25	92.26	0.257	1.036	0.140	0.090
SE	0.01	0.01	0.01	3.32	0.028	0.095	0.041	0.051
LSD (0.05)	0.02	0.04	0.03	9.69	0.082	0.278	0.119	0.149

Appendix -3 (XII). Mean effect of nitrogen on traits of wheat during 2017-18

Nitrogen dose	NDI	NDVIrgb	NDVIgreen\	SAVIgreen	GMR	SR	VARI	NDI
N0 (0.0 kg/ha N_2)	0.106	0.483	0.854	0.099	0.085	1.202	0.144	0.026
N1 (80.0 kg/ha N_2)	0.081	0.441	0.962	0.075	0.065	1.078	0.114	0.021
N2 (100.0 kg/ha N_2)	0.060	0.471	0.959	0.055	0.047	1.065	0.085	0.015
N3 (120.0 kg/ha N_2)	0.041	0.460	1.005	0.037	0.031	1.005	0.061	0.010
N4(160.0 kg/ha N_2)	0.038	0.506	0.992	0.035	0.029	1.021	0.057	0.009
SE	0.017	0.020	0.048	0.016	0.014	0.055	0.023	0.004
LSD (0.05)	0.050	0.058	0.139	0.047	0.041	0.160	0.067	0.012

Appendix -3 (XIII). Mean effect of nitrogen on digital traits of wheat during 2017-18

Nitrogen dose	BRAVIsr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb	HUEp	BRAVI
N0 (0.0 kg/ha N_2)	0.215	0.104	0.093	0.134	0.563	78.108	0.009
N1 (80.0 kg/ha N_2)	0.201	0.079	0.070	0.102	0.608	70.888	0.010
N2 (100.0 kg/ha N_2)	0.198	0.060	0.051	0.075	0.598	68.828	0.015
N3 (120.0 kg/ha N_2)	0.191	0.043	0.034	0.051	0.615	65.077	0.026
N4(160.0 kg/ha N_2)	0.190	0.041	0.032	0.048	0.596	65.434	0.021
SE	0.007	0.017	0.015	0.022	0.016	3.446	0.004
LSD (0.05)	0.021	0.048	0.044	0.063	0.048	10.058	0.012

Appendix -4 (I). Interaction effect of nitrogen doses and varieties on NDVI of wheat during 2017-18

	NDVI							
Inter-action	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N0×V_1	0.44	0.52	0.57	0.64	0.70	0.75	0.75	0.75
N_1×V_1	0.62	0.69	0.72	0.76	0.80	0.84	0.82	0.80
N_2×V_1	0.69	0.72	0.75	0.79	0.87	0.92	0.90	0.87
N_3×V_1	0.73	0.78	0.81	0.85	0.92	0.97	0.95	0.93
N4×V_1	0.77	0.83	0.87	0.91	0.97	0.69	0.97	0.95
N0×V_2	0.45	0.52	0.55	0.60	0.67	0.71	0.70	0.67
N_1×V_2	0.54	0.60	0.63	0.69	0.73	0.79	0.77	0.75
N_2×V_2	0.56	0.67	0.71	0.75	0.80	0.85	0.83	0.80
N_3×V_2	0.61	0.69	0.75	0.80	0.86	0.90	0.88	0.87
N4×V2	0.65	0.76	0.80	0.85	0.92	0.96	0.92	0.90
N0×V_3	0.48	0.54	0.59	0.62	0.67	0.70	0.67	0.65
N_1×V_3	0.52	0.60	0.64	0.68	0.73	0.78	0.75	0.74
N_2×V_3	0.58	0.62	0.69	0.75	0.80	0.85	0.86	0.83
N_3×V_3	0.64	0.67	0.75	0.81	0.87	0.93	0.90	0.86
N4×V3	0.72	0.76	0.80	0.85	0.93	0.97	0.94	0.91
SE	0.01	0.01	0.01	0.01	0.01	0.08	0.01	0.02
LSD (0.05)	0.03	0.03	0.04	0.04	0.04	0.22	0.04	0.06

Appendix -4 (II). Interaction effect of nitrogen doses and varieties on SPAD value of wheat during 2017-18

	SPAD							
Inter-action	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N0×V_1	35.40	40.67	44.03	47.97	51.33	52.60	51.43	50.00
N_1×V_1	42.03	44.77	49.13	51.30	55.10	57.77	56.87	55.10
N_2×V_1	46.43	49.60	54.07	58.23	60.57	61.77	60.73	59.70
N_3×V_1	50.33	54.20	59.37	63.30	65.60	67.30	64.30	62.37
N4×V_1	55.73	58.43	64.37	68.47	71.10	73.10	71.83	70.70
N0×V_2	39.40	42.40	45.77	49.93	50.37	51.23	50.80	49.00
N_1×V_2	46.13	49.87	55.13	57.10	60.33	62.27	61.00	59.70
N_2×V_2	49.00	54.20	58.57	62.43	65.30	67.07	65.70	63.40
N_3×V_2	51.37	58.50	63.13	68.07	69.43	70.90	69.83	68.30

SPAD								
Inter-action	10DAS	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS
N4×V2	55.60	62.63	68.17	70.83	73.50	75.07	73.20	71.63
N0×V_3	35.50	37.87	40.77	43.93	45.67	47.80	46.20	44.80
N_1×V_3	44.33	47.77	52.10	54.70	57.87	59.27	58.13	56.70
N_2×V_3	48.40	54.30	58.47	62.00	64.97	66.43	64.87	63.20
N_3×V_3	53.57	59.97	63.43	67.00	68.83	70.30	69.57	67.47
N4×V3	59.53	65.10	67.63	70.30	74.70	75.67	74.30	73.23
SE	0.63	0.77	0.79	0.81	0.73	0.68	0.79	0.89
LSD (0.05)	1.84	2.25	2.30	2.38	2.12	1.98	2.31	2.59

Appendix -4 (III). Interaction effect of nitrogen doses and varieties on plant height of wheat during 2017-18

PH									
Inter-action	20DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS	110DAS
N0×V_1	36.67	42.00	45.67	53.00	60.33	67.33	74.00	77.67	80.33
N_1×V_1	43.00	49.67	52.67	60.00	69.67	75.33	81.00	84.67	88.33
N_2×V_1	47.33	54.00	56.67	66.00	75.67	81.67	86.00	91.33	93.67
N_3×V_1	49.67	58.00	60.33	69.33	80.67	85.67	92.00	96.00	99.00
N4×V_1	54.00	62.00	65.00	74.00	86.67	92.00	95.33	99.00	101.00
N0×V_2	38.00	42.67	46.33	52.67	58.67	67.33	76.00	78.67	81.33
N_1×V_2	40.33	48.00	53.67	59.67	67.00	72.67	85.33	86.00	89.67
N_2×V_2	43.00	53.67	58.67	65.67	70.00	80.00	89.67	93.00	95.00
N_3×V_2	46.33	58.67	63.67	70.00	73.67	88.33	93.67	97.00	99.00
N4×V2	49.67	62.67	67.00	74.00	79.00	92.00	96.67	100.33	102.33
N0×V_3	37.00	43.00	46.67	51.33	55.67	60.33	71.33	75.00	75.00
N_1×V_3	42.00	51.00	55.00	58.00	65.33	67.00	78.00	84.67	88.33
N_2×V_3	48.33	54.00	60.33	59.67	70.33	76.00	85.00	89.33	91.00
N_3×V_3	50.00	57.67	64.67	63.67	74.33	81.33	90.67	92.33	96.00
N4×V3	54.00	62.00	68.00	70.00	80.33	86.67	93.67	98.33	100.67
SE	0.64	0.78	0.85	0.81	0.74	1.26	0.93	0.96	0.93
LSD (0.05)	1.85	2.27	2.49	2.35	2.16	3.69	2.70	2.80	2.71

Appendix -4 (V). Interaction effect of nitrogen doses and varieties on leaf area of wheat during 2017-18

LA					
Inter-action	20DAS	40DAS	50DAS	60DAS	70DAS
N0×V_1	3677.60	5854.00	6957.90	7206.00	7115.70
N_1×V_1	4710.13	6952.87	7866.17	8173.80	8103.47
N_2×V_1	5734.79	7933.97	8897.60	6590.20	6020.13
N_3×V_1	6403.77	8886.90	9768.90	1197.27	1136.90
N4×V_1	6986.83	6603.57	4033.33	4995.10	1253.03
N0×V_2	3621.90	5527.03	6855.03	7567.27	7454.47
N_1×V_2	4910.07	6309.97	7551.87	8037.70	8040.93
N_2×V_2	5688.93	6868.23	8111.17	8649.93	8512.63
N_3×V_2	6130.77	7657.43	8834.60	9402.73	9223.10
N4×V2	6825.10	8707.93	3832.53	1134.13	1100.93
N0×V_3	3794.97	4936.10	5235.37	6729.70	6550.03
N_1×V_3	4624.82	5638.27	5893.07	6530.27	6431.23
N_2×V_3	5810.91	6330.53	6700.10	7008.17	6618.47
N_3×V_3	6650.93	7432.03	7806.87	8073.87	7879.13
N4×V3	7182.57	7956.67	8463.80	9026.83	9119.33
SE	107.52	755.10	1064.00	1144.08	689.54
LSD (0.05)	313.81	2203.94	3105.50	3339.24	2012.58

Appendix -4 (VI). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of wheat during 2017-18

Inter-action	Chl a070118	C hl b070118	Chl (ab)070118	Car070118	SPMS	SPS
N0×V_1	0.51	0.617	1.270	0.019	150.67	11.67
N_1×V_1	0.53	0.708	1.349	0.022	178.00	13.67
N_2×V_1	0.57	0.735	1.329	0.015	253.33	15.33
N_3×V_1	0.60	0.791	1.310	0.020	292.00	17.67
N4×V_1	0.65	0.849	1.322	0.015	322.33	19.00
N0×V_2	0.51	0.726	1.293	0.011	154.00	13.33
N_1×V_2	0.58	0.861	1.335	0.018	196.33	15.67
N_2×V_2	0.64	0.892	1.289	0.016	250.00	17.67
N_3×V_2	0.67	0.914	1.281	0.012	299.67	18.67
N4×V2	0.70	0.951	1.314	0.022	314.67	19.67
N0×V_3	0.51	0.640	1.290	0.014	166.00	12.67
N_1×V_3	0.55	0.713	1.338	0.017	223.33	14.67
N_2×V_3	0.59	0.782	1.265	0.013	252.00	16.67
N_3×V_3	0.62	0.862	1.262	0.008	286.33	18.00
N4×V3	0.65	0.895	1.294	0.012	319.33	19.67
SE	0.01	0.011	0.030	0.005	7.34	0.40
LSD (0.05)	0.02	0.031	0.087	0.015	21.42	1.17

Appendix -4 (VII). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of wheat during 2017-18

Inter-action	GPS	Sl	TDM	GYPMS	HI%	YTPH
N0×V_1	36.67	5.87	321.33	159.33	49.79	3.70
N_1×V_1	45.00	6.97	314.00	181.33	57.74	3.55
N_2×V_1	47.33	8.33	332.00	210.67	63.47	4.00
N_3×V_1	51.33	9.67	441.67	308.00	69.76	4.18
N4×V_1	57.00	11.00	625.67	499.67	79.89	3.20
N0×V_2	37.33	6.33	340.00	194.33	57.16	2.22
N_1×V_2	43.00	8.33	401.67	256.33	63.90	2.93
N_2×V_2	48.00	9.67	439.67	299.67	68.19	2.68
N_3×V_2	51.67	11.00	556.67	377.33	67.89	2.80
N4×V2	58.00	12.33	640.00	465.00	72.71	3.27
N0×V_3	42.67	6.33	279.00	156.33	56.14	2.63
N_1×V_3	50.67	7.67	396.33	248.67	62.70	3.05
N_2×V_3	55.00	8.67	452.67	293.33	64.80	3.00
N_3×V_3	57.33	10.00	537.33	369.33	68.71	3.37
N4×V3	59.00	11.33	649.00	538.00	82.88	3.10
SE	1.13	0.34	15.89	10.35	1.56	0.29
LSD (0.05)	3.31	0.98	46.38	30.21	4.56	0.84

Appendix -4 (VIII). Interaction effect of nitrogen doses and varieties on yield and yield contributing characters of wheat during2017-18

	TDM			
Inter-action	TDM070 118(g)	TDM160 118(g)	TDM220118(g)	TDM290118(g)
N0×V_1	166.67	196.67	246.67	293.33
N_1×V_1	210.00	236.67	276.67	323.33
N_2×V_1	246.67	263.33	303.33	363.33
N_3×V_1	273.33	296.67	333.33	383.33
N4×V_1	296.67	336.67	366.67	416.67
N0×V_2	173.33	216.67	250.00	283.33
N_1×V_2	226.67	256.67	273.33	326.67
N_2×V_2	256.67	283.33	303.33	350.00
N_3×V_2	273.33	313.33	323.33	376.67
N4×V2	306.67	346.67	373.33	406.67
N0×V_3	156.67	183.33	223.33	283.33
N_1×V_3	183.33	216.67	253.33	303.33
N_2×V_3	203.33	243.33	283.33	316.67
N_3×V_3	223.33	263.33	316.67	363.33
N4×V3	253.33	303.33	343.33	390.00

TDM				
Inter-action	TDM070 118(g)	TDM160 118(g)	TDM220118(g)	TDM290118(g)
SE	4.19	3.13	3.63	3.94
LSD (0.05)	12.24	9.14	10.58	11.51

Appendix -4 (IX). Interaction effect of nitrogen doses and varieties on digital traits of wheat during 2017-18

Inter-action	PPixel	CCover	R	G	B	SumRGB
$N0\times V_1$	14578200.00	0.72	111.00	140.00	63.33	314.33
$N_1\times V_1$	16606300.00	0.82	111.00	107.00	66.00	284.00
$N_2\times V_1$	17778600.00	0.88	102.00	96.67	70.33	269.00
$N_3\times V_1$	17975100.00	0.89	101.33	94.00	68.33	263.67
$N4\times V_1$	17938700.00	0.89	98.00	97.00	65.33	260.33
$N0\times V_2$	13137500.00	0.65	112.67	140.67	66.00	319.33
$N_1\times V_2$	15837700.00	0.79	102.33	122.67	61.67	286.67
$N_2\times V_2$	15981900.00	0.79	105.67	121.67	65.00	292.33
$N_3\times V_2$	16687200.00	0.83	104.33	111.33	67.33	283.00
N4×V2	15973400.00	0.79	105.33	123.00	67.67	296.00
$N0\times V_3$	15806200.00	0.78	108.33	121.67	63.00	293.00
$N_1\times V_3$	16523000.00	0.82	104.33	112.33	59.67	276.33
$N_2\times V_3$	15846600.00	0.79	110.00	120.67	59.33	290.00
$N_3\times V_3$	16788500.00	0.83	106.00	108.33	59.33	273.67
N4×V3	17436300.00	0.87	105.67	97.33	71.00	274.00
SE	1135200.00	0.06	4.33	13.97	2.30	17.25
LSD (0.05)	3313330.00	0.16	12.65	40.77	6.71	50.34

Appendix -4 (X). Interaction effect of nitrogen doses and varieties on digital traits of wheat during 2017-18

Inter-action	r	g	b	INT	SAT	HUE	EIG	MEGI
$N0\times V_1$	0.35	0.44	0.20	104.78	0.39	1.39	0.326	0.326
$N_1\times V_1$	0.39	0.37	0.23	94.67	0.30	0.90	0.143	0.097
$N_2\times V_1$	0.38	0.36	0.26	89.67	0.22	0.83	0.076	0.064
$N_3\times V_1$	0.38	0.36	0.26	87.89	0.22	0.79	0.069	0.000
$N4\times V_1$	0.38	0.37	0.25	86.78	0.25	1.02	0.117	0.038
$N0\times V_2$	0.35	0.44	0.21	106.44	0.38	1.40	0.315	0.315
$N_1\times V_2$	0.36	0.43	0.22	95.56	0.35	1.32	0.277	0.235
$N_2\times V_2$	0.36	0.41	0.22	97.44	0.33	1.26	0.244	0.202
$N_3\times V_2$	0.37	0.39	0.24	94.33	0.28	1.13	0.175	0.158
N4×V2	0.36	0.41	0.23	98.67	0.30	1.32	0.231	0.231
$N0\times V_3$	0.37	0.41	0.22	97.67	0.34	1.07	0.239	0.232
$N_1\times V_3$	0.38	0.40	0.22	92.11	0.35	1.12	0.213	0.192
$N_2\times V_3$	0.38	0.41	0.21	96.67	0.38	1.17	0.241	0.200
$N_3\times V_3$	0.39	0.40	0.22	91.22	0.35	1.09	0.187	0.141
N4×V3	0.39	0.36	0.26	91.33	0.22	0.77	0.072	0.000
SE	0.01	0.02	0.02	5.75	0.05	0.17	0.071	0.088
LSD (0.05)	0.03	0.07	0.05	16.78	0.14	0.48	0.206	0.258

Appendix -4 (XI). Interaction effect of nitrogen doses and varieties on digital traits of wheat during 2017-18

Inter-action	NDI	NDVIrgb	NDVIgreen	SAVIgreen	GMR	SR	VARI
$N0\times V_1$	0.107	0.492	0.809	0.101	0.088	1.253	0.143
$N_1\times V_1$	0.083	0.399	1.083	0.077	0.065	0.960	0.121
$N_2\times V_1$	0.057	0.506	1.066	0.052	0.042	0.948	0.090
$N_3\times V_1$	0.038	0.485	1.080	0.034	0.028	0.927	0.061
$N4\times V_1$	0.005	0.500	1.010	0.005	0.004	0.990	0.008
$N0\times V_2$	0.104	0.500	0.812	0.098	0.084	1.243	0.141
$N_1\times V_2$	0.087	0.499	0.852	0.081	0.070	1.197	0.118
$N_2\times V_2$	0.068	0.496	0.885	0.063	0.055	1.154	0.092
$N_3\times V_2$	0.062	0.499	0.953	0.057	0.048	1.064	0.090
N4×V2	0.067	0.541	0.876	0.062	0.053	1.152	0.095

N0×V_3	0.105	0.457	0.940	0.098	0.084	1.110	0.149
N_1×V_3	0.074	0.425	0.952	0.068	0.059	1.077	0.102
N_2×V_3	0.054	0.410	0.924	0.050	0.044	1.091	0.072
N_3×V_3	0.023	0.398	0.981	0.021	0.018	1.022	0.032
N4×V3	0.041	0.478	1.090	0.037	0.031	0.921	0.067
SE	0.030	0.034	0.083	0.028	0.024	0.095	0.040
LSD (0.05)	0.086	0.101	0.241	0.081	0.071	0.276	0.115

Appendix -4 (XII). Interaction effect of nitrogen doses and varieties digital traits of wheat during 2017-18

Inter-action	BRAVI	BRAVIsr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb	HUEp
N0×V_1	0.026	0.221	0.104	0.096	0.136	0.549	80.09
N_1×V_1	0.023	0.186	0.078	0.069	0.105	0.654	65.83
N_2×V_1	0.015	0.180	0.064	0.047	0.071	0.613	64.09
N_3×V_1	0.010	0.178	0.043	0.031	0.047	0.624	60.00
N4×V_1	0.001	0.186	0.006	0.004	0.006	0.603	60.00
N0×V_2	0.026	0.219	0.104	0.092	0.132	0.548	80.64
N_1×V_2	0.021	0.213	0.087	0.077	0.110	0.559	76.35
N_2×V_2	0.017	0.208	0.068	0.060	0.086	0.569	72.98
N_3×V_2	0.015	0.196	0.065	0.052	0.077	0.587	71.03
N4×V2	0.017	0.205	0.071	0.059	0.085	0.556	76.30
N0×V_3	0.027	0.204	0.105	0.091	0.133	0.594	73.60
N_1×V_3	0.019	0.202	0.071	0.064	0.093	0.612	70.48
N_2×V_3	0.014	0.207	0.049	0.047	0.068	0.613	69.41
N_3×V_3	0.006	0.198	0.022	0.020	0.029	0.633	64.20
N4×V3	0.011	0.178	0.047	0.034	0.052	0.628	60.00
SE	0.007	0.012	0.029	0.026	0.037	0.029	5.97
LSD (0.05)	0.021	0.036	0.084	0.077	0.109	0.083	17.42

Appendices (Rice)

Appendix -1(I). ANOVA for leaf area (LA) of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS
Replication	2	0.583	0.003	0.002	0.006
Variety	2	216.750	0.001	0.001	0.008
Error(a)	4	1.083	0.001	0.001	0.002
Nitrogen	3	50.917	0.000	0.001	0.003
Variety: Nitrogen	6	122.417	0.001	0.001	0.001
Error(b)	18	1.028	0.001	0.004	0.002

Appendix -1(II). ANOVA for SPAD of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS
Replication	2	0.022	0.023	0.001	0.060
Variety	2	0.294	0.010	0.004	0.389
Error(a)	4	0.014	0.006	0.004	0.015
Nitrogen	3	0.306	0.013	0.001	0.185
Variety: Nitrogen	6	0.431	0.013	0.005	0.626
Error(b)	18	0.009	0.008	0.004	0.005

Appendix -1(III). ANOVA for plant height of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS
Replication	2	0.034	0.019	1.000	0.002
Variety	2	0.044	0.422	104.250	0.001
Error(a)	4	0.019	0.014	1.375	0.002
Nitrogen	3	0.029	0.585	124.917	0.000
Variety: Nitrogen	6	0.029	0.192	64.917	0.000
Error(b)	18	0.007	0.014	0.917	0.001

Appendix -1(IV). ANOVA for leaf area of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS	70DAS
Replication	2	0.018	0.003	0.003	0.013	0.014
Variety	2	0.070	0.198	18.278	466.878	0.148
Error(a)	4	0.006	0.020	0.003	0.002	0.008
Nitrogen	3	0.037	0.110	3.070	9.880	0.099
Variety: Nitrogen	6	0.047	0.218	19.638	13.308	0.109
Error(b)	18	0.010	0.009	0.012	0.011	0.010

Appendix -1(V). ANOVA for leaf nitrogen (N_2) content of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS	70DAS
Replication	2	0.019	0.000	1129.690	0.003	0.000
Variety	2	1.141	111.994	242727.000	0.006	0.000
Error(a)	4	0.009	0.000	1108.360	0.006	0.000
Nitrogen	3	2.904	80.514	59743.500	0.001	0.000
Variety: Nitrogen	6	4.828	36.107	91515.500	0.002	0.000
Error(b)	18	0.009	0.013	1111.130	0.002	0.000

Appendix -1(VI). ANOVA for TDM of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS
Replication	2	0.003	0.043	0.004	0.001
Variety	2	0.006	0.143	0.154	0.018
Error(a)	4	0.006	0.011	0.015	0.010
Nitrogen	3	0.003	0.069	0.069	0.009
Variety: Nitrogen	6	0.003	0.039	0.035	0.010
Error(b)	18	0.003	0.006	0.007	0.005

Appendix -1(VII). ANOVA for TDM of different growth stage of rice during 2017-18

Source	df	30DAS	60DAS	90DAS	120DAS
Replication	2	5.333	1.083	0.053	0.003
Variety	2	5845.750	105.250	61.028	0.011
Error(a)	4	1.333	0.333	0.013	0.002
Nitrogen	3	1852.330	2.917	21.180	0.001
Variety: Nitrogen	6	1202.080	138.917	26.168	0.000
Error(b)	18	0.445	1.139	0.004	0.001

Appendix -1(VIII). ANOVA for different traits of rice during 2017-18

Source	df	Chl a070118	C hl b070118	Chl (ab)070118	Car070118	SPMS	SPS	GPS	Sl
Replication	2	0.000	4.194	921472000000.000	1.333	0.000	0.000	0.012	0.030
Variety	2	6303.250	2320.530	2674930000000.000	16.750	0.000	0.002	0.005	0.000
Error(a)	4	0.000	0.069	841613000000.000	0.333	0.000	0.000	0.006	0.008
Nitrogen	4	65.667	404.250	401378000000.000	75.000	0.000	0.001	0.011	0.000
Variety: Nitrogen	8	66.917	414.417	697604000000.000	2.750	0.000	0.003	0.004	0.000
Error(b)	24	1.334	1.000	561715000000.000	1.111	0.000	0.000	0.002	0.008

Appendix -1(IX). ANOVA for different traits of rice during 2017-18

Source	df	SPMS	SPS	GPS	Sl	GYPMS	HI%	YTPH
Replication	2	0.022	0.001	9.786	0.004	0.000	1.333	0.001
Variety	2	0.084	13.480	1.218	0.002	0.002	1359.750	11.778
Error(a)	4	0.008	0.023	3.437	0.026	0.002	1.083	0.005
Nitrogen	4	0.180	3.723	23.173	0.012	0.003	297.583	3.723
Variety: Nitrogen	8	0.143	20.703	8.786	0.028	0.003	247.083	21.271
Error(b)	24	0.009	0.008	4.076	0.033	0.003	0.944	0.012

Appendix -1(X). ANOVA for different digital traits of rice during 2017-18

Source	df	**CCover**	**R**	**G**	**B**	**SumRGB**	**r**	**g**	**b**
Replication	2	0.022	0.035	0.013	0.011	3.583	0.000	0.043	0.0008
Variety (V)	2	0.294	0.002	0.752	0.370	29.250	0.000	0.143	0.0016
Error(a)	4	0.014	0.012	0.003	0.005	0.833	0.000	0.011	0.0003
Nitrogen (N)	4	0.306	0.007	20.543	1.297	54.250	0.000	0.069	0.0019
Variety: Nitrogen	8	0.431	0.084	32.306	0.827	175.250	0.000	0.039	0.0008
Error(b)	24	0.009	0.019	0.011	0.011	0.750	0.000	0.006	0.0008

Appendix -1(XI). ANOVA for different digital traits of rice during 2017-18

Source	df	**INT**	**SAT**	**HUE**	**EIG**	**MEGI**	**NDI**	**NDVIrgb**	**NDVIgreen**
Replication	2	1.71	0.01	0.15	0.01	0.02	0.00	0.00	0.02
Variety (V)	2	139.87	0.01	0.38	0.04	0.06	0.00	0.02	0.07
Error(a)	4	22.88	0.00	0.09	0.01	0.01	0.00	0.00	0.02
Nitrogen (N)	4	195.10	0.02	0.11	0.04	0.06	0.01	0.01	0.03
Variety: Nitrogen	8	32.27	0.01	0.08	0.01	0.01	0.00	0.00	0.01
Error(b)	24	99.15	0.01	0.08	0.01	0.02	0.00	0.00	0.02

Appendix -1(XII). ANOVA for different digital traits of rice during 2017-18

Source	df	**SAVIgre en**	**GMR**	**SR**	**VARI**	**BRAVI**	**BRAVIsr**	**EVIgree n**	**EVIgree n2**
Replication	2	0.0034	0.0026	0.0262	0.0072	0.0003	0.0004	0.0034	0.0030
Variety (V)	2	0.0016	0.0013	0.0903	0.0026	0.0001	0.0012	0.0020	0.0016
Error(a)	4	0.0009	0.0006	0.0161	0.0028	0.0001	0.0003	0.0013	0.0007
Nitrogen (N)	4	0.0065	0.0051	0.0541	0.0123	0.0005	0.0009	0.0062	0.0059
Variety: Nitrogen	8	0.0005	0.0004	0.0153	0.0016	0.0000	0.0003	0.0008	0.0004
Error(b)	24	0.0023	0.0018	0.0269	0.0047	0.0002	0.0004	0.0025	0.0021

Appendix -1(XII). ANOVA for different digital traits of rice during 2017-18

Source	df	**SAVIgre en**	**GMR**	**SR**	**VARI**	**BRAVI**	**BRAVIsr**	**EVIgree n**	**EVIgree n2**
Replication	2	0.0034	0.0026	0.0262	0.0072	0.0003	0.0004	0.0034	0.0030
Variety (V)	2	0.0016	0.0013	0.0903	0.0026	0.0001	0.0012	0.0020	0.0016
Error(a)	4	0.0009	0.0006	0.0161	0.0028	0.0001	0.0003	0.0013	0.0007
Nitrogen (N)	4	0.0065	0.0051	0.0541	0.0123	0.0005	0.0009	0.0062	0.0059
Variety: Nitrogen	8	0.0005	0.0004	0.0153	0.0016	0.0000	0.0003	0.0008	0.0004
Error(b)	24	0.0023	0.0018	0.0269	0.0047	0.0002	0.0004	0.0025	0.0021

Appendix -2 (I). Mean effect of rice varieties on morpho-physiological and digital traits of rice during 2017-18

Variety	B	B	BRAVI	BRAVISR	CHLB	CAR	CCOVER	CHLAB
BRRI dhan 62	60.00	0.29	0.15	0.15	0.725	0.25	0.85	1.34
BRRI dhan 75	64.25	0.28	0.13	0.18	1.000	0.20	0.88	1.70
BRRI dhan 76	68.50	0.30	0.15	0.13	0.992	0.20	0.84	1.55
SE	0.30	0.01	0.01	0.01	0.035	0.02	0.02	0.04
LSD (0.05)	1.18	0.03	0.03	0.05	0.136	0.09	0.07	0.14

Appendix -2 (II). Mean effect of rice varieties on morpho-physiological and digital traitsduring 2017-18

Variety	CHLA	EVIGREEN	G	G	GMR	GW	GWPH	HI
BRRI dhan 62	0.65	0.78	64.00	0.30	0.50	0.65	5.83	17.50
BRRI dhan 75	0.66	1.16	68.00	0.32	0.65	0.73	7.95	29.98
BRRI dhan 76	0.55	0.97	69.75	0.30	0.60	0.48	7.98	23.73
SE	0.04	0.03	0.34	0.01	0.02	0.04	0.02	0.01
LSD (0.05)	0.16	0.14	1.33	0.05	0.09	0.16	0.07	0.05

Appendix -2 (III). Mean effect of rice varieties on morpho-physiological and digital traits during 2017-18

Variety	HUE	HUEP	INT	LNC	MEGI	MEGI	NDI	NDVI
BRRI dhan 62	0.40	85.35	74.58	484.75	0.50	0.00	0.17	0.73
BRRI dhan 75	0.60	85.97	80.68	730.33	0.53	0.00	0.13	0.55
BRRI dhan 76	0.42	85.65	77.75	731.83	0.54	0.00	0.18	0.75
SE	0.03	0.03	0.00	9.61	0.02	0.00	0.02	0.03
LSD (0.05)	0.10	0.11	0.02	37.67	0.09	0.00	0.09	0.12

Appendix -2 (IV). Mean effect of rice varieties on morpho-physiological and digital traits during 2017-18

Variety	NDVIGREE	NDVIRGB	NGPP	NSPP	NTPH	OSVIGREE	PH	PL
BRRI dhan 62	1.35	0.38	139.25	12.50	15.98	0.20	104.25	18.50
BRRI dhan 75	1.22	0.46	154.50	17.75	11.50	0.26	112.00	23.67
BRRI dhan 76	1.44	0.43	182.75	17.50	14.23	0.22	147.25	44.75
SE	0.04	0.03	0.33	0.17	0.03	0.01	0.00	0.08
LSD (0.05)	0.14	0.11	1.31	0.65	0.13	0.05	0.00	0.30

Appendix -2 (V). Mean effect of rice varieties on morpho-physiological and digital traits during 2017-18

Variety	PPIXEL	R	R	RDW	SAT	SAVIGREE	SDW	SDWPH
BRRI dhan 62	18369000.00	99.75	0.40	0.05	0.20	0.20	1.55	15.75
BRRI dhan 75	18088400.00	101.50	0.40	0.06	0.18	0.20	1.39	14.95
BRRI dhan 76	19009500.00	99.25	0.40	0.03	0.16	0.20	1.43	13.65
SE	264829.00	0.17	0.00	0.00	0.02	0.03	0.03	0.04
LSD (0.05)	1038070.00	0.65	0.00	0.00	0.09	0.10	0.10	0.17

Appendix -2 (VI). Mean effect of rice varieties on morpho-physiological and digital traits during 2017-18

Variety	SPAD	SR	SRRGB	SUMRGB	SYPH	SYPM	TDM	TDMPH
BRRI dhan 62	37.55	0.73	0.71	233.50	14.88	0.73	1.66	22.03
BRRI dhan 75	37.03	0.71	0.68	251.00	13.75	1.00	1.67	21.93
BRRI dhan 76	37.60	0.70	0.70	231.75	15.73	0.99	1.64	22.40
SE	0.54	0.05	0.01	0.30	0.02	0.03	0.03	0.02
LSD (0.05)	2.10	0.18	0.05	1.18	0.08	0.14	0.13	0.07

Appendix -2 (VII). Mean effect of rice varieties on morpho-physiological and digital traits during 2017-18

Variety	TFW	TFWTH	TPIXEL	VARI
BRRI dhan 62	2.85	29.00	20155400.00	0.73
BRRI dhan 75	2.70	26.75	20155400.00	0.55
BRRI dhan 76	2.50	26.00	20155400.00	0.75
SE	0.02	0.26	0.00	0.03
LSD (0.05)	0.08	1.03	0.00	0.12

Appendix -3 (I). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	B	B	BRAVI	BRAVIS R	CHLB	CAR	CCOVER	CHLAB
N0 (0.0 kg/ha N_2)	61.00	0.29	0.13	0.13	1.167	0.27	0.86	1.67
N1 (50.0 kg/ha N_2)	64.00	0.29	0.16	0.17	0.756	0.22	0.87	1.37
N2 (100.0 kg/ha N_2)	66.33	0.29	0.13	0.17	0.900	0.18	0.84	1.46
N3 (150.0 kg/ha N_2)	65.67	0.30	0.16	0.13	0.800	0.20	0.86	1.63
SE	0.34	0.01	0.02	0.02	0.032	0.03	0.02	0.02
LSD (0.05)	1.00	0.03	0.06	0.05	0.095	0.09	0.06	0.07

Appendix -3 (II). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	CHLA	EVIGREEN	G	G	GMR	GW	GWPH	HI
N0 (0.0 kg/ha N_2)	0.61	0.61	63.67	0.31	0.57	0.63	6.77	24.97
N1 (50.0 kg/ha N_2)	0.57	0.97	65.00	0.30	0.63	0.47	8.07	23.97
N2 (100.0 kg/ha N_2)	0.60	1.18	72.00	0.31	0.50	0.63	6.90	23.57
N3 (150.0 kg/ha N_2)	0.70	1.12	68.33	0.30	0.63	0.73	7.27	22.43
SE	0.03	0.04	0.32	0.01	0.03	0.03	0.04	0.04
LSD (0.05)	0.08	0.12	0.95	0.03	0.10	0.09	0.11	0.11

Appendix -3 (III). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	HUE	HUEP	INT	LNC	MEGI	MEGI	NDI	NDVI
N0 (0.0 kg/ha N_2)	0.57	85.17	76.97	747.11	0.52	0.00	0.17	0.60
N1 (50.0 kg/ha N_2)	0.50	85.20	75.67	653.33	0.53	0.00	0.13	0.80
N2 (100.0 kg/ha N_2)	0.50	86.32	82.08	647.78	0.53	0.00	0.17	0.67
N3 (150.0 kg/ha N_2)	0.32	85.93	75.97	547.67	0.51	0.00	0.17	0.63
SE	0.03	0.03	0.04	11.11	0.01	0.00	0.02	0.03
LSD (0.05)	0.10	0.09	0.11	33.01	0.04	0.00	0.05	0.08

Appendix -3 (IV). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	NDVIGREE	NDVIRGB	NGPP	NSPP	NTPH	OSVIGREE	PH	PL
N0 (0.0 kg/ha N_2)	1.43	0.38	144.67	16.67	13.20	0.22	123.67	26.67
N1 (50.0 kg/ha N_2)	1.30	0.44	165.00	16.00	16.10	0.23	118.67	31.56
N2 (100.0 kg/ha N_2)	1.23	0.44	176.00	15.67	12.60	0.21	119.00	36.67
N3 (150.0 kg/ha N_2)	1.38	0.43	149.67	15.33	13.70	0.23	123.33	21.00
SE	0.03	0.02	0.22	0.36	0.02	0.01	0.38	0.33
LSD (0.05)	0.08	0.07	0.66	1.06	0.07	0.04	1.14	0.99

Appendix -3 (V). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	PPIXEL	R	R	RDW	SAT	SAVIGREE	SDW	SDWPH
N0 (0.0 kg/ha N_2)	18689300.00	102.00	0.40	0.06	0.21	0.20	1.63	15.00
N1 (50.0 kg/ha N_2)	18628900.00	99.00	0.40	0.06	0.16	0.20	1.40	15.37
N2 (100.0 kg/ha N_2)	18228900.00	103.00	0.40	0.04	0.21	0.20	1.49	13.87
N3 (150.0 kg/ha N_2)	18408800.00	96.67	0.40	0.04	0.14	0.20	1.30	14.90
SE	249826.00	0.35	0.00	0.00	0.02	0.03	0.03	0.03
LSD (0.05)	742268.00	1.04	0.00	0.00	0.05	0.09	0.10	0.09

Appendix -3 (VI). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	SPAD	SR	SRRGB	SUMRGB	SYPH	SYPM	TDM	TDMPH
N0 (0.0 kg/ha N_2)	35.49	0.71	0.72	236.67	14.90	1.17	1.63	22.63
N1 (50.0 kg/ha N_2)	39.36	0.76	0.68	235.67	15.00	0.76	1.69	22.63
N2 (100.0 kg/ha N_2)	37.71	0.67	0.69	247.33	15.37	0.90	1.67	19.90
N3 (150.0 kg/ha N_2)	37.01	0.71	0.70	235.33	13.87	0.80	1.63	23.30
SE	0.67	0.06	0.02	0.32	0.04	0.03	0.05	0.04
LSD (0.05)	2.00	0.18	0.05	0.96	0.11	0.09	0.14	0.10

Appendix -3 (VII). Mean effect of nitrogen on yield and yield contributing characters of rice during 2017-18

Nitrogen dose	TFW	TFWTH	TPIXEL	VARI
N0 (0.0 kg/ha N_2)	2.37	27.00	20155400.00	0.60
N1 (50.0 kg/ha N_2)	2.73	27.33	20155400.00	0.80
N2 (100.0 kg/ha N_2)	2.43	24.33	20155400.00	0.67
N3 (150.0 kg/ha N_2)	3.20	30.33	20155400.00	0.63
SE	0.04	0.29	0.00	0.03
LSD (0.05)	0.10	0.86	0.00	0.08

Appendix -4 (I). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	B	b	BRAVI	BRAVISR	CHLB	CAR	CCOVER	CHLAB
$N0\times V_1$	58.00	0.300	0.13	0.13	1.20	0.40	0.90	1.80
$N_1\times V_1$	64.00	0.300	0.17	0.17	0.80	0.20	0.87	1.50
$N_2\times V_1$	55.00	0.267	0.13	0.17	0.30	0.20	0.83	0.77
$N_3\times V_1$	63.00	0.300	0.17	0.13	0.60	0.20	0.80	1.30
$N4\times V_1$	58.00	0.267	0.10	0.17	1.10	0.20	0.87	1.40
$N0\times V_2$	57.00	0.267	0.17	0.20	1.10	0.20	0.90	1.80
$N_1\times V_2$	76.00	0.300	0.13	0.17	1.20	0.20	0.83	1.80
$N_2\times V_2$	66.00	0.300	0.13	0.17	0.60	0.20	0.90	1.80
$N_3\times V_2$	67.00	0.300	0.17	0.10	1.20	0.20	0.80	1.80
N4×V2	71.00	0.300	0.13	0.13	0.37	0.27	0.83	0.80
$N0\times V_3$	68.00	0.300	0.13	0.17	1.20	0.13	0.87	1.80
$N_1\times V_3$	68.00	0.300	0.17	0.10	1.20	0.20	0.87	1.80
$N_2\times V_3$	0.59	0.015	0.04	0.03	0.06	0.05	0.04	0.04
$N_3\times V_3$	1.74	0.044	0.10	0.08	0.16	0.15	0.11	0.12
SE	0.01	0.01	0.01	0.01	0.01	0.08	0.01	0.02
LSD (0.05)	0.03	0.03	0.04	0.04	0.04	0.22	0.04	0.06

Appendix -4 (II). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	CHLA	EVIGREEN	G	G	GMR	GW	GYPH	HI
$N0\times V_1$	0.60	0.30	61.00	0.30	0.50	0.50	3.20	17.50
$N_1\times V_1$	0.70	0.50	66.00	0.30	0.40	0.40	4.70	18.20
$N_2\times V_1$	0.50	1.30	62.00	0.30	0.50	0.60	4.80	19.80
$N_3\times V_1$	0.80	1.03	67.00	0.30	0.60	1.104	5.10	14.50
$N4\times V_1$	0.63	1.03	66.00	0.33	0.70	0.60	4.80	30.60
$N0\times V_2$	0.60	1.20	62.00	0.30	0.70	0.80	3.10	30.50
$N_1\times V_2$	0.70	1.20	78.00	0.33	0.60	0.70	4.10	30.20
$N_2\times V_2$	0.70	1.20	66.00	0.30	0.60	0.80	4.80	28.60
$N_3\times V_2$	0.60	0.50	64.00	0.30	0.50	0.80	5.30	26.80
N4×V2	0.40	1.20	67.00	0.30	0.80	0.20	4.40	23.20
$N0\times V_3$	0.60	1.03	76.00	0.30	0.40	0.60	2.80	20.70
$N_1\times V_3$	0.60	1.13	72.00	0.30	0.70	0.30	3.10	24.20
$N_2\times V_3$	0.05	0.07	0.55	0.02	0.06	0.05	3.50	0.06
$N_3\times V_3$	0.14	0.20	1.64	0.06	0.17	0.16	3.20	0.18
SE	0.63	0.77	0.79	0.81	0.73	0.68	0.79	0.89
LSD (0.05)	1.84	2.25	2.30	2.38	2.12	1.98	2.31	2.59

Appendix -4 (III). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	HUE	HUEP	INT	LNC	MEGI	MEGI	NDI	NDVI	HUE
$N0 \times V_1$	0.60	84.50	75.10	501.00	0.53	0.00	0.17	0.70	0.60
$N_1 \times V_1$	0.30	86.80	74.20	446.00	0.50	0.00	0.13	0.80	0.30
$N_2 \times V_1$	0.50	85.30	74.40	561.00	0.50	0.00	0.20	0.80	0.50
$N_3 \times V_1$	0.20	84.80	74.60	431.00	0.47	0.00	0.17	0.60	0.20
$N4 \times V_1$	0.60	85.70	80.60	861.00	0.53	0.00	0.13	0.50	0.60
$N0 \times V_2$	0.50	83.70	75.20	548.00	0.53	0.00	0.10	0.80	0.50
$N_1 \times V_2$	0.80	87.27	89.73	721.33	0.53	0.00	0.17	0.40	0.80
$N_2 \times V_2$	0.50	87.20	77.20	791.00	0.53	0.00	0.13	0.50	0.50
$N_3 \times V_2$	0.50	85.30	75.20	879.33	0.50	0.00	0.20	0.60	0.50
N4×V2	0.70	85.10	77.60	966.00	0.57	0.00	0.17	0.80	0.70
$N0 \times V_3$	0.20	86.40	82.10	661.00	0.57	0.00	0.13	0.80	0.20
$N_1 \times V_3$	0.27	85.80	76.10	421.00	0.53	0.00	0.20	0.80	0.27
$N_2 \times V_3$	0.06	0.05	0.06	19.25	0.02	0.00	0.03	0.05	0.06
$N_3 \times V_3$	0.17	0.16	0.19	57.18	0.07	0.00	0.09	0.13	0.17
SE	0.64	0.78	0.85	0.81	0.74	1.26	0.93	0.96	0.93
LSD (0.05)	1.85	2.27	2.49	2.35	2.16	3.69	2.70	2.80	2.71

Appendix -4 (IV). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	NDVIGREE	NDVIRGB	NGPP	NSPP	NTPH	OSVIGREE	PH	PL	NDVIGREE
$N0 \times V_1$	1.60	0.33	104.00	11.00	13.10	0.20	102.00	15.00	1.60
$N_1 \times V_1$	1.20	0.43	141.00	11.00	18.10	0.20	104.00	19.00	1.20
$N_2 \times V_1$	1.20	0.37	162.00	6.00	13.10	0.20	104.00	17.00	1.20
$N_3 \times V_1$	1.40	0.40	150.00	22.00	19.60	0.20	107.00	23.00	1.40
$N4 \times V_1$	1.20	0.37	158.00	17.00	14.40	0.27	117.00	28.00	1.20
$N0 \times V_2$	1.27	0.43	161.00	21.00	12.10	0.27	103.00	22.67	1.27
$N_1 \times V_2$	1.10	0.57	151.00	18.00	10.10	0.23	112.00	26.00	1.10
$N_2 \times V_2$	1.30	0.47	148.00	15.00	9.40	0.27	116.00	18.00	1.30
$N_3 \times V_2$	1.50	0.43	172.00	22.00	12.10	0.20	152.00	37.00	1.50
N4×V2	1.43	0.47	193.00	16.00	18.10	0.23	149.00	53.00	1.43
$N0 \times V_3$	1.40	0.40	215.00	23.00	14.60	0.20	141.00	67.00	1.40
$N_1 \times V_3$	1.43	0.43	151.00	9.00	12.10	0.23	147.00	22.00	1.43
$N_2 \times V_3$	0.05	0.04	0.38	0.62	0.04	0.02	0.67	0.58	0.05
$N_3 \times V_3$	0.15	0.12	1.14	1.83	0.11	0.07	1.98	1.72	0.15
SE	0.64	0.78	0.85	0.81	0.74	1.26	0.93	0.96	0.93
LSD (0.05)	1.85	2.27	2.49	2.35	2.16	3.69	2.70	2.80	2.71

Appendix -4 (V). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	PPIXEL	R	R	RDW	SAT	SAVIGREE	SDW	SDWPH	PPIXEL
$N0 \times V_1$	18291200.00	101.00	0.40	0.07	0.20	0.20	1.40	13.40	18291200.00
$N_1 \times V_1$	17921500.00	98.00	0.40	0.02	0.13	0.20	1.50	14.40	17921500.00
$N_2 \times V_1$	18489700.00	103.00	0.40	0.03	0.27	0.20	1.80	16.60	18489700.00
$N_3 \times V_1$	18773700.00	97.00	0.40	0.08	0.20	0.20	1.50	18.60	18773700.00
$N4 \times V_1$	18622800.00	103.00	0.40	0.09	0.23	0.20	1.80	16.50	18622800.00
$N0 \times V_2$	18545500.00	101.00	0.40	0.09	0.17	0.20	1.40	15.40	18545500.00
$N_1 \times V_2$	17399800.00	105.00	0.40	0.05	0.20	0.20	1.27	12.40	17399800.00
$N_2 \times V_2$	17785300.00	97.00	0.40	0.03	0.13	0.20	1.10	15.50	17785300.00
$N_3 \times V_2$	19153900.00	102.00	0.40	0.01	0.20	0.20	1.70	15.10	19153900.00
N4×V2	19419800.00	98.00	0.40	0.07	0.17	0.20	1.30	16.30	19419800.00
$N0 \times V_3$	18797100.00	101.00	0.40	0.03	0.17	0.20	1.40	12.60	18797100.00
$N_1 \times V_3$	18667300.00	96.00	0.40	0.02	0.10	0.20	1.30	10.60	18667300.00
$N_2 \times V_3$	432711.00	0.61	0.00	0.00	0.03	0.05	0.06	0.05	432711.00
$N_3 \times V_3$	1285650.00	1.81	0.00	0.00	0.08	0.16	0.17	0.15	1285650.00
SE	0.64	0.78	0.85	0.81	0.74	1.26	0.93	0.96	0.93
LSD (0.05)	1.85	2.27	2.49	2.35	2.16	3.69	2.70	2.80	2.71

Appendix -4 (VI). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	SPAD	SR	SRRGB	SUMRGB	SYPH	SYPM	TDM	TDMPH	SPAD
N0×V_1	37.67	0.70	0.73	237.00	15.50	1.20	1.70	21.10	37.67
N_1×V_1	37.90	0.77	0.67	238.00	15.10	0.80	1.50	21.30	37.90
N_2×V_1	37.27	0.77	0.73	232.00	16.30	0.30	1.70	19.50	37.27
N_3×V_1	37.37	0.67	0.70	227.00	12.60	0.60	1.73	26.20	37.37
N4×V_1	34.00	0.77	0.73	247.00	10.60	1.10	1.70	19.10	34.00
N0×V_2	38.33	0.80	0.67	238.00	13.40	1.10	1.77	25.10	38.33
N_1×V_2	38.63	0.50	0.63	272.00	14.40	1.20	1.77	21.10	38.63
N_2×V_2	37.13	0.77	0.70	247.00	16.60	0.60	1.43	22.40	37.13
N_3×V_2	34.80	0.67	0.70	226.00	18.60	1.20	1.50	27.70	34.80
N4×V2	41.83	0.70	0.70	231.00	16.50	0.37	1.80	21.50	41.83
N0×V_3	37.23	0.73	0.70	238.00	15.40	1.20	1.53	19.10	37.23
N_1×V_3	36.53	0.70	0.70	232.00	12.40	1.20	1.73	21.30	36.53
N_2×V_3	1.17	0.10	0.03	0.56	0.06	0.06	0.08	0.06	1.17
N_3×V_3	3.46	0.31	0.09	1.67	0.19	0.16	0.24	0.18	3.46
SE	0.64	0.78	0.85	0.81	0.74	1.26	0.93	0.96	0.93
LSD (0.05)	1.85	2.27	2.49	2.35	2.16	3.69	2.70	2.80	2.71

Appendix -4 (VII). Interaction effect of nitrogen doses and varieties on morpho-physiological and digital traits of rice during 2017-18

Inter-action	TFW	TFWTH	TPIXEL	VARI
N0×V_1	2.50	25.00	20155400.00	0.70
N_1×V_1	2.30	24.00	20155400.00	0.80
N_2×V_1	2.40	23.00	20155400.00	0.80
N_3×V_1	4.20	44.00	20155400.00	0.60
N4×V_1	2.40	24.00	20155400.00	0.50
N0×V_2	3.10	31.00	20155400.00	0.80
N_1×V_2	2.50	25.00	20155400.00	0.40
N_2×V_2	2.80	27.00	20155400.00	0.50
N_3×V_2	2.20	32.00	20155400.00	0.60
N4×V2	2.80	27.00	20155400.00	0.80
N0×V_3	2.40	25.00	20155400.00	0.80
N_1×V_3	2.60	20.00	20155400.00	0.80
N_2×V_3	0.06	0.50	0.00	0.05
N_3×V_3	0.18	1.49	0.00	0.13
SE	0.64	0.78	0.85	0.81
LSD (0.05)	1.85	2.27	2.49	2.35

Expt. No. 1 : Effect of nitrogen on morpho-physiological traits of *T. Aman* rice

Gazipur

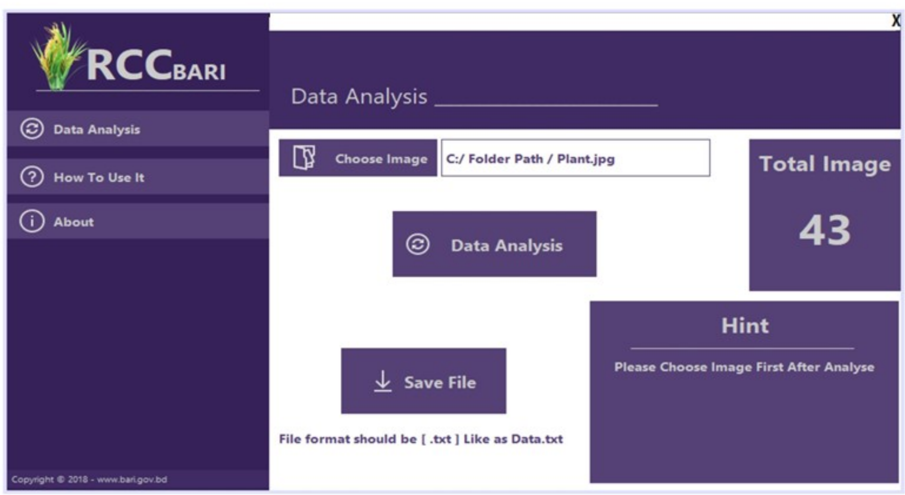
Dinajpur

Chittagong

Expt. No. 2 : Effect of nitrogen on morpho-physiological traits of wheat

Expt. No. 3 : Effect of nitrogen on morpho-physiological traits of maize

RCC (Rice Canopy Cover) BARI Software development under Progress



Output

Name	Date	TPixel	PPixel	CCover	R	G	B	SumRGB	r	g	b	INT	SAT
csm_plot (10).JPG	1/7/2018 11:46	20155392	11311249	56.12%	101	142	72	315	0.32	0.45	0.23	105.00	0.31
csm_plot (11).JPG	1/7/2018 11:46	20155392	10277513	50.99%	105	146	65	316	0.33	0.46	0.21	105.33	0.38
csm_plot (12).JPG	1/7/2018 11:46	20155392	10475145	51.97%	110	152	69	331	0.33	0.46	0.21	110.33	0.37
csm_plot (13).JPG	1/7/2018 11:46	20155392	11864674	58.87%	105	146	63	314	0.33	0.46	0.20	104.67	0.40
csm_plot (14).JPG	1/7/2018 11:47	20155392	12954472	64.27%	104	147	69	320	0.33	0.46	0.22	106.67	0.35
csm_plot (15).JPG	1/7/2018 11:47	20155392	13120133	65.09%	105	148	70	323	0.33	0.46	0.22	107.67	0.35
csm_plot (16).JPG	1/7/2018 12:25	20155392	12853888	63.77%	102	144	64	310	0.33	0.46	0.21	103.33	0.38
csm_plot (17).JPG	1/7/2018 12:25	20155392	9380012	46.54%	100	139	68	307	0.33	0.45	0.22	102.33	0.34
csm_plot (18).JPG	1/7/2018 12:26	20155392	12940885	64.21%	101	142	73	316	0.32	0.45	0.23	105.33	0.31
csm_plot (19).JPG	1/7/2018 12:26	20155392	12858277	63.80%	97	139	73	309	0.31	0.45	0.24	103.00	0.29
csm_plot (20).JPG	1/7/2018 11:44	20155392	14255893	70.73%	102	146	71	319	0.32	0.46	0.22	106.33	0.33
csm_plot (21).JPG	1/7/2018 12:26	20155392	14335750	71.13%	97	140	71	308	0.31	0.45	0.23	102.67	0.31
csm_plot (22).JPG	1/7/2018 12:27	20155392	10805175	53.61%	99	138	66	303	0.33	0.46	0.22	101.00	0.35
csm_plot (23).JPG	1/7/2018 12:27	20155392	14703625	72.95%	98	141	66	305	0.32	0.46	0.22	101.67	0.35
csm_plot (24).JPG	1/7/2018 12:27	20155392	8377737	41.57%	100	138	66	304	0.33	0.45	0.22	101.33	0.35

Name	HUE	EIG	MEGI	NDI	NDVIrgb	NDVIgreen	SAVIgreen	GMR	SR	VARI	BRAVI	BRAVIbr	EVIgreen	EVIgreen2	OSVIgreen	SRrgb	HUEp
csm_plot (10).JPG	1.67	0.35	0.35	-0.17	0.66	0.71	0.15	0.13	1.41	0.24	0.04	0.23	0.20	0.15	0.21	0.47	95.14
csm_plot (11).JPG	1.58	0.39	0.39	-0.16	0.57	0.72	0.15	0.13	1.39	0.22	0.04	0.23	0.17	0.14	0.20	0.50	90.37
csm_plot (12).JPG	1.58	0.38	0.38	-0.16	0.58	0.72	0.15	0.13	1.38	0.22	0.04	0.23	0.17	0.14	0.20	0.50	90.36
csm_plot (13).JPG	1.56	0.39	0.39	-0.16	0.55	0.72	0.15	0.13	1.39	0.22	0.04	0.23	0.17	0.14	0.20	0.50	89.64
csm_plot (14).JPG	1.63	0.38	0.38	-0.17	0.62	0.71	0.16	0.13	1.41	0.24	0.04	0.23	0.19	0.15	0.21	0.48	93.08
csm_plot (15).JPG	1.63	0.37	0.37	-0.17	0.62	0.71	0.16	0.13	1.41	0.23	0.04	0.23	0.19	0.15	0.21	0.48	93.08
csm_plot (16).JPG	1.60	0.39	0.39	-0.17	0.58	0.71	0.16	0.14	1.41	0.23	0.04	0.23	0.18	0.15	0.21	0.49	91.50
csm_plot (17).JPG	1.63	0.36	0.36	-0.16	0.63	0.72	0.15	0.13	1.39	0.23	0.04	0.23	0.18	0.14	0.20	0.48	92.96
csm_plot (18).JPG	1.68	0.35	0.35	-0.17	0.67	0.71	0.15	0.13	1.41	0.24	0.04	0.23	0.20	0.15	0.21	0.47	95.65
csm_plot (19).JPG	1.73	0.35	0.35	-0.18	0.71	0.70	0.16	0.14	1.43	0.26	0.04	0.23	0.22	0.15	0.22	0.46	98.18
csm_plot (20).JPG	1.67	0.37	0.37	-0.18	0.65	0.70	0.16	0.14	1.43	0.25	0.04	0.23	0.20	0.15	0.22	0.47	95.20
csm_plot (21).JPG	1.71	0.36	0.36	-0.18	0.69	0.69	0.16	0.14	1.44	0.26	0.04	0.23	0.22	0.16	0.23	0.46	97.39
csm_plot (22).JPG	1.62	0.37	0.37	-0.16	0.61	0.72	0.15	0.13	1.39	0.23	0.04	0.23	0.18	0.14	0.20	0.49	92.50
csm_plot (23).JPG	1.66	0.39	0.39	-0.18	0.63	0.70	0.16	0.14	1.44	0.25	0.04	0.23	0.20	0.16	0.22	0.47	94.40
csm_plot (24).JPG	1.60	0.36	0.36	-0.16	0.60	0.72	0.15	0.13	1.38	0.22	0.04	0.23	0.17	0.14	0.20	0.49	91.67