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Principle Component Analysis (PCA) and Character Interrelationship of Irrigated Blackgram [*Vigna mungo* (L.) *Hepper*] Influenced by Liquid Organic Biostimulants in Western Zone of Tamil Nadu

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ABSTRACT

Background: Blackgram [*Vigna mungo* (L.) *Hepper*] has significant agronomic and nutritional significance. Its productivity is insufficient to fulfil the expanding local demand in India. Increasing its productivity using appropriate agronomic practices is crucial. With this background, an experiment was conducted to study the effect of foliar application of liquid organic bio-stimulants on development, production and physiological characteristics of blackgram under irrigated conditions.

Methods: Seven treatments comprising recommended dose of fertilizers (RDF) with foliar spray of dhasagavya, liquid rhizobium, fish amino acid, panchagavya, PPFM and seaweed extract at 1% and 3%, respectively were tested in randomised block design with three replications. The dimension of blackgram quantitative characters, *viz*., grain yield, plant height, number of branches per plant, dry matter production (DMP), leaf area index (LAI), number of pods per plant, number of seeds per pod, pod weight per plant, pod length, crop growth rate, total chlorophyll content, soluble protein content and nitrate reductase activity were reduced using principal component analysis (PCA).

Result: The PCA was performed on all the attributes as correlation between the quantitative characters was found to be stronger among most of the biometric observations. It was noticed that almost 67% of the data's total variability, as reflected by the first two principal components. It demonstrated that grain production, DMP, nitrate reductase activity, pods per plant and leaf area index were the primary contributors.

Key words: Blackgram, Correlation, Growth, Physiological characters, Principal component analysis (PCA).

INTRODUCTION

Pulses are important crops in India because of their low cost and high quality protein. They play a major role in providing a balanced protein component in the diet of the people. Among pulses, blackgram [*Vigna mungo* (L.) *Hepper*], occupies a unique place. It is grown both as a pure and mixed crop along with maize, cotton, sorghum and other millets (Ajaykumar *et al*., 2022a).

The yield of blackgram is low due to various reasons including poor management practices, physiological, biochemical and inherent factors associated with the crop. Insufficient partitioning of assimilates, flower dropping and poor pod setting are mainly due to lack of nutrients during critical crop growth resulting in poor yield. Fertilizer application is an important practice to increase the yield of blackgram (Ajaykumar *et al*., 2022b). Organic substances are known to influence a wide array of physiological parameters like alteration of plant architecture, assimilate partitioning, promotion of photosynthesis, uptake of nutrients (mineral ions), enhancing nitrogen metabolism, promotion of flowering, uniform pod formation, increased mobilization of assimilates to defined sinks, improved seed quality, induction of synchrony in flowering and delayed senescence of leaves (Pradeep and Elamathi 2007).

The role of foliar applied panchagavya and dhasagavya in the production of many plantation crops has been well

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documented in India (Selvaraj, 2003). The use of fermented, liquid organic fertilizers and effective microorganisms (EM) as foliar fertilizers have been introduced to modern agriculture in recent years to produce food with good quality and safety (Galindo *et al*., 2007).

Fish amino acid (FAA) is a liquid and great value to both plants and microorganisms in their growth. It has abundant amount of nutrients and various types of amino acids. Seaweed concentrates benefit plants as they contain growth-promoting hormones (IAA, IBA and cytokinins), trace elements, vitamins and amino acids (Khan *et al.,* 2009). Integrated use of seaweed liquid fertilizer in combination with chemical fertilizer and their proper management for better growth and yield is very essential. In green gram, foliar application of liquid bio fertilizers during vegetative and flower bud initiation stages increased number of flowers, pods and seeds per plant and seed yield. Foliar application of organic substance increased the chlorophyll content and promoted epicotyls elongation of soybean, mungbean and pea (Senthil *et al*., 2003).

Exogenous application of pink-pigmented facultative methylotrophs (PPFM) produces some benefits in alleviating the adverse effects of drought stress and also improves germination, growth, development, quality and yield of crop plants (Hayat *et al*., 2010). Agronomists frequently assess a great diversity of characteristics for appraisal and characterization. In such situations, principal component analysis (PCA) is used to reduce massive data sets containing multiple variables into their principal components to acquire a deeper understanding of the data (Amy and Pritts, 1991). This statistical technique is frequently utilised for data compression, reduction and transformation (Mishra *et al*., 2017). Principle component analysis is a mathematical procedure that transforms a number of (possibly related) variables into a (smaller) number of principal component variables (García and García, 2010). The eigenvalue of a specific principal component represents the degree of variance in attributes that is explained by that principal component, which is extremely valuable for crop production trait selection (Singh *et al*., 2020). The PCA is widely utilized in examining elite growth and physiological features, it simultaneously analyses several parameters of each individual under investigation. PCA evaluates the significance and contribution of each variable to the overall variance (Leonard and Peter, 2009).

When evaluating materials based on a variety of characteristics, there are numerous crucial factors to consider. Consequently, PCA is used to study the relationships between traits and efficiently visualise the similarities between individuals or treatments in which various factors exert strong effects on growth, yield and physiological traits. Under these conditions, it is considerably more difficult to visually summarise a set of agronomic data by describing agronomic features; hence, multivariate methods should be employed. In recent years, numerous research efforts have been focused on agronomic physiological characters that influence yield. PCA is a useful technique for the reduction of large data set with many variables into important principal components for a better understanding of information. Keeping these points in view, the present investigation was conducted to assess the relationship among characters of blackgram under irrigated conditions.

MATERIALS AND METHODS

A field experiment was conducted during 2021 in Vanavarayar Institute of Agriculture, Pollachi. The experiment comprised of seven treatments *viz*., 100% RDF along with the foliar application of dhasagavya at 3% (T_1), 100% RDF along with foliar application of liquid rhizobium at 1% (T_2). 100% RDF along with foliar application of fish amino acid at 1% (T_3), 100% RDF along with foliar application of panchagavya at 3% (T_4), 100% RDF along with the foliar application of PPFM at 1% (T_5), 100% RDF along with the foliar application of seaweed extract at 3% (T_6), control (T_7) and was laid out in randomized block design with in three replications. Liquid biofertilizers and organic bio-stimulants were purchased from Tamil Nadu Agricultural University, Coimbatore. Blackgram variety 'VBN 8' was used for the study.

The recommended doses of N, P_2O_5, K_2O were 25, 50, 25 kg ha^{-1}, respectively. Full dose of nitrogen, phosphorus, potassium in the form of urea, SSP, MOP were applied basal as per treatments. In addition to this, gypsum 20 kg ha^{-1} and soil application of 25 kg $ZnSO_4$ ha^{-1} were applied. Liquid bio fertilizers and organic bio stimulants were given as foliar spray at 30 and 45 days after sowing of blackgram. All other agronomic practices were adopted as per the need of the crop.

The growth characters *viz*., plant height, number of branches per plant, leaf area index (LAI) and dry matter production (DMP) were recorded. The maximum plant height was measured from the base of the stem to the tip of the longest trifoliate leaf. Numbers of branches were counted by manual and LAI was measured by using leaf area meter (LICOR 3000). DMP of various plant parts was arrived at by taking the sum of all the plant parts after keeping the sample in oven at 80°C for 48 hours. The physiological biochemical parameters *viz*., crop growth rate, chlorophyll content, soluble protein and Nitrate reductase activity were estimated. The CGR was computed using the formula suggested by Watson (1958). Chlorophyll content of leaves was recorded as described by Yoshida *et al*., (1976). Soluble protein content of the leaf was estimated at by using folinciocalteau reagent by adopting the procedure described by Lowry *et al.,* (1950). Nitrate reductase activity (NRase activity) (Nicholas *et al*., 1976) were also estimated. Yield attributes *viz*., number of pods per plant, number of seeds per pod, pod weight per plant, pod length and grain yield were recorded during harvest stage. These thirteen quantitative characteristics were considered for the study.

The primary data were subjected to PCA using XLSTAT software. It reduces the dimensions of multivariate data to a small number of principal axes, generates an eigenvector for each principal axis and produces component scores for the characters. The PCA analysis was done to investigate the link between attributes and establish selection criteria and the optimum factors for yield estimation. In agronomy, the forms of PCA visualisation for improved decision-making are typically a cloud of dots or a circle of correlations between variables. They reflect the directions in which the data exhibits the greatest variance and the greatest dispersion. PCA was employed to the replicated data to sort out the large amount of quantitative data.

RESULTS AND DISCUSSION

The descriptive statistics *viz.,* mean, maximum, minimum, standard deviation (SD) and coefficient of variation (CV) were measured for 13 characters recorded under irrigated conditions. The results revealed that the highest variation was found in crop growth rate with a CV of 36.76 per cent (Table 1). The pod length had the lowest coefficient of variation (11.89 per cent). It was noticed that most of the variables were highly correlated among themselves (Table 2 and Fig 1). Strong correlations were found between the grain yield and plant height (0.72), number of branches per plant (0.84), DMP (0.82), crop growth rate (0.74), total chlorophyll content (0.75), nitrate reductase activity (0.85); plant height

Table 1: Descriptive statistics of quantitative characters of blackgram.

Statistic	Minimum	Maximum	Mean	SD	CV (%)
Grain yield	432.00	1089.00	813.71	152.03	18.68
Plant height (PH)	20.20	40.40	29.64	4.74	15.99
No. of branches per plant (NB/P)	3.07	7.42	5.29	1.07	20.29
No. of pods per plant (NP/P)	16.00	37.10	27.04	5.14	18.99
No. of seeds per pod (NS/P)	4.40	8.60	6.85	1.29	18.80
Dry matter production (DMP)	1190.00	2891.00	2103.00	471.26	22.41
Pod weight per plant (PW/P)	8.67	15.59	12.41	1.72	13.85
Pod length (PL)	3.95	6.06	5.05	0.60	11.89
Leaf area index (LAI)	2.12	5.97	4.09	0.91	22.20
Crop growth rate (CGR)	0.29	6.62	4.44	1.63	36.76
Total chlorophyll content (TCC)	1.99	3.79	3.07	0.44	14.29
Soluble protein content (SPC)	6.98	12.78	9.84	1.43	14.54
Nitrate reductase activity (NRA)	37.14	103.22	74.75	14.26	19.08

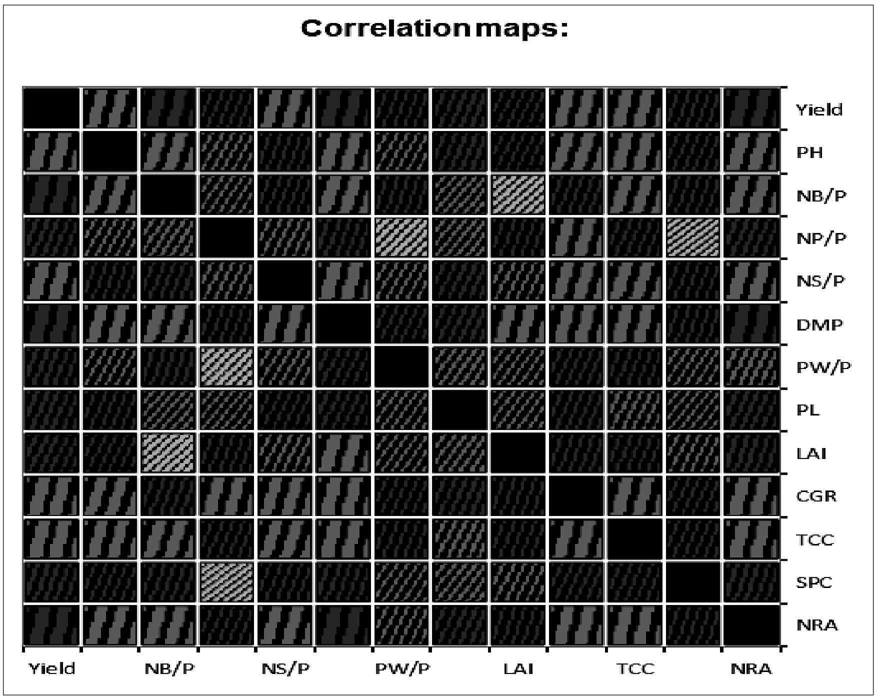

Fig 1: Pictorial representation of the correlation matrix of quantitative characters of blackgram.

Table 2: Matrix of correlation coefficients of the quantitative characters of blackgram.

Variables	Grain yield	Plant height (PH)	No. of branches per plant (NB/P)	No. of pods per plant (NP/P)	No. of seeds per pod (NS/P)	Dry matter production (DMP)	Pod weight per plant (PW/P)	Pod length (PL)	Leaf area index (LAI)	Crop growth rate (CGR)	Total chlorophyll content (TCC)	Soluble protein content (SPC)	Nitrate reductase activity (NRA)
Grain yield	1												
Plant height (PH)	0.72	1											
No. of branches per plant (NB/P)	0.84	0.61	1										
No. of pods per plant (NP/P)	0.48	0.35	0.30	1									
No. of seeds per pod (NS/P)	0.69	0.56	0.51	0.40	1								
Dry Matter Production (DMP)	0.82	0.69	0.62	0.55	0.74	1							
Pod weight per plant (PW/P)	0.52	0.35	0.59	0.20	0.33	0.42	1						
Pod length (PL)	0.47	0.48	0.22	0.24	0.41	0.43	0.28	1					
Leaf area index (LAI)	0.40	0.40	0.18	0.53	0.39	0.68	0.28	0.27	1				
Crop growth rate (CGR)	0.74	0.60	0.52	0.71	0.66	0.79	0.44	0.47	0.57	1			
Total chlorophyll content (TCC)	0.75	0.72	0.63	0.47	0.61	0.76	0.51	0.40	0.50	0.72	1		
Soluble protein content (SPC)	0.58	0.46	0.56	0.14	0.50	0.57	0.30	0.25	0.39	0.43	0.47	1	
Nitrate reductase activity (NRA)	0.85	0.66	0.66	0.47	0.68	0.88	0.39	0.45	0.60	0.76	0.78	0.59	1

and total chlorophyll content (0.72); number of pods per plant and crop growth rate (0.71); DMP and crop growth rate (0.79), total chlorophyll content (0.76), nitrate reductase activity (0.88); crop growth rate and total chlorophyll content (0.76); total chlorophyll content and nitrate reductase activity (0.78). Since most of the correlation coefficients between the variables were greater than 0.3, all the variables included in the correlation analysis were subjected to the principal component analysis (Rymuza *et al*., 2012).

On the basis of data of seven treatments, principal component analysis was performed to find the most important growth and physiological characteristics. PCA revealed that, out of thirteen principal components, only five had eigen values greater than 0.5 and accounted for 85.35 percent of the analysed traits' variability, while the remaining eight principal components contributed just 14.65 per cent. A scree plot (Fig 2) depicted the proportion of variance linked with eigen values and principal components for each graphed principal component (PC). PC1 produced the most variance, 57.95 per cent, followed by PC2 (9.57 per cent), PC3 (6.44 per cent), PC4 (6.31 per cent) and PC5 (6.31 per cent) (5.07 per cent). Principal component approach permitted the reduction of thirteen core traits to eight new variables from five principal components while retaining a substantial portion of the variation of primary data. Jeberson *et al*. (2018) assessed the principal components of twenty-five blackgram genotypes and reported that the first three components accounted for 84.52 per cent of the overall variation, while the remaining four components accounted for just 15.48 per cent.

On the basis of factor loadings (Table 3), the first principal component increases with grain yield, DMP and nitrate reductase activity. This implies that increase in one variable *viz*., grain yield would increase the other variables like DMP and nitrate reductase activity. Meanwhile, the second component is represented by the number of pods per plant and leaf area index. The third, fourth and fifth components carried the information related to pod length, soluble protein content and leaf area index, respectively. Overall, PCA was able to identify the crucial agronomic characteristics responsible for population variability. Jeberson *et al*. (2018); Sridhar *et al*. (2020); Girgel (2021); Beyzi *et al*. (2019); Mohi-Ud-Din *et al*. (2021); Singh *et al*. (2020); Qaseem *et al*. (2019); Zafar *et al*. (2021) and Kakar *et al*. (2021) conducted similar studies related to agronomic trait selection.

Several researchers utilised the PCA biplot to investigate the link between traits in various crops (Mohanlal *et al*., 2020; Aslam *et al*., 2017 and Maqbool *et al*., 2016). The length of the vector was determined by the character's contribution to the primary component (Fig 3). In addition, the angle of the character vectors reflected the relationship between variables. A positive correlation existed if the angle between two trait vectors was less than 90° degrees (acute angle). The biplot of the PCA showed that all vectors were concentrated in the first and fourth quadrants. It implied that most of the traits were closer to each other and highly

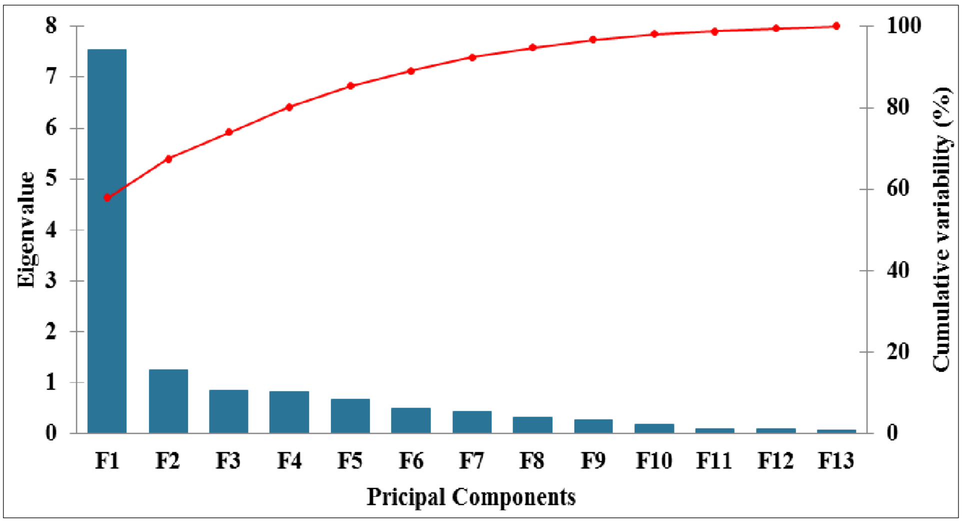

Fig 2: Screen plot representing the variation in the principal component.

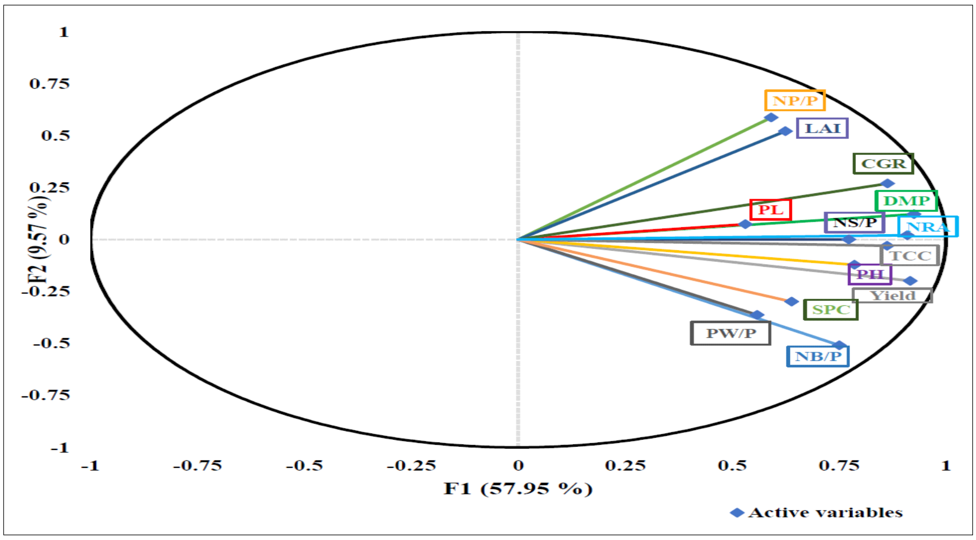

Fig 3: Biplot of factor coordinates for PC1 and PC2 of the quantitative characters in blackgram.

Table 3: Eigen value, factor scores and contribution of the first five principal component axes to variation in blackgram.

Particulars	PC1	PC2	PC3	PC4	PC5
Eigenvalue	7.533	1.245	0.838	0.820	0.659
Variability (%)	57.948	9.573	6.446	6.309	5.071
Cumulative (%)	57.948	67.521	73.968	80.276	85.347
Grain yield	0.334	-0.178	-0.003	-0.044	-0.205
Plant height (PH)	0.286	-0.109	0.233	0.024	-0.176
No. of branches per plant (NB/P)	0.273	-0.456	-0.242	-0.114	-0.220
No. of pods per plant (NP/P)	0.216	0.526	-0.256	-0.285	-0.303
No. of seeds per pod (NS/P)	0.281	0.000	0.146	0.172	-0.200
Dry matter production (DMP)	0.337	0.109	-0.047	0.157	0.015
Pod weight per plant (PW/P)	0.204	-0.325	-0.237	-0.577	0.552
Pod length (PL)	0.194	0.066	0.837	-0.231	0.224
Leaf area index (LAI)	0.228	0.468	-0.188	0.207	0.559
Crop growth rate (CGR)	0.315	0.242	-0.032	-0.163	-0.103
Total chlorophyll content (TCC)	0.314	-0.027	-0.045	-0.094	-0.024
Soluble protein content (SPC)	0.233	-0.268	-0.062	0.595	0.261
Nitrate reductase activity (NRA)	0.331	0.019	-0.006	0.171	-0.025

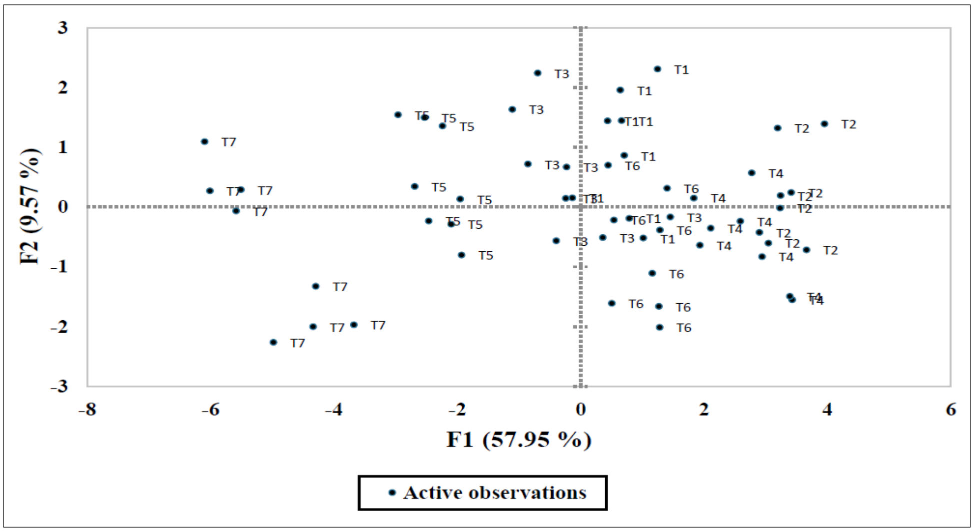

Fig 4: Scatter plot of the various treatment groups represented in two major principal components.

correlated among themselves which was earlier evident in the above-mentioned correlation results. If the angle between the two traits exceed 90° degrees (an obtuse angle), it shows a negative correlation. In this study, all the traits had acute angles between themselves, which indicated the absence of negative correlation. The variables that exhibited lesser or zero relations were pod length and DMP; number of seeds per plant, nitrate reductase activity, pod weight per plant and number of branches per plant.

A scatter plot drawn between the first and second principal components depicted clear projections of the cases on a factor plane (Fig 4). The distribution of the active observations based on PC1 and PC2 illustrated that the treatment variations within the population and explained how they were widely dispersed along both axes. PC1 and PC2 demonstrated a very distinct separation between the seven treatments with minimal overlap, indicating that the treatments were distinct.

The analysis allowed the reduction of thirteen primary traits to five new variables which illustrated 67.52 per cent of the variability from the first two principal components. According to Sivaprakash *et al*. (2004), the features that comprise the first, second and subsequent principal components have the greatest discriminating power and they differentiate the studied treatments. On the whole, traits such as grain yield, DMP and nitrate reductase activity had a high influence on PC1. Meanwhile, numbers of pods per plant and leaf area index were the characters that exhibited higher influences on PC2.

CONCLUSION

Principal component analysis (PCA) was performed to determine the most advantageous traits and to determine the relationship between characters in various treatments in blackgram. The primary components that contributed most to the quantitative characters based on the interaction between treatments and vector were grain yield, DMP, nitrate reductase activity, number of pods per plant and leaf area index. In the study, the reduction of thirteen investigated features to two principal components explains approximately 67.52 per cent of the total input data variability. The generated non-correlated variables may be used in further analyses when the co-linearity of variables is not assumed.

Conflict of interest: None.

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