

ASSESSMENT OF DIFFERENT POTATO VARIETIES TO ENHANCE PRODUCTIVITY IN NALANDA DISTRICT UNDER ZONE-IIIB OF BIHAR

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ABSTRACT: Potato is a major crop of the Solanaceae family, ranks fourth globally in food consumption after rice, wheat and maize. India, the second-largest potato producer, contributes about 15.0% of global production, with Bihar emerging as a key potato-producing state, particularly Nalanda district, which is known for its higher-than-average yield of 36.46 t/ha. However, during 2023–24, a comparatively lower yield of this important crop was recorded, possibly due to the lack of quality, disease-free and heat-tolerant varieties suitable for the agro-climatic conditions of Bihar. Significant variability was observed for traits such as main stem height, number of tubers per plant, plant height, tuber dimensions, average tuber weight and yield. Kufri Pukhraj and Kufri Uday showed superior performance with higher tuber numbers, greater average tuber weight and higher yields, indicating their potential as superior genotypes. High heritability and genetic advance were observed for yield and tuber weight, suggesting good potential for direct selection. Moderate heritability for plant height and tuber diameter indicates the need for indirect selection and improved environmental management. Cluster analysis revealed grouping of yield-attributing traits such as tuber weight, number of tubers and plant density in a primary cluster, highlighting their combined influence on yield. These findings will help in formulating effective breeding strategies for developing high-yielding and disease-resistant potato varieties suitable for intensive cropping systems in Bihar, thereby contributing to sustainable agriculture and food security.

KEYWORDS: Potato varieties, Genetic Variability, Clustering, Correlation, Yield

INTRODUCTION

Potato (*Solanum tuberosum* L.) is considered as the king of vegetables that comes under Solanaceae family, which contains 100 genera and 2,500 species (Olmstead *et al.*, 2008). It is also considered as staple food and ranks fourth after rice, wheat and maize in terms of food consumption (Li *et al.*, 2026). It has been recognized as a wholesome food and the richest source of energy where it forms

an important component of the daily diet. As efficient starch producing plants it contains more carbohydrates per unit area and time, rich in digestible protein, minerals, vitamins and high-quality dietary fibre. According to FAOSTAT (2024), China is the leading producer, contributing 25.5% of the global production, followed by India i.e., 15.0%. In India, the major potato-producing states include Uttar Pradesh (15.89 million tonnes),

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West Bengal (12.6 million tonnes), Bihar (9.13 million tonnes), Gujarat (3.78 million tonnes), Madhya Pradesh (3.58 million tonnes), Punjab (2.85 million tonnes), Haryana (0.77 million tonnes), Assam (0.762 million tonnes) and Jharkhand (0.73 million tonnes). Nalanda district in Bihar is particularly known for potato production with an average yield of 36.46 t/ha, which is higher than the state average of 27.60 t/ha (Anonymous, 2021). However, there is a huge possibility for increasing the potato yield in Bihar while, the key challenge for enhancing potato yields is the lack of availability of healthy, disease-free seed tubers along with awareness about new improved varieties developed by ICAR-CPRI, Shimla.

Globally potato is a major cash crop, consumed everyday by millions of people (FAO, 2015), and this wonder crop originated from the mountains of South America, where they have been a staple food for centuries. Increasing potato productivity per unit of farmland is crucial to meeting the global demand for this crop. Low yield of potato is due to use of local seed tubers and cultivation of old varieties (Ibrahim *et al.*, 2018). It is important for breeders to provide food at cheaper rate to the millions of people numbers around the world by increasing the production of potatoes per unit area and per unit time (Zelege *et al.*, 2021). The presence of enough genetic variability in the population for yield and yield related traits should be considered as prerequisite support for any breeding programme. Moreover, the application of perfect breeding method is dependent on estimation of genetic gain of the characters for successful selection as to develop desirable traits (Umiyah *et al.*, 2010). Genetic variability is the basis of all crop improvement programmes (Basvaraj *et al.*, 2005). The nature of variability and association of yield with its components traits

is important for identification of superior parents in any breeding program (Rahman, 2015). Therefore, the present study was conducted to assess the genetic variability of improved potato genotypes with the prime objective to identify superior high yielding and good quality potato varieties for the agro-climatic conditions of Bihar.

MATERIALS AND METHODS

The present research work was conducted at the research farm of NCOH Noorsarai. The site is located at 24.47°–25.16°N latitude and 84.12°–85.27°E longitude, at an altitude of 67 meters above mean sea level in the Indo-Gangetic plains of northeastern India. The varieties include Kufri Neelkanth, Kufri Lima, Kufri Pukhraj, Kufri Thar-2, Kufri Mohan, Kufri Uday/ Yushimap, BARI Aloo/7015 and Kufri Sangam, its mini-tubers (G_0) were procured from the Potato Technology Centre, Shamgar (Karnal). These varieties were assessed in the Agro-climatic Zone-IIIB of Bihar during the *Rabi* 2023-2024. The mini-tubers (G_0) used in this experiment were the purest seed material and almost free from viruses, diseases and pests.

The soil was sandy loam with a pH of 7.2, providing adequate fertility for crop growth. The region experiences a tropical to subtropical climate with hot summers and cold winters. Average temperatures range from 9°C to 43°C and the relative humidity fluctuates between 65% to 90%. The average annual rainfall was 1,035 mm, with 90% of it occurring during the southwest monsoon. Weather parameters, such as weekly precipitation, temperature and relative humidity, were recorded throughout the cropping season.

The data were analyzed using Analysis of Variance (ANOVA) as described by Panse and Sukhatme (1978). The genotypic (V_g) and phenotypic (V_p) variances were calculated

using standard statistical formulas. The genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated by applying the methods proposed by Burton (1952). Heritability in the broad sense (h^2_b) was determined according to Lush (1940) and the expected genetic advance as a percentage of the mean was calculated using the approach of Burton and Devane (1953) and Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Performance of Potato Genotypes

The evaluation of eight potato genotypes under the agro-climatic conditions of Zone-IIIB of Bihar revealed considerable variability for most of the studied traits, indicating substantial scope for genetic improvement. Significant differences among genotypes were observed for traits such as main stem height, number of tubers per plant, number of plants per hill, plant height, maturity duration, tuber length, tuber diameter, average tuber weight and yield (q/ha).

The data presented in Table 1 indicated statistically significant variation among the genotypes. The height of the main stem varied significantly, with Bari Aloo-7015

exhibiting the tallest stems (69.00 cm), whereas Kufri Neelkanth recorded the shortest stems (42.90 cm). Such variation in stem height may be attributed to both genetic and environmental factors, as genotype $\times$ environment interactions often influence vegetative growth (Gupta *et al.*, 2021).

The number of tubers per plant showed significant variation among the genotypes. Kufri Sangam (12.77) and Kufri Uday (12.67) produced the highest number of tubers per plant, indicating their potential contribution to higher yield. Bari Aloo-7015 showed the highest plant height (70.26 cm), followed by Kufri Pukhraj (68.76 cm), which is in agreement with the findings of Singh *et al.* (2019).

The varieties Kufri Mohan (12.33) and Kufri Sangam (12.00) recorded the highest number of plants per hill, an important parameter for efficient utilization of resources and yield stability, as reported by Mishra *et al.* (2020). Among the evaluated genotypes, Kufri Uday (Yusimap) showed the earliest maturity (100 days), making it suitable for regions with shorter growing seasons and enabling its integration into intensive cropping systems. Similar observations were reported by Gupta *et al.* (2018).

Table 1. Mean value of morphological traits in different potato varieties

Genotypes	Height of main stem	No. of tuber/plant	Plant height (cm)	No. of plant/hill	Maturity duration (days)	Tuber length (cm)	Tuber diameter (cm)	Average tuber weight (g)	Tuber yield (q/ha)
Kufri Neelkanth	42.90*	10.73	58.65*	10.67	105.00	8.07*	5.17	89.53*	290.32
Kufri Mohan	47.10*	11.47	60.31*	12.33*	101.67*	7.13	4.77	92.23*	317.49*
Bari Aloo- 7015	69.00	11.33	70.26	10.00	108.67	7.00	5.20	88.82	301.98*
Kufri Pukhraj	46.53*	11.45	68.76	10.00	107.67	7.63	5.43*	95.21*	326.82*
Kufri Uday/ Yusimap	62.83	12.67	62.22	10.67	100.00*	7.50	4.97	82.81	314.85*
Kufri Sangam	50.67	12.77*	62.77	12.00*	110.67	7.33	4.63	71.22	272.32
Kufri Lima	49.03*	10.33	59.11*	10.67	113.67	7.83*	5.77*	94.93*	294.00
Kufri Thar-2	43.67*	10.13*	63.02	11.33*	109.33	8.10*	5.13	93.20*	282.91
CV (%)	18.30	8.60	6.77	7.90	4.30	5.41	7.02	9.11	13.18
CD at 5% d.f.	7.14	0.74	3.24	0.70	3.50	0.31	0.30	6.11	17.31

Regarding tuber characteristics, Kufri Thar-2 produced the longest tubers (8.10 cm), whereas Kufri Lima recorded the largest tuber diameter (5.77 cm), traits that are often preferred in the consumer market. The highest average tuber weight was observed in Kufri Pukhraj (95.21 g) followed by Kufri Lima (94.93 g), which are important yield-contributing traits as supported by Prakash *et al.* (2021); Kumar *et al.* (2025).

Overall, the superior performance of Kufri Pukhraj and Kufri Uday may be attributed to their higher tuber numbers, favorable tuber size and greater average tuber weight. These findings are consistent with Kumar *et al.* (2021), who emphasized the importance of identifying high-yielding genotypes for improving potato productivity in similar agro-climatic regions.

GCV, PCV, Heritability and Genetic advance

The genetic parameters including genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as percentage of mean were estimated and are presented in Table 2. In general, PCV values were slightly higher than GCV values for all traits, indicating the influence of environmental factors on

the expression of these traits. However, the relatively small differences between GCV and PCV suggest that most of the variability observed was primarily genetic in nature. Similar results were reported by Seid *et al.* (2020), Zeleke *et al.* (2021), Annigeri and Hiremath (2022), Anoumaa *et al.* (2022) and Gebreselassie (2023).

High heritability estimates were observed for tuber length (93.08%), tuber diameter (85.54%) and average tuber weight (83.82%), indicating that these traits are largely governed by genetic factors and can be effectively improved through direct selection. Moderate heritability was recorded for plant height (29.27%), suggesting that environmental factors play a relatively larger role in determining this trait.

Tuber yield showed moderate heritability (9.97%) but relatively higher genetic advance, indicating the possibility of improving yield through selection based on associated yield-contributing traits. The highest genetic advance was observed for tuber yield, suggesting strong selection potential for improving productivity. Similar findings were reported by Luthra *et al.* (2018), Narasimhamurthy *et al.* (2018), Prajapati *et al.* (2020), Gadissa *et al.* (2020), Tessema *et al.* (2022) and Zanzam *et al.* (2023).

Table 2. GCV, PCV, Heritability and GA% of mean in potato genotypes

Character	GCV (%)	PCV (%)	Heritability (h^2b)	GA	GA% of mean
Height of main stem	17.44	19.91	76.71	6.12	11.90
No. of tubers/ plant	11.76	5.28	16.79	0.87	7.70
Plant height (cm)	5.04	9.31	29.27	3.51	5.56
No. of plant/ hill	2.44	13.19	3.42	0.86	7.88
Maturity duration (days)	3.16	5.94	1.98	3.80	3.54
Tuber length (cm)	5.35	5.54	93.08	0.25	3.31
Tuber diameter (cm)	6.83	7.38	85.54	0.23	4.41
Average tuber weight (g)	8.83	9.64	83.82	5.10	5.76
yield (q/ha)	0.04	13.90	9.97	24.90	8.30

Correlation Analysis

Correlation analysis revealed important associations among yield and its component traits. The height of the main stem showed a negative genotypic correlation with tuber length (-0.611). Plant height exhibited a moderate positive genotypic correlation with yield-related traits, indicating that increased vegetative growth may contribute to improved photosynthetic capacity and ultimately higher productivity. Similar findings were reported by Prakash and Pathak (2021).

Tuber length and tuber diameter showed moderate correlations with yield. Phenotypically, tuber length showed a strong positive association with yield (0.849), suggesting that larger tuber size may contribute significantly to overall productivity.

These results are consistent with the observations reported by Kumar *et al.* (2021).

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was used to visualize the relationships among potato genotypes and agronomic traits. The PCA biplot revealed that the first principal component (PC1) accounted for 37.7% of the total variation, while the second principal component (PC2) explained 28.7% of the variation (Table 3). Together, PC1 and PC2 explained 66.4% of the total variability, indicating that the biplot provided a reliable representation of the relationships among genotypes and traits (Fig 1).

Traits positioned close to each other in the biplot indicated positive correlations, whereas traits located in opposite directions indicated negative correlations (Abdi and

Table 3. Genotypic and Phenotypic Correlation

Traits	Correlation	Height of main stem	No. of tubers/plant	Plant height (cm)	No. of plant/hill	Maturity duration (days)	Tuber length (cm)	Tuber diameter (cm)	Average tuber weight (g)	yield (q/ha)
Height of main stem	Genotypic	1.000*								
	Phenotypic	1.000*								
No. of tubers/plant	Genotypic	0.367 ^{NS}	1.000*							
	Phenotypic	0.610*	1.000*							
Plant height	Genotypic	0.381 ^{NS}	0.199 ^{NS}	1.000*						
	Phenotypic	0.381 ^{NS}	0.098 ^{NS}	1.000*						
No. of plant/hill	Genotypic	-0.074 ^{NS}	0.060 ^{NS}	0.218 ^{NS}	1.000*					
	Phenotypic	-0.054 ^{NS}	0.047 ^{NS}	0.133 ^{NS}	1.000*					
Maturity duration	Genotypic	-0.028 ^{NS}	-0.312 ^{NS}	-0.024 ^{NS}	0.054 ^{NS}	1.000*				
	Phenotypic	-0.017 ^{NS}	-0.259 ^{NS}	0.022 ^{NS}	0.089 ^{NS}	1.000*				
Fruit length	Genotypic	-0.611*	-0.407*	-0.511*	0.011 ^{NS}	0.031 ^{NS}	1.000*			
	Phenotypic	-0.693*	-0.388 ^{NS}	-0.519*	0.020 ^{NS}	-0.010 ^{NS}	1.000*			
Fruit diameter	Genotypic	-0.109 ^{NS}	-0.436*	-0.210 ^{NS}	-0.380 ^{NS}	0.299 ^{NS}	0.394 ^{NS}	1.000*		
	Phenotypic	-0.219 ^{NS}	-0.442*	-0.074 ^{NS}	-0.436*	0.273 ^{NS}	0.400 ^{NS}	1.000*		
Average fruit weight	Genotypic	0.234 ^{NS}	-0.440*	0.136 ^{NS}	-0.206 ^{NS}	0.074 ^{NS}	0.323 ^{NS}	0.558*	1.000*	
	Phenotypic	-0.348 ^{NS}	-0.418*	0.050 ^{NS}	-0.246 ^{NS}	0.274 ^{NS}	0.378 ^{NS}	0.530*	1.000*	
yield (q/ha)	Genotypic	0.197 ^{NS}	0.672*	0.314 ^{NS}	-0.106 ^{NS}	-0.317 ^{NS}	-0.147 ^{NS}	0.018 ^{NS}	0.365 ^{NS}	1.000*
	Phenotypic	0.322 ^{NS}	0.551*	0.274 ^{NS}	-0.177 ^{NS}	-0.383 ^{NS}	-0.128 ^{NS}	-0.012 ^{NS}	0.329 ^{NS}	1.000*

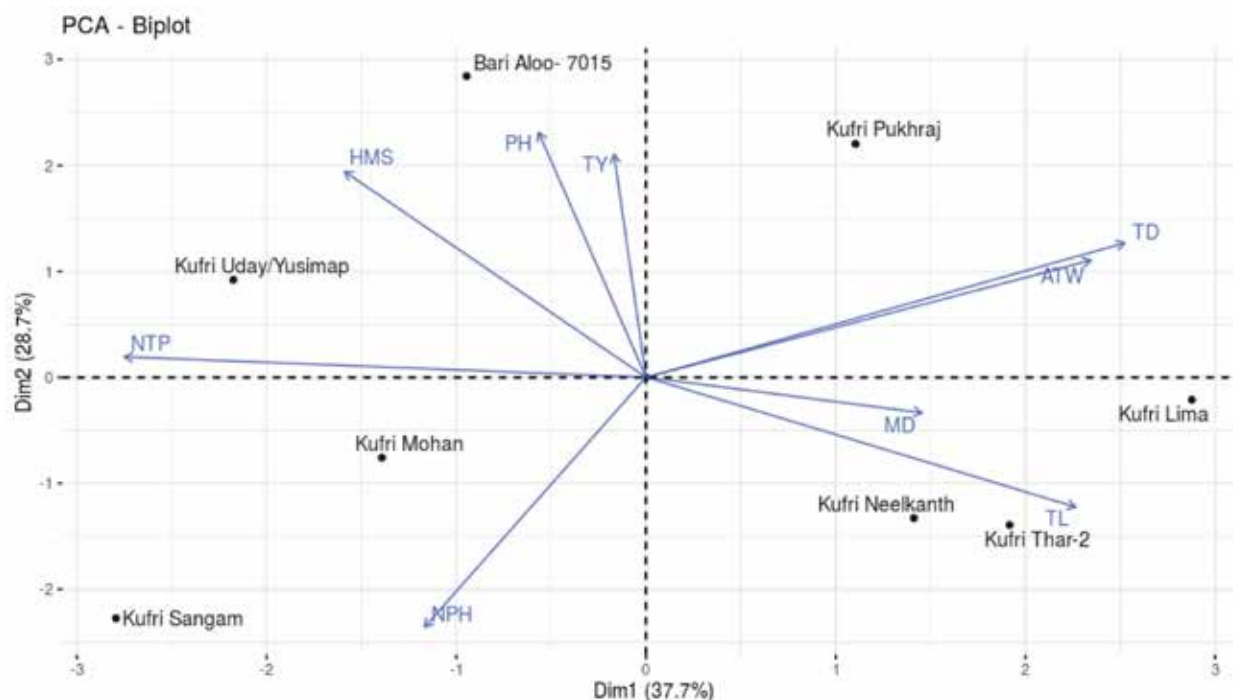


Fig. 1. Principal Component Analysis of Potato Varieties

Williams, 2010). The length of the vectors represented the magnitude of contribution of each trait to the total variation.

Traits such as average tuber weight and total yield were located in the positive region of PC1 and were closely clustered, indicating a strong positive association between these traits. PCA is widely used in potato breeding programs as it helps identify key traits contributing to genetic variability and assists breeders in selecting promising genotypes (Manrique *et al.*, 2019).

The genotypes Kufri Mohan and Kufri Pukhraj were positioned close to each other, indicating similar trait performance, whereas Bari Aloo-7015 and Kufri Sangam were located farther apart, suggesting greater divergence among their agronomic traits. The dispersion pattern observed in the PCA plot corroborated the cluster analysis results, confirming the existence of substantial genetic variability among the evaluated genotypes.

Cluster Analysis

The dendrogram constructed using hierarchical clustering of the eight potato genotypes based on Euclidean distance clearly illustrated the genetic similarity and dissimilarity among the varieties. Two distinct genotype pairs exhibited close similarity: Kufri Neelkanth and Kufri Thar-2 showed the lowest Euclidean distance, indicating a high degree of similarity in their agronomic characteristics. Similarly, Kufri Mohan and Kufri Uday were also closely associated, suggesting comparable performance across several evaluated traits (Fig.2). The results are in conformity with the findings of Kumar *et al.* (2025).

From the hierarchical classification, Bari Aloo-7015 and Kufri Pukhraj formed an independent cluster, which later merged with a larger cluster comprising Kufri Lima, Kufri Neelkanth and Kufri Thar-2. Finally, all genotypes converged into a single cluster at

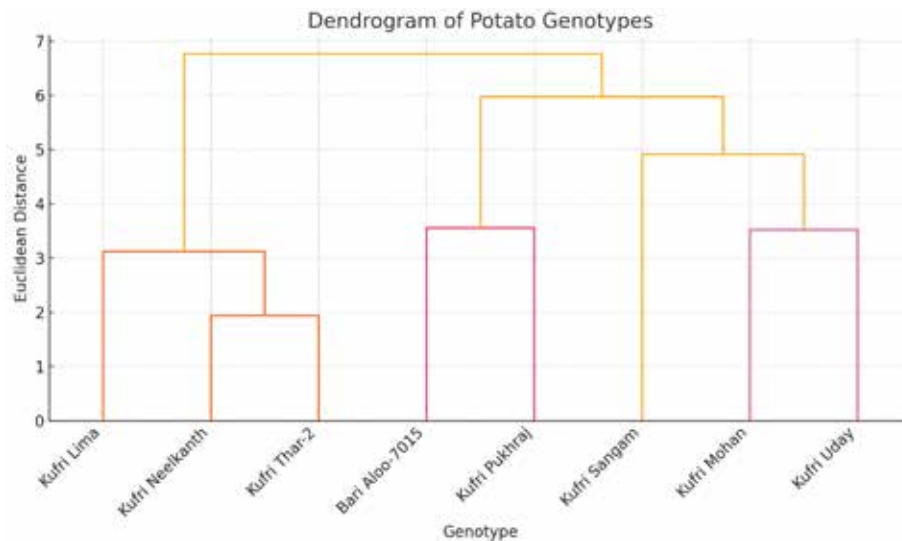


Fig. 2. Dendrogram showing the clustering of eight potato genotypes based on their agronomic traits

a higher Euclidean distance (6.8), indicating the presence of significant genetic divergence among the major groups.

Such clustering patterns provide valuable insights for breeders in selecting genetically diverse parents for hybridization programs aimed at improving yield and other desirable traits.

CONCLUSION

Among the evaluated genotypes, Kufri Uday (Yusimap) and Kufri Pukhraj emerged as the most promising varieties, showing superior performance in terms of tuber number, average tuber weight and overall yield. These traits exhibited positive genotypic and phenotypic associations with yield, highlighting their importance as key yield-contributing characters.

The observed variability in maturity duration, plant height and tuber characteristics indicate the presence of substantial genetic diversity among the tested genotypes. Such diversity can be effectively utilized in breeding programs to develop high-yielding and disease-resistant potato varieties suitable for the agro-climatic conditions of Bihar.

Overall, the results provide valuable insights for potato improvement programs and support the development of potato varieties adapted to intensive cropping systems, thereby contributing to sustainable agricultural production and food security, particularly in Zone-IIIB of Bihar.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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