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Evaluation and Characterization of Local Potato Cultivars Collected from the Northern Part of West Bengal Based on Phenology

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ABSTRACT

The objective of the present investigation was to characterize local potato cultivars found in the northern part of West Bengal utilizing recent morphometric techniques with respect to qualitative traits. In the present investigation, some local potato cultivars were evaluated for 30 qualitative traits to explore their genetic information that was unrevealed following the Kruskal-Wallis non-parametric test, spearman rank correlation analysis, different diversity indices and dendrogram analysis.All qualitative traits showed significant variation ($P < 0.005$) in accordance with the Kruskal-Wallis non-parametric test. Spearman rank correlation analysis suggested a positive association among the different desirable traits of local potato cultivars. Different diversity indices like the Shannon diversity index (H), Simpson diversity index (D) and Nei's diversity index (N) were estimated to find the dominant traits in the population as well as variation among the different traits. Finally, cluster and principal coordinate analysis identified four distinct groups among the local potato cultivars with high levels of genetic dissimilarities. Overall, this study will be helpful in managing the potato germplasm and DUS characterization by the potato breeders.

Keywords: *Solanum tuberosum* L., Genetic relatedness, Qualitative traits, Phenotypic variants, Kruskal-Wallis test, Diversity indices

INTRODUCTION

The northern part of West Bengal, India, is rich in crop biodiversity, including tuber and root crops (Asati and Yadav 2004, Bhattacharya et al. 2015a,b, Subba et al. 2018). Among the different crops, local potato cultivars are important vegetables (Singh et al. 2014, De et al. 2009), which is mainly consumed by local people and sold in local markets by farmers for their livelihood in this region. Presently, these local potatoes are threatened by genetic erosion due to introduced of high-yielding varieties. It is necessary and important task to characterize all local genetic resources for crop improvement in developing countries like India (William et al. 1991, Kolech et al. 2016). Local potato cultivars are useful breeding materials for successful hybridization to increase sustainable potato production (Ortiz 2001, Kolech et al. 2016). The genetic makeup of such local potatoes found in the northern part of West Bengal is yet to be explored. Estimation of the genetic relatedness of local potatoes is the basic step for improvement of productivity (Mwanga et al. 2017). Morhological as well as phenome studies based on the measurement of vegetative and reproductive structure of plants are important steps for the characterization and utilization of local cultivars (Martins et al. 2006, Balkaya and Ergun 2008, Anoumaa et al. 2016, Huaman 1999). Previous morphological characterization has some drawbacks like time-consuming and erroneous trait measurements (Kumar et al. 2015). Recently, a number of methods for phenome and morphometric

analysis have been raised to estimate the genetic diversity in crop plants (Gehan et al. 2017). A similar approach has been used by many researchers to estimate genetic diversity in targeted crops and produce fruitful knowledge for breeding strategies (Fajardo et al. 2008, Ames et al. 2008, Chitwood et al. 2013, 2014, Lockhart 2013). Therefore, the objective of the present investigation was to characterize local potato cultivars found in the northern part of West Bengal utilizing recent morphometric techniques with respect to qualitative traits.

MATERIALS AND METHODS

Plant materials and description of the experiments

Fourteen potato genotypes, including some local cultivars, were considered in this study (Table 1). These genotypes were collected from different parts of North Bengal by the Central Germplasm Conservation Unit, Directorate of Research, Uttar Banga Krishi Viswavidyalaya (Fig. 1). The tubers were allowed to sprout and later utilized for planting to determine the similarity and diversity among them with respect to their qualitative traits.

The present investigation was conducted at the Agricultural Research Farm, Regional Research Station, Terai zone, Pundibari, Cooch Behar, West Bengal during the rabi season of 2017-18 and 2018-19. The area is situated at 26^{0}23'25" N latitude and 89^{0}23'21" E longitude, and the elevation of the area was 44 m.a.s.l. The experiment was laid out in a randomized block design (RBD) with three replications each. An area of 35 m × 11 m was divided into three equal blocks. Each block consisted of 14 plots where 14 germplasm were allotted randomly. The size of each plot was 3 m × 2 m. The distances between the two successive blocks and plots were 1 m and 0.5 m, respectively. All cultural practices were followed according to Thamburaj and Narendra (2016) and Choudary et al. (2009).

Table 1. List and sources of potato clones/genotypes used in this study

Name of Genotypes	Place of Collection	Type
UBD-1 (G-1) & UBD-2 (G-2)	Dinhata, Coochbehar, West Bengal, India	Local Cultivars
UBC-1 (G-3), UBLG-1 (G-4) & UBK-1 (G-5)	Falakata, Jalpaiguri, West Bengal, India	
UBB-1 (G-6) & UBB-2 (G-7)	Jaigaon, Jalpaiguri, West Bengal, India	
UBH-1 (G-8), UBT-1 (G-9) & UBLP-1 (G-10)	Pundibari, CoochBehar, West Bengal, India	
Kufri Ashoka (G-11), Kufri Arun (G-12), Kufri Pukhraj (G-13) & Kufri Jyoti (G-14)	CPRI, Shimla, Himachal Pradesh, India	Release Varieties

Data collection and statistical analysis

Morphological data were recorded on five randomly

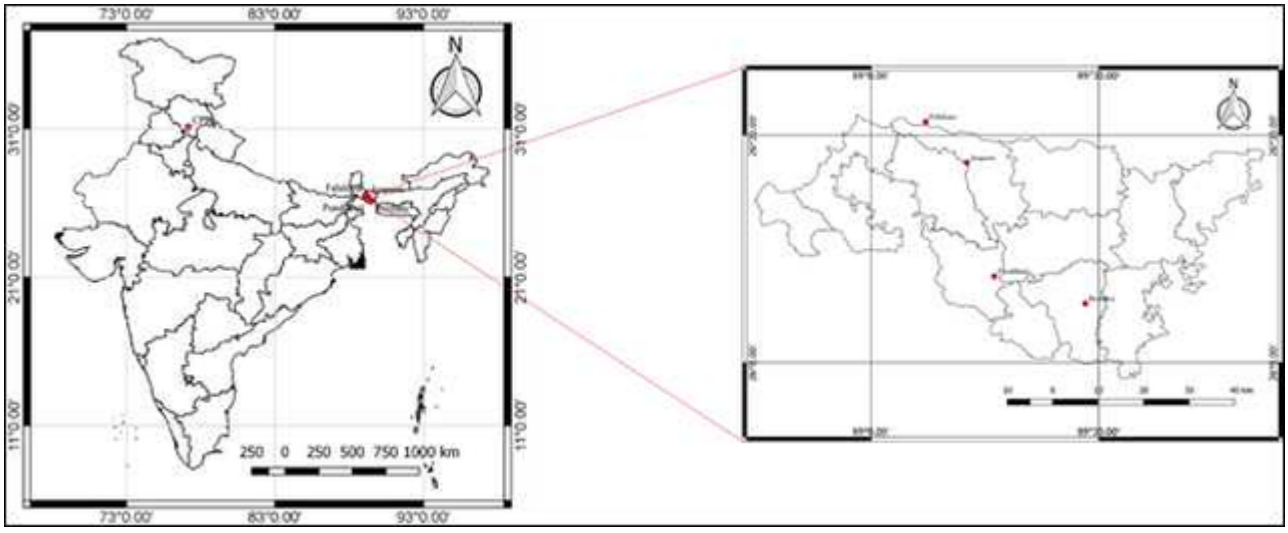

Figure 1. Graphical presentation of different collection areas of potato cultivars used in present study

selected plants, excluding the plants located at borders to avoid border effects so that the highest precision could be achieved. A total of 30 different qualitative traits (Table 2) comprising sprouting, vegetative and reproductive phases were recorded (Human et al. 1977, IBPGR 1985, Human and Spooner 2002, Anoumaa et al. 2016). All the data evaluation, plotting and genetic relationships among the cultivars based on quantitative traits were performed using the R package (Maechler et al. 2018, Rosero et al. 2019).

RESULTS AND DISCUSSION

In the present investigation, fourteen potato cultivars were evaluated based on 30 qualitative traits, of which 5 were sprout characters, 7 were plant and stem characters, 8 were leaf and leaflet characters and 10 were tuber characters. All 30 traits were distributed in 91 different phenotypic variants (Supplementary Table 1). The average performance of potato cultivars based on qualitative traits is illustrated in Table 3. The assessed qualitative traits showed significant differences ($P < 0.005$) among the cultivars in accordance with the Kruskal-Wallis non-parametric test. Red and purple tuber predominant skin colour (TPSC) are the preffered traits by the local people of this region. These preferred traits are found in cultivars namely UBD-1, UBD-2, UBB-1, UBB-2 and UBT-1.

Association analysis among different qualitative traits

Among the 30 qualitative traits considered in this study, highly significant and positive Spearman rank correlations were observed between SPC and ACBS ($r = 0.82$; $p < .01$), SPC and LACM ($r = 0.83$; $p < .01$), ACBS and ACTS ($r = 0.63$; $p < .01$), ACBS and DCC ($r = 0.66$; $p < .01$), ACBS and LACM ($r = 0.78$; $p < .01$), SCC and DCC ($r = 0.82$; $p < .01$), SCC and LACM ($r = 0.64$; $p < .01$), DCC and LACM ($r = 0.75$; $p < .01$), TSCF and TDSCF ($r = 0.78$; $p < .01$), LACM and TPCF ($r = 0.68$; $p < .01$). Significant and negative associations were found between LWDH and LLS ($r = -0.74$; $p < .01$), LWDH and TDSCF ($r = -0.77$; $p < .01$), LGUS and TSCF ($r = -0.64$; $p < .01$), LGUS and TDSCF ($r = -0.71$; $p < .01$). The association between the evaluated qualitative traits of the potato cultivars based on the Spearman rank correlation coefficient is presented in Figure 2 (Supplementary Table 2).The results from the correlation analysis indicated that linkage may exist among the loci controlling sprout predominant colour (SPC), anthocyanin colouration at the sprout base and tip (ACBS and ACTS), anthocyanin colouration of leaf midrib (LACM), stem secondary coloration (SSC), distribution of secondary coloration (DCC) and tuber predominant colour of flesh (TPCF). Selection through these traits may be helpful for the identification of anthocyanin-rich potato cultivars by plant breeders. Similar findings

Table 2. Qualitative traits observed for the characterization of genotypes

Plant organ	Qualitative traits
Light sprout	Predominant colour (SPC), Shape (SS), Intensity of Anthocyanin colouration at base of sprout (ACBS), Intensity of Anthocyanin colouration at sprout tip (ACTS) and Pubescence base (PBS)
Plant	Foliage structure (FLS), Height of main stem (HMS), Wing (PWN) and Wing type (PWT)
Stem	Solidity (SLD), Secondary colouration (SSC) and Distribution of secondary colour (DCC)
Leaf	Structure (LST), Anthocyanin colouration of rachis (LACR), Anthocyanin colouration of midrib (LACM), Length (LLNT) and Width (LWDH)
Leaflet	Lateral leaflet shape (LLS) , Waviness of margin (LWM) and Glossiness of upper side (LGUS)
Tuber	Predominant skin Colour (TPSC), Secondary skin colour (TSSC), Distribution of secondary skin colour (TDSSC), Skin type (TSTP), Shape (TSP), Depth of Eye (TDEY), Colour of Eye (TCEY), Predominant colour of flesh (TPCF), Secondary colour of flesh (TSCF) and Distribution of secondary colour of flesh (TDSCF)

Table 3. Different phenotypic variant of 30 qualitative traits in fourteen potato cultivars

Traits	G-1	G-2	G-3	G-4	G-5	G-6	G-7	G-8	G-9	G-10	G-11	G-12	G-13	G-14	KWSL
SPC	1	1	1	1	2	3	3	4	3	1	2	4	3	1	0.0046
SS	1	1	1	2	1	1	1	1	1	3	1	1	2	2	0.0015
ACBS	2	2	1	2	1	3	3	3	3	1	2	3	3	2	0.0015
ACTS	1	1	1	1	1	3	3	1	3	1	1	1	3	2	0.0015
PBS	3	1	1	3	2	2	2	3	1	3	2	2	2	1	0.0015
FLS	3	3	2	2	1	1	2	2	2	2	2	2	2	2	0.0015
SLD	1	1	1	1	1	1	1	1	1	1	1	2	1	1	0.0003
HMS	1	1	1	1	1	1	1	1	1	1	1	2	1	1	0.0003
SSC	2	1	1	2	1	2	2	2	2	1	1	2	1	2	0.0003
DCC	2	2	1	2	1	2	3	4	2	1	1	4	1	2	0.0046
PWN	1	1	2	2	2	2	2	2	2	2	2	2	2	1	0.0003
PWT	1	1	1	1	1	1	1	1	1	2	2	2	2	1	0.0003
LST	1	1	1	1	2	1	1	1	1	1	1	2	2	1	0.0003
LACR	1	1	2	2	2	1	1	1	1	1	2	1	2	2	0.0003
LACM	1	1	1	1	1	2	2	3	2	1	1	2	1	1	0.001
LLNT	1	1	2	1	2	1	1	1	1	1	2	3	3	2	0.001
LWDH	1	1	2	3	3	2	2	2	2	1	3	3	2	3	0.001
LLS	4	4	4	2	3	4	4	4	4	4	4	1	4	2	0.0046
LWM	1	2	1	2	1	2	2	1	2	1	1	2	1	2	0.0003
LGUS	1	1	1	2	1	3	3	1	1	1	2	2	1	2	0.0015
TPSC	4	4	1	3	1	5	5	2	4	6	3	4	1	3	0.02
TSSC	1	1	1	1	1	1	1	1	1	2	1	1	1	1	0.0003
TDSSC	1	1	1	1	1	1	1	1	1	2	1	1	1	1	0.0003
TSTP	1	1	1	1	1	1	1	1	1	1	1	2	1	1	0.0003
TSP	1	1	1	2	2	4	4	3	1	5	3	2	4	2	0.011
TDEY	1	1	2	1	3	2	2	1	1	3	1	1	2	1	0.001
TCEY	3	3	1	3	1	5	5	2	4	7	3	4	1	3	0.023
TPCF	2	2	2	2	1	3	3	3	2	3	1	3	2	2	0.0015
TSCF	3	3	2	1	1	1	1	4	2	4	1	3	2	1	0.0016
TDSCF	2	2	2	1	1	1	1	2	2	3	1	1	1	1	0.0015

Note: For description of genotype names and traits, refer to Table 1 and Table 2.

were also reported by Mashilo et al. (2016) in bottle gourd landraces.

Frequency of phenotypic variants and diversity index analysis

Characterization of germplasm utilizing qualitative traits is an essential alternative for molecular tools to estimate the genetic diversity in plants (Ngompe-Deffo et al. 2017, Bonny et al. 2019). In the present study, fourteen local potato cultivars were evaluated using 30 qualitative traits with 91 phenotypic variants. The number of phenotypic variants noticed for each trait ranged from two to seven, which proved that all the traits under study were polymorphic in nature. These results indicate that a higher degree of phenotypic variability is present among the local potato cultivars. Moreover, a predominance of some phenotypic variants was observed for all traits through frequency distribution analysis (Supplementary Table 1). Amount of the diversity of different traits based on the phenotypic variants was measured using three different diversity indices (Supplementary Table 3): Shannon diversity index (H), Simpson diversity index (D) and Nei diversity index (N). According to the Shannon diversity index and Simpson diversity index highest diversity was shown by the colour of the tuber eye (TCEY) and the lowest diversity was shown by the type of tuber skin (TSTP). However, the results of the Nei diversity index indicate that the waviness of

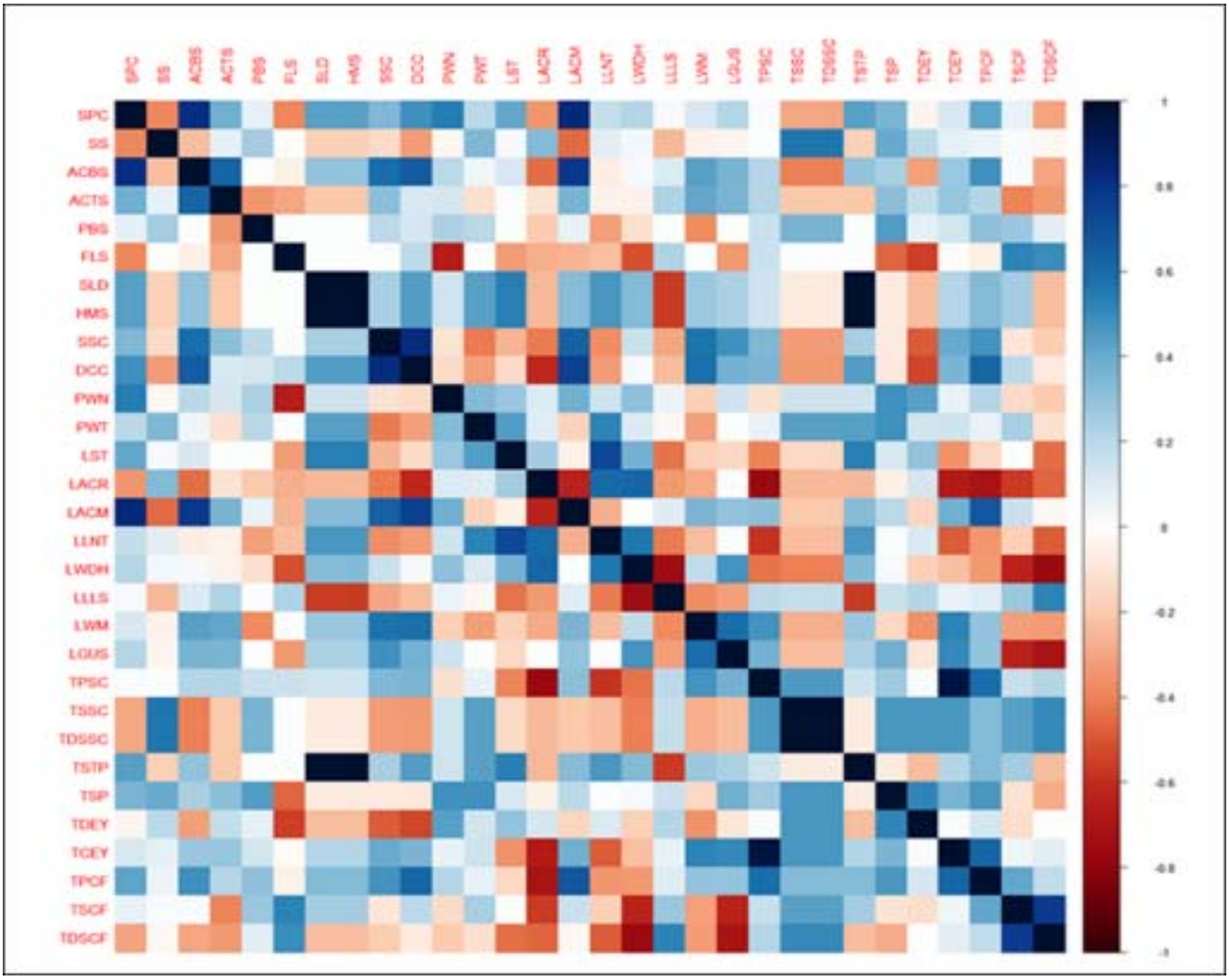

Figure 2. Spearman's rank correlation coefficient among the 30 qualitative traits in potato

leaflet margin (LWM) has a higher diversity and secondary colour of tuber skin (TSSC), distribution of secondary tuber skin colour (TDSSC) and type of tuber skin (TSTP) had the lowest diversity (Fig. 3). The findings of this analysis indicate that qualitative traits have a wide distribution of phenotypic variants and the presence of different genetically distinct genotypes in local potato cultivars. All the diversity indices were unequally correlated with each other according to Pearson correlation analysis. Shannon and Simpson diversity indices were dependent on each other, but the Nei diversity index was independent (Fig. 4).

Genetic relatedness analysis

The hierarchical dendrogram of qualitative traits based on UPGMA grouped all the potato cultivars into four clusters at a 0.48 similarity level (Fig. 5). The genetic similarity for the 30 qualitative traits ranged from 0.19 (UBLP-1 and Kufri Arun) to 0.89 (UBD-1 and UBD-2 and UBB-1 and UBB-2) with a mean similarity of 0.42 (Supplementary Table 4).

Cluster I contained eight genotypes from the total population and was further subdivided into two subgroups. The common phenotypic variants of subgroup I, which consist of four genotypes (UBD-1, UBD-2, UBLG-1 and Kufri Jyoti) are white sprout colour, short stem height, straight plant wing type, open leaf structure, anthocyanin colouration of midrib of leaflets, shallow depth of tuber eye, whitish cream colour of tuber eye and yellow tuber flesh colour. Subgroup II also consists of four genotypes (UBB-1, UBB-2, UBT-1 and UBH-1) with some common phenotypic variants, such as the spherical

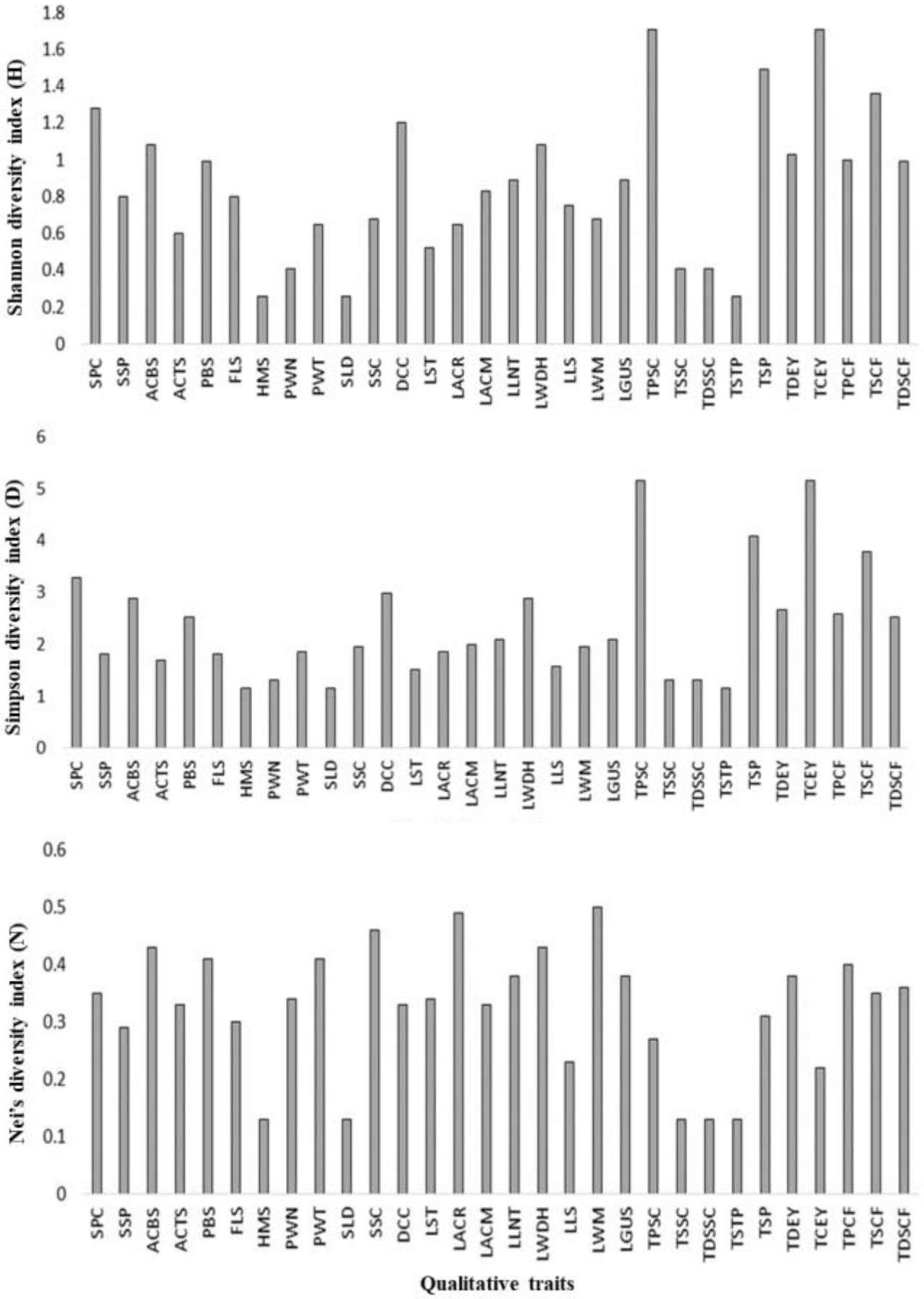

Figure 3. Distribution of three diversity indices value revealed from the 30 qualitative traits of potato cultivars

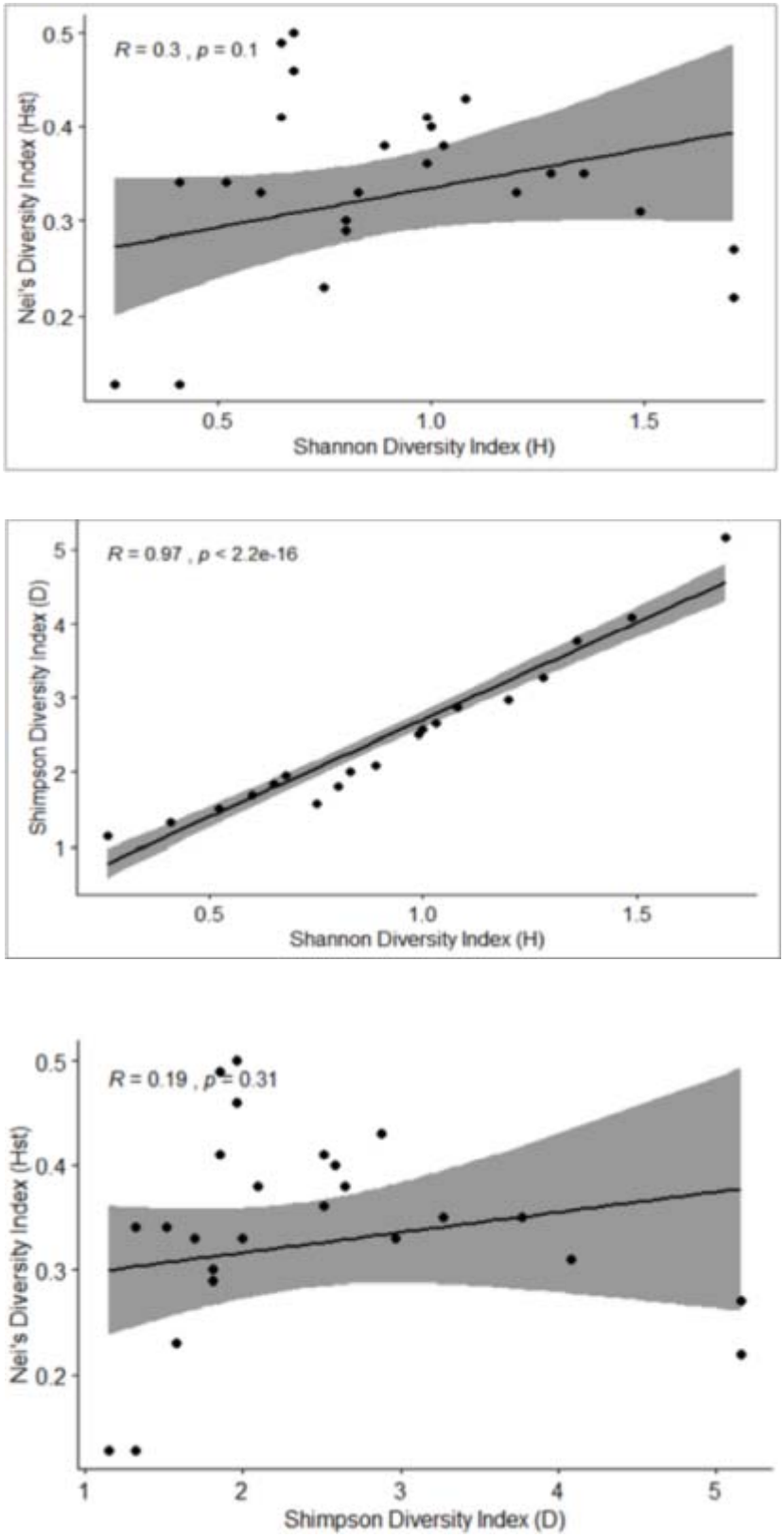

Figure 4. Relationship among the three diversity indices based on the 30 qualitative traits of local potato cultivars

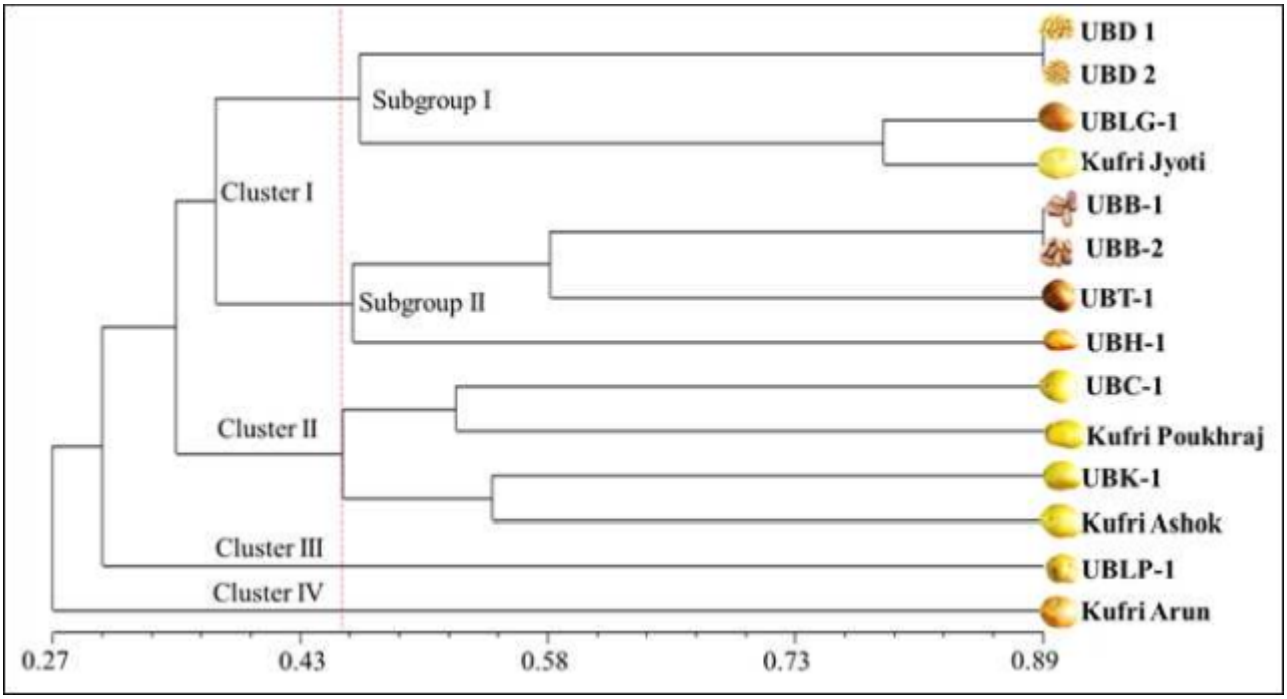

Figure 5. Dendrogram showing relationships among 14 genotypes of potato classified by UPGMA method using 30 qualitative traits with 91 phenotypic variants

shape of tuber sprout, purple secondary coloration in stem, poorly developed plant wing, small leaf length and width, presence of anthocyanin in leaf rachis and ovate lanceolate leaf shape. Cluster II contained five genotypes that were similar for their characteristics like absence of anthocyanin in leaf rachis and midrib of leaf and weak waviness of leaf margin. Cluster III included only one genotype (UBLP-1) with some unique phenotypic variants, which are pink colour of the tuber eye and vascular ring type distribution of secondary tuber flesh colour. Cluster IV also has one genotype (Kufri Arun) with some special phenotype variants like rough tuber skin type, oval leaflet shape, medium stem height and hollow stem. Based on 30 qualitative traits, including 91 phenotypic variants, a principal coordinates analysis was performed, which illustrated that the first eleven coordinate (eigenvalue >1) accounted for 98.38% of the total phenotypic variation (Table 4). These principal coordinates also separated the potato genotypes into four groups, which was also supported by cluster analysis (Fig. 6). The results from the cluster and principal coordinate analysis indicate that qualitative traits are essential markers to distinguish local potato cultivars.

Table 4. Eigenvalue and percent of variance produced by the principal coordinates

PCs	Eigenvalue	Percent of Variance	Cumulative percent of Variance
1	15.98	17.56	17.56
2	14.56	16.00	33.55
3	13.64	14.99	48.54
4	13.00	14.29	62.83
5	8.62	9.48	72.31
6	7.13	7.84	80.14
7	5.72	6.29	86.43
8	3.77	4.14	90.57
9	2.87	3.16	93.73
10	2.61	2.87	96.60
11	1.62	1.78	98.38

CONCLUSIONS

The results of the present investigation suggest that local potato cultivars collected from the northern part of West Bengal showed a high level of genetic variation for 30 qualitative traits with 91 phenotypic variants. In addition, association analysis among the different qualitative traits will be helpful for the plant breeder to select the preferred genotypes for further

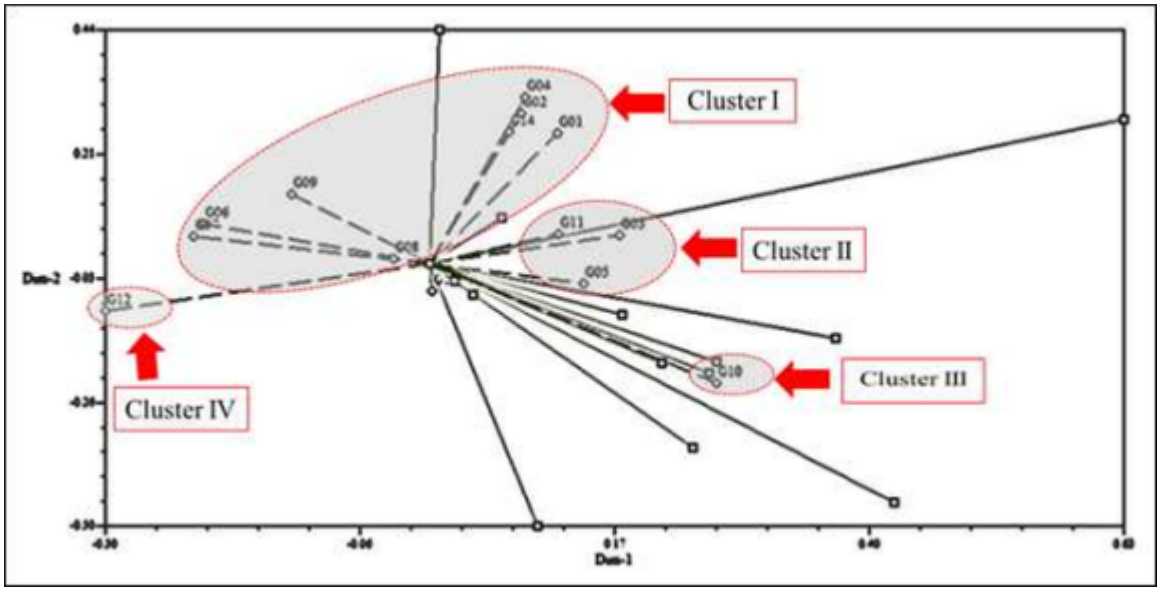

Figure 6. Principal coordinate analysis based on 91 phenotypic variants of 30 qualitative traits

improvement. Genetic relatedness in potato cultivars revealed in this investigation can be useful for potato breeders to manage potato germplasm. Finally, the data obtained from this study will also be helpful for the DUS characterization and identification of the unique traits according to the genotypes.

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Conflict of Interest: Authors declare that they do not have any conflict of interest

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Supplementary Table 1. Frequency distribution of 91 phenotypic variants of 30 qualitative traits in potato

Sl. No	Qualitative character	Phenotypic Variant	PVP
1.	Lightsprout: Predominant colour	White	42.86
		Green	14.29
		Purple	28.57
		Red purple	14.29
2.	Lightsprout: Shape	Spherical	71.43
		Conical	14.29
		Cylindrical	14.29
3.	Lightsprout: Intensity of Anthocyanin colouration at base of sprout	Light	28.57
		Medium	28.57
		Dark	42.86
4.	Lightsprout: Intensity of Anthocyanin colouration at sprout tip	Light	71.43
		Dark	28.57
5.	Lightsprout: Pubescence base	Absent	14.29
		Weak	50.00
		Strong	35.71
	sprout		
6.	Plant: Foliage structure	Open	14.29
		Semi-compact	71.43
		Compact	14.29
7.	Plant: Height of main stem (cm)	Short	92.86
		Medium	7.14
8.	Plant: Wing	Highly developed	14.29
		Poorly developed	85.71
9.	Plant: Wing type	Straight	64.29
		Wavy	35.71
10.	Stem: Solidity	Solid	92.86
		Hallow	7.14
11.	Stem: Secondary colouration	Absent	42.86
		Purple	57.14
12.	Stem: Distribution of secondary colour	Absent	42.86
		Lightly scattered throughout	35.71
		Only at lower node	7.14
		Highly scattered	14.29
13.	Leaf: Structure	Open	78.57
		Intermediate	21.43
14.	Leaf: Anthocyanin colouration of rachis	Present	64.29
		Absent	35.71
15.	Leaf: Anthocyanin colouration of midrib	Absent	64.29
		Present only at the base	28.57
		Present throughout	7.14
16.	Leaf: Length	Small	64.29
		Medium	21.43
		Large	14.29
17.	Leaf: Width	Narrow	28.57
		Medium	42.86
		Broad	28.57
18.	Lateral leaflet shape	Oval	7.14
		Ovate	7.14
		Lanceolate	7.14
		Ovate lanceolate	78.57
19.	Leaflet: Waviness of margin	Weak	57.14
		Medium	42.86

Contd...

Supplimentary table 1. Contd...

Sl. No	Qualitative character	Phenotypic Variant	PVP
20.	Leaflet: Glossiness of upper side	Weak	64.29
		Medium	21.43
		Strong	14.29
21.	Tuber: Predominant skin Colour	Yellow	21.43
		Orange	7.14
		Whitish cream	14.29
		Red	28.57
		Purple	14.29
		Brown	14.29
22.	Tuber: Secondary skin colour	Absent	85.71
		Pink	14.29
23.	Tuber: Distribution of secondary skin colour	Absent	85.71
		Confined to eyes	14.29
24.	Tuber: Skin type	Smooth	92.86
		Rough	7.14
25.	Tuber: Shape	Round	35.71
		Oblong	21.43
		Ovoid	14.29
		Long oblong	21.43
		Irregular	7.14
26.	Tuber: Depth of Eye	Shallow	50.00
		Medium deep	28.57
		Deep	21.43
27.	Tuber: Colour of Eye	Yellow	14.29
		Orange	7.14
		Whitish cream	28.57
		Red	14.29
		Purple	14.29
		Pink	21.43
28.	Tuber: Predominant colour of flesh	White	14.29
		Cream	42.86
		Yellow	42.86
29.	Tuber: Secondary colour of flesh	Absent	35.71
		Yellow	21.43
		Red purple	21.43
		Cream	21.43
30.	Tuber: Distribution of secondary colour of flesh	Absent	50.00
		Inner cortex	35.71
		Vascular ring	14.29

Supplementary Table 2. Correlation among the 30 qualitative traits of local potato cultivars

Traits	SPC	SS	ACBS	ACTS	PBS	FLS	SLD	HMS	SSC	DCC	PWN	PWT	LST	LACR	LACM	LLNT	LWDH	LLLS	LWM	LGUS	TPSC	TSSC	TDSSC	TSTP	TSP	TDEY	TCEY	TPCF	TSCF	TDSCF
SPC	1	-0.39	0.82**	0.38	0.07	-0.39	0.44	0.44	0.34	0.49*	0.55	0.21	0.41	-0.34	0.83**	0.17	0.21	0.03	0.11	0.22	0.01	-0.29	-0.29	0.44	0.35	-0.03	0.11	0.43	0.07	-0.3
SS	-0.39	1	-0.24	0.07	0.25	0	-0.17	-0.17	-0.14	-0.32	-0.03	0.35	0.03	0.34	-0.46*	0.08	0.03	-0.24	-0.04	-0.04	0	0.56*	0.56*	-0.17	0.41	0.2	0.07	0.05	0.01	-0.02
ACBS	0.82**	-0.24	1	0.63**	0	-0.05	0.29	0.29	0.59*	0.66**	0.21	0.04	0.12	-0.44	0.78**	-0.06	0.03	0.1	0.44	0.37	0.22	-0.41	-0.41	0.29	0.24	-0.32	0.27	0.49*	0.02	-0.3
ACTS	0.38	0.07	0.63**	1	-0.35	-0.29	-0.2	-0.2	0.32	0.11	0.13	-0.12	0	-0.11	0.36	-0.04	-0.04	0.23	0.42	0.35	0.22	-0.2	-0.2	-0.2	0.31	0.18	0.29	0.21	-0.4	-0.33
PBS	0.07	0.25	0	-0.35	1	0	0	0	0.19	0.13	0.23	0.21	0	-0.19	0.07	-0.32	-0.11	0	-0.38	0	0.16	0.37	0.37	0	0.45	0.08	0.13	0.31	0.27	0.08
FLS	-0.39	0	-0.05	-0.29	0	1	0	0	0	0.19	-0.65**	0	-0.33	-0.27	-0.25	-0.22	-0.52*	0.23	0	-0.34	0.15	0	0	0	-0.46*	-0.56*	-0.02	-0.05	0.52*	0.49*
SLD	0.44	-0.17	0.29	-0.2	0	0	1	1	0.24	0.44	0.14	0.44	0.53	-0.24	0.33	0.46*	0.33	-0.56*	0.28	0.23	0.14	-0.08	-0.08	1	-0.07	-0.23	0.21	0.34	0.25	-0.24
HMS	0.44	-0.17	0.29	-0.2	0	0	1	1	0.24	0.44	0.14	0.44	0.53*	-0.24	0.33	0.46*	0.33	-0.56*	0.28	0.23	0.14	-0.08	-0.08	1	-0.07	-0.23	0.21	0.34	0.25	-0.24
SSC	0.34	-0.14	0.59*	0.32	0.19	0	0.24	0.24	1	0.82**	-0.1	-0.41	-0.25	-0.42	0.64**	-0.36	0.15	-0.29	0.58*	0.48*	0.35	-0.32	-0.32	0.24	-0.07	-0.48*	0.41	0.47*	-0.09	-0.18
DCC	0.49*	-0.32	0.66**	0.11	0.13	0.19	0.44	0.44	0.82**	1	-0.14	-0.31	-0.14	-0.61**	0.75**	-0.32	0.03	-0.24	0.59	0.37	0.35	-0.33	-0.33	0.44	-0.09	-0.54*	0.35	0.61**	0.19	-0.07
PWN	0.55*	-0.03	0.21	0.13	0.23	-0.65**	0.14	0.14	-0.1	-0.14	1	0.33	0.27	0.1	0.38	0.15	0.3	0.05	-0.17	0.15	-0.11	0.14	0.14	0.14	0.49*	0.44	0.07	0.21	-0.14	-0.2
PWT	0.21	0.35	0.04	-0.12	0.21	0	0.44	0.44	-0.41	-0.31	0.33	1	0.44	0.09	-0.16	0.53	0.11	-0.02	-0.32	0	0.06	0.44	0.44	0.44	0.48*	0.13	0.14	0.06	0.25	-0.11
LST	0.41	0.03	0.12	0	0	-0.33	0.53*	0.53*	-0.25	-0.14	0.27	0.44	1	0.25	-0.05	0.73**	0.37	-0.43	-0.17	-0.15	-0.4	-0.14	-0.14	0.53*	0.11	0.29	-0.36	-0.14	0	-0.44
LACR	-0.34	0.34	-0.44	-0.11	-0.19	-0.27	-0.24	-0.24	-0.42	-0.61**	0.1	0.09	0.25	1	-0.64**	0.60*	0.61**	-0.34	-0.29	0	-0.77**	-0.24	-0.24	-0.24	-0.06	0.12	-0.66**	-0.71	-0.57*	-0.47*
LACM	0.83**	-0.46*	0.78**	0.36	0.07	-0.25	0.33	0.33	0.64**	0.75**	0.38	-0.16	-0.05	-0.64**	1	-0.27	0	0.1	0.36	0.3	0.32	-0.2	-0.2	0.33	0.2	-0.16	0.39	0.68**	0.15	-0.03
LLNT	0.17	0.08	-0.06	-0.04	-0.32	-0.22	0.46*	0.46*	-0.36	-0.32	0.15	0.53	0.73	0.60*	-0.27	1	0.56*	-0.42	-0.24	0	-0.58*	-0.23	-0.23	0.46*	0.01	0.1	-0.48*	-0.34	-0.17	-0.49*
LWDH	0.21	0.03	0.03	-0.04	-0.11	-0.52*	0.33	0.33	0.15	0.03	0.3	0.11	0.37	0.61**	0	0.56*	1	-0.74**	0.19	0.48*	-0.44	-0.41	-0.41	0.33	0.02	-0.17	-0.23	-0.33	-0.63**	-0.77**
LLLS	0.03	-0.24	0.1	0.23	0	0.23	-0.56*	-0.56*	-0.29	-0.24	0.05	-0.02	-0.43	-0.34	0.1	-0.42	-0.74**	1	-0.38	-0.32	0.19	0.17	0.17	-0.56*	0.16	0.21	0.07	0.1	0.28	0.53*
LWM	0.11	-0.04	0.44	0.42	-0.38	0	0.28	0.28	0.58*	0.59*	-0.17	-0.32	-0.17	-0.29	0.36	-0.24	0.19	-0.38	1	0.60*	0.47*	-0.28	-0.28	0.28	-0.15	-0.36	0.53*	0.29	-0.32	-0.32
LGUS	0.22	-0.04	0.37	0.35	0	-0.34	0.23	0.23	0.48*	0.37	0.15	0	-0.15	0	0.3	0	0.48*	-0.32	0.60*	1	0.38	-0.23	-0.23	0.23	0.38	-0.1	0.50*	0.29	-0.64**	-0.71
TPSC	0.01	0	0.22	0.22	0.16	0.15	0.14	0.14	0.35	0.35	-0.11	0.06	-0.4	-0.77**	0.32	-0.58*	-0.44	0.19	0.47*	0.38	1	0.46*	0.46	0.14	0.26	0.02	0.96**	0.60*	0.16	0.22
TSSC	-0.29	0.56*	-0.41	-0.2	0.37	0	-0.08	-0.08	-0.32	-0.33	0.14	0.44	-0.14	-0.24	-0.2	-0.23	-0.41	0.17	-0.28	-0.23	0.46*	1	1	-0.08	0.46*	0.46*	0.46*	0.34	0.43	0.51*
TDSSC	-0.29	0.56*	-0.41	-0.2	0.37	0	-0.08	-0.08	-0.32	-0.33	0.14	0.44	-0.14	-0.24	-0.2	-0.23	-0.41	0.17	-0.28	-0.23	0.46*	1	1	-0.08	0.46*	0.46*	0.46*	0.34	0.43	0.51*
TSTP	0.44	-0.17	0.29	-0.2	0	0	1	1	0.24	0.44	0.14	0.44	0.53*	-0.24	0.33	0.46	0.33	-0.56*	0.28	0.23	0.14	-0.08	-0.08	1	-0.07	-0.23	0.21	0.34	0.25	-0.24
TSP	0.35	0.41	0.24	0.31	0.45	-0.46*	-0.07	-0.07	-0.07	-0.09	0.49*	0.48*	0.11	-0.06	0.2	0.01	0.02	0.16	-0.15	0.38	0.26	0.46*	0.46	-0.07	1	0.51*	0.35	0.47*	-0.11	-0.28
TDEY	-0.03	0.2	-0.32	0.18	0.08	-0.56*	-0.23	-0.23	-0.48*	-0.54*	0.44	0.13	0.29	0.12	-0.16	0.1	-0.17	0.21	-0.36	-0.1	0.02	0.46*	0.46	-0.23	0.51*	1	0.02	0.12	-0.12	-0.01
TCEY	0.11	0.07	0.27	0.29	0.13	-0.02	0.21	0.21	0.41	0.35	0.07	0.14	-0.36	-0.66**	0.39	-0.48*	-0.23	0.07	0.53*	0.5	0.96**	0.46*	0.46	0.21	0.35	0.02	1	0.61**	0.04	0.08
TPCF	0.43	0.05	0.49*	0.21	0.31	-0.05	0.34	0.34	0.47*	0.61**	0.21	0.06	-0.14	-0.71**	0.68**	-0.34	-0.33	0.1	0.29	0.29	0.60*	0.34	0.34	0.34	0.47*	0.12	0.61**	1	0.41	0.18
TSCF	0.07	0.01	0.02	-0.4	0.27	0.52	0.25	0.25	-0.09	0.19	-0.14	0.25	0	-0.57*	0.15	-0.17	-0.63**	0.28	-0.32	-0.64**	0.16	0.43	0.43	0.25	-0.11	-0.12	0.04	0.41	1	0.78**
TDSCF	-0.3	-0.02	-0.3	-0.33	0.08	0.49*	-0.24	-0.24	-0.18	-0.07	-0.2	-0.11	-0.44	-0.47*	-0.03	-0.49*	-0.77**	0.53*	-0.32	-0.71**	0.22	0.51*	0.51*	-0.24	-0.28	-0.01	0.08	0.18	0.78**	1

Supplementary Table 3. Different diversity indices of 30qulatitative traits in potato cultivars

Sl. No	Qualitative character	Code	H	D	N
1	Lightsprout: Predominant colour	SPC	1.28	3.27	0.35
2	Lightsprout: Shape	SSP	0.8	1.81	0.29
3	Lightsprout: Intensity of Anthocyanin colouration at base of sprout	ACBS	1.08	2.88	0.43
4	Lightsprout: Intensity of Anthocyanin colouration at sprout tip	ACTS	0.6	1.69	0.33
5	Lightsprout: Pubescence base	PBS	0.99	2.51	0.41
6	Plant: Foliage structure	FLS	0.8	1.81	0.3
7	Plant: Height of main stem (cm)	HMS	0.26	1.15	0.13
8	Plant: Wing	PWN	0.41	1.32	0.34
9	Plant: Wing type	PWT	0.65	1.85	0.41
10	Stem: Solidity	SLD	0.26	1.15	0.13
11	Stem: Secondary colouration	SSC	0.68	1.96	0.46
12	Stem: Distribution of secondary colour	DCC	1.2	2.97	0.33
13	Leaf: Structure	LST	0.52	1.51	0.34
14	Leaf: Anthocyanin colouration of rachis	LACR	0.65	1.85	0.49
15	Leaf: Anthocyanin colouration of midrib	LACM	0.83	2	0.33
16	Leaf: Length	LLNT	0.89	2.09	0.38
17	Leaf: Width	LWDH	1.08	2.88	0.43
18	Lateral leaflet shape	LLS	0.75	1.58	0.23
19	Leaflet: Waviness of margin	LWM	0.68	1.96	0.5
20	Leaflet: Glossiness of upper side	LGUS	0.89	2.09	0.38
21	Tuber: Predominant skin Colour	TPSC	1.71	5.16	0.27
22	Tuber: Secondary skin colour	TSSC	0.41	1.32	0.13
23	Tuber: Distribution of secondary skin colour	TDSSC	0.41	1.32	0.13
24	Tuber: Skin type	TSTP	0.26	1.15	0.13
25	Tuber: Shape	TSP	1.49	4.08	0.31
26	Tuber: Depth of Eye	TDEY	1.03	2.65	0.38
27	Tuber: Colour of Eye	TCEY	1.71	5.16	0.22
28	Tuber: Predominant colour of flesh	TPCF	1	2.58	0.4
29	Tuber: Secondary colour of flesh	TSCF	1.36	3.77	0.35
30	Tuber: Distribution of secondary colour of flesh	TDSCF	0.99	2.51	0.36

H = Shannon Diversity Index; D= Simpson Diversity Index; N= Nei Diversity Index

Supplementary Table 4. Genetic similarity among the 14 potato cultivars revealed by 91 phenotypic variants

Genotypes	UBD-1	UBD-2	UBC-1	UBLG-1	UBK-1	UBB-1	UBB-2	UBH-1	UBT-1	UBLP-1	Kufri Ashok	Kufri Arun	Kufri Poukhraj	Kufri Jyoti
UBD-1	1													
UBD-2	0.8889	1												
UBC-1	0.4468	0.4468	1											
UBLG-1	0.4167	0.4783	0.36	1										
UBK-1	0.283	0.2593	0.5111	0.3333	1									
UBB-1	0.3333	0.36	0.3077	0.3077	0.3077	1								
UBB-2	0.3077	0.3333	0.3333	0.3077	0.283	0.8889	1							
UBH-1	0.4783	0.4167	0.4167	0.2593	0.283	0.4167	0.4468	1						
UBT-1	0.5111	0.5455	0.4468	0.3333	0.2593	0.5814	0.5814	0.5111	1					
UBLP-1	0.36	0.3077	0.3878	0.193	0.3077	0.2364	0.2593	0.3878	0.2593	1				
Kufri Ashok	0.36	0.3333	0.4468	0.4783	0.5455	0.3077	0.3333	0.36	0.3077	0.3333	1			
Kufri Arun	0.2321	0.2545	0.1695	0.2545	0.2545	0.3019	0.3269	0.3269	0.3529	0.1897	0.3019	1		
Kufri Poukhraj	0.2642	0.2407	0.5227	0.2885	0.4255	0.3958	0.4255	0.3137	0.4255	0.3137	0.4255	0.2593	1	
Kufri Jyoti	0.4783	0.4783	0.36	0.7895	0.36	0.36	0.36	0.36	0.3878	0.283	0.5111	0.3019	0.3137	1