Potato J (2018) 45 (2): 107-115

GENETIC PARAMETERS FOR TUBER YIELD COMPONENTS, LATE BLIGHT RESISTANCE AND KEEPING QUALITY IN POTATOES (*SOLANUM TUBEROSUM* L.)

SK Luthra[1], VK Gupta[1], Mehi Lal[1] and JK Tiwari[2]

ABSTRACT: Genetic parameters were assessed in 24 potato genotypes for 15 characters related to tuber yield, late blight resistance and keeping quality based field trials conducted during 2015-16 and 2016-17 in winter crop season at Modipuram. High coefficient of variation (genotypic and phenotypic) associated with high heritability and genetic advance were observed for rottage weight loss (%), sprout weight loss (%) and sprouting (%). Tuber yield showed positive association with plant vigour and marketable tuber yield but negative association with tuber dry matter. Thus for selecting varieties for table potatoes, high yielding with moderate tuber dry matter, and for selecting processing potatoes, moderate tuber yield with high tuber dry matter (> 20%) should be considered. The area under disease progress curve (late blight) showed low but significant correlation with detached leaf lesion area (cm^2). Keeping quality was dependent on appearance of tubers after storage as it was negatively associated with sprouting (%), sprout weight loss (%) and physiological weight loss (%). Twenty four genotypes could be grouped into six clusters. The grouping of genotypes in clusters indicated that morphological diversity is not related to geographical diversity. Maximum contributions to genetic divergence were of sprouting (%) and sprout weight loss (%) followed by total tubers, tuber dry matter and marketable tuber yield. Though the maximum inter-cluster distances was observed between cluster III and VI, however desirable traits for improvements were available in cluster I and Cluster II. These result would be helpful in selection of superior parents aiming to generate diverse segregating population for effective selection in potato breeding programme.

KEY WORDS: genetic divergence and variability, heritability, keeping quality, late blight resistance, potato

INTRODUCTION

Potato (*Solanum tuberosum* L.), the most important non-cereal food crops of the world, is cultivated in nearly 150 countries. Potato is the main source of diet and basic nutrients in many developing countries, besides the developed nations, and also generates employment and income for livelihood of farmers. The tuber yield is a complex polygenic trait (Killick, 1977) determined by interactions among various genetic as well as environmental factors. The genetic variability in a population along with heritability gives a reliable idea of the genetic advance to be expected from selection for a given character. Correlations among different characters could be effectively utilized in selection of superior parents (Luthra, 2001). Potato is a highly heterozygous crop and increase in its heterozygosity results in hybrid vigour (Tarn and Tai, 1977). Crosses involving genetically diverse parents are likely to produce high heterotic effects (Gopal and Minocha 1997, Luthra *et al*. 2005, 2009). In India, more than 90% potato area and production is confined to sub-tropical plains, where potatoes are cultivated during winter season. The high tuber yield, desirable tuber attributes, good keeping quality and moderate level of resistance to late blight (*Phytophthora infestans*) are the selection criteria for varietal improvement (Luthra *et al*. 2006). The successful development of new potato variety

[1]ICAR-Central Potato Research Institute, Regional Station, Modipuram-250110, Meerut, Uttar Pradesh, India
[2]ICAR-Central Potato Research Institute, Shimla 171001, Himachal Pradesh, India
Email: skluthra@hotmail.com

is up dependent on selection of promising parents, creation of genetically variable population and finally selection of superior clones for targeted environment. For meeting the varietal requirement of such vast area in the country, genetically diverse parents with high tuber yield as well as desirable tuber attributes are required.

Hence, the present study was designed to investigate the genetic parameters like genetic variability, heritability, genetic advance, character association and genetic diversity based on tuber yield components, late blight resistance and keeping quality in the common potato genotypes.

MATERIALS AND METHODS

Plant materials

The material of the present investigation was composed of 24 potato genotypes including 10 advanced stage hybrids (MCIP/10-15, MCIP/11-163, MCIP/12-185, MCIP/12-286, MP/11-472, MS/10-1529, MS/11-664, MS/12-0935, MS/12-1283 and MS/12-2116) form Indian breeding programme, four exotic advanced hybrids (CP4388, CP4393, CP4404 and CP4406) from International Potato Center, Lima, Peru and 10 indigenous varieties (Kufri Arun, Kufri Bahar, Kufri Chipsona-3, Kufri Garima, Kufri Lalima, Kufri Lalit, Kufri Mohan, Kufri Pukhraj, Kufri Sindhuri and Kufri Surya).

Field experiments

Field trials were executed during two successive winter crop seasons during 2015-16 and 2016-17 at ICAR-Central Potato Research Institute, Regional Station, Modipuram, Meerut (29°N and 76°E; 222 m above mean sea level), Uttar Pradesh, India. The trials were planted in rabi season on 20th October in both the years in a randomized complete block design with three replications. Sixty well sprouted tubers of each genotype per replication were planted at 60 cm (row to row) and 20 cm (plant to plant) spacing in four rows with 3 m length of each row. Crops were raised as per the standard package of practices of the region. Dehaulming was done at 90 days after planting (DAP) followed by harvesting after 10 days of dehaulming.

Morphological and tuber yield traits

Observations for various traits were recorded at various growth stages such as plant stand (%) at 45 DAP; plant vigour (1-5 scale; 1- very poor and 5- very good) at 60 DAP; foliage maturity (1-5 scale; 1- very late and 5- very early) at 75 DAP; tuber number per plant (marketable,> 20 g tuber size; and total), tuber yield per plant (marketable and total), tuber yield (t/ha) marketable and total (g) and general impression (on 1-5 scale; 1- very poor and 5- very good).

Tuber dry matter

Five randomly selected tubers of each genotype were used for estimation of dry matter. Standard procedure was followed as described by Luthra *et al*. (2003; 2013). Chopped tuber pieces were mixed thoroughly and a 50 g sample of each genotype in three replications were used for an oven drying at 80 °C for 72 h. Then dry matter was estimated when weight of the sample reached to a constant level.

Late blight resistance

Genotypes were evaluated for late blight resistance in replicated trials under main winter crop season (3 replications) and detached-leaf assay (5 replications at Modipuram, Meerut. Disease incidence (% foliage with late blight lesions) was recorded on four different dates starting from 76 DAP (i.e. after the appearance of late blight spots on the susceptible control-Kufri Bahar followed by 5-day intervals. Further, the area under the disease progress curve (AUDPC: 100 % maximum) was calculated (Shaner and Finney 1977). The detached leaf assay was performed by challenge inoculation with *P. infestans* using a filter-paper discs (0.3 cm^2) pre-dipped into the zoospore suspension (6×10^4/ ml) as described by Luthra *et al.* (2016). The leaf lesion area was measured and the genotypes were grouped into highly resistant (up to 1.0), resistant (1.1-2.5), moderately resistant (2.51-5.0) and susceptible (>5.0) grades according to the lesion area (Lal *et al*. 2013, 2018).

Keeping quality assessment

Standard procedure was followed to assess keeping quality of genotypes as described by Luthra *et al*. (2016). Five kilogram of clean and uniform size tubers of each genotype were packed in Hessian cloth bag (each bag formed one replication) and stored at room temperature for 75 days (6th March to 19th May) during 2016 and 2017 having enough space for air movement across and between the bags. The temperature ranged between 16 to 33 °C (minimum) and 24 to 40 °C (maximum) with mean minimum (24.59 °C) and maximum (33.49 °C) during the storage periods. Relative humidity (RH) ranged between 25-82% (day) and 24-78% (night) with mean RH 44.12% (day) and 51.02% (night) during the storage. Tubers sprouting (calculated in per cent with š 1 sprouts of > 2 mm length size), weight and number (healthy and rotted) were recorded at 45, 60 and 75 days after storage.

Statistical analysis

The quantitative data were statistically analyzed using the software Windostat 8.5 (Ameerpet, Hyderabad, India). Homogeneity of error variance over two years was tested by Bartlett's test for different traits and was found to be homogenous. Hence, the data were pooled over years for analysis and interpretations of results.

RESULTS AND DISCUSSION

Variability, heritability and genetic advance

The result on analysis of variance indicated significant differences among the genotypes for all the characters indicating presence of genetic variability. The mean, range, coefficients of genotypic and phenotypic variation, heritability and genetic advance for 15 characters are presented (**Table 1**). In general, phenotypic coefficients of variation (PCV) were higher than their corresponding genotypic coefficient of variation (GCV) indicating implication of environment on these characters. The highest values of PCV as well as GCV were observed for rottage weight loss (%), sprout weight loss (%), sprouting (%), AUDPC, lesion area (cm^2), total weight loss (%) and tuber numbers indicating that these characters will respond to selection. Researchers had also found high GCV/PCV for tuber number (Birhman *et al.* 1984; Singh *et al.* 2004; Luthra 2001). Heritability values (broad sense) for various characters ranged between 0.90 (plant vigour and detached leaf-lesion area (cm^2)) to 1.00 (sprouting weigh loss %). These estimates were high enough for selection to be effective for all the traits. High GCV and PCV associated with high heritability were observed for rottage weight loss (%) sprout weight loss (%) and sprouting (%). Expected genetic advance was converted into percentage of mean so that comparisons could be made among various characters, which had different units of measurement. The maximum genetic advance was observed in sprout weight loss (%), rottage weight loss (%) and sprouting (%). The high genetic variation for keeping quality traits than tuber yield traits indicates prevalence of more opportunities of less exploited traits than regularity exploited yield traits in the present study.

Table 1. Estimates of genetic parameters for 15 traits in potatoes

Characters	Mean	Range	Coefficient of variations		h^2 (Broad Sense)	Genetic Advancement	Genetic Advancement as % of Mean
			GCV	PCV			
Plant vigour	4.62	4.00-5.00	6.46	6.83	0.90	0.58	12.59
Foliage maturity	3.07	1.58-4.13	14.79	15.51	0.91	0.89	29.07
Marketable tubers	6.32	4.81-7.86	12.71	12.82	0.98	1.64	25.95
Total tubers	8.84	5.99-12.16	15.85	15.98	0.98	2.86	32.39
Marketable yield (t/ha)	41.12	31.05-50.16	11.53	11.58	0.99	9.73	23.66
Total yield (t/ha)	43.35	33.43-52.33	10.70	10.74	0.99	9.52	21.96
Tuber dry matter (%)	18.08	14.85-21.87	8.99	9.05	0.99	3.32	18.39
AUDPC	450.46	95.84-1002.32	40.91	42.66	0.92	364.07	80.82
Detached leaf -lesion area (cm^2)	5.10	1.34-9.96	33.50	35.32	0.90	3.34	65.46
Sprouting (%)	57.51	0.00-100.00	58.14	58.58	0.99	68.36	118.85
Rottage weight loss (%)	1.35	0.00-7.57	133.66	137.40	0.95	3.62	267.82
Sprouting weight loss (%)	0.21	0.0-1.08	131.77	132.12	1.00	0.57	270.73
Physiological weigh loss (%)	7.76	5.45-10.42	18.44	19.01	0.94	2.86	36.83
Total weight loss (%)	9.32	6.11-14.22	20.67	21.58	0.92	3.80	40.76
Appearance	4.01	3.00-4.63	10.74	10.88	0.98	0.88	21.86

Selection intensity at 5%
PV: Plant viogour (1-5 scale; 1- very poor and 5- very good) at 75 DAP; **FM:** Foliage maturity (1-5 scale; 1- very late and 5- very early) at 90 DAP; **MTN:** Marketable tuber number (> 20 g tuber size); **TTN:** Total tuber number; **MTY:** Marketable tuber yield (t/ha) (> 20 g tuber size); **TTY:** Total tuber yield (t/ha); **TDMC:** Tuber dry matter content (%); **AUDPC:** Area under disease progress curve; Detached leaf - Lesion area (cm^2): Up to 1.0- Highly resistant (HR); 1.1 to 2.5- Resistant (R); 2.51-5.0- Moderately resistant (MR), > 5.0 –Susceptible (S); **S:** Sprouting at 75 days (%); **RWL:** Rottage weight loss (%); **SWL:** Sprouting weight loss (%); **PWL:** Physiological weigh loss (%); **TWL:** Total weight loss (%); **A:** Appearance at 75 days of storage

Character association

Genotypic correlations were in general higher than the phenotypic correlations reflecting that though there was an inherent association among the characters, the phenotypic associations among them were adversely influenced by environment and were used for establishing the relationship. The plant vigour showed positive relationship with marketable tuber yield (0.56**) and total tuber yield (0.53**) indicating the use of character for identifying genotypes with high yield (**Table 2**). The negative association of plant vigour with AUDPC (-0.46*) and lesion area (-0.49*) revealed that vigorous genotypes exhibited low AUDPC value and lesion area and reflected resistance to late blight. Foliage maturity showed positive association with AUDPC (0.77**) and lesion area (0.50*) indicating while making selection one should select the genotypes with late maturity to cut the cost on chemicals. The present finding confirms the results of Visker *et al*. (2004) that resistance against *P. infestans* coincides with late foliage maturity.

Marketable tubers possessed high and positive association with total tubers (0.88**). Potato genotypes with many thin stems are known to produce numerous small sized tubers and such genotypes could be exploited in breeding for production of varieties suitable for baby potato. For production of high yielding table potato varieties, a compromise needs to be made between tuber number versus average tuber weight. Gopal *et al.* (1994) and Luthra (2001) suggested that a standard may be fixed for the maximum number of tubers required in the selected genotype before employing selection for tuber yield and average tuber weight.

Marketable yield and total tuber yield were negatively correlated with tuber dry matter (-0.49*, -0.47*) thus indicating that while making selection, the usage criterion of table/processing be applied as table potato variety with moderate tuber dry matter could be selected but for processing purpose, high tuber dry matter is one of the basic requirement. Marketable yield and total tuber yield were also negatively correlated with detached leaf lesion area (-0.47*, 0.43*) revealing that for achieving high tuber yield late blight resistance is essential (**Table 2**).

Area under disease progress curve (AUDPC) and detached leaf lesion area (cm^2), though showed positive correlation (0.40*), however the magnitude of the correlation was low. Therefore, field evaluation (AUDPC) should be considered better option as genotypes are exposed against *P. infestans* in natural environment with all existing climatic factors (temperature, humidity, light and precipitation etc.). However, laboratory results may be taken as initial information for late blight resistance, because controlled environment may not adequately mimic the complexities of a field trial (Lal *et al.* 2013, 2018). Interestingly detached leaf lesion area exhibited positive relationship with sprout weight loss (0.41*) suggesting that late blight susceptible genotypes are prone to high sprout weight loss (%). This holds true also as susceptible variety Kufri Bahar having maximum leaf lesion area (9.96 cm^2) showed maximum sprout weight loss (1.08%) among the genotypes. The high sprout weight loss is known to impact the overall keeping quality of the potatoes as it not only provides more surface for evaporative losses (physiological

Table 2. Relationship among 15 traits in potatoes

Characters	Foliage maturity	Market-able tubers	Total tubers	Market-able yield	Total yield	Tuber dry matter	AUDPC	Lesion area	Sprou-ting	Rottage Weight loss	Sprouting weight loss	Physiological weight loss	Total weight loss	Appea-rance
Plant vigour	-0.39	0.05	-0.04	0.56**	0.53**	-0.42*	-0.46*	-0.49*	0.14	-0.17	-0.08	0.09	-0.09	-0.21
Foliage maturity		-0.15	0.00	-0.41*	-0.39	0.01	0.77**	0.50*	-0.03	-0.05	0.23	-0.09	-0.07	-0.23
Marketable tubers			0.88**	0.15	0.24	-0.15	-0.07	0.07	0.32	-0.26	0.27	0.30	0.02	-0.09
Total tubers				-0.07	0.04	-0.08	0.09	0.13	0.13	-0.22	0.19	0.26	0.01	-0.02
Marketable yield					0.99**	-0.49*	-0.35	-0.47*	0.10	-0.17	-0.26	0.18	-0.06	0.02
Total yield						-0.47*	-0.31	-0.43*	0.12	-0.21	-0.22	0.24	-0.05	-0.01
Tuber dry matter							-0.08	0.28	0.05	0.14	0.11	-0.10	0.07	-0.08
AUDPC								0.40*	-0.07	-0.10	0.30	0.15	0.06	-0.10
Lesion area (cm^2)									0.24	-0.05	0.41*	0.23	0.19	-0.32
Sprouting										-0.38	0.72**	0.66**	0.23	-0.71**
Rottage weight loss											-0.33	-0.34	0.63**	0.37
Sprouting weight loss												0.71**	0.35	-0.70**
Physiological weight loss													0.51**	-0.60**
Total weight loss														-0.19

**,* significant at 1% and 5% level of significance, respectively.

weight loss) but also diminishes the tuber appearance.

Shelf life is important during storage for regular supply of potatoes to the consumers or industry. Sprouting (%) was positively correlated with sprout weight loss (r=0.72**), physiological weight loss (r=0.66**) and negatively correlated with appearance (r=0.71**) indicating that sprouting not only increased sprout/physiological weight loss but also diminishes the appearance of tubers reflecting marketability of the produce (**Table 2**). Rottage weight loss was positively correlated with total weight loss (r=0.63**). Sprouting weight loss was positively related with physiological weight loss (r=0.71**) but negatively correlated with appearance (r=-0.70**). Physiological weight loss was positively co-related with total weight loss (r=0.51**) but negatively correlated with appearance (r=-0.60**). The relationship on keeping quality attributes suggest that for better marketability, genotypes should possess better tuber appearance, low physiological and sprout weight loss. Gupta et al (2015) also reported that total weight loss had highly significant and positive correlation with sprout weight (r=0.76**), physiological weight loss (r=0.97**).

Genetic divergence

The analysis of variance revealed highly significant differences among the 24 potato genotype for the 15 characters studied. The multivariate analysis by 'V'-statistic, which in turn utilizes Wilk's criterion was used as simultaneous test of differences between mean values of 15 correlated variables. Calculated 'V'-statistic (2191.02) was highly significant (Table Chi-Square value for P>0.001 is 460.58 at 345 d.f.). Hence, further analysis was done to estimate the D^2 values corresponding to all possible 276 combinations involving paired comparisons among 24 genotypes.

Based on D^2 values, 24 genotypes were grouped into six clusters (**Table 3**). The first cluster consisted of 14 genotypes and second cluster consisted of six genotypes, while remaining four cluster consisted only one genotype each. The grouping pattern showed that exotic and Indian genotypes were grouped together in cluster I and II as reported earlier (Gaur 1978; Gopal 1999; Luthra *et al*. 2005, 2009) confirming thereby that morphological diversity is not related to geographical diversity. Intra- and inter-cluster distances (**Table 4**) revealed that intra-cluster distances were lower than the inter-cluster distances. The maximum inter-cluster distance (48.51) was observed between cluster III and VI.

The present material, in general, represents the advanced breeding lines/varieties developed by crossing *Solanum tubersoum* with *tuberosum*, *andigena* or wild species at some stage of the breeding programme. However,

Table 3. Distribution of 24 potato genotypes in different clusters

Cluster No.	No of genotypes	Genotypes
1	14	CP4388, CP4404, CP4406, MCIP/10-15, MP/11-472, MS/11-664, MS/12-0935, MS/12-2116, K Arun K Garima, K. Lalima, K Lalit, K Pukhraj, K Surya
2	6	CP4393, MCIP/12-185, MCIP/12-286, MS/12-1283, K Chipsona-3, K Mohan
3	1	MS/10-1529
4	1	MCIP/11-163
5	1	K Sindhuri
6	1	K Bahar

Table 4. Average inter- and intra-cluster (D2 values) distances in potatoes

Cluster No.	1	2	3	4	5	6
1	21.89	29.38	28.57	30.28	28.15	43.65
2		22.52	38.24	32.72	36.04	46.79
3			0	38.19	22.96	48.51
4				0	40.38	25.74
5					0	43
6						0

after several cycles of crossing and selection, most of them have the features of *tuberosum* group. Due to this all hybrids /lines could be grouped in just six clusters and intra- and inter-group morphological distances did not correspond to the differences in the pedigree of various genotypes as enumerated above. This also indicates that genetic differences among various hybrids/lines as revealed by morphological diversity, though significant, actually had very narrow genetic base. It has been pointed to the narrow genetic base of most of the cultivated potato varieties resulting from a very limited number of breeding clones (Simmonds 1962; Gaur *et al*. 1978; Gopal 1999; Luthra *et al.* 2005, 2009) which may be inter-related through common ancestors (Hougas, 1956). The poor progress made in the improvement of *tuberosum* can, therefore, be largely attributed to a low level of diversity in the base population.

Relative importance of various characters to genetic divergence

For all the combinations (i.e. n (n-1)/2 = 276, in this case) each character was ranked on the basis of differences in the means of a pair of genotypes (i.e. di values). Rank 1 was given to the highest mean differences and rank p (p = number of characters, i.e. 15 in this case) to the lowest mean differences. Per cent contribution based on the number of times each character appeared first in ranking was calculated. Maximum contributions to genetic divergence were of sprouting and sprout weight loss (18.48%) followed by total tuber (15.94%), tuber dry matter (15.58%), and marketable tuber yield (11.96%). Total tuber yield, contributed only 1.45% to the total genetic divergence. The reason for low contribution by tuber yield to genetic diversity may be due to the fact, that genotypes had been subjected to selection for this character and out of 24 genotypes, 20 were improved potato hybrids or varieties released by CPRI, which possess good yield potential in the North Indian Plains. This conforms earlier reports that characters not subjected to selection contribute more to genetic divergence (Gaur *et al*. 1978; Gopal, 1999; Luthra *et al.* 2005, 2009).

The cluster mean values for 15 characters studied in 24 potato genotypes indicated large variability in different clusters (**Table 5**). Desirable cluster values were observed for characters in cluster II (marketable and total tuber yield, AUDPC), cluster III (plant vigour, sprouting (%), physiological weight loss and total weight loss), Cluster IV (dry matter and rottage weight loss), cluster V (marketable and total tubers, lesion area, appearance) and cluster VI (foliage maturity). The results based on cluster mean values (Table 5) of various characters indicated that for aiming yield improvement, crossing of genotypes of cluster II and cluster III would produce desirable progenies as particularly tuber yield, low AUDPC would be derived from cluster I, and high plant vigour and low sprouting, physiological and total weight loss be achieved from cluster III. However for increasing the tuber dry matter with low rottage weight loss, crossing of cluster IV with cluster II would be desirable. For increasing the number of tuber accompanied with adequate tuber yield, crossing between clusters II and cluster V would be desirable. Although based on D^2 values, crossing

Table 5. Cluster mean values for 15 traits in potatoes

Characters	Clusters					
	1	2	3	4	5	6
Plant vigour	4.54	4.82	5	5	4.42	4
Foliage maturity	3.1	2.83	3	3.17	3	4.13
Marketable tubers	5.88	7.05	6.32	5.72	7.86	7.24
Total tubers	8.11	9.61	10.28	7.94	12.16	10.59
Marketable yield (t/ha)	40.49	45.26	40.4	40.81	36.17	31.05
Total yield (t/ha)	42.44	47.79	42.67	43.08	39.42	34.44
Tuber dry matter (%)	18.34	17.53	16.01	19.05	18.54	18.37
AUDPC	460.94	315.52	355.83	548.84	557.87	1002.32
Lesion area (cm^2)	4.96	5.03	4.8	4.13	3.82	9.96
Sprouting (%)	45.3	89.18	0	98.51	12.6	100
Rottage weight loss (%)	1.62	0.52	2.13	0	3.76	0.79
Sprouting weight loss (%)	0.1	0.28	0.01	0.85	0.02	1.08
Physiological weigh loss (%)	7.22	8.61	6.3	10.38	6.5	10.42
Total weight loss (%)	8.93	9.42	8.44	11.23	10.28	12.3
Appearance	4.15	3.74	4.34	3.42	4.63	3.25

between cluster III and VI have been advocated but cluster II possesses moderate values for most desirable attributes excepting high values of foliage maturity. The mean values suggest crossing cluster II (CP4388, CP4404, CP4406, MCIP/10-15, MP/11-472, MS/11-664, MS/12-0935, MS/12-2116, K Arun K Garima, K. Lalima, K Lalit, K Pukhraj, K Surya) and cluster II (CP4393, MCIP/12-185, MCIP/12-286, MS/12-1283, K Chipsona-3, K Mohan).

In conclusions, high coefficient of variation (genotypic and phenotypic) associated with high heritability were observed for rottage weight loss, sprout weight loss and sprouting (%). Tuber yield had positive relationship with plant vigour and marketable tuber yield but negative association with tuber dry matter, which suggest to select for high yielding table potatoes with moderate tuber dry matter or moderate yielding processing potatoes with high tuber dry matter. The positive relationship of AUDPC and lesion area suggest either of the trait could provide resistance level to late blight of genotypes. The better appearance of the tubers is indicative of good keeping quality of the stored potatoes as appearance was negatively associated with sprouting (%), sprout weight loos and physiological weight loss. Based on D^2 values, 24 genotypes were grouped into six clusters. Intra- and inter-cluster distances revealed that intra-cluster distances were lower than the inter-cluster distances. The results on grouping of genotypes in clusters revealed that morphological diversity is not related to geographical diversity. Maximum contributions to genetic divergence were of sprouting and sprout weight loss followed by total tuber, tuber dry matter and marketable tuber yield. Though the maximum inter-cluster distances was observed between cluster III and VI, however desirable traits for improvements were available in cluster I and Cluster II. These results could be helpful in selection of genotypes having diverse genetic background for improvement in potatoes

ACKNOWLEDGEMENTS

The authors are grateful to the Director, ICAR-CPRI, Shimla for providing necessary facilities under the institute project (HORTCPRICIL201500200130).

LITERATURE CITED

Birhman RK, Verma SM and Anand SK (1984) Phenotypic and genotypic variation for some important quantitative characters in potato (*Solanum tuberosum* L). *Indian J Agric Res* **18**: 137-42.

Gaur PC, Gupta PK and Kishore H (1978) Studies on genetic divergence in potato. *Euphytica* **27**: 361-368.

Gopal J, Gaur PC and Rana MS (1994) Heritability, and intra- and intergeneration associations between tuber yield and its components in potato (*Solanum tuberosum* L.). *Plant Breeding* **112**: 80-83.

Gopal J and Minocha JL (1997) Genetic divergence for cross prediction in potato. *Euphytica* **97**: 269-75.

Gopal J (1999) In vitro versus vivo genetic divergence in potato. *Theor Appl Genet* **98**: 299-304

Gupta VK, Luthra SK and Singh BP (2015) Storage behaviour and cooking quality of Indian potato varieties. *J Food Sci technol* **52**(8): 4863–4873

Hougas, RW and Ross H (1956) The use of foreign introductions in breeding American potato varieties. *Am Potato J* **33**: 328-339.

Lal M., Luthra SK, Singh BP and Yadav S (2013) Sreening of genotypes against potato late blight. *Potato J*. **40** (1): 80-83.

Lal M, Luthra SK, Gupta VK and Yadav S (2018) Evaluation of Potato Genotypes for Foliar and Tuber Resistance against *Phytophthora infestans* Causing Late Blight of Potato under Subtropical Plains of India. *Intern J Current Microb Applied Sci* **7** (3): 1234-1242

Luthra SK (2001) Heritability, genetic advance and character association in potato. Journal of Indian Potato Association **28**: 1-3.

Luthra, SK (2009) Genetic divergence of germplasm accessions in potato (*Solanum tuberosum* subsp. *tuberosum*). *Indian J Plant Gen Resources*. **22**(2): 98-101.

Luthra SK, Gopal J and Pandey SK (2003) Selection of superior parents and crosses in potato for developing cultivars suitable for early planting in Uttar Pradesh. *J Indian Potato Assoc* **30**: 1-2.

Luthra SK, Gopal J and Sharma PC (2005) Genetic divergence and its relationship with heterosis in potato. *Potato J* **32**: 37-42.

Luthra SK, Malik K, Gupta VK and Singh BP (2013) Evaluation of potato genotypes under high temperature stress conditions. *Crop Improvement* **40**: 74-80.

Luthra SK, Pandey SK, Singh BP, Kang GS, Singh SV and Pande PC (2006) Potato Breeding in India. CPRI, Shimla. Tech Bull 74, 90p

Luthra SK, Tiwari JK, Lal M, Chandel P, Kumar V and Singh BP (2016) Breeding potential of potato somatic hybrids: Evaluations for adaptability, tuber traits, late blight resistance, keeping quality and backcross (BC_1) progenies. Potato Research **59**: 375-391.

Shanner G and Finney RE (1977) The effect of nitrogen fertilization on the expression of slow mildewing resistance in knox wheat. *Phytopathol* **67**: 1057-66

Simmonds NW (1962) Variability in crop plants, its use and conservation. Biol. Rev. **37**: 422-65.

Singh SV, Pandey SK and Manivel P (2004) Genetic divergence in advanced hybrid of potato using non-hierarchical Euclidian cluster analysis. *Indian J Hort* **61**: 51-54.

Tarn TR and Tai GCC (1977) Heterosis and variation of yield components in F_1 hybrids between group Tuberosum and group Andigena potatoes. *Crop Sci* **17**: 517-521.

Visker MHPW, van Raaij HMG, Keizer LCP, Struik PC, Colon LT (2004) Correlation between late blight resistance and foliage maturity type in potato. *Euphytica* **137**: 311–323

MS received : 30 November 2018; Accepted: 21 December 2018