Indian J. Plant Genet. Resour. 27(2): 142-148 (2014)
DOI 10.5958/0976-1926.2014.00009.6

Evaluation of Chinese Potato [*Plectranthus rotundifolius* (Poir.) Spreng.] for Yield Contributing Traits

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(Received: 27 March 2014; Revised: 6 September 2014; Accepted: 10 September 2014)

A replicated field evaluation trial was conducted involving 26 accessions of Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.], an under-utilised tuber crop. In the present study, there were significant differences for the yield contributing characters between the accessions. Maximum yield was observed in IC468968 which showed highest value for both single plant yield (216.25g) and average weight of single marketable tuber (56.63g) and can be directly utilised in the crop improvement programme. IC412975 performed very poorly and had least value for all characters except for length of unmarketable tuber. A positive significant correlation between all the yield and yield contributing characters except tuber length and width of both marketable and unmarketable tuber was observed. Accessions grouped in the first cluster were high yielders with more than 150 g tubers/ plant, which can be further enhanced by adopting improved agronomic practices.

Key Words: Clustering, Evaluation, Tuber yield, Variability

Introduction

Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.; syn. *Coleus parviflorus* Benth., *Solenostemon rotundifolius* (Poir.) J.K. Morton] is an important under-utilized tuber crop mainly grown in the tropical regions of India, Indonesia, Malaysia, Sri Lanka and Africa. It belongs to family Lamiaceae and is believed to have originated in Central or East Africa (Shoeninger *et al.*, 2000; Edison *et al.*, 2006) and spread throughout the tropics. The crop is cultivated for its edible underground tubers which are used as vegetables. Tubers are small with dark brown peel and creamish flesh, produced in clusters at the base of the stem. The aromatic flavour of the tuber makes it a sought vegetable and is reported to have medicinal properties due to the presence of flavanoids that help to lower the cholesterol level of blood (Horvath *et al*., 2004; Abraham and Radhakrishnan, 2005; Sandhya and Vijayalakshmi, 2005) and enzyme inhibitors (Prathiba *et al*., 1995). Tuber contains nutritional and large amount of secondary metabolites which helps in improving body immune system and defense against diseases (Anbuselvi and Hemapriya, 2013). Commercially, tuber size, shape and appearance are important physical quality features that determine both market value and consumer preference in Chinese potato. The most unfavourable feature of Chinese potato is the small and non-uniform size and often odd shape of the tuber due to which cleaning and de-skinning for culinary preparations becomes time consuming.

Chinese potato is normally propagated vegetatively by suckers or soft wood cuttings. Hence, gene flow among the individuals in a population is limited and heterogeneity in population is largely due to environmental variations. Lack of seed setting in the species is also responsible for low genetic variability. Highly irregular meiosis is reported to be a reason for sterility of the species (Ramachandran, 1976; Rajmohan, 2007). Hence, genetic component of the population variation from different regions can be identified and exploited through selection of superior populations.

Studies on characterisation and evaluation of Chinese potato in India are very limited (Muraleedharan *et al.* 1985; Sreekumari and Abraham, 1985; Amalraj *et al.* 1989). Mutation studies have been done in the past to introduce variability (Vasudevan and Jos, 1988, 1992; Abraham and Radhakrishnan, 2005). Though most of the morphological characters among the accessions studied showed less variation, tuber yield was found to vary significantly among them. An extensive study on morpho-agronomic characterization of 155 accessions of Chinese potato in Ghana was done by Nanema *et al.* (2009). They also observed variability in quantitative morphological traits within the germplasm collection. The research on improvement of Chinese potato is very scanty. Only few varieties have been released in this crop which includes Nidhi, Sreedhara and CO-1 from Kerala Agricultural University, Thrissur, Kerala; Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala

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and Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, respectively.

The study of agro-morphological variability is the traditional method of assessing genetic diversity. Agro-morphological characterization, however, is often hindered by the limited number of polymorphic features and the need for multiple test environments (Kresovich *et al*., 1997). The present investigation was done to study the extent of genetic diversity in local collections of Chinese potato, using cluster analysis based on yield parameters with the aim to identify some promising genotypes.

Materials and Methods

The plant materials for the present study consisted of 26 accessions of Chinese potato collected from different parts of Goa (1), Karnataka (1) and Kerala (24) along with the check variety, Nidhi. The experiment was laid out in a completely randomised block design with two replications. One month old terminal shoot cuttings were used for planting. The cuttings were planted on raised beds at a distance of 1 m × 1 m between beds and 50 cm between plants in each bed during August 2013. Ten cuttings were planted on single bed size of 4.5 m × 0.50 m × 0.50 m dimension. Package of practices recommendations of Kerala Agricultural University, Kerala, India were followed (http://www.kau.edu/pop/contents.htm). The tubers were harvested separately for individual plants in each replication. Five randomly selected plants per replication per accession were used for recording yield data. The tubers were classified manually as marketable (having tuber circumference > 7 cm) and unmarketable (tuber circumference 0-7 cm) tubers, based on visual scrutiny for recording observation. The total rainfall obtained during the crop season was 110 cm with 54 rainy days. The minimum and maximum temperature observed were 22.2^{o}C and 32.6^{o}C, respectively. Flowering of all the accessions were observed during October-November. It started from 60 days of planting and continued for 2 months.

A total of nine yield contributing characters, namely, single plant yield and weight, length, diameter and circumference of tubers were recorded for five marketable and unmarketable tubers, respectively, and averaged for each replication and accession at the time of harvest. The length and diameter of the tuber was measured using Zoom Digimatic Calliper (Model no. Mitutoyo 500-322). The single plant yield in grams was measured using Docbel Braum Balance of maximum capacity of 1kg and minimum grading 5g. The weight of 5 marketable and unmarketable tubers was recorded separately using Afcoset Electronic Balance with a precision of 0.01g. Freely downloadable OPSTAT Package developed by CCS Haryana Agricultural University, Hisar, India was used for statistical analysis (http://www.hau.ernet.in/opstat.html). Cluster analysis was done using NTSYS (Rohlf, 2000).

Results and Discussion

Morphological Characterization

The crop was harvested after five months of planting. Significant differences between accessions were observed for all the characters except for average weight and width of single unmarketable tuber (Fig.1). Hence, there exists wide variability for yield contributing characters in the Chinese potato accessions under study (Table 1).

Table 1. ANOVA for yield characters in 26 Chinese potato accessions

Source of variation	Replication	Treatment	Error
DF	1	26	26
Single plant yield	5,007.41	4388.311**	577.13
Marketable tuber weight	400.493	199.891**	89.88
Marketable tuber length	1.376	0.818**	0.329
Marketable tuber width	0.252	0.423**	0.12
Marketable tuber circumference	1.457	3.792**	0.967
Unmarketable tuber weight	18.177	4.001	3.131
Unmarketable tuber length	2.311	0.179**	0.104
Unmarketable tuber width	0.955	0.033	0.026
Unmarketable tuber circumference	7.752	0.377**	0.206

DF= Degrees of freedom; ** Significant at 1% level

The tuber yield varied among the accessions from 58.50 g to 216.25 g on a per plant basis. Tarpaga (2001) and Nanema *et al*. (2009) observed mean single plant yield of 369.31 g and 62.07 g, respectively. After inducing mutation on 45 days old single node cuttings, Abraham and Radhakrishnan (2005) obtained single plant yield ranging from 54-126 g according to the cultivar.

Mean weight of marketable tubers was 36.51 g with a range of 8.74-56.63 g. The weight of unmarketable tubers ranged from 2.22-9.71 g with a mean value of 3.90 g. The mean length, breadth and circumference of marketable and unmarketable tubers observed were

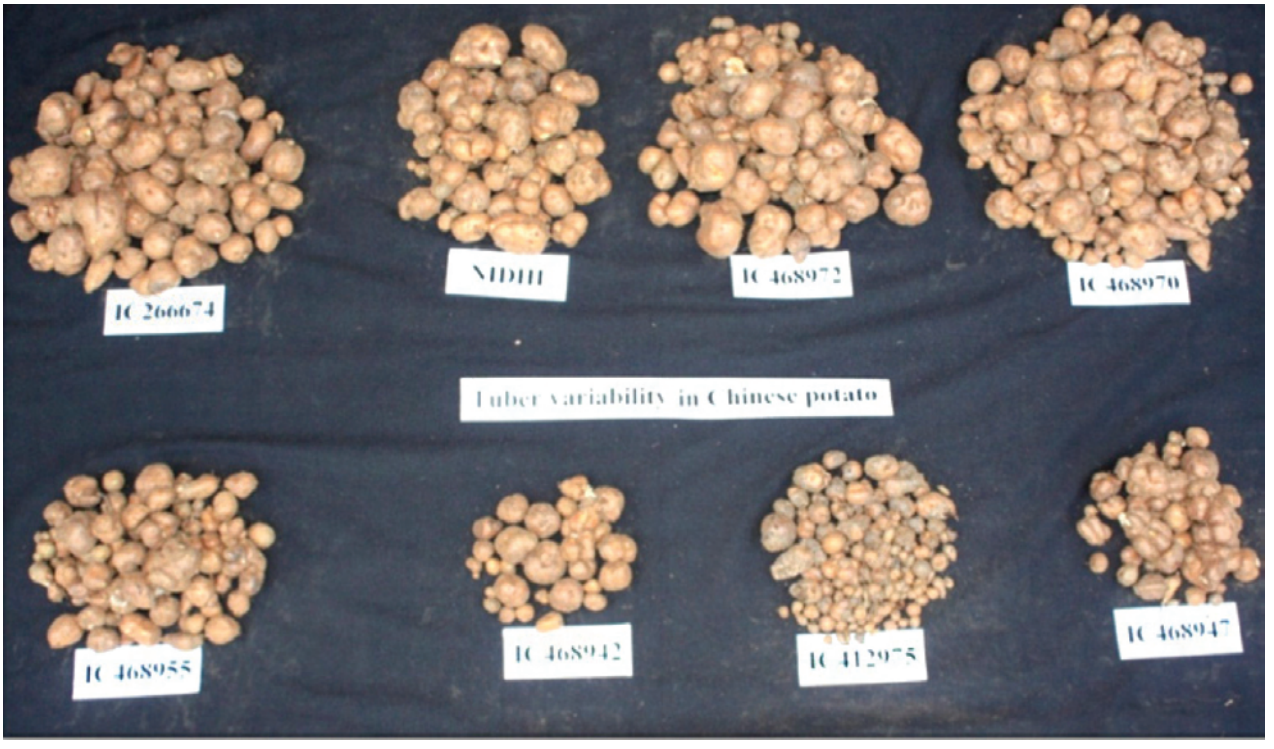

Fig. 1. Tuber variability in Chinese potato accessions

Table 2. Statistical and genetic parameters for yield contributing characters of 26 Chinese potato accessions

Traits	Range			PCV	GCV	H^2	Genetic advance	Genetic gain
	Minimum (g)	Maximum (g)	Mean (g)	(%)	(%)	(%)		(%)
Single plant yield (g)	58.50	216.25	145.89	34.15	29.92	76.75	157.57	54.00
Weight of marketable tuber (g)	8.74	56.63	36.51	32.97	20.32	37.97	9.41	25.79
Length of marketable tuber (cm)	2.66	5.86	4.12	18.40	12.01	42.57	0.66	16.14
Width of marketable tuber (cm)	2.29	4.37	3.83	13.61	10.17	55.90	0.60	15.67
Circumference of marketable tuber (cm)	7.07	13.74	12.12	12.72	9.80	59.37	1.89	15.56
Weight of unmarketable tuber (g)	2.22	9.71	3.90	48.38	16.90	12.20	0.48	12.16
length of unmarketable tuber (cm)	1.49	2.79	2.07	18.15	9.34	26.47	0.21	9.90
Width of unmarketable tuber (cm)	1.41	1.95	1.70	10.11	3.41	11.37	0.04	2.37
Circumference of unmarketable tuber (cm)	4.63	6.47	5.50	9.82	5.33	29.42	0.33	5.95

4.12 cm, 3.83 cm, 12.12 cm for marketable tubers and 2.07 cm, 1.70 cm and 5.50 cm for unmarketable tubers respectively. Nanema *et al*. (2009) recorded comparatively low values for average weight, length and diameter of big and small tubers in their study on morpho-agronomic characterisation of Chinese potato germplasm from Ghana. According to them, the average weight, length and diameter of big and small tubers were 0.34 g, 6.15 cm, 2.85 cm for big tubers and 46.06 g, 3.55 cm and 1.30 cm for small tubers, respectively.

In general, phenotypic coefficient of variation (PCV) was higher than its genotypic counterpart (GCV) for all the characters studied. PCV which measure total relative variance was high for single plant yield, average weight of single marketable and unmarketable tubers. It is likely that continuous vegetative propagation and selection has contributed to the phenotypic diversity observed. Relatively low to moderate GCV was recorded in all the characters except for single plant yield and average weight of single marketable tuber. Broad sense heritability

(H^2) ranged from11.37% (unmarketable tuber width) to 76.75% (single plant yield). High estimates of all the genetic parameters viz. PCV, GCV, H^2 and genetic gain as percentage of mean were observed for single plant yield character, was in consistent with the earlier study by Abraham and Radhakrishnan (2005), which indicate the presence of additive gene action. Hence, direct selection can easily be done for improvement of this character. Unmarketable tuber characters showed low values of PCV, GCV, heritability and genetic gain, depicting very low genetic variability for this character. Low variability in this species is attributed mainly to pollen sterility and problems of seed set (Rajmohan, 2007).

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Table 3 depicts the estimates of mean for yield contributing characters in 26 Chinese potato accessions. IC266674 (179.25 g), IC468961 (197.75 g), IC468963 (185.75 g), IC468964 (198.00 g), IC468966 (170.25 g), IC468967 (171.50 g), IC468968 (216.25 g), IC468969 (206.00 g), IC468970 (209.25 g), IC468972 (199.00 g) and IC469741 (187.00 g) out-yielded the check variety Nidhi (157.75 g) for single plant yield. Maximum yield was observed in IC468968 (216.25 g), which also showed highest values for marketable tuber weight (56.63 g) and was collected from Vettithodi area of Palakkad district (Kerala). IC412975 performed very poor and has recorded least values for all characters except unmarketable tuber

Table 3. Estimates of mean for yield contributing characters of 26 Chinese potato accessions and check variety Nidhi

Accn. No.	Single plant yield (g)	Marketable tuber weight (g)	Marketable tuber length (cm)	Marketable tuber width (cm)	Marketable tuber circum-ference (cm)	Unmarketa-ble tuber weight (g)	Unmarket-able tuber length (cm)	Unmarket-able tuber width (cm)	Unmarketable tuber circum-ference (cm)
IC266674	179.25	49.17	4.56	4.35	13.34	3.13	1.91	1.69	5.49
IC412974	122.25	32.63	3.51	4.13	12.96	3.65	2.27	1.71	5.61
IC468942	70.75	35.31	3.63	4.11	12.88	3.25	1.62	1.75	5.39
IC468945	96.25	35.76	3.43	3.98	13.31	3.16	1.49	1.81	5.25
IC468946	108.25	40.34	4.07	4.04	12.53	3.86	2.15	1.78	5.67
IC468947	81.75	27.52	3.57	3.62	11.65	2.76	1.81	1.59	5.33
IC468948	97.25	24.01	4.44	3.28	10.14	2.80	1.88	1.55	4.98
IC468950	91.00	27.93	3.79	3.79	11.62	3.22	1.92	1.74	5.58
IC468952	137.00	49.71	4.37	4.23	13.74	3.75	2.09	1.64	5.41
IC468955	105.00	26.77	3.75	3.49	10.72	3.38	2.03	1.60	4.92
IC468956	129.25	34.11	3.82	3.71	12.33	3.62	1.99	1.61	5.16
IC468957	115.00	29.76	3.40	3.98	12.78	2.95	1.90	1.54	4.94
IC468960	137.50	45.66	4.37	4.37	12.96	2.93	1.76	1.74	5.51
IC468961	197.75	43.83	4.68	3.85	12.20	9.71	2.15	1.66	5.37
IC468963	185.75	28.53	3.77	3.63	11.32	3.61	2.02	1.70	5.66
IC468964	198.00	33.44	4.13	2.91	11.08	3.51	2.10	1.52	5.33
IC468965	156.00	44.55	4.34	4.36	13.64	4.44	2.10	1.89	6.29
IC468966	170.25	35.02	4.21	3.93	12.58	3.62	2.10	1.74	5.69
IC468967	171.50	39.21	4.87	3.74	11.73	4.22	2.52	1.66	5.39
IC468968	216.25	56.63	5.08	4.36	13.56	3.52	1.94	1.67	5.36
IC468969	206.00	40.73	5.86	3.69	10.98	4.31	2.59	1.64	5.39
IC468970	209.25	39.82	4.57	3.77	11.87	3.21	2.05	1.63	5.21
IC468972	199.00	45.28	4.53	4.20	12.98	5.82	2.79	1.95	6.13
IC469690	155.50	29.14	3.49	3.76	12.13	5.24	2.47	1.89	6.15
IC469741	187.00	33.57	4.01	3.92	12.32	4.67	2.43	1.87	6.07
NIDHI	157.75	48.61	4.27	4.01	12.94	4.91	2.18	1.87	6.47

length (2.27 cm). No accession surpassed the control variety Nidhi (6.47 cm) for small tuber circumference.

Correlation studies were done in order to analyze the relationship between the yield characters in Chinese potato accessions. A positive significant correlation was observed between most of the yield characters studied except between single plant yield and marketable tuber width and between marketable tuber length and width. Unmarketable tuber length also did not correlate positively with unmarketable tuber width (Table 4). The lack of significant correlation between tuber yield with tuber length and girth was also observed by Sreekumari and Abraham (1985) and was stated to be due to the high heterogeneity of tubers observed among the accessions.

Cluster Analyses

The accessions were clustered into 3 groups based on the yield characters at a Euclidean distance of 27.88 (Fig. 2). Fourteen accessions were grouped in cluster I including the check variety Nidhi, 10 accessions in Cluster II and 3 in cluster III. The mean value for all other characters except marketable tuber width was maximum for cluster 1 as compared to cluster II and III. All the accessions grouped in the first cluster were high yielders having average single plant yield of 166.75 g (Table 5) which were collected from varied locations ie, one each from Mysore (Karnataka), South Goa (Goa), Kasaragod (Kerala) and 10 accessions from Palakkad (Kerala) districts.

All the yield characters recorded for accessions in cluster III were the lowest. However, accessions in the second cluster yielded between 91.00g to 137.50 g whereas accessions in the third cluster were low yielders with yield less than 82.00 g/plant. The accessions grouped in cluster II and III were from Palakkad and Malappuram districts of Kerala. Hence, on comparing the geographic locations of collections, homogeneity among accessions for yield characters were present even though there are collections from Goa and Mysore in first cluster.

This pattern of grouping of genotypes belonging to same location in different clusters and genotypes inhabiting from different localities in same cluster was earlier reported by Abraham and Radhakrishnan (2005) and indicated that factors other than geographical diversity may be responsible for such clustering. Absence of parallelism between geographical distribution and the

Table 4. Correlation matrix between different tuber characters in 26 Chinese potato accessions and check variety Nidhi

	Single plant yield (g)	Marketable tuber weight (g)	Marketable tuber length (cm)	Marketable tuber width (cm)	Marketable tuber circum-ference (cm)	Unmarket-able tuber weight (g)	Unmarket-able tuber length (cm)	Unmarket-able tuber width (cm)	Unmarketable tuber circum-ference (cm)
Single plant yield (g)	1								
Marketable tuber weight (g)	0.705**	1							
Marketable tuber length (cm)	0.846**	0.654**	1						
Marketable tuber width (cm)	0.260NS	0.880**	0.236NS	1					
Marketable tuber circumference (cm)	0.303*	0.836**	0.235NS	1.001**	1				
Unmarketable tuber weight (g)	1.351**	1.365**	1.443**	0.904**	0.662**	1			
Unmarketable tuber length (cm)	1.055**	0.750**	1.060**	0.491**	0.441**	1.080**	1		
Unmarketable tuber width (cm)	0.796**	1.842**	0.764**	2.013**	1.852**	0.330*	0.232NS	1	
Unmarketable tuber circum-ference (cm)	0.694**	1.000**	0.464**	1.157**	1.033**	0.453**	0.584**	1.200**	1

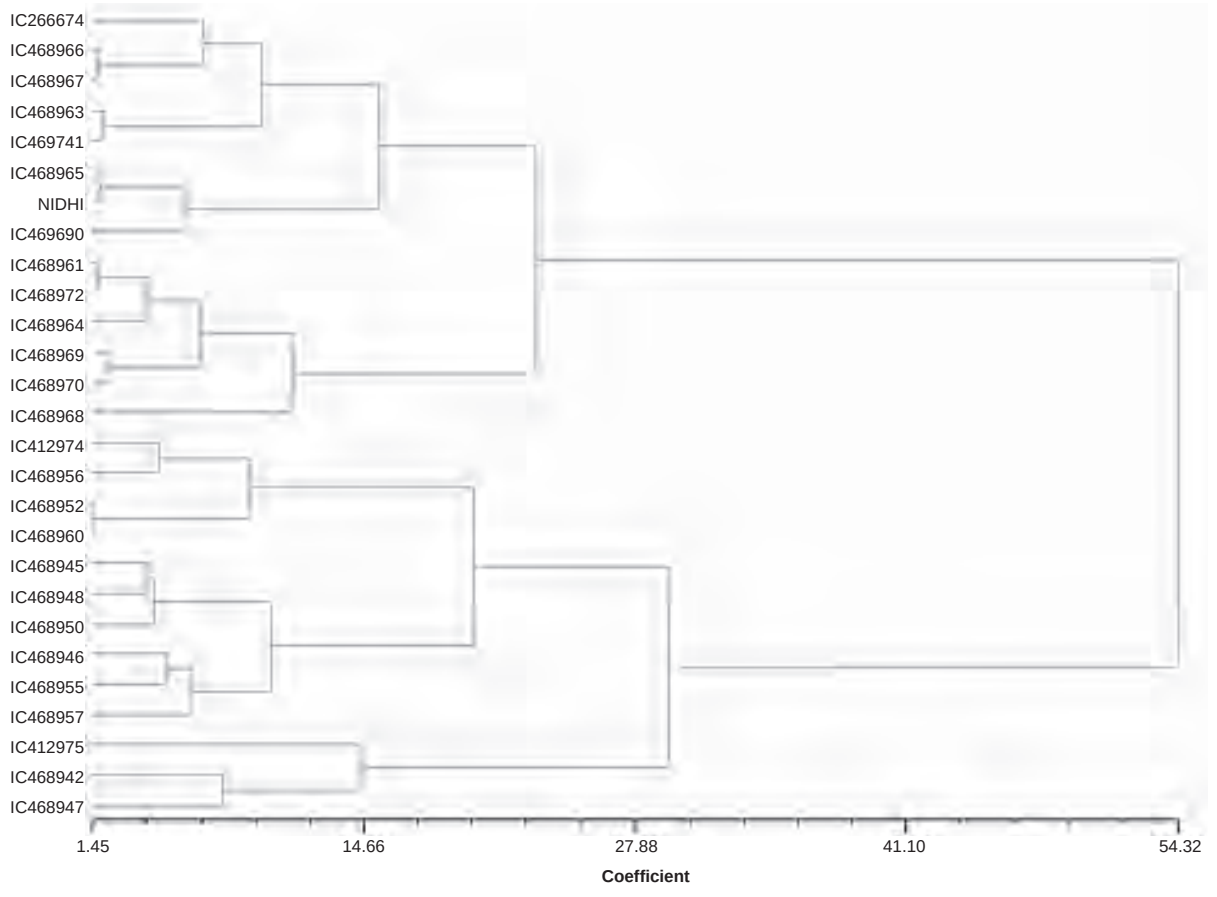

Fig. 2. Cluster analysis based on yield contributing characters in Chinese potato

Table 5. Cluster means for the characters under study in 26 Chinese potato accessions and check variety Nidhi

Trait	Cluster I 14 IC266674, IC468966, IC468967, IC468963, IC469741, IC468965, IC469690, IC468961, IC469972, IC468969, IC468964, IC468970, IC468968 and Nidhi	Cluster II 10 IC412974,IC468956, IC468952, IC468960, IC468945, IC468948, IC468950, IC468946, IC468955 and IC468957	Cluster III 3 IC412975, IC468942 and IC465947
Single plant yield (g)	166.75	113.89	70.33
Marketable tuber weight (g)	40.54	34.66	23.86
Marketable tuber length (cm)	4.45	3.89	3.28
Marketable tuber width (cm)	3.89	3.90	3.34
Marketable tuber circumference (cm)	12.33	12.31	10.53
Unmarketable tuber weight (g)	4.56	3.33	2.74
Unmarketable tuber length (cm)	2.24	1.95	1.71
Unmarketable tuber width (cm)	1.74	1.67	1.58
Unmarketable tuber circumference (cm)	5.71	5.30	5.12

genetic diversity was observed by Mannan *et al*. (1993) in *Colocasia*.

The single plant yield was found to be very significant among the accessions studied. High estimates of all the genetic parameters *viz.*, PCV, GCV, H^2 and genetic gain as percentage of mean observed for single plant yield character indicate the presence of additive gene action. Hence simple direct selection can be easily done for improvement of this character. IC468968 is a promising accession which can be further utilized in the crop improvement programme. The present study envisaged that the variability in Chinese potato can only be enriched by widening the germplasm collections. This underexploited tuber can be popularized among farmers by integrating in the sole cropping as well as to different farming systems such as rotation and intercropping.

Acknowledgement

Authors acknowledge with thanks for the guidance and help provided by the Director, National Bureau of Plant Genetic Resources, New Delhi.

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