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Diversity studies in Coleus (*Plectranthus rotundifolius* (Poir.) Spreng.) genotypes based on quantitative traits

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Abstract
A replicated field evaluation trial was conducted involving 9 accessions of Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.]. In the present study, there were significant differences for the yield contributing characters between the accessions. In the first year (2022), Maximum yield was observed in treatment T_3, a local collection from Palakkad district which showed highest value for single plant yield (437.10), single plant yield of marketable tubers (324.15) and average marketable single tuber weight (35.32 g) and can be directly utilized in the crop improvement programme. Numbers of marketable tubers as well as unmarketable tuber circumference were also high for this treatment, T_3. On the other hand, yield of unmarketable tubers as well as its number was the lowest for our released variety, Nidhi (T_1). Performance of T_1 and T_5 were low in terms of yield contributing characters under Anakkayam conditions. A positive significant correlation between the yield and yield contributing characters like single plant yield, single plant marketable yield as well as unmarketable yield and the least significance was recorded by weight and circumference of unmarketable tubers. As per cluster analysis, cluster three performed as the best treatment followed by cluster 2.As per the statistical analysis of genetic parameters genetic advance was comparatively high for single plant yield of marketable tubers (46.49).

Keywords: Coleus, Chinese potato, quantitative traits, yield

Introduction
The minor tuber crops offer excellent potential for use in food production, nutrition, and other applications. Since food and nutritional security is very important nowadays, its requirement can be met through traditionally known and sustainability feasible minor tubers. The principal amino acids present in the protein of these lesser root and tuber crops are arginine, aspartic and glutamic acids. The tubers are also a rich source of dietary energy and mean starch percentage on dry matter basis. Due to the rapid increase in human population and consequent shortages of grain crops, collection, improvement and utilization of underutilized tuber crops such as Chinese potato are of supreme importance. Besides its nutritional attributes, *Plectranthus rotundifolius* holds strong economic potential and could be financially rewarding to the farm economy (Enyiukwu *et al.*, 2014) [1]. *Plectranthus rotundifolius* is a very important food crop which can contribute to improving food security. Besides its agricultural importance, it has ornamental, medicinal, culinary and many other use (Kwarteng *et al.*, 2018) [2]. As reported by Olojede (2013) [3], the crops hold strong potential to becoming commodity crops for food and nutrition security, poverty alleviation and economic growth in Nigeria. They have good potential in increasing the range of tuber crops available for human consumption. Therefore, as mentioned by Chivenge *et al.* (2015) [4], there are many neglected crops that have the potential to contribute to food security but investigation should be done to clearly demonstrate their potentialities and the priorities in term of research on these crops. Local varieties of *Plectranthus rotundifolius* produce many (up to 70/plant) small sized tubers; 3.78 cm long and 1.53 cm width (Nanéma *et al.*, 2009) [21]. The potential yield reported in West Africa ranged from 7 to 20 T/ha (Enyiukwu *et al.*, 2014) [1]. The tubers contain significant rate of reducing sugar (26 mg/100 g), protein (13.6 to 14.6 mg/100 g), crude fat (1.2%), crude fiber (1.6%), phosphorus (36 mg/100 g), calcium (29 mg/100 g), vitamins A and C, respectively 13.6 mg/100 g and 10.3 mg/100 g, and antioxidants (Anbuselvi and Priya, 2013) [5]. They are commonly consumed as a curry, baked or fried, or cooked (Agyeno *et al.*, 2014) [6]. *Plectranthus rotundifolius* is also known to be one of the most adapted tuber crops of West Africa. It is suited for cultivation on marginal areas in the dry savannah regions with poor

fertility soils (Aculey *et al*., 2011) [7]. The potential yield reported in West Africa ranged from 7 to 15 t/ha (Enyiukwu *et al.*, 2014) [1]. Chinese potato [*Plectranthus rotundifolius* (Poir.) Spreng.; syn. *Coleus parviflorous* Benth, *Solenostemon rotundifolius* (Poir) J.K. Morton, annual herbaceous plant belonging to the family Lamiaceae, is an important underutilized tropical tuber crop. It is one of the staple crops in Western Africa but currently its genetic resources are in a process of disappearing. Studies on characterization and evaluation of Chinese potato in India are very limited (Muraleedharan *et al.*1985; Sreekumari and Abraham, 1985; Amalraj *et al*., 1989) [8, 9, 10]. Chinese potato is generally vegetatively propagated by suckers or soft wood cuttings which leaded to the limited gene flow among individuals in a population. Heterogeneity in population is mainly 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) [11, 12].

Only a few varieties are released in India which includes Nidhi, Sreedhara and CO-1. In India, it is grown in most of the homestead gardens of Tamil Nadu and Kerala. Chinese potato is mainly confined to central Kerala and Malabar in laterite soils and sandy coastal soils sometimes extending to Mangalore district of Karnataka. Due to its wide acceptance as an aromatic tuber vegetable in Kerala and Tamil Nadu there is a gradual spread of the crop even to black soils in Tamil Nadu as an irrigated commercial crop and of late it is intensely cultivated in more than 500 ha in South Tamil Nadu. In Coleus, four species *viz, C. aromaticus, C forskholii, C. zeylanicus and C. spicata*, (wild or semicultivated) are present in South India. (Edison *et al.* 2006) [13].

Plectranthus rotundifolius has different names in different localities which include Chinese potato, Sudan potato, country potato, Fra Fra potato, etc. while in Kerala, it is known as ‘Koorka’. It grows well in regions receiving annual rainfall between 700 and 1000 mm (Ouédraogo *et al*., 2007). Yield usually range from 7 to 15 t/ha under favorable conditions, it may reach 18 to 20 t/ha (NRI, 1987), 30 t/ha (Tarpaga, 2001) [15], or 45t/ha (Nkansah, 2004) [16]. It is usually cultivated as a monocrop but may sometimes be intercropped with yam, okra, maize, rice, sorghum, cowpea and bambara groundnut. It is usually grown on mounds and sometimes on ridges but not on the flat. Tubers are mostly used for propagation but softwood stem cuttings can also be used. Constraints to production, in descending order of importance, include rapid tuber deterioration in storage, lack of adequate planting materials, pests and diseases, and insufficient soil moisture for maturing the crop. Tetteh, J.P. And Guo, J. I. (1997) [17]. The plant has prostrate or ascending stems and branches. Leaves have glands or sacs which contain volatile oils. Flowers are small with pink, white, pale violet or blue colours arranged in raceme- like inflorescence. Generally plant attains a height of 15-30 cm but in some species it may go up to 60 cm. The crop is grown for its underground tuberous roots. Mutation studies have been done in the past to introduce variability (Vasudevan and Jos, 1992; Abraham and Radakrishnan, 2005) [18, 19].

The researches carried out in *S.rotundifolius* germplasm by Opoku-Agyeman *et al.*, 2007; Nanéma *et al.*, 2009 [20, 21] contributed some useful traits which can be used for the identification and description of this crop. Some research activities highlighted the influence of genetic variability in nutritional and medicinal properties of tubers and their behavior in conservation (Jayakodi *et al.*, 2005; Anbuselvi and Priya, 2013) [22, 5].

The present study was conducted for evaluating the genetic diversity in local collections as compared to the released varieties of Chinese potato and evaluating their performance with respect to the climatic and topographic conditions of Anakkayam. The main objectives were Evaluation and characterization of Coleus for quantitative characters and to identify promising genotypes and Development of high yielding cultivars with better quantitative characters in order to increase the marketable value of the crop.

Materials and Methods

The current investigation was carried out at the Agricultural Research Station, Anakkayam under the Kerala Agricultural University with the objective of evaluation of Coleus for quantitative characters contributing to yield and for the development of high yielding cultivars with better performance in order to increase the marketable value of crop.

The plant material for the present study consisted of nine accessions of Chinese potato (PML1, ALR, CP74, TCM9, TSR1, M131, MKD1) planted in the field collected from different parts of Kerala along with the released varieties Nidhi and Sreedhara. Nidhi is a variety of Chinese potato released from RARS; Pattambi (KAU). The trial was conducted in the field of Agricultural Research Station, Anakkayam, Malappuram district, Kerala. The site was located at 11º0.05’00.6’’N and 76.07’03.0’’E longitude at an altitude of 47m above MSL. Initially the plants were grown in the primary nursery inside the polyhouse and later it was transplanted to the main field. One month old terminal shoot cuttings were used for planting. The cuttings were planted on raised beds at a spacing of 30 cm × 15 cm. Twenty five terminal shoot cuttings were planted on the bed. Package of practices recommendations of Kerala Agricultural University, Kerala, India were followed. The fertilizers were applied in the field as per the package of practice recommendations, KAU (i.e., 60:60:100 NPK/ha).

The design followed was RBD with three replications for each treatment. There were 9 treatments or varieties in total. The tubers were ready to harvest when the plants were dried. The harvesting of the tubers started on 5th January 2023. The tubers from the plants of each replication of the nine accessions were harvested separately. Five randomly selected plants per replication per accession were used for recording yield data. The length, width and circumference of all the individual tubers from each plant were measured using ruler and recorded. The tubers were classified as marketable (tuber circumference > 7 cm) and unmarketable (tuber circumference< 7 cm) tubers, based on visual scrutiny for recording observations. The weights of the marketable, unmarketable and total weight of each plant from each replication were measured using Electronic weighing balance and were recorded for the determination of yield. Statistical analysis was done using the software SPSS.

Results

The crop was harvested after 5 months of planting. Significant differences were observed for the characters single, plant yield, single plant yield of marketable tubers and marketable tuber width. According to the observations of the recordings, the following results were obtained.

Table 1: ANOVA for yield characteristics

Source of variation	Replication	Treatment	Error
DF	2	8	16
Single plant yield (g)	25993.157**	6846.845*	1875.55
Single plant yield of marketable tubers (g)	9034.636**	4840.425*	1416.55
Single plant yield of unmarketable tubers(g)	5012.286**	964.50	492.83
Marketable tuber weight (g)	142.56	132.18	186.51
Marketable tuber length (cm)	0.04	0.07	0.04
Marketable tuber width (cm)	0.13	0.194*	0.06
Marketable tuber circum-ference (cm)	0.30	0.38	0.28
Unmarketa-ble tuber weight (g)	0.33	3.03	1.55
Unmarket-able tuber length (cm)	0.52	0.42	1.07
Unmarket-able tuber width (cm)	0.29	0.33	0.48
Unmarketable tuber circum-ference (cm)	1.547*	0.78	0.33
Number of Un Marketable tubers	75.00	26.33	43.00
Number of Marketable tubers	49.00	62.33	43.50
Total Number of tubers	244.00	133.92	132.42

Chinese potato accessions under study exhibited wide variability for some of the yield contributing characters. The ANOVA was determined with the help of SPSS Software and the data is given in Table 1. The observations of marketable tubers, unmarketable tubers and total tubers from all the nine varieties were measured and the data is presented in the Table 2. Marketable tubers are the tubers with circumference more than 7 cm.

Table 2: Estimates of mean for yield characteristics

Treatments	1	2	3	4	5	6	7	8	9
Single plant yield (g)	269.94	320.49	437.10	338.25	299.97	379.85	356.45	336.61	331.26
Single plant yield of marketable tubers (g)	191.38	201.92	324.15	251.27	218.87	270.98	234.91	220.09	247.56
Single plant yield of unmarketable tubers(g)	78.56	118.58	112.95	86.97	81.10	108.87	121.53	116.53	83.70
Marketable tuber weight (g)	35.02	19.48	35.32	28.13	22.61	31.55	29.88	16.89	30.99
Marketable tuber length (cm)	4.94	4.52	4.62	4.61	4.77	4.50	4.74	4.64	4.91
Marketable tuber width (cm)	4.19	3.85	3.77	3.93	3.80	3.78	3.99	3.48	4.35
Marketable tuber circum-ference (cm)	8.40	8.04	8.07	8.43	7.84	8.21	8.15	8.02	9.05
Unmarketa-ble tuber weight (g)	3.74	5.65	2.67	3.93	5.37	3.93	5.60	4.22	3.87
Unmarket-able tuber length (cm)	4.00	3.17	3.60	2.83	3.57	3.00	3.47	3.70	3.17
Unmarket-able tuber width (cm)	2.60	2.07	2.43	2.50	3.00	2.00	2.87	2.33	2.33
Unmarketable tuber circum-ference (cm)	5.00	4.47	5.83	5.30	5.17	4.30	5.10	5.77	5.10
Number of Un Marketable tubers	6.67	11.33	10.33	9.00	9.67	10.67	16.33	15.00	12.00
Number of Marketable tubers	15.67	14.33	19.33	16.00	8.67	15.00	18.33	25.67	18.00
Total Number of tubers	22.33	25.67	29.67	25.00	18.33	25.67	34.67	40.67	30.00

Note: Values expressed as Mean
T_1-Nidhi T_2-Sreedhara T_3- ALR T_4 –TCM9 T_5-M131, T_6-CP74, T_7-MKD1, T_8-PML1, T_9-TSR1

Table 3 depicts the estimates of mean for yield contributing characters in 9 Chinese potato accessions (PML1, ALR, CP74, TCM9, TSR1, M131, MKD1 and released varieties Nidhi and Sreedhara). The length, width, weight, number and circumference of tubers of five randomly collected Coleus plants from all nine varieties were measured and recorded. Observations were recorded for marketable as well as unmarketable tubers separately. Most of the accessions out-performed the check variety Nidhi (T_1) for single plant yield, whereas, no accession surpassed the control variety Nidhi for marketable as well as unmarketable tuber length.

The results revealed highest length, width and circumference of individual tubers in the treatment, T_9 whereas, the highest weight of individual tuber was recorded by the treatment T_3, which was on par with the control variety Nidhi (T_1). Similarly number of marketable tubers was recorded highest by T_8 followed by T_1.

The tuber yield varied among the accessions from 214.74 g to 536.86 g on a per plant basis. Tarpaga (2001) [15] and Nanema *et al*. (2009) [21] 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) [19] obtained single plant yield ranging from 54-126 g according to the cultivar.

Mean weight of marketable tubers was 27.76 g with a range of 8.26-68.07 g. The weight of unmarketable tubers ranged from 1.50-7.41 g with a mean value of 8. g. The mean length, breadth and circumference of marketable and unmarketable tubers observed were 4.7 cm, 3.9 cm, 8.24 cm for marketable tubers and 3.39 cm, 2.46 cm and 5.11 cm for unmarketable tubers respectively which was in accordance with the findings of Suma *et al* (2014) [25]. According to them, the mean length, breadth and circumference of marketable and unmarketable tubers observed were4.12 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) [21] recorded comparatively high values for average length and diameter of marketable tubers in their study on morpho-agronomic characterization of Chinese potato germplasm from Ghana. According to them, the average weight, length and diameter of marketable 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. As per their findings, the observations for unmarketable tubers were comparatively low whereas the mean single plant yield was in accordance with our finding for marketable tubers (341 g).

Table 3: Statistical and genetic parameters for yield characters

Trait	Range		Mean	PCV (%)	GCV (%)	H^2 (%)	Genetic Advance	Genetic Gain (%)
	Minimum	Maximum						
Single plant yield (g)	214.74	536.86	341.10	17.42	11.93	46.91	57.43	16.84
Single plant yield of marketable tubers (g)	155.26	396.90	240.12	21.06	14.07	44.62	46.49	19.36
Single plant yield of unmarketable tubers (g)	59.48	188.64	100.98	25.25	12.42	24.19	12.70	12.58
Marketable tuber weight (g)	8.26	68.07	27.76	51.52	15.31	8.85	2.61	9.39
Marketable tuber length (cm)	4.32	5.24	4.70	4.81	2.32	23.21	0.11	2.30
Marketable tuber width (cm)	3.28	4.80	3.90	8.36	5.36	41.21	0.28	7.09
Marketable tuber circum-ference (cm)	7.40	9.91	8.24	6.75	2.26	11.22	0.13	1.56
Unmarketa-ble tuber weight (g)	1.50	7.41	4.33	33.01	16.26	24.26	0.71	16.49
Unmarket-able tuber length (cm)	2.00	5.10	3.39	33.43	13.57	16.89	0.39	11.63
Unmarket-able tuber width (cm)	1.30	4.50	2.46	29.50	8.95	9.38	0.14	5.70
Unmarketable tuber circum-ference (cm)	3.00	6.00	5.11	13.56	7.54	30.95	0.44	8.64
Number of Un Marketable tubers	3.00	32.00	11.22	62.09	20.94	11.44	1.64	14.64
Number of Marketable tubers	6.00	34.00	16.78	42.05	14.93	12.61	1.83	10.92
Total Number of tubers	12.00	60.00	28.00	41.17	2.53	0.38	0.09	0.32

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 marketable tuber weight of single tuber as well as number of marketable as well as 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 average weight as well as of single plant yield of marketable tuber. Broad sense heritability (H2) ranged from 0.38% (unmarketable tuber numbers) to 46.91% (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) [19], 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) [12].

Plate 1: Tubers collected from ALR.

Plate 2: Comparison of sample tubers from each accession.

Table 4: Correlation matrix between different tuber characteristics

	SPY (g)	MSPY (g)	UMSPY (g)	MTWT (g)	MTL (cm)	MTW (cm)	MTC (cm)	UMWT (g)	UML (cm)	UMW (cm)	UMC (cm)	UMTN	MTN	TTN
SPY (g)	1													
MSPY (g)	0.91	1												
UMSPY (g)	0.7	0.35	1											
MTWT (g)	0.03	0.16	-0.2	1										
MTL (cm)	-0.1	0.04	-0.29	0.08	1									
MTW (cm)	-0.21	-0.01	-0.45	0.25	0.57	1								
MTC (cm)	-0.18	-0.02	-0.38	0.49	0.51	0.66	1							
UMWT (g)	-0.06	-0.17	0.15	-0.13	0.09	0	-0.12	1						
UML (cm)	0.14	0.1	0.14	-0.23	0.37	-0.23	-0.21	0.15	1					
UMW (cm)	-0.12	-0.07	-0.17	-0.14	0.11	0.02	-0.21	-0.14	0.39	1				
UMC (cm)	0.05	0.12	-0.1	-0.08	0.17	-0.07	-0.04	-0.32	0.17	0.5	1			
UMTN	0.43	0.23	0.6	-0.54	-0.15	-0.24	-0.4	0.19	0.24	0.07	0.17	1		
MTN	0.38	0.3	0.35	-0.33	0	-0.21	-0.19	-0.18	0.22	-0.12	0.12	0.57	1	
TTN	0.45	0.3	0.53	-0.49	-0.08	-0.25	-0.33	-0.01	0.26	-0.04	0.16	0.87	0.9	1

SPY-Single plant yield (g); MTSPY-Single plant yield of marketable tubers (g) UMSPY- Single plant yield of unmarketable tubers(g); MTWT-Marketable tuber weight (g); MTL-Marketable tuber length (cm); MTW-Marketable tuber width (cm); MTC-Marketable tuber circum-ference (cm); UMWT-Unmarketa-ble tuber weight (g); UML-Unmarket-able tuber length (cm); UMW-Unmarket-able tuber width (cm); UMC-Unmarketable tuber circum-ference (cm); UMTN-Number of Un Marketable tubers; MTNNumber of Marketable tubers; TTN -Total Number of tubers

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 length and width and circumference. It was observed that the unmarketable tuber weight and width correlated negatively with the single plant yield (Table 4). The lack of significant correlation between tuber yield with tuber length and girth was also observed by Sreekumari and Abraham (1985) [9] and was stated to be due to the high heterogeneity of tubers observed among accessions. A highly positive significant correlation was observed between single plant yield and single plant yield of marketable tubers.

Table 5: Cluster means for the characters under study

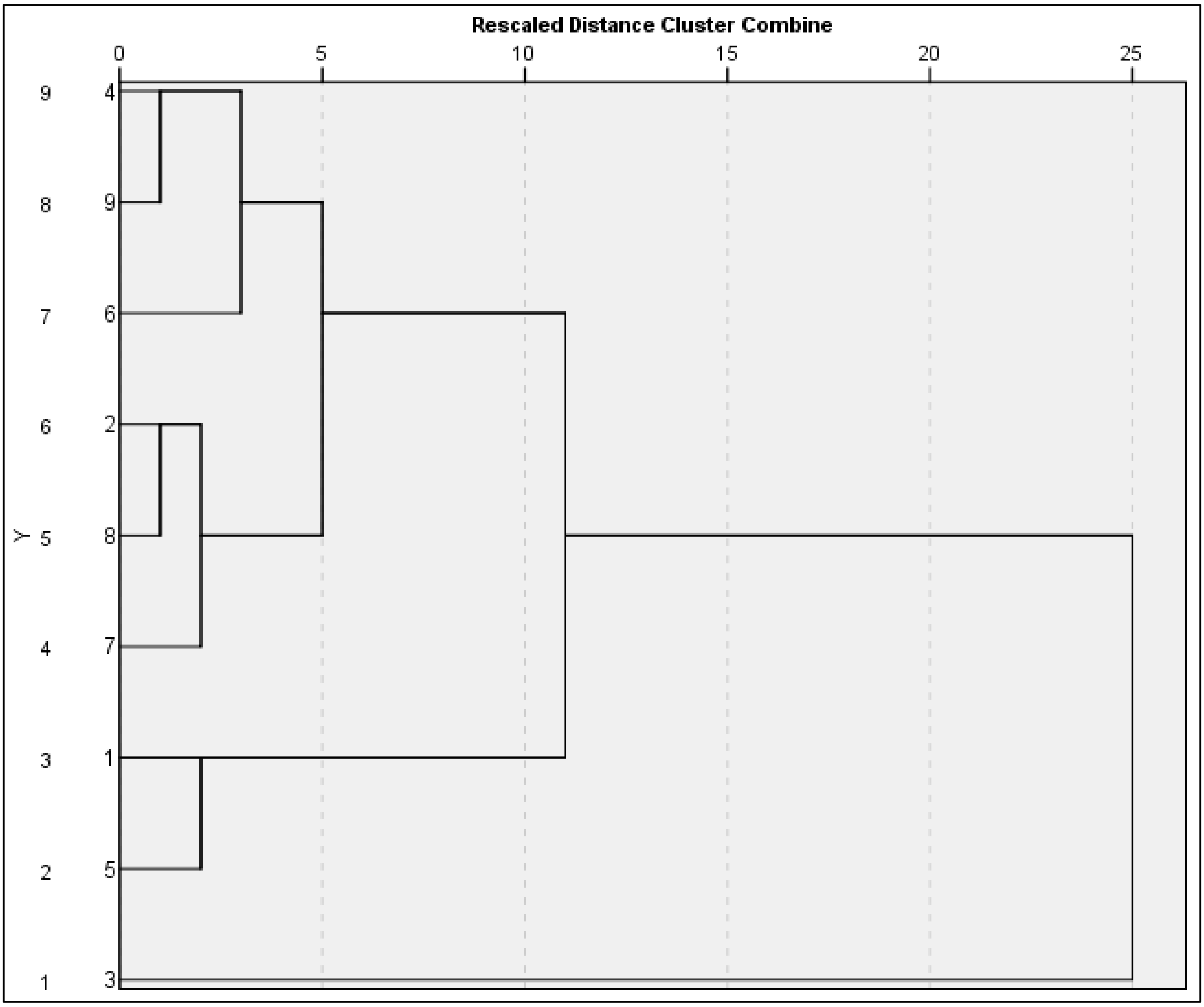
Trait	Cluster I	Cluster II	Cluster III
	(T_1 & T_5)	(T_2, T_4, T_6, T_7, T_8, T_9)	(T_3)
Single plant yield of marketable tubers (g)	205.12	237.79	324.15
Single plant yield of unmarketable tubers(g)	79.83	106.03	112.95
Single plant yield (g)	284.95	343.82	437.1
Marketable tuber weight (g)	28.82	26.15	35.32
Marketable tuber length (cm)	4.86	4.65	4.63
Marketable tuber width (cm)	4	3.9	3.77
Marketable tuber circumference (cm)	8.12	8.32	8.06
Unmarketable tuber weight (g)	4.56	4.53	2.67
Unmarketable tuber length (cm)	3.78	3.22	3.6
Unmarketable tuber width (cm)	2.8	2.35	2.43
Unmarketable tuber circumference (cm)	5.08	5.01	5.83
Number of Un Marketable tubers	8.17	12.39	10.33
Number of Marketable tubers	12.17	17.89	19.33
Total Number of tubers	20.33	30.28	29.67

Cluster analysis

The accessions were grouped into different clusters based on the yield characters (Table 5). Two accessions were grouped in cluster I including the check variety Nidhi, 6 accessions in Cluster II and one accession, in cluster III. The mean value for all other characters except marketable tuber length, width, circumference and unmarketable tuber weight, was maximum for cluster III as compared to cluster I and II. The accessions grouped in the third cluster is observed as the high yielder having average single plant yield of 437 g (Table 5) which was collected from Palakkad district.

All the yield characters recorded for accessions in cluster I were the lowest. However, accessions in the second cluster yielded between 320.49 g to 379.85 g whereas accessions in the first cluster were low yielders with mean yield 205.12 g/plant. The accessions grouped in different clusters were from Palakkad, Thrissur and Malappuram districts of Kerala. Hence, on comparing the geographic locations of collections, homogeneity among accessions in each clusters for yield characters were present even though those were collections from different locations.

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) [19] and indicated that factors other than geographical diversity may be responsible for such clustering.



Dendrogram

Discussion

The results revealed, highest marketable tuber weight, single plant yield of marketable tubers as well as number of tubers in the treatment T_3 (ALR) followed by T_6 (CP74), whereas, highest marketable tuber length was recorded by control, T_1. Hence, in this study, T_3 performed as the best accession with good yield parameters. Mean weight of marketable tubers is 27.76 g with range of 8.26 g – 68.07 g. The weight of unmarketable tubers ranged from 1.5 g to 7.41 g, with a mean of 4.33 g. Marketable tubers recorded 4.7 cm, 3.9 cm, and 8.24 cm, length, width, and circumference respectively, but unmarketable tubers exhibited 3.39 cm, 2.46 cm, and 5.11 cm, respectively. According to the study by A. Suma *et al.* (2014) [25] the average weight of marketable tubers was 36.51 g, with a range of 8.47 to 56.63 g. Unmarketable tubers had a mean weight of 3.90 g and a range of 2.22 – 9.71 g. According to them, the average length, width, and circumference of marketable tubers were 4.12 cm, 3.83 cm, and 12.12 cm, respectively, whereas those that were unmarketable were 2.07 cm, 1.70 cm, and 5.50 cm. Nanéma *et al.*, (2009) [21] recorded average weight, length and diameter of marketable tubers tubers as 46.06 g, 6.15 cm and 2.85 cm and that of small tubers as 0.34 g, 3.55 cm and 1.30 cm respectively.

In the present study, it is concluded that length, width and circumference has no significance effect on yield, whereas number of tubers per plant presented a positive significance on yield. Similarly, Sreekumari and Abraham (1985) [9] revealed that there is no correlation between tuber yield and tuber length or girth. It was claimed that the cause for this was the significant tuber heterogeneity seen among the accessions. In the study conducted by A. Suma *et al.*, 2014 [25] most of the yield characters studied showed a positive significant correlation, with the exception of single plant yield and marketable tuber width and between marketable tuber length and width. On the other hand, M. Velmurugan *et al.*, (2009) [24] stated that, the plant height, number of branches, number of leaves, number of tubers, tuber length, and tuber girth had a positive and highly significant correlation with yield.

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 indicates the presence of additive gene action. Hence simple direct selection can be easily done for improvement of this character. ALR (T_3) 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.

Chinese potato is one of the neglected and underutilized crops which exhibit superior performance under extreme soil and climatic conditions. Chemical mutagens and tissue culture technologies have been employed to regenerate plantlets with desired variations and broadening the genetic base of the crop. The experiments by researchers utilizing the different cultivars of Chinese potato indicated that this plant produces small size tubers and in some cases 'branched' tubers. The future research programme has to be planned to overcome these problems. Breeders, therefore, need to develop high yielding cultivars with non-tuber branching capacity in addition to withstanding the fluctuations of the weather.

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Declaration

We declare that this manuscript is original, has not been published before and is not currently being considered for publication elsewhere. We know of no conflict of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome. As corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors

References

1. Enyiukwu ON, Awurum AN, Nwaneri JA. Potentials of Hausa potato (*Solenostemon rotundifolius* (Poir.) J.K. Morton) and management of its tuber rot in Nigeria. Greener Journal of Agronomy Forestry and Horticulture. 2014b;2(2):27-37.
2. Kwarteng AO, Ghunney T, Adu Amoah R, Nyadanu D, Abogoom J, Nyam KC, *et al*. Current knowledge and breeding avenues to improve upon Frafra potato (*Solenostemon rotundifolius* (Poir.) J K Morton). Genetic Resources and Crop Evolution. 2018;65:659-69.
3. Olojede AO. Sugar beets and minor root and tuber crops; c2013. www.nrcri.gov.ng/pages/sugar.htm Retrieved November 10, 2013.
4. Chivenge P, Mabhaudhi T, Modi AT, Mafongoya P. The potential role of neglected and underutilised crop species as future crops under water scarce conditions in sub-saharan Africa. International Journal of Environmental Research and Public Health. 2015;12(6):5685-5711.
5. Anbuselvi S, Hemapriya M. Nutritional and anti nutritional constituents of *Plectranthus rotundifolius*. Int. J Pharm. Sci. Rev. Res. 2013;22:213-215.
6. Agyeno OE, Jayeola AA, Ajala BA, Mamman BJ. Exomorphology of vegetative parts support the combination of *Solenostemon rotundifolius* (Poir.) JK Morton with Plectranthus esculentus NE Br. Natal (Lamiaceae)with Insight into Intra-Specific Variability. International Journal of Bioflux Society. 2014;6(1):16-25.
7. Aculey K, Quainoo AK, Mahanu G. Feasibility studies on the potential of grafting and budding of Frafra potato (*Solenostemon rotundifolius*). Journal of Horticulture and Forestry. 2011;3(10):327-332.
8. Muraleedharan VK, Velayudhan KC, John L. Variation in a collection of Coleus parviflorus Benth. In: Ramanujan T, PG Rajendran, M Thankappan, C Balagopal and KB Nair (eds) Tropical Tuber Crops, Production and Utilisation. Indian Society of Root Crops, Sreekaryam. Thiruvanathapuram, Kerala; c1985. p. 83-88.
9. Sreekumari MT, Abraham K. Variation and correlation studies in Chinese potato Africa. African Technology Development Forum Journal. 1985;6(3):9-15.
10. Amalraj VA, Velayudhan KC, Muraleedharan VK. Teratological variation in *Coleus parviflorus*. J. Root Crops. 1989;15:61-62.
11. Ramachandran K. Cytology of the genus Coleus. Cytologia. 1976;32:474-480.
12. Rajmohan K. Coleus (*Coleus parviflorus* Benth.). In: KV Peter (ed.) Underutilized and Under exploited Horticultural Crop. New India Publishing Agency, New Delhi, India; c2007. p. 29-36.
13. Edison S, Unnikrishnan M, Vimala B, Pillai SV, Sheela MN, Sreekumari MT, *et al*. Biodiversity of Tropical Tuber Crops in India National Biodiversity Authority. National Biodiversity Authority Chennai: Tamil Nadu, India; c2006.
14. Ouédraogo A, Sedego A, Zongo JD. Perceptions paysannes de la culture et des utilisations du «fabirama» (*Solenostemon rotundifolius* (Poir.) J.K. Morton) dans le plateau central du Burkina Faso. Ann. Bot. Afr. Ouest. 2007;4:13-21.
15. Tarpaga WV. Etude de la variabilité agromorphologique d'une collection de *Solenostemon rotundifolius* du Burkina Faso. Mém. d'Ing. de Dev. Rural, Univ. Bobo-Dsso, Bobo Dsso; c2001. p. 56.
16. Nkansah GO. *Solenostemon rotundifolius* (Poir), PROTA 2: Vegetables/legumes (CD-ROM). PROTA, Wageningen, Netherland; c2004.
17. Tetteh JP, Guo JI. Problems of Frafra potato in Ghana. Dissertation, School of Agriculture, University of Cape Coast *Ghana journ*. Linn. Soc. Lond., Bot. 1997;58:272.
18. Vasudevan K, Jos JS. Variation for yield and quality in Coleus mutants. Madras Agric. J. 1992;79:130-138.
19. Abraham M, Radhakrishnan VV. Assessment and induction of variability in Coleus (*Solenostemon rotundifolius*). Indian Journal of Agricultural Sciences. 2005;75(12): 834-836.
20. Opoku-Agyeman MO, Bennett-Lartey SO, Vodouhe RS, Osei C, Quarcoo E, Boateng SK, *et al*. Morphological characterization of frafra potato (*Solenostemon rotundifolius*) germplasm from the savannah regions of Ghana. Plant Genetic Resources and Food Security in West and Central Africa. Regional Conference, Ibadan, Nigeria; c 2004 Apr 26-30**.** p.116-123.
21. Nanema RK, Traore ER, Batiano/Kando P, Zongo JD. Morpho-agronomical characterization of *Solenostemon rotundifolius* (Poir.) JK Morton (Lamiaceae) germplasm from Burkino Faso. Int. J Biol. Chem. Sci. 2009;3:1100-1113.
22. Jayakody L, Hoover R, Liu Q, Weber E. Studies on tuber and root starches. I. Structure and physicochemical properties of innala (*Solenostemon rotundifolius*) starches grown in Sri Lanka. Food Research International. 2005;38:615-629.

23. Abraham M, Radakrishnan VV. Induced Mutations in Coleus (*Solenostemon rotundifolius* (Poir.) J. K. Mortan)- An Under-Utilized Medicinal Tuber. Proceedings of International Symposium on Induced mutations in plants. IAEA and FAO, 12-15 Aug, Vienna, Austria; c2008.
24. Velmurugan M, Rajamani K, Paramaguru P, Gnanam R, Bapu KJR. Studies on Correlation and Path Analysis in Mutants of Coleus (*Coleus forskohlii* Briq.) for Yield and forskolin Content in V2M1 Generation. Journal of Horticultural Sciences. 2009 Jun;4(1):63-67.
25. Uchida H, Itaka K, Nomoto T, Ishii T, Suma T, Ikegami M, *et al*. Modulated protonation of side chain aminoethylene repeats in N-substituted polyaspartamides promotes mRNA transfection. Journal of the American Chemical Society. 2014 Sep 3;136(35):12396-12405.