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Morphological and biochemical characteristics of promising Indian sweetpotato cultivars and identification of virus infecting sweetpotato in India

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Abstract. Phylogenetic relationship of twenty-two promising Indian sweetpotato (*Ipomoea batatas*) cultivars was determined through morphological and yield parameters. Mahalanobis Multivariate D^2 analysis was performed with a view of tracing relationship among the cultivars. Based on sixteen significant characters, four distinct clusters (Gr. I- 11, Gr.II- 9, Gr.III- 1 and Gr.IV- 1) were obtained. This grouping was concordant with the other characters used in cladistic analysis. Association of morphological characters with yield and yield attributing factors were also studied to work out the direct or indirect effect of different characters on yield. The biochemical parameters of the tubers viz. carbohydrate, crude and soluble protein, ascorbic acid, dry matter content were determined. Significant variation of the proximate nutritional composition was observed in the tested cultivars. The mineral profile viz. Fe, Mn, Cu and Zn in the tubers was different among the cultivars. Occurrence of the viruses among the cultivars was also determined visually and by NCM-ELISA. Twelve different types of virus symptoms were found in the test cultivars. NCM-ELISA gave positive results for some viruses. The present studies have provided a detailed insight among the twenty-two sweetpotato cultivars, which would contribute to the crop improvement programme.

Introduction

Sweetpotato (*Ipomoea batatas* L. (Lam) is considered to be the world's most important subsistence crop (Hall, 2003). This crop is grown mostly in China, followed by Sub-Saharan Africa, Indonesia and India. Over 98% of global sweetpotato output is currently cultivated and consumed in developing countries. In India sweetpotato cultivation is increasing dramatically, with cultivation mostly in Orissa, Bihar, Uttar Pradesh, West Bengal and in South-Indian states (Edison, 2000). The average productivity of sweetpotato is, however, declining as a result of several biotic and abiotic factors. Thus, there is an urgent need for selection and development of high yielding improved cultivars. The rich genetic biodiversity of sweetpotato in India offers prospects of broadening the genetic base to incorporate highly adapted, high yielding cultivars (Naskar, 1996; Thomas and Raman, 2000). Thus information of genetic diversity and relationships among the genotypes of sweetpotato is essential for efficient utilization of the genetic resources. The crop exhibits great diversity in morphological and

phenotypic traits. In biosystematics, mature morphological features and the biochemical studies are the conventional criteria used to establish taxonomic status, which provide a formidable set of characters for correlation with other features and 21 key sweetpotato descriptors such as growth habit, mature leaf shape, color, foliage and floral characters, tuber colour its quality have been described (Huaman, 1992). Sweetpotato is the crop with high contents of dietary fiber, complex carbohydrates, protein, vitamin A, C and B6, and minerals. It contains virtually no fat and are low in sodium. Presently sweetpotato is receiving much attention in human nutrition and in animal husbandry. The assessment of biochemical characters will provide data that will supplement conventional quality parameters. Several reports on the nutritive values of the sweetpotato and differences in the cultivars have been studied (Bradbury *et al*., 1985; Ravindran *et al*., 1995; Hall, 2003). In recent years, post harvest processing of sweetpotato has become popularized and opening up a new dimension for farmers and entrepreneurs. Though the crop has high adaptability and tolerance to abiotic stresses, one of the major constraints for its production is attack by virus diseases. Several researchers have made intensive studies on the occurrence of several sweetpotato viruses, their severity and yield loss in different countries but only a little effort has been made in India. The current challenge is to utilise novel Indian sweetpotato genetic resources to broaden the genetic base for improvement of the crop into high yielding, nutritive and disease resistant cultivars.

In the present investigation, phenotypic diversity of twenty-two Indian cultivars were studied. Nutritive value of the selected cultivars was analyzed for proximate composition of carbohydrate, proteins, vitamin-C and minerals. The variation in the symptoms on virus-like diseases in the test cultivars were studied and detected by NCM-ELISA.

Materials and Methods

Some promising Indian sweetpotato cultivars viz. Tripty, IBM-95-229, WBSP-4, IBM-95-220, Kamala Sundari, Pol-20-6-2, Pol-4-4-5, BCSP-14, IBM-95-206, BCSP-10, RNSP-1, RNSP-2, IGSP-6, IGSP-7, IGSP-8, IGSP-9, NDSP-9, NDSP-10, BCSP-7, CO-3 were characterized for the morphological parameters, nutritional content and qualitative traits based on descriptors of Huaman *et al.* (1992) and Das and Mukherjee (1996). The experiments were conducted at the Horticultural Experimental Field of Bidhan Chandra Krishi Viswavidyalaya, Kalyani during 2000-2003. The vines of the cultivars were planted at inter row and intra row spacing of 60 x 20 cm, respectively, in a Randomised Block Design. Data on the morphological parameters like plant habit, vine characters including stem and foliage characters, floral descriptions and crop canopy were recorded 90 days after planting. Leaf area index (LAI) was determined using Sun Scan type SS-1CE Delta T-devices (UK) model canopy analyser. Tuber yield was determined for five plants randomly selected from each plot and converted to yield/ha after 120 days. The observation on physical characters like colour of stem, leaves, flowers, floral parts and tubers were recorded from fresh samples. The multivariate divergence analysis based on Mahanalabis D^2 statistics method (Chowdhury and Singh, 1995) was performed to assess the genetic variability, intensity and genetic distance, cluster analysis among twenty-two sweetpotato cultivars in respect to sixteen morphological characters, yield components.

The proximate nutritional composition of the cultivars were analysed from fresh tubers after harvest. Dry matter content was estimated as the difference between the fresh and dry tuber weight of each cultivar following oven drying of tuber slices at 60° C for 72 hr. Total carbohydrate, crude protein, vitamin C, and mineral compositions were determined on dry weight basis (dwb) and

soluble protein on fresh weight basis (fwb) for each cultivar. The freshly harvested tubers of uniform size were washed thoroughly, sliced, sun dried and then oven dried at 60° C for 18 hr. The dried slices were ground into a fine powder and stored in airtight containers until use. Total carbohydrate was determined by Anthrone method. Crude protein was estimated from nitrogen content by Micro-Kjeldahl method (Sadasivam and Manickam, 1997). The soluble proteins in fresh tubers were precipitated with 10% tricholoroacetic acid (TCA), dissolved in 1N NaOH and analysed spectrophotometrically according to Lowry (1951). The method for analysing vitamin C was based on titration with 2,6-dichloro-phenol-indophenol (Sadasivam and Manickam, 1997).

The analysis of mineral composition like iron, manganese, copper and zinc were carried out by digesting the samples with perchloric, nitric and acetic acid mixture and determined by atomic absorption spectrophotometer.

The natural incidences of sweetpotato virus like diseases were determined. Characteristics symptoms were also noted. The fresh leaf samples from the plants showing symptoms were tested using NCM-ELISA for the presence of eight viruses namely: sweetpotato (SP) feathery mottle virus (SPFMV), sweetpotato mild mottle virus (SPMMV), sweetpotato latent virus (SwPLV), sweetpotato chlorotic flecks virus (SPCFV), sweetpotato mild speckling virus (SPMSV), C-6 virus, sweetpotato chlorotic stunt virus (SPCSV) and sweetpotato caulimo like virus (SPCaLV). The detection of the viruses by NCM-ELISA was done according to International Potato Centre (CIP) method. The NCM-ELISA kit was also kindly provided by the CIP, Peru.

Results

The data of Mahalanobis multivariate divergence analysis on the morphological and yield determining factors are summarized in Table 1. A significant phylogenetic diversity and links among the cultivars was observed.

The analysis of variance showed highly significant differences among the twenty-two sweetpotato cultivars for all characters (Table 2). Most of the characters showed high heritability; tuber yield, carpel length, flower length, flower diameter and LAI. The estimated genetic advance (GA) values were found to be very high in the characters for vine length, tuber yield, tuber length and inflorescence length and lowest for tuber weight (Table 2). A very close relationship of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed among most of the characters while lamina length, anther length and number of tubers per five plants showed wide differences between GCV and PCV.

Genotypic and phenotypic correlations were calculated for sixteen characters (Table 3). At phenotypic level, flower length and diameter and sepal length had a significant correlation with yield. At the same time flower diameter, sepal length and number of tubers also showed a positive correlation. Similarly, flower length and diameter, length of sepal and anther were also found to be positively correlated with yield.

The genotypic and phenotypic path coefficient analysis revealed direct and indirect effects of most morphological traits on tubers (Tables 4). Among the sixteen characters considered in this study, all with the exception of character X_{15} (number of tuber per five plants) were introduced in the path coefficient analysis of yield at both genotypic and phenotypic levels. Among the significantly correlated morphological characters like flower length and diameter, sepal length and anther length had a positive effect on the yield. On the other hand, stamen length (X_9) and LAI (X_{12}) did not show significant correlation with yield.

The divergence analysis (Table 5 a, b, c) revealed different cluster combinations at specific similarity level or genetic distance (D). This analysis generated two major clusters (I

Table 1: Mahalanobis multivariate D^2 analysis of twenty-two Indian sweet potato cultivars with respect to the morphological and attributing factors.

Sweet potato cultivars	1.Vine length	2.Petiole length	3.Lamina length	4.Inflores-cence length	5.Pedicel length	6.Flower length	7. Flower diameter	8.Sepal length	9.Stamen length	10.Anther length	11.Carpel length	12. LAI	13.Tuber length	14.Tuber breadth	15.Weight of tuber/5 plants	16. Tuber yield (t/ha)
Tripty	93.67	11.5	8.67	7.9	0.67	3.65	2.88	1.2	1.65	0.5	2.2	0.8	17.83	4.67	2.77	38.13
IBM-95-229	64.17	12.57	7.67	6.47	0.5	3	2.67	0.87	0.9	0.25	1.15	1.5	15.5	3.25	2.2	32.27
WBSP-4	80.5	13.9	9.83	16.33	1.33	4.15	3.5	1	1.7	0.4	2.15	1.7	18.23	4.67	2.6	38.33
IBM-95-220	96.73	14.2	11.37	10.8	0.9	3.9	3.35	1	1.85	0.5	2.07	1.6	17.47	3.77	1.23	22.43
Kamala Sundari	101.8	11.27	9	14.67	1.47	5	4.55	1.47	1.05	0.5	1.1	2.2	15.27	7.53	2.63	32.9
Pol-20-6-2	40.53	8.4	9.37	5.6	0.67	4.35	3.5	1	0.95	0.3	1.2	0.1	16.3	5.23	1.21	20.25
Pol-4-4-5	92.9	12	8.77	10.43	0.83	3.65	3	1.03	1	0.3	1.17	0.9	14.07	4.97	1.1	18.44
BCSP-14	81.7	7.77	9.57	6.7	0.97	3.55	3.1	0.93	1.1	0.35	2	0.9	18.47	6.93	2.06	20.97
S-1221	87.67	11.53	8.13	12.67	0.97	3.6	3	1.07	1.2	0.2	1.75	0.9	25.33	7.9	1.95	32.45
BCSP-5	70.7	11.83	8.4	7.5	1	4.1	3.5	0.97	1.1	0.3	1.57	1.1	12.9	3.77	2.23	35.8
IBM-95-206	73.4	9.73	8.57	10.77	0.87	2.43	3.97	0.73	1.1	0.3	1.3	2.4	23.47	4.83	1.15	18.3
BCSP-10	120	13.8	8.6	6.27	1.07	3.5	2.9	1.03	0.9	0.35	1.2	1.1	20.1	6.83	1.1	18.2
RNSP-1	79	13.63	9.47	6.67	0.53	3.15	2.65	0.8	1	0.2	1.5	2	15.33	3.4	0.16	2.55
RNSP-2	53.17	9.47	8.8	8.2	0.8	3.3	2.8	0.9	1.2	0.25	1.7	1.9	10.33	4.77	0.54	6.9
IGSP-6	64.17	11.1	9.23	10.63	0.93	2.75	2.4	1	1.6	0.4	2	2.1	19.37	4	22.78	10.5
IGSP-7	70.33	17.2	10.47	6.17	0.63	3	2.8	0.97	1.55	0.25	1.9	2.1	13	4.4	0.68	9.77
IGSP-8	92	11.57	7.87	13.4	0.97	4.1	3.65	1	1	0.35	1.5	3	18.27	4.4	0.95	15.55
IGSP-9	89.67	15.2	9.03	11.17	1.07	3.3	2.85	0.97	1.5	0.3	1.95	2.3	22.77	6.13	1.23	20.77
NDSP-9	85.83	7.47	8.93	9.7	1.67	2.65	2	0.87	0.9	0.2	1.2	0.6	16.9	3.83	1.05	15.3
NDSP-10	65	9	9.47	9.47	1.1	3.4	3.15	1.13	1	0.3	1.9	0.9	15.63	3.9	28.98	15.83
BCSP-7	76	7.47	7.53	9.73	0.73	3.35	2.65	0.8	1.6	0.35	2.1	1.3	17.4	4.43	1.27	20.6
CO-3	85.67	12.13	8.23	14.2	0.93	3.6	2.5	0.93	0.8	0.3	1.1	1.1	19.3	3.7	0.65	10.8
SEM±	8.42	12.92	54.17	8.22	7.81	52.92	62.89	37.61	41.2	0.19	28.8	10.1	8.32	25.79	7.7	70.18
LSD (p>0.05)	24.08	36.88	15.46	23.46	22.3	151.1	179.5	107.3	117.6	NS	8.7	28.8	23.7	73.61	21.98	20.03

Table 2: Analysis of genotypic and phenotypic variability in twenty-two Indian sweet potato cultivars.

Character	HeritabilityB.S	GA (K=2.06)	Genotypic Coefficient of variation (%)	Phenotypic Coefficient of variation (%)
X_1 Vine length	0.520	22.52	18.91	26.23
X_2 Petiole length	0.501	3.27	19.53	27.59
X_3 Lamina length	0.366	0.89	7.96	13.16
X_4 Inflorescence length	0.811	5.48	30.15	33.47
X_5 Pedicel length	0.804	0.51	29.28	32.65
X_6 Flower length	0.977	1.21	16.89	17.09
X_7 Flower diametr	0.965	1.15	19.17	19.52
X_8 Sepal length	0.837	0.28	14.97	16.36
X_9 Stamen length	0.951	0.63	25.93	26.59
X_{10} Anther length	0.040	0.03	18.41	92.00
X_{11} Carpel length	0.985	0.80	24.2	24.39
X_{12} . LAI	0.942	1.40	47.55	49.01
X_{13} Tuber length	0.851	6.55	19.78	21.44
X_{14} Tuber breadth	0.892	2.58	27.14	28.65
X_{15} Weight of tuber per 5 plants	0.000	0.0	0.86	364.51
X_{16} Tuber yield (ton/ha)	0.986	20.91	49.2	49.55

and II) and two small clusters consisting of a single cultivar each. The clusters I and II (Table 5a) comprised of eleven and nine cultivars respectively. The single cluster cultivars were WBSP-4 and Kamala Sundari. Average performance and inter and intra cluster distance showed considerable variations among the groups (Table 5b). Cultivars in cluster II were distantly related with the cultivars of cluster IV, whereas low genetic distances were found between the cluster II and III. Cluster analysis based on the sixteen morphological characters and yield attributes are summarized in Table 5c. Tuber yield, LAI, carpel and flower length had the highest level of divergence of 29.44, 24.68, 20.35 and 10.82% respectively. These are the most indiscriminate characters among the cultivars. High values for characters length of vine, pedicel, flower, sepal and anther flower diameter and LAI were observed in cluster IV. Cluster I had the lowest value of petiole and anther length, LAI, and tuber yield. Clusters III showed maximum lamina, inflorescence, sepal and carpel length, and total tuber yield.

Variations were also observed in the qualitative and physical characteristics (Table 6). The colour of stem, leaf, leaf veins, petiole, sepal surface and shape, colour of filament and anther, style length, tuber skin and flesh colour had positive correlation with genotypic and phenotypic coefficient of variation. The cultivars, WBSP-4 and Kamala Sundari from groups III and IV were quite distinct from other cultivars.

Significant differences were observed among tubers for dry matter content and total carbohydrate (Table 7). The average dry matter ranged from 15.62% to 28.83%. Total carbohydrates were also high (37.20%). The average crude and soluble protein content varied from 1.85 to 9.33% (dry weight basis) and 25.9 to 6.61 mg/gm^{-1} (fresh weight basis), respectively. Among the cultivars, orange skinned Kamala Sundari, and red skinned BCSP-5, IBM-95-229, IBM-95-220 had high levels of crude and soluble proteins although S-1221 and NDSP-9 had the highest amounts of soluble protein. Vitamin-C content was significantly influenced by cultivars and ranged from 10.88 to 35.39% (dry weight basis). Most of the cultivars were very good source of minerals and significant levels of

Table 3: Genotypic and phenotypic correlation among sixteen morphological descriptors.

	X_1 Vine length	X_2 Petiole length	X_3 Lamina length	X_4 Infloresc-ence length	X_5 Pedicel length	X_6 Flower length	X_7 Flower Diameter	X_8 Sepal length	X_9 Stamen length	X_{10} Anther length	X_{11} Carpel length	X_{12} LAI	X_{13} Tuber length	X_{14} Tuber breadth	X_{15} Weight of tuber/5 plants	X_{16} Tuber yield (ton/ha)
X_1		0.267	0.14	0.244	0.33	0.17	0.156	0.25	0.004	0.08	-0.06	0.09	0.272	0.305	-0.02	0.174
X_2	0.413		0.307	0.036	-0.14	0.04	0.116	0.04	0.232	0.19	0.086	0.35	0.077	0.001	-0.11	0.026
X_3	-0.2	0.421		-0.06	0.07	0.05	0.132	0.09	0.355	0.22	0.272	0.01	-0.19	-0.1	0.047	-0.13
X_4	0.405	0.115	-0.09		0.46	0.3	0.251	0.31	0.133	-0.1	0.037	0.32	0.326	0.137	-0.02	0.229
X_5	0.435	-0.23	0.106	0.617		0.2	0.192	0.31	-0.06	-0.14	-0.09	-0	0.157	0.238	0.105	0.201
X_6	0.246	0.069	0.106	0.345	0.24		0.926	0.65	-0.01	0.03	-0.07	-0.1	-0.18	0.345	-0.09	0.48
X_7	0.193	0.153	0.222	0.285	0.24	0.95		0.69	0.044	0.03	0.012	0.08	-0.24	0.369	0.019	0.445
X_8	0.442	0.182	0.2	0.303	0.4	0.71	0.761		0.055	-0.01	0.002	0.05	-0.06	0.435	0.115	0.419
X_9	0.054	0.39	0.572	0.19	-0.11	-0.01	0.043	0.06		0.05	0.832	0.22	0.07	-0.07	0.042	0.227
X_{10}	0.499	0.5	0.552	-0.17	-0.81	0.29	0.348	-0.1	0.211		0.047	0.11	-0.09	-0.08	0.002	-0.13
X_{11}	-0.08	0.126	0.477	0.041	-0.12	-0.07	0.012	0.01	0.856	0.23		0.09	0.096	-0.04	0.155	0.155
X_{12}	0.152	0.487	0.04	0.373	-0.02	-0.11	0.073	-0.1	0.241	0.77	0.11		0.07	-0.06	-0.01	-0.23
X_{13}	0.429	-0.02	-0.19	0.395	0.18	-0.19	-0.25	-0.1	0.105	-0.3	0.1	0.07		0.404	0.003	0.173
X_{14}	0.48	-0.08	-0.05	0.172	0.34	0.37	0.391	0.5	-0.06	-0.66	-0.03	-0.1	0.444		-0.11	0.281
X_{15}	58.67	-48.4	43.05	18.12	21.3	-40.8	-16.9	60.4	16.74	-63.5	65.43	-12	-1.11	-40.2		-0.06
X_{16}	0.244	0.04	-0.21	0.251	0.22	0.49	0.457	0.46	0.233	-0.67	0.154	-0.2	0.186	0.302	-33.8	

iron (Fe), manganese (Mn) and copper (Cu) were detected.

The preliminary indexing of twenty-two cultivars for sweetpotato virus diseases in the field was made on the basis of symptoms appearance. Symptoms ranged from mild to severe and included clorosis, vein clearing, stunting and feathery mottle like symptoms. Following serological tests using NCM-ELISA, the viruses detected were: SPCSV, SPFMV, SOMMV, SPCaLV, SPCFVM SPMSV and C-6.

Discussion

The advantage of using the phenotypic characters in systematic studies is subjected to the diversity of factors that prevail in the case of mature plants. In the present study, morphological parameters were useful in resolving the cultivars of sweetpotato and making probable links. The closer the value of GCV towards PCV implicated less environmental impact on the characters studied. It is suggested that fourteen characters are controlled by the gene action with the environment having little influence. Lamina length and weight of tuber per five plants are controlled by environmental factors with gene action playing a minimal role.

Geographical distribution of the sweetpotato cultivars was not related to genetic diversity (Naskar, 1996). Somda and Kays (1990) also made similar observation on the change in petiole and lamina length and leaf size with the season. It is suggested from our results that the characters of vine, inflorescence and tuber length and total tuber harvest are the important contributing factors during direct selection of sweetpotato lines. Rajendran and Amma (1996) considered the flower characters one of the important descriptors to understand the spectrum of variation in the traits of sweetpotato for a breeding programme. In our study, it is evident that flower length and diameter and length of sepal and anther have positive correlation with tuber yield. The genetic uniformity and non-uniformity is reflected by the genetic

Table 4 : Genotypic and phenotypic path coefficient analysis showing direct or indirect effect on the tuber yield of sweetpotato.

Genotype														
1	1.175	-0.103	0.153	0.922	-0.508	-2.265	1.974	-0.725	0.101	0.030	0.132	-0.502	-0.095	-0.044
2	0.486	-0.249	-0.321	0.261	0.274	-0.640	1.565	-0.299	0.729	0.030	-0.199	-1.607	0.004	0.007
3	-0.236	-0.105	-0.763	-0.211	-0.123	-0.974	2.273	-0.328	1.069	0.033	-0.754	-0.132	0.041	0.005
4	0.475	-0.029	0.071	2.279	-0.721	-3.182	2.908	-0.496	0.354	-0.010	-0.065	-1.230	-0.087	-0.016
5	0.512	0.058	-0.080	1.406	-1.168	-2.189	2.412	-0.662	-0.202	-0.048	0.190	0.057	-0.040	-0.031
6	0.289	-0.017	-0.081	0.786	-0.277	-9.223	9.712	-1.166	-0.020	0.017	0.113	0.351	0.042	-0.034
7	0.227	-0.038	-0.170	0.648	-0.276	-8.766	10.218	-1.247	0.080	0.021	-0.018	-0.241	0.056	-0.036
8	0.519	-0.045	-0.153	0.690	-0.471	-6.557	7.771	-1.640	0.120	-0.005	-0.014	0.269	0.020	-0.046
9	0.063	-0.097	-0.436	0.432	0.126	0.100	0.436	-0.106	1.868	0.013	-1.353	-0.795	-0.023	0.006
10	0.586	-0.125	-0.421	-0.396	0.943	-2.624	3.557	0.151	0.393	0.060	-0.363	-2.555	0.065	0.060
11	-0.098	-0.031	-0.364	0.094	0.140	0.660	0.120	-0.014	1.599	0.014	-1.581	-0.364	-0.022	0.003
12	0.179	-0.121	-0.030	0.849	0.020	0.981	0.745	0.134	0.450	0.046	-0.175	-3.300	-0.016	0.006
13	0.504	0.005	0.143	0.900	-0.212	1.753	-2.578	0.147	0.196	-0.018	-0.158	-0.234	-0.220	-0.041
14	0.564	0.020	0.038	0.392	-0.398	-3.419	3.991	-0.820	-0.114	-0.039	0.047	0.232	-0.098	-0.092

Residual effect = 0.0025

b. Phenotypic

1	0.084	0.022	-0.049	0.014	0.018	-0.050	0.131	0.006	0.002	-0.003	0.015	-0.048	0.071	-0.039
2	0.022	0.084	-0.108	0.002	-0.008	-0.013	0.098	0.001	0.132	-0.006	-0.020	-0.177	0.020	0.000
3	0.012	0.026	-0.352	-0.004	0.004	-0.016	0.111	0.002	0.201	-0.006	-0.064	-0.003	-0.049	0.013
4	0.021	0.003	0.022	0.057	0.024	-0.091	0.210	0.007	0.076	0.003	-0.009	-0.162	0.085	-0.017
5	0.028	-0.012	-0.025	0.026	0.053	-0.060	0.161	0.007	-0.034	0.004	0.022	0.019	0.041	-0.030
6	0.014	0.004	-0.018	0.017	0.010	-0.303	0.777	0.014	-0.006	-0.001	0.017	0.045	-0.047	-0.043
7	0.013	0.010	-0.047	0.014	0.010	-0.280	0.839	0.015	0.025	-0.001	-0.003	-0.040	-0.063	-0.047
8	0.021	0.003	-0.030	0.018	0.016	-0.196	0.577	0.022	0.031	0.000	0.001	0.026	-0.016	-0.055
9	0.000	0.019	-0.125	0.008	-0.003	0.003	0.037	0.001	0.568	-0.001	-0.195	-0.113	0.020	0.008
10	0.007	0.016	-0.076	-0.006	-0.007	-0.010	0.025	0.000	0.027	-0.030	-0.011	-0.053	-0.024	0.010
11	-0.005	0.007	-0.096	0.002	-0.005	0.021	0.010	0.000	0.473	-0.001	-0.235	-0.047	0.025	0.005
12	0.008	0.029	-0.002	0.018	-0.002	0.027	0.067	-0.001	0.127	-0.003	-0.022	-0.506	0.018	0.008
13	0.023	0.006	0.066	0.019	0.008	0.054	-0.202	-0.001	0.044	0.003	-0.023	-0.035	0.262	-0.051
14	0.026	0.000	0.036	0.008	0.013	-0.104	0.310	0.009	-0.038	0.003	0.009	0.031	0.106	-0.126

Table 5a: Clustering of genotypes according to the D square analysis

Cluster	Number of genotypes	Name of the genotypes
I	11	Pol-4-4-5, BCSP-10, CO-3, NDSP-9, Pol-20-6-2, BCSP-5, IBM-95-229, RNSP-1, NDSP-10, IGSP-8, RNSP-2
II	9	IGSP-7, IGSP-6, BCSP-7, IGSP-9, IBM-95-220, IBM-95-206, BCSP-14, Tripty, S-1221
III	1	WBSP-4
IV	1	Kamala Sundari

Table 5 b: Average intra and inter cluster distance SQRT (D^2) values.

Cluster	1	2	3	4
I	24.435			
II	31.678	22.491		
III	38.798	27.539	0.000	
IV	39.034	47.575	37.907	0.000

distance value. Comparatively lower *D*-values are indicative of a greater genetic uniformity or *vice versa* (St. Pierre *et al*., 1990). Tarafdar and Chatterjee (2003) also reported the genetic relationships with consistence phenotypic characters in turmeric.

In the present grouping, cultivars belonging to the clusters II and III have a lower cluster distance value and, hence, are genetically more uniform. Whereas the single cultivar, Kamala Sundari of cluster IV is quite different from the other cultivars in group II. Kamala Sundari, is quite distinct from other cultivars in the colour of the stem, leaf, leaf veins, flower and it has hairy sepals with acuminate tip, stamen as long as style and having orange tuber skin and flesh colour. The cultivars of group II and III share many similar traits. Hossain *et al.* (2000) described the significant relationship among the root diameter, tuber weight per plant and yield in sweetpotato.

Sweetpotatos is an important source of many nutrients. It contains high amount of protein, minerals, vitamins, and amino acids, although it contains virtually no fat and are low in sodium (Hall, 2003). Sweetpotato tuber is rich in total carbohydrate but poor in protein content. Among the nutritional parameters analyzed, considerable variation was observed in dry matter, total carbohydrate, crude and soluble protein and vitamin-C. Less variation was observed in mineral composition. Red and orange varieties showed higher amount of carbohydrate than white tubers. A similar result was reported by Osumdahunsi *et al.* (2003). Crude protein in these cultivars ranged from 1.85 to 9.33 gm/ 100gm. Similar trends have been reported by Ravindran *et al*. (1995), Babu (1996) and recently by Osumdahunsi *et al*. (2003). Hartana *et al*. (1998) also reported that the orange-fleshed sweetpotato clones were the most potential breeding lines because of their higher carotene, dry matter, protein and carbohydrate content with high yield and resistance to scab diseases. In this study identification of such characters linked to the yield attributing factors, nutritional values and field response to sweetpotato viral diseases is valuable to the breeding programme for the genetic improvement of sweetpotato.

The moderate to high incidence of virus diseases was observed among the cultivars.

Table 5 c: Cluster means of sweet potato cultivars and contribution sixteen different morphological characters towards divergence.

Cluster	X_1 Vine length	X_2 Petiole length	X_3 Lamina length	X_4 Infloresc-ence length	X_5 Pedicel length	X_6 Flower length	X_7 Flower Diameter	X_8 Sepal length	X_9 Stamen length	X_{10} Anther length	X_{11} Carpel length	X_{12} LAI	X_{13} Tuber length	X_{14} Tuber breadth	X_{15} Weight of tuber/5 plants	X_{16} Tuber yield (ton/ ha)
I	77.179	11.079	8.689	8.9	0.9154	3.527	2.9381	0.9572	0.9772	0.3727	1.3809	1.2909	15.879	4.368	3.6518	17.444
II	81.48	11.744	9.174	9.615	0.86	3.28	3	0.874	1.461	0.35	1.918	1.6	19.456	5.228	3.902	21.546
III	80.5	13.9	9.83	16.33	1.33	4.15	3.5	1	1.7	0.4	2.15	1.7	18.23	4.67	2.6	38.33
IV	101.83	11.27	9	14.67	1.47	5	4.55	1.47	1.05	0.5	1.1	2.2	15.27	7.53	2.63	32.9
	0	0	0	0	0	10.82	0	0	6.93	0	20.35	24.68	1030	6.49	0	29.44

The viruses most commonly detected were sweetpotato C-6 virus, SPCaLV and SPCFV. The less common ones were SPFMV, SPMMV and SwPLV. Schaefers and Terry (1976), Stobbs *et al*. (1991), Marinho and Dusi (1995), Cohen *et al*. (1997), noticed a wide range of variation in symptoms produced by the different viruses in sweetpotato. The detection of viruses in our cultivars will direct priorities for future research. This is the first time sweetpotato viruses have been reported in West Bengal, India. Although the cultivars, WBSP-4, Pol-20-6-2, S-1221, BCSP-10, BCSP-10, IGSP-8, NDSP-10 and BCSP-7 showed wide range of virus-like symptoms, no viruses were detected in them. More studies are needed to ascertain whether they are caused by viruses, and if so, the identity of the viruses.

Implications

The morphological and biochemical analyses showed some congruent groupings among the Indian sweetpotato cultivars. Inclusion of different cultivars in different groups may be a meaningful indicative of their origin or divergence from a common stock. Analysis of physical and qualitative parameters supplemented the morphological based interpretation. Attention will be put on checking the spread of the prevalent viruses among the cultivars. These studies have provided an insight into the interrelationship among twenty-two cultivars of sweetpotato and its virus diseases, which could give a new arena in the sweetpotato improvement programme.

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Table 6: Qualitative assessments of some morphological and physical characteristics of twenty-two sweetpotato cultivars.

Cultivar	Habit	Stem colour	Stem surface	Leaf margin	Leaf texture	Leaf colour	Vein colour	Base of the leaf	Apex of the leaves	Petiole colour	Sepal surface	
Tripty	Annual –erect	Pinkish green	Hairy	Entire	Thin	Deep green	Light purple	Cordate	Acuminate	Greenish purple	Glabrous	
IBM-90-229	Annual -erect	Green	Hairy	Lobed	Thin	Bass green	Whitish green	Cordate	Acuminate	Light pinkish green	Glabrous	
WBSP-4	Annual -erect	Pinkish green	Hairy	Wavy	Thin	Purple green	Purple	Cordate	Acuminate	Deep green	Glabrous	
IBM-95-220	Annual -erect	Green	Hairy	Wavy	Thin	Bass green	Whitish green	Cordate	Acuminate	Purplish green	Glabrous	
Kamala Sundari	Annual -erect	Purple-green	Hairy	Entire	Thin	Deep Purple Green	Purplish green	Truncate	Acuminate	Purplish green	Hairy	
Pol-20-6-2	Annual -erect	Green	Hairy	Pinnatifid	Thin	Purple green	Light green	Truncate	Acuminate	Light green	Glabrous	
Pol-4-4-5	Annual -erect	Pinkish green	Hairy	Lobed	Thin	Purple green	Purplish green	Cordate	Acuminate	Bass green	Glabrous	
BCSP-14	Annual -erect	Green	Hairy	Entire	Thin	Bass green	Light green	Cordate	Acuminate	Purplish green	Glabrous	
S-1221	Annual -erect	Green	Glabrous	Entire	Thin	Deep green	Whitish green	Truncate	Acuminate	Light green	Glabrous	
BCSP-5	Annual -erect	Green	Glabrous	Lobed	Thin	Bass green	Whitish green	Cordate	Acuminate	Light green	Glabrous	
0IBM-95-206	Annual -erect	Green	Glabrous	Lobed	Thin	Deep green	Purplish green	Cordate	Acuminate	Purplish green	Glabrous	
BCSP-10	Annual -erect	Green	Glabrous	Palmate	Thin	Deep green	Purple	Cordate	Capsidate	Purplish green	Glabrous	
RNSP-1	Annual -herb	Green	Hairy	Palmate	Thin	Deep green	Whitish green	Cordate	Acuminate	Light green	Glabrous	
RNSP-2	Annual -erect	Green	Glabrous	Lobed	Leathery	Bass green	Whitish green	Cordate	Acuminate	Bass green	Glabrous	
IGSP-6	Annual -erect	Green	Glabrous	Palmate	Leathery	Bass green	Pinkish green	Cordate	Acuminate	Bass green	Glabrous	
IGSP-7	Annual -erect	Green	Glabrous	Pinnatifid	Thin	Bass green	Green	Truncate	Acuminate	Bass green	Glabrous	
IGSP-8	Annual -herb	Green	Hairy	Entire	Thin	Deep green	Purple	Truncate	Acuminate	Purplish green	Glabrous	
IGSP-9	Annual -erect	Green	Glabrous	Palmate	Thin	Bass green	Whitish green	Truncate	Acuminate	Bass green	Glabrous	
NDSP-9	Annual training	Green	Glabrous	Palmate	Thin	Light green	Purple	Cordate	Acuminate	Whitish green	Glabrous	
NDSP-10	Annual -erect	Pinkish green	Glabrous	Entire	Leathery	Purple green	Purple	Truncate	Acuminate	Purplish green	Glabrous	
BCSP-7	Annual -erect	Green	Glabrous	Entire	Thin	Bass green	Whitish green	Truncate	Acuminate	Bass green	Glabrous	
CO-3	Annual -erect	Green		Palmate	Thin	Purple green	Whitish green	Truncate	Acuminate	Light green	Glabrous	

	Sepal tip	Sepal shape	Petal colour	Corolla eye	Filament colour	Anther colour	No. of Carpel	Ovary chamber	Style as long as stamen /longer	Tuber shape	Tuberskin colour	Tuber flesh colour
Tripty	Ligulate	LL	PP	Present	Pink	PP	2	3	Longer	Spindle	Cream white	Cream white
IBM-95-229	Ligulate	OO	Purple	Present	White	White	2	3	Longer	Long thin	Deep red	Yellowish cream
WBSP-4	Ligulate	LL	PP	Present	Purple	PP	2	2	Longer	Elliptical	CreamWhite	Yellow-White
IBM-95-220	Ligulate	LL	PP	Present	Purple	Reddish	2	2	Longer	Long	Carlet red	Pinkish white
Kamala Sundari	Acuminate	LL	Purple	Present	Purple	PP	2	2	Long as stamen	Long-blunt	Orange	Bright orange
Pol-20-6-2	Ligulate	LL	PP	Present	White	White	2	2	Longer	Long	Pink red	White
Pol-4-4-5	Ligulate	OO	PP	Absent	Yellow	PP	2	2	Longer	Long	Cream white	Pinkish white
BCSP-14	Ligulate	LL	PP	Absent	White	PP	2	2	Longer	LC	Deep pink	Cream
S-1221	Ligulate	LL	PP	Present	Purple	PP	2	2	Longer	Slender long	Yellowish pink	Whitish yellow
BCSP-5	Ligulate	OO	PP	Present	Purple	White	2	3	Longer	Cylindrical	Deep red	White
IBM-95-206	Rounded	OO	PP	Present	White	White	2	3	Longer	LSP	Cream white	Cream white
BCSP-10	Ligulate	LL	PP	Present	White	White	2	2	Longer	LC	Pink red	Light yellow
RNSP-1	Ligulate	Broad ovate	PP	Present	Purple	White	2	2	Longer	Spindle	White	Orange yellow
RNSP-2	Ligulate	OO	PP	Present	White	White	2	2	Longer	Oval	Light pink	Cream yellow
IGSP-6	Ligulate	OO	White	Absent	White	White	2	2	Longer	LE	Carlet red	Cream yellow
IGSP-7	Ligulate	LL	White	Absent	Yellow	Yellow	2	2	Longer	LE	Pinkish red	Cream white
IGSP-8	Rounded	OO	PP	Absent	Purple	PP	2	3	Longer	LE	Oranges pink	Whitish yellow
IGSP-9	Ligulate	OO	PP	Present	Purple	White	2	2	Longer	LE	White	Cream
NDSP-9	Ligulate	OO	PP	Absent	White	White	2	2	Longer	LC	Cream	Cream white
NDSP-10	Ligulate	LL	PP	Present	Purple	White	3	2	Longer	LS	Pinkish red	Cream white

LL: Linear lanceolate; OO: Ovate oblong; PP: Pale purple; LE: long elliptical; LC: Long cylindrical; LS: Long slender; LSP: Long spindle.

Table 7: Dry matter percentage and proximate nutritional composition of sweetpotato tubers from twenty-two Indian cultivars.

Cultivar	Dry matter %	Total Carbo-hydrate gm/100	Protein (Crude) gm/100 gm (dwb)	Protein (soluble) mg/gm^{-1} (fwb)**	Vit.C gm/100 gm (dwb)	Femg/100 gm (dwb)	Mnmg/ 100 gm (dwb)	Cumg/ 100 gm (dwb)	Znmg/ 100 gm (dwb)
Tripty	20.13	27.75	6.13	15.77	10.88	12.0	0.65	0.25	1.60
IBM-90-229	18.23	30.60	7.46	18.48	15.99	10.5	0.50	0.75	1.50
WBSP-4	22.33	29.89	5.24	21.04	18.88	10.0	0.45	0.35	1.55
IBM-95-220	28.83	24.07	7.75	21.50	27.94	9.0	0.45	0.35	1.55
Kamala Sundari	18.50	38.4	7.79	19.71	20.39	9.0	0.70	0.40	1.45
Pol-20-6-2	24.72	37.20	7.25	11.93	25.87	14.0	0.85	0.60	1.35
Pol-4-4-5	24.53	34.28	7.13	07.15	26.18	13.5	0.95	0.75	1.50
BCSP-14	25.50	37.20	2.90	09.28	14.8	16.0	1.00	0.50	1.45
S-1221	15.62	33.03	4.92	25.90	14.3	13.0	0.85	0.45	1.45
BCSP-5	27.54	31.71	9.33	19.61	10.88	15.0	0.70	0.50	1.55
IBM-95-206	23.10	26.20	3.50	06.61	12.66	17.0	0.65	0.25	1.45
BCSP-10	23.47	33.72	1.85	09.69	16.18	15.0	0.90	0.25	1.50
RNSP-1	20.49	33.30	4.36	09.88	31.18	13.5	1.01	0.75	1.35
RNSP-2	22.27	26.69	3.24	18.70	16.94	13.0	1.10	0.25	1.45
IGSP-6	19.97	23.46	4.25	21.65	27.84	13.5	0.70	2.05	1.50
IGSP-7	20.71	24.59	4.55	19.84	12.55	14.5	0.65	0.30	1.60
IGSP-8	20.13	23.88	3.94	21.30	16.47	15.0	0.60	0.30	1.45
IGSP-9	24.62	28.10	3.50	18.87	18.43	16.0	0.90	0.35	1.50
NDSP-9	23.26	35.07	4.63	27.63	35.39	17.5	0.85	1.35	1.55
NDSP-10	22.53	26.63	5.23	18.49	14.84	17.0	1.01	0.75	1.50
BCSP-7	24.65	28.88	6.51	17.05	29.89	15.0	0.80	0.30	1.50
CO-3	24.61	24.73	3.57	16.36	12.8	15.0	0.85	0.35	1.60
SEM±	0.84	0.80	0.33	0.57	4.13	0.37	0.07	0.03	0.03
C.D. p=0.05%	2.41	1.63	0.94	1.64	8.36	1.08	0.21	0.09	0.10

*dwb : Dry weight basis, **fwb: Fresh weight basis.

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