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Multivariate analysis of yield associated traits in *Safed musli* (*Chlorophytum borivilianum*) genotypes under semi-arid conditions

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ABSTRACT

The study on the genetic variability, association between traits and direct and indirect effects of different traits on root yield of *safed musli* is required for the development of high yielding varieties. Hence, the interrelationship of 17 quantitative traits (leaf width, leaf length, No. of leaves/ plant, leaf area, No. of capsules/inflorescence, No. of seeds, No. of inflorescences/ tuber, length of inflorescences, size of seeds, No. of flowers/ inflorescence, floral width, No. of tubers, tuber length, tuber girth, fresh weight of tubers) in 52 *safed musli* genotypes of were evaluated at ICAR-DMAPR during 2015 and 2016. Standard deviation and analysis of variance revealed high genetic variation among studied genotypes for all traits in which coefficient of variation ranged from 205.52 (leaf area) to 19.57 (floral width). Based on mean performance DCB-48 (129 g), DCB-17 (110.2 g), DCB-18 (108 g), DCB-5 (107.6 g), DCB- 37 (105 g) were the top five genotypes for fresh tuber yield per plant. Pearson correlation coefficient showed the positive and significant relation of number of tubers per plant (0.83), and tuber length (0.77) with yield (tuber FW). According to path analysis, number of tubers (0.84) possessed the highest positive direct effect followed by leaf width (0.14) and size of seeds (0.11 mm) on dependent variable yield (tuber fresh weight) of *safed musli*. The result of stepwise regression analysis revealed that tuber length and tuber girth has considerable effects on tuber yield.

Key words: Genetic variability, path analysis, *Safed musli*, root yield, trait association.

INTRODUCTION

Chlorophytum borivilianum popular as *Safed musli* is known for aphrodisiac potential with no side effects and prescribe for enhancing male potency and overcoming signs of fatigue (Joshi *et al*., 10). The species originated from the southern part of India belongs to family Liliaceae and reported to be a cross-pollinated with tetraploid chromosome number 2n = 4x = 28 (Geetha and Maiti, 7). Among the 215 species, *C. borivilianum* yields highest steroidal saponins, known as borivilianosides as the main bioactive compounds present in its root (Bordia *et al*., 4). *Safed musli* is distributed in the forest area of tropical and sub-tropical region with altitude of 1500 m and cultivated mainly in Southern Rajasthan, Western Madhya Pradesh, North Gujarat and few parts of Karnataka. At present, the estimated global market demand and production is approximately 35,000 t/annum and 5000 t/annum respectively which fulfill less than 15% of the required demand (Kothari and Singh, 11). Its high economic value and unsustainable collection from the natural habitat has resumed the attention to develop high root yielding varieties with desirable quantity and quality of saponin. Determination of correlation coefficients is an important statistical procedure to evaluate breeding programs for high yield as well as to examine direct and indirect variables contributions to yield (Sadat *et al*., 13).

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MATERIALS AND METHODS

A total of 52 germplasm accessions (Table 1) of *Safed musli* (Fig. 1) were evaluated in randomized block design with three replication at the experimental farm of ICAR-Directorate of Medicinal and Aromatic Plant Research, Anand, Gujarat for two years 2015 and 2016. The experimental field was located at 19°35 north, longitude 40°51 east altitude 1,000 m above the sea level, soil with sandy loam texture and an average annual precipitation greater than 174 mm. Fasciculated roots of *Safed musli* were planted in last week of June, 2015-16 on ridges of 15-20 cm height in single row plot of 4 m length, keeping row to row and plant to plant spacing of 45 and 30 cm, respectively. Crop management undertaken to maintain a healthy crop.

Data were collected on 17 traits (quantitative and qualitative) in all replications on 10 randomly selected normal plants per plot. The two year data (2015 & 2016) were combined and simple phenotypic correlation coefficient among all observed components. Correlation coefficients between traits were computed based on Pearson`s method and later separated into direct and indirect effects *via* path

Table 1. Studied *Safed musli* genotypes and their place of collection.

Sl. No.	Genotype	Place of collection	Sl. No.	Genotype	Place of collection
1.	DCB 1	Anand, Gujarat	27.	DCB 27	Rajasthan
2.	DCB 2	Anand, Gujarat	28.	DCB 28	Rajasthan
3.	DCB 3	Valsad, Gujarat	29.	DCB 29	Rajasthan
4.	DCB 4	Vasidanta Gujarat	30.	DCB 30	Rajasthan
5.	DCB 5	Akola, Maharashtra	31.	DCB 31	Rajasthan
6.	DCB 6	Rajasthan	32.	DCB 32	Akola, Maharashtra
7.	DCB 7	Anand, Gujarat	33.	DCB 33	Akola, Maharashtra
8.	DCB 8	Dang, Gujarat	34.	DCB 34	Akola, Maharashtra
9.	DCB 9	Dang, Gujarat	35.	DCB 35	Akola, Maharashtra
10.	DCB 10	Jabalpur, MP	36.	DCB 36	Akola, Maharashtra
11.	DCB 11	Jabalpur, MP	37.	DCB 37	Akola, Maharashtra
12	DCB 12	Mandsaur, MP	38.	DCB 38	Akola, Maharashtra
13.	DCB 13	Mandsaur, MP	39.	DCB 39	Akola, Maharashtra
14.	DCB 14	Mandsaur, MP	40.	DCB 40	Akola, Maharashtra
15.	DCB 15	Anand, Gujarat	41.	DCB 41	Akola, Maharashtra
16.	DCB 16	Anand, Gujarat	42.	DCB 42	Akola, Maharashtra
17.	DCB 17	Anand, Gujarat	43.	DCB 43	Akola, Maharashtra
18.	DCB 18	Dang, Gujarat	44.	DCB 44	Akola, Maharashtra
19.	DCB 19	Dang, Gujarat	45.	DCB 45	Akola, Maharashtra
20.	DCB 20	Mandsaur, MP	46.	DCB 46	Akola, Maharashtra
21.	DCB 21	Mandsaur, MP	47.	DCB 47	Anand, Gujarat
22.	DCB 22	Mandsaur, MP	48.	DCB 48	Anand, Gujarat
23.	DCB 23	Mandsaur, MP	49.	DCB 49	Anand, Gujarat
24.	DCB 24	Mandsaur, MP	50.	DCB 50	Mandsaur, MP
25.	DCB 25	Mandsaur, MP	51.	DCB 51	Mandsaur, MP
26.	DCB 26	Mandsaur, MP	52.	DCB 52	Mandsaur, MP

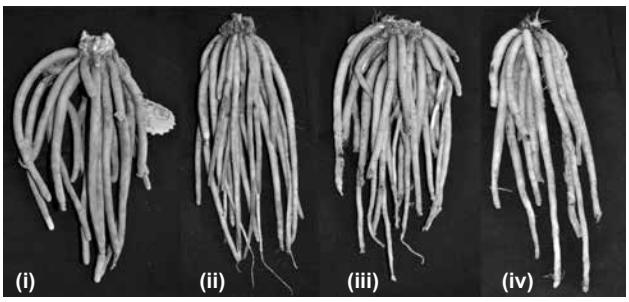

Fig. 1. Variation in root length, number of fingers and girth in studied genotypes. (i) DCB-48; (ii) DCB-35; (iii) DCB-7; and (iv) DCB-26.

coefficient analysis based on the procedure of Ahmed *et al*. (1) for determination of the direct and indirect effects of the traits on yield of tubers. Stepwise multiple regression analysis was carried out using SAS version 9.3 statistical programme by assessing the cumulative effect of yield components on tubers yield, taking number of tubers per plant as the dependent variable and other traits as independent variables. Biplot graphical display was performed based on principal component analysis in order to identify best performing germplasm and a cluster was used for classification of variable genotypes.

RESULTS AND DISCUSSION

The variability prevalent among the germplasm lines of *C. borivilianum* has been well described by several authors (Jat, 8; Bordia *et al.*, 4; Jat and Sharma, 9; Kothari and Singh, 11; Geetha and Maiti, 6; Bhagat and Jadeja, 2). In Tables 2-4, correlation analysis showed that the root yield per plant have positive and highly significant correlation with leaf width (0.17), leaf length (0.36), number of fingers

Table 2. Analysis of descriptive statistics of evaluated traits in 52 genotypes of *Safed musli.*

Trait	Range	Mean ± SE (m)	SD	CV	Student`s test
Leaf width (cm)	0.08 - 1.84	1.11 ± 0.04	0.33	29.76	24.22
Leaf length (cm)	2.12 - 21.62	13.38 ± 0.56	4.04	30.25	23.83
No. of leaves/ plant	1.40 - 8.20	5.66 ± 0.22	1.62	28.72	25.10
Leaf area (m^2)	37.49 - 2284.38	147.44 ± 42.02	303.03	205.52	3.50
No. of capsules/ inflorescence	0.0 - 21.00	7.65 ± 0.69	5.01	65.54	11.00
No. of seed/ capsules	0.0 - 11.00	3.71 ± 0.38	2.79	75.13	9.59
No. of inflorescence/ tuber	0.40 - 4.40	1.95 ± 0.14	1.04	53.34	13.51
Inflorescence length (cm)	2.14 - 37.04	23.46 ± 1.20	8.68	37.01	19.48
Size of capsule (mm)	0.0 - 6.47	3.25 ± 0.27	1.97	60.69	11.88
Length of flower spikes (cm)	1.08 - 18.00	9.18 ± 0.50	3.61	39.30	18.34
Size of seeds (mm)	0.0 - 2.76	1.38 ± 0.11	0.79	57.29	12.58
No. of flowers/ inflorescence	3.20 - 29.80	14.83 ± 0.69	5.01	33.76	21.35
Floral width (cm)	0.64 - 3.28	2.54 ± 0.06	0.49	19.57	36.84
No. of tubers	6.20 - 69.40	26.7 ± 1.98	14.29	53.52	13.47
Tuber length (cm)	3.48 - 18.71	12.88 ± 0.46	3.32	25.83	27.90
Tuber girth (mm)	1.26 - 7.27	5.65 ± 0.16	1.16	20.60	34.99
Tuber fresh weight (g)	9.60 - 110.20	51.91 ± 3.83	27.67	53.31	13.52

SD = Standard deviation; CV = Coefficient of variation

per root (0.83) and root girth (0.77). Kumar *et al*. (12) also reported that increase of leaf length, and width is a sign of positive correlation with root yield as the spreading of canopy provide large photosynthetic efficiency to plant. Plant population had positive and significant correlation with fresh root yield (Chandra *et al*., 5). The negative correlation of number of capsules per plant (e) and number of seeds per capsules (f) (r = -0.04, -0.03, respectively) showed that these two variables (e) and (f) associated with a decrease in fresh root yield (q). A negative correlation demonstrates a connection between two variables in the same way a positive correlation coefficient does, and the relative strengths are the same. The reason for low negative value of these variables probably due to the nature of cross-pollination with vegetative propagation of crop as well as poor seed germination showed no meaningful relationship between variables and yield, may lead to some undesirable selection based on these characters. To improve the yield components that have negative association with one another, suitable recombinants may be obtained through biparental mating, mutation breeding or diallel selective mating by breaking undesirable linkages.

Path and regression analysis with standardized variables determined relationships among the traits and the relative importance of their direct and indirect effects on yield, and the correlation coefficients to be segregated to the direct and indirect effects (Bhatt, 3). The highest positive direct effects on grain yield per plant were exhibited by number of fingers per plant (0.84) followed by length of inflorescence (0.18) and leaf width (0.14), while leaf length, number of capsules per inflorescence, size of capsules, length of flower spike, floral width, had negative but non-significant direct effects on fresh weight of roots (yield) with a value of -0.19, -0.04, -0.08, -0.15 and -0.11, respectively (Table 5). Highest positive indirect effects on yield were observed for root length (0.45) and root girth (0.33) and these traits caused increasing of root yield indirectly. High values of indirect effects *via* tuber length and tuber girth suggested that indirect selection for root girth may also increase the yield of roots (Table 3). Biplot display based on the plot of Principle component 2 on Principle component 1

Table 3. Result of stepwise regression analysis of studied traits for *Safed musli* yield.

Variable	CV	R-square	Adj R-square	MSE	F value
o	20.505	0.7856	0.6847	6.973	7.79
p	24.713	0.9790	0.9692	2.9791	99.24
q	26.237	0.894	0.848	150.07	19.68

Table 4. Pearson correlation coefficients between fresh root weight and other related traits in *safed musli.*

Trait	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q
a	1.00																
b	0.52*	1.00															
c	-0.14	-0.12	1.00														
d	0.04	0.01	-0.01	1.00													
e	0.33	0.29	-0.04	0.20	1.00												
f	0.32	0.27	-0.03	0.08	0.61*	1.00											
g	0.40	0.20	-0.04	-0.06	0.27	0.56*	1.00										
h	0.52*	0.41	-0.07	0.10	0.58*	0.64*	0.63*	1.00									
i	0.40	0.33	-0.03	0.14	0.67*	0.87*	0.67*	0.67*	1.00								
j	0.44	0.33	-0.08	0.15	0.63*	0.50	0.55*	0.83*	0.63*	1.00							
k	0.35	0.35	-0.04	0.10	0.67*	0.79*	0.63*	0.64*	0.96*	0.63*	1.00						
l	0.30	0.08	-0.12	0.03	0.20	0.2	0.38	0.51*	0.23	0.55*	0.30	1.00					
m	-0.22	-0.26	0.96*	-0.01	-0.02	-0.02	-0.04	-0.05	-0.02	-0.04	-0.02	-0.05	1.00				
n	0.01	0.23	-0.10	-0.14	-0.09	-0.01	0.01	-0.09	-0.01	-0.03	0.03	-0.14	-0.14	1.00			
o	0.37	0.54*	-0.09	0.07	0.19	0.33	0.37	0.35	0.38	0.37	0.38	0.19	-0.15	0.56*	1.00		
p	-0.24	-0.24	0.97*	-0.02	-0.08	-0.05	-0.09	-0.15	-0.07	-0.14	-0.07	-0.15	0.97*	-0.07	-0.10	1.00	
q	0.17	0.36	-0.15	-0.08	0.10	0.25	0.30	0.22	0.32	0.21	0.35	0.04	-0.18	0.83*	0.77*	-0.14	1.00

*Significant at P< 0.01. (a) Leaf width (cm), (b) Leaf length (cm), (c) No. of leaves/plant, (d) Leaf area (cm²), (e) No. of capsules/ inflorescence, (f) No. of seeds/capsule, (g) No. of inflorescences/plant, (h) Length of inflorescence (cm), (i) Size of capsule (mm), (j) Length of flower spike (cm), (k)Size of seed (mm), (l) No. of flowers/inflorescence, (m) Floral width (cm), (n) No. of tubers, (o)Tuber length (cm), (p) Tuber girth (cm) and (q) Fresh weight of tubers (gm).

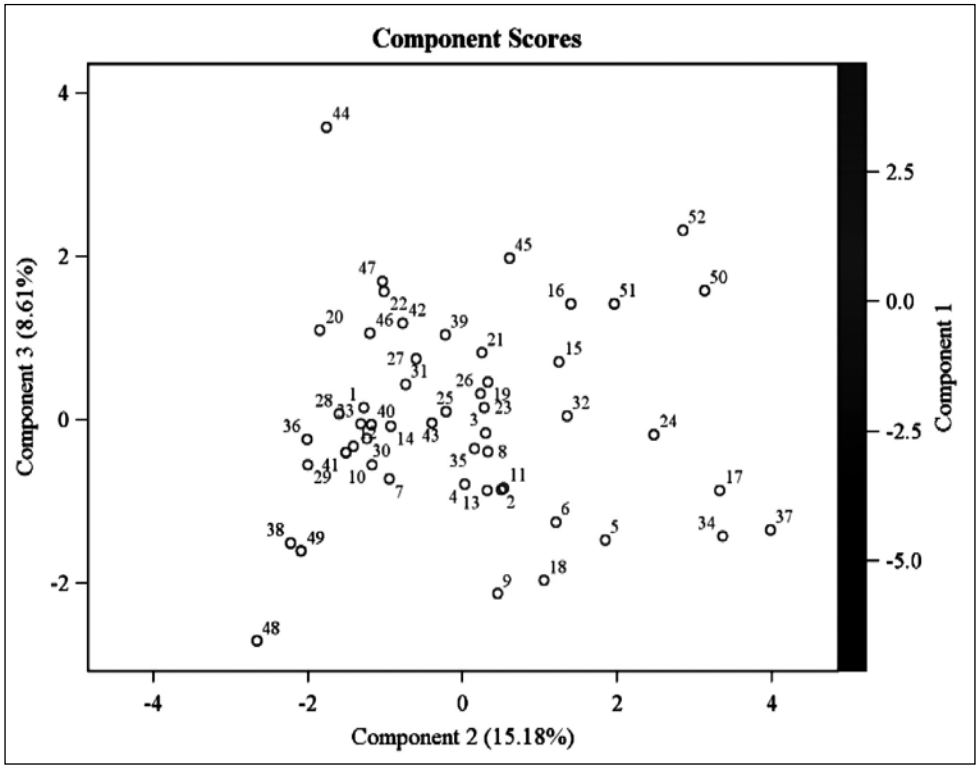

Fig. 2. Biplot display of 52 *Safed musli* genotypes based on principal component analysis.

Table 5. Direct and indirect effects of morphological traits and yield components on tubers yields using path analysis.

Trait	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	Genotypic corr. with q
a	0.14*	-0.14	0.01	-0.27	-0.02	0.01	0.04	0.11	-0.05	-0.08	0.06	0.01	-0.06	0.19	0.04	0.04	0.35
b	0.10	-0.19	0.01	-0.19	-0.01	0.08	0.02	0.08	-0.02	-0.05	0.03	0.05	-0.04	0.29	0.02	0.03	0.3
c	0.09	-0.14	0.01	-0.14	-0.01	0.01	0.04	0.09	-0.03	-0.07	0.05	0.02	-0.04	0.19	0.03	0.03	0.32
d	0.01	0.02	-0.21	0.02	-0.07	-0.016	-0.08	0.02	-0.44	-0.08	-0.05	-0.01	-0.01	-0.12	0.02	0.01	-0.09
e	0.06	-0.04	-0.92	-0.03	-0.04	0.02	0.02	0.13	-0.06	-0.11	0.08	0.03	-0.06	-0.05	0.01	0.02	0.08
f	0.06	-0.05	-0.12	-0.12	-0.03	0.03	0.03	0.13	-0.07	-0.1	0.1	0.02	-0.05	0.12	0.02	0.02	0.3
g	0.07	-0.04	-0.2	-0.23	-0.01	0.01	0.08	0.12	-0.05	-0.08	0.07	0.03	-0.04	0.18	0.03	0.02	0.46
h	0.08	-0.08	-0.18	-0.27	-0.03	0.02	0.05	0.18	-0.06	-0.13	0.09	0.04	-0.08	0.1	0.03	0.03	0.32
i	0.08	-0.06	-0.17	-0.01	-0.03	0.02	0.05	0.14	-0.08	-0.11	0.11	0.03	-0.06	0.15	0.03	0.03	0.4
j	0.07	-0.07	-0.16	0.02	-0.03	0.02	0.04	0.16	-0.06	-0.15	0.08	0.04	-0.08	0.06	0.02	0.03	0.22
k	0.08	-0.06	-0.16	-0.01	-0.03	0.02	0.05	0.14	-0.08	-0.11	0.11	0.03	-0.06	0.13	0.03	0.03	0.38
l	0.02	-0.01	-0.78	-0.52	-0.02	0.01	0.04	0.1	-0.03	-0.08	0.05	0.08	-0.05	-0.03	0.01	0.01	0.12
m	0.07	-0.07	-0.14	0.04	-0.02	0.01	0.03	0.13	-0.04	-0.1	0.06	0.03	-0.11	0.12	0.02	0.04	0.24
n	0.03	-0.06	-0.86	-0.03	0.03	0.04	0.02	0.02	-0.01	-0.01	0.01	-0.03	-0.02	0.84*	0.036	0.02	0.92
o	0.08	-0.08	-0.2	-0.09	-0.01	0.02	0.04	0.08	-0.03	-0.04	0.05	0.09	-0.04	0.45	0.07	0.04	0.67
p	0.08	-0.1	-0.21	-0.04	-0.01	0.01	0.03	0.1	-0.03	-0.07	0.05	0.02	-0.07	0.33	0.04	0.06	0.5

*Significant at P<0.01. (a) Leaf width (cm), (b) Leaf length (cm), (c) No. of leaves/ plant, (d) Leaf area (cm²), (e) No. of capsules/ inflorescence, (f) No. of seeds/ capsule, (g) No. of inflorescences/ plant, (h) Length of inflorescence (cm), (i) Size of capsule (mm), (j) Length of flower spike (cm), (k) Size of seed (mm), (l) No. of flowers/ inflorescence, (m) Floral width (cm), (n) No. of tubers, (o) Tuber length (cm), (p) Tuber girth (cm) and (q) Fresh weight of tubers (g).

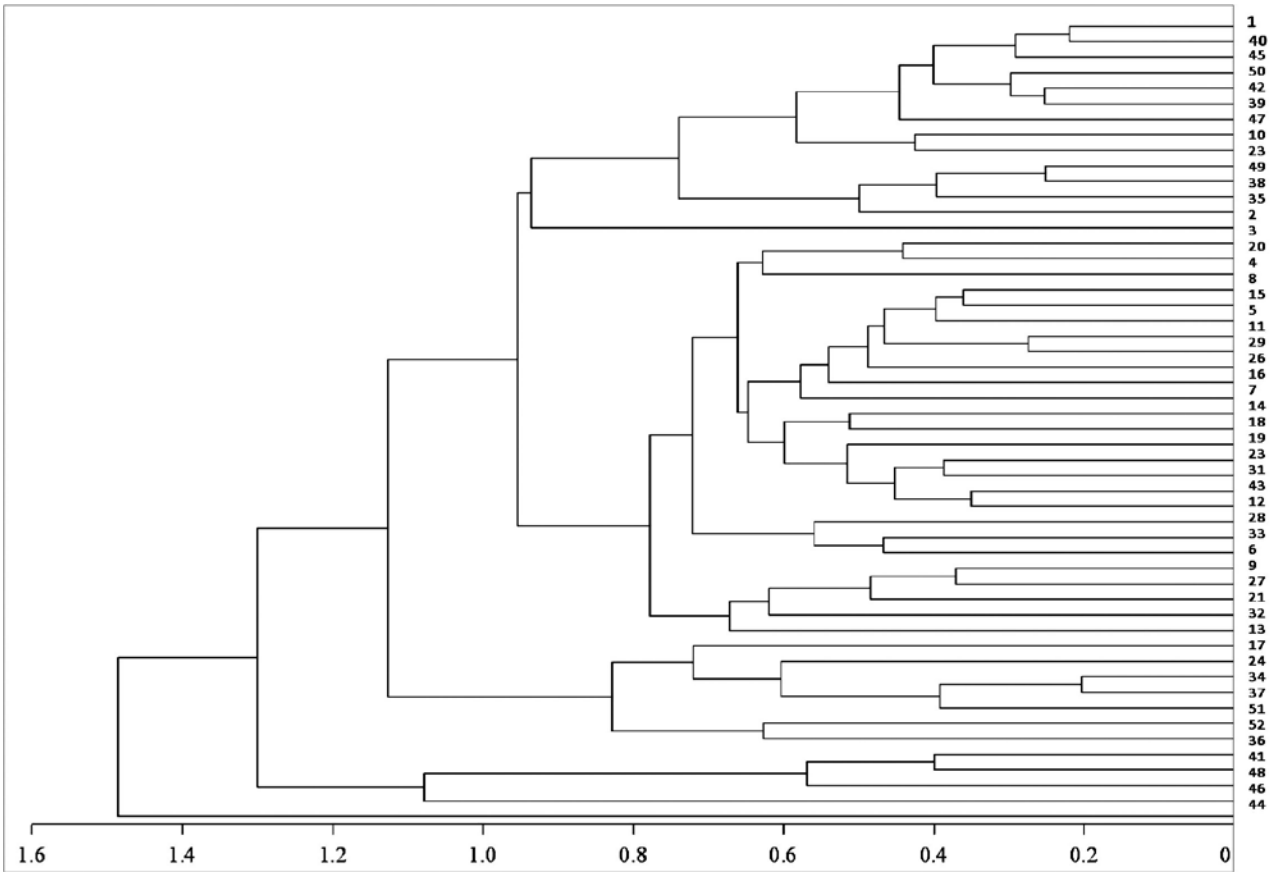

Fig. 3. Phenotypic-based cluster analysis to classify variables based on Ward`s method.

classified the genotypes in four groups (Fig. 2 & 3) that one of them comprises genotypes having the more number of roots and girth ability for fresh root yield production (DCB- 44, 45, 52, 50, 51, 47, 42, 26, 24, 32, 39, and 42). These genotypes were selected as the suitable population for breeding programmes and improvement of important traits.

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