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Research Article

Genetic variability, association and path analysis for yield and fruit quality components in yellow- berried nightshade (*Solanum surattense*)

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Abstract
A study was conducted to investigate the selection criteria in 54 *kantakari* accessions based on 14 morphological and qualitative traits employing correlation, path analysis, principal component analysis and cluster analysis. The traits *viz*., plant spread (N-S), plant spread (E-W), number of branches per plant, number of flower clusters per plant, number of berries, fresh berry yield per plant, dry berry yield per plant, dry berry yield per hectare, total proteins, total phenols, total flavonoid content, total antioxidant activity, FRAP activity and solasodine were recorded. For seven quantitative attributes, simple descriptive statistics revealed a normal distribution. Plant spread (N-S) (1.309), fresh berry production per plant (0.751), dry berry yield per plant (0.808), dry berry yield per hectare (0.816) and total flavonoid content (1.215) were all significant and showed positive skewnesses. Plant spread, branches per plant, flower clusters per plant, number of berries per plant, fresh berry yield per plant, total flavonoid content and total proteins all exhibited highly positive significant correlations with dry berry yield per plant. The quantity of berries per plant, total protein content, total flavonoid content and fresh berry yield per plant all showed a significant direct effect on yield. Quantity of berries per plant and fresh berry yield revealed as the primary incidental variables for positive or negative correlation of a number of features with dry berry yield per plant. Principal component analysis revealed that the first five components with Eigen values greater than one accounted for a maximum of 74.32 percent of the variability. Number of berries per plant (0.901), fresh berry yield per plant (0.938), dry berry yield per plant (0.962), and dry berry yield per hectare were the attributes contributing to the most variance in PC1, which was responsible for 26.97% of the overall variation (0.964). The accessions were divided into two main clusters using the Wards method of hierarchical cluster analysis. Cluster II contributed more significantly to berry quality and solasodine content than Cluster I, which comprised of high yielding accessions. To effectively exploit promising genotypes in future breeding programmes, it would be advantageous to categorise kantakari accessions based on numerous yield and quality parameters.

Keywords: Variability, correlation, path, *Solanum surattense*

INTRODUCTION

The genus *Solanum surattense* Burm. f. is known as yellow -berried nightshade which is a significant therapeutic perennial herb in the Solanaceae family. Important alkaloids including Solasodine, Solasonine, Solamargine, and Diosgenin are abundant in this prickly shrub. The plant extract possesses solasodine which has anti-spermatogenic properties and this plant contains solamargine, which has anticancer effects. Diosgenin from *Solanum surattense* Burm. f. is reported to be efficient for reducing fatty acid synthase (FAS) expression in HER 2 breast cancer cells (Singh and Singh, 2010). The fruits of this plant also include traces of the glucoalkaloids solanocarpine, carpesterol, solanocarpidine, isochlorogenic, neochronogenic, chronogenic and caffeic acids. From ancient times, this herb has been utilised in India to treat a variety of illnesses. Powder of the herb is excellent for treating asthma, shortness of breath and allergies of the respiratory system. Moreover, it has astringent, digestive and carminative uses. The herb is very helpful in treating cardiac disorders linked to edoema because it stimulates the heart and purifies blood. Males can use the fruit as an aphrodisiac and females can use the seeds to treat dysmenorrhea and irregular menstruation. It also encourages female fertility (Revathi and Parimelazhagan, 2010). This plant's roots are commonly used for bronchial disorders, catarrhal and febrile affliction, cough, chest discomfort, flatulence, sore throat, and toothaches. This plant's leaves are also used to treat rheumatic discomfort. (Narayanan *et al.,* 2011).

Due to its numerous therapeutic benefits, *S. surratense* is considered an important plant in both ayurveda and contemporary drug research fields. It is non-toxic and safe for human consumption. The taxonomic description of the genus Solanum, the most widespread and diversified genus in the Solanaceae family, based mostly on morphometrical characteristics, left many questions unanswered. For any programme aimed at improving plants, the existence of genetic variation among species is crucial. To understand genetic variation, it is crucial to analyse genotypes generated from various geographic regions. Thus, growth and yield studies would provide novel insights into population variability and aid in understanding the physiology and agronomy of the crop. Information on the relationship and effect of component characteristics on yield and quality is revealed by the correlation and path analysis. A more effective breeding strategy may be achieved with understanding of the characteristics that affect yield and quality. Thus, a study was conducted to determine the level of variability present in the *kantakari* accessions and to examine the relationship between fruit quality characteristics for pharmaceutical use and yield components.

MATERIALS AND METHODS

A total of 54 *S. surattense* accessions collected from different regions of India were planted with a spacing of 60 x 60 cm. The 54 accessions were evaluated for variation in growth, yield and quality (**Table 1**). The experiment was laid at Department of Medicinal and Aromatic Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University (TNAU), Coimbatore during 2021-22, in randomized block design with three replications of plot size was 100 m^2 (15 ridges), accommodating 10 plants per ridge. Morphological observations were recorded in five randomly-chosen plants in each accession. The berries were harvested at colour- breaking stage and about 20 berries were dried and powdered which was used to determine quality parameters. The powdered samples were extracted using Microwave-assisted extraction with parameters of methanol: 70%, microwave power: 160 W, and time: 100 s (Gu *et al.*, 2019). The technique used by Khandani *et al*. (2019) was used to extract and analyse the alkaloid solasodine in HPLC (LC-20A) of Shimadzu make. The solvent system was a 30% HPLC gradient of water (20 mM phosphate buffered pH 3.5) (A) and 70 % methanol (B) for 15 min followed by washing for 30 min; injection sample volume was 10μl. Biochemical analysis *viz.* total phenolic content, total flavonoid content, total proteins, anti-oxidant activity by DPPH (2,2-diphenylpicrylhydrazyl) and FRAP (ferric reducing ability of plasma) assay were carried out by following modified procedure of Rakesh *et al.* (2021). The breeding tool INDOSTAT was used to calculate the correlation and path analysis estimations. The statistical software SPSS 16.0 was used to perform PCA and basic descriptive statistics. Wards method of hierarchical clustering (Ward, 1963) was used to perform the cluster analysis using STAR statistical software.

RESULTS AND DISCUSSION

Basic descriptive statistics for 14 yield attributing and qualitative traits of *kantakari* accessions are presented in **Table 2**. Fresh berry yield per plant had the highest level of variation (18.93%), followed by plant spread (E-W) (CV= 12.12%), dry berry yield per plant (10.29), and dry berry yield per hectare (10.36). With a CV of 0.3%, solasodine has seen the least variation. Of the 14 studied traits, eight were significantly and positively skewed, including plant spread (N-S) (1.309), fresh berry yield per plant (0.751), dry berry yield per plant (0.808), dry berry yield per hectare (0.816), total flavonoid content (1.215), total protein content (1.216), and solasodine (1.241). Excess kurtosis was assessed for the fourteen attributes and seven traits *viz*, plant spread (N-S) (4.206), plant spread (E-W) (1.055), total phenol content (1.280), total flavonoid content (4.907), total protein (4.915), DPPH activity (1.498) and solasodine showed a significant leptokurtic distribution (1.093).

The correlation coefficient is a vital biometrical tool for formulating selection index since it illustrates the degree to which the characteristics in a group are related to one another. In the current study, there was a highly significant positive correlation between fresh berry yield per plant, number of berries, total flavonoid content, total protein, number of flower clusters, and plant spread (N-S) (**Table 3**). According to correlation studies on brinjal, fruit yield ha-1 was positively correlated with fruit weight and fruit weight per plant, but negatively with total phenols

Table 1. List of Kantakari accessions evaluated in this study

S. No.	Accession No.	Place of collection	Longitude (ºE)	Latitude (ºN)	Altitude (m MSL)
1.	*Ss* - 1	Govinthapuram, Thanjavur, Tamil Nadu	79.47	10.97	24
2.	*Ss* - 2	Parivallikottai, Ottapidaram,Tamil Nadu	77.97	8.62	47
3.	*Ss* - 3	Kollankinaru, Ottapidaram,Tamil Nadu	78.02	8.90	127
4.	*Ss* - 4	Ottapidaram, Tuticorin, Tamil Nadu	78.02	8.91	38
5.	*Ss* - 5	Onamakulam,Ottapidaram, Tamil Nadu	80.29	13.09	127
6.	*Ss* - 6	Sillangulam, Ottapidaram, Tamil Nadu	78.02	8.90	38
7.	*Ss* - 7	Kilakottai, Ottapidaram, Tamil Nadu	80.29	13.09	83
8.	*Ss* - 9	Maruthanvalvoo, Ottapidaram, Tamil Nadu	80.29	13.09	38
9.	*Ss*- 10	Kothali, Belgum, Karnataka	74.44	16.74	655
10.	*Ss* - 11	Seelaipilayarpudur, Trichy, Tamil Nadu	80.16	13.13	88
11.	*Ss* - 12	Nagayanallur, Trichy, Tamil Nadu	78.23	11.01	88
12.	*Ss* - 13	Karur, Tamil Nadu	78.07	10.96	101
13.	*Ss* - 14	Kattuputhur, Trichy, Tamil Nadu	78.21	10.99	102
14.	*Ss* - 15	Jabalpur, Madhya Pradesh	79.98	23.18	412
15.	*Ss* - 17	Mayanur, Trichy, Tamil Nadu	78.08	10.91	88
16.	*Ss* - 18	Unniyur, Trichy, Tamil Nadu	79.43	1202	88
17.	*Ss* - 19	Aalampalayampudur, Trichy,Tamil Nadu	80.16	13.13	88
18.	*Ss* - 20	Chinnapallipalayam, Trichy, Tamil Nadu	78.19	10.97	88
19.	*Ss* - 21	Sullipalayam, Trichy, Tamil Nadu	77.92	11.26	105
20.	*Ss* - 22	Kalamboli, Maharashtra	73.10	19.03	580
21.	*Ss* - 23	Manmad, Maharashtra	74.43	20.26	580
22.	*Ss* - 24	Yeola, Maharashtra	74.48	20.04	580
23.	*Ss* - 25	Andakudi, Sivagangai, Tamil Nadu	79.67	10.94	9
24.	*Ss* - 26	Sithakur, Pudukottai, Tamil Nadu	78.99	10.00	78
25.	*Ss* - 27	Keerani, Sivagangai, Tamil Nadu	54.49	7.62	75
26.	*Ss* - 31	Thalamalaipatti, Trichy, Tamil Nadu	78.69	10.77	85
27.	*Ss* - 32	Kadaladi, Ramnad, Tamil Nadu	78.29	9.13	10
28.	*Ss* - 33	Madesampalayam,Namakkal, Tamil Nadu	78.19	11.77	75
29.	*Ss* - 34	Mohanur, Namakkal, Tamil Nadu	78.14	11.05	178
30.	*Ss* - 35	Puliyur, Karur, Tamil Nadu	78.14	10.93	101
31.	*Ss* - 36	Sankari, Salem, Tamil Nadu	77.86	11.47	221
32.	*Ss* - 38	Manaparai, Trichy, Tamil Nadu	78.41	10.62	88
33.	*Ss* - 39	Tiruparankundram, Madurai,Tamil Nadu	78.07	9.88	320
34.	*Ss* - 41	Kagmala, Rajasthan	73.43	27.39	136
35.	*Ss* - 42	Roadside, Rajasthan	73.25	28.59	125
36.	*Ss* - 43	Bhatwas – 1, Rajasthan	75.12	27.61	130
37.	*Ss* - 44	Bhatwas – 2, Rajasthan	75.12	27.61	130
38.	*Ss* - 45	CSWRI, Avikanagar, Rajasthan	75.75	26.21	320
39.	*Ss* - 48	Ottanchathiram, Tamil Nadu	77.75	10.49	302
40.	*Ss* - 49	Adikanpatti, Perambalur, Tamil Nadu	78.87	11.23	70
41.	*Ss* - 50	Ottampatti - 1, Trichy, Tamil Nadu	78.19	11.19	66
42.	*Ss* - 51	Ottampatti - 2, Trichy, Tamil Nadu	78.19	11.19	66
43.	*Ss* - 52	FC & RI, Mettupalayam, Tamil Nadu	77.56	11.19	300
44.	*Ss* - 53	Pudukottai, Tamil Nadu	78.80	10.38	88
45.	*Ss* - 54	Erode, Tamil Nadu	77.71	10.34	183
46.	*Ss* - 55	Arkad, Tamil Nadu	79.81	11.92	3
47.	*Ss* - 56	Kollidamriver, Ariyalur, Tamil Nadu	78.84	11.18	76
48.	*Ss* - 57	Chinnamanur, Theni, Tamil Nadu	77.38	9.84	280
49.	*Ss* - 58	Aniyapuram, Namakkal, Tamil Nadu	78.16	11.12	175
50.	*Ss* - 62	Bahala, Rajasthan	71.15	27.77	320
51.	*Ss* - 63	Chalanda, Gujarat	71.47	23.99	28
52.	*Ss* - 64	Dasada, Gujarat	71.83	23.32	33
53.	*Ss* - 65	Pipava port, Gujarat	71.30	20.54	29
54.	*Ss* - 66	Girsomnath, Gujarat	70.71	21.01	107

Table 2. Characteristic means and variations of 54 kantakari accessions

Variable	Mean	SD	CV	Maximum	Accessions	Minimum	Accessions	Skewness	Kurtosis
PSNS	100.95	17.39	9.88	163.53	*Ss* - 17	63.40	*Ss* – 33	1.309*	4.206
PSEW	97.61	14.01	12.12	131.53	*Ss* - 62	62.20	*Ss* – 58	0.006	1.055
NB	5.47	0.84	7.77	7.60	*Ss* - 48	3.34	*Ss* – 23	-0.328	0.248
NFC	14.80	3.51	7.07	20.33	*Ss* - 55	5.66	*Ss* – 33	-0.900	0.716
NBR	72.41	27.51	8.21	131.23	*Ss* - 13	30.98	*Ss* – 50	0.641	-0.483
FBY	176.32	71.72	18.93	358.47	*Ss* - 13	69.84	*Ss* – 4	0.751*	-0.306
DBY	54.92	17.93	10.29	99.85	*Ss* - 13	28.06	*Ss* – 24	0.808*	0.180
DBYH	1217.46	397.82	10.36	2218.67	*Ss* - 13	623.42	*Ss* – 24	0.816*	0.192
TPC	7.13	1.65	2.44	10.96	*Ss* - 12	2.14	*Ss* – 6	-0.766	1.280
TFC	132.69	29.67	2.64	258.70	*Ss* - 13	72.41	*Ss* – 38	1.215*	4.907
TP	13.27	2.97	2.74	25.87	*Ss* - 13	7.24	*Ss* – 38	1.216*	4.915
DPPH	131.08	7.04	2.21	150.98	*Ss* - 48	112.28	*Ss* – 65	0.285	1.498
FRAP	41.48	21.33	2.97	98.15	*Ss* - 48	0.60	*Ss* – 34	0.511	0.426
SOLASODINE	0.03	0.03	0.3	0.1149	*Ss* - 48	0.0020	*Ss* – 35, *Ss* – 45, *Ss* – 54	1.241*	1.093

PSNS- Plant spread (N-S), PSEW- Plant spread (E-W), NB- Number of branches per plant, NFC- Number of flower clusters per plant, FBY- Fresh berry yield per plant (g), DRBY- Dry berry yield per plant (g), DBYH- Dry berry yield per hectare (kg), TPC- Total phenol content (mg GAE/g), DPPH- Total antioxidant activity (mg ASAE/DW), TFC- Total flavonoid content (mg QE/g), TP- Total proteins (mg/g), FRAP- Ferric reducing antioxidant activity (mg GAE/DW), SOL- Solasodine (%).

Table 3. Correlation coefficients among the 14 quantitative characters in kantakari

	PSNS	PSEW	NB	NFC	NBR	FBRY	TPC	DPPH	TFC	FRAP	TP	SOL
PSNS	**1.000**											
PSEW	0.357**	**1.000**										
NB	-0.105	0.018	**1.000**									
NFC	0.306*	0.297*	0.010	**1.000**								
NBR	0.264	0.049	0.281*	0.279*	**1.000**							
FBRY	0.299*	-0.037	-0.166	0.299*	0.806***	**1.000**						
TPC	-0.069	0.206	0.123	-0.074	0.075	0.210	**1.000**					
DPPH	0.294*	0.080	0.215	0.185	0.131	0.022	0.349**	**1.000**				
TFC	0.037	-0.089	-0.015	-0.069	0.238	0.382**	0.313*	0.040	**1.000**			
FRAP	0.096	-0.052	0.062	0.021	-0.070	0.067	0.303*	0.131	0.096	**1.000**		
TP	0.037	-0.089	-0.016	-0.069	0.238	0.382**	-0.092	0.041	1.000	0.096	**1.000**	
SOL	-0.239	-0.176	-0.051	-0.112	-0.144	-0.184	0.157	0.299*	0.326*	0.345*	0.126	**1.000**
DRBY	0.285*	0.007	-0.215	0.300*	0.840***	0.929***	0.182	-0.072	0.336*	0.062	0.336*	-0.170

*** Correlation is significant at 0.001 level (two tailed) ** Correlation is significant at 0.01 level (two tailed) * Correlation is significant at 0.05 level (two tailed)

PSNS- Plant spread (N-S), PSEW- Plant spread (E-W), NB- Number of branches per plant, NFC- Number of flower clusters per plant, FBRY- Fresh berry yield per plant (g), TPC- Total phenol content (mg GAE/g), DPPH- Total antioxidant activity (mg ASAE/DW), TFC- Total flavonoid content (mg QE/g), TP- Total proteins (mg/g), FRAP- Ferric reducing antioxidant activity (mg GAE/DW), SOL- Solasodine (%), DRBY- Dry berry yield per plant (g)

(Konyak *et al*., 2020). By contrast, Nazir *et al*. (2019) observed a positive correlation between plant height and fruit production. Similar, to the findings of Koundinya *et al*. (2019), in this study also the number of fruits per plant and total phenols were correlated with fruit yield per plant. Intercorrelation between the various yield components were essential for investigating because if two variables were positively associated, improving one would also increase the performance of the other. Important intercorrelations included the positive relationship between fresh berry yield per plant and the number of berries (0.806) and flowers (0.299); the relationship between plant spread (N-S) and plant spread (E-W) (0.357); the relationship between the number of flower clusters and plant spread (N-S) and plant spread (E-W) (0.306); and the relationship between the number of berries and the number of branches (0.297) and the number of flower clusters (0.299). Owing to a rise in the number of branches, the plant growth could have been more vegetative. Due to the increased photosynthate synthesis, this in turn causes the development of more flowers and berries per plant. The findings were quite consistent with those of brinjal by Chattopadhyay *et al.* (2011), Karak *et al.* (2012), Prabhu and Natarajan (2008), and Thangamani and Jansirani (2012). Number of berries per plant, fresh berry yield, and marketable yield plant^{-1} all had greater magnitude of positive direct impacts than total yield plant-1, which suggests a true, positive relationship.

In the present study, positive correlations were observed between TPC and DPPH, TFC and FRAP, and solasodine and DPPH, FRAP. Jung *et al*. (2011) reported a significant positive connection between the total phenol content and the DDPH and FRSC of brinjal. Positive correlations between total phenols, antioxidants, and solasodine were found in various correlation investigations. Due to their capacity to donate hydrogen atoms to free radicals, phenols and flavonoid molecules are crucial antioxidant components that deactivate free radicals. Moreover, they possess the appropriate structural qualities for scavenging free radicals (Amarowicz *et al*., 2004). Because of this, the phenolic and flavonoid groups play a significant role in the antioxidant activity of *kantakari* extracts. Due to the antioxidant property of the solasodine contained in the species, *S. surattense* is mostly used to treat lung issues and asthma (Pandurangan *et al*., 2010, Arora *et al*., 2017, Sarker *et al*., 2012).

A positive and substantial phenotypic association between yield and plant spread, number of flower cluster, number of berry, and fresh berry yield per plant was observed in the study. Solasodine, however, had a negative connection with yield. The repulsive connection of the gene(s) governing the direct and indirect effects would have caused this apparent negative association to develop at the genetic level. On the other hand, the coupling stage of linkage could be responsible for positive correlation. This is in conformity with past research on medicinal coleus by Geetha and Prabhakaran (1987) and Prabhakar *et al*. (1994). The correlation coefficients showed which characters exerted positive connection with others and highlighted the fact that one component character results in the contemporaneous improvement of the other component characters. The current findings in accordance with those of Kavitha (2005) for coleus and Narayanpur and Hanamashetti (2003) for turmeric. Designing breeding programmes for yield enhancement would benefit from the current knowledge of the degree and direction of correlation of these component traits on dry berry yield as well as the *inter se* relationship among them.

As yield is influenced by several other features both directly and indirectly, the correlation coefficient between any two characters would not provide an accurate picture of the situation. Path coefficient analysis provides a way to assess both the direct impact of each feature on yield as well as the indirect impact through other traits under such circumstances. Dewey and Lu's, (1959) and Wright's (1921) route analysis provide explanations for the importance of knowledge on direct and indirect effects on yield (1959). The interactions between the component characters and yield show what can be expected from choosing them to simultaneously improve yield and desirable characteristics.

Genotypic path coefficient values for the various traits for 54 accessions are presented in **Table 4**. Since that the residual impact was so negligibly small (0.05), it is clear that the number of characteristics used for the study was perfectly suitable for estimating crop yield in *kantakari*. Majority of the features, including plant spread (N-S), number of branches, number of berries, fresh berry yield, total phenol, total flavonoid, total protein, and solasodine content, had positive direct influences on dry berry yield. Fresh berry yield per plant (0.6214) had the highest direct impact on yield among these factors, followed by total protein content (0.7619), total flavonoid content (0.7598) and the number of berries per plant (0.5972).

Dry berry yield per plant exhibited a direct and substantial positive link with traits including the number of berries per plant, fresh berry yield per plant, plant spread (N-S), total flavonoid content, and total proteins. It would be beneficial to choose accessions depending on these characters. Although having a negative direct influence (-0.0401) on dry berry yield per plant, the number of flower clusters per plant showed a considerably positive correlation with dry berry yield per plant, indicating that the high indirect effect through fresh berry production per plant (0.2311) was the main reason for the observation of such a correlation coefficient.

Principal component analysis, a data reductionist technique that uses a linear combination of optimally weighted observed variables and helps find the plant traits that contribute most to the overall variance, was applied to the mean data of 14 quantitative traits. The top five components in the PCA analysis contributed to a maximum of 74.32 percent of the variability among the 54 accessions. The scree plot and a threshold Eigen value larger than 1 led to the retention of these five main components (**Table 5,6 Fig. 1 and 2**). The Eigen values for PCs 1, 2, 3, 4, and 5 were, respectively, 4.30, 2.00,

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Table 4. Path Coefficient (Genotypic) values of various characters showing direct (Bold) and indirect effects on dry berry yield per plant

	PSNS	PSEW	NB	NFC	NBR	FBRY	TPC	DPPH	TFC	FRAP	TP	SOL	Correlation
PSNS	**0.0035**	0.0013	-0.0004	0.0011	0.0009	0.0010	-0.0002	0.0010	0.0001	0.0003	0.0001	-0.0008	0.285
PSEW	-0.0010	**-0.0028**	0.0000	-0.0007	-0.0001	0.0001	-0.0006	-0.0002	0.0002	0.0001	0.0002	0.0005	0.007
NB	-0.0009	0.0002	**0.0084**	0.0001	-0.0021	-0.0014	0.0010	0.0018	-0.0001	0.0005	-0.0001	-0.0004	-0.215
NFC	0.0070	0.0120	0.0003	**-0.0401**	0.0162	0.2351	0.0020	0.0005	0.0003	0.0051	0.0143	0.0001	0.300
NBR	0.0015	0.0003	-0.0015	0.0010	**0.5972**	0.0047	0.0004	0.0008	0.0014	-0.0004	0.0014	-0.0008	0.840
FBRY	0.0064	-0.0008	-0.0036	0.0021	0.0173	**0.6214**	0.0045	0.0005	0.0082	0.0014	0.0082	-0.0016	0.929
TPC	-0.0001	0.0002	0.0001	-0.0001	0.0001	0.0002	**0.0011**	0.0001	0.0003	-0.0001	0.0003	0.0002	0.182
DPPH	-0.0012	-0.0003	-0.0009	-0.0008	-0.0005	-0.0001	-0.0002	**-0.0041**	-0.0002	-0.0005	-0.0002	-0.0004	-0.072
TFC	-0.0280	0.0675	0.0117	0.0524	-0.1807	-0.2901	-0.2303	-0.0307	**0.7598**	-0.0727	-0.7598	-0.0959	0.336
FRAP	-0.0006	0.0003	-0.0004	-0.0001	0.0004	-0.0004	0.0006	-0.0008	-0.0006	**-0.0062**	-0.0006	-0.0022	0.062
TP	0.0283	-0.0677	-0.0118	-0.0524	0.1813	0.2909	0.2308	0.0308	0.7619	0.0731	**0.7619**	0.0962	0.336
SOL	-0.0015	-0.0011	-0.0003	-0.0007	-0.0009	-0.0005	0.0010	0.0007	0.0008	0.0022	0.0008	**0.0064**	-0.170

PSNS- Plant spread (N-S), PSEW- Plant spread (E-W), NB- Number of branches per plant, NFC- Number of flower clusters per plant, FBRY- Fresh berry yield per plant (g), TPC- Total phenol content (mg GAE/g), DPPH- Total antioxidant activity (mg ASAE/DW), TFC- Total flavonoid content (mg QE/g), TP- Total proteins (mg/g), FRAP- Ferric reducing antioxidant activity (mg GAE/DW), SOL- Solasodine (%), DRBY- Dry berry yield per plant (g)

Table 5. Eigen vectors and Eigen values of 5 principal components for 14 characters of kantakari accessions

	PC 1	PC 2	PC 3	PC 4	PC 5
Eigen value	4.309	2.004	1.700	1.387	1.004
Variance %	26.973	15.317	12.219	10.707	9.104
Cumulative %	26.973	42.291	54.510	65.217	74.320

Table 6. Eigen values and cumulative variability in different PCs for yield and related traits in kantakari accessions

Characters	Component				
	1	2	3	4	5
Plant spread (N-S)	0.255	0.026	0.718	-0.299	0.000
Plant spread (E-W)	-0.092	0.034	0.799	0.183	-0.002
Number of branches/plant	-0.188	-0.006	-0.115	-0.011	0.813
Number of flower clusters / plant	0.119	-0.138	0.604	-0.034	0.092
Number of berries/ plant	0.901	0.034	0.147	0.014	-0.043
Fresh berry yield per plant	0.938	0.206	0.044	-0.019	0.005
Dry berry yield per plant	0.962	0.155	0.057	-0.022	-0.090
Dry berry yield per hectare	0.964	0.158	0.055	-0.017	-0.084
Total phenol content (mg GAE/g)	0.138	0.414	0.082	0.662	0.324
Total flavonoids (mg QE/g)	0.206	0.958	-0.062	-0.052	0.000
Total proteins (mg/g)	0.206	0.958	-0.062	-0.052	0.000
Total antioxidant activity (mg ASAE/DW)	0.025	0.015	0.316	-0.199	0.658
FRAP (mg GAE/DW)	0.025	0.135	-0.070	-0.582	0.205
Solasodine (%)	-0.049	-0.067	-0.173	0.742	-0.087

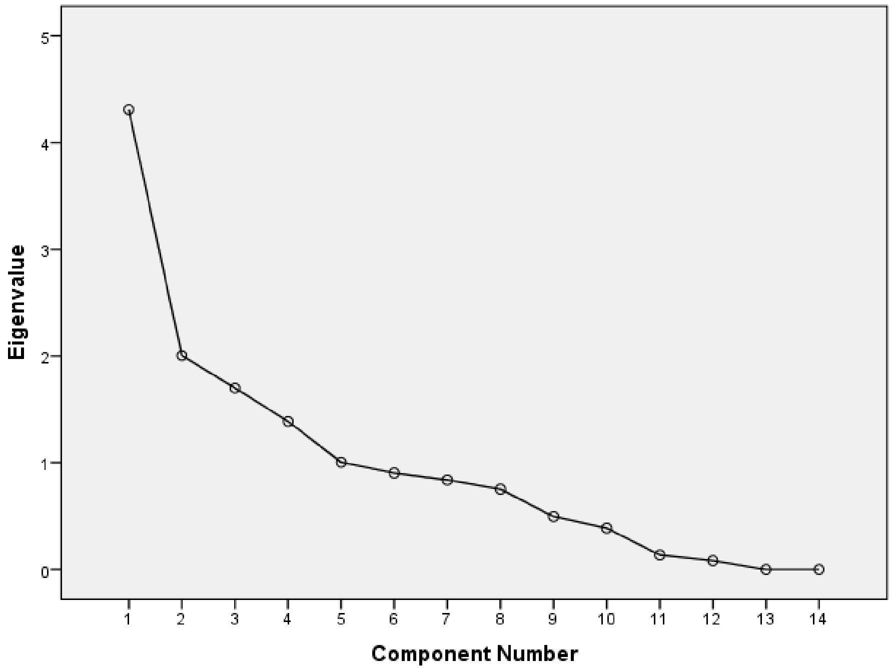

Fig. 1. Scree plot for 14 quantitative traits in kantakari accessions

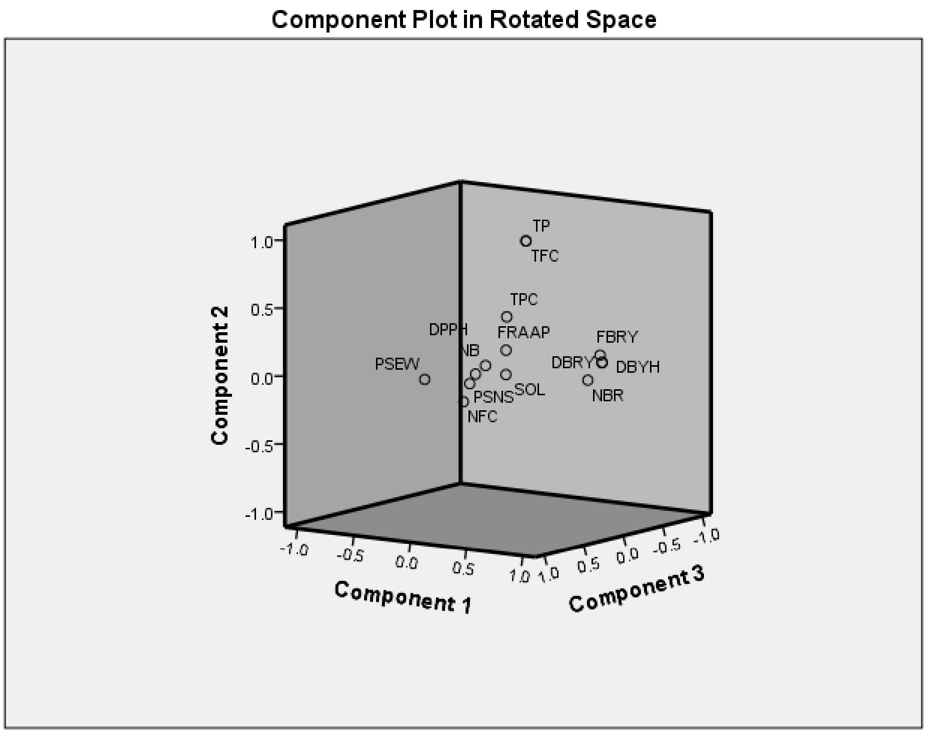

Fig. 2. Three dimensional component plots for 14 quantitative traits in kantakari accessions

1.70, 1.39, and 1.00. The number of berries per plant, fresh berry production per plant, dry berry yield per plant, and dry berry yield per hectare were the contributing characteristics of the first principal component PC1, which explained 26.97% of the total variance. It was clear from PC 1 that a higher number of berries yielded more fresh and dry berries. The components of PC 3 were related to the reproductive behaviour of the accessions, whereby an increase in plant spread resulted in a proportional increase in the number of flower clusters per plant. PC 3 accounted for 12.21% of the overall variance. The quality behaviour of the accessions contributed to PC2, PC4, and PC5, which together accounted for 15.31, 10.70, and 9.10% of the overall variance. It was clear that an increase in phenols, flavonoids and solasodine content leads in increased antioxidant activity. Similar findings were reported by Sehgal *et al.* (2021) in Tomato. Positive contributions show the significance of these qualities in affecting berry quality, making them crucial for selection based on berry quality.

Using Ward's approach, the hierarchical clustering methodology produced two significant clusters from the 14 quantitative trait data. With a total of 13 accessions, Cluster I had high mean values for fresh berry yield per plant (137 g), number of berries per plant (72.47) and dried berry yield per plant (55 g). Based on yield performance, the cluster 1 was further divided into two sub-clusters. A single sub-cluster IA was formed by the accession Ss-13 with the maximum fruit yield, which averaged around 99.08g of dry berry yield per plant. In comparison to accessions in other sub-clusters, the accessions in sub-cluster IB have accessions with greater plant spread, with a mean of 100 cm, as well as higher fresh berry yield per plant. Cluster II contains 41 accessions grouped into 3 sub clusters. Out of these first two sub-clusters, one displayed poor performance for single plant yield and yield attributing traits and was characterised by low plant spreading (**Fig. 3**). However sub-cluster IIC was predominated by high solasodine lines and berry quality parameters.

In a study on tomato genotypes conducted by Evgenidis *et al.* (2011), three clusters were identified. A major cluster, which corresponds to the cluster I of the current study, was formed by genotypes with the greatest plant height, the greatest number of secondary branches, the greatest number of seeds per plant, and more number of fruits per plant. Sadarunnisa *et al.* (2015) revealed that genotypes with higher fruit yield and yield components aggregated within a single cluster in brinjal, which is consistent with the clusters produced from the current study. The diverse genotype variability observed in the kantakari germplasm holds great significance for its use in hybrid breeding projects, allowing breeders to select parental lines with desirable traits. Hence, crossing programmes involving selecting accessions from cluster I with cluster II C would be useful in breeding for high yielding as well as high alkaloid content kantakari lines.

The current study shows that the kantakari accessions demonstrated significant genetic variability for majority of the traits. The characteristics, fresh berry yield per plant and number of berries per plant, were found to be the major yield attributing traits as they had the maximum direct impact and substantial positive relationship with

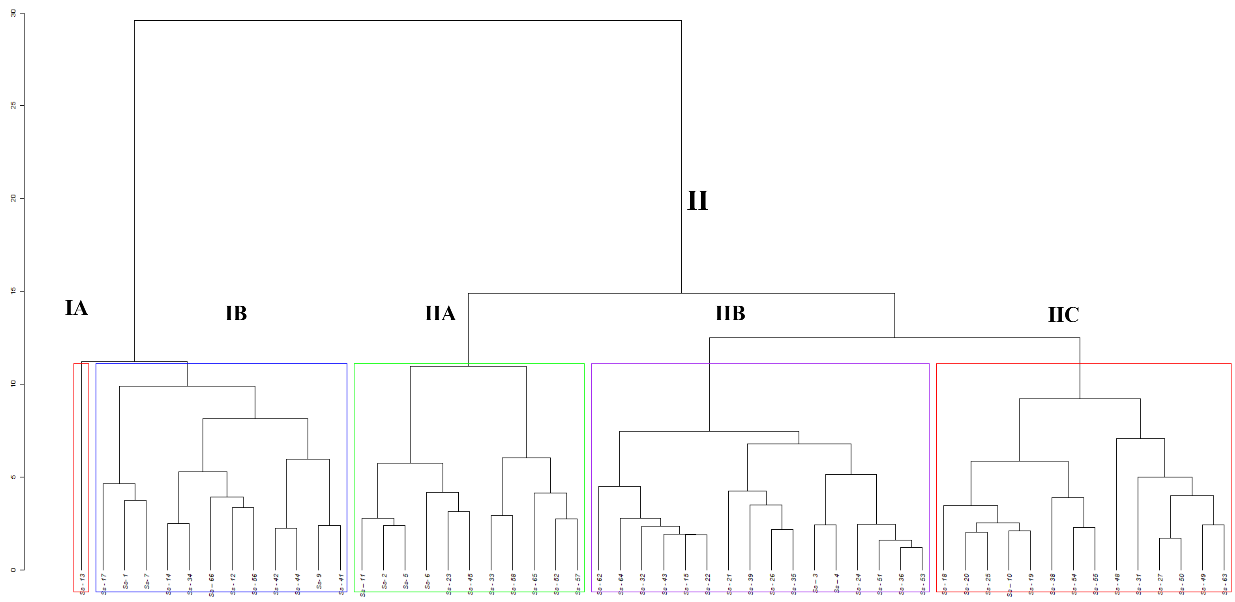

Fig. 3. Dendrogram based agglomerative clustering in kantakari accessions

single plant yield as well as the most variance in the PCA's first component. Clustering of accessions based on various morphological and biochemical parameters has also assisted in selecting suitable parents to generate superior recombinants. Notably, accessions *Ss*-13, *Ss*-17, *Ss*-48, *Ss*-55, and *Ss*-62 show promise for future breeding programs aimed at producing high-yield and high-quality kantakari varieties.

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