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Genetic variability, correlation and path coefficient analysis in Veldt grape (*Cissus quadrangularis* Linn.) ecotypes

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Abstract
The current investigation was conducted to estimate genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance (GA) along with correlation and path coefficient from the data collected on fifty veldt grape ecotypes during 2018-20. High estimates (>35%) of GCV and PCV for number of matured leaves, number of twiners, number of primary roots and plant height indicated the presence of adequate genetic variation among the genotypes and suitability of these attributes for further improvement by selection. Correlation and path coefficient analysis among fourteen morphological characters studied in fifty veldt grape ecotypes indicated higher genotypic correlation coefficients than the corresponding phenotypic correlation coefficient, suggesting that the environmental influence reduces the relationship between stem yield and stem yield contributing characters of veldt grape. All the genetic parameters are positively and significantly correlated with stem yield, except days taken for rooting where it is negatively correlated in both genotypic and phenotypic correlation coefficients, number of twiners (0.97^{**}) are positively and significantly correlated with plant height in the genotypic correlation. Root weight is positively and significantly correlated with number of primary roots (0.88^{**}) and root length (0.87^{**}) in genotypic correlation. Number of twiners are positively and significantly correlated with plant height (0.51^{**}) in phenotypic correlation coefficients. Days taken for rooting is negatively correlated with root weight (-0.37), number of lateral roots (-0.31) and root length (-0.28) in phenotypic correlations coefficients. Path coefficient analysis revealed direct positive effect of number of lateral roots (1.24) and root length (0.56) on stem yield. The number of lateral roots and root length had the highest positive direct effect on stem yield and positive significant genotypic correlation between these two traits indicating that direct selection through these traits would be much effective for the yield improvement of *Cissus* ecotypes.

Keywords: GCV, PCV, path coefficient, heritability, genetic advance, veldt grape, *Cissus quadrangularis* Linn

Introduction
Veldt grape (*Cissus quadrangularis* Linn.), is one of the pharmaceutically important medicinal crop which is widely distributed in tropical regions of India. It is succulent, evergreen, perennial climber belonging to the Vitaceae family under the order Vitales (Joseph *et al*., 2011) [7]. It has simple tendrils, opposite to the leaves. The leaves are simple or lobed, cordate, broadly ovate, serrate and 3 foliate or glabrous. Flowers are small, greenish white in color, bisexual, tetramerous, and the arrangement of the flower on floral axis is umbellate cymes. The fruit is dark purple to black, with single seeded fleshy berries and globose in shape. It is commonly propagated through stem cuttings. Veldt grape is a potential source of dietary calcium and plays vital role in healing the bone fractures without any side effects. The whole plant also utilized for heftiness, diabetes, a bunch of coronary illness hazard factors called metabolic disorder and elevated cholesterol. The plant stem looks like the state of bones and joints in the body (Raj *et al*., 2011) [9]. The plant contains different therapeutic components in the leaves and stems such as Vitamin C, stilbene, triterpenoids, flavonoids derivatives, apart from the presence of ascorbic acid, triterpene, β-sitosterol, ketosteroid, two asymmetrical tetracyclic triterpenoids and calcium **(**Jainu 2004, Enechi 2003**)** [6, 3]**.** Though this crop has high potential for its medicinal properties, still it is an underexploited one in India. The market for this essential medicinal herb is based on the availability of raw material which was collected through local or wild collections. Due to paucity of research, there are no named varieties available in India till date. The methodology of breeding for genetic improvement for yield and its components are depends upon the nature and magnitude of variability present in the genotypes. The assessment of genetic parameters such as, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), correlation coefficients and path analysis are helpful in effective selection for improving the base population.

Understanding the nature of interrelationships among different characters will improve the effectiveness of selection of superior genotypes. Path analysis further unravels the cause of such associations by determining the direct and indirect contribution of independent variables (Giridharan and Jindal, 1995) [4]. Considering the industrial importance of this crop, the current investigation was carried out to estimate the genetic variability, correlation and path coefficient for yield and its components in veldt grape ecotypes.

Materials and Methods

The current investigation was conducted at Botanical Garden, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore which is situated in the 11˚ 7' N latitude and 77˚ 59' E longitude and at an altitude of 426.26 m above mean sea level. Fifty ecotypes of veldt grape collected from various agro-climatic zones of Tamil Nadu and maintained in the Department of Medicinal and Aromatic Crops, Horticultural College and Research Institute; Coimbatore were used as the genetic stock for this research work (Table 1). The experiment was laid out in Randomized Block Design with three replications. Each ecotype was raised in grow bags at a spacing of 1 m x 1 m and observations were taken up on the number of sprouts, number of matured leaves, leaf length, leaf width, number of twiners, stem girth, days taken for rooting, root weight, root length, root width, number of primary roots, number of secondary roots, plant height and stem yield.

Phenotypic and genotypic coefficients of variations were calculated by using the formula given below (Burton, 1952) it is based on the assessment of genotypic and phenotypic variance as follows.

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sigma_p}{\text{Mean}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sigma_g}{\text{Mean}} \times 100$$

$$\text{Environmental coefficient of variation (ECV)} = \frac{\sigma_e}{\text{Mean}} \times 100$$

Simple correlation refers to the association between two variables. It is also known as total correlation or zero order correlation coefficient were worked out using the following formula as outlined by Johnson *et al*., (1955). Simple correlation was calculated using the following formula

$$r_{xy} = \frac{\sum xy - \frac{\sum x . \sum y}{N}}{\sqrt{\sum x^2 - \frac{(\sum x)^2}{N} . \sum y^2 - \frac{(\sum y)^2}{N}}}$$

Where, N is the number of observations on variable x and y. The calculated r can be tested for significance comparing with table r value at N-2 degrees of freedom. Path coefficient analysis was carried out as suggested by Dewey and Lu (1959). The direct and indirect effects were classified based on the scale given by Lenka and Misra (1973). The statistical analysis was done by utilizing the assistance of TNAUSTAT and SPSS 20.0 version.

Results and Discussion

Genetic variability

The results of the current investigation relevant to genetic variability are presented in Table 2. Significant differences were observed among the ecotypes for all the 14 traits taken for this study. High estimates (>35%) of GCV for number of matured leaves (51.65), number of twiners (45.8) and number of primary roots (37.5), plant height **(**38.5) and PCV for number of sprouts (37.01) number of matured leaves (58.35), number of twiners (49.02) and number of primary roots (41.51), plant height **(**41.09) indicated the presence of adequate genetic variation among the genotypes and suitability of these attributes for further improvement by selection. High heritability estimates (>90%) coupled with high genetic advance as percentage of mean (>70%) for number of matured leaves (0.72), leaf length (0.77), leaf width (0.89), stem girth (0.73), days taken for rooting (0.72), root weight (0.73), root length, (0.75), root girth (0.72) and stem yield (0.89) confirmed that these traits are under the control of additive gene and phenotypic selection for their improvement will be effective. Kumar *et al.* (2002) observed that berry weight to be under strong additive genetic control of grape accessions. Similarly, high heritability estimates for berry weight, bunch weight and bunch number were also reported in grapes by Wei *et al*. (2003) [11] which supports the results of the present study. Likewise, the estimates of GCV and PCV for root length and root girth were low in magnitude, yet these were close to each other indicating the little effect of environment in the inheritance of these traits. The results are in corroboration with the findings of Gupta *et al.,* (2015) [5] who reported high GCV and PCV for bunch weight followed by bunch number, high heritability for fruit yield and high values of genetic advance for bunch number in 20 accessions of grapes.

Correlation coefficients

Phenotypic correlation, genotypic correlation and path co-efficient of fifty ecotypes of veldt grape between stem yield and associated characters are given in Table 3 and 4. In general, genotypic correlation coefficients were higher than their corresponding phenotypic correlation coefficients, indicating that there is a strong inherent association between the characters studied (Zahid *et al*., 2011). All the genetic parameters are positively and significantly correlated with stem yield except days taken for rooting (-0.656 and -0.295) where it had negative correlation in both genotypic and phenotypic levels. It indicates that improvement of these traits through selection except days for rooting will definitely improve the stem yield of veldt grape. Kliewer and Dokoozlia (2000) and Gupta *et al.* (2015) [5] also reported positive and significant correlation between yield and bunch length, bunch breadth, bunch weight. Bunch weight showed positive and highly significant correlation with number of berries per bunch, berry length, berry breadth and number of seeds per berry in grape accessions. Number of twiners (0.97**) are positively and significantly correlated with plant height in the genotypic correlations, root weight is positively and significantly correlated with number of primary roots (0.88**) and root length (0.87**) in genotypic correlation. Kandalkar *et al.,* (1993) also obtained similar results of root branches, root diameter and root length positively correlated with plant height, dry root yield per plant, number of berries per plant, number primary and secondary branches in ashwagandha. Hence, the improvement of the primary roots and root length will improve the root weight which in turn will increase the stem yield. Number of twiners are negatively correlated with days taken for rooting (-0.94) in genotypic coefficient of variation. Number of twiners (0.51**), number of lateral roots (0.49**) are positively correlated with plant height in phenotypic correlation coefficients. Hridhik *et al*., (2015) also revealed that root length showed significant positive

correlation with plant height and leaf breadth showed significant positive correlation with root length and development of this traits seems to improve the plant height Days taken for rooting is negatively correlated with root weight (-0.91 and -0.37), root length (-0.86 and -0.28), root girth (-0.26 and -0.05) in both genotypic and phenotypic correlations coefficients indicating that improvement of root weight, root length, root girth will affect the days taken for rooting. Number of sprouts are positively correlated with leaf length (0.32*), leaf width (0.18), days taken for rooting (0.03) in phenotypic correlation but it has negatively correlated in genotypic correlation coefficients. The results are in coincidence with the findings of Dayal *et al.* (1983) in potato; Data *et al*. (2005) in fenugreek; Golani *et al.* (2007) in hyacinth bean and Ramaprasad *et al.* (2007) in French bean

Path coefficient analysis

Path coefficient analysis presented in the table 5 showed the results of direct and indirect effects of various contributing traits on veldt grape stem yield. The number of lateral roots (1.24), root length (0.56), leaf length (0.52) had direct positive effect, but root weight (-0.91), days taken for rooting (-0.74) and number of twiners (-0.51) has direct negative effect on stem yield. Dubey (2010) [1] and Rameshkumar *et al.,* (2011) also noticed the major contribution of root length and root diameter towards dry root yield per plant in ashwagandha. The number of primary roots had positive indirect effect on stem yield through days taken for rooting (1.58), root length (0.75) and number of secondary roots (1.95). Root weight had positive indirect effect on stem yield through days taken for rooting (0.68), number of lateral roots (1.10). Number of primary roots had indirect negative effect on stem yield through plant height (-0.78). Hence, it was observed that the number of lateral roots and root length had the highest positive direct effect on stem yield and positive significant genotypic correlation between these two traits indicates that direct selection through this trait would be much effective for the improvement of stem yield. Similar findings were reported by Chitra and Rajamani (2010) [2] in Glory Lily. The estimated residual effect was 0.32 indicating that about 68 % of the variability in stem yield was contributed by the characters studied in path analysis. This residual effect towards stem yield in the present study might be due to many reasons *viz* other traits which are not included in the investigation, environmental factors and sampling errors.

Thus from the above investigation with varied ecotypes of *Cissus quadrangularis*, there exist substantial genetic variability and heritability in the characters studied to deserving selection of beneficial accessions for further improvement. The present character association study on veldt grape revealed appreciable interaction of one trait with other traits which would be helpful to improve the trait of interest by selecting the correlated traits. The high genetic variance components and heritability estimates coupled with significantly positive correlations and high direct effects of number of lateral roots and root length on stem yield which could be listed in selection criteria for good parental lines in a *Cissus* breeding programme. Based on the above information, suitable plant breeding strategies are to be formulated for better understanding of improvement of the veldt grape.

Table 1: Veldt grape (*Cissus quadrangularis* Linn.) ecotypes utilised for the character association analysis

Ecotypes	Village/town	District	Latitude	Longitude
TNCq 1	Kuniamuthur	Coimbatore	10.957505	76.953535
TNCq 2	Nambhiyazhagan palayam	Coimbatore	11.011699	76.891406
TNCq 3	Poluvampatti	Coimbatore	10.882763	76.839177
TNCq 4	Kadukkanpalayam	Erode	11.468791	77.447665
TNCq 5	Kumarapalayam	Erode	11.437271	77.722959
TNCq 6	Krishnapuram	Perambalur	11.381267	78.789883
TNCq 7	Nemizhi	Vellore	12.599981	78.516298
TNCq 8	Keezhveeranam	Vellore	12.984488	79.475448
TNCq 9	Marugattuthalai	Tirunelveli	9.0591802	77.257606
TNCq 10	Savalapperi	Tirunelveli	8.8222024	77.850258
TNCq 11	Vadakarai	Tirunelveli	9.0406648	77.273598
TNCq 12	Puliyampatti	Tuticorin	8.8300265	77.847758
TNCq 13	Alandha	Tuticorin	8.8083056	77.857242
TNCq 14	N. Pudhur	Tuticorin	9.2950398	78.136379
TNCq 15	Kangaikondan	Tuticorin	8.8583092	77.782306
TNCq 16	Malaippatti	Tuticorin	8.9356666	77.887258
TNCq 17	Kasalingapuram	Tuticorin	8.7761819	77.887465
TNCq 18	Parayappatti	Dharmapuri	12.134601	78.477108
TNCq 19	Sindhalpadi	Dharmapuri	12.077550	78.358141
TNCq 20	Thandipadi	Tiruvannamalai	12.108260	78.834596
TNCq 21	Thandarampet	Tiruvannamalai	12.154465	78.948612
TNCq 22	Nallavanpalayam	Tiruvannamalai	12.203409	79.046448
TNCq 23	Thakkalai	Kanyakumari	8.2449166	77.322300
TNCq 24	Pollachi	Coimbatore	10.661398	77.005016
TNCq 25	Thumpichavalayam	Tirupur	11.123060	77.357972
TNCq 26	Kallippalayam	Tirupur	10.915256	77.332280
TNCq 27	Sempatti	Dindigul	10.281261	77.872413
TNCq 28	Kannivadi	Dindigul	10.382170	77.831178
TNCq 29	Periyakulam hills	Theni	10.116354	77.544751
TNCq 30	Thevadhanampatti	Theni	10.146388	77.642376
TNCq 31	Manjalar dam	Theni	10.186436	77.624964
TNCq 32	Endapulippatti	Theni	10.086147	77.576477
TNCq 33	Vennaimalai	Karur	10.990210	78.073276
TNCq 34	Semmadi	Karur	11.011164	78.068203

TNCq 35	Maruthappatti	Virudhunagar	9.4598252	77.800493
TNCq 36	Marudhappatti east	Virudhunagar	9.5734343	77.963502
TNCq 37	Marudhappatti west	Virudhunagar	9.5351770	77.939990
TNCq 38	Chatrappatti east	Virudhunagar	9.5629394	77.942394
TNCq 39	Chatrappatti west	Virudhunagar	9.4169260	77.597587
TNCq 40	Peranayakkanpatti	Virudhunagar	9.4211912	77.785922
TNCq 41	Madurai(anamalai) hills	Virudhunagar	9.9685573	78.195364
TNCq 42	Kadampur	Perambalur	11.425639	78.720852
TNCq 43	Kallappatti	Perambalur	11.434620	78.723555
TNCq 44	Therkumedu	Salem	11.488630	78.798563
TNCq 45	Veeraganur	Salem	11.481054	78.733520
TNCq 46	Karpaganadhar kulam	Tiruvarur	10.414491	79.637877
TNCq 47	Vaimedu	Nagappattinam	10.413075	79.685595
TNCq 48	Kamlappatti	Dharmapuri	12.244234	78.081856
TNCq 49	Nallampalayam	Tirupur	10.728098	77.618002
TNCq 50	Nallampalayam	Tirupur	10.728098	77.618002

Table 2: Genetic parameters for veldt grape (*Cissus quadrangularis* Linn.) ecotypes

Characters	GCV	PCV	ECV	Heritability (h^2)	Genetic Advance (GA)
No. of sprouts	34.54	37.01	2.47	0.69	27.41
No. of matured leaves	51.65	58.35	6.70	0.72	21.59
Leaf length	18.1	22.90	4.80	0.77	23.17
Leaf width	17.25	20.53	3.28	0.89	42.60
No. of Twiners	45.8	49.02	3.22	0.68	38.34
Stem girth	21.65	23.67	2.02	0.73	36.62
Days taken for rooting	19.2	22.82	3.62	0.72	45.79
Root weight	6.20	7.81	1.60	0.73	40.15
Root length	8.4	10.39	1.99	0.75	38.61
Root girth	5.75	7.85	2.10	0.72	34.36
No. of primary roots	37.5	41.51	4.01	0.64	32.59
No. of secondary roots	27.5	30.95	3.45	0.57	43.62
Plant height	38.5	41.09	2.59	0.65	38.56
Stem yield	19.99	21.13	6.84	0.89	38.97

Table 3: Genotypic Correlation coefficient between yield and yield contributing characters of veldt grape (*Cissus quadrangularis* Linn.) ecotypes

Characters	No. of sprout	No. of Matured leaves	Leaf length	Leaf width	No. of Twiners	Stem girth	Days taken for rooting	Root weight	Root length	Root girth	No. of Primary roots	No. of Lateral roots	Plant height	Stem yield
No. of sprouts	1	0.34*	-0.137	-0.01	0.83**	0.349*	-0.55	0.398*	0.684**	0.044	0.619**	0.168	0.401*	0.584**
No. of matured leaves		1	0.327*	0.843**	0.532**	0.499**	-0.748	0.194	0.632**	0.029	0.839**	0.508**	0.769**	0.897**
Leaf length			1	0.586**	0.384*	0.711**	-0.135	0.026	-0.139	-0.021	0.244	0.369*	0.105	0.18
Leaf width				1	0.419*	0.749**	-0.259	0.097	0.119	0.2	0.544**	0.509**	0.38*	0.442*
No. of Twiners					1	0.422*	-0.945	0.636**	0.778**	0.055	0.64**	0.529**	0.97**	0.51
Stem girth						1	-0.607	0.199	0.074	-0.072	0.15	0.514**	0.454**	0.318*
Days taken for rooting							1	-0.916	-0.864	-0.266	-0.45	-0.622	-0.565	-0.656
Root weight								1	0.879**	0.053	0.65**	0.885**	0.848**	0.791**
Root length									1	0.571**	0.556**	0.568**	0.87**	0.868**
Root girth										1	0.683**	0.167	0.334*	0.162
No. of primary roots											1	0.576**	0.75**	0.678**
No. of secondary roots												1	1.163	0.564**
Plant height													1	0.653**
Stem yield														1

*significant at 5% level. **significant at 1% level

Table 4: Phenotypic Correlation coefficient among yield and yield contributing characters of veldt grape (*Cissus quadrangularis* Linn.) ecotypes

Characters	No. of sprout	No. of Matured leaves	Leaf length	Leaf width	No. of Twiners	Stem girth	Days taken for rooting	Root weight	Root length	Root girth	No. of Primary roots	No. of Lateral roots	Plant height	Stem yield
No. of sprouts	1	0.323*	0.182	0.13	0.243	0.123	0.033	0.085	-0.001	-0.012	0.171	0.057	0.262*	0.197
No. of matured leaves		1	0.239	0.334*	0.368*	0.126	-0.115	0.133	0.168	-0.121	0.126	0.236	0.37*	0.263*
Leaf length			1	0.509**	0.151	-0.023	-0.015	-0.023	0.021	-0.11	0.009	0.112	0.14	0.079
Leaf width				1	0.164	0.174	-0.06	0.026	0.044	-0.111	0.107	0.18	0.246	0.206
No. of Twiners					1	0.178	-0.278	0.301*	0.307*	-0.012	0.187	0.34*	0.518**	0.411*
Stem girth						1	-0.074	0.063	0.093	0.033	0.096	0.051	0.191	0.139
Days taken for rooting							1	-0.377	-0.285	-0.053	-0.188	-0.314	-0.278	-0.295
Root weight								1	0.424	0.017	0.367*	0.447*	0.37*	0.553**
Root length									1	0.156	0.34*	0.358*	0.354*	0.475**

Root girth										1	0.055	0.089	0.154	0.071
No of primary roots											1	0.399*	0.325*	0.53**
No of secondary roots												1	0.499**	0.598**
Plant height													1	0.686**
Stem yield														1

*significant at 5% level. **significant at 1% level

Table 5: Path co-efficient analysis of stem yield and stem yield contributing characters of veldt grape (*Cissus quadrangularis* Linn.) ecotypes

Characters	No. of sprouts	No. of Matured leaves	Leaf length	Leaf width	No. of Twiners	Stem girth	Days taken for rooting	Root weight	Root length	Root grith	No. of Primary roots	No. of Lateral roots	Plant height
No. of sprouts	0.143	-0.139	0.035	-0.005	-0.423	0.016	0.856	-0.364	0.385	-0.023	0.074	0.209	-0.181
No. of matured leaves	0.048	-0.409	-0.085	0.444	-0.271	0.064	0.557	-0.177	0.355	-0.015	0.100	0.631	-0.347
Leaf length	-0.019	-0.133	-0.262	0.309	-0.196	0.032	0.100	-0.024	-0.078	0.010	0.029	0.458	-0.047
Leaf width	-0.001	-0.345	-0.153	0.527	-0.213	0.034	0.193	-0.088	0.066	-0.104	0.065	0.632	-0.171
No. of Twiners	0.119	-0.217	-0.100	0.221	-0.510	0.019	0.704	-0.582	0.437	-0.028	0.197	1.278	-0.437
Stem girth	0.050	-0.573	-0.186	0.395	-0.215	0.046	0.452	-0.182	0.041	0.037	0.017	0.638	-0.204
Days taken for rooting	-0.165	0.306	0.035	-0.136	0.482	-0.028	-0.744	0.838	-0.486	0.138	-0.253	-1.518	0.526
Root weight	0.057	-0.079	-0.006	0.051	-0.324	0.009	0.682	-0.915	0.494	-0.027	0.133	1.100	-0.382
Root length	0.098	-0.258	0.036	0.062	-0.396	0.003	0.644	-0.805	0.562	-0.297	0.159	1.452	-0.392
Root girth	0.006	-0.011	0.005	0.105	-0.028	-0.003	0.198	-0.048	0.321	-0.520	0.081	0.207	-0.150
No. of primary roots	0.088	-0.343	-0.064	0.286	-0.840	0.006	1.580	-1.022	0.751	-0.356	0.119	1.959	-0.789
No. of secondary roots	0.024	-0.207	-0.096	0.268	-0.524	0.023	0.910	-0.810	0.657	-0.086	0.188	1.243	-0.525
Plant height	0.057	-0.315	-0.027	0.200	-0.494	0.021	0.868	-0.776	0.49	-0.174	0.209	1.446	-0.451

Bold figures are direct effects; Residual effect: 0.32

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