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Stability, correlation and path coefficient analysis for yield and quality traits in betelvine (*Piper betle* L.) genotypes under three different sets of conditions

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Abstract

Betelvine (*Piper betle* L.) is commonly consumed as betel quid or paan with areca nut and/or tobacco; and also utilized in Indian medicine systems and in religious ceremonies. The betel production is highly erratic and so is the income of farmers due to natural climatic factors and spoilage during transport. It is therefore important to improve its productivity per vine and per unit area to meet the demand. Correlation, path coefficient and stability analysis was carried out in fifteen genotypes of betelvine including 3 checks under three protected structures, namely, *Bareja* (E1), Poly tunnel (E2) and Net tunnel (E3). Among the three structures, Net tunnel was found suitable for the cultivation of betelvine in Chhattisgarh. With respect to quality parameters, Meetha paan (2.65 g/100g) followed by Billori (2.23 g/100g) found to have high protein content. Meetha paan (5.89g/100g) followed by Meetha-cum-bangla (5.36g/100g) was also found to possess high starch content. However, low fiber content was recorded in Meetha pan (1.83g/100g), whereas high potassium content was found in Ramtake meetha (933mg/100g) followed by Bidhan pan (991mg/100g). The genotype, Karapaku possessed high potassium content (2.67mg/g). Hedonic five point scale for organolaptic test showed Meetha paan (2.3/5) followed by Bali paan (2.4/5) were less pungent among genotype studied. Highest shelf life was found in genotype Karapaku and Bhaichigudi (18days). The results indicated that number of leaves per vein were positively correlated with leaf width (0.802 and 0.819) followed by leaf area (0.790 and 0.808), leaf area index (0.782 and 0.800), leaf length (0.745 and 0.759), specific leaf weight (0.681 and 0.709), petiole length (0.658 and 0.705), diameter of internodes (0.484 and 0.559) and R-value (0.112 and 0.110) at both phenotypic and genotypic level, respectively. Path analysis identified leaf width (0.8772) and leaf length (0.4712) had direct effects on leaf yield at phenotypic level. Highest positive direct effect on leaf yield was exerted by leaf area (1.3544) followed by leaf width (0.8986) at genotypic level. These characters can be used as selection criterion in a breeding programme to develop varieties of betelvine with high leaf yield. The stability analysis under three different protected structures *viz;* E1, E2, E3 indicated that the genotypes, Karapaku, Bhaichigudi and Maghai pan are stable across the environment for leaf yield.

Key words: Betelvine, correlation, path analysis, phenotypic, genotypic, stability, quality

Introduction

Betelvine (*Piper betel* L.) belongs to family Piperaceae is a evergreen perennial, dioecious creeper (Hassan and Shahadat 2005) originated from Malaysia is under cultivation in India and many other Asian countries on commercial scale (Kumar et al. 2010). The betelvine growers invariably named their cultivars with local vernacular names. Therefore, the cultivars are nothing but landraces which differ from each other in organoleptic properties (Verma et al. 2004). Genetic diversity at morphological and molecular levels has been worked out earlier by many workers who reported that most of the betelvine genotypes are dissimilar (Patra et al. 2011) in respect of the morpholigical and quality traits. However, substantial genetic diversity exists among the genotypes cultivated by farmers (Patra et al. 2011) in respect of the morphological and quality traits. The betel leaf is mostly consumed in Asia and elsewhere in the world by some Asian emigrants as betel quid or in paan with areca nut and/or tobacco. Betel leaves are rich in vitamins, minerals, protein and essential oil, which is used as raw material

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for manufacturing medicine, perfumes, mouth freshner and additives etc. (Guha 2006; Das et al. 2016). Besides, pan leaves are also used as medicine in different religious ceremonies in India. The leaves are also traditionally offered as a mark of respect and auspicious beginning. The betel production is highly erratic and so is the income of farmers due to several factors such as rainfall pattern, temperature and spoilage rates of 35% to 70% during transport over infrastructure. The betel leaf yield varies by region and vine variety. Hence, for better growth and yield of betelvine, climatic factors like soil, temperature, relative humidity and lux intensity play a crucial role (Walker 1965). Under National Agriculture Research Programme (NARP), the country has been divided into 15 agro-climatic zones, Chhattisgarh falls under agro-climatic zone No. 7. In general the climate of Chhattisgarh is hot and humid because of its proximity to the tropic of cancer and it is depend on the monsoon for rains. The hot season starts from March and continues till mid June where temperature reaches up to 45^{o}C (113^{o}F). The rainy season is humid which begins in late June and ends in September and the season receive average rainfall of 1292 mm. The winter season sets in November and ends in January, however, temperature starts decreasing in September. The cultivation of betelvine in Chhattishgarh is possible only under protected structure as the summer is dry with more than 45^{o}C and winter is cold. The betelvine plant require humidity 65% and temperature less than 35^{o}C for its cultivation which is possible only under micro climate maintained under protected structure. Also the cultivation of betelvine under these structures may economic and scientifically justifiable. The area comes under dry and sub-arid condition. In such climatic condition the cultivation of betelvine is not possible in an open condition. Therefore for better plant growth, a right decision for protected environment cover material is a pivotal issue (Sapounas et al. 2010). For any crop improvement programme, systematic study and evaluation of germplasm is important for genetic improvement. A successful selection based on the information on the association of agro-morphological traits with leaf yield is important. Correlation is the mutual relationship between the variables, when there is positive correlation between major yield components, breeding strategies would be very effective. The estimates of correlation coefficients alone may be often misleading due to mutual cancellation of component characters. Therefore, the study of correlation coupled with path analysis is more effective tool in breeding for yield its contributing traits. The relationship between yield and its attributing traits estimated by correlation coupled with path coefficient analysis can help to identify the traits which can be used in the breeding programme to enhance the productivity of the betel leaf. The knowledge regarding the association among different agronomic characters for improvement of leaf yield attributes and stability of betelvine genotypes under different environment conditions is lacking. Keeping in view the above facts, the present investigation was undertaken to determine the character associations utilizing correlations and path coefficient among the various agronomic and quality traits and to evaluate the stability of genotypes under different environments. The evaluation of qualitative traits of betel leaves was also carried out.

Materials and methods

Fifteen genotypes including three checks collected from different states of India (Table 1) were considered for the study. The experiment was carried out during 2017-18 at three different protected structures namely, *Bareja* (E1), the traditional structure made of bamboo and grasses traditionally practiced by Tambola tribes well known for betelvine cultivation; advance structure, Poly tunnel (E2) and Net tunnel (E3) at research cum instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh. The objective was to create a microclimate for betelvine for its proper growth and development. Chhattisgarh is located between 17°14'N and 24°45'N latitude and 73°30'E and 84°15'E longitude. Raipur the state capital which lies at 21°16'N latitude and 81°36'E longitude with an elevation of 289.60 meters above the mean sea level. The average rainfall is around 1385 mm received mostly during June to September.

The experiment was laid out in Randomized Complete Block Design with three replications. The genotypes were evaluated for quality traits such as, protein content (g/100g), starch content (g/100g), fiber content (g/100g), potassium content (mg/g), chlorophyll content (mg/g), hedonic five point scale for organolaptic test and shelf life as quality parameters. Ten quantitative traits like, internode length (cm), diameter of internodes (cm), petiole length (cm), leaf length (cm), leaf width (cm), leaf area (cm^2), specific leaf weight (mg/cm^2), leaf area index, R-value and leaf yield (no. of harvestable leaves/vein) of betel leaves were also recorded. The correlations between yield and its contributing traits were estimated using the method described by Searle (1961). Estimates of direct and indirect effect for leaf yield were calculated

Table 1. Source of collection of genotype

S.No.	Genotypes	Source of collection
1	Bhaichigudi	Orissa
2	Meetha	Madhya Pradesh
3	Bidhan Pan	West Bengal
4	Karapaku	Andhra Pradesh
5	Awni	Assam
6	Ramtek meethapan	Maharashtra
7	Ramtek Bangla	Maharashtra
8	Ramtek kapoori	Maharashtra
9	Maghai pan	Bihar
10	Bali pan	Orissa
11	Uttkal sudama	Orissa
12	Meetha-cum-bangla	Maharashtra
13	Bangla (L)	Chhattisgarh
14	Billori (L)	Chhattisgarh
15	Kapoori (L)	Chhattisgarh

Table 2. Mean performance of betelvine genotypes for leaf yield under different protected structures

S.No	Genotypes	*Bareja* (E1)	Poly tunnel (E2)	Net tunnel (E3)	Mean	S^2di	Bi
1	Bhaichigudi	105.61	114.72	120.96	113.76	-0.09	1.56
2	Meetha	76.25	82.98	84.10	81.11	2.19	0.83
3	Bidhan pan	80.87	93.42	98.72	91.00	1.42	1.84
4	Karapaku	111.52	118.23	121.96	117.23	-0.11	1.06
5	Awni	74.34	91.05	94.08	86.49	13.43	2.08
6	Ramtek meethapan	71.06	61.53	65.41	66.00	23.81	-0.67
7	Ramtek Bangla	70.55	65.50	68.57	68.20	9.42	-0.26
8	Ramtek kapoori	72.57	77.76	80.70	77.01	-0.14	0.83
9	Maghai pan	82.64	86.07	89.99	86.23	0.62	0.73
10	Bali pan	65.27	72.76	78.24	72.09	-0.01	1.31
11	Uttkal sudama	47.41	52.59	57.59	52.53	0.61	1.02
12	Meetha-cum-bangla	58.72	68.33	71.81	66.28	1.39	1.35
13	Bangla (L)	75.67	75.94	78.79	76.80	1.62	0.29
14	Billori (L)	73.79	82.72	85.82	80.77	1.36	1.25
15	Kapoori (L)	79.54	92.79	96.17	89.50	5.75	1.74
	Mean	76.38	82.42	86.19			
	C.V.	0.78	0.74	0.57			
	SE of difference	0.48	0.50	0.40			
	CD 95%	0.99	1.02	0.83			
	CD 99%	1.34	1.38	1.12			

through path coefficient analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959). The stability parameters regression coefficient (bi) and deviation from regression (S^2di) were estimated according to Eberhart and Russel method (1966). Estimation of chlorophyll content was done by acetone method. During the acid and subsequent alkali treatment, oxidative hydrolytic degradation of the native cellouse and considerable degradation of lignin occur. The residue obtained after final filtration is weighed, incinerated, cooled and weighed again. The loss in weight gives the crude fiber content. Estimation of starch content was done by anthrone reagent. For estimation of protein content in plant samples, first nitrogen content is calculated. To determine the nitrogen content in the given plant sample estimated by method given by Kjeldahl (1883). Estimation of potassium content in plant samples was done as per Flame photometer method. Pungency of the leaf was evaluated by classifying the leaf into highly pungent, pungent, mild pungent, less pungent and not acceptable based on organoleptic evaluation by allotting maximum of 5, 4, 3, 2 and 1 points, respectively (Lim 2011) by using Hedonic five point scale. Finally, the observations given by evaluators were averaged and grouped into the particular class. Ten betel leaves were stored at room temperature and the keeping quality of leaves (Days for 50% rotting) was taken on weight basis.

Results and discussion

The protected structure *Bareja* (E1), a traditional low cost method of cultivation of betelvine has some draw backs like, un-uniform light inside the structure, the dry grasses and bamboo starts rotting after sometime and becomes house for many pest and diseases. During rains the bamboo structure starts rotting and the spores from the rotten dry grass of roof fall on betelvine plant causing diseases which sometimes become difficult to control. The average performances of the 18 betel vine genotypes along with 3 checks are shown in Table 2.The mean yield of all the varieties was lower than other two structures (Table 2). More over, the *Bareja* structure needs continuous repair and thus maintenance add to the extra cost of cultivation. In improved protected structure Poly house (E2) during summer temperature rises to more than 50°C which burn the plant and leaves, reduce the size of internodes and leaves. The mean performance recorded in poly tunnel (E2) was higher than the E1. On the other hand, in the Net tunnel (E3) the performance was better over both E1 and E2, likely because the light intensity, temperature or microclimate is even, cross ventilation reduce the temperature in summer, cost is less than polyhouse (E2) and it is durable than *Bareja* (E1). The both improved structure had facility of drip irrigation and micro fogger to reduce temperature and maintaining humidity, respectively.

Quality parameters

Analysis of variance worked out for different qualitative characters indicated that the Mean sum of squares due to genotypes were highly significant for all the characters (Table 3). Significant mean sum of square due to the qualitative characters revealed existence of considerable variability in the material studied for the improvement of various traits and better chances of improvement through selection on the basis of these traits.

The five quality parameters were studied and the values were compared with checks and market sample (Table 4). Organolaptic test for pungency and shelf life was also conducted. Awni and Meetha paan recorded the maximum contents (2.68 g/100g and 2.64 g/100g, respectively) of protein which may not be significantly different than the market sample (Meetha). The genotype Awni and Meetha paan were found significantly different than local check Billori at 5% probability level while rest of the genotypes were found non-significant. However, on comparing with the market sample Meetha, the genotype Awni and Meetha paan were not found significantly different at 5% probability

Table 3. Analysis of variance for different qualitative characters in betelvine

Source of variation	D.F.	Shelf life (in days)	Chlorophyll content (mg/g)	Potassium (mg/100g)	Starch content (g/100g)	Fiber content (g/100g)	Protein content (g/100g)
Replication	2	12.25**	0.01	124.70	0.02	0.03	0.04
Treatment	17	223.87**	4.19**	571581.9**	19.60**	5.27**	7.89**
Error	34	53.07	0.23	1981.96	0.33	0.24	0.37

*, ** Significant at 5% and 1% probability level, respectively

level, whereas rest of the genotypes were significantly different indicating that no variety of betelvine exceeded the control variety Meetha in the protein contents except Awni and Meetha paan. Sashidhar (2006) and Guha (2006) also analysed the quality parameters and reported a wide range of protein contents in paan.

In betelvine leaves low content of fiber is preferred. While comparing the mean values of fiber content with local check Kapoori (2.23 g/100g), Meetha paan (1.75) and a market sample paan Meetha (1.72 g/100g) were at par and but significantly superior to Kapoori (Table 4). The remaining genotypes were significantly inferior in fibre contents. With respect to mean value for starch content, the genotype, Kapoori (LC) is found superior (4.65 g/100g) as compared to market sample the genotypes Meetha (5.85 g/100g) and Meetha paan (5.86g|100g) were found superior. Most of the varieties, including the local checks, were significantly inferior to market sample Meetha. The genotypes, Bidhan pan, Ramtek meetha paan were the only varieties, which produced higher contents of potassium as compared to lacal check Bangla (860 mg|100g) and the market sampla Meetha (862 mg|100g) (Table 4). However, the varieties, Bhaichugdi and Meetha-cum Bangla were inferior in potassium comtents as compared to lacal checks and market samples. The chlorophyll contents in the genotypes, Karapaku (2.73 mg|g) and Awni (2.60 mg|g) were significantly highert than the local checks and market samples (Table 4) which recorded the maximum mean values of 2.45 mg|g) and 2.37 mg|g), respectively. The remaining genotypes had mean values at par or less than that of some check genotypes or market samples.

The keeping quality (shelf life) of betelvine genotypes was evaluated on the bases of 50% loss in leaf weight. Under 12 to 18 days storage, the intensity of deterioration of leaf varied with genotypes. Pariari et al. (2008) had also considered a similar criterion to judge the shelf life of betelvine and reported variation among the varieties They further advocated that the differences in enzymatic reactions, fibre content in leaf, etc. are the primary reasons for quality deterioration. Keeping quality of betel leaves in highly influenced by different methods of cultivation and environmental variation during the season it is being grown (Imam and Pariari 2012). The genotypes like Karapaku and Bhaichigudi had the highest shelf life duration of >19 days (Table 4), whereas the lowest shelf life (about 12 days) was recorded in Ramtek meetha paan and control variet Kapoori. Sashidhar (2006) also reported similar observations but in a different set of material. Most of the popular varieties such as Maghai, Meetha-cum-bangla etc. and liked by the paan chewers do not exceed in quality content and possess moderate value of protein, starch, fibre, potassium and chlorophyll contents. These genotypes were also categorized for shelf life by Sashidhar (2006). Keeping quality of betelvine is most important trait for pan growers and therefore, the breeders must consider the trait of shelf life as most important while selecting the suitable genotype. A large number of genotypes must be screened for this trait to select the suitable parents. Crosses should be attempted between the genotypes having shelf life for maximum number of days such as Karapaku and Bichugdi to look for transgressive segregants. A study carried out by Sashidhar (2006) also reported similar findings. Guha (2006) also studied nutritional composition and other parameters in betel leaf and reported that values for phosphorus, potassium and calcium ranged from 0.05 to 0.60%, 1.1 to 4.6% and 0.20 to 0.50%, respectively.

Ranking of different betelvine cultivars based on pungency was done by organoleptic test. The Hedonic five point scale was used for this study. The genotype Meetha (2.30/5.00) and Bali paan (2.40/5.00) recorded lower scores for pungency indicating low pungent characters as reported earlier (Arulmozhiyan et al. 2004). The pungency varies among the paan varieties and ranges from less pungent to highly pungent genotypes. However, there is also a variation among the pan chewers to like pungency or not and hence the improvement of betelvine should be focused based on the choice of the consumers.

Correlation and path analysis

Correlation coefficient between ten character pair of fifteen betelvine genotypes were computed in all possible combination at phenotypic and genotypic level and the results are presented in Table 5 and 6, respectively. The results indicated that in most of the cases, genotypic and phenotypic correlation was similar in direction, whereas, genotypic correlation was higher than the corresponding phenotypic correlation. A similar trend in correlations was reported by Diyali et al. (2014). These estimates of genotypic correlations along with phenotypic correlations display clear picture of the extent of inherent association as well as indicate the extent to which these phenotypically expressed correlations are influenced by the environment. The

Table 4. Leaf quality attributes of betelvine genotypes

S.No.	Genotypes	Protein (g/100g)	Fiber (g/100 g)	Starch (g/100 g)	Potassium (mg/100 g)	Chlorophyll (mg/g)	Shelf life (in days)
1	Bali pan	1.91	2.15	5.13	736.00	2.13	15.00
2	Bidhan pan	2.17	2.25	4.35	989.00	2.20	18.00
3	Karapaku	2.08	2.65	3.71	815.00	2.73	19.00
4	Uttkal sudama	1.75	2.02	5.04	792.00	1.91	16.00
5	Awni	2.68	1.85	4.35	712.00	2.60	17.00
6	Ramtek bangla	1.78	2.09	4.54	668.00	2.11	15.00
7	Ramtek kapoori	1.51	2.15	4.74	776.00	1.86	13.00
8	Bhaichigudi	1.73	2.62	3.86	591.00	1.84	19.66
9	Maghai pan	1.43	2.48	3.92	752.00	2.10	16.66
10	Meetha pan	2.64	1.75	5.86	852.00	1.93	14.67
11	Ramtek meetha pan	1.83	1.96	5.26	940.00	2.03	12.33
12	Meetha-cum- bangla	1.36	2.08	5.37	584.00	2.13	13.33
13	Kapoori (L)	1.84	2.23	4.65	820.00	1.74	12.66
14	Billori (L)	2.35	2.64	4.35	755.00	2.38	16.66
15	Bangla (L)	2.24	2.60	4.61	860.00	2.45	15.00
	Market sample						
16	Bangla	2.52	2.72	4.53	857.00	2.37	16.33
17	Meetha	2.63	1.72	5.85	862.00	1.92	14.00
18	Kapoori	1.83	2.14	4.45	785.00	1.75	16.00
	CV%	4.02	3.83	2.10	0.97	3.95	8.02
	C.D.	0.17	0.14	0.16	12.66	0.13	2.07

yield attribute in terms of number of leaves per vein could be increased with increase in leaf width (0.802 and 0.819) followed by leaf area (0.790 and 0.808), leaf area index (0.782 and 0.800), leaf length (0.745 and 0.759), specific leaf weight (0.681 and 0.709), petiole length (0.658 and 0.705), diameter of internodes (0.484 and 0.559) and R-value (0.112 and 0.110) as these characters were positively associated with number of leaves per vein at both phenotypic and genotypic level, respectively. Das et al. (1999) in their study also reported that the number of leaves per vine had positive correlation with leaf area, leaf length, leaf width, number of laterals per vine, vine length, diameter of internodes, chlorophyll a and b contents and 100 leaf weight. Verma et al. (2003) studied in betelvine that number of nodes was having significant positive association (0.423) with yield. Correlation does not reflect the clear picture of contribution of each component traits. At the same time, as more variables are included in association studies, the direct association becomes complex. Under such situation, path coefficient analysis permits separation of correlation coefficients into components of direct and indirect effects. Partitioning of total correlation into direct and indirect effects provides actual information on contribution of characters and thus forms the basis for selection to improve the yield.

The path-coefficient analysis at phenotypic level revealed that highest positive direct effect on leaf yield was exerted by leaf width (0.8772) followed by leaf length (0.4712), leaf area (0.2560), diameter of internodes (0.1993) and petiole length (0.1277), while highest negative direct effect was imposed by specific leaf weight (–1.0665), internode length (–0.2663), R-value (–0.2033) and leaf area index (–0.0917) (Table 7). At genotypic level, it was found that highest positive direct effect on leaf yield was exerted by leaf area (1.3544) followed by leaf width (0.8986), leaf length (0.2650), petiole length (0.1486) and diameter of internodes (0.1032), it reveals actual relationships between them and direct selection for this traits will be rewarding for improvement for leaf yield while highest negative direct effect was imposed by leaf area index (-1.7389), specific leaf weight (-0.7394), internode length (-0.7356) and R-value (-0.1942). The estimation of residual effect is negligible for phenotypic (0.0423) and genotypic (0.0258) which shows that the trait under study contributes for leaf yield.

Stability analysis

The estimates of stability parameters (mean, regression coefficient bi and deviation mean squares S^2di) for fifteen betelvine genotypes for ten quantitative traits are given in Table 7. An ideal genotype according to Eberhart and Russel (1966) would be one with high mean, unit regression coefficient (bi=1) and low deviation mean squares ($S^2di=0$). They further pointed out that the varieties exhibiting high regression coefficient (bi>1) could be considered as below average stable varieties. Such varieties will do well only in favorable environments and their performance will be poor in poor environments. The varieties with low regression coefficient (bi<1) have above average stability and are adapted specifically to poor environments. Considering overall performance in respect of internode length, diameter of internodes, petiole length, leaf area (cm^2), leaf area index, leaf length, leaf width, specific leaf weight (mg/cm^2), R-value and leaf yield (No. of harvestable leaves per vine) under different environments, genotypes were ranked based on the stability of all the traits studied. Karpaku was stable (9|10), except for internode length, for diameter of internodes, petiole length, leaf length, leaf width, leaf area, leaf area index, specific leaf weight and leaf yield over all environments while Bhaichigudi followed Karpaku and ranked second (6|10) and showed stability in six

Table 5. Correlation coefficient analysis at phenotypic and genotypic level in betelvine

Character	Internode length (cm)	Diameter of internodes (cm)	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Specific leaf weight (mg/cm^2)	Leaf area index	R-value
Internode length (cm)	**1.0000**								
Diameter of internodes (cm)	-0.3641** **-0.5758****	**1.0000**							
Petiole length (cm)	-0.5435** **-0.6271****	0.4059** **0.5358****	**1.0000**						
Leaf length (cm)	-0.7239** **-0.8343****	0.4027** **0.4847****	0.6991** **0.7472****	**1.0000**					
Leaf width (cm)	-0.7055** **-0.7960****	0.5665** **0.6735****	0.7569** **0.7981****	0.8349** **0.8477****	**1.0000**				
Leaf area (cm^2)	-0.7812** **-0.8744****	0.5629** **0.6769****	0.6744** **0.7041****	0.8448** **0.8551****	0.9174** **0.9232****	**1.0000**			
Specific leaf weight (mg/cm^2)	-0.6887** **-0.7682****	0.6086** **0.7325****	0.6923** **0.7261****	0.8373** **0.8602****	0.9188** **0.9319****	0.9422** **0.9526****	**1.0000**		
Leaf area index	-0.7793** **-0.8742****	0.5590** **0.6735****	0.6755** **0.7041****	0.8492** **0.8623****	0.9144** **0.9226****	0.9946** **0.9978****	0.9420** **0.9514****	**1.0000**	
R-value	0.0147 **-0.0035**	-0.0264 **-0.0816**	0.2964** **0.3485****	0.3220** **0.3307****	0.1799* **0.1755***	-0.0152- **0.1030***	0.0027 **0.0022**	-0.0842 **-0.0890**	**1.0000**
Leaf yield (No. of harvestable leaves per vine)	-0.7653 **-0.9199**	0.4840 **0.5598**	0.6588 **0.7050**	0.7459 **0.7598**	0.8025 **0.8197**	0.7905 **0.8087**	0.6814 **0.7097**	0.7828 **0.8009**	0.1128 **0.1107**

Table 6. Path coefficient analysis for leaf yield at phenotypic and genotypic level in betelvine

Character	Internode length (cm) (cm)	Diameter of internodes	Petiole length (cm)	Leaf length (cm)	Leaf width (cm)	Leaf area (cm^2)	Specific leaf weight (mg/cm^2)	Leaf area index	R-value
Internode length (cm)	-0.2663 **-0.7356**	0.0970 **0.4236**	0.1447 **0.4613**	0.1928 **0.6137**	0.1879 **0.5855**	0.2081 **0.6432**	0.1834 **0.5651**	0.2075 **0.6430**	-0.0039 **0.0025**
Diameter of internodes (cm)	-0.0726 **-0.0594**	0.1993 **0.1032**	0.0809 **0.0553**	0.0803 **0.0500**	0.1129 **0.0695**	0.1122 **0.0698**	0.1213 **0.0756**	0.1114 **0.0695**	-0.0053 **-0.0084**
Petiole length (cm)	-0.0694 **-0.0932**	0.0518 **0.0796**	0.1277 **0.1486**	0.0893 **0.1111**	0.0966 **0.1186**	0.0861 **0.1047**	0.0884 **0.1079**	0.0862 **0.1047**	0.0378 **0.0518**
Leaf length (cm)	-0.3411 **-0.2211**	0.1898 **0.1284**	0.3294 **0.1980**	0.4712 **0.2650**	0.3934 **0.2246**	0.3981 **0.2266**	0.3945 **0.2279**	0.4002 **0.2285**	0.1517 **0.0876**
Leaf width (cm)	-0.6188 **-0.7153**	0.4970 **0.6052**	0.6639 **0.7172**	0.7324 **0.7618**	0.8772 **0.8986**	0.8048 **0.8296**	0.8060 **0.8374**	0.8021 **0.8290**	0.1578 **0.1577**
Leaf area (cm^2)	-0.2000 **-1.1843**	0.1441 **0.9168**	0.1726 **0.9536**	0.2162 **1.1581**	0.2348 **1.2503**	0.2560 **1.3544**	0.2412 **1.2902**	0.2546 **1.3514**	-0.0269 **-0.1395**
Specific leaf weight (mg/cm^2)	0.7345 **0.5681**	-0.6490 **-0.5417**	-0.7383 **-0.5369**	-0.8929 **-0.6361**	-0.9800- **0.6891**	-1.0048 **-0.7044**	-1.0665 **-0.7394**	-1.0047 **-0.7035**	-0.0029 **-0.0016**
Leaf area index	0.0714 **1.5202**	-0.0513 **-1.1712**	-0.0619 **-1.2244**	-0.0779 **-1.4495**	-0.0838- **1.6043**	-0.0912 **-1.7351**	-0.0864 **-1.6545**	-0.0917 **-1.7389**	0.0077 **0.1548**
R-value	-0.0030 **0.0007**	0.0054 **0.0158**	-0.0602 **-0.0677**	-0.0654 **-0.0642**	-0.0366- **0.0341**	0.0214 **0.0200**	-0.0006 **-0.0004**	0.0171 **0.0173**	-0.2033 **-0.1942**
Leaf yield (No. of harvestable leaves per vine)	-0.7653- **0.9199**	0.4840 **0.5598**	0.6588 **0.7050**	0.7459 **0.7598**	0.8025 **0.8197**	0.7905 **0.8087**	0.6814 **0.7097**	0.7828 **0.8009**	0.1128 **0.1107**
Partial R^2	0.2038 **0.6767**	0.0965 **0.0578**	0.084 1**0.1048**	0.3515 **0.2013**	0.7040 **0.7366**	0.2023 **1.0952**	-0.7267 **-0.5248**	-0.0718 **-1.3927**	-0.0229 **-0.0215**

traits over all checks. All the genotypes were classified as: Genotypes stable over all the environment, desirable for favourable environment, desirable for poor environment, genotypes with low mean, bi > 1 and genotypes poor for all the environments. Meetha was stable for leaf length. Bidhan pan was stable for diameter of internodes, petiole length, leaf length, leaf area index and R-value. Thus cultivar Bhaichigudi, Karapaku and Maghai could be considered widely adapted and stable or these genotypes showed ability to express its potential in a range of environmental conditions for leaf yield. Raharman et al. (1997) also reported phenotypic stability for yield and yield attributing traits for twenty-seven genotypes of betel vine during winter, summer and rainy season under field conditions to check the extent and nature of Genotype × Environmental interaction. However, the present study was conducted under protected structure.

Positive and significant association of yield with leaf width, leaf area, leaf area index, leaf length, specific leaf weight, petiole length, diameter of internodes and R-value and the negative significant correlation with internode length indicated that direct selection for these traits may be advantageous in selecting the high yielding genotypes of betelvine from

Table 7. Mean performance and stability for leaf yield and its components in betelvine under protected environments

	Genotypes	Internode length (cm)			Diameter of internodes (cm)			Petiole length (cm)		
		μ	Bi	S^2di	μ	bi	S^2di	μ	Bi	S^2di
1	Bhaichigudi	6.33	1.34	0.05*	2.47	0.81	-0.02	7.66	1.21	0.00
2	Meetha	6.99	0.96	-0.01	1.89	0.60	-0.01	5.12	0.93	0.02
3	Bidhan pan	7.02	1.34	0.01	2.09	1.44	0.03	7.19	1.17	0.01
4	Karapaku	6.78	1.39	0.01	2.22	0.74	-0.01	7.22	1.43	-0.01
5	Awni	7.01	1.37	-0.01	2.36	0.93	-0.01	6.17	0.61	-0.01
6	Ramtek meethapan	7.51	0.52	0.01	1.70	0.45	-0.01	4.69	0.70	0.00
7	Ramtek Bangla	7.31	0.51	-0.01	2.08	0.47	-0.01	6.17	0.94	0.00
8	Ramtek kapoori	7.48	0.84	-0.01	2.01	1.01	-0.02	5.62	0.87	-0.02
9	Maghai pan	7.24	0.44	-0.01	2.11	1.38	-0.01	6.29	1.40	0.21***
10	Bali pan	7.33	1.68	-0.01	2.14	1.61*	-0.02	6.20	1.64	0.08*
11	Uttkal sudama	7.87	0.53	0.00	1.94	0.88	-0.02	5.94	0.97	0.02
12	Meethacum bangla	7.49	0.87	0.04	1.94	1.75	-0.01	4.50	0.85	-0.01
13	Bangla (L)	7.45	0.74	-0.01	2.03	0.84	-0.01	6.93	1.02	0.08*
14	Billori (L)	6.97	1.28	-0.01	2.21	1.08	-0.02	6.30	0.46	0.00
15	Kapoori (L)	6.94	1.20	-0.01	1.69	1.00	-0.02	7.01	0.81	0.00
	Population mean	7.18	2.07	6.21						

Genotypes	Leaf length (cm)			Leaf width (cm)			Leaf area (cm^2)			Specific leaf weight (mg/cm^2)		
	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di	μ	bi	S^2di
1	12.03	2.54	0.03	8.43	0.78	0.03	112.76	0.78	0.15	6.02	0.76	0.01
2	9.29	0.85	0.01	4.52	0.55	0.03	44.38	0.62*	-0.10	3.16	0.53	-0.01
3	10.54	1.43	-0.02	7.37	1.58	-0.01	78.87	1.30	0.97**	4.73	0.36	-0.01
4	11.15	1.39	0.17**	7.56	1.21	-0.02	82.13	0.96	-0.10	5.35	1.39	0.00
5	8.91	0.99	0.03	6.82	0.76	0.04	58.37	0.83	0.34*	4.71	-0.04	0.00
6	5.99	0.39	-0.01	4.29	0.45	-0.01	29.29	0.99	0.69**	2.56	0.87	-0.02
7	7.41	0.76	0.01	4.86	0.94	-0.02	36.01	0.49*	-0.08	3.57	1.82	0.02
8	5.77	0.58	0.01	4.09	1.11	-0.01	29.08	0.87*	-0.11	2.51	0.76	-0.02
9	6.37	0.80	0.07*	5.03	1.30	-0.02	31.83	1.60	3.59***	2.74	0.75	-0.02
10	8.42	0.88	0.04	4.53	1.17	0.02	34.99	1.29*	-0.10	3.26	0.99	-0.01
11	6.26	0.64	-0.02	4.72	1.30	-0.01	37.25	1.20	-0.04	3.50	1.00	0.02
12	6.93	1.19	0.11*	4.71	1.05	-0.02	31.39	0.83	0.13	2.94	1.32	-0.01
13	10.14	0.73	0.02	5.98	0.80	0.00	40.21	1.06	8.67***	3.76	2.09	-0.02
14	10.46	1.14*	-0.02	6.11	1.17*	-0.02	74.43	1.06	0.09	5.20	0.24	-0.02
15	9.70	0.69	-0.01	5.65	0.85	-0.01	48.24	1.13	0.31	3.49	2.16	-0.02
Population mean		8.63			5.64			50.81			3.83	

Table continued…

Genotypes	Leaf area index			R-value			Leaf yield (no. of harvestable leaves/vein)		
	μ	Bi	S^2di	μ	bi	S^2di	μ	Bi	S^2di
1	11.31	1.51	0.09*	0.89	0.87	0.01*	113.77	1.06*	-0.09
2	3.58	0.94	-0.02	0.95	0.86	0.00	81.11	0.83	2.20***
3	6.25	0.99	0.00	1.08	1.06	0.00	91.01	1.84	1.42**
4	7.478	1.24*	-0.02	1.03	1.00	0.00	117.24	1.07	0.11
5	5.14	1.81	0.01	1.04	0.58	0.01*	86.49	2.08	13.43***
6	1.38	0.67	0.00	0.89	1.07	0.01*	66.01	-0.67	23.82***
7	2.40	1.13	-0.02	1.02	0.86	0.00	68.21	-0.26	9.42***
8	1.57	0.49	-0.01	0.88	1.08	0.00	77.01	0.83	-0.14
9	1.61	0.85	-0.02	1.04	1.85	0.00	86.24	0.73	0.03*
10	2.21	0.48*	-0.02	1.10	1.22	0.00	72.09	1.31	0.00
11	2.71	0.43	0.00	0.79	1.04	0.00	52.54	1.02	0.61*
12	1.90	0.76	-0.01	1.03	1.08	0.00	66.29	1.36	1.40**
13	3.05	1.58	-0.01	1.51	0.58	0.00	76.81	0.29	1.62**
14	6.45	0.57	0.02	0.85	0.75	0.00	80.78	1.25	1.36**
15	3.95	1.56	0.02	1.14	1.10	0.00	89.50	1.74	5.75***
Population mean		**4.07**			**1.01**			**81.67**	

* = Significant at 5% probability level, ** = Significant at 1% probability level, *** = Significant at 0.5% probability level

available germplasm accessions. However, the study is conducted on limited number of genotypes, it is advocated therefore, to study the large number of germplasm lines to make the selection more effective. Path coefficient analysis also suggested that the traits leaf area, leaf width, leaf length, petiole length and diameter of internodes are not affected by other component characters and environment. The study further indicated that the association was true of such character and direct effect of these character on leaf yield (no. of leaves harvested/vein) was the major causal factor in determining the various correlation coefficient estimates and the role of indirect effect in counter, balancing the direct effect. Therefore, direct selection for this character will be beneficial in improving the leaf yield in betelvine. Growing of betelvine under Net tunnel may be considered optimum for better growth and higher leaf yield under closed type system of cultivation. Considering the mean, bi and S^2di for all the parameters, all the genotypes showed different response to adaptability under different sets of environment. From the economic point of view the cultivar Karapaku, Bhaichigudi and Maghai may be considered as suitable for cultivating in closed conservatories under Raipur region of Chhattisgarh.

Authors' contribution

Conceptualization of research (AT, ATa, TT); Designing of the experiments (AT, VR); Contribution of experimental materials (AT, ATa); Execution of field/ lab experiments and data collection (AT, SSP, NK); Analysis of data and interpretation (AT, PK); Preparation of manuscript (AT, PK).

Declaration

The authors declare no conflict of interest.

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