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Trait Association and Path Coefficient analysis of Burmese Grape (*Baccaurea sapida* Muell. Arg.)

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***Abstract*— This experiment was conducted to select the suitable yield and yield contributing characters of twenty-five burmese grape genotypes by correlation coefficient and path coefficient analysis. Correlation coefficient analysis revealed that fruits yield per plant (kg.) had a highly significant positive correlation with base girth (0.68), canopy spreading at east-west direction (0.65), Canopy spreading at north-south direction (0.54) and plant height (0.52). Fruits yield per plant (kg.) showed a significant positive correlation with the weight of seeds per fruit (0.5) and the number of seeds per fruit (0.42) which indicated that yield could be increased by the emphasis upon these traits. The number of fruits per plant (1.067) showed the highest positive direct effect on fruits yield per plant and the considerable positive direct effect observed in fruit length (0.715) followed by plant height (0.566), base girth (0.341), edible percentage (0.329) and canopy spreading at north-south direction (0.275) and most other traits linked upon fruit yield per tree have indirect contribution within these traits. Therefore, it might be assumed that these traits could be considered as the most significant yield contributing traits in Burmese grape to develop improved quality and high yielding burmese grape variety.**

Keywords— Burmese grape; correlation; path analysis.

I. INTRODUCTION

Burmese grape (*Baccaurea sapida* Muell. Arg.) is a dioecious under-utilized fruit crop under the family Euphorbiaceae, which is originated in South-east Asian region [1]–[3]. It grows as wild and under cultivation largely in Bangladesh, Bhutan, India, Malaysia, Myanmar, Nepal, South China, Indo-China, and Thailand [3]–[6]. It is an evergreen, short to medium height, shade loving plant with slow-growing nature and the cropping pattern is mild biennial [7]–[9]. Due to shade-loving nature of the plant, it can be cultivated where other crops cannot be grown because of shade. So, the tree plays an important role in the agroforestry system to use the lands properly by growing under the big trees like jackfruit, mango, coconut, litchi and so on. In Bangladesh, this is a minor fruit crop that is grown in the homestead garden and forest [1], [10]. It is cultivated mainly in Gazipur, Kishoregonj, Narsingdi, Moulvibazar, Netrokona, and Sylhet districts of Bangladesh and among these, the cultivation of Burmese grape is the highest in the Narshingdi district due to red soil which is favorable for the production of large and sweet Burmese grape [1], [11]. The total production of Burmese grape in Bangladesh was 877 metric tons in 2018-2019 [12]. Locally in Bangladesh, the fruit is called 'Latkan' which is slightly acidic and mainly consumed as fresh fruit [1], [13] and chutney, sauce, pickle, and squash can be made by its fruit pulp [14], [15]. The fruit is a good source of pectin which is used to make valuable products such as jam and jelly. Likewise, it can be used for good quality wine preparation [1], [16], [17]. In Bangladesh, young leaves are eaten as a vegetable and also used as flavoring agents in the minced meat and curries [1], [5], [18]. Moreover, valuable "annatto" dye is produced from Burmese grape seeds, which is used for coloring (mainly orange color) different textile materials such as silk and cotton [1], [5], [6], [17], [19].

Burmese grape has good nutritional value which contains ash, protein, carbohydrate, fat (negligible), minerals (i.e. calcium, potassium, phosphorus, and sodium), and vitamins. Moreover, the fruit gains importance as a novel food additive due to the presence of large amount of vitamin C, protein, and iron [5], [16], [17], [20], [21]. The fruit contains carbohydrate (51.9%), water (35.6%), fiber (20.4%), protein (5.58%), ash (3.85%), and lipid (0.73%) per 100 gm of fruit pulp. It also contains some minerals namely 730 mg potassium, 504mg magnesium, 132 mg phosphorous, 100 mg iron, 75 mg calcium, and 35 mg sodium and vitamins e.g. vitamin C (273 mg) per 100gm of fruit pulp [5], [6]. From the medicinal point of view, the entire plant of Burmese grape is significant and several studies have been conducted to investigate the health benefits of various parts of the plant such as leaves, bark, roots, fruits, wood, and seeds. It is used as anodyne and antiphlogistic against rheumatoid arthritis, cellulitis, abscesses, treat injuries [1], [5], [6], [15], [17], [22] and skin disease treatment [23], [24]. Similarly, constipation can be treated by fresh bark taken orally as juice or chewed [1], [5], [6], [13], [15], [17]. Moreover, antiviral and antioxidant attributes are present in the fruit and diuretic characteristics present in the stem bark [5], [16], [22]. It is also used as a medicinal plant by hill-tribes of Northern Thailand [17], [25]. The fruit has a balanced sodium and potassium ratio, which can help to prevent non-communicable diseases (NCDs) significantly, namely hypertension, chronic kidney stone formation, cardiovascular diseases [5], [6], [26], [27]. Due to its versatile use, nutritional properties and health benefits, it is gaining popularity in Bangladesh day by day, but very few studies were done on Burmese grape to improve this fruit. Correlation is the biometrical method to get precise knowledge about the nature and degree of relationship between various traits indicating yield, while path analysis splits the correlation coefficient into direct and indirect effect for measuring the relative contribution of each variable towards the yield. Correlation with path coefficient analysis give information about the direct and indirect contribution of one trait upon another and would provide a clear outline of genetic association among different traits [28]–[30]. Therefore, this study aims to investigate the correlation and path coefficient analysis of various horticultural parameters contributing toward the yield, which will be helpful for the selection of traits to improve the fruit.

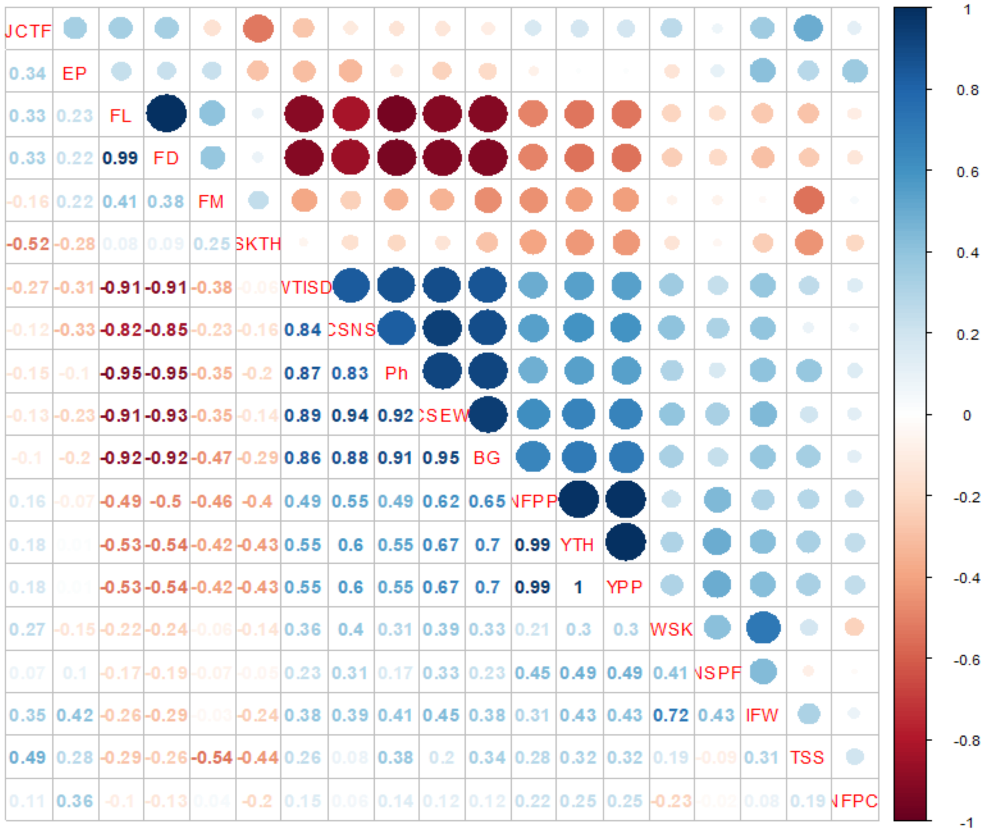

Figure 1. Correlation co-efficient between 18 yield and yield contributing characters in 25 Burmese grape genotypes. Where, **PH**= Plant Height (cm), **BG**= Base girth (cm), **CSNS**= Canopy spreading at north-south direction (cm), **CSEW**= Canopy spreading at east-west direction (cm), **DFM**= Days to fruit maturity (days), **NFPC**= Number of fruits per cluster, **IFW**= Individual fruit weight (g), **FL**= Fruit length (mm), **FD**= Fruit diameter (mm), **WPL**= Weight of peel (g), **NSPF**= Number of seeds per fruit, **WTSD**= Weight of seeds per fruit (g), **SKTK**= Peel thickness (mm), **EP**= Edible percentage, **JCTF**= Juice content per ten fruits (ml), **TSS**=% Brix, **NFPP**= Number of fruits per plant, **FYPP**=Fruits yield per plant (kg.), **YTH**= Fruit yield (t/ha)

II. MATERIALS AND METHODS

The experiment was conducted at fruit genetic resources collection and conservation block of Regional Agricultural Research Station, Bangladesh Agricultural Research Institute, Akbarpur, Moulvibazar, Bangladesh during February to September, 2018. The experiment was performed with twenty-five Burmese grape genotypes grown in shades of mixed agroforestry gardening having Jackfruits (Artocarpus heterophyllus Lam.) and white siris (Albizia procera Roxb.). The plants were laid out in randomized complete block design and each plant was considered as a replication. The distance from plant to plant was 4 m and row to row was 4 m. Individual plants were fertilized with cow dung (20 kg), urea (500 g), TSP (500 g), MP (500 g), gypsum (200 g), Zinc (4 g), boron (4 g) in two equal splits, one at the onset and other at the end of rainy season [31]. Irrigation, weeding and other crop management practices were followed as to have a good healthy plant. Data on plant height (m), canopy spreading (m), number of flowers per cluster, number of fruits per plant, individual fruit weight (g), fruit length (cm) and breadth (cm), number of segments per fruit, number and weight (g) of seeds per fruit, edible percentage, % Brix (TSS) and yield per plant (kg.) were recorded. The correlation coefficients were calculated as per [32]. Path coefficients were estimated according to [29], where fruit yield per plant (kg.) was kept as resultant variable and other contributing characters as causal variables. The path and correlation analyses were analyzed using R version 3.6.3 [33]. for correlation and path analysis and visualization with agricolae and corrplot packages [34], [35].

III. Results and Discussions

CORRELATION COEFFICIENT ANALYSIS

Various quantitative characters influence yield which is a complex trail. To investigate the association among the characters and their correlation with yield is very much crucial for selection criteria. Because plant breeders continuously search for genetic variation among characters to select the desired character for crop improvement. The correlation coefficient study showed both positive and negative relationships with different levels of significance among the characters studied (Figure 1 and Supplementary Table 1).

Plant height showed highly significant positive correlation with canopy spreading at east-west direction (0.92), followed by base girth (0.91), weight of seeds per fruit (0.86), canopy spreading at north-south direction (0.82), and fruits yield per plant (0.52), whereas, positive and significant correlation was observed in case of number of fruits per plant (0.45). [36] observed that plant height had a significant correlation with canopy spreading at north-south direction, number of fruits per plant, fruit diameter, and fruits yield per plant in pummelo. [37] was observed positive correlation of plant height with canopy spread, number of fruits per plant, and fruit yield per plant in sapota. Plant height showed positive significant interrelationship with yield in potato but positive non-significant relationship in tomato also [38], [39], On the other hand, fruit length (-0.95) and fruit diameter (-0.95) exhibited a highly significant negative relationship with plant height. Moreover, plant height showed a non-significant positive correlation with number of fruits per cluster, individual fruit weight, weight of peel, number of seeds per fruit, and TSS and negative non-significant correlation with days to fruit maturity, peel thickness, edible percentage and juice content per ten fruits.

Base girth exhibited highly significant positive correlation with canopy spreading at east-west direction (0.95), canopy spreading at north-south direction (0.88), weight of seeds per fruit (0.85), fruits yield per plant (0.68), and number of fruits per plant (0.63), highly significant negative correlation with fruit diameter (-0.92) and fruit length (-0.91), whereas, days to fruit maturity (-0.48) showed a significant negative relationship with base girth. Furthermore, the number of fruits per cluster, individual fruit weight, weight of peel, number of seeds per fruit, and TSS showed a non-significant positive correlation, while, peel thickness, edible percentage, and juice content per ten fruits exhibited a non-significant negative relationship with base girth. Canopy spreading at north-south direction showed highly significant positive correlation with canopy spreading at east-west direction (0.94), weight of seeds per fruit (0.82), and fruits yield per plant (0.54) and positive significant relationship with number of fruits per plant (0.5). This may be due to higher photosynthesis area with more light harvest resulting higher partitioning of assimilates to the sink such as fruits [36], [37]. A highly significant negative correlation was observed in the case of fruit diameter (-0.85) and fruit length (-0.82). Canopy spreading at north-south direction showed a significant positive correlation with canopy spreading at east-west direction but significant positive correlation with fruit diameter and number of seeds per fruit showed significant negative correlation in pummelo research conducted by [38]. Moreover, number of fruits per cluster, individual fruit weight, weight of peel, number of seeds per fruit, and TSS had non-significant positive relationship and days to fruit maturity, peel thickness, edible percentage, and juice content per ten fruits had a non-significant negative correlation with canopy spreading at north-south direction. Canopy spreading at east-west direction exhibited highly significant positive correlation with weight of seeds per fruit (0.88), fruits yield per plant (0.65), and number of fruits per plant (0.6), while, individual fruit weight (0.42) presented significant positive correlation. On the other hand, canopy spreading at east-west direction showed a highly significant negative correlation with fruit diameter (-0.93) and fruit length (-0.91). Moreover, canopy spreading at east-west direction had a non-significant positive correlation with number of fruits per cluster, weight of peel, number of seeds per fruit, and TSS and non-significant negative correlation with days to fruit maturity, peel thickness, edible percentage, and juice content per ten fruits.

Days to fruit maturity showed a significant positive correlation with fruit length (0.42) and significant negative correlation with number of fruits per plant (-0.48) and weight of seeds per fruit (-0.4). But TSS (-

0.54) showed a highly significant negative correlation with days to fruit maturity. Furthermore, days to fruit maturity had a non-significant positive correlation with number of fruits per cluster, fruit diameter, peel thickness, and edible percentage and non-significant negative correlation with individual fruit weight, weight of peel, number of seeds per fruit, juice content per ten fruits and fruits yield per plant. The number of fruits per cluster exhibited a non-significant positive correlation with individual fruit weight, weight of seeds per fruit, edible percentage, juice content per ten fruits, TSS, number of fruits per plant, and fruits yield per plant. [8] was observed a negatively significant correlation between number of fruit and TSS and [42] reported that number of fruits per plant had a highly significant positive correlation with fruit yield in mango. On the other hand, a non-significant negative correlation was observed in the case of fruit length, fruit diameter, weight of peel, number of seeds per fruit, and peel thickness.

Individual fruit weight was in a highly significant positive correlation with weight of peel (0.71), a similar result was found by [8] and a significant positive correlation with edible percentage (0.41). Moreover, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, TSS, number of fruits per plant, and fruits yield per plant exhibited non-significant positive correlation and fruit length, fruit diameter, and peel thickness exhibited a non-significant negative relationship with individual fruit weight. In case of pummelo, individual fruit weight showed a highly significant positive correlation with fruit diameter, fruits yield per plant, and significant positive correlation with fruit length, a study conducted by [38]. Moreover, [43] found that fruit weight had a highly significant positive correlation with number of fruits per tree and yield per tree in jackfruit. In case of lime, same findings were reported by [44] between fruit weight and yield of lime. [45] also observed significant positive correlation between fruit weight and yield. Again, in tomato, negative and highly significant correlation between individual fruit weight and TSS (-0.62) were found by [40], [46]. Fruit length showed a highly significant positive correlation with fruit diameter (0.99), while, weight of seeds per fruit (-0.9) and fruits yield per plant (-0.51) showed a highly significant negative correlation but number of fruits per plant (-0.47) exhibited a significant negative correlation with fruit length. [43] reported that fruit length had a highly significant positive correlation with fruit diameter, fruit weight, number of fruits per tree, and yield per tree in jackfruit. [47] were observed a significantly positive correlation between fruit length and fruit yield per plant in sapota. Furthermore, fruit length had a non-significant positive correlation with peel thickness, edible percentage, and juice content per ten fruits and non-significant negative correlation with weight of peel, number of seeds per fruit, and TSS. Fruit diameter was in highly significant negative correlation with weight of seeds per fruit (-0.91) and fruits yield per plant (-0.52) but significant negative correlation with number of fruits per plant (-0.47), whereas, [38] found a significant positive correlation between fruit diameter and fruits yield per plant in pummelo. A significantly positive relationship between fruit yield per plant and fruit diameter in sapota was reported by [47]. Fruit diameter showed a non-significant positive correlation in case of peel thickness, edible percentage, and juice content per ten fruits and non-significant negative correlation with weight of peel, number of seeds per fruit, and TSS. Weight of peel exhibited a significant positive correlation with number of seeds per fruit (0.4), weight of seeds per fruit, juice content per ten fruits, TSS, number of fruits per plant and non-significant positive correlation with fruits yield per plant, while, peel thickness and edible percentage exhibited a non-significant negative correlation with weight of peel.

The number of seeds per fruit had a significant positive correlation with fruits yield per plant (0.42), a similar correlation was observed by [38] in pummelo. Weight of seeds per fruit, edible percentage, juice content per ten fruits, and number of fruits per plant exhibited a non-significant positive correlation with number of seeds per fruit, whereas, peel thickness and TSS showed a non-significant negative correlation with number of seeds per fruit. [38] found that number of seeds per fruit had a highly significant strong relationship with weight of seeds per fruit in pummelo. Weight of seeds per fruit showed a significant positive correlation with fruits yield per plant (0.5) and number of fruits per plant (0.45). [38] reported similar relationship between weight of seeds per fruit and fruits yield per plant in pummelo. A non-significant positive correlation was observed in the case of TSS and non-significant negative correlation in case of peel thickness, edible percentage, and juice content per ten fruits. Peel thickness exhibited a negative correlation with all the characters namely edible percentage, juice content per ten fruits, TSS, number of fruits per plant, fruits yield per plant. Among these characters, juice content per ten fruits (-0.52) showed a highly significant negative correlation, and TSS (-0.44) and fruits yield per plant (-0.43) showed significant negative correlation but non-significant negative correlation with edible percentage and number of fruits per plant. The edible percentage was in non-significant positive correlation with juice content per ten fruits and TSS, while, number of fruits per plant and fruits yield per plant exhibited a non-significant negative correlation with edible percentage. Juice content per ten fruits showed a significant positive correlation with TSS (0.49) and non-significant positive correlation number of fruits per plant and fruits yield per plant. TSS had a non-significant positive correlation with number of fruits per plant and fruits yield per plant.

IV. PATH COEFFICIENT ANALYSIS

Path coefficient analysis revealed the direct and indirect contribution of characters toward the yield of Burmese grape (Table 1). The number of fruits per plant showed the highest positive direct effect (1.067) on fruits yield per plant. Similarly, the highest positive direct effect of number of fruits per plant on yield was reported by [38] in pummelo, [42] found in case of mango and [43] reported number of fruits per plant had a strong positive direct effect on yield per tree of jackfruit. Moreover, [48] observed that number of fruits per branch had the highest direct effect on yield per plant in kinnow mandarin. The positive indirect effect was observed via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, and weight of seeds per fruit and the negative indirect effect was observed via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, juice content per ten fruits, and TSS. Positive non-significant correlation (0.99) between number of fruits per plant and fruits yield per plant was the cumulative contribution of these direct and indirect effects. Fruit length had a positive direct effect (0.715) on fruits yield per plant. [49] reported that fruit length had a strong positive direct effect (1.35) on fruits yield per plant in the case of red tamarind and [43] observed considerable positive direct effect in case of jackfruit. Indirect effect via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, peel thickness, edible percentage, and TSS were positive. Indirect effect via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant were negative. A negative highly significant correlation (-0.51) between fruit length and fruits yield per plant was the cumulative contribution of these direct and indirect effects.

Plant height showed a positive direct effect (0.566) on fruits yield per plant. The indirect effect via base girth, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant were positive and via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, and TSS were negative. A positive highly significant correlation (0.52) between plant height and fruits yield per plant was the cumulative contribution of these direct and indirect effects. Base girth had a positive direct effect (0.341) on fruits yield per plant. The indirect effect via plant height, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant were positive, whereas, via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, and TSS were negative. Canopy spreading at east-west direction (-0.766) revealed the maximum indirect effect on fruits yield per plant among all other characters. The indirect effect via juice content per ten fruits was very poor. A positive highly significant correlation (0.68) between base girth and fruits yield per plant was the cumulative contribution of these direct and indirect effects. Canopy spreading at north-south direction showed a positive direct effect (0.275) on fruits yield per plant. The indirect effect via plant height, base girth, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit,

Table 01. Genotypic path coefficient analysis showing direct (diagonal bold) and indirect (non-diagonal) effect of 18 characters on yield of 25 Burmese grape genotypes

Traits	PH	BG	CSNS	CSEW	DFM	NFPC	IFW	FL	FD	WPL	NSPF	WTSD	PLTK	EP	JCTF	TSS	NFPP	FYPP
PH	**0.566**	0.311	0.225	-0.742	0.008	-0.003	-0.089	-0.679	0.243	0.068	0.004	0.229	-0.023	-0.043	0.002	-0.036	0.480	0.52
BG	0.515	**0.341**	0.242	-0.766	0.011	-0.003	-0.082	-0.650	0.235	0.072	0.006	0.226	-0.034	-0.076	0.001	-0.031	0.672	0.68
CSNS	0.464	0.300	**0.275**	-0.758	0.006	-0.001	-0.082	-0.586	0.217	0.091	0.008	0.218	-0.017	-0.125	0.002	-0.006	0.533	0.54
CSEW	0.520	0.324	0.258	**-0.806**	0.008	-0.003	-0.098	-0.650	0.238	0.088	0.011	0.234	-0.016	-0.082	0.002	-0.018	0.640	0.65
DFM	-0.204	-0.164	-0.069	0.282	**-0.023**	-0.001	0.007	0.300	-0.100	-0.014	-0.003	-0.106	0.030	0.072	0.002	0.051	-0.512	-0.45
NFPC	0.074	0.038	0.008	-0.089	-0.001	**-0.025**	-0.016	-0.064	0.031	-0.056	-0.002	0.035	-0.024	0.118	-0.001	-0.018	0.224	0.23
IFW	0.215	0.120	0.096	-0.339	0.001	-0.002	**-0.235**	-0.164	0.066	0.165	0.015	0.090	-0.028	0.135	-0.004	-0.029	0.277	0.38
FL	-0.537	-0.311	-0.225	0.734	-0.010	0.002	0.054	**0.715**	-0.253	-0.047	-0.004	-0.239	0.008	0.082	-0.004	0.026	-0.501	-0.51
FD	-0.537	-0.314	-0.233	0.750	-0.009	0.003	0.061	0.707	**-0.256**	-0.054	-0.005	-0.242	0.008	0.082	-0.004	0.024	-0.501	-0.52
WPL	0.164	0.106	0.107	-0.306	0.001	0.006	-0.167	-0.143	0.059	**0.233**	0.015	0.090	-0.016	-0.053	-0.003	-0.017	0.203	0.28
NSPF	0.057	0.055	0.060	-0.226	0.002	0.002	-0.091	-0.079	0.033	0.093	**0.038**	0.040	-0.002	0.023	-0.001	0.011	0.405	0.42
WTSD	0.486	0.290	0.225	-0.710	0.009	-0.003	-0.080	-0.643	0.233	0.079	0.006	**0.266**	-0.004	-0.115	0.004	-0.024	0.480	0.5
PLTK	-0.107	-0.096	-0.038	0.105	-0.006	0.005	0.054	0.050	-0.018	-0.030	-0.001	-0.008	**0.121**	-0.092	0.006	0.042	-0.416	-0.43
EP	-0.074	-0.079	-0.104	0.202	-0.005	-0.009	-0.096	0.179	-0.064	-0.037	0.003	-0.093	-0.034	**0.329**	-0.004	-0.026	-0.107	-0.02
JCTF	-0.090	-0.038	-0.038	0.121	0.004	-0.003	-0.082	0.250	-0.089	0.063	0.002	-0.077	-0.063	0.109	**-0.012**	-0.046	0.171	0.18
TSS	0.215	0.113	0.016	-0.153	0.012	-0.005	-0.073	-0.200	0.064	0.042	-0.005	0.067	-0.053	0.092	-0.006	**-0.095**	0.288	0.32
NFPP	0.255	0.215	0.137	-0.484	0.011	-0.005	-0.061	-0.336	0.120	0.044	0.015	0.120	-0.047	-0.033	-0.002	-0.026	**1.067**	0.99

Where, **Residual Effect: 0.11763**

PH= Plant Height (cm), **BG**= Base girth (cm), **CSNS**= Canopy spreading at north-south direction (cm), **CSEW**= Canopy spreading at east-west direction (cm), **DFM**= Days to fruit maturity (days), **NFPC**= Number of fruits per cluster, **IFW**= Individual fruit weight (g), **FL**= Fruit length (mm), **FD**= Fruit diameter (mm), **WPL**= Weight of peel (g), **NSPF**= Number of seeds per fruit, **WTSD**= Weight of seeds per fruit (g), **PLTK**= Peel thickness (mm), **EP**= Edible percentage, **JCTF**= Juice content per ten fruits (ml), **TSS**=% Brix, **NFPP**= Number of fruits per plant, **FYPP**=Fruits yield per plant (kg.).

weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant were positive and indirect effect via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, and TSS were negative.

The indirect effect via number of fruits per cluster was very poor. A positive highly significant correlation (0.54) between canopy spreading at north-south direction and fruits yield per plant was the cumulative contribution of these direct and indirect effects. Canopy spreading at east-west direction had a negative direct effect (-0.806) on fruits yield per plant. The positive indirect effect was observed via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant, whereas, negative indirect effect was observed via number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, and TSS. A positive highly significant correlation (0.65) between canopy spreading at east-west direction and fruits yield per plant was the cumulative contribution of these direct and indirect effects.

The edible percentage had a positive direct effect (0.329) on fruits yield per plant. The positive indirect effect was observed via canopy spreading at east-west direction, fruit length, and number of seeds per fruit, whereas, the negative indirect effect was observed via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, number of fruits per cluster, individual fruit weight, fruit diameter, weight of peel, weight of seeds per fruit, peel thickness, edible percentage, juice content per ten fruits, TSS, and number of fruits per plant. Negative non-significant correlation (-0.02) between edible percentage and fruits yield per plant was the cumulative contribution of these direct and indirect effects.

Fruit diameter showed a negative direct effect (-0.256) on fruits yield per plant, whereas, [43] reported a strong negative direct effect in the case of jackfruit. Indirect effect via canopy spreading at east-west direction, number of fruits per cluster, individual fruit weight, fruit length, peel thickness, edible percentage, and TSS were positive. Canopy spreading at east-west direction (0.750) showed the highest positive indirect effect on fruits yield per plant among all characters. On the other hand, indirect effect via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, weight of peel, number of seeds per fruit, weight of seeds per fruit, juice content per ten fruits, and number of fruits per plant were negative. A negative highly significant correlation (-0.52) between fruit diameter and fruits yield per plant was the cumulative contribution of these direct and indirect effects.

Individual fruit weight showed negative direct effect (-0.235) on fruits yield per plant, in contrasts, [43] reported strong positive direct effect in case of jackfruit but [38] found that individual fruit weight showed a considerable positive direct effect on fruit yield per plant in pummelo. The positive indirect effect was observed via plant height, base girth, canopy spreading at north-south direction, days to fruit maturity, fruit diameter, weight of peel, number of seeds per fruit, weight of seeds per fruit, edible percentage, and number of fruits per plant and the negative indirect effect was observed via canopy spreading at east-west direction, number of fruits per cluster, fruit length, peel thickness, juice content per ten fruits, and TSS. The indirect effect via days to fruit maturity was very poor. Positive non-significant correlation (0.38) between individual fruit weight and fruits yield per plant was the cumulative contribution of these direct and indirect effects. Saha, 2004[50] found highest positive direct effect for average weight of fruit on yield in lemon. Majumder et. al., 2012[42] observed positive direct effect of average fruit weight on yield in case of mango. TSS had a negative direct effect (-0.095) on fruits yield per plant. Positive non-significant correlation (0.32) between TSS and fruits yield per plant was the cumulative contribution of these direct and indirect effects. The number of fruits per cluster had a negative direct effect (-0.025) on fruits yield per plant. The indirect effect via plant height, base girth, canopy spreading at north-south direction, fruit diameter, weight of seeds per fruit, edible percentage, and number of fruits per plant was positive, whereas, indirect effect via canopy spreading at east-west direction, days to fruit maturity, individual fruit weight, fruit length, weight of peel, number of seeds per fruit, peel thickness, juice content per ten fruits, and TSS were negative. Indirect effects via days to fruit maturity and juice content per ten fruits were very poor. Positive non-significant correlation (0.23) between number of fruits per cluster and fruits yield per plant was the cumulative contribution of these direct and indirect effects.

The residual effect (R) of path analysis was high (0.11763) which meant that the traits studied in the experiment contributed to 88.24 % of the fruits yield per plant. It also indicated that some other factors like environmental factors and sampling errors contributed 11.76 % to the fruits yield per plant which were not studied in this research. Similar finding was also observed in potato [41] and pummelo [43].

V. CONCLUSION

Correlation and path coefficient analysis revealed that number of fruits per plant, individual fruit weight, fruit length and canopy spreading were the most important contributors to fruit yield per plant in Burmese grape. Thus, emphasis should be given for the selection of these characters for the improvement of Burmese grape. Moreover, further study is also required for more precise results.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Supplementary Table 1. Correlation co-efficient between 18 yield and yield contributing characters in 25 Burmese grape genotypes

Traits	BG	CSNS	CSEW	DFM	NFPC	IFW	FL	FD	WPL	NSPF	WTSD	PLTK	EP	JCTF	TSS	NFPP	FYPP
PH	0.91**	0.82 **	0.92 **	-0.36	0.13	0.38	-0.95**	-0.95**	0.29	0.10	0.86 **	-0.19	-0.13	-0.16	0.38	0.45*	0.52 **
BG		0.88 **	0.95 **	-0.48*	0.11	0.35	-0.91**	-0.92**	0.31	0.16	0.85 **	-0.28	-0.23	-0.11	0.33	0.63 **	0.68 **
CSNS			0.94 **	-0.25	0.03	0.35	-0.82**	-0.85**	0.39	0.22	0.82**	-0.14	-0.38	-0.14	0.06	0.5*	0.54**
CSEW				-0.35	0.11	0.42*	-0.91**	-0.93**	0.38	0.28	0.88**	-0.13	-0.25	-0.15	0.19	0.6**	0.65**
DFM					0.04	-0.03	0.42*	0.39	-0.06	-0.07	-0.4*	0.25	0.22	-0.16	-0.54**	-0.48*	-0.45
NFPC						0.07	-0.09	-0.12	-0.24	-0.06	0.13	-0.2	0.36	0.11	0.19	0.21	0.23
IFW							-0.23	-0.26	0.71**	0.39	0.34	-0.23	0.41*	0.35	0.31	0.26	0.38
FL								0.99**	-0.2	-0.11	-0.9**	0.07	0.25	0.35	-0.28	-0.47*	-0.51**
FD									-0.23	-0.13	-0.91**	0.07	0.25	0.35	-0.25	-0.47*	-0.52**
WPL										0.4*	0.34	-0.13	-0.16	0.27	0.18	0.19	0.28
NSPF											0.15	-0.02	0.07	0.06	-0.12	0.38	0.42*
WTSD												-0.03	-0.35	-0.29	0.25	0.45*	0.5*
PLTK													-0.28	-0.52**	-0.44*	-0.39	-0.43*
EP														0.33	0.28	-0.1	-0.02
JCTF															0.49*	0.16	0.18
TSS																0.27	0.32

df = 25-2 = 23; r0.05 = 0.396, r0.01 = 0.505, ** Significant at 1% level * Significant at 5% level.

PH= Plant Height (cm), **BG**= Base girth (cm), **CSNS**= Canopy spreading at north-south direction (cm), **CSEW**= Canopy spreading at east-west direction (cm), **DFM**= Days to fruit maturity (days), **NFPC**= Number of fruits per cluster, **IFW**= Individual fruit weight (g), **FL**= Fruit length (mm), **FD**= Fruit diameter (mm), **WPL**= Weight of peel (g), **NSPF**= Number of seeds per fruit, **WTSD**= Weight of seeds per fruit (g), **PLTK**= Peel thickness (mm), **EP**= Edible percentage, **JCTF**= Juice content per ten fruits (ml), **TSS**=% Brix, **NFPP**= Number of fruits per plant, **FYPP**=Fruits yield per plant (kg.)