Original Research Article

Appraisement of Variability and Association among the Jackfruit (*Artocarpus heterophyllus* Lam.) Genotypes found in North-East India

ABSTRACT

The present investigations were carried out on forty genotypes of jackfruit (*Artocarpus heterophyllus* Lam.) to determine the extent of variability present in the material and association among different traits. The genotypes were collected from six north-eastern states of India *viz.* Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Tripura during the two years 2016 and 2017. Selection and identification of superior genotypes were done following IPGRI jackfruit descriptor. The experiment was laid using randomized block design with three replications during the year 2016 and 2017 under Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, East Siang, Arunachal Pradesh. The phenotypic coefficients of variability and genotypic coefficients of variability were recorded highest values for weight of fresh flake without seed (52.69 % & 50.52 %, respectively), stalk length (51.09 % & 49.06 %, respectively) and fruit weight (48.11 % & 45.86 %, respectively). High heritability coupled with high genetic gain was observed for stalk length, fruit weight, weight of fresh flake with seed and weight of fresh flake without seed traits. Genetic advance was recorded highest for 100-seed weight followed by stalk length and lowest for flake/fruit ratio followed by seed width traits. Yield per plant showed significant and positive genotypic correlation coefficient with fruit diameter, rachis diameter, fruit weight, petiole length, fruit length and flake length traits. The path coefficient analysis revealed that weight of fresh flake with seed has maximum positive direct effect on fruit yield per tree followed by weight of flakes per kg of fruit.

Keywords: *Artocarpus heterophyllus*, *correlation, heritability, jackfruit, path analysis, variability*

1. INTRODUCTION

The jackfruit (*Artocarpus heterophyllus* Lam.) is a commercially important minor fruit crop of India. It is reported to be indigenous to the rainforest of the Western Ghats of India (Jagadeesh *et al*., 2007). Barrau (1976) suggests that Malaysia could be the centre of origin due to the presence of wide variability of cultivars but no wild trees have been observed there. Jackfruit is tetraploid with a somatic chromosome number of 56 (2n=4x=56). It belongs to the family Moraceae along with fig, mulberry and hedge apple (Popenoe, 1974; Chandler, 1958). The genus *Artocarpus* includes about 50 species with milky latex in the tropical Asia and Polynesia (Corner, 1988; Campbell, 1984; Barrau, 1976).

Jackfruit is cultivated throughout the tropical lowlands in south and south-east Asia, parts of central and eastern Africa and Brazil. Major jackfruit producers are Bangladesh, India, Myanmar, Thailand, Vietnam, China, the Philippines, Indonesia, Malaysia, Sri Lanka and Nepal. India is the second largest producer of the jackfruit and is widely distributed in the states of Assam, Tripura, Bihar, Uttar Pradesh, Kerala, Karnataka and Tamil Nadu (APAARI, 2012). In north-eastern India, the leading jackfruit producing states are Tripura, Meghalaya, Sikkim, Manipur and Assam (Singh *et al.*, 2018). The region comprising Assam and Tripura produces major share of jackfruit in India and the total annual production in Assam is estimated to be nearly 1,75,000 tonnes (APAARI, 2012). The area under jackfruit cultivation in homestead gardens of Tripura is approximately 2,200 hectares with the production of 12,500 MT (Singh *et al.*, 2018).

Jackfruit tree is a multipurpose tree bearing largest edible fruit in the world and providing food, timber, fuel, fodder and medicinal products (Rahman *et al.*, 2016). The tree is evergreen, medium-sized typically reaching 8-25 m in height producing fruits weighing upto 35 kg (Shyamalamma *et al.*, 2008). The fruit is a rich source of carbohydrates, proteins, vitamins, minerals and dietary fibre. It possesses anti-inflammatory, antioxidant, antifungal, immuno- modulatory, anti-diabetic, anti-bacterial and anti-helmintic properties (Prakash *et al.*, 2009). The ripe fruit is eaten as raw and tender immature fruits can be used as vegetable. The fruits can be canned and processed into products like wine, ice-cream, chips, jellies (Jagadeesh *et al.*, 2009), dehydrated bulbs and squash (Bhatia *et al.*, 1956), vinegar (Datta and Biswas, 1972), Preserve (Ukkuru and Pandey, 2005) and ready-to-serve beverages (Singh *et al.*, 2001).

There exists a lot of variability among jackfruit genotypes in north-eastern region since most are raised from seeds. The phenotypic and genotypic coefficients of variability are an important tool for estimating the amount of variations present in the investigated genotypes. The knowledge of linkage of yield with other yield contributing traits is a vital instrument as yield is not an independent character. This inter-relationship study is helpful in determining the components of yield but path coefficients analysis provides a clear picture of nature and extent of contribution made by number of traits.

Jackfruit is an important component of homestead garden in north-east India. But there is a lack of study on the diversity and variability of jackfruit in north-east India. Recently, there was a study carried out by Singh *et al.* (2018) in Tripura. There is no study till date which has covered the entire north-eastern region. Therefore, the present investigation was taken to study the nature and extent of genetic variability and association of different horticultural traits with yield among the jackfruit genotypes found in the north-east India.

2. MATERIALS AND METHODS

The present investigation entitled "Appraisement of Variability and Association among the Jackfruit (*Artocarpus heterophyllus* Lam.) Genotypes found in North-East India" was carried out on forty genotypes of jackfruit during the two years 2016 and 2017 under Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, East Siang, Arunachal Pradesh. The selected genotypes were collected from six states of Northeast India *viz.* Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Tripura (Table 1). Physical parameters were recorded on site and plant samples *viz.* leaves and fruit samples were collected for further physical and biochemical analysis. Selection and identification of superior genotypes were done following

IPGRI jackfruit descriptor (Anonymous, 2000). The experiment was laid in randomized block design with three replications. For fruit and leaf characters analysis, three fruits and twenty leaves are randomly selected from each replicaton for two consecutive years *i.e.* 2016 and 2017. The statistical analysis was carried out for each observed character by using MS-Excel, OPSTAT and SPAR 1.0 packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1983) for Randomized Complete Block Design.

Table 1: Experimental materials used and their source of collection

Sl. No.	Types	Source of collection
1	T_1	Tripura
2	T_2	Tripura
3	T_3	Tripura
4	T_4	Tripura
5	T_5	Tripura
6	T_6	Tripura
7	T_7	Tripura
8	T_8	Tripura
9	T_9	Tripura
10	T_{10}	Tripura
11	T_{11}	Tripura
12	T_{12}	Tripura
13	T_{13}	Tripura
14	T_{14}	Tripura
15	T_{15}	Tripura
16	T_{16}	Tripura
17	T_{17}	Tripura
18	T_{18}	Tripura
19	T_{19}	Tripura
20	T_{20}	Tripura
21	T_{21}	Manipur
22	T_{22}	Manipur
23	T_{23}	Manipur
24	T_{24}	Manipur
25	T_{25}	Assam
26	T_{26}	Assam
27	T_{27}	Assam
28	T_{28}	Assam
29	T_{29}	Assam
30	T_{30}	Arunachal Pradesh
31	T_{31}	Arunachal Pradesh
32	T_{32}	Arunachal Pradesh
33	T_{33}	Arunachal Pradesh
34	T_{34}	Arunachal Pradesh
35	T_{35}	Mizoram
36	T_{36}	Mizoram
37	T_{37}	Meghalaya
38	T_{38}	Meghalaya
39	T_{39}	Meghalaya

40	T_{40}	Meghalaya

The Genotypic and Phenotypic Coefficients of variability were calculated as per formulae given by Burton and De Vane (1953).

a) Genotypic Coefficient of Variation (GCV)

$$GCV\ (\%) = \frac{\sqrt{\text{Genotypic variance (Vg)}}}{\text{General mean of population } (\bar{x})} \times 100$$

b) Phenotypic Coefficient of Variation (PCV)

$$PCV\ (\%) = \frac{\sqrt{\text{Phenotypic variance (Vp)}}}{\text{General mean of population } (\bar{x})} \times 100$$

PCV and GCV values were categorized as low (0-10%), moderate (10-20%) and high (>20%) values as indicated by Sivasubranian and Menon (1973).

Heritability in broad sense was calculated by the formula as suggested by Allard (1960).

$$\text{Heritability (\%)} = \frac{Vg}{Vp} \times 100$$

Where,

Vg = Genotypic variance [Vg = (Mg - Me) / r]

Vp = Phenotypic variance [Vg + Ve]

Heritability was classified as suggested Robinson *et al.* (1949) into low (0-30%), moderate (30.1-60%) and high (>60%).

The expected genetic advance (GA) was worked out as suggested by Allard (1960).

Genetic advance = H x б p x K

Where,

K = 2.06 (Selection differential at 5 per cent selection index)

б p = Phenotypic standard deviation

H = Heritability in broad sense

Genetic gain expressed as per cent ratio of genetic advance and population mean was calculated by the method given by Johanson *et al.* (1955).

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{\text{General mean of population } (\bar{x})} \times 100$$

The GAM% was categorized into low (0–10%), moderate (10.1–20%) and high (>20%) as suggested by Johnson *et al.* (1955).

The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958).

a) Genotypic correlation coefficient between X and Y

$$r_g = \frac{Vg\,XY}{\sqrt{Vg\,X \times Vg\,Y}}$$

Where,

Vg XY = Genotypic covariance between X and Y

Vg X = Genotypic variance of X

Vg Y = Genotypic variance of Y

b) Phenotypic correlation coefficient between X and Y

$$r_p = \frac{Vp\,XY}{\sqrt{Vp\,X \times Vp\,Y}}$$

Where,

Vp XY = Phenotypic covariance between X and Y

Vp X = Phenotypic variance of X

Vp Y = Phenotypic variance of Y

Genotypic variance (Vg) = (Mg - Me) / r

Phenotypic variance (Vp) = (Vg + Ve)

The genotypic and phenotypic correlation coefficients were used in finding out their direct and indirect contribution towards yield per plant.

The direct and indirect paths were obtained by following Dewey and Lu (1959). The path coefficients were obtained by simultaneous selection of the following equations, which expresses the basic relationship between genotypic correlation 'r' and path coefficients (P).

$r_{14} : P_{14} + P_{24}\, r_{12} + P_{34}\, r_{13}$

$r_{24} : P_{14}\, r_{21} + P_{24} + P_{34}\, r_{23}$

$r_{34} : P_{14}\, r_{31} + P_{24}\, r_{32} + P_{34}$

Where,

r_{14}, r_{24} and r_{34} are genotypic correlations of component characters with yield (dependent variable) and r_{12}, r_{13} and r_{23} are the genotypic correlations among component characters (independent variables).

The direct effects were calculated by the following set of equations:

$P_{14} = C_{11}\, r_{14} + C_{12}\, r_{24} + C_{13}\, r_{34}$

$P_{24} = C_{21}\, r_{14} + C_{22}\, r_{24} + C_{23}\, r_{34}$

$P_{34} = C_{31}\, r_{14} + C_{32}\, r_{24} + C_{33}\, r_{34}$

Where, C_{11}, C_{22}, C_{23} and C_{33} are constants derived by using abbreviated Doulittle's technique as explained by Goulden (1959).

$r_{12}\, P_{24}$, $r_{13}\, P_{34}$, $r_{21}\, P_{14}$, $r_{23}\, P_{34}$, $r_{31}\, P_{14}$, $r_{32}\, P_{24}$ are indirect effects

The variation in the dependent variable which remained undetermined by including all the variables was assumed to be due to variable (s) not included in the present investigation. The degree of determination of such variable (s) on dependent variable was calculated as follows:

$$1 = P^2x_4 + P_{14}^{\ 2} + P_{24}^{\ 2} + P_{34}^{\ 2} + 2P_{14}\, r_{12}\, P_{24} + 2P_{14}\, r_{13}\, P_{34} + 2P_{24}\, r_{23}\, P_{34}$$

3. RESULTS AND DISCUSSION

3.1 VARIABILITY STUDIES

The phenotypic and genotypic coefficients of variability are an important tool for estimating the amount of variations present in the available or investigated genotypes. Among all the studied traits, phenotypic coefficients of variability were higher in magnitude than genotypic coefficients of variability which indicate that these traits are influenced by environmental factors (Table 2). Coefficients of variability varied in magnitude from character to character which shows the presence of diversity in the evaluated genotypes. As jackfruit trees are cross-pollinated and mostly seed propagated, they showed high degree of variability. The phenotypic coefficients of variability (PCV) were high for weight of fresh flake without seed (52.69 %), stalk length (51.09 %), fruit weight (48.11 %), fruit yield per tree (44.76 %), fruit rind weight (44.06 %), weight of fresh flake with seed (41.22 %), number of seeds/ kg of fruit (37.59 %), number of flakes/kg fruit (36.18 %), rachis diameter (32.96 %), flake width (31.25 %), reducing sugars (30.62 %), 100-seed weight (28.08 %), petiole length (27.85 %), stalk diameter (27.67 %), flake/ fruit ratio (24.36 %), weight of flakes/kg of fruit (24.32 %), total sugars (24.23 %), rachis length (23.75 %), total carbohydrate of seed (20.88 %) and TSS (20.82 %)whereas, moderate phenotypic coefficients of variability (PCV) were recorded for flake length (19.03 %), fruit length (18.72 %), fruit diameter (17.25 %), seed width (16.95 %), leaf blade length (16.61 %), leaf blade width (16.11 %), protein content of seed (15.55 %) and seed length (12.56 %). The genotypic coefficients of variability (GCV) were recorded high for weight of fresh flake without seed (50.52 %), stalk length (49.06 %), fruit weight (45.86 %), weight of fresh flake with seed (39.49 %), fruit yield per tree (39.24 %), fruit rind weight (38.93 %), number of seeds/ kg of fruit (36.92 %), number of flakes/kg fruit (35.62 %), reducing sugars (29.04 %), flake width (28.94 %), rachis diameter (25.28 %), stalk diameter (25.13 %), 100-seed weight (22.94 %), total sugars (22.77 %), weight of flakes/kg of fruit (21.88 %), flake/ fruit ratio (21.61 %) and rachis length (20.56 %)whereas, moderate genotypic coefficients of variability (GCV) were recorded for TSS (19.83 %), petiole length (17.65 %), total carbohydrate of seed (17.14 %), fruit length (16.66 %), flake length (16.45 %), fruit diameter (16.25 %), protein content of seed (13.68 %), seed width (13.12 %), leaf blade length (12.58 %) and leaf blade width (11.28 %)whereas, low GCV was recorded for seed length (9.47 %) (Table 2).

Table 2: Variability parameters for different characters

S. No.	Traits	Mean	Variance		GCV (%)	PCV (%)
			Genotypical	Phenotypical		
1	Leaf blade length (cm)	14.30	3.24	5.64	12.58	16.61
2	Leaf blade width (cm)	7.93	0.80	1.63	11.28	16.11
3	Petiole length (mm)	19.60	11.98	29.82	17.65	27.85
4	Stalk length (mm)	209.25	10540.81	11430.64	49.06	51.09
5	Stalk diameter (mm)	23.53	35.00	42.41	25.13	27.67
6	Fruit length (cm)	23.83	15.77	19.91	16.66	18.72
7	Fruit diameter (cm)	16.34	7.05	7.95	16.25	17.25
8	Fruit weight (kg)	3.16	2.10	2.31	45.86	48.11
9	Fruit rind weight (kg)	1.32	0.26	0.34	38.93	44.06
10	No. of flakes/kg fruit	28.65	104.16	107.50	35.62	36.18
11	Weight of flakes/kg of fruit (g)	464.26	10327.75	12758.22	21.88	24.32
12	Weight of fresh flake with seed (g)	18.10	51.13	55.69	39.49	41.22
13	Weight of fresh flake without seed (g)	12.18	37.89	41.21	50.52	52.69
14	Flake/ Fruit ratio	0.46	0.01	0.013	21.61	24.36
15	Flake length (cm)	4.43	0.53	0.71	16.45	19.03
16	Flake width (cm)	2.84	0.67	0.78	28.94	31.25
17	Rachis length (cm)	16.74	11.85	15.82	20.56	23.75
18	Rachis diameter (cm)	5.73	2.09	3.56	25.28	32.96
19	Seed length (cm)	2.82	0.07	0.12	9.47	12.56
20	Seed width (cm)	1.83	0.05	0.09	13.12	16.95
21	100-Seed weight (g)	592.21	18456.72	27667.68	22.94	28.08
22	No. of seeds/ kg of fruit	28.79	113.06	117.19	36.92	37.59
23	TSS (°Brix)	18.97	14.16	15.60	19.83	20.82
24	Total sugars (%)	14.00	10.17	11.52	22.77	24.23
25	Reducing sugars (%)	8.26	5.75	6.40	29.04	30.62
26	Total carbohydrate of seed (mg/g)	185.97	1016.14	1508.25	17.14	20.88
27	Protein content of seed (µg/g)	788.62	11643.56	15038.40	13.68	15.55
28	Fruit yield per tree (kg)	126.45	2462.93	3204.44	39.24	44.76

Table 3: Heritability, genetic advance and genetic gain of different characters

S. No.	Traits	Heritability % (broad sense)	Genetic advance	Genetic gain (%)
1	Leaf blade length (cm)	57.40	2.80	19.64
2	Leaf blade width (cm)	49.10	1.29	16.29
3	Petiole length (mm)	40.20	4.52	23.06
4	Stalk length (mm)	92.20	203.09	97.05
5	Stalk diameter (mm)	82.50	11.07	47.04
6	Fruit length (cm)	79.20	7.28	30.55
7	Fruit diameter (cm)	88.70	5.15	31.53
8	Fruit weight (kg)	90.80	2.84	90.04
9	Fruit rind weight (kg)	78.10	0.93	70.87
10	No. of flakes/kg fruit	96.90	20.69	72.22
11	Weight of flakes/kg of fruit (g)	80.90	188.35	40.57
12	Weight of fresh flake with seed (g)	91.80	14.11	77.95
13	Weight of fresh flake without seed (g)	91.90	12.16	99.81
14	Flake/ Fruit ratio	78.70	0.18	39.51
15	Flake length (cm)	74.70	1.29	29.29
16	Flake width (cm)	85.80	1.56	55.23
17	Rachis length (cm)	74.90	6.13	36.65
18	Rachis diameter (cm)	58.80	2.28	39.95
19	Seed length (cm)	56.80	0.41	14.70
20	Seed width (cm)	60.00	0.38	20.93
21	100-Seed weight (g)	66.70	228.57	38.59
22	No.of seeds/ kg of fruit	96.50	21.51	74.70
23	Fruit yield per tree (kg)	76.90	89.62	70.87
24	TSS (°Brix)	90.80	7.38	38.93
25	Total sugars (%)	88.30	6.17	44.08
26	Reducing sugars (%)	89.90	4.68	56.74
27	Total carbohydrate of seed (mg/g)	67.40	53.90	28.98
28	Protein content of seed (µg/g)	77.40	195.59	24.80

These finding corroborate with the finding of Sharma *et al*. (2005) and Maiti *et al*. (2003). Sharma *et al*. (2005) observed high genotypic and phenotypic coefficient of variation for weight of bulbs without seed, weight of bulbs with seed and fruit weight. The phenotypic and genotypic coefficient of variation does not fully estimate the total heritable variations and therefore, computation of heritability becomes necessary. Burton and De-Vane (1953) has suggested that genetic coefficient of variability and heritability estimates would provide a reliable proof of expected amount of improvement through selection. The broad sense heritability estimates were found to be highest for the characters number of flakes/kg fruit (96.90 %), number of seeds/ kg of fruit (96.50 %), stalk length (92.20 %), weight of fresh flake without seed (91.90 %), weight of fresh flake with seed (91.80 %), fruit weight (90.80 %), TSS (90.80 %), reducing sugars (89.90 %), fruit diameter (88.70 %),total sugars (88.30 %), flake width (85.80 %),stalk diameter (82.50 %), weight of flakes/kg of fruit (80.80 %), fruit length (79.20 %), flake/fruit ratio (78.70 %), fruit rind weight (78.10 %), protein content of seed (77.40 %), fruit yield per tree (76.90 %), rachis length (74.90 %), flake length (74.70 %), total carbohydrate of seed (67.40 %), 100-seed weight (66.70 %) and seed width (60.00 %) (Table 3).

The value of genetic advance ranged from 0.18 to 228.57. The highest genetic advance was recorded for 100-seed weight (228.57) followed by stalk length (203.09), protein content of seed (195.59), weight of flakes/kg of fruit (188.35), fruit yield per tree (89.62) and total carbohydrate of seed (53.90). High heritability coupled with high genetic advance was observed for the traits weight of flake/kg of fruit, fruit yield per tree, 100-seed weight, stalk length and protein content of seed indicating that these traits are highly heritable and likely to provide high selection response (Table 3). The genetic gain was found high for the characters *viz*. weight of fresh flake without seed (99.81 %), stalk length (97.05 %), fruit weight (90.04 %), weight of fresh flake with seed (77.95 %), number of seeds/ kg of fruit (74.70 %), number of flakes/kg fruit (72.22 %), fruit rind weight (70.87 %), fruit yield per tree (70.87 %), reducing sugars (56.74 %), flake width (55.23 %), stalk diameter (47.04 %), total sugars (44.08 %), weight of flakes/kg of fruit (50.57 %), rachis diameter (39.95 %), flake/ fruit ratio (39.51 %), TSS (38.93 %), 100-seed weight (38.59 %), rachis length (36.65 %), fruit diameter (31.53 %), fruit length (30.55 %), flake length (29.29 %),total carbohydrate of seed (28.98 %), protein content of seed (24.80 %),petiole length (23.06 %) and seed width (20.93 %). Similar result was obtained by Wangchu *et al*. (2013) and Maiti *et al*. (2003).

3.2 CORRELATION STUDIES

Knowledge of degree of association of yield with its components is of great importance, because yield is not an independent character, but it is the resultant of the interactions of a number of component characters among themselves as well as with the environment in which the plants grow. Further, each character is likely to be modified by the action of genes present in the genotypes of plant and also by the environment and it becomes difficult to evaluate this complex character directly. Therefore, correlation study of yield with its component traits has been executed, to find out the yield contributing traits. The correlation coefficients among different characters were worked out at phenotypic and genotypic levels. The phenotypic correlation coefficients among different characters revealed that fruit yield per tree had positive and significant correlation with fruit diameter (0.526), fruit weight (0.454), rachis diameter (0.433), fruit length (0.378), rachis length (0.355), fruit rind weight (0.325), flake length (0.319), reducing sugars (0.262), stalk length (0.255), seed length (0.255), petiole length (0.248), total sugar (0.244) and 100-seed weight (0.213) (Table 4). Similar results were obtained by Maiti (2010) who recorded significant association of yield with fruit weight and fruit rind weight. These results are also in line with the work of Sharma *et al*. (2006) indicating the scope of effective selection from these characters. Fruit weight was significantly positively correlated with fruit diameter followed by fruit length and fruit rind weight. Similar results was obtained by Wangchu *et al*. (2013) who observed high significant positive association of rind weight, rachis length, fruit length and flake length with fruit

Table 4: Correlation matrix showing relationship at phenotypic level with respect to vegetative, fruit yield and quality characters.

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	1.000																											
2	0.742*	1.000																										
3	0.573*	0.560*	1.000																									
4	0.258*	0.055	0.208**	1.000																								
5	0.152	0.113	0.101	0.061	1.000																							
6	0.250**	0.217**	0.230**	0.293*	0.159	1.000																						
7	0.291*	0.179	0.277*	0.505*	-0.099	0.622*	1.000																					
8	0.336*	0.231**	0.377*	0.451*	0.050	0.805*	0.838*	1.000																				
9	0.206**	0.209**	0.153	0.073	0.070	0.721*	0.555*	0.775*	1.000																			
10	-0.022	-0.063	0.005	-0.050	0.392*	0.042	-0.137	-0.042	-0.062	1.000																		
11	0.126	-0.086	0.235**	0.536*	-0.166	0.198**	0.502*	0.454*	-0.122	-0.001	1.000																	
12	0.126	0.094	0.250**	0.265*	-0.338*	0.114	0.379*	0.272*	0.024	-0.721*	0.478*	1.000																
13	0.119	0.085	0.217**	0.237**	-0.340*	0.068	0.351*	0.209**	-0.016	-0.721*	0.445*	0.982*	1.000															
14	0.084	-0.148	0.140	0.516*	-0.159	0.151	0.450*	0.381*	-0.153	0.030	0.972*	0.442*	0.418*	1.000														
15	0.191	0.188	0.303*	0.361*	-0.228**	0.337*	0.645*	0.567*	0.337*	-0.355*	0.472*	0.572*	0.545*	0.415*	1.000													
16	-0.031	-0.026	0.065	0.093	-0.330*	0.010	0.224***	0.122	0.051	-0.590*	0.281*	0.803*	0.810*	0.262*	0.407*	1.000												
17	0.233**	0.204**	0.198	0.254*	0.214**	0.968*	0.544*	0.742*	0.665*	0.089	0.139	0.013	-0.026	0.091	0.180	-0.070	1.000											
18	0.229**	0.083	0.126	0.353*	0.030	0.542*	0.774*	0.630*	0.457*	0.082	0.266*	0.056	0.041	0.251**	0.071	-0.025	0.561*	1.000										
19	0.083	0.052	0.255*	0.297*	-0.052	0.238**	0.413*	0.412*	0.110	-0.233**	0.441*	0.437*	0.359*	0.405*	0.463*	0.178	0.168	0.195**	1.000									
20	-0.025	-0.005	0.176	0.200**	-0.193	0.167	0.292*	0.251**	0.101	-0.486*	0.333*	0.645*	0.585*	0.301*	0.448*	0.509*	0.087	0.055	0.518*	1.000								
21	0.106	0.096	0.283*	0.273*	-0.204**	0.249**	0.346*	0.412*	0.173	-0.453*	0.428*	0.694*	0.548*	0.371*	0.461*	0.477*	0.162	0.094	0.575*	0.635*	1.000							
22	-0.035	-0.087	-0.041	-0.052	0.388*	0.019	-0.156	-0.072	-0.073	0.987*	-0.015	-0.720*	-0.715*	0.050	-0.377*	-0.588*	0.065	0.082	-0.240**	-0.492*	-0.468*	1.000						
23	-0.087	-0.077	0.072	0.225**	-0.012	0.008	0.062	-0.057	-0.207**	-0.030	0.149	0.179	0.195**	0.145	0.070	0.012	-0.001	-0.026	0.042	0.138	0.050	-0.038	1.000					
24	-0.044	-0.136	-0.142	0.293*	0.020	0.090	0.362*	0.161	0.099	-0.130	0.077	0.131	0.147	0.102	0.154	0.230**	0.093	0.324*	0.096	0.072	0.020	-0.103	0.023	1.000				
25	0.153	0.019	0.034	0.208**	0.092	0.029	0.291*	0.173	0.066	-0.000	0.106	0.039	0.047	0.112	0.117	0.108	0.044	0.269*	0.122	-0.002	-0.007	0.013	-0.198**	0.718*	1.000			
26	-0.026	-0.147	-0.062	0.092	-0.186	-0.122	-0.061	-0.083	-0.225**	-0.396*	0.324*	0.370*	0.361*	0.332*	0.033	0.296*	-0.144	-0.109	0.079	0.311*	0.267*	-0.373*	-0.024	-0.027	-0.074	1.000		
27	-0.067	-0.187	-0.125	0.056	-0.052	-0.058	-0.065	-0.066	-0.162	-0.327*	0.200**	0.263*	0.247**	0.203**	-0.026	0.289*	-0.058	-0.069	0.082	0.208**	0.227**	-0.317*	-0.109	-0.027	-0.242**	0.672*	1.000	
28	**0.133**	**0.184**	**0.248****	**0.255***	**-0.017**	**0.378***	**0.526***	**0.454***	**0.325***	**0.078**	**0.147**	**0.081**	**0.039**	**0.106**	**0.319***	**0.015**	**0.355***	**0.433***	**0.255***	**0.169**	**0.213****	**0.065**	**0.049**	**0.244****	**0.262***	**-0.082**	**-0.105**	**1.000**

* significance at 1% level of significance.

** significance at 5% level of significance.

Where, 1= Leaf blade length (cm), 2= Leaf blade width, 3= Petiole length (mm), 4= Stalk length (mm), 5= Stalk diameter (mm), 6= Fruit length (cm), 7= Fruit diameter, 8= Fruit weight (kg), 9= Fruit rind weight (kg), 10= Number of flakes/kg fruit, 11= Weight of flakes/kg fruit, 12= Weight of fresh flake with seed (g), 13= Weight of fresh flake without seed (g), 14= Flake/fruit ratio, 15= Flake length (cm), 16= Flake width (cm), 17= Rachis length (cm), 18= Rachis diameter, 19= Seed length (cm), 20= Seed width (cm), 21= 100-seed weight (g), 22= Number of seeds/kg fruit, 23= TSS (˚B), 24= Total sugar (%), 25= Reducing sugar (%), 26= Total carbohydrate (mg/g), 27= Protein content (µg/g), 28= Fruit yield per tree

Table 5: Correlation matrix showing relationship at genotypic level with respect to vegetative, fruit yield and quality characters

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	1.000																											
2	0.785	1.000																										
3	0.703	0.632	1.000																									
4	0.323	0.088	0.347	1.000																								
5	0.190	0.175	0.178	0.018	1.000																							
6	0.343	0.317	0.442	0.325	0.195	1.000																						
7	0.382	0.226	0.492	0.556	-0.127	0.617	1.000																					
8	0.445	0.321	0.613	0.480	0.055	0.815	0.845	1.000																				
9	0.311	0.345	0.345	0.051	0.070	0.768	0.565	0.801	1.000																			
10	-0.038	-0.095	-0.003	-0.051	0.441	0.032	-0.150	-0.052	-0.055	1.000																		
11	0.179	-0.139	0.374	0.641	-0.179	0.236	0.588	0.526	0.001	-0.043	1.000																	
12	0.175	0.143	0.414	0.303	-0.381	0.138	0.406	0.299	0.094	-0.756	0.460	1.000																
13	0.176	0.140	0.363	0.272	-0.384	0.084	0.381	0.237	0.043	-0.753	0.431	0.990	1.000															
14	0.161	-0.188	0.286	0.626	-0.175	0.193	0.538	0.458	-0.043	0.000	0.987	0.422	0.401	1.000														
15	0.263	0.297	0.564	0.426	-0.296	0.440	0.784	0.685	0.421	-0.391	0.600	0.658	0.627	0.525	1.000													
16	-0.034	-0.019	0.135	0.118	-0.385	-0.008	0.234	0.122	0.097	-0.655	0.249	0.849	0.855	0.233	0.487	1.000												
17	0.333	0.290	0.365	0.285	0.266	0.982	0.538	0.754	0.711	0.083	0.174	0.030	-0.017	0.137	0.310	-0.102	1.000											
18	0.411	0.144	0.312	0.488	0.032	0.591	0.872	0.720	0.513	0.097	0.401	0.076	0.068	0.381	0.388	-0.023	0.575	1.000										
19	0.090	0.084	0.490	0.439	-0.101	0.415	0.577	0.599	0.262	-0.293	0.561	0.494	0.434	0.491	0.723	0.262	0.325	0.274	1.000									
20	-0.040	0.025	0.380	0.268	-0.258	0.263	0.391	0.351	0.189	-0.630	0.422	0.824	0.784	0.378	0.627	0.743	0.165	0.063	0.528	1.000								
21	0.123	0.114	0.533	0.363	-0.266	0.346	0.412	0.502	0.298	-0.563	0.471	0.776	0.681	0.404	0.626	0.594	0.238	0.095	0.634	0.788	1.000							
22	-0.030	-0.103	-0.044	-0.056	0.432	0.015	-0.168	-0.079	-0.070	0.995	-0.052	-0.757	-0.752	0.005	-0.422	-0.649	0.068	0.093	-0.319	-0.640	-0.579	1.000						
23	-0.147	-0.148	0.112	0.233	-0.005	0.013	0.073	-0.064	-0.237	-0.038	0.146	0.192	0.205	0.142	0.053	0.009	0.004	0.002	0.083	0.215	0.080	-0.047	1.000					
24	-0.069	-0.203	-0.202	0.305	0.018	0.124	0.423	0.190	0.117	-0.142	0.108	0.163	0.180	0.138	0.183	0.290	0.130	0.469	0.136	0.084	0.042	-0.112	0.021	1.000				
25	0.196	0.021	0.021	0.226	0.107	0.042	0.334	0.188	0.073	-0.001	0.133	0.053	0.060	0.149	0.133	0.122	0.065	0.394	0.174	0.017	0.009	0.018	-0.212	0.747	1.000			
26	-0.157	-0.279	-0.217	0.103	-0.263	-0.167	-0.076	-0.113	-0.298	-0.488	0.432	0.468	0.460	0.465	0.043	0.405	-0.176	-0.163	0.117	0.471	0.378	-0.464	-0.034	-0.040	-0.109	1.000		
27	-0.202	-0.360	-0.240	0.063	-0.067	-0.079	-0.080	-0.088	-0.210	-0.382	0.245	0.312	0.294	0.249	-0.036	0.358	-0.060	-0.103	0.149	0.323	0.310	-0.376	-0.129	-0.041	-0.305	0.692	1.000	
28	0.208**	0.359*	0.430*	0.284*	-0.017	0.389*	0.556*	0.466*	0.310*	0.109	0.202**	0.084	0.034	0.149	0.381*	0.025	0.358*	0.523*	0.326*	0.184	0.287*	0.085	0.058	0.299*	0.318*	-0.187	-0.133	1.000

* significance at 1% level of significance.

** significance at 5% level of significance.

Where, 1= Leaf blade length (cm), 2= Leaf blade width, 3= Petiole length (mm), 4= Stalk length (mm), 5= Stalk diameter (mm), 6= Fruit length (cm), 7= Fruit diameter, 8= Fruit weight (kg), 9= Fruit rind weight (kg), 10= Number of flakes/kg fruit, 11= Weight of flakes/kg fruit, 12= Weight of fresh flake with seed (g), 13= Weight of fresh flake without seed (g), 14= Flake/fruit ratio, 15= Flake length (cm), 16= Flake width (cm), 17= Rachis length (cm), 18= Rachis diameter, 19= Seed length (cm), 20= Seed width (cm), 21= 100-seed weight (g), 22= Number of seeds/kg fruit, 23= TSS (˚B), 24= Total sugar (%), 25= Reducing sugar (%), 26= Total carbohydrate (mg/g), 27= Protein content (µg/g), 28= Fruit yield per tree.

weight. The genotypic correlation coefficients of different characters showed that fruit yield per tree had significant and positive correlation with fruit diameter (0.556), rachis diameter (0.523), fruit weight (0.466), petiole length (0.430), fruit length (0.389), flake length (0.381), leaf blade width (0.359), rachis length (0.358), seed length (0.326), reducing sugar (0.318), fruit rind weight (0.310), total sugar (0.299), 100-seed weight (0.287), stalk length (0.284), leaf blade length (0.208) and weight of flakes per kg of fruit ((0.202) (Table 5). Similar correlations of yield with various other horticultural traits had also been reported by Sharma and Sharma (2006) in strawberry, who observed that yield per plant was significantly and positively associated with fruit length and fruit breadth. In the present study, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for most of the traits, this means that there is a strong association between any two characters, but the phenotypic values are lessened by the significant interaction of environment. Sharma *et al*. (2006) also found higher genotypic correlation coefficients than phenotypic correlation coefficients for most of the characters. The characters such as number of flakes per kg of fruit, weight of fresh flake with seed, weight of fresh flake without seed, flake/fruit ratio, flake width, seed width, number of seeds per kg of fruit and total soluble solids showed no significant association with yield revealed that yield was independent of these characters. These findings is not in accordance with the finding of Maiti (2010) who observed significant correlation of fruit weight with number of seeds and number of flakes.

3.3 PATH ANALYSIS

Although correlation studies are helpful in determining the components of yield but it does not provide a clear picture of nature and extent of contributions made by number of independent traits. Path coefficient analysis devised by Dewey and Lu (1959), provides a realistic basis for allocation of appropriate weightage to various attributes while designing a pragmatic programme for the improvement of yield. The path coefficient analysis at phenotypic level revealed that weight of fresh flake without seed (21.1008) has maximum positive direct effect on fruit yield per tree followed by 100-seed weight (5.6297), number of seeds per kg of fruit (1.7891), weight of flakes per kg of fruit (0.6414), rachis length (0.5074), fruit diameter (0.3871), flake length (0.3136), reducing sugar (0.2413), leaf blade width (0.1527), total carbohydrate content of seed (0.1512), rachis diameter (0.1393), protein content of seed (0.1220), TSS (0.0992), fruit weight (0.0835), seed width (0.0769), petiole length (0.0753), stalk length (0.0700) and seed length (0.0345) (Table 6). In accordance with present investigation, Wangchu *et al*. (2013) also observed positive direct effect of stalk length, fruit weight, weight of flakes per kg of fruit, flake length and 100-seed weight on fruit yield per tree. Further, the negative direct effect of weight of flake with seed, flake/fruit ratio, number of flakes per kg of fruit, fruit length, leaf blade length, stalk diameter, fruit rind weight, total sugar and flake width was observed on fruit yield per tree. Under this situation indirect selection for such traits should be practiced to reduce the undesirable direct effect. At genotypic level, weight of fresh flakes with seed (96.5952) has maximum positive direct effect on fruit yield per tree followed by weight of flakes per kg of fruit (9.7365), number of seeds per kg of fruit (6.5417), fruit length (4.3799), protein content of seed (1.6243), rachis diameter (1.6010), flake length (1.4732), reducing sugar (1.3496), leaf blade width (1.0691), seed width (0.9405), TSS (0.8564), fruit rind weight (0.6448), total sugar (0.3028), leaf blade

Table 6: Estimates of direct and indirect effects on fruit yield per tree at phenotypic level

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	**-0.2131**	-0.1582	-0.1223	-0.0550	-0.0326	-0.0534	-0.0620	-0.0716	-0.0440	0.0049	-0.0269	-0.0270	-0.0255	-0.0180	-0.0407	0.0067	-0.0498	-0.0488	-0.0177	0.0055	-0.0226	0.0075	0.0186	0.0095	-0.0326	0.0056	0.0144
2	0.1134	**0.1527**	0.0856	0.0085	0.0173	0.0332	0.0274	0.0353	0.0319	-0.0097	-0.0131	0.0145	0.0130	-0.0227	0.0288	-0.0041	0.0312	0.0127	0.0080	-0.0008	0.0147	-0.0134	-0.0118	-0.0208	0.0029	-0.0225	-0.0286
3	0.0432	0.0422	**0.0753**	0.0157	0.0077	0.0174	0.0209	0.0284	0.0115	0.0004	0.0177	0.0189	0.0164	0.0106	0.0229	0.0049	0.0150	0.0095	0.0193	0.0133	0.0214	-0.0031	0.0055	-0.0107	0.0026	-0.0047	-0.0094
4	0.0181	0.0039	0.0146	**0.0700**	0.0043	0.0205	0.0354	0.0316	0.0051	-0.0036	0.0375	0.0186	0.0167	0.0362	0.0253	0.0065	0.0178	0.0247	0.0208	0.0141	0.0192	-0.0037	0.0158	0.0205	0.0146	0.0065	0.0040
5	-0.0249	-0.0185	-0.0166	-0.0101	**-0.1632**	-0.0260	0.0162	-0.0082	-0.0115	-0.0640	0.0272	0.0552	0.0555	0.0260	0.0372	0.0539	-0.0351	-0.0049	0.0085	0.0315	0.0333	-0.0633	0.0020	-0.0033	-0.0151	0.0304	0.0086
6	-0.1151	-0.0998	-0.1059	-0.1346	-0.0732	**-0.4594**	-0.2859	-0.3700	-0.3314	-0.0196	-0.0913	-0.0525	-0.0313	-0.0696	-0.1548	-0.0047	-0.4449	-0.2492	-0.1095	-0.0771	-0.1147	-0.0088	-0.0039	-0.0416	-0.0137	0.0563	0.0270
7	0.1126	0.0695	0.1072	0.1954	-0.0385	0.2409	**0.3871**	0.3247	0.2150	-0.0530	0.1946	0.1468	0.1359	0.1742	0.2500	0.0868	0.2108	0.2997	0.1600	0.1133	0.1342	-0.0606	0.0240	0.1401	0.1129	-0.0239	-0.0255
8	0.0281	0.0193	0.0315	0.0377	0.0042	0.0673	0.0701	**0.0835**	0.0648	-0.0035	0.0379	0.0227	0.0175	0.0319	0.0474	0.0102	0.0620	0.0527	0.0344	0.0210	0.0345	-0.0060	-0.0048	0.0135	0.0144	-0.0070	-0.0055
9	-0.0311	-0.0314	-0.0230	-0.0110	-0.0106	-0.1085	-0.0835	-0.1166	**-0.1504**	0.0094	0.0184	-0.0037	0.0025	0.0231	-0.0507	-0.0078	-0.1000	-0.0688	-0.0166	-0.0153	-0.0261	0.0110	0.0312	-0.0150	-0.0100	0.0339	0.0245
10	0.0273	0.0763	-0.0061	0.0610	-0.4700	-0.0512	0.1641	0.0506	0.0750	**-1.1980**	0.0022	0.8646	0.8642	-0.0364	0.4257	0.7079	-0.1071	-0.0992	0.2793	0.5826	0.5436	-1.1831	0.0365	0.1566	0.0003	0.4755	0.3920
11	0.0810	-0.0552	0.1511	0.3439	-0.1069	0.1275	0.3225	0.2912	-0.0786	-0.0012	**0.6414**	0.3068	0.2854	0.6240	0.3029	0.1807	0.0894	0.1710	0.2830	0.2140	0.2750	-0.0098	0.0956	0.0498	0.0681	0.2079	0.1288
12	-3.0931	-2.3171	-6.1209	-6.4945	8.2717	-2.7913	-9.2717	-6.6580	-0.6002	17.6422	-11.6928	**-24.4453**	-24.0170	-10.8251	-13.9866	-19.6476	-0.3237	-1.3852	-10.6846	-15.7789	-16.9809	17.6047	-4.3937	-3.2223	-0.9612	-9.0623	-6.4378
13	2.5234	1.7988	4.5903	5.0197	-7.1831	1.4364	7.4079	4.4238	-0.3459	-15.2217	9.3888	20.7311	**21.1008**	8.8329	11.5099	17.1025	-0.5655	0.8726	7.5755	12.3579	11.5719	-15.1045	4.1336	3.1203	1.0044	7.6305	5.2140
14	-0.1022	0.1797	-0.1706	-0.6262	0.1933	-0.1835	-0.5453	-0.4624	0.1864	-0.0368	-1.1788	-0.5366	-0.5072	**-1.2117**	-0.5036	-0.3182	-0.1105	-0.3052	-0.4907	-0.3649	-0.4498	-0.0607	-0.1762	-0.1240	-0.1363	-0.4030	-0.2467
15	0.0599	0.0590	0.0953	0.1134	-0.0715	0.1057	0.2025	0.1778	0.1058	-0.1114	0.1481	0.1794	0.1710	0.1303	**0.3136**	0.1278	0.0565	0.0223	0.1454	0.1407	0.1448	-0.1184	0.0221	0.0484	0.0369	0.0106	-0.0084
16	0.0008	0.0007	-0.0016	-0.0023	0.0081	-0.0002	-0.0055	-0.0030	-0.0013	0.0144	-0.0069	-0.0196	-0.0198	-0.0064	-0.0100	**-0.0244**	0.0017	0.0006	-0.0044	-0.0124	-0.0117	0.0144	-0.0003	-0.0056	-0.0027	-0.0072	-0.0071
17	0.1185	0.1035	0.1008	0.1292	0.1091	0.4914	0.2764	0.3765	0.3375	0.0454	0.0707	0.0067	-0.0136	0.0463	0.0914	-0.0359	**0.5074**	0.2851	0.0853	0.0445	0.0826	0.0333	-0.0006	0.0474	0.0226	-0.0733	-0.0298
18	0.0319	0.0116	0.0176	0.0492	0.0042	0.0756	0.1079	0.0879	0.0637	0.0115	0.0371	0.0079	0.0058	0.0351	0.0099	-0.0036	0.0783	**0.1393**	0.0272	0.0077	0.0132	0.0114	-0.0038	0.0452	0.0375	-0.0152	-0.0097
19	0.0029	0.0018	0.0088	0.0103	-0.0018	0.0082	0.0143	0.0142	0.0038	-0.0081	0.0152	0.0151	0.0124	0.0140	0.0160	0.0062	0.0058	0.0067	**0.0345**	0.0179	0.0199	-0.0083	0.0015	0.0033	0.0042	0.0027	0.0029
20	-0.0020	-0.0004	0.0136	0.0155	-0.0149	0.0129	0.0225	0.0193	0.0078	-0.0374	0.0257	0.0497	0.0451	0.0232	0.0345	0.0392	0.0068	0.0042	0.0399	**0.0769**	0.0489	-0.0379	0.0107	0.0056	-0.0002	0.0239	0.0161
21	0.5973	0.5417	1.5975	1.5413	-1.1503	1.4051	1.9520	2.3241	0.9763	-2.5545	2.4138	3.9106	3.0874	2.0897	2.5995	2.6897	0.9169	0.5330	3.2392	3.5784	**5.6296**	-2.6364	0.2834	0.1160	-0.0416	1.5065	1.2829
22	-0.0626	-0.1570	-0.0743	-0.0947	0.6945	0.0342	-0.2800	-0.1290	-0.1309	1.7668	-0.0273	-1.2885	-1.2807	0.0896	-0.6756	-1.0523	0.1176	0.1468	-0.4309	-0.8812	-0.8379	**1.7891**	-0.0681	-0.1858	0.0246	-0.6681	-0.5681
23	-0.0087	-0.0077	0.0072	0.0223	-0.0012	0.0008	0.0061	-0.0057	-0.0206	-0.0030	0.0148	0.0178	0.0194	0.0144	0.0070	0.0013	-0.0001	-0.0027	0.0042	0.0138	0.0050	-0.0038	**0.0992**	0.0024	-0.0197	-0.0024	-0.0108
24	0.0032	0.0097	0.0101	-0.0208	-0.0014	-0.0064	-0.0257	-0.0115	-0.0071	0.0093	-0.0055	-0.0093	-0.0105	-0.0073	-0.0109	-0.0164	-0.0066	-0.0230	-0.0068	-0.0051	-0.0015	0.0074	-0.0017	**-0.0709**	-0.0510	0.0019	0.0019
25	0.0369	0.0046	0.0083	0.0503	0.0223	0.0072	0.0704	0.0417	0.0161	-0.0001	0.0256	0.0095	0.0115	0.0271	0.0284	0.0262	0.0107	0.0649	0.0295	-0.0006	-0.0018	0.0033	-0.0479	0.1733	**0.2413**	-0.0179	-0.0585
26	-0.0040	-0.0223	-0.0094	0.0140	-0.0282	-0.0185	-0.0093	-0.0126	-0.0341	-0.0600	0.0490	0.0561	0.0547	0.0503	0.0051	0.0448	-0.0219	-0.0165	0.0120	0.0471	0.0405	-0.0565	-0.0036	-0.0041	-0.0112	**0.1512**	0.1016
27	-0.0083	-0.0228	-0.0153	0.0069	-0.0064	-0.0072	-0.0080	-0.0081	-0.0199	-0.0399	0.0245	0.0321	0.0302	0.0249	-0.0033	0.0353	-0.0072	-0.0085	0.0101	0.0255	0.0278	-0.0387	-0.0133	-0.0033	-0.0296	0.0820	**0.1220**
28	**0.1334**	**0.1844**	**0.2487**	**0.2552**	**-0.0171**	**0.3785**	**0.5268**	**0.4540**	**0.3252**	**0.0786**	**0.1478**	**0.0817**	**0.0397**	**0.1067**	**0.3193**	**0.0158**	**0.3555**	**0.4339**	**0.2552**	**0.1692**	**0.2133**	**0.0651**	**0.0498**	**0.2446**	**0.2626**	**-0.0820**	**-0.1052**

Residual effect= 0.7241

Where, 1= Leaf blade length (cm), 2= Leaf blade width, 3= Petiole length (mm), 4= Stalk length (mm), 5= Stalk diameter (mm), 6= Fruit length (cm), 7= Fruit diameter, 8= Fruit weight (kg), 9= Fruit rind weight (kg), 10= Number of flakes/kg fruit, 11= Weight of flakes/kg fruit, 12= Weight of fresh flake with seed (g), 13= Weight of fresh flake without seed (g), 14= Flake/fruit ratio, 15= Flake length (cm), 16= Flake width (cm), 17= Rachis length (cm), 18= Rachis diameter, 19= Seed length (cm), 20= Seed width (cm), 21= 100-seed weight (g), 22= Number of seeds/kg fruit, 23= TSS (˚B), 24= Total sugar (%), 25= Reducing sugar (%), 26= Total carbohydrate (mg/g), 27= Protein content (µg/g), 28= Fruit yield per tree

Table 7: Estimates of direct and indirect effects on fruit yield per tree at genotypic level

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	**0.108**	0.084	0.076	0.035	0.020	0.037	0.041	0.048	0.033	-0.004	0.019	0.019	0.019	0.017	0.028	-0.003	0.036	0.044	0.009	-0.004	0.013	-0.003	-0.015	-0.007	0.0212	-0.0170	-0.0219
2	0.839	**1.069**	0.676	0.094	0.187	0.339	0.242	0.343	0.369	-0.102	-0.149	0.152	0.150	-0.201	0.317	-0.020	0.310	0.154	0.090	0.027	0.122	-0.110	-0.158	-0.217	0.0230	-0.2992	-0.3849
3	-0.810	-0.728	**-1.151**	-0.400	-0.205	-0.510	-0.567	-0.706	-0.398	0.003	-0.430	-0.477	-0.419	-0.329	-0.650	-0.156	-0.421	-0.360	-0.565	-0.438	-0.614	0.051	-0.129	0.233	-0.0250	0.2510	0.2764
4	-0.023	-0.006	-0.024	**-0.071**	-0.001	-0.023	-0.039	-0.034	-0.003	0.003	-0.045	-0.021	-0.019	-0.044	-0.030	-0.008	-0.020	-0.034	-0.031	-0.019	-0.025	0.004	-0.016	-0.021	-0.0161	-0.0074	-0.0045
5	-0.122	-0.112	-0.114	-0.012	**-0.643**	-0.125	0.081	-0.035	-0.045	-0.283	0.115	0.245	0.247	0.113	0.190	0.248	-0.171	-0.020	0.065	0.166	0.171	-0.278	0.003	-0.011	-0.0693	0.1692	0.0433
6	1.503	1.388	1.939	1.423	0.856	**4.379**	2.702	3.571	3.366	0.143	1.034	0.608	0.371	0.849	1.931	-0.035	4.304	2.592	1.820	1.155	1.518	0.067	0.057	0.544	0.1838	-0.7328	-0.3476
7	-1.137	-0.672	-1.462	-1.653	0.377	-1.832	**-2.970**	-2.512	-1.679	0.445	-1.747	-1.208	-1.132	-1.600	-2.331	-0.697	-1.599	-2.591	-1.716	-1.162	-1.224	0.499	-0.217	-1.257	-0.9934	0.2265	0.2385
8	0.028	0.020	0.039	0.030	0.003	0.052	0.053	**0.063**	0.051	-0.003	0.033	0.019	0.015	0.029	0.043	0.007	0.048	0.045	0.038	0.022	0.032	-0.005	-0.004	0.012	0.0120	-0.0072	-0.0056
9	0.201	0.222	0.222	0.033	0.045	0.495	0.364	0.516	**0.644**	-0.035	0.000	0.060	0.028	-0.028	0.272	0.062	0.459	0.331	0.169	0.122	0.192	-0.045	-0.153	0.075	0.0474	-0.1923	-0.1355
10	0.164	0.412	0.014	0.221	-1.898	-0.141	0.645	0.226	0.238	**-4.300**	0.188	3.252	3.242	-0.000	1.684	2.818	-0.360	-0.417	1.262	2.710	2.425	-4.280	0.165	0.611	0.0046	2.1026	1.6431
11	1.742	-1.361	3.641	6.249	-1.745	2.298	5.726	5.128	0.008	-0.425	**9.736**	4.484	4.197	9.609	5.844	2.432	1.699	3.905	5.467	4.108	4.586	-0.509	1.421	1.052	1.2971	4.2087	2.3895
12	16.924	13.808	40.046	29.321	-36.823	13.415	39.283	28.934	9.117	-73.038	44.490	**96.595**	95.655	40.804	63.643	82.012	2.904	7.410	47.809	79.681	74.985	-73.158	18.573	15.788	5.1606	45.2793	30.1779
13	-14.418	-11.513	-29.767	-22.292	31.420	-6.939	-31.206	-19.390	-3.588	61.678	-35.268	-81.021	**-81.817**	-32.838	-51.298	-69.960	1.446	-5.570	-35.584	-64.155	-55.721	61.524	-16.824	-14.760	-4.9084	-37.7079	-24.0875
14	-1.627	1.898	-2.885	-6.312	1.770	-1.953	-5.428	-4.620	0.438	-0.001	-9.945	-4.256	-4.044	**-10.076**	-5.298	-2.353	-1.382	-3.842	-4.951	-3.815	-4.079	-0.054	-1.440	-1.399	-1.5042	-4.6903	-2.5103
15	0.387	0.437	0.831	0.628	-0.436	0.649	1.156	1.010	0.621	-0.577	0.884	0.970	0.923	0.774	**1.473**	0.718	0.458	0.572	1.065	0.923	0.923	-0.622	0.078	0.270	0.1961	0.0647	-0.0532
16	0.062	0.034	-0.241	-0.211	0.687	0.014	-0.418	-0.218	-0.174	1.167	-0.445	-1.513	-1.524	-0.416	-0.868	**-1.782**	0.183	0.041	-0.468	-1.324	-1.059	1.158	-0.016	-0.518	-0.2182	-0.7225	-0.6396
17	-1.529	-1.331	-1.674	-1.308	-1.222	-4.502	-2.466	-3.458	-3.261	-0.383	-0.799	-0.137	0.081	-0.628	-1.424	0.470	**-4.581**	-2.635	-1.490	-0.756	-1.092	-0.314	-0.020	-0.599	-0.2988	0.8088	0.2770
18	0.658	0.230	0.500	0.781	0.051	0.947	1.396	1.153	0.822	0.155	0.642	0.122	0.109	0.610	0.621	-0.037	0.920	**1.601**	0.440	0.101	0.152	0.149	0.003	0.752	0.6320	-0.2623	-0.1651
19	-0.049	-0.046	-0.268	-0.240	0.055	-0.227	-0.315	-0.327	-0.143	0.160	-0.306	-0.270	-0.237	-0.268	-0.395	-0.143	-0.177	-0.150	**-0.546**	-0.288	-0.346	0.174	-0.045	-0.074	-0.0956	-0.0640	-0.0814
20	-0.038	0.024	0.358	0.252	-0.243	0.248	0.367	0.330	0.178	-0.592	0.396	0.775	0.737	0.356	0.589	0.699	0.155	0.059	0.497	**0.940**	0.741	-0.602	0.202	0.079	0.0162	0.4433	0.3040
21	-2.251	-2.090	-9.716	-6.612	4.853	-6.313	-7.509	-9.156	-5.429	10.271	-8.580	-14.139	-12.404	-7.373	-11.418	-10.823	-4.341	-1.736	-11.554	-14.366	**-18.213**	10.546	-1.462	-0.779	-0.1692	-6.9015	-5.6529
22	-0.198	-0.674	-0.290	-0.370	2.827	0.100	-1.099	-0.518	-0.457	6.511	-0.342	-4.954	-4.919	0.035	-2.764	-4.251	0.448	0.608	-2.088	-4.187	-3.787	**6.541**	-0.309	-0.738	0.1210	-3.0405	-2.4608
23	-0.125	-0.126	0.096	0.200	-0.004	0.011	0.062	-0.054	-0.203	-0.033	0.125	0.164	0.176	0.122	0.045	0.007	0.003	0.001	0.071	0.184	0.068	-0.040	**0.856**	0.018	-0.1820	-0.0292	-0.1108
24	-0.021	-0.061	-0.061	0.092	0.005	0.037	0.128	0.057	0.035	-0.043	0.032	0.049	0.054	0.042	0.055	0.088	0.039	0.142	0.041	0.025	0.013	-0.034	0.006	**0.302**	0.2262	-0.0121	-0.0125
25	0.265	0.029	0.029	0.305	0.145	0.056	0.451	0.254	0.099	-0.001	0.179	0.072	0.081	0.201	0.179	0.165	0.088	0.532	0.236	0.023	0.012	0.025	-0.286	1.008	**1.3496**	-0.1480	-0.4117
26	0.005	0.008	0.006	-0.003	0.008	0.005	0.002	0.003	0.009	0.015	-0.013	-0.014	-0.014	-0.014	-0.001	-0.012	0.005	0.005	-0.003	-0.014	-0.012	0.014	0.001	0.001	0.0035	**-0.0316**	-0.0219
27	-0.329	-0.584	-0.389	0.103	-0.109	-0.128	-0.130	-0.143	-0.341	-0.620	0.398	0.507	0.478	0.404	-0.058	0.582	-0.098	-0.167	0.242	0.525	0.504	-0.611	-0.210	-0.067	-0.4954	1.1241	**1.6243**
28	**0.208**	**0.359**	**0.430**	**0.284**	**-0.017**	**0.389**	**0.556**	**0.466**	**0.310**	**0.109**	**0.202**	**0.084**	**0.034**	**0.149**	**0.381**	**0.025**	**0.358**	**0.523**	**0.326**	**0.184**	**0.287**	**0.085**	**0.058**	**0.299**	**0.3185**	**-0.1875**	**-0.1339**

Residual effect= 0.3207

Where, 1= Leaf blade length (cm), 2= Leaf blade width, 3= Petiole length (mm), 4= Stalk length (mm), 5= Stalk diameter (mm), 6= Fruit length (cm), 7= Fruit diameter, 8= Fruit weight (kg), 9= Fruit rind weight (kg), 10= Number of flakes/kg fruit, 11= Weight of flakes/kg fruit, 12= Weight of fresh flake with seed (g), 13= Weight of fresh flake without seed (g), 14= Flake/fruit ratio, 15= Flake length (cm), 16= Flake width (cm), 17= Rachis length (cm), 18= Rachis diameter, 19= Seed length (cm), 20= Seed width (cm), 21= 100-seed weight (g), 22= Number of seeds/kg fruit, 23= TSS (˚B), 24= Total sugar (%), 25= Reducing sugar (%), 26= Total carbohydrate (mg/g), 27= Protein content (µg/g), 28= Fruit yield per tree

width (0.1082) and fruit weight (0.0638). While, negative direct effect of weight of fresh flake without seed, 100-seed weight, flake/fruit ratio, rachis length, number of flakes per kg of fruit, fruit diameter, flake width, petiole length, stalk diameter, seed length, stalk length and total carbohydrate content of seed was observed on fruit yield per tree (Table 7). These findings will help in selecting superior genotypes. This is in accordance with some of the findings of Wangchu *et al.* (2013) who recorded direct effect of fruit length, fruit weight, flake length and number of seed per kg of fruit on fruit yield.

4. CONCLUSION

The phenotypic coefficients of variability and genotypic coefficients of variability were recorded high for weight of fresh flake without seed, stalk length and fruit weight whereas low for seed length, leaf blade width and leaf blade length, respectively. High heritability coupled with high genetic gain was observed for stalk length, fruit weight, weight of fresh flake with seed and weight of fresh flake without seed. Genetic advance was recorded highest for 100-seed weight followed by stalk length and lowest for flake/fruit ratio followed by seed width. The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. Genotypic correlations in general, were higher in magnitude than phenotypic ones. Yield per plant showed significant and positive genotypic correlation coefficient with fruit diameter, rachis diameter, fruit weight, petiole length, fruit length, flake length, leaf blade width, rachis length, seed length, reducing sugar, fruit rind weight, total sugar, 100-seed weight, stalk length, leaf blade length and weight of flakes per kg of fruit. At phenotypic level, yield per plant was positively and significantly associated with fruit diameter, fruit weight, rachis diameter, fruit length, rachis length, fruit rind weight, flake length, reducing sugars, stalk length, seed length, petiole length, total sugar and 100-seed weight. The path coefficient analysis revealed that weight of fresh flake with seed has maximum positive direct effect on fruit yield per tree followed by weight of flakes per kg of fruit, number of seeds per kg of fruit, fruit length, protein content of seed, rachis diameter, flake length, reducing sugar and leaf blade width on fruit yield at genotypic level. At phenotypic level, weight of fresh flake without seed has maximum positive direct effect on fruit yield per tree followed by 100-seed weight and number of seeds per kg of fruit. From this it is clear that there is a true relationship of these characters with yield and direct selection for this trait will be rewarding for the yield improvement in jackfruit.

ACKNOWLEDGEMENT

The author is thankful to the Department of Fruit Science and Department of Basic Sciences and Humanities, College of Horticulture and Forestry, Central Agricultural University, Pasighat for providing fund and support for conducting this research.

Ethical: NA

Consent: NA

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