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Variability, Association and Path Coefficient Analysis of Yield and Yield Components of Dioecious Papaya Genotypes in Ethiopia

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ABSTRACT

In Ethiopia, there has been no information on the extent of variability and association of traits in dioecuous papaya genotypes. An experiment was conducted at Melkassa Agricultural Research Center to estimate variability, correlation and path coefficient analysis for yield and yield contributing traits. Fifteen promising dioecious papaya genotypes were evaluated for twelve traits using randomized complete block design in three replications. The analysis showed significant amount of variation in their mean performances with respect to the traits studied except canopy width which indicated the presence of sufficient variability for genotypes studding of superior desirable traits. High heritability couple genetic advance were observed for total number of fruit per plant (87.9, 56.4), total fruit yield (90.7, 53.7), girth diameter (87.2, 34.1) and plant height (92.6, 30.2), respectively indicating that these traits are predominantly governed by additive gene action. From correlation component, fruit yield per plant exhibited highly significant positive association was obtained from total number of fruit (0.872, 0.856) and marketable fruit yield per plant (0.989, 0.989) at both genotypic and phenotypic levels, respectively. Average fruit weight had the highest direct effect (2.91) on fruit yield per plant followed by total number of fruit per plant (2.75), and plant height at flowering (1.2). In general, result of this study indicated total number of fruit per plant, average fruit weight and plant height showed high heritability coupled genetic advance, correlation and positive direct path coefficient. Hence, selecting these traits can be used as primary selection criteria for dioecious papaya yield improvement program.

Keywords: "Heritability" "Genetic advance" "Association" "Path analysis"

INTRODUCTION

Papaya Ethiopia plays important roles in income generation, export market, employment opportunities, stabilizing the environment [3, 22] and source of antioxidants, carotene, vitamins, and flavonoids [14]. Presently, due to its easy growing and early fruiting ability papaya occupied significant position in homestead, kitchen garden, home back space for family use and commercial production. Over the last 10 years, the production in the country has been continuously increased by 381.57 % from 2005 to 2015 [3,4] due to increased pull factors such as population growth, income and awareness of households in consuming papaya and the wide opportunity for export in neighboring countries [3,7]. Currently, three hermaphrodite papaya varieties were nationally released in Ethiopia by Melkassa Agricultural Research Center for fresh consumption (MARC) [18].

In the last 20 years, efforts have been made on dioecious papaya varietal development to identify suitable varieties for local and export market as well as processing industries. Nowadays due to lack of improved and uniform dioecious papaya varieties in the country growers are forced to use unknown open pollinated genotypes and segregating generation; caused with that are reduce in successive performance in growth, yield and yield component. Tropical fruits breeding program at MARC has made collections and continuous controlled pollination of papaya genotypes to develop varieties with desirable traits, mainly respect to yield and yield components. Sib-mating is the commonly adopted breeding method which for the development of dioecious papaya genotypes [13], However, efforts to improve dioecious papaya genotypes have been constrained mainly by lack of adequate information on the genetic control of yield and yield related traits of the genotypes.

Fruit yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations [11]; whereas yield component traits are less complex in inheritance and influenced by the environment to a lesser extent. In plant breeding programme, direct selection for fruit yield as such could be misleading [8]. A successful selection depends upon the information on the genetic variability and association of morpho-agronomic traits with fruit yield. Correlation studies along with path coefficient analysis can provide a better understanding of the association of different traits with fruit yield. Path coefficient analysis separates the direct effects from the indirect effects through other related traits by partitioning the correlation coefficient [2]. Hence, the aim of the present study was to estimate the genetic variation, heritability, genetic advance and association of traits of promising dioecious papaya genotypes and to evaluate suitable selection criteria for further breeding program.

MATERIALS AND METHODS

Fifteen promising inbred lines of dioecious papayas (seven generation) were developed through continues sib-mating controlled pollination. These genotypes namely MK-114,L#177; Wn-140,L#484; KK-102,L#214; WN-139,L#532, MK-114,L#164; Bs-138,L#70; Zw-129,L#615; Zw-130,L#227; Zw-132,L#104; WN-140,L#482; CMF-018,L#90; Wn-140,L#488; MK-113,L#714; Bs-137,L#674 and MK-108,L#701 were used . The genotypes were planted at MARC from 2011 to 2013. The experimental site is located in the Central Rift Valley of Ethiopia at 8^o 24'N latitude and 39^o 21'E longitude. It has an elevation of 1550 m.a.s.l. The area receives mean annual rainfall of 763 mm, about 70% of which is received during the main rain season from June to September. The mean annual temperature is 21.2°C with a minimum of 14°C and maximum of 28.4°C [16].

The genotypes were arranged in Randomized Complete Block Design (RCBD) with three replications. Five seeds were sown per pot and raised in the green house. At four to five leaves stage the five seedlings were transplanted to the experimental field. Then at flowering stage the seedlings were thinned to one female plant, but one male plant was left as pollinator for each plot. The spacings of plantation were 2.5 meters between plants and 2.5 meters between rows. Standard field cultural practices were applied as per the package of recommendations. The mean of the following data were collected: plant height at first flower (cm); girth diameter at 30 cm above the ground (cm); canopy diameter (cm); leaf number per tree at first flowering; inter-node length (cm); marketable fruit yield per plant (kg); number of marketable fruit per plant; total fruit yield per plant; total number of fruit per plant; fruit length (cm); fruit diameter (cm) and fruit weight (kg).

Data analysis

Phenotypic (PCV) and genotypic coefficients (GCV) of variations were estimated according to the methods suggested by [17]. Broad sense heritability was calculated as the percentage of the ratio of the genotypic variance to the phenotypic variance and was estimated on genotype mean basis as described by [1]. Similarly, genetic advance as percent of the mean, with selection of 10% of the genotypes was estimated in accordance with the methods illustrated [10]. The genotypic and phenotypic correlations coefficients were calculated using Genes free software (VS 2009.7.0.). Phenotypic and genotypic correlation coefficients among traits significance were tested using the formula suggested by [21], and [19], respectively. Path coefficient analysis was performed following the procedures of [5] for plant and fruit traits contributing to fruit yield per plant, with a view to their direct and indirect contribution and to assess the relative importance of each factor affecting fruit yield. The coefficient of variance, GCV and PCV were categorized as suggested by [10]. 0–10% = low, 10–20% = moderate and 20% and above = high. Heritability percentage was categorized as demonstrated by Robinson et al. (1949): 0–30% = low, 30–60% = moderate and 60% and above = high.

RESULTS AND DISCUSSION

Analysis of Variance

Mean square for genotypes showed highly significant differences for all the traits except canopy diameter (Table 1). This indicates that there is sufficient variability for the traits in the genotypes studied, showing the existence of high scope for further selection and breeding superior and desirable genotypes or varieties. Similar results were reported by [8] that are plant height, number of fruits per plant, average fruit weight, length of fruit, fruit diameter and fruit yield per plant of papaya.

Table1. *Mean values, coefficients of variation and mean squares of traits of fifteen dioecious papaya genotypes at Melkassa Agricultural Research Center.*

			Mean square value		
Trait	Treatment mean	CV	Replication	Treatment	Error
NMF	63.0	20.56	180.73	944.90***	167.78
MY	61.6	17.14	418.59	987.32***	111.53
TNF	66.7	20.59	245.90	1179.11***	188.44
TY	64.1	16.93	434.49	1031.03***	117.90
FL	18.2	6.85	2.02	8.76***	1.55
FD	11.0	3.91	0.19	1.87***	0.18
AFW	1.0	11.42	0.02	0.07***	0.01
PH	161.1	8.38	143.51	2115.86***	182.36
GD	22.5	12.87	22.32	48.66***	8.41
CW	133.4	13.11	149.41	567.77 ^{n}	305.64
LN	19.7	10.79	31.65	29.29***	4.53
IL	2.9	25..98	2.46	1.99***	0.57

** = Significant at p < 0.05; ** = Significant at p < 0.01; *** = Significant at p < 0.001; CV = Coefficients of variation PH= plant height at first flower (cm); GD= girth diameter 30 cm above the ground (cm); CW= canopy width (cm); LN= leaf number per tree; IL= inter node length (cm); MY= marketable yield per plant (kg); NMF= number of marketable fruit/plant; TY= total fruit yield per plant; TNF = total number of fruit/plant; FL= fruit length (cm) ; FD= fruit diameter (cm) and AFW= average fruit weight (kg).*

Variance Components

Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) estimates of various traits are presented in Table 2. According to the categories of Johnson et al. (1955), both GCV and PCV were high for total number of fruit per plant (32.02, 34.16), inter-node length (31.64, 34.98), number of marketable yield per plant (30.57, 32.79), marketable fruit yield per plant (31.05 , 32.59) and total fruit yield per plant (30.51, 32.04), respectively. The high values of PCV and GCV indicated the existence of substantial variability, ensuring better scope for their improvement through selection of these traits [11]. The moderate values of GCV and PCV were recorded for fruit length (10.18, 10.92), average fruit weight (16.51, 17.78), plant height 17.18, 17.85), girth diameter (19.35, 20.73), canopy diameter (12.79, 14.86) and leaf number (17.02, 18.12); while low for fruit diameter (7.54, 7.87), respectively. This indicates low sensitivity of most of the traits to environmental adjustments, and expressions of these traits are dependent more on genetic factors rather than on environmental factors. Higher phenotypic coefficients of variation (PCV) than genetic coefficient of variation (GCV) indicated the role of environment for expression of the traits. The present findings are in agreement with the report of [8] and [11] who found high to moderate value of GCV and PCV estimate on total number of fruit per plant, total fruit yield per plant, fruit size and average fruit size, respectively.

Table2. *Variability, heritability and expected genetic advance as percent of mean of some relevant traits of dioecious papaya lines at Melkassa Agricultural Research Center.*

Trait	Range	Mean	GCV %	PCV %	ECV%	(H^2)	GAM %
NMF	26-129	62.99	30.57	32.79	11.872	86.9	53.8
MY	33-126	61.63	31.05	32.59	9.893	90.8	54.7
TNF	26-132	66.67	32.02	34.16	11.887	87.9	56.4
TY	33.2-12	64.14	30.51	32.04	9.774	90.7	53.7
FL	14.2-24.7	18.21	10.18	10.92	3.947	86.9	17.9
FD	9.7-12.8	10.96	7.54	7.87	2.235	91.9	13.3
AFW	0.65-1.3	1.00	16.51	17.78	6.612	86.2	29.1
PH	104.5-245	161.09	17.18	17.85	4.840	92.6	30.2
GD	12-34	22.54	19.35	20.73	7.427	87.2	34.1
CW	100-180	133.54	12.79	14.86	7.567	74.1	22.5
LN	12-29	19.73	17.02	18.12	6.227	88.2	29.9
IL	1.4-5.25	2.93	31.64	34.98	14.928	81.8	20.3

PH= plant height at first FDower (cm); GD= girth diameter 30 cm above the ground (cm); CW= canopy width (cm); LN= leaf number per tree; IL= inter node length (cm); MY= marketable yield per plant (kg); NMF= number of marketable fruit/plant; TY= total fruit yield per plant; TNF = total number of fruit/plant; FD= fruit length (cm) ; FD= fruit diameter (cm) and AFW= average fruit weight (kg).

Heritability and Genetic Advance

The effectiveness of selection for any trait depends not only on the extent of genetic variability but also on the extent of transferring gene from one generation to the other generation [24]. According to [20], greater than 60% estimates of broad sense heritability of the traits indicating that the traits were predominantly controlled by genetic factors. In this study heritability (H^2) varied from 92.6 to 74.1% and the highest estimate of heritability was observed for plant height (92.6%) followed by fruit diameter (91.9%), total (91.9%) and marketable (91.8%) fruit yield per plant (Table 2). Whereas estimates of heritability was moderately high recorded for plant canopy diameter (74.1%). Similarly observations were also made by [12] who found high heritability estimate for fruit size and total fruit yield per plant. According to [22] when heritability of a trait is more than 80%, selection could fairly be easy due to the relative small contribution of the environment to the phenotype. However, for traits with low heritability, selection may be considerably difficult or virtually impractical due to the masking effect of the environment.

Heritability alone provides no indication of the amount of genetic improvement that would result from selection of individual genotypes [24]. Hence knowledge about genetic advance coupled with heritability is very useful. A trait exhibiting high heritability may not necessarily give high genetic advance. According to [10] high heritability accompanied by high genetic advance could help arrive at more reliable conclusion. In the present investigation high to moderate heritability coupled with high to moderate genetic advance as percent of the mean were observed for total number of fruit per plant, total fruit yield, girth diameter, plant height and average fruit weight. These traits, therefore, could be improved more easily than the rest of the traits. This result is in agreement with [8] who reported high heritability with considerably high genetic advance as percent of the mean for plant height at flowering and fruit yield per plant.

Character Association

Association of fruit yield with yield component was detected (Table 3) most genotypic coefficient were slightly higher than the corresponding phenotypic correlation coefficient values. This indicated that there were strong inherent relations among the traits studied.

Fruit yield per plant had significant and positively genetic and phenotypic correlation with total number of fruit (0.872, 0.856) and marketable fruit yield (0.989, 0.989), respectively. However, none significant positive correlation in case of fruit length, diameter, fruit weight and number of marketable fruit per plant at both genotypic and phenotypic levels. Marketable fruit yield per plant had also significant positive correlation with total fruit yield (0.989, 0.989) and number of fruit per plant (0.812, 0.800) genetic and phenotypic levels, respectively. These findings are in accordance with [6, 12] who reported significant positive association fruit yield per plant with number of fruit per plant at both genotypic and phenotypic levels. Mean total number of fruits had positive and significant genotypic correlations with marketable fruit yield (0.812), canopy diameter (0.429), inter-node length (0.311) and total fruit yield (0.989). Average fruit weight also showed significant positive association with fruit diameter (0.830, 0.814), length (0.286, 0.373) and number of marketable fruit yield (0.620, 0.339) per plant at both genotypic and phenotypic levels, respectively. However, significant negative correlations were observed with total number of fruit and leaf number at both genotypic and phenotypic levels. Similarly, [6, 8] reported that average fruit weight showed significant positive correlation with fruit diameter, length, and number of marketable fruit yield per plant at both levels.

Plant height had significant and positive correlation with canopy diameter (0.820, 0.655), leaf number (0.650, 0.598), girth diameter (0.883, 0.835), while negative and significant correlation was observed with fruit length (0.560, 0.472) at both genotypic and phenotypic levels. Similar, results were reported by, [11] that plant height showed significant positive genotypic correlation with leaf number and girth diameter. Inter-node length showed significant positive genotypic correlation with total number of fruit per plant (0.438), total fruit yield (0.392) and fruit diameter (0.687); whereas it was significantly negative correlation with leaf number (-0.564), canopy diameter (-0.813), number of marketable fruit per plant (-0.668) and girth diameter (-0.308) at genotypic level. However, leaf number per plant at first flowering had a significant positive association with plant height (0.650, 0.598), stem girth diameter (0.901, 0.819) and canopy width (0.940, 0.775) whereas a high significantly negative association was noted with fruit length (-0.915,-0.777) at both genetic and phenotypic levels.

Table3. *Phenotypic correlation (r_p) (above diagonal) and genotypic correlation coefficients (r_g) (below diagonal) of twelve traits for dioecious papaya genotypes*

	NMF	MY	TNF	TY	FL	FD	AFW	PH	GD	CW	LN	IL
NMF		0.088^{n}	-0.082^{n}	0.046^{n}	0.359**	0.046^{n}	0.339**	-0.105^{n}	-0.066^{n}	-0.037^{n}	0.000^{n}	-0.249^{n}
MY	0.331*		0.800***	0.989***	0.109^{n}	0.254^{n}	0.244^{n}	0.061^{n}	-0.136^{n}	0.289^{n}	-0.194^{n}	0.188^{n}
TNF	0.060^{n}	0.812***		0.856***	-0.038^{n}	-0.263^{n}	-0.325**	0.015^{n}	-0.001^{n}	0.235^{n}	-0.078^{n}	0.325*
TY	0.243^{n}	0.989***	0.872***		0.108^{n}	0.192^{n}	0.185^{n}	0.003^{n}	-0.152^{n}	0.259^{n}	-0.214^{n}	0.264^{n}
FL	0.659***	0.123^{n}	0.030^{n}	0.122^{n}		-0.136^{n}	0.373**	-0.472**	-0.505**	-0.632***	-0.727***	0.484**
FD	0.076^{n}	0.272^{n}	-0.238^{n}	0.209^{n}	-0.232^{n}		0.814***	0.246^{n}	0.079^{n}	0.408**	0.081^{n}	-0.185^{n}
AFW	0.620***	0.294 *	-0.262^{n}	0.230^{n}	0.286*	0.830***		-0.136^{n}	-0.268^{n}	-0.021^{n}	-0.253^{n}	-0.093^{n}
PH	-0.154^{n}	0.033^{n}	-0.021^{n}	-0.028^{n}	-0.560**	0.271^{n}	-0.146^{n}		0.835***	0.655**	0.598**	-0.241^{n}
GD	-0.174^{n}	-0.222^{n}	-0.053^{n}	-0.240^{n}	-0.626***	0.112^{n}	-0.315*	0.883***		0.753***	0.819***	-0.245^{n}
CW	-0.076^{n}	0.429**	0.307*	0.388*	-0.043^{n}	0.695***	0.067^{n}	0.820***	0.936***		0.775***	-0.321*
LN	0.089^{n}	-0.302*	-0.123^{n}	-0.315*	-0.915***	0.047^{n}	-0.341*	0.650***	0.901***	0.940 ***		-0.508**
IL	-0.668***	0.311*	0.438**	0.392*	0.687***	-0.168^{n}	-0.059^{n}	-0.299 *	-0.308*	-0.813***	-0.564**	

*^{n,} *, **, ***=non-significant, significant at 5, 1, 0.1% probability level, respectively PH= plant height at first flower (cm); GD= girth diameter 30 cm above the ground (cm); CW= canopy width (cm); LN= leaf number per tree; IL= inter node length (cm); MY= marketable yield per plant (kg); NMF= number of marketable fruit/plant; TY= total fruit yield per plant; TNF = total number of fruit/plant; FL= fruit length (cm) ; FD= fruit diameter (cm) and AFW= average fruit weight (kg).*

Path Coefficient Analysis

Significant genetic correlation coefficient between two traits does not always indicate the presence of linkage between them [15]. Path analyses the partitioning of the correlations into direct and indirect effects.

The present study was done at genetic level and the results are given in Table 4. Average fruit weight exhibited the highest positive direct effect (2.91) on fruit yield per plant; and had also indirect positive effects on girth diameter, leaf number and inter-node length. The second maximum positive direct effect was exerted by total number of fruit per plant (2.75) and had positive and significant correlation with fruit yield per plant. This suggests that the correlation has revealed the true relation and direct selection through this trait could be effective. Total number of fruit per plant had also positive indirect effect on leaf number, and stem girth and fruit diameter. Hence, the direct selection of average fruit weight and total number of fruit were found important for fruit yield improvement due to its direct high positive effect on fruit yield and positive indirect effect on other traits. Similarly, results were reported by[8, 9] who found positive direct effect of average fruit weight and total number of fruit per plant on fruit yield per plant. The third high positive direct effect was exerted by plant height at flowering (1.20). However, the trait had low to moderate indirect negative contribution to fruit yield through important fruit yield contributing traits except fruit length and number of marketable fruit yield per plant. The direct effect of inter node length was positive and negligible. Thus, considering only plant height and inter node length in the selection program is not rewarding for yield improvement.

Marketable fruit yield had a high direct negative effect on total fruit yield (-1.6), but indirect positive effect on total number of fruit, average fruit weight, girth diameter, leaf number and plant height . The correlation coefficient of the traits was significantly high and positive. Matching of significantly high positive correlation and negative direct effect of this trait indicated that the indirect effect of this trait seem to be the cause of correlation. Fruit diameter had the second high negative direct effect on fruit yield (-1.34); nevertheless, it had moderate to high indirect positive effect on average fruit weight, plant height and internodes length. Fruit length had the third high direct negative effect on fruit yield (-1.24), but it showed indirect high positive effect on average fruit and canopy width, and moderate on fruit diameter and leaf number. Girth diameter ((-0.51), leaf number (-0.35), canopy diameter (-0.44) and number of marketable fruit yield (-0.17) were other traits which had low to moderate negative direct effects on total fruit yield per plant. Hence, direct selections of these traits are not found important for yield improvement as their positive effects were indirect through other major yield components. Similar finding was reported by [8] for marketable fruit yield per plant were direct negative effect on total number of fruit and average fruit weight.

Table.4. *Direct and indirect effects of path coefficient analysis of eleven traits for dioecious papaya genotypes*

	NMF	MY	TNF	FL	FD	AFW	PH	GD	CW	LN	IL	rg
NMF	**-0.17**	-0.53	0.16	-0.82	-0.10	1.81	-0.18	0.09	0.03	-0.03	-0.02	0.24
MY	-0.05	**-1.60**	2.23	-0.15	-0.36	0.86	0.04	0.11	-0.19	0.11	0.01	0.99
TNF	-0.01	-1.30	**2.75**	-0.04	0.32	-0.76	-0.03	0.03	-0.13	0.04	0.01	0.87
FL	-0.11	-0.20	0.08	**-1.24**	0.31	0.83	-0.67	0.32	0.46	0.32	0.02	0.12
FD	-0.01	-0.44	-0.65	0.29	**-1.34**	2.42	0.32	-0.06	-0.30	-0.02	0.00	0.21
AFW	-0.10	-0.47	-0.72	-0.36	-1.11	**2.91**	-0.17	0.16	-0.03	0.12	0.00	0.23
PH	0.03	-0.05	-0.06	0.70	-0.36	-0.43	**1.20**	-0.45	-0.36	-0.23	-0.01	-0.03
GD	0.03	0.36	-0.15	0.78	-0.15	-0.92	1.06	**-0.51**	-0.41	-0.32	-0.01	-0.24
CW	0.01	-0.69	0.84	1.30	-0.93	0.20	0.98	-0.48	**-0.44**	-0.39	-0.02	0.39
LN	-0.01	0.48	-0.34	1.14	-0.06	-0.99	0.78	-0.46	-0.48	**-0.35**	-0.01	-0.32
IL	0.11	-0.50	1.20	-0.85	0.22	-0.17	-0.36	0.16	0.36	0.20	**0.03**	0.39

PH= plant height at first flower (cm); GD= girth diameter 30 cm above the ground (cm); CW= canopy width (cm); LN= leaf number per tree; IL= inter node length (cm); MY= marketable yield per plant (kg); NMF= number of marketable fruit/plant; TY= total fruit yield per plant; TNF = total number of fruit/plant; FL= fruit length (cm) ; FD= fruit width (cm) and AFW= average fruit weight (kg).

CONCLUSIONS

The study showed significant amount of variation in their mean performances with respect to most of the traits studied of dioecious papaya genotypes. High heritability and genetic advance was observed in total number of fruit per plant, total fruit yield, girth diameter, plant height and average fruit weight. Significant positive phenotypic and genetic association observed between yield with total number of fruit and marketable yield. From path analysis, average fruit weight, total number of fruit per plant and plant height at first flowering were exhibited the highest direct positive effect in which one can improve the fruit yield through direct selection of either of these characters. Overall, results of this study indicated average fruit weight, total number of fruit per plant and plant height showed moderate to high heritability and genetic advance, association and direct path coefficient effect on fruit yield per plant. Therefore, additive gene action governing the traits and improvement of any of these traits could be made for improving the fruit yield of dioecious papaya genotypes as standard selection methods.

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REFERENCES

[1] Allard, R. W. (1960) Principles of Plant Breeding. John Willy and Sons, Inc., New York, USA.

[2] Begum S., A. Ahmed, S. H. Omy. 2016. Genetic variability, trait association and path analysis in maize (zea mays l.) Bangladesh J. Agril. Res. 41(1): 173-182

[3] CSA (Central Static Agency). (2005) Agriculture Sample Survey Report on area and production for major Crop. Statical Volume. 1. Central Static Authority of Ethiopia, Addiss Abeba, Ethiopia. 10-20

[4] CSA (Central Static Agency). (2015) Agriculture Sample Survey Report on area and production for major Crops. Statical Volume.1. Central Static Authority of Ethiopia, Addiss Abeba, Ethiopia. pp: 11-19.

[5] Dewey, D. and Lu, K. H. (1959) A correlation and path coefficient analysis of components of crested wheat grass seed production. Agronomy Journal 51: pp: 515-518

[6] da Silva, F. F., Pereira, M. G., Ramos, H. C. C., Junior, P. C. D., Pereira, T. N. S., Gabriel, A. P. C., Viana, A. P. and Ferreguetti, G. A. (2007) Selection and estimation of the genetic gain in segregating generations of papaya. Crop Breed. Appl. Biotechnol. 8 (1): pp: 1-8.

[7] EIC (Ethiopian Investment Commission). (2014) Business opportunity for horticulture: http://ethioinvest.net/investmentopportunities/ stratei-sectors/horticulture. pp: (Accessed on May 22, 2016).

[8] Jambhale, V. M., Kute, N. S. and Pawar, S. V. (2014) Studies on genetic variability parameters, trait association and path analysis among yield and yield contributing traits in papaya carica papaya (l.) the bioscan. 9 (4): pp: 1711-1715

[9] Jana, B.R., Rai, M., Das, B. and Nath, V. (2006) Genetic variability and association of component traits for fruit yield in papaya (Carica papaya L.). Orissa J Hort 34 (1): 22-27.

[10] Johnson, H. W., H. F. Robinson, and Comstock, R. E. (1955) Estimates of genetic and environmental variability in soybeans. Agronomy Journal 47: pp: 314-318.

[11] Karunakaran, G., Ravishankar, H. and Dinesh, M.R. (2010) Genetical studies in papaya (Carica papaya L.). Acta Hort 851: 103-108.

[12] Kumar, M., Prasad, K. M., Prakash, S. and Kumar, S. (2015) Evaluation of Genetic Variability, Genetic advance, Heritability and Character association for Yield and its Contributing traits in Papaya (Carica papaya L.). VEGETOS. Vol. 28 (2): pp: 99-102

[13] Lee, E.A. and Kannenberg, L.W.W. (2004) Effect of Inbreeding Method and Selection Criteria on Inbred and Hybrid performance. University of plant agriculture, crop science Building guelpb, oN,NIG2w1 Canada. pp 191-197.

[14] Maisarah, N. A., Asmah, B. R. and Fauziah, O. (2013) Antioxidant analysis of different parts of Carica papaya‟ 'International Food Research Journal' 20(3): 1043-1048

[15] Majumder, D. A.N., Hassan, L., Rahim, M.A. and Kabir, M. A. (2012) correlation and path coefficient analysis of mango (Mangifera Indica L.). Bangladesh J. Agril. Res. 37(3): 493-503

[16] MARC (Melkassa Agricultural Research Center). (2008) Ethiopian Institute of Agricultural Research, Center Profile, Melkassa, Ethiopia

[17] Miller, P. A., Williams, J. C., Robinson, H. F. and Comstock, R. F. (1958) Estimation of genotypic and environmental variances and covariances in upland cotton and their implications in selection. Agronomy Journal 50: pp: 126-131.

[18] MoARD (Ministry of Agriculture and Rural Development). (2016) National crop Variety Registry Issue.18: 280-300.

[19] Robertson, G. E. (1959) The sampling variance of the genetic correlation coefficient. Biometrics 15: pp: 469-485

[20] Robinson, H. F., Comstock, R. E. and Harvey, V. H. (1949) Agronomy Journal. 41

[21] Sharma, J.R. (1998). Statistical and Biometrical Techniques in Plant Breeding. New Age

[22] International Limited Publishers. Calcutta, India.

[23] Singh, B.D. (1990) Plant Breeding: Principles and Methods. Kalyani Publishing, New Delhi.

[24] Tsegaye, D., Ahmed, A.and Dilnesaw, Z. (2009) Availability and consumption of fruits and vegetables in nine regions of Ethiopia with special emphasis to vitamin a deficiency. Ethiop. J. Health Dev.; 23 (3): Pp 216-222

[25] Wassu, M., Kebede, W.T., Tekalign, T. and Kiflemariam, Y. (2013) Genetic Variability and Distance of East Africa Cooking Banana (Musa sp.) Clones for Morpho-physicochemical Traits. East African Journal of Sciences. Volume 7 (2) 67-76