PLANT BREEDING AND SEED SCIENCE
Volume 57 2008

K. Ofori[1], E.T. Blay[1], D.K. Gamedoagbao[2]

[1] Department of Crop Science, University of Ghana, Legon, Ghana E-mail: ofori_k@samoa.usp.ac.fj,
[2] Plant Genetic Resources Centre, CSIR, Bunso, Ghana

INTER-RELATIONSHIPS BETWEEN AGRONOMIC TRAITS AND FRUIT YIELD IN SCARLET EGGPLANT (*SOLANUM AETHIOPICUM* (L.) GILO GROUP)

ABSTRACT

Genotypic correlations and path–coefficients were determined for nine yield-related agronomic traits using 10 accessions of scarlet eggplant. There were significant ($p < 0.05$) differences among the 10 accessions for all traits and differences were largely due to genetic effects. There was no significant positive correlation of any trait with fruit yield, but number of days to flowering, plant height at flowering and number of days to fruit maturity were significantly ($p < 0.05$) and negatively correlated with fruit yield. Path-coefficient analyses showed that number of fruits per plant had the highest direct effect on fruit yield, followed by fruit diameter. Low correlation between number of fruits per plant and fruit yield was due to large negative indirect effects via fruit diameter, fruit length and fruit weight. Despite the significant negative relationship with fruit yield, number of days to flowering had a positive direct path towards fruit yield. The negative correlation resulted from large negative indirect effects via days to fruit maturity, fruit diameter, fruit length and fruit weight. Selection for high yield should be exploited through correlated response of number of fruits per plant, fruit diameter and number of days to flowering, which were the major determinants of fruit yield.

Key words: African eggplants, garden egg, genotypic correlation, path analysis selection, *Solanum aethiopicum*

INTRODUCTION

Scarlet eggplant (garden egg or African eggplant) (*Solanum aethiopicum)* is one of the most important fruit vegetables in West Africa (Daunay *et al.* 2001). Statistics on production levels of the crop are not readily available as for brinjal eggplant or aubergine (*Solanum melongena)*. The crop is cultivated in most parts of the humid as well as in some dry areas of Africa and South America (Schippers 2000). They are often cultivated under rain-fed conditions with other vegetables in gardens or small fields near villages or grown as monocrop and irrigated during dry season (Lester *et al.* 1990). Immature fruits are exported fresh or canned from West Africa to Europe (Anon. 1999).

Communicated by Ludwik Spiss

Fruits are eaten immature or ripe, raw or cooked. According to Lester *et al.* (1990), the regions of greatest morphological diversity in *S. aethiopicum* are Ivory Coast and neighbouring countries, with the most abundant group being the *Gilo* type. A large proportion of the cultivars in Africa are under the control of farmers and improvement programmes are rather limited (Olufolaji and Makinde 1994). Ofori (1999) has described genetic variability among some scarlet eggplant landraces from Ghana. Scarlet eggplant cultivars vary in fruit shape, immature colour, length, breadth, weight, seed content and taste. Cultivars also vary in growth habit, leaf and petiole characteristics, time to flowering and maturity (Blay 1991, Ofori 1999).

Knowledge of the strength of relationship of various agronomic traits with fruit yield would provide some indication of the causal influence of these traits on fruit yield. Such causative relationships have been determined for *S. melongena* (Vadivel and Bapu 1990, Ushakumari and Subramanian 1993), but are not available for *S. aethiopicum*. This information is necessary for developing efficient selection strategies aimed at improving fruit yield and quality of scarlet eggplant.

The objective of this study was to determine the relative importance of various agronomic traits in determining fruit yield in scarlet eggplant through examination of their direct and indirect relationships.

MATERIALS AND METHODS

Ten scarlet eggplant accessions obtained from the Plant Genetic Resources Centre (PGRC), Bunso, were grown at the University of Ghana, Legon, from January to June 2001 and again from February to July 2002. The accessions were GH5180, GH5177, GH4921, GH5165, GH5167, GH4922, GH4927, GH5183, GH5154 and GH5174.

Seeds of the 10 genotypes were nursed in sterilized topsoil in wooden boxes. At 10 days after emergence, the seedlings were pricked out on raised beds. The seedlings were transplanted to the field at five weeks after emergence in 2001, following two conservative rainy days. In 2002, however, seedlings were transplanted to the field at six weeks after emergence, to coincide with similar soil moisture conditions as in the previous year. In both years, a randomized complete block design with four replications was used. A four-row plot in each replication represented each accession. The rows were 90 cm apart and each was 10.8 m long. Plants were spaced at 90 cm apart within a row.

Manual weeding was done with a hoe at three weeks after transplanting and subsequently at monthly intervals. Fertilizer was applied in three splits with the first application done at two weeks after transplanting and the second application three weeks later. At the first and second splits, 50 kg N × ha^{-1}, 30 kg P × ha^{-1} and 30 kg K × ha^{-1} were applied. Additional ni-

trogen (N) at 25 kg ha^{-1} was applied at flowering (Blay 1991). Supplementary irrigation was provided from sprinklers whenever there was no rain for three consecutive days. Insect pests were controlled with karate at 3 ml. $litre^{-1}$ sprayed at three-weekly intervals beginning from four weeks after transplanting.

In both years, data were collected from each of 10 non-border plants from the two central rows of each accession plot per replicate, using five plants randomly selected from each of the two rows. Data collected were as follows:

i) Number of days from transplanting to flowering;
ii) Plant height at flowering;
iii) Number of days from transplanting to fruit maturity;
iv) Number of fruiting branches;
v) Number of fruits × $plant^{-1}$;
vi) Fruit weight;
vii) Fruit length;
viii) Fruit diameter;
ix) Seeds × $fruit^{-1}$;
x) Fruit yield × $plant^{-1}$.

Fruits were harvested at commercial fruit maturity or market stage, when fruits just changed colour (Ofori 1999). Fruit dimensions, weight and seed content were determined using the first 10 fruits from each record plant. Fruit yield per plant was determined as the cumulative fruit weight over 10 weeks of harvesting.

Analysis of variance of the combined data sets was used due to non-significant year and year x genotype effects. Statistical analysis was carried out using GenStat statistical software (GenStat 2002). Phenotypic and genotypic coefficients of variation and genotypic correlations were determined using variance components (Yassin 1975). Estimates of direct and indirect effects of traits on fruit yield were determined by path analysis (Dewey and Lu 1959).

RESULTS

The accessions varied in fruit shape and immature fruit colour (Table 1). The different shapes and immature fruit colours observed in this study represented the common types available commercially on the city markets.

There were significant ($p<0.05$) differences among genotypes for flowering and maturity dates, plant height at flowering and number of fruiting branches per plant (Table 2). The earliest accession to flower, GH5174, was at least 19 days earlier than any of the other nine and five weeks ahead of the last accession to flower, GH5154. The number of days from flower opening to mature fruit did not follow the same pattern as flowering date and ranged from 20 to 32 days among the accessions. Plant height at flowering showed

the highest variability among genotypes. The number of days to flowering and maturity and the number of branches had low variation among accessions compared to the other traits.

Table 1

Some qualitative characteristics of scarlet eggplant accessions

Accession name	Leaf blade lobing	Leaf blade tip angle	Corolla colour	Fruit shape	Commercial fruit colour	Ripe fruit colour
GH5180	Intermediate	Acute	white	Broader than long	Light green	Red
GH5177	Intermediate	Acute	white	Longer than broad	Light green	Red
GH4921	Intermediate	Acute	white	Longer than broad	Light yellow	Red
GH5165	Intermediate	Acute	white	Longer than broad	White	Red
GH5167	Intermediate	Acute	white	Broader than long	Light yellow	Red
GH4922	Intermediate	Acute	white	Longer than broad	White	Red
GH4927	Intermediate	Acute	white	Broader than long	Greenish yellow	Red
GH5183	Intermediate	Acute	white	Broader than long	White	Red
GH5154	Intermediate	Acute	white	Longer than broad	Light green	Red
GH5174	Intermediate	Acute	white	As long as broad	Light green	Red

Table 2

Means and coefficients of variation of flowering and maturity dates, plant height and number of branches in scarlet eggplant

Accession name	Days to flowering	Days to maturity	Height at flowering [cm]	Branches at maturity
H5180	46	78	44.5	7
GH5177	54	78	46.8	5
GH4921	54	83	33.3	6
GH5165	55	80	39.3	6
GH5167	60	80	44.0	6
GH4922	54	84	39.0	5
GH4927	46	75	30.0	5
GH5183	43	74	32.8	7
GH5154	61	87	60.0	6
GH5174	24	55	27.8	5
GCV (%)	13.2	8.3	48.5	10.0
PCV (%)	13.4	9.0	61.8	17.6
LSD (5%)	6.0	11.0	8.5	1.0

Number of days after transplanting , GCV: Genotypic coefficient of variation,
PCV: Phenotypic coefficient of variation

Table 3

Means and coefficients of variation of fruit number, size, seed content and yield in scarlet eggplant

Accession name	Fruits per one plant	Fruit length [cm]	Fruit diameter [cm]	Fruit weight [g]	Seeds per one fruit	Yield per one plant [g]
GH5180	27	3.8	6.2	66.3	902	1484
GH5177	31	4.9	4.4	52.0	243	1305
GH4921	37	5.3	4.8	37.6	477	1316
GH5165	39	7.1	4.2	56.8	334	1703
GH5167	49	2.4	3.8	21.3	622	999
GH4922	26	6.3	5.0	67.2	554	1271
GH4927	26	4.3	6.5	81.3	626	1664
GH5183	64	3.0	4.4	29.3	571	1713
GH5154	29	5.2	4.5	44.2	627	1032
GH5174	44	5.4	5.3	61.8	427	1875
GCV (%)	34.2	16.4	29.6	29.8	33.4	19.5
PCV (%)	34.9	20.3	29.7	31.4	33.8	22.7
LSD (5%)	8.0	0.7	0.6	8.4	82.0	483.0

GCV: Genotypic coefficient of variation
PCV: Phenotypic coefficient of variation

Fruit number, size, yield and seed content of the 10 scarlet eggplant accessions are presented in Table 3. There were significant ($p < 0.05$) differences among accessions for all fruits characteristics scored. Phenotypic and genotypic variability for all fruit characteristics were high, especially for the number of fruits per plant, fruit weight and the number of seeds per fruit, which varied more than three-fold among the accessions. The ratio of genotypic coefficient of variation (GCV) to phenotypic coefficient of variation (PCV) gives the square root of the heritability estimate. Heritability of flowering date, fruits per plant, fruit diameter, fruit weight and seed content of fruits were high, indicating that differences in these traits were largely genetically determined.

Genotypic correlations of various agronomic traits with fruit yield are presented in Table 4. Fruit yield did not have a significant positive correlation with any of the traits investigated. However, fruit yield had significant ($p < 0.05$) negative correlations with number of days to flowering, plant height at flowering and number of days to fruit maturity. Fruit weight and fruit diameter showed medium and positive genotypic correlations with fruit yield, while fruits per plant and fruit length had rather low positive correlations with fruit yield.

Table 4

Direct (marked with bold) and indirect effects of agronomic traits on fruit yield of scarlet eggplant

Trait	Days to flowering	Height at flowering	Days to maturity	No. of branches	Fruits per one plant	Fruit length [cm]	Fruit diameter [cm]	Fruit weight [g]	Seeds per one fruit	Genotypic Correlation with fruit yield
Days to flowering	**0.67**	0.10	-0.68	0.03	-0.31	0.01	-0.47	-0.16	-0.01	-0.82* *
Height at flowering	0.46	**0.15**	-0.46	0.02	-0.39	-0.01	-0.35	-0.11	-0.06	-0.75*
Days to maturity	0.63	0.10	**-0.72**	0.07	-0.40	-0.04	-0.28	-0.11	-0.06	-0.73*
No. of branches	0.07	0.01	-0.17	**0.32**	0.55	-0.24	-0.09	-0.22	-0.19	0.04
Fruits per one plant	-0.18	-0.05	0.25	0.15	**1.15**	-0.23	-0.54	-0.34	0.06	0.27
Fruit length	0.01	-0.001	-0.06	-0.15	-0.53	**0.51**	-0.001	0.23	0.20	0.21
Fruit diameter	-0.31	-0.05	0.20	-0.03	-0.60	-0.001	**1.02**	0.39	-0.19	0.43
Fruit weight	-0.23	-0.04	0.16	-0.15	-0.81	0.24	0.82	**0.48**	-0.03	0.44
Seeds per one fruit	0.02	0.02	-0.12	0.16	-0.17	-0.26	0.52	0.04	**-0.38**	-0.17

* , * *: Significant at 5% and 1% level respectively.

The path-coefficient analysis provided a more detailed breakdown of the observed correlations of various traits with fruit yield (Table 4). The number of fruits per plant had the highest positive direct effect (1.15) on fruit yield. This was followed by fruit diameter (1.02) and number of days to flowering (0.67). The number of days to maturity and seeds per fruit were the only traits with direct negative effects on fruit yield. Negative indirect relationships with all other fruit traits particularly fruit length, fruit diameter and fruit weight rather weakened the direct effect of fruit number on fruit yield. The positive direct effect of fruit diameter on fruit yield was offset to a large extent by negative indirect effects through number of fruits per plant and number of days to flowering. Large negative indirect effects via number of fruits, fruit diameter and fruit weight were responsible for the observed significant negative correlation between fruit yield and number of days to flowering. These same negative indirect effects contributed to the negative relationship of fruit yield and maturity date.

DISCUSSION

The large variability in plant height, number of fruits per plant, fruit diameter, fruit weight and seed content were similar to those reported for aubergine/eggplant **(***Solanum melongena***)** (Badea *et al.* 1996, Hitomi *et al.* 1998). Among 32 accessions of scarlet eggplant from Ghana, Ofori (1999) found large variability in all fruit characters as observed in the present study. A large proportion of the variability of the traits in the present study was genetically determined. In aubergines, Vadivel and Bapu (1990) have reported high heritability estimates for fruits per plant and fruit diameter, while Mandel and Dana (1993) also reported high heritability and genetic advance in number of fruiting branches, plant height at flowering and number of days to fruit maturity. High genotypic coefficient of variation along with high heritability would provide better information for selection than either parameter alone. Plant height, number of fruits per plant, fruit diameter, fruit weight and seed content of fruit, which exhibited high genotypic coefficients of variation and heritability estimates, should respond effectively to selection among scarlet eggplant genotypes.

There is a dearth of information on correlations among yield components in scarlet eggplant. In aubergines, however, there have been several reports of positive correlations between fruit yield and number of fruits per plant, fruit diameter, fruit length, number of fruiting branches, fruit weight and plant height at flowering (Khurana *et al.* 1988; Kumar *et al.* 1990; Vadivel and Bapu 1990; Bora and Shadeque 1993; Ushakumari and Subramanian 1993). The significant negative correlations of number of days to flowering and number of days to fruit maturity with fruit yield per plant, indicated that accessions that combine earliness to fruiting and high fruit yield were avail-

able in the collection. Since fruiting tends to be continuous throughout the growing season, plants flowering early, when they are very short would end up with high yield, compared to plants that build up a large vegetative growth before flowering and fruiting.

The path coefficients served as indices of causal importance towards fruit yield. The number of fruits per plant, fruit diameter and number of days to flowering were therefore the major determinants, directly and indirectly influencing fruit yield in scarlet eggplant. Vadivel and Bapu (1990) found that number of fruits per plant had the largest effect on fruit yield in eggplant, but that its effects through fruit length and weight were negative. Their results were therefore similar to those observed in the scarlet eggplant collection. Their results showed clearly that the main traits directly affecting fruit yield in descending order of importance were number of fruits per plant, number of fruiting branches, plant height at flowering and fruit weight. Mishra and Mishra (1990) also reported that number of fruits per plant and number of branches had the highest influence on fruit yield in eggplant. These were followed by fruit length. In this study, the direct effect of number of days to flowering on fruit yield indicated that when other traits are kept constant, early flowering would result in high yield.

The residual effect of 0.28 indicated that variability in fruit yield was not completely explained on the basis of relationships of fruit yield with the characters studied. Hence, there may be other important traits that were not utilized in this study. Fruit set, number of fruiting nodes and dry matter accumulation at flowering, may be considered and incorporated as components of the path analysis in order to select final traits. The amount of environmental influence on traits is of considerable importance in the evaluation of plant genotypes. The selection of traits, which when taken simultaneously would give large response to selection, is equally necessary (Singh and Singh 1979). Considering that the heritability estimates were high to very high for all traits, emphasis should be placed on the direct effects of traits on fruit yield. Hence number of fruits per plant, fruit diameter and number of days to flowering should be given primary consideration in selection aimed at increasing fruit yield in scarlet eggplant.

CONCLUSIONS

There was significantly large variability in all traits among the genotypes of scarlet eggplant evaluated. The relative sizes of phenotypic and genotypic coefficients of variation indicated that the traits were not much affected by environmental fluctuations. The path coefficients gave more insight into the relationships between fruit yield and the various traits than using only the correlation coefficients. Number of fruits per plant, fruit diameter and number of days to flowering were identified as the traits with

large direct influence on fruit yield. These traits should therefore be given priority in selection for high fruit yield among scarlet eggplant genotypes.

REFERENCES

Anonymous, 1999. Agriculture in Ghana. Facts and figures. Ministry of Food and Agriculture, Accra. 25 pp.

Blay, E.T. 1991. Garden eggplant production in Ghana. Legon Agric. Res. Ext. Jour. 3:97-100.

Daunay, M-C., Lester, R.N., Ano, G. 2001. Eggplant. In: Charrirer, A, Jacquot, M, Hamon, S. and Nicholas, D. (eds.) Tropical plant breeding, pp 199-222. CIRAD and Science Publishers Inc. Plymouth, U.K.

Dewey, D.R., Lu, K.H. 1959. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. Agron. J. 9:515-518.

GenStat, 2002. GenStat for Windows, 7th edition.VSN International Ltd. Oxford.

Lester, R.N., Jaeger, P.M.L., Bleijendaal-Spieringe, B.H.J., Bleijendaal, H.P.O., Holloway, H.L.O. 1990. African eggplants- a review of collecting in West Africa. Plant Genet Resour. Newsl. 81/82:17-26.

Ofori, K. 1999. Multivariate analysis of genetic diversity of the garden eggplant (*Solanum aethiopicum* (G.)) from Ghana. Agron. Afric. 11: 1-6.

Olufolaji, A.O. and Makinde, M. J. 1994. Evaluation, characterization and fruit production pattern of eggplant germplasm. Capsicum and Eggplant Newsletter 13:100-103.

Schippers, R.R. 2000. African indigenous vegetables:-An overview of the cultivated species. Natural Resources Institute, Chatham, U.K. 214 pp.

Ushakamari, R and Subramanian, M. 1993. Causal influence of background traits on fruit yield in brinjal (*Solanum melongena*). Indian J. Hort. 50:64-67.

Vadivel, E and Bapu, J.R.K. 1990. Path analysis of yield components in eggplant. Capsicum Newsletter 9:68-69.

Yassin, T. E. 1973. Genotypic and phenotypic variances and correlations in field beans (*Vicia faba* L.) J. Agric. Sci. (Cambridge) 81: 445-448.