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Genotypic stability and correlation among quantitative characters in genotypes of aromatic pepper grown over years

Abu, Ngozi E[1]*, Uguru, M. I.[2] and Obi, I .U.[2]

[1]Department of Plant Science and Biotechnology, University of Nigeria, Nsukka.
[2]Department of Crop Science, University of Nigeria, Nsukka.

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Breeding efforts for fruit yield improvement in *Capsicum annuum* have gradually shifted from individual trait selection to simultaneous improvement of several traits which contribute to yield. The objectives of this research were to assess the correlation among quantitative characters and to determine stable pepper genotypes for fresh fruit yield in derived savanna ecology of Nigeria. Ten genotypes of *C. annuum* were evaluated for three years under rainfed conditions using a randomized complete block design of three replications. The analysis of variance of the data collected showed significant differences among genotypes. The genotype x year (g x y) interaction was significant for most of the traits. Results of the correlation analysis showed significant positive correlations among traits, however some were negatively correlated. The yield stability analysis established four groups of yield stability conditions namely high yield and low variation, high yield and high variation, low yield and low variation and low yield and high variation. Three genotypes were in yield stability group 1 having high yield and low variation. This suggests stability of these genotypes to fluctuations in the random environment across years. Selecting stable genotypes and traits with high correlation among themselves and with fresh fruit yield would sustain high yield in *C. annuum* genotypes especially as yield components are complementary in action.

Key words: Genotype, character, stability, environment, correlation, *Capsicum annuum.*

INTRODUCTION

Peppers are valuable on account of their richness in ascorbic acid, which is an important vitamin. Pepper is the only source of capsaicin, an alkaloid that is a digestive stimulant and important ingredient of daily diet (Bosland and Votava, 2000). The fruit colour is due to the presence of total carotenoid pigments. Most *C. annuum* genotypes have unique aroma that is highly cherished in traditional diets of many countries. Pepper flavour together with colour, texture and nutrition forms the cornerstone of contemporary food industries throughout the world (Blenford,1997; Bosland and Votava, 2000). In Nigeria, peppers occupy the third position among the cultivated vegetables and consumers place a high premium on the aromantic types (Uzo, 1982). Nigeria is the largest producer of pepper in Africa covering about 50% of total Africa production (Adetule and Olakojo, 2006). Nigeria was named as number 12 among top producing countries of dry chillies and peppers (148508 to 50000) metric tons in 2008 FAO report (Hays, 2009). Peppers are widely grown in different environments and it has been reported that aroma was not affected by differences in environment (Uguru, 2000).

*Corresponding author. E-mail: ngozi.abu@unn.edu.ng. Tel:+234 8064664555.

Yield is a complex polygenic character which is directly or indirectly dependent on a number of traits known as yield components (Ahmed et al., 1997; Elewanya et al., 2005). The knowledge of the association of yield components with yield and among themsleves will be helpful in the improvements of a complex trait like yield for which direct selection is not effective. Quantitative characters such as number of nodes per plant, number of branches per plant, number of fruits per plant, fruit length, fruit diameter and pericarp thickness have been reported to be of great economic importance in pepper production (Nandadevi and Hosamani, 2003) .

The evident of strong correlation between desirable characters makes easy the breeding process, however, correlation could also be difficult when undesirable traits are strongly correlated. Kumar and Dubey (2001) reported that correlation coefficients are specific to the material and environmental conditions, emphasizing that associations between quantitative traits are subject to environmental fluctuatations. Before embarking on fresh fruit yield, it is necessary to understand the relationships existing between fruit yield and other metric traits in *C. annuum* complex. The interconnection of the association between characters in years is very vital as it has been reported that *C. annuum* genotypes like other economic plants are affected by environmental fluctuations (Uguru, 2000). Correlation coefficient establishes the extent of assosication between yield and it's components, so that yield components may form additional criteria for selection in breeding programme (Todorova et al., 2003). These authors suggested that estimating correlation across years helps the breeder in establishing universal link between characters that show consistency in correlation estimates over years or across different environments.

Genotype by environment interaction (g x e) is said to exist when the phenotypic response invoked by change in environment is not the same for all genotypes (Yan and Kang, 2003). Plant breeders often have to select one or more superior genotypes under such conditions. In this case, mean yield, the most common description of a genotype's performance is inadequate as it does not fully indicate consistency of performance. Unpredictable year - to - year fluctuations often cause large genotype x year and genotype x location x year interactions (Francis and Kannenberg, 1978). Abu et al. (2011) using genotype by trait (GT) biplot reported that the *C. annuum* genotypes were affected diversely by different environmental stresses prevalent in each of the years of genotypic assessment. Stability parameters are usually employed in order to select stable genotypes that are less responsive to environmental influences. Francis and Kannenberg (1978) reported that the term stable genotype has often been used to describe a genotype that has constant performance over environments, these genotypes, some times may have below average yield. These researchers developed the mean yield – coefficient of variation (CV) approach for determinig genotypic stability and described it as a simple and descriptive method for grouping genotypes on the basis of yield and consistency of performance. Stable genotypes are those whose CVs are below the mean CV and yield above the grand mean yield of all the genotypes. The genotypic stabibility of yield over environments or seasons reveals anticipated consistency of yield from such genotype(s) across spatial or temporal environment.

The utilizaton of stability of yield traits could be used in selecting predictable pepper genotypes in the derived savanna agro-ecology. Inferences from significant correlations between yield and its components across years and in a combined analysis could serve as a guide to selection of traits that contribute to yield in *C. annuum* peppers. The objectives of the work were to: (i) determine the specific adaptation and group genotypes using stability parameters. (ii) evaluate the relationship among yield and yield components of *C. annuum* genotypes in derived savannah ecology by estimating the correlation coefficients in separate years and in a combined analysis.

MATERIALS AND METHODS

Ten aromatic pepper genotypes were used in this study; five were obtained from the pepper germplasm of the Department of Crop Science, University of Nigeria Nsukka while the other five genotypes were bought from the open market. All the genotypes were grown for 3 cycles in the Botanical garden before the onset of the experiment. All ten genotypes were evaluated in the field under rainfed conditions for three years in the Faculty of Agriculture Research Field, University of Nigeria, Nsukka. Nsukka lies within latitude 06°51'N, longitude 07°29'E and an altitude of 400 m above sea level. A randomized complete block design (RCBD) with three replications was used. Each block was divided into ten plots measuring 2.9 m x 2 m (5.8 m^2). Seeds of the different genotypes were raised in nursery baskets before transplanting to the field. The nursery medium was a 3:2:1 mixture of top soil, poultry manure and river sand, respectively (Uguru, 1996). Transplanting was done at four weeks after emergence and the plant spacing was 45 cm x 60 cm intra- and inter–row spacing, respectively (Bosland and Votava, 2000). The seeds collected at harvest after each year's sowing were used for the following year's planting. Data were collected on morphological and agronomic characters for each of the three years and included; plant height, main stem length, number of nodes on the mainstem, number of nodes per branch, number of nodes per plant, canopy diameter, number branches per plant, number of leaves per plant, number of fruits per plant as well as percent fruit moisture content, fruit diameter, fruit dry weight, fruit length, pericarp (fruit wall) thickness, single fruit weight and fresh fruit yield in tons per hectare. Pericarp thickness was measured with vernier callipers after the fruit had been cut open. Moisture content (expressed in percentage) is the difference in weight when the fruits had dried to a constant weight.

Genstat package (Genstat 5.0, release 4.23DE, discovery edition 1) was used for the analysis of variance while Statistical package for Social Sciences (SPSS) was used in estimating the correlation coefficients between characters for each of the three years and the combined correlation analysis. The genotypic stability of yield were estimated by mean CV approach using the procedure described by Francis and Kannenberg (1978). In this approach, mean CV and the grand mean yield divides the table into four

Table 1. Mean square values of *C. annuum* yield and yield components for three years

Sources of variation	Df	Single fruit wt (g)	Number of branches/plt	Number of leaves/plt	Number of nodes/plt	Number of fruits/plt	Fresh fruit yield (t/ha)
Year	2	17.32**	94889.4**	179013.2**	387900**	9953.5**	113.59**
Genotype	9	48.67**	5163.1**	9996.4**	30814**	2467.4**	25.9**
G x Y	18	7.82**	2549**	1303.6	4395	945.8**	13.36**
Error	58	0.42	775.9	679.4	3342	105.4	2.23

**Significant at P = 0.01; G x Y = genotype by year; df = degrees of freedom.

groups. The four groups of yield stability conditions estimated were as follows: group 1: high yield and low variation; group 2: high yield and high variation; group 3: low yield and low variation; group 4: low yield and high variation

RESULTS AND DISCUSSION

Genotype, year and genotype x year (g x y) effects were highly significant (P = 0.01) for the yield and yield component traits used in estimating the genotypic stability (Table 1). However, number of leaves per plant and number of nodes per plant had a no significant g x y effects. The significant year effects indicate that there were wide variations across the three years. The genotypes were genetically different from each other hence significant mean square values were observed in all the traits. The significant g x y could be a result of differences in the reaction of the genotypes to the different prevailing environmental stimuli across the years. A combined analysis of variance is commonly used to identify the existence of g x e interaction (GEI) in both predictable and unpredictable environments (Francis and Kannenberg, 1978). Akcura et al. (2005b) stated that when GEI results from variations in unpredictable environmental factors such as year to year variation in rainfall distribution, the breeder needs to develop stable genotypes that can perform reasonably well under a range of conditions. The traits with nonsignificant g x y effect might be showing consistency inspite of the various differences that existed in years (Kang, 1998). Wide variations were shown by the genotypes in the expression of the traits across the years (Table 2). The fresh fruit yield across the years ranged from 0.7-7.38 t/ha, 3.13-10.14 t/ha and 3.26-11.10 t/ha in each of the years while the mean yield were 2.56 t/ha, 6.02 t/ ha and 5.83 t/ha for year 1, year 2 and year 3, respectively. Plant breeders often have to select one or more superior genotypes even when the phenotypic response invoked by a change in environment is not the same for all genotypes, in this case, mean yield is the most common statistic. Francis and kanneberg (1978) reported that mean yield, the most common description of a genotype's performance, is inadequate as it does not fully indicate consistency of performance.

The number of branches per plant and single fruit weight grouped the genotypes into each of the 4 groups (Table 3) while the number of nodes per plant and number of leaves per plant grouped the genotypes into 3, there was no genotype in group 2 (high mean and high variation). In the mean number of fruits plotted against the mean CV (%) estimates (Figure 1) the genotypes were distributed into four groups based on their mean and CV (%) values. G1, G2 and G10 were in group 1, high yield and low variation and may be considered as stable based on the mean number of fruits per plant. G1 and G10 genotypes could also be considered as land races having been cultivars grown by farmers in Nsukka, derived savanna agro-ecology. The stability analysis conducted on fresh fruit yield across the three years showed a mean CV value of 59% while the grand mean of the genotypic means was 4.8 t/ha (Figure 2). The grand mean value and the mean CV (%) divided the stability plot into four groups in which genotypes were grouped depending on their mean fruit yield and CV (%) values. Genotypes G1, G2 and G4 occurred in Group 1 under high mean and low variation with mean yield ranging from 6.35 to 7.74 t/ha and a CV (%) range of 38.39 (G2) to 56.48 (G1). The rest of the genotypes are distributed into the remaining three groups based on their mean and CV (%) values. G1, G2 and G4 may be considered stable under the prevailing conditions of unpredictable environmental factors, such as year to year variation in rainfall distribution and other climatic factors.

G4 had the highest mean fruit yield (7.74 t/ha) with a CV(%) value below the mean CV (%). This genotype could be considered as the most widely adapted cultivar. A variety or genotype is considered to be more adaptive or stable if it had a high mean yield but low degree of fluctuations in yielding ability when grown over diverse environments (Arshad et al., 2003). G4, the most stable genotype also had a high mean and low variation in other yield component characters that have high correlation values with fruit yield such as number of branches per plant, number of nodes per plant and number of leaves per plant. This genotype was also observed in group 2 for single fruit weight and number of fruits per plant (Table 3). Several abilities were combined together by G4 genotype as an advantage in outperforming even the land races which according to a previous report should have been more stable having incorporated a variety of environmental stimuli into their developmental pathways (Scandalios, 1990).

Table 2. Range and mean in years of the different characters with the various F-LSD (P = 0.05) values.

Character	Year 1 Min Max	Year 2 Min Max	Year 3 Min Max	Year 1	Year 2	Year 3	Grand mean	FLSD (P= .05) (For comparing the year means)
Plant height (cm)	13.20-27.26	27.10 - 54.88	36.0 - 61.6	20.59	40.05	44.6	35.08	2.22
Main stem length (cm)	12.2-32.12	17.45 - 29.11	12.1 - 22.53	18.14	23.95	15.69	19.26	1.35
Number of nodes on mainstem	14.97 - 23.67	19.21 - 38.00	14.33 - 21.5	19.89	28.39	18.65	22.31	1.07
Number of nodes/branch	10.93 - 22.4	11.51 - 15.35	6.62 - 19.0	19.2	13.25	10.96	14.47	1.15
Number of nodes/plant	39.50 - 243.17	277.4 - 449.0	83.87 - 392.43	116.27	343.56	223.43	227.75	29.88
Canopy diameter (cm)	15.94 - 29.03	33.84 - 48.31	37.9 - 56.6	21.79	40.05	49.44	37.09	2.94
Number of branches/plant	5.44 - 35.34	71.92 - 163.33	55.65 - 215.18	14.12	114.78	107.92	78.94	14.40
Number of leaves/plant	26.54 - 122.22	148.27 - 276.37	64.27 - 241.10	53.03	207.53	130.7	130.42	13.47
Number of fruits/plant	1.33 - 29.34	10.04 - 92.48	14.83 - 77.35	17.23	43.69	52.14	37.69	5.31
Fruit moisture content	83.44 - 88.14	83.34 - 88.11	66.21 - 88.31	86.58	86.72	84.93	86.07	2.79
Fruit diameter (cm)	1.7 - 3.47	0.75 - 2.17	0.71 - 3.03	2.61	1.61	1.69	1.97	0.10
Fruit dry weight.	1.77 - 34.26	13.29 - 49.66	17.49 - 101.47	12.48	30.24	37.98	26.9	3.98
Fruit length (cm)	2.64 - 7.52	2.09 - 9.44	1.92 - 9.32	4.34	4.57	4.45	4.45	0.18
Pericarp thickness (mm)	1.7 - 3.2	1.58 - 3.47	1.44 - 3.54	2.19	2.03	1.97	2.06	0.12
Single fruit weight (g)	2.93 - 15.68	2.83 - 9.3	2.87 - 6.65	5.4	4.83	3.89	4.71	0.37
Fresh fruit yield (t/ha)	0.7 - 7.38	3.13 - 10.14	3.26 - 11.10	2.56	6.02	5.83	4.8	0.77

Francis and Kannenberg (1978) reported that genotypes belonging to group 1 in yield are considered to be stable although group 3 is consistent, it is deemed unstable because it performs poorly in most environments. Only G10 belong to this group. The genotypes in group 4 are mostly undesirable because of the unusual combination of low mean yield and large CV(%). However in this data set there are four genotypes in this group for fresh fruit yield. G7 which had the lowest mean yield (2.37 t/ha) had significantly the the highest mean single fruit weight value of 10.57g though with high variation, it therefore sets only few fruits per plant and has the advantage of its preference as a non pungent vegetable based on single fruit weight value. The seemingly high CV values observed in this study may not necessarily be due to the heterogenous nature of the genotypes but could be attributed to high instability in wheather variables across the three years. This may have influenced genetic expression across the random environments of the years.

The correlation coefficients estimated among the morphological and agronomic characters in years 1 and 2 evaluation seasons showed significant correlation between traits (Tables 4 and 5). The estimated correlation coefficient for year 3 and the combined correlation are shown in Tables 6 and 7. Correlation coefficients establish the extent of association between yield and its components so that the yield components may form additional criteria for selection in breeding program. Plant height had significant positive correlation with main stem length, number of nodes on main stem, number of of branches per plant and fruit length in year 1 evaluation season. Across the other years of assessment and the combined analysis, main stem length and fruit length maintained consistent positive relationship with plant height. The consistent positive correlation between plant height and mainstream length suggests that taller plants had longer primary stem length before the characteristic three branches that give pepper plants their peculiar architectural posture. Taller plants equally seem to have longer fruits.There was a consistent negative relationship between plant height and fruit diameter in all the years of assessment and the combined analysis, however, this association was only significant in year 3 and in the total correlation by the following values -0.71* and -0.95** respectively. Selection of tall genotypes for ease of picking in hand harvesting would mean selecting for longer fruits and selection against fruits with larger diameters.

Table 3. Grouping of pepper genotypes by mean-CV(%) values of yield component traits.

Group	Number of branches/plant	Number of nodes/plant	Number of leaves/plant	Single fruit weight (g)
High yield and low variation	G2 (UNS3) G4 (*Shombo*)	G2 (UNS3) G3 (*Nsky-lp*) G4 (*Shombo*) G9 (*Oshosho*) G10 (*Nsky-rw*)	G2 (UNS3) G4 (*Shombe*) G9 (*Oshosho*) *G10* (*Nsky-rw*)	G9 (*Oshosho*)
High yield and high variation	G8 (*Dangarawa*)	-	-	G7 (*Tatase*) G4 (*Shombo*)
Low yield and low variation	G1 (UNS2) G6 (*Tarugu*) G9 (*Oshosho)*) G10 (*Nsky-rw*)	G1 (UNS2) G5 (*Nsky-se*) *G6* (*Tarugu*)	G5 (*Nsky-se*) *G6* (*Tarugu*)	G2 (UNS3) G5 (*Nsky-se*) G10 (*Nsky-rw*)
Low yield and high variation	G3 (*Nsky-lp*) G7 (*Tatase*) *G5* (*Nsky-se*)	G7 (*Tatase*) G8 (*Dangarawa*)	G1 (UNS2) *G3 (Nsky-lp*) G7 (*Tatase*) G8 (*Dangarawa*)	G1 (UNS2) G3 (*Nsky-lp*) G6(*Tarugu*) G8 (*Dangarawa*)

In year 1 assessment season, number of nodes per plant had significant positive correlations with canopy diameter, number of branches per plant, number of leaves per plant, fruit dry weight, fruit length and number of fruits per plant (Table 4). The association between number of nodes per plant and some of the above traits were maintained at significant level with an additional significant positive correlation (0.70*) with fresh fruit yield in the third year (Table 6). In the combined analysis, number of nodes per plant had significant positive correlation with number of nodes on main stem, canopy diameter, number of branches per plant and number of leaves per plant. Similarly, this trait had highly significant positive correlation with number of fruits per plant, fruit dry weight and fresh fruit yield (Table 7). Canopy diameter in year 1 evaluation season had significant positive association with number of fruits per plant and a highly significant positive association with number of branches per plant, number of leaves per plant and fresh fruit yield.

Canopy diameter in year 2, had a significant positive association with only the number of fruits per plant. In the combined analysis canopy diameter had a significant positive association with four characters including number of fruits per plant (0.87**) and significant negative relationship with pericarp thickness and single fruit weight (-0.70 and -0.76*) respectively. The negative association between single fruit weight and canopy diameter is suggestive of the fact that genotypes with wider canopies had smaller single fruit size. This is being strengthened by the equally negative association between single fruit weight and the number of fruits per plant. This implies that genotypes with wider canopies had more number of fruits with a consequent decrease in fruit size.

Number of branches per plant had positive association with number of leaves per plant, fruit dry weight and fresh fruit yield in year 1, year 3 and in the combined analysis. The correlation value between number of branches and fresh fruit yield were 0.95** in year 3 and 0.78* in combined analysis. Ahmed et al. (1997) reported a positive association between number of branches and canopy diameter with number of fruits per plant. Number of leaves per plant had a positive significant association with number of fruits per plant. Agronomic traits, such as, canopy diameter, number of branches and nodes per plant significantly contributed to number of fruits per plant and fresh fruit yield. This seems to suggest that these characters have universal link with both fresh fruit yield and the important yield component character of number of fruits per plant.

Todorova et al. (2003) suggested that estimating

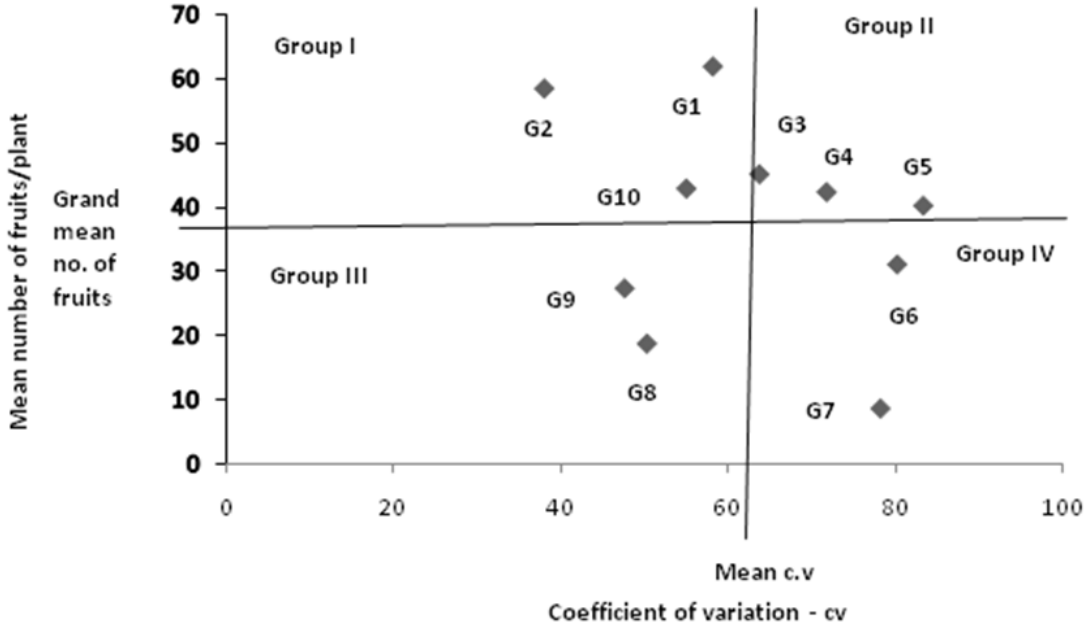

Figure 1. Mean number of fruits per plant plotted against the CV from data collected on ten genotypes of pepper grown over three years.

correlation in years helps the breeder in establishing universal link between characters that show consistency in correlation estimates over years or across different environments. This link is of immense importance to the breeder as slight alteration in one will definitely cause changes in the other. Pericarp thickness showed significant positive correlation with single fruit weight in year 2 and in total correlation. Selections aimed at increasing pericarp thickness especially for the suitability of puree industries should target selecting genotypes with higher single fruit weight.

The consistent negative correlation between fruit length and fruit moisture content in the separate years and in the combined correlation is a pointer to the fact that long fruited genotypes had less water content in their fruits. This trait could be traced to the *frutescens* origin of long fruited *annuum* peppers (Nwankiti, 1976; Morakinyo and Falusi, 1992). Fruit length seems to have universal links and any selection aimed at increasing this trait, decreases the percent moisture content and to some extent reduces the fruit diameter which also maintained a negative relationship with fruit length. Fruit diameter had consistent positive association with percent fruit moisture content and therefore genotypes with higher fruit diameter had more water content.

Fruit diameter and single fruit weight maintained a negative correlation with most morphological and yield component characters, though some are not significant. It might probably be that environmental conditions that encourage luxuriant growth and more number of fruits in *C. annuum* peppers disadvantages single fruit size by reducing the fruit diameter. The presence of negative association among traits complicate selection for traits in the breeding programme. In this type of relationship the breeder must assess further which character to be given more preference based on inter-relationship of these traits with the rest of the yield components. Number of fruits per plant had consistent negative relationship with single fruit weight in all the years of assessment; however, this relationship is only significant in year 3 and in the combined analysis with values: 0.84** and -0.76* respectively. Number of fruits per plant maintained significant positive correlation with fresh fruit yield in all the years of evaluation and the combined correlation being a major character contributing to yield. Similar associations were

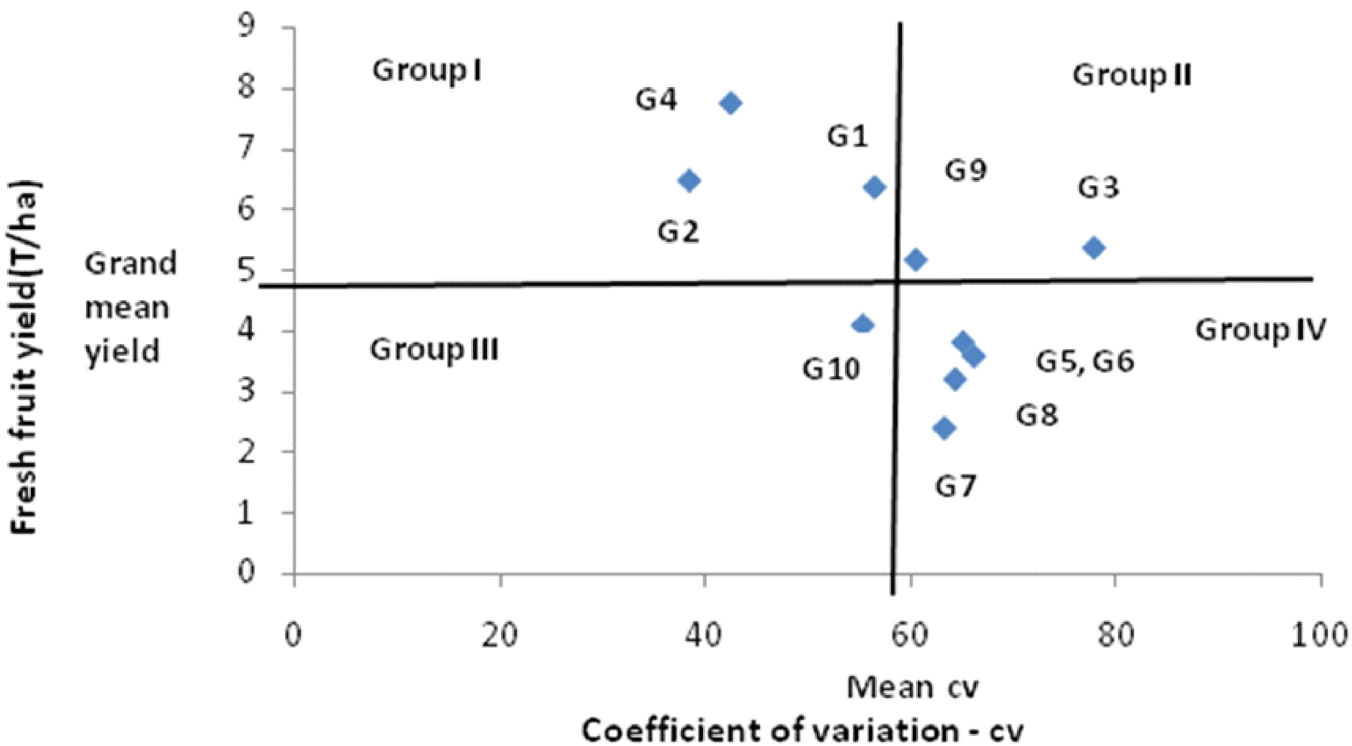

Figure 2. Mean yield plotted against the CV from data collected on ten genotypes of pepper grown over three years.

also estimated by other researchers working on *C. annuum* (Nandadevi and Hosamani, 2003; Todorova et al., 2003).

The observed weak expression of interlinks in character association in year 2 seems to raise a caution as regards the reliability of correlation estimates in diverse environments as an effective breeder's statistic. Todorova et al. (2003) also observed weakness of correlation estimates in connecting interlink in characters in one of years of assessment of *C. annuum* genotypes of Bulgaria. This seems to point out the need to combine the results of correlation analysis with other statistic available to the breeder in making final deductions, however, selections based on those characters that have universal link with fresh fruit yield via consistent significant correlations in diverse environments, may be highly effective in yield improvement of *C. annuum* genotypes.

Conclusion

Genotypes with high values in number of nodes per plant, number of leaves per plant, canopy diameter and number of fruits per plant that have high positive correlations among themselves and with fresh fruit yield should be selected for higher fresh fruit yield in derived savanna agro-ecology. Selections aiming at fruits with wider diameter would also imply selecting for higher moisture content and lesser number of fruits per plant. In selecting taller plants for ease in hand harvesting, longer fruits would invariably be selected due to their high and consistent positive correlation.

Genotypes G1, G2 and G4 showed higher fresh fruit yield than the grand mean and their CV% values were below the mean CV (%). These genotypes were considered the best in terms of adaptation to the random environments of the three years and could be recommended for derived savanna agro-ecology under rainfed conditions. Among these three genotypes G4 had the highest mean fresh fruit yield and the lowest CV (%) value and therefore this genotype was the most stable genotype. Genotypes G3 and G9 had high fresh fruit yields with CV (%) values higher than the mean CV (%). They were therefore considered sensitive to environmental changes and would not be recommended since random environments are highly unpredictable. Genotype G10 with a low fresh fruit yield and a CV (%) value below the mean CV (%) was less sensitive to environmental changes and did not respond to inputs. G10 may therefore be recommended for poor environments. The fresh fruit yield of G5, G6, G7 and G8 had unusual combinations of low yield and high CV (%) indicating sensitivity to changes in environment. These genotypes cannot be recommended due to their overall poor performance.

Table 4. Correlation coefficients estimated among the morphological and agronomic characters in year 1 assessment season.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant height (cm)	0	0.98**	0.64*	-0.30	0.59	0.16	0.71*	0.60	0.30	-0.90**	-0.38	0.60	0.88**	0.16	-0.09	0.52
Main stem length (cm)		0	0.59	-23	0.61	0.56	0.74*	0.64*	0.23	-0.88**	0.41	0.60	0.91**	0.25	0.02	0.55
Number of nodes on mainstem			0	-69*	0.61	0.52	0.57	0.53	0.41	-0.72**	-0.18	0.54	0.60	0.10	-0.55	0.55
Number of nodes/branch				0	-0.49	-0.50	-0.26	-0.34	-0.47	0.32	-0.30	-0.38	-0.28	0.12	0.94**	0.39
Number of nodes/plant					0	0.82**	0.96**	0.97**	0.75*	-0.74*	-0.15	0.95**	0.81**	0.31	-0.21	-0.32
Canopy diameter (cm)						0	0.86**	85**	0.75	-0.65*	0.12	0.79**	0.81**	0.52	0.04	0.95**
Number of branches/plant							0	0.96**	0.66*	-77**	-0.12	0.81**	0.81**	0.52	0.04	0.82**
Number of leaves/plant								0	64*	-0.74*	-0.11	0.89**	0.79**	0.47	-0.47	0.92**
Number of fruits/plant									0	-0.55	-0.17	0.81**	0.44	-0.25	-0.39	0.78**
Fruit moisture content										0.0	0.52	-0.79**	-0.85**	0.0.05	0.13	-0.68*
Fruit diameter (cm)											0	-0.38	-0.41	0.36	-34	-0.24
Fruit dry weight0.												0	0.82**	-0.10	0.0.13	0.0.97**
Fruit length (cm)													0	0.29	0.01	0.79**
Pericarp thickness (mm)														0	0.37	0.20
Single fruit weight (g)															0	-0.06
Fresh fruit yield (t/ha)																0

**Significant at P = 0.01, *significant at P = 0.05.

Table 5. Correlation coefficients estimated among the morphological and agronomic characters in year 2 assessment Season.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant height (cm)	0	0.81**	00.16	0.09	0.07	-0.43	-0.27	0.29	-0.05	-0.64*	-0.54	0.31	0.80**	0.45	0.51**	0.24
Main stem length (cm)	0	0	0.53	0.43	0.37	0.14	-0.14	0.26	0.33	-0.55	-0.54	0.58	0.55	0.17	0.02	0.43
Number of nodes on mainstem			0	0.56	-0.28	0.72*	0.32	0.25	0.82**	-0.24	-0.31	0.85**	0.16	-0.10	-0.45	0.72*
Number of nodes/branch				0	-0.17	0.50	-0.21	0.27	0.20	-0.31	-0.62	0.22	0.13	-0.30	-0.48	-0.03
Number of nodes/plant					0	0.49	0.67*	0.27	0.45	0.11	0.04	0.46	-0.04	-0.21	-0.16	0.49
Canopy diameter (cm)						0	0.49	0.11	0.68**	0.08	-0.05	0.51	-0.34	-0.55	-0.77**	0.40
Number of branches/plant							0	0.44	0.47-0.	-0.07	0.01	0.42	-0.08	-0.30	-0.15	0.52
Number of leaves/plant								0	-0.03	-0.59	-0.45	0.20	0.36	0.09	0.28	0.06
Number of fruits/plant									0	0.12	0.07	0.89**	-0.16	-0.16	-0.61	90**
Fruit moisture content										0	0.86	-0.32	-0.91**	0.14	-0.22	0.14
Fruit diameter (cm)											0	-0.26	-0.79*	0.26	-0.02	0.08
Fruit dry weight0.												0	0.29	-0.10	-0.38	0.95**
Fruit length (cm)													0	0.11	0.43	0.19
Pericarp thickness (mm)														0	0.74*	-0.02
Single fruit weight (g)															0	-0.31
Fresh fruit yield (t/ha)																0

**Significant at P = 0.01, *significant at P = 0.05.

Table 6. Correlation coefficients estimated among the morphological and agronomic characters in year 3 assessment season.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant height (cm)	0	90*	0.13	-0.36	0.15	-0.21	0.34	0.56	-0.12	-0.60	-0.71*	0.54	0.82**	0.25	0.48	0.40
Main stem length (cm)		0	0.09	-0.01	0.18	-0.31	0.34	0.52	0.04	-0.46	-0.68	-54	0.75	0.3	0.29	0.46
Number of nodes on mainstem			0	0.12	0.59	0.47	0.17	0.47	0.01	-0.50	-48	-0.09	0.28	-75*	0.02	0.08
Number of nodes/branch				0	0.29	0.12	-0.07	0.14	0.51	-0.36	-0.06	-0.10	-0.30	-0.13	-0.64*	0.05
Number of nodes/plant					0	0.77**	0.65*	0.78**	0.73*	-0.20	-0.40	0.55	0.33	-0.71*	-0.57	0.70*
Canopy diameter (cm)						0	65*	0.52	0.64*	0.20	-0.18	0.38	-0.20	-0.88**	-0.53	0.55
Number of branches/plant							0	0.85**	0.58	0.17	-0.31	0.81**	0.14	0.44	-0.14	0.95**
Number of leaves/plant								0	0.58	-0.25	-0.44	0.87**	0.57	-0.37	0.18	0.91**
Number of fruits/plant									0	0.31	-0.16	0.67*	0.01	-0.42	-0.84**	0.73*
Fruit moisture content										0	0.47	-0.10	-0.86**	0.01	-0.33	0.09
Fruit diameter (cm)											0	0.02	-58	0.24	0.02	-0.36
Fruit dry weight0.												0	0.44	-0.14	0.78**	0.91**
Fruit length (cm)													0	0.12	0.21	0.30
Pericarp thickness (mm)														0	0.49	-0.36
Single fruit weight (g)															0	-0.30
Fresh fruit yield (t/ha)																0

**Significant at P = 0.01, *significant at P = 0.05.

Table 7. Correlation coefficients estimated among the morphological and agronomic characters from the combined analysis.

Character	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant height (cm)	0	96**	0.27	0.05	0.24	-0.17	0.01	0.50	-0.06	-0.87**	-0.95**	0.52	0.94**	0.30	0.35	0.45
Main stem length (cm)		0	0.41	-0.10	0.06	-0.03	0.06	0.53	0.12	-0.86**	-0.95**	0.57	0.93**	0.18	0.17	0.54
Number of nodes on mainstem			0	-0.72*	0.88**	0.74*	0.41	0.49	0.83**	-0.55	-0.47	0.67	0.48	-0.62	-0.62	0.75*
Number of nodes/branch				0	0.66	-0.76*	-0.47	-0.34	-0.64	0.28	0.22	-0.43	-0.18	0.86**	0.87**	-0.51
Number of nodes/plant					0	0.79*	0.74*	0.76*	0.87**	-0.37	-0.47	0.82**	0.43	-0.55	-0.52	0.93**
Canopy diameter (cm)						0	0.69*	0.53	0.87**	-0.02	-0.11	0.62	0.04	-0.70*	-0.76*	0.61
Number of branches/plant							0	0.85*	0.55	0.01	-0.21	0.76*	0.20	-0.28	-0.23	0.78*
Number of leaves/plant								0	0.46	-0.41	-0.63	0.90**	0.61	-0.08	-0.02	0.86**
Number of fruits/plant									0	-0.06	-0.22	0.63	0.11	-0.65	-0.76*	0.71*
Fruit moisture content										0	0.85**	-0.47	-0.91**	0.05	-0.05	-0.45
Fruit diameter (cm)												-0.70*	-0.94**	-0.05	-0.08	-0.64
Fruit dry weight00.												0	0.69*	-0.14	-0.16	0.94**
Fruit length (cm)													0	0.16	-0.08	0.63
Pericarp thickness (mm)														0	0.93**	-0.27
Single fruit weight (g)															0	-0.23
Fresh fruit yield (t/ha)																0

**Significant at P = 0.01; *significant at P = 0.05.

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