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ANALYSIS OF TRAITS ASSOCIATION IN SWEET CORN INBRED LINES AS GROWN UNDER ORGANIC CROP MANAGEMENT

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SUMMARY

A sweet corn breeding program aimed at developing superior varieties for organic production should be devised based on reliable selection criteria. The objective of this study was to elucidate the nature of association among sweet corn traits as to the determination of selection criteria for the development of superior varieties uniquely adapted to organic crop management. Eight F5 sweet corn inbred lines were evaluated in a randomized complete block design with 7 replications. Analysis of variance, correlation analysis, factor analysis, and path analysis were performed for plant height, leaf number, stem diameter, ear length, ear diameter, kernel row number, kernel number/row, and ear yield/plant (fresh unhusked ear weight/ plant). Significant differences between means were detected in the lines for all traits. Most of the traits, except for kernel row number, exhibited significant and positive correlations to ear yield. Factor analysis extracted the 8 observed traits into two important factor axes, which totally accounted for 64.78% of the total variation. The first factor (51.12%) was strongly associated with all traits except kernel row number, while the second factor (13.66%) was unique to kernel row number. Path analysis revealed that ear diameter, ear length, and kernel number/row had strong direct effects on ear yield, whereas the rest of the traits affected the yield by indirect effects through ear diameter and ear length. Accordingly, this study suggested that ear diameter, ear length, and kernel number/row could be employed as selection criteria for yield improvement in the organic sweet corn breeding program.

Key words: sweet corn, organic crop management, correlation, factor analysis, path analysis, selection criteria, ear yield

Key findings: Ear diameter, ear length, and kernel number/row can serve as selection criteria in sweet corn breeding for ear yield improvement under organic crop management.

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INTRODUCTION

The development of sweet corn varieties specifically intended for organic production has lagged far behind than that of varieties for conventional production. Accordingly, organic sweet corn growers have limited options in making a decision on what varieties to choose for crop production. In most cases, they have to rely primarily on varieties bred for a conventional production management. A number of studies have shown that the performance of such varieties declines under organic production management (Yusuff *et al.*, 2007; Murmu *et al.*, 2013). Although, some studies also indicated that the application of organic soil amendment could produce a comparable crop performances (Efthimiadou *et al.*, 2010; Amanolahi-Baharvand *et al.*, 2014; Simon and Balabbo, 2015).

Ear yield is considered the most important trait in determining the productivity of a sweet corn variety. Under conventional production management, yield improvement can be attained by the application of high fertilizer and crop protection inputs with agro-chemical products. Under organic production management, the improvement would involve a crop variety that is efficient in using limited nutrients available in the soil (De Neve *et al.*, 2006; Akter *et al.*, 2013) and resilient in dealing with pests, diseases, and weed suppressions (Letourneau and van Bruggen, 2006). Breeding of sweet corn varieties aimed for organic production should be carried out under organic production management to warrant consistency of the crop yield performances (van Bueren *et al*., 2011).

Ear yield is a quantitative trait and does not act independently but reliant other related traits (Saleh *et al*., 2002; Kashiani *et al.*, 2010). Effectiveness and efficiency of sweet corn breeding for ear yield improvement relies on the magnitude of genetic variation and the related traits in the breeding population. Correlation analysis is a common method of determining the degree and direction of the association. It is not sufficient to reveal the pattern of the association or causal relationship among the traits when the breeder needs to establish selection criteria to be implemented in the breeding program. Factor analysis is a multivariate technique designed to reduce the dimensionality of correlated variables into a smaller number of latent variables (Stevens, 2009). In a breeding program, factor analysis is employed to elucidate the structure of traits interrelation and to classify the traits into distinctive groups (Haruna *et al.*, 2012; Janmohammadi *et al.*, 2014). Path analysis helps the breeder in determining the causal type of relationship between traits by partitioning correlation coefficient into direct and indirect effects (Ali *et al.*, 2009; Bello *et al.*, 2010) to enable setting up a selection criteria that will efficiently help maximize the crop yield. This study was undertaken to reveal the nature of association between sweet corn traits as to the determination of selection criteria for the development of superior varieties uniquely adapted to organic crop management.

MATERIALS AND METHODS

The research work was carried out at the Curup field laboratory for Closed Agriculture Production System, Faculty of Agriculture, University of Bengkulu, Indonesia (600 m above sea level). The evaluation was made on eight F_5 sweet corn inbred lines, i.e., Caps 2, Caps 3, Caps 5, Caps 15, Caps 17A, Caps 17B, Caps 22, and Caps 23 developed from a series of selection trials for their performances under organic crop management. Table 1 records the pedigree and origin of the lines. A randomized complete block design with 7 replications was employed to assign the lines on the experimental plots. Seeds from each line were sown in a single row plot of 4 m long with 20 cm plant-to-plant spacing and 70 cm row-to-row spacing. Cow manure at 10 ton/ha was applied on each row as basal fertilizer. A locally made liquid organic fertilizer (Fahrurrozi *et al*., 2016) was sprayed to the plants four times during the growth period with two weeks interval. Hand weeding was practiced as required. Five days following pollination, ears were thinned to keep a single ear for each plant. Five plants were randomly selected from the middle part of each row and harvested at 25 days following pollination. Observations were made on plant height, leaf number, stem diameter, ear length, ear diameter, kernel row number, kernel

Table 1. The pedigree and origin of eight F_5 sweet corn inbred lines.

Lines	Pedigree	Origin
Caps 2	Bs - 1-2-1-1-2	Hybrid variety
Caps 3	Gd -2-2-1-1-2	Open pollinated variety
Caps 5	Mto C-2-1-1-3	Open pollinated variety
Caps 15	Sb -1-5-1-4-2	Hybrid variety
Caps 17A	Sg -2-1-1-2-1	Hybrid variety
Caps 17B	Sg -2-4-1-3-1	Hybrid variety
Caps 22	Bm -3-3-1-3-2	Open pollinated variety
Caps 23	Si -2-1-1-8-1	Hybrid variety

number/row, and ear yield/plant (fresh unhusked ear weight/plant).

The collected data were subjected to preliminary statistical analysis of variance using CoStat 6.4. The coefficient of correlation that measures the degree of association between pair of traits was estimated using Pearsons' product moment (simple correlation) analysis. Factor analysis with the principal component as the method of factor extraction was performed on the correlation matrix to elucidate the pattern of traits association. Both correlation and factor analyses were run on XLSTAT 5.03 for Microsoft Excel 2007. Path analysis was carried out using Microsoft Excel 2007 by matrix operation as described by Singh and Choudhary (1976), where ear yield was ascribed as the resultant variable and rest of the traits as the causal variables.

RESULTS AND DISCUSSION

Variance analysis showed significant variations among the inbred for all traits studied (Table 2). These results indicated that the breeding population involved in this study contained sufficient genetic variation to be exploited by selection practices for crop improvement. Most of the traits, except kernel row number, exhibited positive and significant correlations to yield. The correlation between ear yield and vegetative traits ranged from moderate to high ($0.44 < r < 0.64$) (Table 3). These results were in line with the earlier finding reported by Saleh *et al.* (2002) and Kashiani *et al.* (2010) but in contrary to those reported by Oktem (2008). Ear yield was also highly correlated with ear length, ear diameter, and kernel number/row, with the maximum value was depicted by the association between ear yield and ear diameter. These were also in accordance with the works of Saleh *et al.* (2002).

The factor analysis performed on the correlation matrix had resulted in 8 independent factors (latent variables) and their important relatives are illustrated in scree plot presented in Figure 1. Based on the rule of eigenvalue greater than 1 (Kaiser, 1960), only the first two factors, which explained 64.78% of total variance, were retained and considered as important factors (Table 4). The loading of each factor represented the coefficient of correlation between the initial traits and the corresponding factors and the communality indicated the proportion of trait variance explained by the both retained factors. The loading of a trait on the factor is considered to be significant if its value $\geq$ 0.3 and taken as meaningful when interpreting a factor (Kline, 2014). Factor 1, accounted for 51.12% of total variance, was highly related (loading > 0.50) and had the same direction to plant height, leaf number, stem diameter, ear length, ear diameter, kernel number per row, and ear yield. Factor 2 that encompassed 13.66% of total variance seemed uniquely characterized in the same direction by kernel row number. Figure 2 displays the structure of traits association as plotted on the two-factor axes. This finding confirmed with the correlation analysis that kernel row number was virtually had no association with the rest of the traits studied. Thus, it can be inferred that higher ear yield would be characterized by higher leaf number, larger stem and ear diameters, longer ear, and to some extent, higher plant stature and more fully developed kernel in each row.

Table 2. Means squares for 8 traits observed of sweet corn inbred lines as grown under organic crop management.

Source	DF	Plant height	Leaf number	Stem diameter	Ear length	Ear diameter	Kernel-row number	Kernel number/ row	Ear yield/ plant
Rep	6	203.40	0.07	0.09	2.01	12.59	0.89	2.19	1997.03
Line	7	861.15*	1.36**	0.90**	56.29**	65.32**	2.17**	55.19**	11999.75**
Error	42	327.21	0.31	0.05	4.54	9.34	0.70	12.25	972.56

* and ** statistically significant at 5% and 1 %, respectively

Table 3. Coefficient of correlation among 8 traits of sweet corn inbred lines as grown under organic crop management.

Trait	Leaf number	Stem diameter	Ear length	Ear diameter	Kernel-row number	Kernel number/ row	Ear yield/ plant
Plant height	0.52**	0.29*	0.42**	0.39**	-0.14ns	0.41**	0.44**
Leaf number		0.48**	0.58**	0.41**	0.10ns	0.33*	0.46**
Stem diameter			0.74**	0.66**	-0.09ns	0.20ns	0.64**
Ear length				0.61**	0.08ns	0.28*	0.72**
Ear diameter					-0.09ns	0.51**	0.83**
Kernel-row number						-0.020ns	0.05ns
Kernel number/ row							0.66**

* and ** statistically significant at 5% and 1 %, respectively, ns = non significant

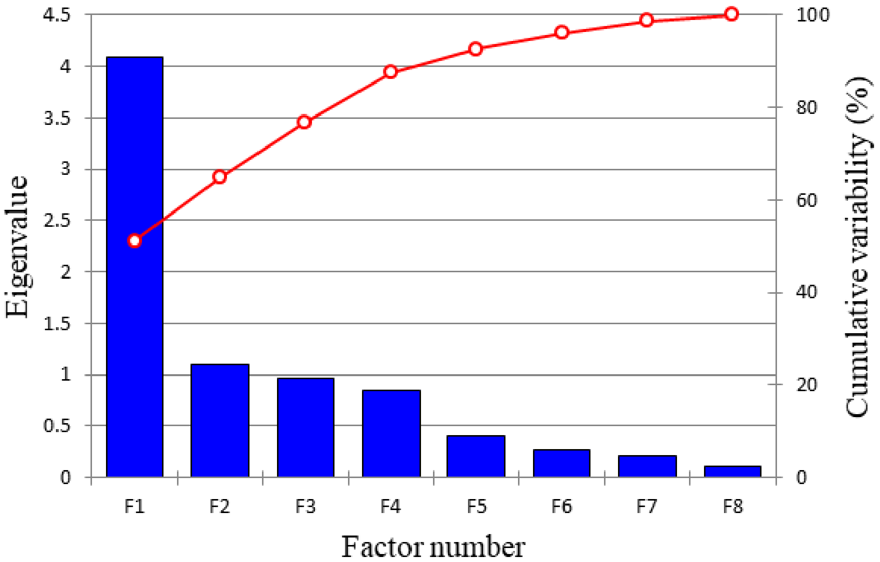
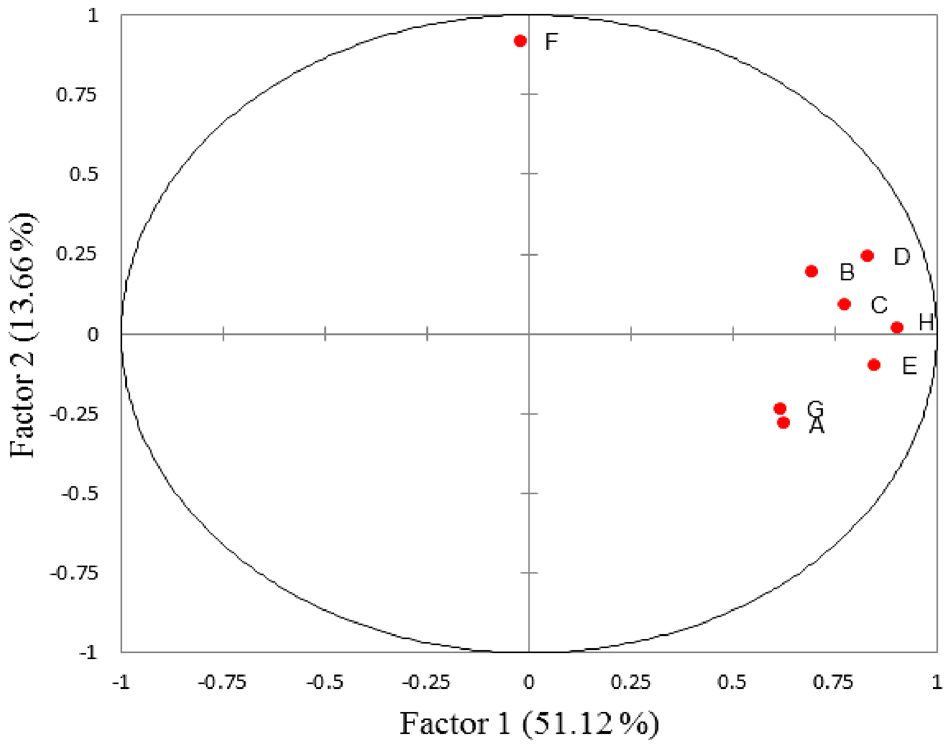


Figure 1. Scree plot showing eigenvalues and cumulative contribution to total variance of 8 factors estimated from coefficients of correlation among 8 traits of sweet corn inbred lines as grown under organic crop management.

Table 4. Loading of the two important factors of 8 traits of sweet corn inbred lines as grown under organic crop management.

Traits	Factor 1	Factor 2	Communality
Plant height	**0.62**	-0.28	0.47
Leaf no.	**0.70**	0.20	0.52
Stem diameter	**0.78**	0.09	0.61
Ear length	**0.83**	0.24	0.75
Ear diameter	**0.85**	-0.10	0.73
Kernel row number	-0.02	**0.92**	0.84
Kernel number/ row	**0.62**	-0.24	0.44
Ear yield/ plant	**0.91**	0.02	0.82



A. Plant height
B. Leaf number
C. Stem diameter
D. Ear length
E. Ear diameter
F. Kernel row number
G. Kernel number/ row Ear yield/ plant

Figure 2. Structure of traits association in organically grown sweet corn inbred lines as plotted on two-factor axes.

Table 5. Direct (diagonal and bolded) and indirect effects (upper and lower of the diagonal line) various traits on ear yield in organically grown sweet corn inbred lines path coefficient analysis.

Traits	Plant height	Leaf number	Stem diameter	Ear length	Ear diameter	Kernel-row number	Kernel number/ row	Ear yield/ Plant
Plant height	**0.03**	-0.04	0.03	0.13	0.17	-0.01	0.14	0.44
Leaf number	0.01	**-0.08**	0.04	0.18	0.18	0.01	0.11	0.46
Stem diameter	0.01	-0.04	**0.09**	0.23	0.29	-0.01	0.07	0.64
Ear length	0.01	-0.05	0.06	**0.31**	0.27	0.01	0.10	0.72
Ear diameter	0.01	-0.03	0.06	0.19	**0.44**	-0.01	0.17	0.83
Kernel row number	0.00	-0.01	-0.01	0.03	-0.04	**0.09**	-0.01	0.05
Kernel number/ row	0.01	-0.03	0.02	0.09	0.22	0.00	**0.35**	0.66

Residual effect = 0.15

The elucidation of casual relationships using path analysis by means of partitioning correlation coefficient between all contributing traits and ear yield into direct and indirect effect was presented in Table 5. The maximum positive direct effect was exhibited by ear diameter, followed by kernel number per row, and ear length. These results were consistent with those reported by Yue *et al.* (2007). In all cases, ear diameter served as an intermediary trait for indirect effects of other traits that strongly related to ear yield. Although, all vegetative traits also involved ear length as an intermediary trait for their indirect effect on ear yield. The residual effect was estimated as 0.15, and indicated that there were other traits that contributed to ear yield and were not yet considered in this experiment.

CONCLUSION

Analysis of variance revealed that sufficient genetic variation for important traits is present in the breeding materials to make an efficient selection program. Combined information derived from correlation analysis, factor analysis, and path analysis leads to the conclusion that concurrent attention must be given to ear length, ear diameter, and kernel number/row in the selection practice for improving ear yield of sweet corn under organic crop management.

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