CORRELATION AND PATH ANALYSIS OF BABY CORN CHARACTERS IN FIELD CORN AND SWEET CORN TYPES

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ABSTRACT

Information of relationship among baby corn characters and their direct and indirect effects are necessary to know for increasing effectiveness of selection in plant breeding programs. The objective of this study was to determine baby corn's characters association and direct effect characters related on number of ears per plant and ear length without husked on field corn and sweet corn types. This study was evaluated by using randomize complete block design with three replications, using 42 genotypes consisted of 23 genotypes of field corn and 19 genotypes of sweet corn types. Correlation analysis of baby corn characters were analyzed separately between field corn and sweet corn types. Harvesting duration in field corn and sweet corn types had significant positive correlation and high direct effect with number of ears per plant. The correlation coefficient of harvesting duration in field corn type was r_p=0.722 and the direct effect was 0.617. In sweet corn type, the correlation coefficient of harvesting duration was r_p=0.662 and the direct effect was 0.594. Baby corn's characters which had significant positive correlation and high direct effect with ear length without husked in field corn and sweet corn types were ear weight without husked. The correlation coefficient of ear weight without husked in field corn type was r_p=0.903 and the direct effect was 1.004. In sweet corn type, the correlation coefficient of ear weight without husked was r_p=0.838 and the direct effect was 0.910. These characters can be used as selection criteria for selecting genotypes that had high baby corn's production with good quality.

Keywords: characters association, direct effect, ear per plant, production, selection, selection criteria

INTRODUCTION

Nowadays, Maize is grown as horticulture purpose like baby corn for increasing added value and diversification. Baby corn is unfertilized ear of maize which is harvested 1-3 days after silking based on ear development and size (Bar-zur and Saadi, 1990). In Indonesia, farmers usually use field corn varieties for baby corn production, so the productivity is low and various ear size (Sutjahjo *et al.,* 2005; Yudiwanti *et al.,* 2010). Based on this information, baby corn's quality and productivity in Indonesia are still need to be improved. Improvement of baby corn characters that associated with production and quality can be determined based on correlation and path analysis for choosing the desire genotypes.

Information of baby corn characters that have association with productivity and quality is still limited. Understanding type of plant characters by using correlation and path coefficient analysis is a reliable statistical technique which provides means not only to quantity the interrelationships but also indicates whether the influence is directly related or takes some other pathway for ultimate effects (Mohsin *et al*., 2009). The correlation coefficient describes the magnitude and direction of the association between two characters, but can't explain the causal relationship between them. Path coefficient analysis partitions the components of correlation coefficient into direct and indirect effects and illuminates the relationship in a more meaningful way (Majumder *et al.,* 2008). Coefficient of path analysis can assist breeder when identifying characters that used as selection criteria for improving the characters (Surek and Beser, 2003). Production improvement in maize can be achieved by increasing number of ear per plant, so indirect selection can be used to find characters that affecting the yield component (Weish, 1981; Viola *et al*., 2003). Ear length without husked can be used as characters that determine the quality of baby corn. The international standard CODEX classified quality of baby corn into class A, B, and C based on ear length (FAO, 2007). In this study, field corn and sweet corn types are used to be harvested as baby corn because these maize types are usually cultivated by farmers in Indonesia. There was no difference in baby corn production from field corn and sweet corn types (Aekatasanawan, 2001).

The objective of this study was to determine baby corn's characters association and direct effect characters related on number of ears per plant and ear length without husked on field corn and sweet corn types.

MATERIALS AND METHODS

Genetic Materials

This study was conducted on January-April 2017 in Cikarawang experimental stations and Plant Breeding Laboratory, Department of Agronomy and Horticulture, Bogor Agricultural University. The genetic materials consisted 42 genotypes, divided into 23 genotypes of field corn type, and 19 genotypes of the sweet corn type. 23 genotypes of field corn consisted of five progenitors (S_0), four genotypes of first generation of half-sib (HS_1), four genotypes of second generation of half-sib (HS_2), five genotypes of first generation of selfing (S_1) and five genotypes of second generation of selfing (S_2). The field corn progenitor consist of P21, Srikandi Kuning, Lokal Madura, Genjah Melati, and Mutiara. 19 genotypes of sweet corn type consisted of four genotypes of S_0, four genotypes of HS_1, three genotypes of HS_2, four genotypes of S_1 and four genotypes of S_2. The sweet corn progenitor consisted of Laksmi, Hawaii, Golden, Baruna. The genotypes of HS_2 from the sweet-corn type that were not evaluated from Hawaii, whereas from field corn-type was HS_1 and HS_2 genotypes from Local Madura.

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each genotypes was grown in single line consist of 15 plants with spacing 0.75 x 0.25 m. The standard maize growing technique was practiced and harvesting was done by hand. The data were recorded on days to tasseling (days after planting-DAP), harvesting duration (days), ear height (cm), plant height (cm), number of node stem, length of segment (cm), plant diameter (mm), number of ear per plant, tassel length (cm), number of tassel branches, ear weight with husked (g), ear weight without husked (g), ear length with husked (cm), ear length without husked (cm), ear diameter with husked (mm), and ear diameter without husked (mm).

Statistical Analysis

Correlation analysis of baby corn characters was performed separately or combined between field corn and sweet corn type was determined based on the result of analysis of variance. If the most of baby corn characters was significant differences then analysis of correlation was performed separately. The correlation coefficient was calculated using the following formula:

$$r_{xy} = \frac{cov_{(xy)}}{V_x V_y}$$

Where:

r_{xy} : correlation coefficient between x and y characters
$cov_{(xy)}$: covariance of x and y characters
V_x : variance of x characters
V_y : variance of y characters
(Singh dan Chaundary, 1979).

Path analysis was used to identify the components that directly or indirectly affected targeted characters. Baby corn characters which was analized by path analysis, were determined by stepwise regression model. The stepwise regression model was analyzed using STAR software. Path analysis was calculated with the formula as expressed by Singh and Chaundary (1979):

$$C = R_y R_x^{-1}$$

$$\begin{bmatrix} r1y \\ r2y \\ \vdots \\ rpy \end{bmatrix} = \begin{bmatrix} r11 & r12 & \dots & r1p \\ r21 & r22 & \dots & r2p \\ \vdots & \vdots & \dots & \vdots \\ rp1 & rp2 & \dots & rpp \end{bmatrix} \begin{bmatrix} C1 \\ C2 \\ \vdots \\ Cp \end{bmatrix}$$

Where:

C = path coefficient
R_x^{-1} = inverse correlation matrix between independent baby corn characters
R_y = vector correlation coefficient between dependent and independent baby corn characters

RESULTS AND DISCUSSION

Correlations Analysis of Baby Corn Characters

Correlation analysis between baby corn characters were needed for determining relationship between two characters so the effectiveness of selection would increase. Number of ears per plant described baby corn production, while ears length without husked described the quality of baby corn. Number of ears per plant had significant positive correlation with corn production (Keweti & Wegary, 2016), whereas according to FAO (2007), ear length without husked was the most important characters that determined class of marketable baby corn.

Correlation analysis of baby corn characters was performed separately between field corn and sweet corn types because most of the baby corn characters of field corn were significantly different with sweet corn types (Table 1). There was significant differences in baby corn characters like days to tasseling, ear height, plant height, number of node per plant, tassel length, number of tassel branches, ear weight with husked, ear length with husked, ear length without husked, ear diameter with husked, and ear diameter without husked.

Correlations analysis of baby corn characters were presented in Table 2 for field corn type and Table 3 for sweet corn type. Number of ear per plant showed positive and significant phenotypic associations with many of characters studied. Harvesting duration was the highest correlation coefficient in field corn (rp=0.7222) and sweet corn type (rp=0.662) that associated with number of ear per plant. Positive and significant correlation of baby corn characters in field corn type was days to tasseling, harvesting duration, number of node, and ear length with husked, while in sweet corn type was observed in days to tasseling, harvesting duration, ear height, plant height, number of node, segment length, and ear weight with husked (Table 2 and Table 3). The positive associations of the above mentioned characters with number of ear per plant indicated that were the most important ones to be considered for indirect selection to improve number of ear per plant simultaneously in both of maize types. Level of association between number of ear per plant with harvesting duration in field corn type was higher than sweet corn type. Chakraborty & Sah (2012) reported positive and significant association of number of ears per plant with ear weight with husked and ear weight without husked in baby corn genotype. Possitive and significant correlation with number of ears per plant also found associated with days after maturity, days after silking, and plant height in field corn type when early maturing maize (Keweti & Wegary, 2016), also found positive and significant correlations of number of ears per plants with ear diameter (Mesenbet *et al.,* 2017). Number of baby corn per plant exhibited positive significant correlations with baby corn yield (Vaghela *et al.,* 2009).

Table 1. Analysis of variance for baby corn traits in field corn and sweet corn type

Characters	Mean square	Pr>f
Days to tasseling	283.61	<.0001
Harvesting duration	35.00	0.3936
Ear height	18162.76	<.0001
Plant height	17630.54	<.0001
Number of nodes	77.61	<.0001
Plant diameter	523.46	<.0001
Segment length	0.12	0.8525
Number of ear per plant	0.15	0.3448
Tassel length	513.23	<.0001
Number of tassel branches	302.57	<.0001
Ear weight with husked	1154.26	0.0112
Ear weight without husked	9.13	0.1245
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The major baby corn characters that determined quality of marketable ears was ear length without husked. Result showed that ear length without husked had the most positive value and significant correlation with ear weight without husked in field corn type (rp=0.903) and sweet corn type (rp=0.838) (Table 2 and Table 3). Baby corn characters with positive and significant correlation in field corn and sweet corn type were ear length, ear height, number of node stem, length of segment, plant diameter, tassel length, number of tassel branches, ear weight with husked, ear weight without husked, ear length with husked, ear length without husked, ear diameter with husked, ear diameter without husked. Incontradiction with the results Tiwari and Verma (1999) and Kabdal *et al.* (2003) reported negative correlation between ear length and ear diameter. Similar observation was reported by Nataraj *et al.,* 2014, there was significant positive association between ear length and ear weight.

Correlation coefficient described direction and magnitude of relationship targeted characters with attributes characters caused by genetic factor, environmental factor and interaction between genetic and environment (Rachmawati *et al.,* 2014; Jakhar *et al.,* 2017). Positive coefficient correlation showed simultaneous relationship between dependent and independent characters in selection (Eleweanya *et al.,* 2005). Selection based on yield component was more effective for increasing yield if breeder used selection criteria with high and positive correlation and highly inherited (Khodambashi *et al.,* 2012). The low phenotypic correlation could arise due to the modifying effect of environment on the association character at genetic level (Alake *et al.,* 2008).

Path Analysis of Baby Corn Characters

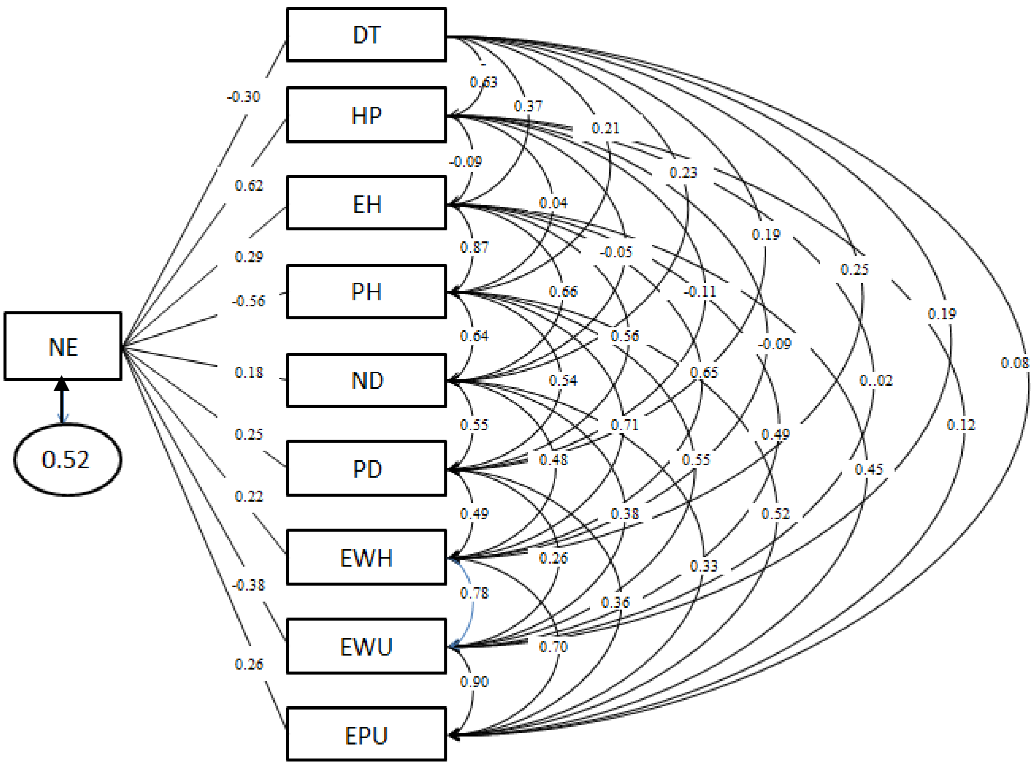
Information like association between characters and relative contribution of each characters either directly or indirectly effect were needed for determining selection criteria in plant breeding. Path analysis allows separating direct effect and their indirect effects through other attributes by partitioning correlation coefficient (Wreight, 1921). Path analysis of number of ears per plant was presented in Table 4 for field corn type and Table 5 for sweet corn type, while path analysis of ear length without husked was presented in Table 6 for field corn type and Table 7 for sweet corn type. Baby corn characters that were used for path analysis were independent variable from the best stepwise regression models.

The best stepwise regression model for number of ear per plant in field corn type was Y=-0.04DT + 0.08HD + 0.00EH - 0.01PH + 0.06ND + 0.03PD + 0.01EWH -0.09EWU + 0.10EPU + 3.04, where DT-days to tasseling, HD-harvesting duration, EH-ear height, PH-plant height, ND-number of node per plant; PD-plant diameter, EWH-ear weight with husked, EWU-ear weight without husked, and EPU–ear length without husked was independent variables and number of ears per plant was dependent variable (Y). The coefficient of determination from that regression model was 71.03%. Path coefficient analysis (Table 4 and Figure 1) showed that harvesting duration had exhibited the largest positive direct effect on number of ear per plant (0.617) and also showed significant positive phenotypic correlation (rp=0.722) followed by ear height (0.289), ear length without husked (0.261), plant diameter (0.246) and number of node (0.182). The best stepwise regression model for number of ear per plant in sweet corn type was Y= -0.03DT + 0.09HD + 0.01EH + 0.02EWH-0.09EDH + 4.53, where DT - days to tasseling, HD - harvesting duration, EH - ear height,

Table 4. Path analysis showing direct and indirect effect of baby corn traits on number of ear per plant in field corn type

Charac-ters	Direct effect	DT	HD	EH	PH	ND	PD	EWH	EWU	EPU	Correlation coefficient
DT	-0.298		-0.388	0.108	-0.119	0.043	0.047	0.055	-0.073	0.022	-0.603**
HD	0.617	0.187		-0.024	-0.023	-0.009	-0.028	-0.019	-0.009	0.030	0.722**
EH	0.289	-0.112	-0.052		-0.493	0.121	0.139	0.140	-0.188	0.116	-0.040
PH	-0.569	-0.062	0.025	0.250		0.116	0.132	0.154	-0.209	0.136	-0.026
ND	0.182	-0.070	-0.031	0.192	-0.364		0.135	0.104	-0.144	0.086	0.090
PD	0.246	-0.057	-0.071	0.163	-0.304	0.100		0.106	-0.098	0.093	0.178
EWH	0.217	-0.075	-0.055	0.187	-0.404	0.087	0.120		-0.297	0.183	-0.037
EWU	-0.383	-0.056	0.014	0.142	-0.310	0.068	0.063	0.168		0.236	-0.058
EPU	0.261	-0.025	0.071	0.129	-0.297	0.060	0.088	0.152	-0.346		0.093
Residual	0.523										

DT: days to tasseling; HD: harvesting duration; EH: ear height; PH: plant height; ND: ND: number of nodes; PD: plant diameter; EWH: ear weight with husked; EWU: ear weight without husked; EPU: ear length without husked; **: significantly correlated at α 0.01;



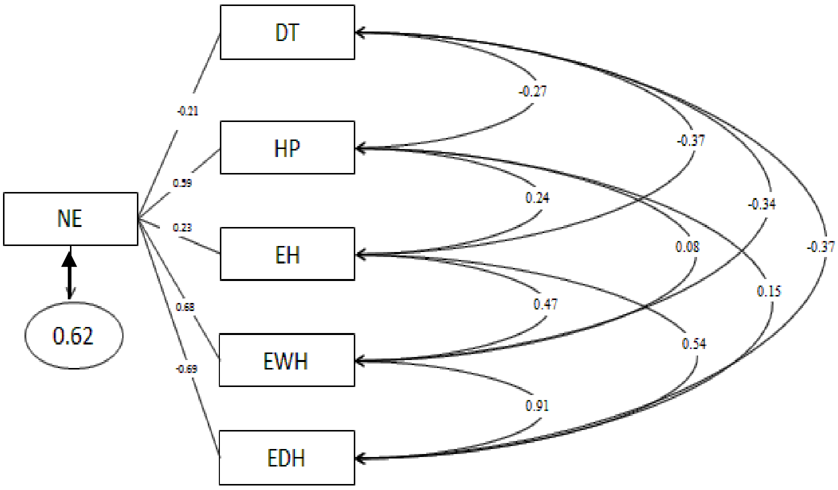
DT: days to tasseling; HD: harvesting duration; EH: ear height; PH: plant height; ND: ND: number of nodes; PD: plant diameter; EWH: ear weight with husked; EWU: ear weight without husked; EPU: ear length without husked

Figure 1. Phenotypic path diagram for number of ears per plant and its attributes in field corn type

Table 5. Path analysis showing direct and indirect effect of baby corn traits on number of ear per plant in sweet corn type

Character	Direct effect	DT	HD	EH	EWH	EDH	Correlation coefficient
DT	-0.214		-0.160	-0.083	-0.230	0.254	-0.433**
HD	0.594	0.058		0.055	0.057	-0.101	0.662**
EH	0.227	0.078	0.143		0.315	-0.370	0.393**
EWH	0.675	0.073	0.050	0.106		-0.626	0.278*
EDH	-0.688	0.079	0.087	0.122	0.614		0.214
Residual	0.620						

DT: days to tasseling; HD: harvesting duration; EH: ear height; EWH: ear weight with husked; EDH: ear diameter with husked; **: significantly correlated at α 0.01



DT: days to tasseling; HD: harvesting duration; EH: ear height; EWH: ear weight with husked; EDH: ear diameter with husked.

Figure 2. Phenotypic path diagram for number of ears per plant and its attributes in sweet corn type

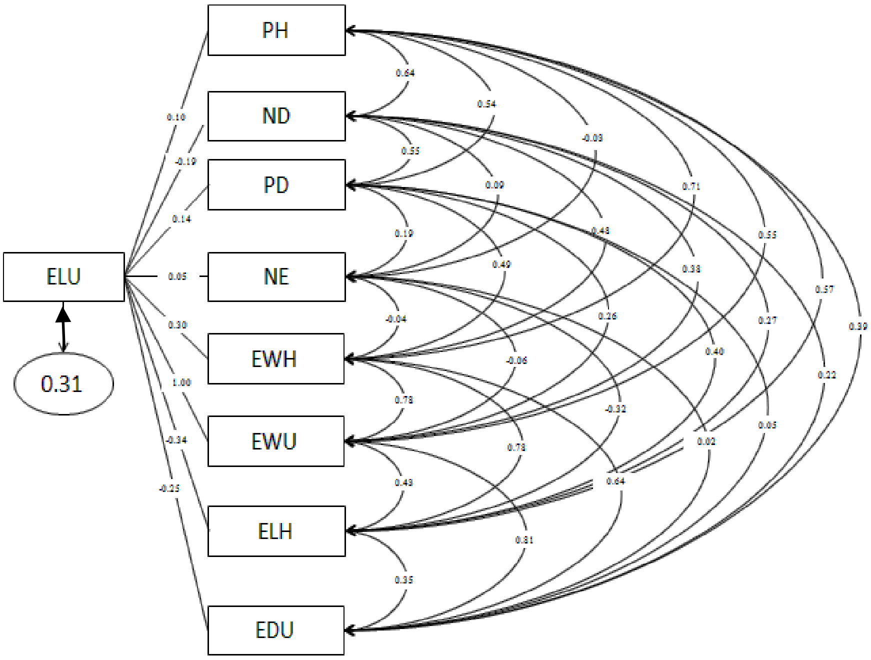
EWH - ear weight with husked, EDH– ear diameter with husked was independent variables and number of ears per plant was dependent variable (Y). The coefficient of determination from that regression model was 61.60%. Path coefficient analysis (Table 5 and Figure 2) showed that harvesting period had exhibited the positive direct effect on number of ear per plant (0.594) and also showed high significant positive phenotypic correlation (rp= 0.662).

Ear per plant, ear diameter, ear length exerted positive phenotypic direct effect on grain yield in field corn type (Mesenbet *et al.,* 2017). Ear number per m^2 had high positive correlation with grain yield but its direct effect on increment of grain yield was scarce in sweet corn type (Khazaaei *et al.,* 2010). Weight of baby corn with husk per plant found high direct effect on cob to corn ratio followed by days to detasseling and number of baby corn per plant (Chakraborty & Sah, 2012). Marketable husked ear weight was considered the most important trait for baby corn production (Izhar & Chakraborty, 2014). Path Coefficient analysis reveals that early silking, early harvest of fresh ears, greater plant height, greater ear length, ear weight and ear height, more number of ears/plant, with lesser ear girth would directly contribute to the increased ear yield in baby corn production (Viola *et al.,* 2012).

Table 6. Path analysis showing direct and indirect effect of baby corn traits on ear length without husked in field corn type

Charac-ter	Direct effect	PH	ND	PD	NE	EWH	EWU	ELH	EDU	Correlation coefficient
PH	0.099		-0.123	0.077	-0.001	0.213	0.547	-0.192	-0.098	0.522**
ND	-0.192	0.064		0.079	0.005	0.143	0.376	-0.090	-0.057	0.329**
PD	0.145	0.053	-0.105		0.009	0.146	0.257	-0.136	-0.013	0.357**
NE	0.052	-0.003	-0.017	0.026		-0.011	-0.058	0.109	-0.005	0.093
EWH	0.300	0.071	-0.092	0.071	-0.002		0.778	-0.263	-0.162	0.700**
EWU	1.004	0.054	-0.072	0.037	-0.003	0.232		-0.145	-0.204	0.903**
ELH	-0.336	0.057	-0.051	0.058	-0.017	0.234	0.433		-0.090	0.289**
EDU	-0.253	0.039	-0.043	0.008	0.001	0.192	0.811	-0.119		0.636**
Residual	0.312									

PH: plant height; ND: number of nodes; PD: plant diameter; NE: number of ear per plant; EWH: ear weight with husked; EWU: ear weight without husked; ELH: ear length with husked; EDU: ear diameter without husked; **: significantly correlated at α 0.01



PH: plant height; ND: number of nodes; PD: plant diameter; NE: number of ear per plant; EWH: ear weight with husked; EWU: ear weight without husked; ELH: ear length with husked; EDU: ear diameter without husked

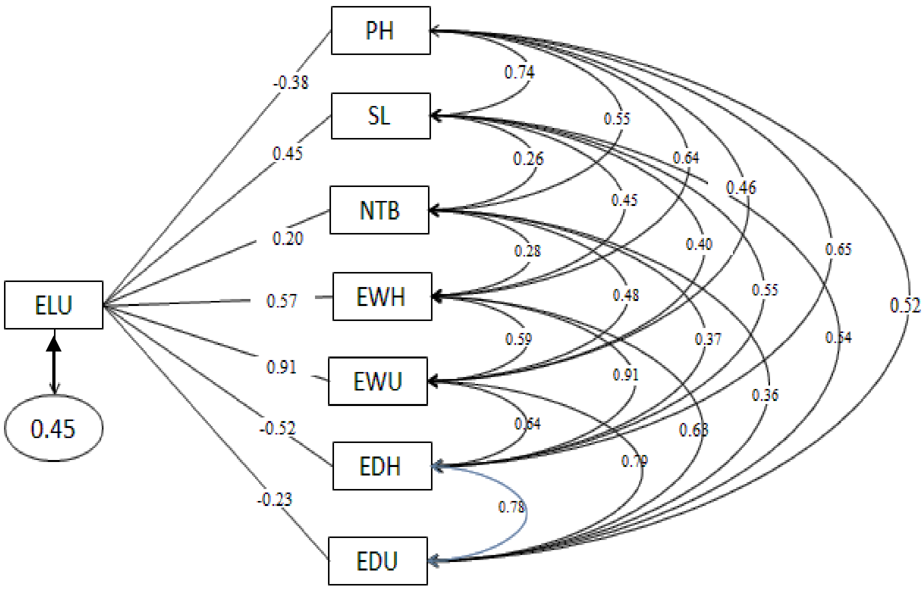
Figure 3. Phenotypic path diagram for ear length without husked and its attributes in field corn type

The path analysis model was able to explain the diversity of number of ears per plant by 47.7% for field corn type and 38.10% for sweet corn type, so it was necessary to observe another baby corn characters that may affect the number of ears per plant. Residual value from the path analysis model was 52.3% for field corn and 62% for sweet corn type. Residual value represented the total value of the undesired remaining direct effect on the unidentified characters. Residual values close to zero indicated that path analysis was used more effectively in explaining the causal relationships of correlation values and observed characters (Rohaeni and Permadi, 2012).

Table 7. Path analysis showing direct and indirect effect of baby corn traits on ear length without husked in sweet corn type

Character	Direct effect	PH	SL	NTB	EWH	EWU	EDH	EDU	Correlation coefficient
PH	-0.375		0.332	0.111	0.360	0.419	-0.335	-0.118	0.393**
PB	0.449	-0.278		0.052	0.255	0.364	-0.287	-0.125	0.431**
NTB	0.201	-0.207	0.117		0.158	0.441	-0.192	-0.083	0.434**
EWH	0.567	-0.239	0.202	0.056		0.535	-0.470	-0.145	0.506**
EWU	0.910	-0.173	0.180	0.097	0.333		-0.329	-0.180	0.838**
EDH	-0.517	-0.244	0.249	0.075	0.515	0.580		-0.177	0.482**
EDU	-0.229	-0.194	0.245	0.073	0.359	0.717	-0.400		0.571**
Residual	0.445								

PH: plant height; SL: segment length; NTB: number of tassel branches; EWH: ear weight with husked; EWU: ear weight without husked; EDH: ear diameter with husked; EDU: ear diameter without husked; **: significantly correlated at α 0.01



PH: plant height; SL: segment length; NTB: number of tassel branches; EWH: ear weight with husked; EWU: ear weight without husked; EDH: ear diameter with husked; EDU: ear diameter without husked

Figure 4. Phenotypic path diagram for ear length without husked and its attributes in sweet corn type

The major characters that determined baby corn quality was ear length without husked, so it was necessary to identify the characters that affected it. The best stepwise regression model for ear length without husked in field corn type was Y=0.00PH - 0.18ND + 0.05PD + 0.23NE + 0.03EWH + 0.58EWU - 0.14ELH - 0.25EDU + 9.24, where PH - plant height, ND - number of node per plant; PD - plant diameter, NE- number of ear per plant, EWH - ear weight with husked, EWU - ear weight without husked, ELH – ear length with husked, and EDU- ear diameter without husked were independent variables and ear length without husked was dependent variable (Y). The coefficient of determination from that regression model was 90.80%. The result of path analysis showed that there were eight baby corn characters in field corn type which could explain the diversity of ear length without husked by 68.83%. Path coefficient analysis (Table 6 and Figure 3) showed that ear weight without husked had exhibited the largest positive direct effect on ear length without husked (1.004) and also showed significant positive phenotypic correlation (rp=0.903). In sweet corn type, the best stepwise regression model for ear length without husked was Y= -0.01PH + 0.23PB + 0.07NTB + 0.04EWH + 0.50EWU - 0.17EDH - 0.17EDU. The coefficient of determination from that regression model was 80.21%. The result of path analysis showed that there were seven baby corn characters in sweet corn type which could explain the diversity of ear length without husked by 55.5%. Path coefficient analysis (Table 7 and Figure 4) showed that ear weight without husked had exhibited the largest positive direct effect on ear length without husked (0.910) and also showed significant positive phenotypic correlation (rp=0.838).

Based on path analysis, baby corn character that can be used as selection criteria for selecting genotypes with high number of ear per plant was harvesting duration in field corn and sweet corn type. In addition for selecting baby corn with good quality, ear weight without husked could be used for selecting the desire genotypes. Path analysis provided information on relationships between characters that improved the process of indirect selection of genotypes during the inbreeding process (Olivoto *et al.*, 2016). Characters that could be used for determining selection criteria in the selection process were highly association with targeted characters, high heritability, and visually observable (Roy, 2000). A change in any one component is likely to disturb the whole network of cause and effect. Thus, each component has two paths of action, the direct influence on grain yield, indirect effect through components which are not revealed from the correlation studies (Jakhar *et al.*, 2017). If the direct effect (coefficient of path analysis) and the total effect (coefficient of correlation) had high and positive value, then correlation coefficient explained the actual relationship between two characters (Singh and Chaundhary, 1979). Indirect effect needed to be considered if the character had low direct effect but highly correlation coefficient (Rachmawati *et al.*, 2014).

CONCLUSION

Harvesting duration in field corn and sweet corn types had significant positive correlation and positive direct effect with number of ears per plant. Baby corn's characters which had significant positive correlation and positive direct effect with ear length without husked in field corn and sweet corn types were ear weight without husked. These characters were recommended as selection criteria for selecting genotypes that had high baby corn's production with good quality.

ACKNOWLEDGEMENT

This research was funded by Directorate of Higher Education, Ministry of Research, Technology and Higher Education of the Republic of Indonesia in the fiscal year of 2015 for Yudiwanti Wahyu as principal investigator.

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