Identification of agronomic characters effecting cob weight of the families BTP1-X purple sweet corn (*Zea mays* L. *Saccharata* Sturt) using path analysis

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Abstract. Food security and climate change in Indonesia pose their challenges for Indonesia. Germplasm exploitation is one of the solutions to solve these problems. Purple sweet corn is germplasm that has not been widely developed in Indonesia. Plant adaptation is important to comprehend so that plans can be developed. The study was conducted in two seasons, on the first season (February), this study was conducted in Cangkringan and on the second season (September) was in Pleret. The study was carried out using open-pollinated purple sweet corn seeds with 20 cobs selected based on the color of the seeds and the surface of the wrinkled seeds. Path analysis was performed to each variable to see the direct and indirect effects on the results. The results showed that the ability of the five growth variables influenced cob weight by 77.8%. Based on path analysis, it is known that the variable of cob length and cob diameter directly influences the cob weight. On the other side, the plant height, cob height, and the number of cob per plant have an indirect effect on the cob weight. The influence of the cob diameter variable on the cob weight gives the highest percentage compared to other variables, which is equal to 58.7%.

1. Introduction

Food availability is a serious problem for every country in the world. One of the success indicators of a country is regarding the issue of food sovereignty, the adequacy of domestic food issues, and the number of population in Indonesia which is increasing every year and affect the food availability in Indonesia. Of course, this issue becomes a challenge for Indonesia on how to regulate and provide safe food for the community at an adequate level. One of the alternatives to solve this problem is food diversification. Food diversification can be implemented by the exploitation of other superior food commodities. Exploration activities certainly add to the collection of new commodities found and become a solution for food diversification in its development. Germplasm is collected according to International Resource Genetic Resources Institute procedures [1]. Preserving germplasm in gene banks is an effective way to preserve large amounts of plant germplasm that can be used by future generations and for future plant breeding [2].
Purple sweet corn is a newly developed commodity in Indonesia. This commodity has not been widely developed at the community or farm level. Evaluation of genetic diversity in maize germplasm is important to identify genotypes that are potential in breeding programs [3, 4]. In order to maintain the sweet nature and purple color of the corn, it should be planted separately from another kind of corn populations. Purple corn is a grain that is one of the sources of anthocyanin which serves as an alternative source of substitute for synthetic dyes [5, 6, 7, 8]. [6] added that purple corn is classified as healthy food.

In this study, an adaptation test was carried out on commodities to see the percentage of growth and to identify agronomic characters that have an important role for crop production, in this case, an approach to the character of cobs is the cob weight without cornhusk. Robi'in [9] stated that the length of the cob and the diameter of the cob is closely related to the yield of a variety.

2. Methodology

The materials used during the research were 20 selected cobs, water, Saromil, bamboo, raffia, plastic, experimental nameplate, label paper, urea, and phonska. The equipment used during the study included hoes, hammers, saws, meters, analytical scales, buckets, digital cameras, ruler, nails and stationery. A total of 20 SGHS families was used in this study. The yield of 10 selected families was then carried out in the next season using 5 selected cobs from each of 10 families. There are 20 SGHS families in mother. The research was conducted in two stages, the first stage was carried out in February-June 2017 in Sindumartani Village, Cangkringan, Sleman, D.I. Yogyakarta is on 7° 66406' LS and 110° 46143’ BT. The second stage is conducted in Pleret, Bantul, D.I. Yogyakarta in September-December 2017 is on 7° 839077’ LS dan 110° 394245’ BT. The study was designed using a Complete Randomized Block Design (RCBD) with three blocks as replications. The correlation and the cross prints of the observed data were analyzed using the IBM SPSS Statistics 24 program. Inter-variable correlation analysis was performed by calculating the value of a simple linear correlation coefficient based on the formula:

$$r = \frac{\Sigma X_1X_2}{\sqrt{(\Sigma X_1^2)(\Sigma X_2^2)}}$$

where $r$ = correlation coefficient, $X_1$ and $X_2$ are the middle values of the observed variables. Cross prints are carried out based on the simultaneous equation as follows [10]:

$$[r_{11} \quad r_{12} \quad \ldots \quad \ldots \quad r_{1p}] \quad [C_1] \quad [r_{1y}]$$
$$r_{21} \quad r_{22} \quad \ldots \quad \ldots \quad r_{2p} \quad C_2 \quad r_{2y}$$
$$\ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots$$
$$r_{p1} \quad r_{p2} \quad \ldots \quad \ldots \quad r_{pp} \quad C_p \quad r_{py}$$

where $R_X$ is a correlation matrix between independent variables in a multiple regression model that has $p$ independent variables, so it is a matrix with elements $r_{X_iX_j}$ (i, j = 1,2, ..., p). $C$ is a
path coefficient vector that shows the direct effect of each standardized free variable, \( Z_i \), on the dependent variable (standard regression coefficient value). \( R_Y \) is the correlation coefficient vector between independent variables \( X_i \) where \( i = 1, 2, ..., p \); and the dependent variable \( Y \). Through the matrix equation, the path coefficient vector \( C \) can be determined as follows:

\[
C = r_x^{-1}r_y
\]

where: \( r_x^{-1} \) is the inverse matrix \( R_X \) and \( R_Y \) is the correlation coefficient vector between the independent variable \( X \) and the independent variable \( Y \). The direct effect of the standardized independent variable on the dependent variable \( Y \) is measured by the path coefficient \( C_i \). The indirect effect of the free variable \( Z_i \) on the independent variable \( Y \) through the independent variable \( Z_j \) (in the model) is measured by \( C_j \cdot r_{ij} \). The effect of the error is explained by the cross-fingerprint model. Effects that cannot be explained by a model are included as error or residual effects measured by the formula:

\[
h (\text{residual}) = \sqrt{1 - C^2 A}
\]

3. Results and Discussion

3.1. Agronomic traits

Based on the results of quantitative character observation (Table 1), it can be seen that the highest average plant height is in family 1-V-7 (1) (175.08 cm) with the lowest average plant height is in family 1-V-1 (1) (122.93 cm). The highest average cob height is in family 3-V-4 (1) (80.66 cm) with the lowest average cob height is in family 1-V-4 (1) (64.93 cm). The highest average number of cob per plant is in family 1-V-5 (2) (1.77) with the lowest average number of cob per plant is in family 1-V-1 (1) (1.29). The highest average cob length is in family 1-V-4 (2) (12.36 cm) with the lowest average cob length is in family 1-V-1 (3) (10.26 cm). Then, the highest average diameter of cob is in family 1-V-7 (1) (11.46 cm) with the lowest average diameter of cob is in family 1-V-1 (3) (9.69 cm).

Table 1. Agronomic traits per family of purple sweet corn

| Family | plant height | cob height | Number of cob per plant | Cob length | Diameter of cob |
|--------|--------------|------------|-------------------------|------------|----------------|
| 1-V-5 (1) | 143.28 | 67.65 | 1.66 | 11.57 | 10.48 |
| 3-V-4 (1) | 157.82 | 80.66 | 1.50 | 11.93 | 10.41 |
| 1-V-7 (1) | 175.08 | 71.78 | 1.41 | 12.25 | 11.46 |
| 1-V-4 (1) | 143.20 | 64.93 | 1.60 | 11.82 | 10.69 |
| 1-V-1 (1) | 122.93 | 67.49 | 1.29 | 10.38 | 10.02 |
| 3-V-4 (2) | 146.34 | 82.51 | 1.72 | 11.03 | 10.36 |
| 1-V-7 (2) | 143.44 | 66.84 | 1.53 | 10.78 | 9.96 |
| 1-V-4 (2) | 153.41 | 68.96 | 1.68 | 12.36 | 10.72 |
| 1-V-1 (2) | 138.34 | 70.59 | 1.65 | 10.95 | 10.61 |
| 1-V-5 (2) | 150.68 | 65.57 | 1.77 | 11.60 | 10.38 |
| 1-V-7 (4) | 149.39 | 72.97 | 1.46 | 11.58 | 11.18 |
| 1-V-1 (4) | 142.92 | 72.62 | 1.68 | 10.31 | 9.89 |
| 1-V-5 (4) | 146.11 | 67.98 | 1.68 | 11.43 | 10.24 |
| 1-V-4 (4) | 156.73 | 77.25 | 1.40 | 12.08 | 11.34 |
3.2. Percentage of living plants
The percentage of living plants in the plants population is presented in Table 1. It can be seen that the percentage of plants that live on average is above 80% except for 1-V-1 (1) plots. The percentage of growth above 80% indicates that the adaptation of growing plants in the experimental environment is appropriate, only further needs to be seen for the characters that correlate with the results (cob weight) to make it easier for selection in plant populations.

| No. | Plot           | Percentage of living plants |
|-----|----------------|------------------------------|
| 1   | 1-V-5 (1)      | 97%                          |
| 2   | 3-V-4 (1)      | 100%                         |
| 3   | 1-V-7 (1)      | 97%                          |
| 4   | 1-V-4 (1)      | 90%                          |
| 5   | 1-V-1 (1)      | 70%                          |
| 6   | 3-V-4 (2)      | 93%                          |
| 7   | 1-V-7 (2)      | 100%                         |
| 8   | 1-V-4 (2)      | 87%                          |
| 9   | 1-V-1 (2)      | 87%                          |
| 10  | 1-V-5 (2)      | 100%                         |
| 11  | 1-V-7 (4)      | 93%                          |
| 12  | 1-V-1 (4)      | 93%                          |
| 13  | 1-V-5 (4)      | 97%                          |
| 14  | 1-V-4 (4)      | 100%                         |
| 15  | 3-V-4 (4)      | 100%                         |
| 16  | 1-V-1 (3)      | 97%                          |
| 17  | 3-V-4 (3)      | 100%                         |
| 18  | 1-V-4 (3)      | 90%                          |
| 19  | 1-V-5 (3)      | 93%                          |
| 20  | 1-V-7 (3)      | 100%                         |

3.3. Correlation Analysis and Path Analysis
Research on correlation analysis has been widely carried out. [11, 12] researched correlation analysis of rice agronomic traits based on additive and dominant genetic models for quantitative traits. [13] added that the correlation coefficient and heritability estimation were found to be suitable as models for the improvement and selection results for the tolerant S. lutea genotype. The correlation table illustrates the magnitude of the correlation coefficient between variables. The significance level used are 0.01 (1%) and 0.05 (5%), a significance level of 0.01 means...
that the level of accuracy of the analysis is 99% and the error is only 1%. While a significance level of 0.05 means that the accuracy level is 95% and the error rate is 5% (Table 2 and Table 3).

Based on the Pearson correlation results (Table 2), the correlation value of plant height vs. cob weight = 0.287 (very strong), cob height vs. cob weight = 0.040 (very weak), number of cobs per plant vs cob weight = -0.032 (negative and very weak), cob length vs cob weight = 0.770 (very strong) and cob diameter vs cob weight = 0.839 (very strong).

A significantly positive correlation coefficient value indicates the greater the value of the character the greater the result (cob weight). Conversely, the smaller the character value the lower the yield in the population. Correlation coefficient value that is real negative indicates the greater the character value the lower cob weight obtained. Conversely, the smaller the character value, the greater cob weight. The height, cob length, and diameter can be used as selection characters for sweet purple corn (Table 2). The previous research on correlation analysis in maize has been investigated by [14, 15] which stated that the length of the cob and the diameter of the cob are significantly positively correlated with the results.

The results of the correlation analysis between quantitative sweet purple maize characters can be seen in Table 3. It shows that the correlation coefficient values are real, very real and not real between plant characters. The correlation between the character of cob diameter with the number of cobs per plant is significantly negative, indicating that the greater the character value of cob diameter, the lower the number of cobs per plant, and vice versa. The significantly positive correlation coefficient values that were significantly positive were on the correlation between the characters of cob height and plant height, correlation between the diameter of cob and plant height, correlation of cob length with plant height, correlation of the number of cob per plant with cob height and the correlation of diameter of cob with cob length. Correlation coefficient values that are a significantly positive indication that the greater the value of a character, the greater the value of other characters.

| Characters (X_i)          | Correlation coefficient value to the cob weight (Y) |
|--------------------------|---------------------------------------------------|
| X_1 Plant height         | 0.287**                                           |
| X_2 Cob height           | 0.040                                             |
| X_3 Number of cob per plant | -0.032                                          |
| X_4 Cob length           | 0.770**                                           |
| X_5 Diameter of cob      | 0.839**                                           |

Studies of correlation coefficients should be carried out further analysis, namely path analysis [16, 17] added that correlation analysis is not enough to describe a relationship between characters. With cross-analysis, each character correlated with the results can be broken down into direct and indirect influences, so that the causal relationship between the correlated characters can be known [10].
Table 4. Results of correlation analysis between quantitative characteristics

|     | TT   | TLT  | JTT  | PT   | DT   |
|-----|------|------|------|------|------|
| TT  | 1    | .392 | 0.07 | .350 | .266 |
| TLT | .392 | 1    | .158 | 0.036| 0.049|
| JTT | 0.07 | .158 | 1    | 0.045| -.090|
| PT  | .350 | 0.036| 0.045| 1    | .681 |
| DT  | .266 | 0.049| -.090| 0.681| 1    |

Note: (*): Real on α = 5%, (**) : Real on α = 1%. TT = Plant Height, TLT= Cob Height, JTT = Number of Plant per Cob, PT= Cob Length, DT= Cob Diameter.

The results of the cross coefficient analysis on purple sweet corn (Table 4) show that the length of the cob and the diameter of the cob have a direct and large total positive effect. Based on Singh and Chaudhary's theory, such conditions mean that the two characters have an actual relationship to the cobs weight (the resulting character) and the direct selection of these characters will be very effective. Furthermore, the characters of plant height, cob height and the number of cobs per plant have a positive direct effect value but the value is relatively small ranging between 0.0009 - 0.0025. In these conditions, direct selection cannot be done. The direct effect is negative or small, the indirect effect that causes the correlation must be considered for simultaneous selection, so that if we want to do the selection based on plant height, cob height and number of cob per plant, then we should consider the indirect effect through the weight character of the cob.

Table 5. The direct and indirect effects of some variables on the results

| Character | Direct effects | Indirect effects |
|-----------|---------------|-----------------|
|           | X1            | X2              | X3              | X4              | X5              |
| X1        | 0.0009        | -0.0000047      | 0.0000011       | 0.0003885       | 0.00046843      |
| X2        | 0.0016        | -0.00000047     | -0.0000032      | -0.0005328      | -0.00011505     |
| X3        | 0.0025        | 0.00000011      | -0.0000032      | 0.0000833       | -0.00026415     |
| X4        | 13.69         | 0.0003885       | -0.0000533      | 0.0000833       | 0.14790639      |
| X5        | 34.4569       | 0.0004684       | -0.0001151      | -0.0002642      | 0.1479064       |

Note: *directly affect the result on α level = 0.05, **directly affect the result on α level= 0.01, X1 = plant height (cm), X2 = cob height (cm), X3 = the number of cob of each plant, X4 = cob length (cm), X5 = cob diameter (cm).

To find out the partial effect/individually t-test is done, while to see the magnitude of the effect a beta number or standardized coefficient is used. Of the five variables tested t, there are only two variables: the length of the cob and the diameter of the cob which has a linear relationship with cob weight. The beta value of the effect of cob length on cob weight was 0.370 or 37% while the effect of cob diameter on cob weight was 0.587 or 58.7%. Meanwhile, three variables, which are plant height, cobs height and number of cobs per plant, were considered to be insignificant, i.e., 0.3, -0.4% and 0.5%. Correlation between the variable of plant height and height of cob location = 0.392. Correlation between the variable the cobs’ height and the number of cobs per plant = 0.158. Correlation between the variable number of cobs per plant with cob lengths = 0.045. Correlation between variable length of cob and cob diameter = 0.681. Correlation between plant height variables and cob diameter = 0.266.
4. Conclusion
Families 3-V-4 tend to give a good average of agronomic traits and families 1-V-1 tend to give a lower scores than other families for agronomic traits. Percentage growth of sweet purple corn plants for 20 numbers (cobs) used an average of above 80% except number 1-V-1 (1) of 70%. The ability of the 5 growth variables to influence the height of the cob weight by 77.8% and there are still 22.2% of other variables that affect the results (cob weight). The effect of cob length on cob weight was 0.370 or 37% while the effect of cob diameter on cob weight was 0.587 or 58.7%. Meanwhile, three variables, which are plant height, cobs height and number of cobs per plant, were considered to be insignificant, i.e., 0.3, -0.4% and 0.5%.

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