Yield Determinants of Some Sweet Potato (Ipomoea batatas L) Clones Using Principal Component Analysis

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Abstract: This study aims to determine the factors influencing the yield of sweet potatoes using the Principal Component Analysis (PCA). Meanwhile, this tool was used to form new set of smaller and mutually independent variables (no longer correlated) based on the research variables which includes Plant Length (PL), Number of Leaves (NL), Number of Shoots (NS), Leaf area (LA), Total Fresh Weight (TFW), Number of Tubers (NT), Fresh Weight of Tuber (FWT), Dry Weight of Tuber (DWT), and Harvest Index (HI). The results showed that the combined effect of TFW, NT, FWT, and DWT, as the main determinants of sweet potatoes yield was 71.048% as indicated by the total variance (cumulative percent of variance). Therefore, treatments in line with these values are important for improved crop yield.

Keywords: Clones, Principal Component Analysis, Reduce, Sweet Potato

1. Introduction
Consumers, usually prefer sweet potato varieties with high dry matter content [1], [2], [3]. It is diversified by the food industry into various cookies such as cakes, chips, ice cream, and porridge [4]. In addition, sweet potato contain starch, dietary fiber (cellulose, hemicellulose), and several types of soluble sugars, including maltose, sucrose, fructose, and glucose [5], [6], [7]. The intrinsic starch content tends to play an essential role in influencing both quality and taste [8].

Furthermore, the average number of tubers, weight, and harvest index have been identified as the most influential factors which affect yield [9]. This is manifested in growth, in terms of number of leaves, leaf area, number of branches, and plant length. Meanwhile, PCA reflects the importance of the largest contributor to the total variation in each axis of differentiation [10]. Each principal component is a linear combination of original variables; therefore, it is often possible to define the result based on the features of the components [11]. This procedure generally consists of correlations between different traits [12]. It transforms the original interrelated variables into new un-correlated forms, by reducing the number thereby, resulting in smaller dimensions. However, this instrument is able to account for most original variable diversifications [13]. Therefore, this study aims to determine the factors affecting the yield of sweet potatoes, using PCA as a multivariate analysis tool. The paper also includes a theoretical portion of the PCA method as well as its implementation in agriculture.
2. Material and method

2.1. Location
The field trial was conducted from March-September to 2019 at the University of Islam Malang Teaching and Research Farm, Malang, Indonesia, 750m above sea level. Besides, the conditions observed include, an average temperature of 28°C, rainfall of 1928 mm/years, and soil types ranging from Entisol and Oxisol, maintained at about 15-22°C.

2.2. Experimental Condition
The planting materials were obtained from Indonesian Legumes and Tuber Crops Research Institute in form of twelve cut sweet potato clones, including BO (K1-27), CIP MFC (K1-28), LSQ (MUARA), SHIROYUTAKA, OR-4 (K1-34), J1 (K2-16), OR-18 (K3-14), JAGO, PUR-8 (K1-10), YEL-1 (K1-30), DEN-2 (MUARA), and PUR-3 (K1-12). The experiment was conducted using a Random Block Design, with three replications. Each cutting was planted in a plot within a space of 30 cm × 40 cm, while fertilizers was applied twice a week, and also one month after planting, at a dose of 105 kg Urea + 105 kg Super Phosphate-36 + 105 kg KCL.ha-1. Harvest was carried out 170 days after planting.

2.3. Observations
The growth and yield of sweet potato were evaluated by measuring Plant Height (PH) (cm), Number of Leaves (NL), Number of Shoots (NS), Leaf Area (LA), Total Fresh Weight (TFW), Number of Tubers (NT), Fresh Weight of Tuber (FWT), Dry Weight of Tuber (DWT), and Harvest Index (HI).

To access the level of dry matter (%), chopped small sweet potatoes weighing 100 g each, were placed in the oven at 80°C for 48 hours, thereafter, the dry matter was weighed.

\[
\text{Water content of sweet potato (\%) = } \frac{(\text{fresh weight} - \text{dry weight})}{(\text{fresh weight})}
\]

(1)

The dry weight of tubers per plot was measured using a formula

\[
\text{Dry weight of tubers per plot} = \frac{\text{Water content}}{100} \times \text{fresh weight of tubers per plot}
\]

(2)

Harvest Index was measured using the formula [14].

\[
\text{Harvest index(\%) = } \frac{\text{fresh weight of tuber per plot}}{\text{total fresh weight of the plant per plot}} \times 100%
\]

(3)

2.4. Statistical Analysis
Statistical analysis was performed using SPSS v17 statistical software (SPSS Inc., Chicago, IL, USA), meanwhile, the data obtained were expressed in terms of means ± standard error. Furthermore, the means were statistically compared using Duncan's multiple range test (DMRT) at p < 5 % level.

3. Result and Discussion
Based on the results, there was no significant differences between the clones of PL, NS, LA, and HI, while NL, TFW, NT, and FWT, indicating high similarity between variables. Whereas, PUR-8 (K1-10), YEL-1 (K1-30), and SHIROYUTAKA yielded the most significant DWT at 28.87 g; 23.66 g; and 23.52 g.
The sweet potato clones were in form of nine observed characters generated using a Barlett Test of Sphericity with a value of 79.975 and a significance level of 0.000, hence the requirements were met at < 5%. Meanwhile, the KMO and Bartlett's test table showed a K-M-O Measure of Sampling Adequacy (MSA), at 0.347, which was below 0.5 (Table 2), hence it was impracticable to carry out further processing [15]. This is potentially resolved by excluding variables without significant results, which include PL, NS, LA, and HI. Consequently, a K-M-O Measure of Sampling Adequacy (MSA) value of 0.692 > 0.5 was obtained (Table 3).

### Table 1. Average Plant Growth and Yield of Some Sweet potato Clones

| Clones | PH     | NL     | NS     | LA     | TFW    | NT     | FWT    | DWT    | HI     |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| BO(K1-27) | 159.28 | 286.22 | c      | 34.56  | 6566.63 | 64.17  | ab     | 134.30 | abc    | 44.73  | ab     | 18.19  | ab     | 69.47  |
| CIP MFC(K1-28) | 197.90 | 175.78 | 30.56  | 6983.6 6 | 61.97  | ab     | 134.70 | abc    | 43.87  | ab     | 17.55  | ab     | 70.94  |
| LSQ(MUARA) | 208.42 | 237.30 | 39.67  | 4946.77 | 63.57  | ab     | 121.30 | abc    | 45.80  | ab     | 18.46  | ab     | 71.62  |
| SHIROYUTAKA | 187.87 | 284.33 | bc     | 32.67  | 6775.32 | 83.33  | b      | 133.00 | abc    | 55.37  | ab     | 23.52  | bc     | 66.70  |
| OR-4(K1-34) | 192.93 | 201.56 | 29.89  | 5490.27 | 77.90  | ab     | 114.70 | ab     | 44.67  | ab     | 18.96  | ab     | 57.37  |
| J1(K2-16) | 251.96 | 248.11 | 29.89  | 8134.86 | 61.30  | ab     | 129.00 | abc    | 42.07  | a      | 16.83  | ab     | 69.03  |
| OR-18(K3-14) | 187.32 | 236.56 | 32.89  | 7178.09 | 61.23  | a      | 133.70 | abc    | 39.27  | a      | 15.71  | a      | 64.39  |
| JAGO | 224.33 | 229.33 | 36.56  | 4560.32 | 67.97  | a      | 156.00 | ab     | 44.00  | ab     | 17.60  | ab     | 65.45  |
| PUR-8(K1-10) | 187.60 | 203.67 | 35.33  | 3890.17 | 72.83  | ab     | 189.70 | c      | 51.57  | ab     | 28.87  | c      | 71.09  |
| YEL-1(K1-30) | 223.64 | 137.00 | a      | 35.89  | 3619.93 | 79.27  | ab     | 163.30 | bc     | 58.73  | b      | 23.66  | bc     | 74.64  |
| DEN-2(MUARA) | 201.13 | 173.44 | 32.11  | 4559.82 | 66.00  | ab     | 123.30 | abc    | 47.80  | ab     | 19.26  | ab     | 72.63  |
| PUR-3(K1-12) | 219.49 | 176.78 | 33.22  | 4740.06 | 67.20  | ab     | 87.30  | a      | 43.93  | ab     | 19.26  | ab     | 65.37  |

Remarks: PH: Plant Height; NL: Number of Leaves; NS: Number of Shoots; LA: Leaf Area; TFW: Total Fresh Weight; NT: Number of Tuber; FWT: Fresh Weight of Tuber; DWT: Dry Weight of Tuber; HI: Harvest Index (%); * no significant

After the Bartlett and Kaiser Meyer Olkin (KMO) tests, the MSA (Measure of Sampling Adequacy) analysis was performed. The results are presented in Table 4. Table 4 shows the MSA (Measure of Sampling Adequacy) values for the studied variables, as indicated in the Anti Image Correlation row, and marked "a". Furthermore, values < 0.5 were taken to be below requirements, as shown in NL (0.480), hence, resulting to exclusion. It is also important to repeat the tests, to obtain MSA values > 0.5, thereby, modifying the KMO and Bartlett output. The results of the retest are shown in Table 5.

### Table 2. Score of KMO and Bartlett’s Test

| Statistics                      | Value (KMO) | Sig. (Bartlett) |
|---------------------------------|-------------|----------------|
| Kaiser-Meyer-Olkin Measure      | 0.347       | 0.000          |
| Approx. Chi-Square              | 79.975      |                |
| Bartlett's Test of Sphericity   | df          |                |
| Sig.                            | 36          |                |
|                                 | 0.000       |                |

### Table 3. Score of KMO and Bartlett’s Test

| Statistics                      | Value (KMO) | Sig. (Bartlett) |
|---------------------------------|-------------|----------------|
| Kaiser-Meyer-Olkin Measure      | 0.692       |                |
| Approx. Chi-Square              | 23.457      |                |
| Bartlett's Test of Sphericity   | df          | 10             |
| Sig.                            | 0.009       |                |
to respectively provide 86.6% and 86.0% interpretation for the variance of the resultant factor. Conversely, the lowest was observed with NT at 0.426, depicting the ability to justify 42.6% of the variance.

Table 4. Measures of Sampling Adequacy (MSA)

| Anti-image Matrices | NL    | TFW   | NT    | FWT   | DWT   |
|---------------------|-------|-------|-------|-------|-------|
| NL                  | .896  | -.104 | -.099 | .104  | .037  |
| TFW                 | -.104 | .307  | .138  | -.158 | -.068 |
| NT                  | -.099 | .138  | .550  | -.060 | -.189 |
| FWT                 | .104  | -.158 | -.060 | .214  | -.097 |
| DWT                 | .037  | -.068 | -.189 | -.097 | .265  |

Table 5. KMO and Bartlett's Test After the NL variable has been excluded

| Kaiser-Meyer-Olkin Measure of Sampling Adequacy | 0.712 |
|-----------------------------------------------|-------|
| Bartlett's Test of Sphericity                 |       |
| Approx. Chi-Square                           | 23.409|
| Df                                            | 6     |
| Sig.                                          | 0.001 |

Table 6. Measures of Sampling Adequacy (MSA)

| Anti-image Matrices | TFW | NT   | FWT  | DWT  |
|---------------------|-----|------|------|------|
| TFW                 | 0.320 | 0.134 | -0.161 | -0.067 |
| NT                  | 0.134 | 0.561 | -0.052 | -0.190 |
| FWT                 | -0.161 | -0.052 | 0.226  | -0.109 |
| DWT                 | -0.067 | -0.190 | -0.109 | 0.267  |

Table 7. Communalities

| Initial | Extraction |
|---------|------------|
| TFW     | 1.000      | .690 |
| NT      | 1.000      | .426 |
| FWT     | 1.000      | .866 |
| DWT     | 1.000      | .860 |

Table 8. Total Variance Explained

| Component | Initial Eigenvalues | Extraction Sums of Squared Loadings |
|-----------|---------------------|--------------------------------------|
|           | Total Variance (%)  | Cumulative (%)                       | Total Variance (%)  | Cumulative (%) |
| 1         | 2.842               | 71.048                               | 2.842               | 71.048         | 71.048 |
| 2         | 0.803               | 20.071                               | 0.803               | 20.071         | 91.119 |
| 3         | 0.202               | 5.045                                | 0.202               | 5.045          | 96.165 |
| 4         | 0.153               | 3.835                                | 0.153               | 3.835          | 100.000 |
Based on the main component analysis, only 1 factor was formed as seen in Figure 1 and Table 8. This is indicated in the Eigenvalue obtained after extracting 71,048, as well as the level off, initiated in the scree plot at the extraction of the initial variables into 1 factor, as seen in Table 8. Therefore, the nine variables were subsequently reduced to 1 component, consisting of TFW, NT, FWT, and DWT, together with a total variance (cumulative percent of variance) of 71,048% [16].

According to [17], the extraction of one factor is assumed to be accurate, when the total variables obtained are below 30. However, only 5 sample variables were utilized in this study, measuring over 250, with an average communality of 0.7 and above. This outcome is congruent with previous interpretations, hence, the extraction of one factor in this analysis is relatively accurate.

![Scree Plot](image)

**Figure 1.** Analysis Scree Plot Result

### 4. Conclusion

Based on the PCA analysis results, variables in form of fresh and dry weight of tuber, impacts significant effects on the output of sweet potatoes. Therefore, treatments in line with these values are important for crop yield.

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