Akaike Information Criterion (AIC) and stepwise regression method to select the areca nut population as across parent material

M R Romadhon and M A Tulalo
Indonesian Palm Research Institute.IAARD, Jl. Raya Mapanget, Mapanget Kotak Pos 1004 Manado 65001, Indonesia

Corresponding author email: roiyannur@gmail.com

Abstract. Areca nut is widely distributed in tropical areas, including Indonesia. Areca nut has a genetic source for hybrid development. Areca nut is a cross-pollinated plant, so the gene constitution is expected to be heterogeneous and heterozygous. A stepwise regression approach can be utilized to identify the best model of several characters for selection. This study aimed to find out the suitable model and selection characters for selecting a potential population of Areca for use as a cross-parent material. The study was conducted at the Kayuwatu Experimental Garden using the Local Areca Accession Population. The research used a single block with 7 local accessions of areca nut and the vegetative and generative characters of 10 plants from each accession were observed. The results showed that the best model for estimating whole fruit weight \( (y) = 86586 - 498 \text{ stem circumference}^* + 11158 \text{ Fruits Per Bunch}^* + 4738 \text{ Number of Leaves} + 38.9 \text{ Number of Fruits Per Bunch}^* + 58.8 \text{ fruit equatorial circumference}^* + 1545 \text{ fruit polar circumference}^* \). Based on stepwise regression, only stem circumference, fruit equatorial circumference, fruit polar circumference, and the number of fruits per bunch might be used as the selection criteria to determine the best population.

Keywords: filial, fruit, hybrid, superior, yield

1. Introduction
Areca nut is a palm plant that is widespread in Indonesia, especially in Sumatra, Kalimantan, Papua, and Sulawesi. Areca nut is a cross-pollinated plant, although there is betel nut that self-pollinate. [1], areca nut has many intermediate benefits because it contains bioactive compounds such as alkaloids (arecoline), fats, polyphenols, flavonoids, tannins, proteins, and fiber which are very useful for the treatment of diabetes, ulcers, heart disease, depression, anti-inflammatory, antioxidants, and other wound healing.

The distribution of areca nut that spreads throughout Indonesia and the existence of environmental influences cause differences from one another and cause a high diversity of areca nut populations. Genetic diversity is one of the capitals in assembling new varieties. The high performance of areca nut populations can be used as genetic material which will eventually produce progenies with high performance. Selection of mother trees can be done by means of selection to get superior parents.

Selection is one of the plant breeding activities in assembling hybrid varieties. One of the selection methods is a weighted selection index to select the desired variables. According to [2], the selection index is obtained from the preferences of participatory plant breeding consumers towards the desired
character in a commodity. The selection index is carried out in the selection of pea plants to assemble a hybrid [3]. Selection activities for cross-pollinated plant genotypes used the index selection method by involving several characters as the selection criteria, and the genotypes were arranged based on the selection index.

The use of index selection has the advantage that it produces genotypes with several characters at once that are balanced according to the breeder's goals [4]. The assembly of the M4 mutant maize hybrid has the advantage of using index selection, namely after using index selection, agronomic performance exceeds all hybrids tested [3].

The selection index is widely used in various uses such as characterization and selection of spring maize, early maturity, and tolerance to drought stress [6, 7]. The use of index selection methods in selection activities has been widely carried out, for example, characterization and selection of early maturing maize genotypes, and nitrogen deficiency stress in Nigeria. One of the index selection methods is to use unweighted index selection and weighted index selection. The selection of the index is not weighted, that is, there is no weighting between variables, while the selection of the weighted index is weighted to the desired variable. Examples of the application of this method include the selection of six hybrids of chili hope [8] and the evaluation of the character of the sweet corn hopeful line [9]. Therefore, this research aims to get the best regression model through the Akaike Information Criterion and to obtain selected accessions that are used as parents in hybrid assembly.

2. Materials and methods

The research was done at the Kayuwatu Garden, Manado Palm Plant Research Institute, North Sulawesi Province in 2019. The genetic material used was seven local accessions, namely GalangSuka, Huntu 1, Malinow 1, Rasau Jaya, Sakernan, Singkawang 1, and Tarean with a Randomized Block Design (RCBD) with three replicates, the number of plants per replication was ten, and the number of plants observed was five per accession (Table 1). Observations were made on quantitative characters including plant height, stem circumference, number of leaves, number of bunches, number of fruit bunches, fruit polar circumference, and fruit equatorial circumference.

1. Stem circumference, calculated from eleven leaf bundles
2. Number of leaves, calculated based on the leaves that open perfectly and there is no pest attack
3. Number of bunches, count the number of bunches in one tree
4. Count fruit per bunch, count the number of fruits in one bunch
5. Fruit polar circumference, measured at the end of the fruit with the base of the fruit in a circle
6. Fruit equatorial circumference, measured at the center of the fruit in a circle
7. Fruit weight, fruit weight was weighed using an analytical balance as many as 15 fruits

Table 1. Seven accessions and regional origin.

| No | Accessions | Origin         |
|----|------------|----------------|
| 1  | GalangSuka | Deli Serdang  |
| 2  | Huntu 1    | Gorontalo      |
| 3  | Malinow 1  | Sulawesi Utara |
| 4  | Rasau Jaya | Kalimantan Barat |
| 5  | Sakernan   | Jambi          |
| 6  | Singkawang 1 | Kalimantan Barat |
| 7  | Tarean     | Deli Serdang  |

The data obtained were then analyzed using the R 4.0.5 software with the agricolae package and further tested by Duncan Multiple Range Test. To find out the best model, a Multiple Regression Test was carried out, and to get the best model, the Akaike Information Criterion (AIC) test was carried out using R 4.0.5 software.
The selection of agronomic character indices was processed using Microsoft Excel 2007. Index selection was initiated by the standardization of the standard deviation of the accession population for each character. The formula for the weighted selection index is as follows:

\[ Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 \]

Information:
Symbol : Description
X1 : Mean Stem circumference
X2 : Mean Number of leaves
X3 : Mean Number of bunches
X4 : Mean Count fruit per bunch
X5 : Mean Fruit polar circumference
X6 : Mean Fruit Equatorial circumference
X7 : Mean Fruit weight

\[ x_{ij} \] is the median value that has been standardized which is obtained from subtracting the mean value from the general mean \( m_i \) then divided by the standard deviation value for that character. The following is the standardized mean value equation (Pi):

\[ P_i = \frac{(x_{ij} - m_i)}{S_i} \]

3. Results and discussion
Correlation is one way to find out the close relationship between two variables. Figure 1 shows that FEC character with FPC has a strong correlation (0.86) so that if there is an increase in the FEC character it will increase the FPC by one unit 0.86.

![Figure 1. Correlation of agronomic characters in the seven accessions tested.](image)

The results of analysis of variance showed that there were characters that were not significantly different, namely the number of bunches, number of leaves, and fruit weight, while the other characters were significantly different so that the performances of the two characters were the same in some of the accessions tested (Table 2).
Table 2. Recapitulation of various agronomic characters

| Characters                   | Pr(>F)       |
|------------------------------|--------------|
| Stem circumference           | 5.97 x10^{-5}** |
| Number of bunches            | 0.1938       |
| Number of leaves             | 0.104        |
| Count Fruit per bunch        | 0.000467**   |
| Fruit Equatorial circumference | 0.00168**   |
| Fruit polar circumference    | 0.000000244**|
| Fruit weight                 | 0.402        |

Notes: *: different α 5% level, **: different α 1% level

3.1. Stem circumference and number of bunches
Accessions Huntu 1 had an average stem circumference that was not significantly different from accessions of Singkawang 1, Sakernan, and Malinow 1 but significantly different from accessions of Galangsuka, Tarean, and Rasau Jaya. A large stem circumference indicates that the trunk’s performance is large. The Singkawang 1 accession had an average number of bunches that was not significantly different from the Galangsuka and Tarean accessions but significantly different from the Huntu 1, Sakernan, Malinow 1, and Rasau Jaya accessions (Table 3). The more the number of bunches, higher-value fruit production.

3.2. Number of leaves and count fruit per bunch
The number of leaves was not significantly different in all tested accessions. The Malinow 1 accession had the highest count fruit per bunch but it was not significantly different from Singkawang 1 and Galangsuka and significantly higher than the accessions Huntu 1, Sakernan, Tarean, and Rasau Jaya (Table 3). The number of fruit bunches is a character that contributes to the high productivity of a plant.

3.3. Fruit equatorial circumference, fruit polar circumference, and fruit weight
The Galangsuka accession had a higher mean equatorial fruit circumference than the other accessions but was not significantly different from the Tarean accession and significantly higher than the Huntu 1, Singakawang 1, Sakernan, Malinow 1, and Rasau Jaya accessions. Galangsuka accessions had a higher average of Nayata fruit pattern circles than the others (Table 3). The size of the fruit circumference, both equatorial and polar, affects productivity. If the size of the fruit's equatorial circumference and the polar circumference of the fruit are almost the same or close to a 1:1 ratio, the fruit size is round. There was no significant difference in the fruit weight of the accessions tested.

Table 3. Agronomic character of 7 accessions observed.

| Accessions   | Stem Circumference | Number of Bunches | Number of Leaves | Number of Fruits Bunch | Fruit Equatorial Circumference | Fruit Polar Circumference | Fruit Weight |
|--------------|---------------------|-------------------|-----------------|------------------------|-------------------------------|---------------------------|-------------|
| Huntu 1      | 58.40a              | 4.86b             | 7.67a           | 20.00d                 | 5.78bc                        | 3.35d                     | 313.33a     |
| Singkawang   | 57.80ab             | 6.40a             | 8.20a           | 63.67ab                | 5.46bc                        | 4.28bc                    | 433.33a     |
| Sakernan     | 56.40abc            | 4.93b             | 7.73a           | 42.50bcd               | 6.14bc                        | 4.48b                     | 486.67a     |
| Malinow 1    | 53.20abc            | 4.36b             | 7.40a           | 71.00a                 | 5.29c                         | 3.59cd                    | 630.00a     |
| Galangsuka   | 52.87bc             | 5.20ab            | 8.20a           | 48.57abc               | 7.37a                         | 6.10a                     | 493.33a     |
| Tarean       | 52.33c              | 5.22ab            | 8.00a           | 31.76cd                | 6.48ab                        | 4.05bcd                   | 633.33a     |
| Rasau Jaya   | 45.67d              | 4.20b             | 7.82a           | 24.12cd                | 5.12c                         | 3.34d                     | 420.00a     |

Note: the same letters in the same column are not significantly different at α 5% level of the DMRT.
The results of the average fruit weight showed that from the seven accessions tested there was a fairly high potential yield of two accessions, namely Malinow 1 and Tarena accessions (Figure 2).

### 3.4. Stepwise method of multiple regression equation for best model selection

The selection of the best model from the six independent variables (x) against the variable y (BB) was chosen by looking at the smallest AIC value, namely model 2 with an AIC value (63.06) (Table 4). The AIC value is low by eliminating the number of leaves and the number of bunches. Akaike as one has the advantage of calculating small samples. The best regression model value is $BB = 86586 - 498 \text{LB}^* + 11158 \text{JT}^* + 4738 \text{JD} + 38.9 \text{JBT}^{**} + 58.8 \text{LE}^* + 1545 \text{LP}^*$. To improve the character of the elders who will serve as parents, it needs to focus on the selection of other characters by regression analysis [11]; [12].

### Tabel 4. The results of selecting the best regression model.

| Variable                        | DF | SS  | MS   | AIC  |
|---------------------------------|----|-----|------|------|
| Number of Bunches               | 1  | 615 | 13704| 63.057|
| Stem Circumference              | 1  | 22381| 35470| 69.714|
| Fruit Polar Circumference       | 1  | 23822| 36910| 69.992|
| Fruit Equatorial Circumference  | 1  | 35915| 49004| 71.976|
| J Number of Fruits Bunch        | 1  | 54547| 67636| 74.232|

Model 2 AIC=63.06

| Variable                        | DF | SS  | MS   | AIC  |
|---------------------------------|----|-----|------|------|
| Stem Circumference              | 1  | 21769| 35473| 67.714|
| Fruit Polar Circumference       | 1  | 29766| 43469| 69.137|
| Fruit Equatorial Circumference  | 1  | 37342| 51046| 70.262|
| J Number of Fruits Bunch        | 1  | 60925| 74629| 72.921|

### 3.5. Selected four characters index selection

The selection of areca nut accessions used a selection index involving several characters at once as selection criteria based on the selection index. Selection of elders with index selection involved 4 characters, namely stem circumference, fruit equatorial circumference, fruit polar circumference, and

![Figure 2. Mean of fruit weight seven accessions.](image-url)
the number of fruits bunch\(^1\). The index selection results are presented in Table 5. Index selection based on these four characters resulted in four elders with high selection index values, namely Accession Tarean, Malinow 1, Galangsuka, and Sakernan. [13]. Index selection on corn plants to produce hybrids that have high adaptability. Index selection is used to a phenotypic selection and recommended to assembly a new variety [14, 15].

**Table 5.** Standardized mean and selection index.

| Accession   | Stem circumference (cm) | Fruit equatorial circumference (cm) | Fruit polar circumference (cm) | Fruit weight (g) | Selection index |
|-------------|-------------------------|-------------------------------------|-------------------------------|------------------|-----------------|
| Tarean      | 39.95                   | -1.07                               | -0.29                         | 629.10           | 667.69          |
| Malinow 1   | 40.82                   | -2.26                               | -0.75                         | 625.77           | 663.58          |
| Galangsuka  | 40.49                   | -0.18                               | 1.76                          | 489.10           | 531.17          |
| Sakernan    | 44.02                   | -1.41                               | 0.14                          | 482.44           | 525.19          |
| Singkawang 1| 45.42                   | -2.09                               | -0.06                         | 429.10           | 472.37          |
| Rasau Jaya  | 33.29                   | -2.43                               | -1.00                         | 415.77           | 445.63          |
| Huntu 1     | 46.02                   | -1.77                               | -0.99                         | 309.10           | 352.36          |

**4. Conclusions and suggestions**

The results of the stepwise regression showed that by removing the number of bunches and the number of leaves, a low AIC value was obtained. The regression equation obtained Fruit weight \(= 86586 - 498\) stem circumference* + 11158 Fruits Per Bunch* + 4738 Number of Leaves + 38.9 Number of Fruits Per Bunch* + 58.8 fruit equatorial circumference* + 1545 fruit polar circumference *. The characters of stem circumference, fruit equatorial circumference, fruit polar circumference, and the number of fruit per bunch were used as selection index so that three selected accessions may be used as parents, namely Tarean, Malinow 1, Galangsuka, and Sakernan accessions.

**References**

[1] Tiwari, S. and Talreja S 2020 *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 11100-8doi: 10.33887/rjpbcscs/2020.11.5.12.
[2] Alary V, Yigezu A, Yigezu, and Filippo MB 2020 *Crop Breeding, Genetics and Genomics*. 2 1-20.doi: 10.20900/cbgg20200014.
[3] Lemos RDC, Abreu ADFB, and Ramalho MAT 2018 *Scientia Agricola*. 771-7 doi: 10.1590/1678-992x-2018-0105.
[4] Jensen NF1988 A *Wiley Interscience Publication, John Wiley & Sons, New York*. Pp 35-50.
[5] Rustikawati, Herison C, and Sutjahjo SH 2010 *Jurnal Ilmu-IlmuPertanian Indonesia*. 1255-60.
[6] Sutjahjo S H, Hadiatmi, and Meyniliyva 2005 *Jurnal Ilmu-IlmuPertanian Indonesia*.735-43.M.
[7] Badu-Apraku B, Fakorede MAB, Oyekunle M, and Akinwale RO 2011 *Maydica*. 5629-41.
[8] Mochamad TK 2008 *Skripsi*. Institut Pertanian Bogor.
[9] Sari HP, Suwarto, Syukur M 2013 *Bul. Agrohorti*. 114-22.
[10] Yanagawa T, Tajiri R 2018 *Japanese Journal of Statistics and Data Science*. 1333–46
[11] Boer D 2011 *J. Agroteknos*. 135-43.
[12] Safuan LO, Boer D, Wijayanto T, and Susanti N 2014 *Agriplus*. 24136-43
[13] de Oliveira RL, Pinho RGV, Ferreira DF, Pires LPM, and Melo WMC 2014 *Hindawi Publishing Corporation The Scientific World Journal* 361-6
[14] de Sandiago S, Lopes C, , Lopes C, Lemos LB, Pires and Moro GV 2019 *African Journal of Agricultural Research* 14787-793
[15] Kumar B, Guleria SK, Khanorkar SM, Dubey RB, Patel J, Kumar V, Parihar CM, Jat SL, Singh V, Yatish KR, Das Abhijit, Sekhar JC, Bhati P, Kaur H, Kumar M, Singh Ak, Varghese E, and Yadav OP 2016 *Crop and Pasture Science* 121-8