Morphology and production character of local eggplant based on principal component analysis

K. Yurlisa*, M. D. Maghfoer, N. Aini, and W. S. D. Yamika
Dept. of Agronomy, Faculty of Agriculture, Universitas Brawijaya, Jalan Veteran, Malang 65145, Indonesia
*Corresponding author: kartikayurlisa2@gmail.com

Abstract. Environmental changes, including loss of biodiversity, threaten agricultural production and quality. The present research investigated morphology and production character in ten accessions of local eggplant. The research was carried out by planting ten plants from each accession in a row, the distance among plants and among beds were 50 cm respectively. The experiment was conducted from March to August 2018 at Agrotechnopark Jatikerto, Malang, East Java. Principal component analysis (PCA) indicated that four components (PC1 to PC4) accounted for about 90% of the total variation among traits in eggplant accession. Out of total principal components PC1, PC2, PC3 with values of 41.6%, 24.4%, and 13.5% respectively contributed greatly to the total variation. The first principal component had the highest positive loading for five characters out of 10 viz. leaf width, leaf length, the length of petiole, stem diameter, and plant height which contributed greatly to the diversity. Limao Eggplant and Blitar local eggplant which has high yield potential. The result of this study could be exploited in the planning and execution of future breeding programme in local eggplant.

1. Introduction

Eggplant (Solanum melongena L.) also known as terung gelatik is an important non-tuberous species of the nightshade family Solanaceae. Eggplant has been planted for centuries in Asia, Africa, Europe and the Near East [1]. Now, around 50 million tons of eggplant is produced in more than 1.800.000 ha worldwide. Eggplant production is concentrated in several countries. China (29.5 million tons) is the primary producer, followed by India (13.5 million tons), Egypt (1.2 million tons), Iran (0.85 million tons) and Turkey (0.82 million tons) [2].

Eggplant is a high-yielding crop that can agronomically adapt and has high economic value [3]. Interest in this plant is overgrowing because it is a good source of antioxidants (anthocyanins and phenolic acids), which are beneficial to human health [4]. Eggplant fruit is known for having low calories and a beneficial mineral composition for human health. It also contains a rich source of potassium, magnesium, calcium, and iron [5]. Furthermore, seventy-seven medicinal properties are recorded for eggplant which shows the importance of this plant in local medicine and its promise as a functional food and the natural product industry [6].

Biodiversity is the result of variations in the morphology of plants, animals, microorganisms, genes in them, and their ecosystems [7]. Environmental changes such as land degradation, climate change, water scarcity and loss of biodiversity threaten the quantity and quality of agricultural products [8]. Eggplant fruit has a variety of fruit shapes, fruit colors, and productivity. Indonesia has a diverse range of eggplant varieties with superior varieties developed by seed producers, and local varieties managed by the farmers. These traditional and local cultivars are the most widely used varieties. Improved
varieties have better agronomic performance than local cultivars. Despite its superior agronomic performance, improved eggplant variety has unique requirements and quality of technology and organoleptic that still meet user needs. This situation continues because of the extra work and costs incurred, and their ability to stand with biotic and abiotic pressures [9]. However, farmers' seeds are generally considered low productivity by agronomic experts, this happen because of traditional agricultural technology. Therefore, the main obstacle in increasing eggplant production in Indonesia is the low yield. Increasing superior varieties with high yield potential that is suitable to the needs of the cultivators is needed. In order to solve the increasing food demand, modern agriculture is further developed and focused not only to select performing varieties but also to diversify cultivars in the seed system [10]. The introduction of high-yielding varieties depends mostly on access to local genetic resources. This local resource indeed is an essential component of food security, which is a raw material used by breeders to improve the quality and productivity of eggplant.

Principal Component Analysis (PCA) can be used to express general differences between genotypes in numerical values, which indicate characters that can be used to differentiate between genotypes [11]. Principal Component Analysis or commonly abbreviated as PCA is a multivariate statistical technique that can be used to simplify and analyze relationships between large numbers of variables in a relatively fast period without removing important information from the original dataset [12]. Information about the morphological character and production of local eggplants in previous studies is still limited. The knowledge of the variety of morphological and output characters is expected to contribute to the development of superior accessions of the local eggplant.

2. Method and Materials

This study aimed to determine the diversity of morphological characters and the production of local eggplant. The materials of the present research consisted of 10 collections of *Solanum melongena* L.

The collection of planting materials was presented in Table 1.

| No. | Local/Trade Name          | Origin   | Status       | Note                                      |
|-----|---------------------------|----------|--------------|-------------------------------------------|
| 1.  | Surabaya Local Eggplant 1 | Surabaya | Accession    | Online Seller Fighter Surabaya            |
| 2.  | Blitar Local Eggplant     | Blitar   | Accession    | Online Seller Trapi Patria               |
| 3.  | Surabaya Local Eggplant 2 | Surabaya | Accession    | Online Seller Fighter Surabaya            |
| 4.  | Kenari                    | Jember   | Variety      | Seed Producers Citra Asia                |
| 5.  | Fullness                  | Magelang | Variety      | Seed Producers Known You Seed, Indonesia |
| 6.  | Jeno F1                   | Purwakarta | Variety    | Seed Producers East West Seed, Indonesia |
| 7.  | Limao                     | Jember   | Variety      | Seed Producers Enno and Company Seed, Indonesia |
| 8.  | IPB Tro1U                 | Bogor    | Variety      | IPB Campus, Leuwikopo, Dramaga, Bogor, Indonesia |
| 9.  | SRITI                     | Jember   | Variety      | Seed Producers Citra Asia, Indonesia      |
| 10. | Surabaya Local Eggplant 3 | Surabaya | Accession    | Online Seller Fighter Surabaya            |

The present research was conducted from March to August 2018, at Universitas Brawijaya Experimental Garden in Jatikerto Village, Kromengan District, Malang Regency, East Java, Indonesia. The seeds were sown. After they have grown, they were transferred to the field. After the seeds had 3-4 whole leaves, the seeds were ready to be planted into the field. Each accession number was planted
tend plants per row and was planted in two rows. The distance among plants was 50 cm, and the distance among accession numbers was 50 cm. The soil was formed in beds with 20 cm in height. 152 kg (with dose of 20 tons/ha) manures were given. The first fertilization was given when the plant was two weeks old. Follow-up fertilization was carried out at intervals of 2 weeks. The fertilizer used was NPK fertilizer at a dose of 500 kg/ha and ZA 150 kg/ha. Fertilizers were given at a distance of 10 cm from the plant. Weeds growing around plants were weeded, and controlling pests and diseases were carried out mechanically.

Observations were made on all individual plants in each population. The characters observed were morphological characters and crop production. Observations were based on descriptors from IBPGR [13] and UPOV [14]. The characters found from each section are as follows:

2.1. The Character of Plant Morphology
Plant morphology was observed into 3 types i.e. visual, fully open and optimal leaf, harvest time. A visual observation included the type of stature, number of primary branches, stem diameter, leaf length (cm), leaf width (cm), upper leaf surface color, leaf curvature, leaf tip angle, leaf stem length (cm). Observation on leaves that fully open and grow optimally was followed by measuring leaf stalks from the base of the stem to the bottom of the leaf blade, leaf stalk color, leaf spines, leaf hair, petal color, number of fruits per plant, fruit length (cm), fruit diameter (cm), fruit body shape, fruit curvature, fruit base shape, ripe age for consumption (day after planting). Observation in the first harvest time included ripe fruit color for consumption, ripe fruit motif for consumption, weight of petals (%), fruit position, physiological ripe age (day after planting), physiological ripe fruit color, number of seeds per fruit, seed color, seed size (mm), weight of 100 grains (g). The time of observation was adjusted to the development of plants.

2.2. The Character of Plant Production
Plant production characters observed were plant height, flowering time (the day after planting), fruit weight of each plant (g). The first harvest of local eggplant can be done when the plants were 45-60 day after planting. Harvesting were done manually by picking eggplants or with pruning shears. Plants that were ready for harvest had a reasonably old age, maximum crop size or leaf formation, and had physical characteristics i.e. ripe color based on the accession/variety, and a proper shape and size for harvest.

2.3. Data Analysis
The qualitative and quantitative characters were analyzed using Principal Component Analysis. This analysis was conducted to determine the essential characteristics that affect plant diversity. Data analysis was performed using xStat software which would produce eigenvalue values and diagrams that described plant groupings. For the character of production, it was compared directly the total harvest per line among accessions/varieties.

3. Results and Discussion
The results of the principal component analysis (PCA) in this study have reduced the characters observed into four main components that have an eigenvalue > 1 and can explain the diversity of the experiment material by 90%, as presented in Table 2.

Table 2 shows the main factors 1 (F1) represents about 41.62% of the diversity, and the highest contributed characters are the length of the leaves and the width of the leaves. The main factor 2 (F2) represents around 24.37% of the diversity, and the highest contributed characters are the leaf tip angle. The main factor 3 (F3) represents about 13.49% of the difference, and the highest contributed character are plant height. The main factor 4 (F4) represents around 10.69% of diversity, and the highest contributed characters are leaf hair. Grouping of Local eggplant accession/varieties is presented in Figure 1.
Table 2. Analysis of the Principal Components of Local Eggplant Accession / Varieties

| Observation Character                              | F1    | F2    | F3    | F4    |
|---------------------------------------------------|-------|-------|-------|-------|
| The length of the leaves                           | 0.911 | 0.017 | -0.297| -0.097|
| Plant height                                       | 0.618 | -0.197| 0.745 | -0.051|
| The width of the leaves                            | 0.936 | -0.155| -0.168| -0.053|
| The length of the stem                             | 0.891 | 0.040 | -0.178| 0.185 |
| Number of leaves eight weeks after planting        | -0.667| -0.119| 0.501 | 0.307 |
| Stem diameter                                      | 0.661 | 0.184 | 0.585 | -0.383|
| Leaf hair                                          | 0.391 | 0.303 | 0.105 | 0.835 |
| Leaf tip angle                                     | 0.151 | 0.917 | 0.179 | 0.039 |
| The shape of leaf curves                           | -0.110| -0.911| 0.095 | -0.008|
| Seed size                                          | 0.457 | -0.749| 0.034 | 0.284 |
| Eigenvalue                                         | 4.162 | 2.437 | 1.349 | 1.069 |
| Proposal (%)                                       | 41.615| 24.368| 13.486| 10.694|
| Cumulative (%)                                     | 41.615| 65.983| 79.469| 90.163|

Figure 1. Grouping of Local Eggplant Accession/Varieties

Based on Figure 1, the accession of the local eggplant is divided into four clusters. Cluster 1 consists of Surabaya Local Eggplant 3 and Sriti Eggplant Jember. Cluster 2 consists of Surabaya Local Eggplant 2, Fullness Eggplant Magelang, and Blitar Local Eggplant. Cluster 3 consists of Limao Eggplant Jember, Kenari Eggplant Jember, Jeno F1 Eggplant Purwakarta, Surabaya Local Eggplant 1. Cluster 4 consists...
of IPB Tro1U Eggplant Bogor. The local eggplant variety/accession morphology is presented in Table 3.

From Table 3, the character of cotyledon color, fruit length, fruit body shape, fruit curvature, fruit base shape, fruit petal weight percentage, fruit position, and seed size have similar properties; while the other characters are varied. A research conducted by Lestari et al. found that the diversity of quantitative characters is more influenced by environmental factors during plant growth [15]. In addition, the variety of morphological characters can be used to produce new recombinants that have superior properties [16].

Production characters are essential to know. By knowing this character, we can also understand the potential results of the plant. Knowledge of possible outcomes is useful for determining how viable plants are to be developed or cultivated widely. The higher the potential yield of a food crop, the higher the value for cultivation is.

Based on Table 4, Limao Eggplant plants produce the highest total yield (2763.74 grams) compared to the other nine accessions / other varieties. Limao Eggplant has high productivity due to this variety already has better adaptability than other varieties/accessions. It is followed by Blitar Local Eggplant accession as the second highest total yield (2307.22 grams). The origin area of this accession has high temperature, therefore it can grow and produce higher than other varieties/accessions. A research conducted by Scheelbeek et al. found that the quality and quantity of plant production are influenced by the adaptability of plants to the environment [8].
Table 3. Local Eggplant Accession/Varieties Morphology

| No. | Character                        | Surabaya Local Eggplant 1 | Blitar Local Eggplant | Surabaya Local Eggplant 2 | Kenari | Fullness | Jeno F1 | Limao | IPB Tro1u | Sriti | Surabaya Local Eggplant 3 |
|-----|----------------------------------|---------------------------|-----------------------|---------------------------|--------|---------|--------|-------|-----------|-------|--------------------------|
| 1.  | Cotiledon color                  | green                     |                       |                           |        |         |        |       |            |       |                          |
| 2.  | Plant height                     | medium                    | short                 | medium                    | short  | medium  | short  | short | short     | short | medium                   |
| 3.  | Type of plant                    | upright                   | medium                | upright                   | medium | medium  | medium | medium | medium    | upright | medium                 |
| 4.  | Stem diameter (mm)               | 9.5–13.2                  | 11.4–13.3             | 10.6–14.4                 | 10.7–11.6 | 14.7–16.8 | 10.4–13.3 | 8.9–11.7 | 9.9–12.8  | 9.2–11.1 | 10.6–10.8               |
| 5.  | The length of the leaves         | medium                    | medium                | medium                    | medium | medium  | medium | medium | medium    | medium | medium                   |
| 6.  | The width of the leaves          | width                     | width                 | width                     | width  | width   | width  | width  | width     | width  | width                     |
| 7.  | The surface color of the leaves  | dark green                | green                 | dark green                | green  | green   | green  | green  | dark green | dark green | green                                 |
| 8.  | The curve of the leaf            | medium                    | medium                | medium                    | within | medium  | medium | medium | medium    | medium | within                  |
| 9.  | Leaf tip angle                   | medium                    | medium                | medium                    | medium | medium  | medium | medium | medium    | medium | medium blunt             |
| 10. | The length of the stem (cm)      | 8–9                       | 9.5–11                | 8.4–9.5                   | 7.9–9  | 10.6–12.5 | 8.3–11 | 7.5–9 | 8.1–9.5  | 8.5–10 | 8.9–5                   |
| 11. | Color of petiole                 | purple                    | green                 | purple                    | purple | green   | green  | green  | purple    | purple | purple                   |
| 12. | Leaf spines                      | a few                     | measly                | measly                    | measly | measly  | measly | measly | measly    | measly | measly                   |
| 13. | Leaf hair                        | measly                    | a few                 | a few                     | a few  | a few   | a few  | a few  | a few     | a few  | a few                     |
| 14. | Flowering time (day after planting) | 22-24                    | 22-24                 | 22-24                     | 22-24  | 22-24   | 22-24  | 22-24  | 32-34     | 32-34  | 43-53                    |
| 15. | Petal Color                      | pale purple               | white                 | pale purple               | white  | white   | white  | pale purple | pale purple | pale purple |
| 16. | Number of fruits per plant       | 11 fruit                  | 13 fruit              | 13 fruit                  | 13 fruit | 13 fruit | 17 fruit | 13 fruit | 16 fruit  | 6 fruit |                       |
| 17. | Fruit weight per plant           | medium                    | medium                | medium                    | medium | medium  | medium | medium | medium    | medium | medium                   |
| 18. | Fruit length                     | medium                    |                       |                           |        |         |        |       |           |       |                          |
| 19. | Fruit diameter                   | medium                    | medium                | thick                     | medium | thick   | thick  | medium | medium    | medium | medium                   |
| 20. | Fruit body shape                 | the same width            |                       |                           |        |         |        |       |           |       |                          |
| 21. | Fruit curvature                  | there is no curve         |                       |                           |        |         |        |       |           |       |                          |
| No. | Character                                      | Surabaya Local Eggplant 1 | Blitar Local Eggplant | Surabaya Local Eggplant 2 | Kenari | Fullness | Jeno F1 | Limao | IPB Trolu | Sriti | Surabaya Local Eggplant 3 |
|-----|-----------------------------------------------|---------------------------|-----------------------|---------------------------|--------|---------|---------|-------|-----------|-------|-------------------------|
| 22. | The basic shape of the fruit                 |                           |                       |                           |        |         |         |       |           |       | rounded                |
| 23. | Ripe age for consumption (the day after planting) | 40-42                     | 32-34                 | 40-42                     | 32-34  | 32-34   | 50-52   | 73-85 | 60-67     |       |                        |
| 24. | Color of ripe fruit for Consumption          | green                     | green                 | green                     | green  | green   | purple  | green | purple    | yellow | purple                 |
| 25. | Motif of ripe fruit for consumption          | striped                   | striped               | striped                   | uniform| striped | uniform | uniform| uniform   | uniform| uniform                |
| 26. | Physiological harvest age (the day after planting) | 73-85                     | 73-85                 | 73-85                     | 73-85  | 73-85   | 73-85   | 50-52 | 88-92     |       |                        |
| 27. | Physiological color of ripe fruit            | yellow                    | yellow                | yellow                    | yellow | yellow  | shiny purple | yellow| purple    | yellow |                        |
| 28. | Percentage of fruit petal weight             | very small                |                       |                           |        |         |         |       |           |       |                        |
| 29. | Fruit position                               | hang                      |                       |                           |        |         |         |       |           |       |                        |
| 30. | Seed size                                    | medium                    |                       |                           |        |         |         |       |           |       |                        |
Table 4. The Productivity of Local Eggplant Accession/Varieties per Row

| No. | Accession/Varieties      | Harvest Period | Total harvest (g) |
|-----|--------------------------|----------------|-------------------|
|     |                          | Period I (g)   | Period II (g)     | Period III (g) |                |
| 1.  | Surabaya Local Eggplant 1| 177.22         | 212.8             | 849.4          | 1239.42        |
| 2.  | Blitar Local Eggplant    | 250.96         | 699.36            | 742            | 2307.22        |
| 3.  | Surabaya Local Eggplant 2| 347.58         | 222.1             | 966.4          | 1536.08        |
| 4.  | Kenari                   | 78.26          | 49.48             | 816.38         | 2238.02        |
| 5.  | Fullness                 | 121.84         | 137.4             | 259.24         |
| 6.  | Jeno F1                  | 86.4           | 188.22            | 1099.44        | 2485.46        |
| 7.  | Limao                    | 37.7           | 162.4             | 836.84         | 2763.74        |
| 8.  | IPB Tro1U                | 168.92         | 584.6             | 819.8          | 1573.32        |
| 9.  | Sriti                    | 46.86          | 254.7             | 1041.7         | 1343.26        |
| 10. | Surabaya Local Eggplant 3| 87.6           | 0                 | 87.6           |

4. Conclusion
Analysis of the main components in the accession of the local eggplant produces four main clusters with 90% diversity proportion. The character of the leaf blade width is the character that contributes greatly to the diversity of total local eggplant accession. The potential high yield eggplant accession/varieties are Limao Eggplant, and followed by Blitar Local Eggplant as the second highest.

References
[1] Bohs, L., and T. Weese. 2010. Eggplant origins: Out of Africa, into the Orient. Taxon. 59: 49-56.
[2] Ferreira da Costa, G. A, Morais, M. G., Saldanha, A. A., Silva, I. C. A., Aleixo, A. A., Ferreira, J. M. S., Soares, A. C., Duarte-Almeida, J. M., and Santos Lima, L. A. R. 2015. Antioxidant, antibacterial, cytotoxic, and anti-inflammatory potential of the leaves of Solanum lycocarpum A. St. Hil. (Solanaceae). Evidence-Based Complementary and Alternative Medicine. 1-8. Food and Agriculture Organization of the United Nations. http://fao.org. (Accessed 21.12.2018).
[3] Hanson, P. M., R. Y. Yang, S. C. S. Tsou, D. Ledesma, L. Engle, and T. C. Lee. 2006. Diversity in eggplant (Solanum melongena) for superoxide scavenging activity, total phenolics, and ascorbic acid. Journal of Food Composition and Analysis. 19:594-600.
[4] Gajewski, M., K. Katarzyna and M. Bajer. 2009. The influence of postharvest storage on quality characteristics of fruit of eggplant cultivars. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 37(2): 200-205.
[5] Zenia M., and B. Halina. 2008. Content of microelements in eggplant fruits depending on nitrogen fertilization and plant training method. J. Elementol. 13(2):269-274.
[6] Meyer, R. S., M. Bamshad, D. Q. Fuller, and A. Litt. 2014. Comparing medicinal uses of eggplant and related Solanaceae in China, India, and the Philippines suggests the independent development of uses, cultural diffusion, and recent species substitutions. Eco. Botany. 1-16.
[7] Rawat, U.S., and N.K. Agarwal. 2015. Biodiversity: concept, threats, and conservation. Environment Conservation Journal. 16(3): 19-28.
[8] Scheelbeek, P.F.D., H.L. Tuomisto, F.A. Bird, A. Haines, and A.D. Dangour. 2017. Effect of environmental change on yield and quality of fruits and vegetables: two systematic reviews and projections of possible health effects. London School of Hygiene and Tropical Medicine, London, UK.
[9] Sihachkr D., M. H. Chaput, L. Serraf, G. Ducreux. 1993. Regeneration of plants from protoplasts of eggplant (Solanum melongena L.). In: Bajaj, Y.P.S. (Ed.), Biotechnology in Agriculture and Forestry, Plant Protoplasts and Genetic Engineering. Springer, Berlin. pp. 108–122.

[10] Wibawa, R. F. C. 2017. Keragaan enam genotipe terung (Solanum melongena L.) di tiga lokasi. Skripsi. Institut Pertanian Bogor.

[11] Balkaya, A., M. Ozbakir and E. Kurtar. 2010. The phenotypic and fruit characterization of winter squash (Cucurbita maxima) populations from the Black Sea region of Turkey. African Journal of Biotechnology. 9(2): 152-162.

[12] Das, S., S.D. Soumitra, C. Indrani, R. Nabarun, K.N. Mallar and S. Debojit. 2009. Principal component analysis in plant breeding. Biomolecule Reports. International eNewsletter.

[13] IBPGR. 1990. Descriptors for Eggplant. International Board for Plant Resources, Rome.

[14] International Union for The Protection of New Varieties of Plants (UPOV). Guidelines for the Conduct of Test for Distinctness, Uniformity & Stability, Egg plant (Solanum melongena L.). Geneva.

[15] Lestari, S.B., S. Pratamaningtyas and U. Sugiarti. 2016. Variety evaluation and genetic potential of seven genotypes of eggplant (Solanum melongena L.). AGRIKA. 10(1): 31-40.

[16] Bashar, A., N. Jahan, F.A. Ahmed, M.K. Hossain, and N. Alam. 2015. Morphological and phytochemical variation in eggplant (Solanum melongena L.). Pharma Science Monitor 6(4): 1-11.

Acknowledgment
The researchers would like to thank to the Ministry of Research, Technology and Higher Education who has funded this research through the Higher Education Applied Research Grant in 2018 No. Contract 054 / SP2H / LT / DRPM / 2018.