Growth performance and fruiting of breadfruit (*Artocarpus altilis*) clonal plantation at vertic soil area in Gunungkidul, Yogyakarta for conservation strategy

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Abstract. Breadfruit is one of the tree species with a wide distribution in the Indonesian archipelago and shows variations in growth morphology, leave, and fruits. Therefore, the breadfruit clonal test plantation was carried out from several origin distributions at vertisol land in Gunungkidul, Yogyakarta, with a spacing of 5 x 5 m. This study aimed to identify the variation in growth and fruit production of 12 breadfruit cultivars at 10 years old. They were collected from Gunungkidul, Kediri, Banyuwangi, Sukabumi, Banten, Bali, Mataram, Lampung, Bone, Malino, Sorong, and Manokwari. The study was conducted by selecting 4 trees from each cultivar that have average growth and replicated five times. The growth characters of breadfruit trees were observed, namely height, stem diameter at breast height, canopy width, and a number of fruits. The observation results showed that there is a significant influence of origin distribution of breadfruit on growth and fruiting performance. The average tree height was 6.1-9.7 m, stem diameter 14.2-22.0 cm, canopy width 3.2-6.1 m, and the number of ripe fruit 3-21 fruit/tree. Breadfruit clones from South Sulawesi (Bone, Malino) and Papua (Sorong, Manokwari) were relatively stable, showing the best performance in all the characters observed. It is indicated that cultivars from South Sulawesi and Papua were adaptable in vertic soil.

1. Introduction
Breadfruit (*Artocarpus altilis* [Parkinson] Fosberg) in Indonesia has a very wide distribution area from Aceh to Papua, which shows a variation on morphology both in habitus, branching, leaf and fruit shape [1,2]. According to [3] all regions of Indonesia are suitable for the development of breadfruit plant types. Based on [4], it showed that the development of breadfruit has been carried out in all provinces in Indonesia with an average fruit production of 104,666 to 125,048 tons per year. Although this species is a very abundant biological resource, until now it has not been optimally developed as one of the national mainstay commodities. Generally, it is cultivated by the community in their yard or mixed garden [5]. Whereas in several countries of the Pacific region, breadfruit has become to be an important staple food for the community and has chosen as one of the mainstay export commodities [6,7].

Based on the morphological characters, it is known that there are variations in terms of shape, size, color and taste among the regions. Therefore, a research study on breadfruit clone planting has been conducted in Gunungkidul, Yogyakarta since 2004-2007. According to [8] there are also several breadfruit varieties in Java and Sumatera. Likewise, it has been reported by [9] when collecting the breadfruit genetic material from several breadfruit distribution regions in Indonesia, namely from Java, Bali, Nusa Tenggara, Sumatra, Sulawesi and Papua. In addition, based on its chemical content both
fruit and other parts of breadfruit tree, also shows variations among regions [10]. The same thing was reported that differences in population origin led to variations in the morphology of breadfruit plants in the Pacific region [11].

Breadfruit planting is usually carried out on fertile lands with relatively deep solum and has high humus soil, but sometime it grows in marginal land [12]. This research was conducted to identify the growth and performance and fruit production of 12 breadfruit cultivars planted in the breadfruit clonal test plot at verstisol area in the Playen Research Forest Station in Gunungkidul District in Yogyakarta.

2. Methods

2.1 Research site

The research was conducted in a breadfruit clonal test plot that established in Plot 93, Playen, Gunungkidul, District in Yogyakarta as shown in Figure 1. The clone test plot was established in 2003-2006, which covered 10 ha with a spacing of 5 x 5 m and intercropped with seasonal agricultural crops such as corn and soybeans. The growth evaluation activities are carried out periodically every six months. The altitude of the research site is 150 meters above sea level, the topography is quite flat with a slope of 0-30%. The soil type is vertisol which has deep cracks during the dry season. The average of rainfall is 1894 mm/year, relative humidity is 80-85%, temperature is of 27°C and a tropical climate type C according to Schmidt & Ferguson in 1951 [13].

![Figure 1. Map of the research site](image)

2.2 Materials and Methods

The material used in this study is breadfruit clonal test in Gunungkidul district. Data of tree height, stem diameter, canopy width and fruit production were recorded. Observation of fruit production was carried out by counting the number of each samples three times (in the first month when the fruit was initiated, the second month when the fruit was young and the third month when the fruit is mature.

To identify the variations in growth and fruiting of breadfruit clones, the data was collected by referring to a Completely Randomized Block Design. The treatment being tested is 12 breadfruit cultivars, namely Sukabumi, Banten, Kediri, Bone and Sorong, Mataram, Banyuwangi and Gunungkidul, Malino, Bali, Lampung and Manokwari. Each treatment consists of 4 samples (breadfruit trees) which shows an average growth conditions in the population. Furthermore, each treatment was repeated 5 times so that the total number of observation units was 240 breadfruit trees.
Observations of the breadfruit clonal test plantation at 10 years old showed the variation on growth performances. Tree height ranges from 4.2-13.0 meters with an average of 7.54 meters. Stem diameter (dbh) ranged from 8.0-27.4 cm with an average of 17.74 cm. The canopy forms are cylindrical to round with a width ranging from 1.65 to 7.60 meters which the average is 4.69 meters. From the growth performance, all observations were analyzed using ANOVA followed by the post hoc Duncan multiple range test and for analysis of fruit production data using regression analysis. Values were considered statistically significant at p < 0.05.

3. Result and discussion

3.1 Growth Performance of Plants

Table 1. Planting materials of breadfruit Clone test in Gunungkidul

| No | Name of regions          | Geographical condition of the location                                                                 |
|----|--------------------------|--------------------------------------------------------------------------------------------------------|
| 1  | Manokwari (West Papua)   | 4°0’13”-0.5’8’45” S and 119°42’-120°30’ E. Location: community land at Sanggeng Village, Giriosi Village, Suwen Village, Amban Village and the state land of Manokwari Forest Research Institute |
| 2  | Bali                     | 8° 35’ 31’-8’ 44’49” S and 115° 10’ 23’-115° 16’ 27’ E. Location: community land at Sempidi Village, Poan Village and Pregaya Village in South Denpasar District |
| 3  | Bone (South Sulawesi)    | 8°13’-5.6’ S and 119°42’-120°30’ E. Location: community land at Manurunge Village in Tacipi District and Palepe Village in Awapone District.             |
| 4  | Gunungkidul (Yogyakarta)| 7° 46’-8°09’ S and 110° 21’-110°50’ E. Location: community land Putat Village, Dengok Village, Ngronggo Village, Ngmun Village, Karangmojo Village in Playen District.  |
| 5  | Mataram (West Nusa Tenggara) | 8°08’-9°7’ S and 116°42’-118°22’ E. Location: community land Sesaot Village, Sempage Village in Narmada District and Camplong District. |
| 6  | Banten                   | 5°7’50”-7°1’11” S and 105°1’11”-106°7’12” E. Location: community land at Kadu Merak Village in Pandeglang District, Cimarga District and Lebak District. |
| 7  | Kediri (East Java)       | 7° 36’ 12”-8° 0’ 32” S and 111°47’ 05”-112°18’ 20” E. Location: community land at Belor Village, Kapas Village, Ngletih Village, Bangkok Village, Brenngglo Village and Kepuhrejo Village |
| 8  | Sukabumi (West Java)     | 6° 49’ 29’-6° 50’44” S and 106° 45’ 50”-106° 45’ 10” E. Location: community land at Citarik Village and Citepus Village in Pelabuhan Ratu District |
| 9  | Malino (South Sulawesi)  | 4°13’-0.5°1601” S and 119°56’-120°40” E. Location: community land at Bolangi Village and Patapang Village |
| 10 | Sorong (West Papua)      | 2° 25’ 40”-4°8’25” S and 134°35’-138°20” E. Locations: community land at Dumb Barat Village, Dumb Timur Village in Dumb Island, coastal area in Soop island and Jefman island |
| 11 | Lampung                 | 6°45’-3°45’ S and 103° 40’-105°50’ E. Location: community land at Tarahan Village, Pagelaran Village, Raman Aji Village and Kalianda Village |
| 12 | Banyuwangi (East Java)   | 7° 40’35”-8° 4’60” S and 113° 35’-114°38’ E. Location: community land at Bubuk Village in Rogojampi District and Benetankidul in Singojuruh District. |

Source: [14]
analysis result, it is known that the location of origin of the plants is significantly influences the growth performance of breadfruit trees (Table 2). The variations in growth character of each breadfruit cultivar are presented in Figure 2-4. Many studies have reported the same thing that the origin of plant material or provenance are greatly influences plant growth in the field, such as [15] on Intsia bijuga; [16] on *Abies alba*; [17] on *Cyclocarya paliurus* and [18] on *Nothofagus glauca* etc.

### Table 2. Variance analysis of growth performance of breadfruit plantation in Gunungkidul

| Source of Variation | Degree of freedom | Mean square | Height | Dbh | Canopy width |
|---------------------|------------------|-------------|--------|-----|--------------|
| Replication         | 4                |             | 1,344  | 6,943 | 0,703        |
| Origin location     | 11               |             | 29,412 | 141,915 | 13,662       |
| Error               | 224              |             | 1,146  | 6,772 | 0,803        |
| Total               | 239              |             |        |      |              |

Remark ns = not significant different, ** = significant different at 0.01 level

### Table 3. Growth performance of breadfruit plantation in Gunungkidul

| Age (year) | Height (m) | Dbh (cm) | Canopy width (m) | Increment | Height (m) | Dbh (cm) | Canopy width (m) |
|------------|------------|----------|------------------|-----------|------------|----------|------------------|
|            |            |          |                  |           |            |          |                  |
| 3          | 2.04       | 4.86     | 2.00             | 0.68      | 1.62       | 0.67     |                  |
| 5          | 5.16       | 11.80    | 2.89             | 1.03      | 2.36       | 0.58     |                  |
| 10         | 7.54       | 17.74    | 4.70             | 0.75      | 1.77       | 0.47     |                  |

Source: [9] [19]

When compared with the plant growth rate at the age of 5 years, there is an increase in the character of tree height by 46.00%, for stem diameter / dbh 50.34% and for canopy width of 63.63%. However, the growth rate has decreased, which is indicated by a reduction in the increment rate for height, dbh and canopy width. The growth increment is not different from the explanation [20], that the growth increment of breadfruit plant height varies according to the fertility conditions of the land, which ranges from 0.5 to 1.5 meters per year until the first 10-12 years of age.

Based on these observations, it is known that there are significant variations between populations in the characters of tree height, stem diameter / dbh and canopy width. In Figure 2 it can be seen that the best average tree heights are shown by the breadfruit cultivars from Bali (9.73 m), Manokwari (9.42 m) and Bone (8.94 m). In Figure 3, it can be seen that the best average stem diameter / dbh is the breadfruit cultivar from Bone (21.98 cm), Malino (20.84 cm), Manokwari (20.55 cm), Bali (19.95 cm) and Sorong (19.71 cm). Furthermore, from Figure 3 it is found that the average width of the widest canopy is the cultivars from Malino (6.07 m), Banyuwangi (5.46 m), Manokwari (5.42 m) and Bone (5.21 m). The character of plant height) and stem diameter showed a strong correlation (R = 0.69), while the correlation was quite weak with crown width (R = 0.26). At 5 years of age observation, breadfruit cultivars from Bone, Manokwari and Sorong have also shown a better growth than other cultivars. Thus, the three of them have excellent adaptability to the site conditions in Gunungkidul.
3.2 Fruit production

Observations of fruit production carried out for 3 months also showed variations in the number of fruits and their shapes which could be divided into 4 groups as mansion in Figure 5, with their respective characteristics presented in Table 4. In the first month, the average number of fruit was 15 fruit / tree with the number of most fruit 81 fruit / tree. In the second month the average number decreased to 11 fruit / tree with the highest number being 68 fruit / tree. In the third month the number decreased again so that the average number was only 9 trees / tree with the highest number of 56 fruits / tree. As the plant ages, it is expected that the amount of fruit production will increase. From BPS data (2015-2018), it can be seen that with an average fruit weight of 1200 grams, an average of number of fruit/tree is 25.
Figure 5. Type of leaves, fruit and the fallen young or immature fruits (Pictures by: Hamdan AA)

Table 4. Breadfruit distribution area and morphology of breadfruit plants from 12 locations

| No  | Origin location                              | Morphological Characteristics of Breadfruit Plants                                                                 |
|-----|----------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 1.  | Manokwari, Sorong (Papua Barat)              | Fruit type is oblong (A), fruit skin is spiny until ripe, medium-large size, yellowish green of fruit skin color. The average fruit length is 15-22 cm, fruit diameter is 13-15 cm and weighs 1200-1700 grams |
| 2.  | Bone, Malino (Sulawesi Selatan)              | Fruit type is oblong (B), fruit skin is spiny until ripe, medium-large size, yellowish green of fruit skin color. The average fruit length is 13-22 cm, fruit diameter is 13-15 cm and fruit weight is 900-1400 grams |
| 3.  | Bali, Mataram (Nusa Tenggara Barat), Kediri, Banyuwangi (Jawa Timur), Sukabumi (Jawa Barat), Banten, Lampung | Fruit type globose to oblong (C), young fruit skin is spiny or rough and smooth after ripe, medium-large size, yellowish green or brownish yellow of fruit skin color. The average fruit length is 13-21 cm, fruit diameter is 14-17 cm and fruit weight is 1000-2600 grams. |
| 4.  | Gunungkidul, Yogyakarta                      | Type of fruit globose-slightly oblong! (D), prickly skin until ripe, small-medium size, yellowish green rind color. The average fruit length is 11-17 cm, fruit diameter is 11-13 cm and fruit weight range 750-850 grams. |

Source:[1]
### Table 5. Fruit development of breadfruit plant at 10 years old

| Source of variation | Degrees of freedom | Number of fruits at 1st month | Mean square | Number of fruits at 2nd month | Number of fruits at 3rd month |
|---------------------|--------------------|------------------------------|-------------|-----------------------------|-----------------------------|
| Replication         | 4                  | 136,756<sup>ns</sup>        |             | 102,339<sup>ns</sup>       | 44,726<sup>ns</sup>       |
| Origin location     | 11                 | 2590,222<sup>**</sup>       |             | 1108,485<sup>**</sup>      | 639,508<sup>**</sup>      |
| Error               | 224                | 98,668<sup>ns</sup>        |             | 56,924<sup>ns</sup>       | 37,564<sup>ns</sup>       |
| Total               | 239                |                              |             |                             |                             |

Remark: ns = not significant different, ** = significant different at 0.01 level

Based on the results of the analysis of variance in Table 5, it is known that the area of origin of the breadfruit plant greatly influences its fruit production. The ability of each breadfruit cultivar to produce fruits is different. These results are in line with previous research that shows the fruit production is influenced by breadfruit cultivars, plant age and climatic conditions. In generally breadfruit tree produce fruit twice a year [21]. Likewise, it was reported on other species that flowering and fruiting influenced by climatic conditions (temperature, rainfall, humidity and sunlight [22, 23, 24, 25]. Figure 6 shows that the variation in the number of fruits between breadfruit cultivars ranged from 4-38 fruit / tree. However, some fruits has fallen before they were mature or ready to be harvested. At the end of the third month there were about 3-22 fruits/tree and the percentage of loose fruit per cultivar ranged from 11.90-71.98%.

**Figure 6. Number of fruits of each origin location**

The growth and development of breadfruit from ovule to mature fruit takes a long time, ranging from 16-20 weeks [3, 26]. During this period many factors can influence its process. Hot climatic conditions and very dry land causes drought stress in plants which has an impact on decreasing fruit production, especially in fruit crops [27]. Fruit production in the wet season is more abundant than in the dry season [28]. Factors that damage the growth and production of breadfruit can be caused by fungal attacks that attack the leaves and fruit [29, 30, 31]. Based on data from [32] it is known that the average rainfall in 2010-2019 was around 2055.90 mm / year with the number of rainy days around 133 days. The condition of the research site in the dry season is cracked with a large and deep fractures and also the lacks of phosphorus and potassium nutrients in the soil [33]. Even though phosphorus and potassium are elements that are indispensable for plants for the growth and development of flowers and fruit [34].

The reduced number of fruit also occurred due to the disturbances from the people whom living around the research site, such as the pruning of leaves and young fruits for their cattle feed. During the dry season, the availability of grass is very limited due to drought, so they cut the leaves and young breadfruit to be chopped and mixed with grass and corn crops. According to [3] the breadfruit plant
leaves and fruit can be used as a source of cattle feed. Breadfruit fruit and leaves also have been made as flour and be used as a mixture of poultry feed which is rich in nutrients [35].

Furthermore, from the regression analysis on the relationship between each growth character of breadfruit, it was known that tree height, stem diameter / dbh and canopy width of breadfruit tree has an effect on fruit production (Table 6). Although the correlation is not strong enough, the three growth characteristics influence the number of resulting fruit. The observations indicate that the breadfruit trees which have a good growth can produce more number of fruit. Breadfruit cultivars from Manokwari, Bone and Sorong showed a better response on fruit production compared with other breadfruit cultivars.

Table 6. Regression analysis of fruit production of breadfruit in Gunungkidul

| Variabel                                      | Coefficient | $R^2$ | Standar error | $T$-statistic | Prob. |
|-----------------------------------------------|-------------|-------|----------------|----------------|-------|
| Effect of tree height on the number of fruit  | 2.94        | 0.10  | 0.57           | 5.12 **        | 0.000 |
| Effect of stem diameter on the number of fruit| 1.47        | 0.13  | 0.24           | 6.01 **        | 0.000 |
| Effect of crown width on the number of fruit  | 2.36        | 0.04  | 0.79           | 2.99 **        | 0.003 |

Remark: ** = significant different at 0.01 level

The dimensions of trees according to [36] play a very important role in producing flowers and fruit. The larger the plant size has a better ability to produce fruit than the smaller plants. The results of this study also show the same things. The characters of tree height, stem diameter and canopy width showed a positive correlation with the number of fruit. From the regression analysis, it is obtained that the R value which is included in the medium correlation category [37] is 0.315 for the tree height character and 0.363 for the stem diameter / dbh character. As for the character of the canopy width, it shows a weak correlation, namely 0.186. However, in line with the increasing of age and the growth of the breadfruit tree, the fruit production also increases but it can vary according to the breadfruit cultivar [21, 38].

4. Conclusion
The breadfruit cultivars were planted in Gunungkidul influenced the growth performance and fruit productivity. Breadfruit cultivars from Manokwari, Bone, and Sorong showed the best adaptability response to vertisol land conditions in Gunungkidul and also produced a higher number of fruits. The average plant height is 7.78 m, stem diameter at breast height (dbh) 19.71 cm, and the average number of mature fruits is 11 fruit/tree. Those breadfruit cultivars can be chosen as one of the multipurpose species that will be planted in the vertisol area in other locations.

Acknowledgements
This research is part of the research activities in the Development of Superior breadfruit clones which are funded by the Government fund/DIPA in 2015-2018. Therefore, the authors would like to express our deepest gratitude to BBPPBPTH and all parties who have helped carry out this research. Special thanks to Bapak Suroto and his team who were assigned to KHDTK Petak 93 Playen, Gunungkidul, Yogyakarta for their assistance during the research and security surveillance at the research station.

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