Influence of spacing and depth of planting to growth and yield of arrowroot (*Marantha arundinacea*)

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Abstract. This study was conducted to determine the optimum spacing and depth of planting to the growth and yield of arrowroot. This research was conducted at the Experimental Field of Agriculture Faculty, Sebelas Maret University on Jumantono, Karanganyar. This research was conducted using Randomized Completely Block Design (RCBD) with two treatment factors of plant spacing and depth of planting. Plant spacing consists of 3 levels, including J1 (30x30 cm), J2 (30x40 cm) and J3 (30x50 cm). Depth of planting consists of 2 levels which are K1 (10 cm) and K2 (20 cm). Data were analyzed by DMRT (Duncan’s Multiple Range Test) at 5% significance level. The results showed that spacing of 30x50 cm have significantly higher plant height, tuber (common names of rhizome) length, and tuber weight per plant. The depth of 20 cm gives a higher yield on the number of tubers per plant and tuber weight per plot variables. Both treatments have no significant interaction on growth and yield.

1. Introduction
The Indonesian population is increasing, causing food demand to increase; meanwhile the availability of food is not enough to meet those needs. One way that can be done to overcome the shortage of food in Indonesia is by increasing the productivity of food crops. One of the crops that can be used as alternative food is arrowroot plant. Arrowroot plants are currently mostly cultivated for its starch content [1][2]. Fresh arrowroot contains 69-72% water, 1.0-2.2% protein, 0.1% fat, 19.4-21.7% starch, 0.6-1.3% fiber, and organic ashes 1.3 -1.4%. Arrowroot starch can be used for wheat substitution up to 50-100% [3]. Therefore, arrowroot starch has a potential to decrease the flour imports that have red 4.10 million tons per year with a value of 3.40 trillion rupiah [4].

Arrowroot is a plant that grows by using rhizomes and usually planted at the beginning of the rainy season. This plant is often found in the countryside and planted in the yard [5]. Arrowroot has a rhizome under the ground that grows long and from the rhizome will grow new shoots [6]. Effort on arrowroot plant development need to be improved because arrowroot plant in Indonesia is only cultivated as an intercrop under the annual crops in the yard [7]. The majority of Indonesia's population still has not planted arrowroot plants as the main crops on a field and the cultivation management of the crops is still relatively low [8]. Increasing the amount of production can be done by continuously improving the cultivation [9]. One point to note in the cultivation of arrowroot is the spacing and the depth of planting. Arrowroot planting by farmers is done without considering the spacing and proper depth of planting so the planting form irregularly.

Plant spacing and depth of planting adjustment is important in the cultivation of arrowroot, because with proper planting spacing and proper depth of planting can increase the plant growth and
development, also increase the yield of arrowroot [8]. This study was conducted to determine the spacing and the proper depth of planting for the growth and yield of arrowroot planted by 6 months age transplanting vegetative seed.

2. Methods
The research was conducted at Experimental field of Agriculture Faculty, Sebelas Maret University Surakarta in Jumantono, Karanganyar on March 2016 until September 2016. The materials used in this research are vegetative seeds of 6 months old arrowroot and organic fertilizer. The tools used in this study include hoes, plow hoe, crowbar, trowel, rulers, scissors, hole stick, watering can, plastic rope, bucket, scales, oven, calipers, and treatment boardsign.

This research uses a Randomized Complete Block Design (RCBD) factorial consisting of two treatment factors of plant spacing and depth of planting. The plant spacing factor consist of 3 treatment levels of plant spacing 30x30 cm (J1), 30x40 cm (J2), and 30x50 cm (J3), while the depth of planting consist of 2 treatment levels of 10 cm (K1) depth and 20 cm depth (K2), so there are 6 treatment combinations obtained. Treatment combination was repeated four times, resulting of 24 experimental units. The arrowroot plant is planted in the treatment plots measuring 1.8 m x 3.2 m.

The variables observed were plant height, number of leaves, number of tillers, number of productive tillers, fresh weight, dry weight, number of tubers (commonly names of rhizome produce) per plant, tuber length, tuber diameter, tuber weight per plant, and tuber weight per plot. Data were analyzed using DMRT (Duncan’s Multiple Range Test) with 5% level.

3. Results and Discussion
3.1 General Condition of Research
This research was conducted at 170 meters altitude above sea level and located at 7° 37’ 48.3” S and 110° 56’ 51.2” E. The rainfall rate on March 2016 to October 2016 at 1517 mm with an average rainfall of 7.09 mm/month. The air temperature of the location is ranged 27-28°C with an average air humidity of 80-86%. The experimental field has a type of Alvisol soil. The Alvisol soil is usually reddish-brown to dark red with a soil structure from grain to pole and soil texture from sandy clay to clay. The content of organic matter on alvisol soils is generally low [10].

3.2 Plant Spacing and Depth of Planting
Result of research on plant spacing and depth of planting on the growth and yield of arrowroot (Maranta arundinacea) shown in Table 1 and Table 2. Plant spacing has significant effect on plant height, number of leaf, fresh weight, dry weight, length of arrowroot tuber weight per plant and tuber weight per plot. The depth of planting significantly affected the number of tubers per plant and tuber weight per plot. Both treatments no significant interaction on growth and yield.

| Variabel                  | Plant Spacing (cm) |
|---------------------------|--------------------|
|                           | 30x30  | 30x40  | 30x50  |
| Plant Height (cm)         | 50.00<sup>a</sup> | 52.50<sup>b</sup>| 62.63<sup>b</sup> |
| Number of Leaf (sheet)    | 12.63<sup>a</sup> | 14.63<sup>ab</sup> | 16.75<sup>b</sup> |
| Number of Tillers (tiller)| 2.38   | 2.38   | 2.63   |
| Number of Productive Tillers (tiller) | 2.25 | 2.63 | 3.75 |
| Fresh Weight (g)         | 67.50<sup>a</sup> | 127.13<sup>ab</sup> | 210.38<sup>b</sup> |
| Dry Weight (g)           | 13.25<sup>a</sup> | 30.00<sup>b</sup> | 41.75<sup>b</sup> |
| Number Of Tubers Per Plant (tuber) | 5.38<sup>a</sup> | 6.50 | 7.38 |
| Tuber Length (cm)        | 16.63<sup>a</sup> | 17.50<sup>a</sup> | 20.25<sup>b</sup> |
| Tuber Diameter(cm)       | 1.88<sup>a</sup> | 2.00   | 2.25   |
| Tuber Weight Per Plant (g)| 85.00<sup>a</sup> | 121.00<sup>b</sup> | 191.25<sup>b</sup> |
| Tuber Weight Per Plot (kg)| 3.75<sup>a</sup> | 4.63<sup>b</sup> | 5.13<sup>b</sup> |

Description: Value in rows followed by the same letters are not significantly different in DMRT of 0.05 levels.
Table 2. Influence depth of planting to growth and yield of arrowroot (*Marantha arundinacea*).

| Variable                                    | Depth of Planting |
|---------------------------------------------|-------------------|
|                                             | 10 cm  | 20 cm  |
| Plant Height (cm)                           | 54.08  | 42.00  |
| Number of Leaf (sheet)                      | 14.33  | 11.25  |
| Number of Tiller (tiller)                   | 1.75   | 2.58   |
| Number of Productive Tiller (tiller)        | 2.42   | 3.33   |
| Fresh Weight (g)                            | 101.33 | 168.67 |
| Dry Weight (g)                              | 21.83  | 34.83  |
| Number of Tuber Per Plant (tuber)           | 5.33\(^a\) | 7.50\(^b\) |
| Tuber Length (cm)                           | 17.75  | 18.50  |
| Tuber Diameter (cm)                         | 2.08   | 2.00   |
| Tuber Weight Per Plant (gr)                 | 119.83 | 145.00 |
| Tuber Weight Per Plot (kg)                  | 3.06\(^a\) | 4.92\(^b\) |

Description: Value in rows followed by the same letters are not significantly different in ANOVA of 0.05 levels.

3.3 Plant Height
Treatment of J1 and J2 was significantly different from treatment J3. The highest average of plant height is found in treatment J3 which is 62.63 cm. The wider planting space will increase the availability of nutrients and water for individual plants so that the growth of the plant increases [11]. Plant spacing adjustment which are too close will cause the availability of nutrients and water to be limited, causing the growth of plants to be inhibited [12][13].

3.4 The Number of Leaf
Treatment J1 was significantly different from treatment J3. The highest number of leaves is found in the treatment of J3 which is 16.75 and the least amount of leaf is found in treatment J1 which is 12.63. Plants with a wide spacing will receive more light than plants with a narrow spacing. Plants that receive more light tend to have more leaves than the less one [14]. This is because the more light received, the photosynthesis will go well [15].

3.5 The Number of Tillers
Spacing and depth of planting did not significantly affect the number of tillers. This can be due to the ability of the plant to produce the seedlings, the age of the planting material and the unsuitable environmental conditions. Age of planting materials that are almost uniform cause the formation of tiller not much different. In the dry season, nutrients and water are scarce than the rainy season [16]. These conditions cause the plant is not able to produce the maximum tillers on both treatments. The occurance of shoots is also influenced by the temperature of the soil. Temperatures that are too high due to high amount of sunlight would cause the occurance time of buds to be longer, because those environmental conditions are not suitable for shoot growth [17].

3.6 The Number of Productive Tillers
Spacing and depth of planting also did not significantly affect the number of productive tillers of arrowroot. This is because the number of tillers that have formed are almost in the same number, resulting in the number of productive tillers that did not show a significant difference. The formation of productive tillers is closely related to the number of maximum tillers, the more the number of the maximum tillers, the more number of productive tillers tends to be [18].
3.7 Fresh Weight
Treatment J1 was significantly different from treatment J3. Treatment of J3 has the most fresh weight at 210.38 gram and J1 treatment has fresh weight of 67.50 gram. The wider use of plant spacing will result in higher fresh plant weight compared to the use of narrow spacing [19]. Tenous spacing provides an opportunity for plants to absorb more water so as to increase fresh weight per plant [20].

3.8 Dry Weight
Treatment J1 was significantly different from treatment of J2 and J3. The lowest result obtained from treatment J1 that is equal to 13.25 gram. Dry weight is a net result of photosynthesis activities thoroughly. Sunlight is a major factor in the photosynthesis process, the more sunlight it receives, the photosynthesis process can run well, resulting in more photosynthate made. Larger photosynthetic production will form larger plant organs which those affecting the increase of dry weight of plants [21].

3.9 The Number of Tuber per Plant
K2 treatment shows more response in the number of tuber per plant than K1 treatment. The treatment of K2 yielded the number of tuber per plant as much as 7.50 tubers, while treatment of K1 have 5.33 tubers. The depth of planting is closely related to the growing season. Planting in the dry season should be planted deeply in order that the roots can per the deepest layer of soil. The deeper depth planting in potato plants produces more tubers than the shallow planting [22]. Competition causes a decrease in tuber yield [23].

3.10 Tuber Length
Treatment of J1 and J2 was significantly different from treatment J3. The longest tuber length found in treatment J3 of 20.25 cm. Wide spacing produces long tubers. This is because at a wide spacing there will be more empty space and no competition in the use of nutrients, water and light that affect photosynthesis. Tubers formed from the accumulation of photosynthate as form of long tubers ([23];[24];[25])

3.11 Tubers Diameter
Plant spacing and depth of planting have no significant effect on diameter of arrowroot. This can be influenced by environmental factors. Environmental factors here derived from water availability factor, nutrients, and soil conditions. In the dry season the availability of water and nutrients tends to be less when compared to the rainy season [26]. The condition of the tubers produced has a size that is relatively uniform. Tuber yield and quality are influenced by texture and soil structure [27]. Alvisol soils at 0-20 cm deep have the same texture of clay. This soil conditions cause plants grown with a depth of 10 cm and 20 cm has a relatively same tuber diameter.

3.12 Tuber Weight per Plant
Treatment of J1 and J2 was significantly different from treatment J3. Treatment of J3 produces tuber weight per plant of 191.25 gram. Treatment J1 yields the smallest tuber weight of 85.00 grams. The tuber fresh weight per plant at a wide spacing is greater than the tuber fresh weight at a narrow plant spacing. This is because the nutrients, water, and sunlight can be received optimally and the competition between plants can be minimized, thereby enlarge the yield of plants in the form of arrowroot tubers.

3.13 Tuber Weight Per Plot
Plant spacing and depth of planting significantly affect the weight of arrowroot tubers per plot. Treatment J1 was significantly different from treatment of J2 and J3. The lowest tuber weight obtained from treatment J1 that is 3.75 kg. This is inconsistent with [28] statement, which says that the narrow spacing treatment resulting higher tuber yield per plot because at a narrow spacing the plant has a larger number of individual plants. This disaccordance can occur because the results of the study indicate a narrow spacing, although the number of plant populations are many but the tubers produced have the number and size is smaller than the wide spacing treatment. In addition, a narrow
plant spacing will only increase tuber yield per plot to a certain spacing limit. The narrower spacing of the optimum spacing limit will decrease tuber yield per plot.

The K1 treatment was significantly different from the treatment of K2. The most weight of tubers obtained from treatment K2 is 4.92 kg. Depth of planting is a factor that can affect tuber yield [29]. In the contrast, the depth of planting has significant effect on potato tuber weight. Potato planting with a depth of 15 cm in the dry season produces the largest tuber weight than the depth of 5 cm and 10 cm. This is because the plant is able to use water in the deepest layer of soil.

4. Conclusion

The plant spacing of 30x50 cm shows higher growth and yield response on plant height, length of arrowroot, and tuber weight per plant variable compared to planting distance treatment of 30x30 cm and 30x40 cm. The 20 cm planting depth brought the higher yield on variables of tubers per plant and tuber weight per plot compared to 10 cm plant depth treatment. Plant spacing and depth of planting have no interaction in all of observed variables.

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