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Performance of Arrowroot (*Marantha arundinacea*) in various light intensities

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Abstract. Arrowroot (*Marantha arundinacea*) is one of the potential food crops to support food security programs. Light intensity is one of the important factors for plant growth. Arrowroot cultivation technology still need further development. Traditionally, arrowroot grows wild under canopy without intensification of cultivating which have low productivity. The purpose of research was to investigate the suitable light intensity for arrowroot. The experiment was conducted at Jumantono as Experimental Field of Faculty of Agricultural, University of Sebelas Maret Surakarta located in Karanganyar, from March to September 2016. The experiment used a complete randomized block design (CRBD) of light intensity level there are 27400 lux (full sun light), 18900 lux (shaded 31%), 13500 lux (shaded 51%) and 7400 lux (shade 72%). Each treatment was replicated six times so there were 24 experimental units. The results showed that arrowroot is a low light adaptive plant. Arrowroot under the light intensity 7400 lux (27% full light), the number of leaves and tillers is not significantly different than under full light, although the plant is higher. The highest tuber diameter and length were 1.91 and 25.06 cm, respectively, and tuber weight reached 607.5-651.67 g per plant.

1. Introduction

Food security requires the attention of the Indonesian government in relation to the rate of function change on agricultural land especially for rice field. Increased population requires an increase in crop production. One of the efforts to overcome food demand is cultivation of alternative plant on suboptimum land or others such as agroforestry system [1], hydroponics [2], or dry land (gripped water) [3]. Arrowroot is one source of potential food in support of food security programs because it has high carbohydrate content [4]. Carbohydrate content of arrowroot bulbs ranged from 19.4% to 21.7%. Cultivation of arrowroot has not been intensive, mostly left to grow wildly without maintenance in the yard which has low productivity. Intensive development of arrowroot cultivation from the beginning of soil processing until harvest will optimize the growth and yield. Arrowroot is able to grow on low soil fertility and relatively low pest disease [5]. Light intensity is one of the important factors for plant growth. The light intensity requirements of each plant vary according to the plant character. Arrowroot is a C₃ plant that has a certain upper limit of light intensity [6]. Light
arrangement (low) using shade to avoid exposure to direct sunlight for optimum level for plant. The optimum conditions make growth and yield of arrowroot obtain optimum yield too [7]. The research investigated the optimum irradiation for arrowroot and intensive cultivation technology.

2. Methods
The experiment was conducted from March to September 2016 at Experimental Field of Faculty of Agriculture, University of Sebelas Maret Surakarta Indonesia (7° 37' 47.1" S and 110° 96' 35" E), with altitude of 187 m above sea level. The experimental design was a complete randomized block design (CRBD) with four levels of light intensity consist of 27.400 lux (full light), 18,900 lux (31% shaded), 13,500 lux (51% shaded), and 7,400 lux (72% shaded). Each treatment replicated six times so there were 24 experimental units. Planting material was arrowroot seedling 6 months age. Polybag 60×60 cm size filled with 25-30 kg mixture of heavy alvisol soil and manure 3:1 (manure 30 ton ha⁻¹) as planting medium. The maintenance of crop included: irrigation (using watering can every two days until a level below field capacity if no rainfall), weed grazing (manually), pest control (taken manually or removed), fertilization (N, P, K fertilizer with dose 150, 75, and 75 kg ha⁻¹). The plants were harvested at 12 months of age (> 50% of the leaves have dried out), the tubers were cut from the plants then air dried. The observed variables included growth components such as plant height (measured from base of the stem to the ends of the plant using a ruler), the number of leaves (counting all the leaves), and the number of tillers (crops grown from the tubers after the parent plant). Production components include tuber weight (weighing tubers after drying by wind), number of tubers (counting the tubers formed), tuber length (measured from tip to base of tuber using ruler), tuber diameter (measured by sliding). Observational data were analyzed using ANOVA 0.05, if among the treatment differ significantly, further analysis by DMRT level of 0.05.

3. Results and discussion

3.1 Growth components

3.1.1 Plant height Plant height as indicator of arrowroot growth was not affected by light intensity. Plant height obtained 43 - 69.16 cm under high light intensity (27400 lux) and low (13500 lux). Other research showed that the high of arrowroot seedlings in various manure between 39.60 until 98.60 cm [8]. Significant effect of treatment only between 43 and 79.33 cm (in middle and low light intensity) (Table 1). This indicates that the arrowroot is adaptive to low light intensity. However, physiologically it appears that at the lower light intensity, the plant grow higher [9]. Correlation coefficient between light intensity and height of plant was very high (correlation coefficient or r: -0.85). Arrowroot height under coconut trees was 113.8 cm [10]. Plants contain auxin as growth regulators, which antagonistic activity with light [11]. In low light intensity auxin activity is high so that the plant becomes longer or taller. Whether low light intensity result arrowroot etiolation will be discussed through the number of leaves.

3.1.2 Number of leaves The number of arrowroot leaves (between 16.16 – 42.33) was not affected by light intensity (Table 1). The number of leaves was calculated from several stems of tillers. When the leaves grow on one stem that experiencing etiolation, the number of leaves decreases because the low light intensity extending the internodes so decrease the number of nodes in which branches or leaves grow. This means that arrowroot has not been etiolated. The reasoning of this explanation is stronger when associated with the number of tillers.
3.1.3 Number of tillers
The arrowroot tiller grows from the shoots of the tubers, grows not simultaneously, the earliest growing shoots produce the parent plant, while the later produce the tillers. The number of tillers gained varied from 4.67 to 10.67, higher than that previous observation, which is only 5-6 [12]. The number of tillers highly correlated (r: 0.91) with the number of leaves reinforcing the assumption that the number of leaves originated from the parent plant and tiller, ensuring that the etiolation was not occurred.

3.1.4 Root canopy ratio
Environmental conditions affect the growth of plants. The light intensity from high to low did not affect root and canopy growth (Table 1). This means that the arrowroot has not been etiolated too although it grows under very low light. The plants which have an etiolated growth were elongated but low plant weight, while roots grow normally. Etiolation results in a lower root canopy ratio.

### Table 1. Arrowroot growth on various light intensity

| LI (x 1000 lux) | PH (cm) | NL | NT  | R/C |
|----------------|---------|----|-----|-----|
| 274            | 48.16<sup>a</sup> | 34.83 | 10.67 | 0.12 |
| 189            | 43<sup>a</sup>   | 16.16 | 4.67  | 0.13 |
| 135            | 69.16<sup>a</sup> | 26.50 | 7.83  | 0.08 |
| 74             | 79.33<sup>b</sup> | 42.33 | 9.83  | 0.11 |

Description: Number in a column followed by different letter showed significant difference in Duncan test 0.05; LI, light intensity; PH, plant height.

Regression analysis show that light intensity determines the height of plant with determination coefficient (R<sup>2</sup>) 0.73, and determines to number of leaves and tillers with R<sup>2</sup> 0.96 and 0.83, respectively (Figure 1 left).

3.2 Yield Component
The arrowroot yielded tubers which are roots modification. Roots as a reinforcing organ ensure the plant to grows upright which also used to absorbs nutrients and water, when the mature stage reached, it swell and turns as a food storage or sink. The weight of arrowroot is the yield quantity obtained at harvest. The weight of the arrowroot tuber is highly dependent on the number of tillers and tuber size determined by the length and diameter. The determination coefficient (R<sup>2</sup>) of the number of tillers to the weight of tuber, number leaves and tuber were 0.81, 0.83, and 0.55, respectively. There is show that the role of number of tillers to the weight of tuber and number of leaves more dominant than to the number of tuber (Figure 1 right and Table 2).

### Table 2. Arrowroot tuber yield on various light intensity

| LI  | TW (g) | NT  | TL (cm) | TD (cm) |
|-----|--------|-----|---------|---------|
| 274 | 705.0  | 20.0| 24.08   | 1.76    |
| 189 | 410.83 | 12.50| 20.83   | 1.72    |
| 135 | 651.67 | 17.16| 22.65   | 1.88    |
| 74  | 607.50 | 14.50| 25.06   | 1.91    |

Description: LI, light intensity (x100 lux); TW, tuber weight; NT, number of tuber; TL, tuber length; TD, tuber diameter.
Figure 1. Arrowroot response to light intensity in form of plant height, number of leaves, and number of tiller (left curve). Tiller number of tillers determine to to number of tubers and greatly determine number of leaf and tuber weight (right curve).

4. Conclusions
Arrowroot is a low light adaptive plant. Arrowroot under the light intensity 7400 lux (27% full light), the number of leaves and tillers were not different than under full light, although the plant is higher. The highest tuber diameter and length were 1.91 and 25.06 cm, respectively, and tuber weight reached 607.5 to 651.67 g per plant.

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