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Nitrogen and Potassium Applications on the Growth of *Amorphophallus muelleri* Blume

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ABSTRACT

Productivity of Amorphophallus muelleri is considered low. Thus, pot experiment was conducted at the Cikabayan Experimental Farm, Bogor Indonesia during rainy season November 2007 to July 2008, in order to determine the optimum fertilizer dose for A. muelleri under 50% shading net. Treatments consisted of four doses of nitrogen (0, 50, 100 and 150 kg ha^{-1} N) and three doses of potassium (0, 50 and 100 kg ha^{-1} K_2O). The results showed that application of N and K fertilizers significantly increased vegetative growth, i.e., number of leaves, number of leaflets and second leaf size, but did not affect harvesting time. Fresh weight and dry matter content of daughter corm were significantly affected by N and K applications. Combination of 50 kg ha^{-1} N and 100 kg ha^{-1} K_2O resulted in higher corm weight than other treatments. It is evident that the application of nitrogen and potassium is important in A. muelleri.

Keywords: disease infection, iles-iles, Indonesian konjac, nitrogen, potassium

ABSTRAK

Produktivitas Amorphophallus muelleri masih rendah dibandingkan dengan potensinya. Penelitian dilakukan menggunakan pot di Kebun Percobaan Cikabayan, Bogor, Indonesia selama musim hujan 2007-2008 dalam rangka mencari dosis optimum untuk pengembangan tanaman A. muelleri. Penelitian dilakukan dibawah naungan paranet 50%. Perlakuan terdiri atas 4 taraf nitrogen yaitu 0, 50, 100 dan 150 kg N ha^{-1}, dan tiga taraf dosis kalium yaitu 0, 50 dan 100 kg K_2O ha^{-1}. Hasil menunjukkan bahwa pemberian N dan K nyata meningkatkan pertumbuhan vegetatif, yaitu pada peubah jumlah daun, jumlah anak daun dan ukuran daun ke dua. Namun demikian, aplikasi N dan K tidak mempengaruhi waktu panen. Bobot segar dan kandungan bahan kering umbi nyata dipengaruhi oleh pemberian N dan K. Kombinasi pemberian N 50 kg ha^{-1} dengan 100 kg K_2O ha^{-1} menghasilkan bobot umbi yang lebih tinggi dibandingkan dengan perlakukan yang lain. Hal tersebut menunjukkan bahwa pemberian N dan K penting untuk meningkatkan produktivitas tanaman iles-iles.

Kata kunci: infeksi penyakit, iles-iles, Indonesian konjac, kalium, nitrogen

INTRODUCTION

Amorphophallus muelleri Blume (synonym *Amorphophallus oncophyllus*) is a native tuber crop in Indonesia (Jansen *et al*., 1996) and its corm contains glucomannan ca. 55% on a dry weight basis (Ohtsuki, 1968; Syaefullah, 1990). Current annual Indonesian export of dried-chips of *A. muelleri* is ca. 300 ton year^{-1}. Glucomannan is a carbohydrate that is widely used in beverage and food industries, as well as medical purposes (Fang and Wu, 2004; Sugiyama and Santosa, 2008).

Many studies in Indonesia have shown that *A. muelleri* (called *porang* or *iles-iles* in Javanese) was suitable for intercropping under timber forest (Jansen *et al*., 1996; Santosa *et al*., 2003; Sugiyama and Santosa, 2008). Thus, introduction of *A. muelleri* to forest timber companies has proven to reduce the illegal logging and forest disturbance in Indonesia (Perhutani, 1995; Santosa *et al*., 2003; Sugiyama and Santosa, 2008). As compared to *A. konjac*, a major source of glucomannan in Japan and China (Fang and Wu, 2004), *A. muelleri* is more tolerant to diseases such as stem rot by *Phytophthora sp* and *Schlerotium rolfsii*, and requires lower agro-inputs (Sugiyama and Santosa, 2008).

Productivity of *A. muelleri* is considered low in Indonesia. According to information from farmers in teak timber agroforestry in East Java, productivity of *A. muelleri* was 6-10 ton fresh tuber ha^{-1} year^{-1}, although it was estimated that under proper cultivation method 40 tons ha^{-1} year^{-1} is expected (Santosa *et al*., 2003; Sugiyama and Santosa, 2008). The low productivity of *A. muelleri* in farmer's field was possibly due to non intensive cultivation management, particularly low fertilization and irrigation applications (Bhagavan *et al*., 2008), and low quality planting materials (Zhang *et al*., 2010).

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Jansen *et al.* (1996) recommended to apply *A. paeoniifolius* with 25 tons manure, 20 kg N, 40 kg P_2O_5 and 80 kg ha^{-1} K_2O at planting and additional 20 kg ha^{-1} N at 2-3 months after planting. Sumarwoto (2004) recommended to apply 7.5 tons ha^{-1} of organic manure and 4 ton ha^{-1} of gypsum for *A. muelleri*. Potassium is important nutrient for many tuberous crops to increase yield, tuber quality and starch content (Singh *et al*., 1993; Das *et al*., 2003; John, 2008). Ashokan and Nair (1984) stated that K removal by taro is much higher than that of N. However, research conducted by Sumarwoto (2004) under canopy of *Albizia falcataria* indicated that application of potassium and phosphorus did not affect the growth of *A. muelleri*. Rumawas (personal communication, 2008) speculated that *A. muelleri* might have low ability to utilize nutrients, but there are little studies on effect of fertilizer application on *A. muelleri* growth. The objective of this experiment was to study effect of nitrogen (N) and potassium (K) applications on *A. muelleri*.

MATERIALS AND METHODS

The experiment was conducted at Cikabayan Experimental Farm IPB, Darmaga (250 m above sea level) using virgin soil of Latosol Darmaga (pH 5.0) from November 2007 to July 2008. The soil contained a low amount of total N (0.09%), medium amount of Bray I phosphorus (18.0 ppm) and medium amount of exchangeable K (17.0 ppm). Temperature during experiment was 25.6 ^oC on average (ranged from 20 to 34 ^oC) with relative humidity 82-86%.

The experiment was carried out using randomized complete block design (RCBD) with two factors, i.e., N and K. Treatments consisted of 4 levels of N, i.e., 0 kg $plant^{-1}$ (0 kg ha^{-1}), 0.25 g $plant^{-1}$ (50 kg ha^{-1}), 0.50 g $plant^{-1}$ (100 kg ha^{-1}), and 0.75 g $plant^{-1}$ (150 kg ha^{-1}), and of 3 levels of K_2O, i.e., 0 kg $plant^{-1}$ (0 kg ha^{-1}), 0.25 g $plant^{-1}$ (50 kg ha^{-1}), and 0.50 g $plant^{-1}$ (100 kg ha^{-1}). Each treatment was replicated three times. Each experimental unit was comprised of 6 plants. The plants were grown under the shade (50% light intensity of no shading) from planting until harvest.

Corms (75 to 100 g) were planted in polyethylene bag (50 cm x 50 cm). Each bag was filled with a media mixture of 10 kg dry soil and 2 kg compost made of *Albizia falcataria* and *Casea sp* leaves (Leguminoceae) one week prior to planting. At planting, seed corm had sprouted with main buds of 10-12 cm height. Phosphorus was applied at the rate of 1.0 g $plant^{-1}$ P_2O_5 (200 kg ha^{-1} P_2O_5) at planting. Depending on treatment, different amount of N and K_2O were applied one week after planting (WAP). Watering was carried out regularly unless there was adequate rain fall. Weeding was carried out manually twice a month. Pest and disease controls were carried out either manually and chemically (using Dithane M-45 and Basudin 25 EC) according to field condition.

Leaf number was counted when it had fully expanded, with an initial leaf was marked as the first and the subsequent leaf as the second, and so on. Time of leaf emergence was calculated from planting, when the bud emerged one cm above soil surface. Leaf size was measured from several variable, i.e., petiole diameter (measured 5 cm from soil surface), number of leaflet, rachis length, and petiole height (measured from soil surface to tripartite of rachises). Since a leaf has three rachises, longer rachis meant larger canopy. The length of rachises was measured from tripartite branch to the longest of leaflet tip. Plant dry weight, root number and root length were observed at 10 week after planting, at a time of maximum vegetative growth. Corms were harvested at 25 WAP when plant entered dormancy. Further statistical analysis was conducted using Duncan Multiple Range Test (DMRT), when ANOVA analysis expressed significant different.

RESULTS AND DISCUSSION

Leaf Number

First leaf emergence was not affected by fertilizer treatment (Table 1). There was no interaction between N and K treatments on leaf life span in any leaf. Table 1 shows that life span of first leaf decreased with an increase in N level, being the longest at 0 kg ha^{-1} N and the shortest (11 weeks) at 150 kg ha^{-1} N. The short life span of the first leaf at higher N application was compensated by emergence of the third leaf, however, the growing period of *A. muelleri* was not affected by N application, ca. 23-25 weeks. Application of 50 and 100 kg ha^{-1} K_2O did not increase significantly the life span of any leaf (Table 1).

Table 2 shows that there were significant interactions between N and K applications on the number of leaves. Leaf number was the highest (2 to 5 leaves with average 3.9) at the combination of 50 kg ha^{-1} N and 100 kg ha^{-1} K_2O. When 50 or 100 kg ha^{-1} of K_2O was applied, N application significantly increased the leaf number. Sugiyama and Santosa (2008) pointed out that the number of *A. muelleri* leaves was dependent on corm size at planting; smaller corm produced larger number of leaf. *A. muelleri* plants had 3 to 5 leaves when planted from seed corms of 50 g, while it had 1 to 3 leaves when planted from 100 g seed corms or larger. In *A. paeoniifolius*, Santosa and Sugiyama (2007) stated that corm weight significantly affect the number of leaf. This study suggested that fertilizer application also affected the number of leaves during the growing season.

In term of number of leaflets, application of N and K did not affect the leaflet number of the first leaf, i.e., 42 to 54 (data not shown), but it affected that of the second and the third leaves (Table 3). It showed that number of leaflets from the second leaf was lower than that of first leaf, i.e., 9-43. By contrast, Sugiyama and Santosa (2008) reported that the first leaf had lower number of leaflets than the second and third leaves when *A. paeoniifolius* planted from seed or skin of corm. Nitrogen application increased the number of leaves and decreased the leaf size, leading to a decrease in the number of leaflets. In the third leaf, the leaflets number is more or less similar to that of second leaf. An increase in K level increased the number of leaflets when N was applied. On the other hand, increased in N level decreased the number of leaflets, irrespective of K level (Table 3).

Table 1. Time of leaf emerge and leaf senesce of *A. muelleri* treated with different nitrogen and potassium[Z]

Treatment	First leaf[Y]		Second leaf		Third leaf	
	Emerge (WAP)	Life span (week)	Emerge (WAP)	Life span (week)	Emerge (WAP)	Life span (week)
N (kg ha^{-1})						
0	1.0	17.4b	8.2	14.2b	-[X]	-
50	1.0	16.4b	8.7	13.1b	-	-
100	1.0	13.8ab	11.0	11.8a	13.0a	10.0b
150	1.0	10.1a	12.7	10.1a	18.5b	5.0a
K_2O (kg ha^{-1})						
0	1.0	15.2ab	10.6	11.8a	16.0ab	8.0b
50	1.0	14.0ab	10.8	11.8a	16.0ab	8.0b
100	1.0	14.0ab	9.6	12.7ab	14.0a	8.0b

Note: Value in a column with the same letter was not significantly different after DMRT at 5% level.
[Z] Fourth and fifth leaves are not included due to many missing data.
[Y] Senescence was indicated by yellowing of leaves. Leaf was numbered sequentially from germination.
[X] no leaf
'-'data was not included in statistical analysis

Table 2. Number of *A. muelleri* leaf from different N and K fertilizer combinations

Level of N (kg ha^{-1})	Level of K_2O (kg ha^{-1})			
	0	50	100	Average
		Number of leaf		
0	1.0 ± 0.0	1.1 ± 0.1c	1.4 ± 0.1b	1.2
50	1.2 ± 0.3	1.5 ± 0.0b	3.9 ± 0.1a	2.2
100	1.2 ± 0.3	1.5 ± 0.7b	1.5 ± 0.3b	1.4
150	1.2 ± 0.1	1.5 ± 0.4b	1.3 ± 0.3bc	1.3
Average	1.1	1.4	2.0	

Note: Value in a column and row followed by the same letter are not significantly different after DMRT at 5% level; Mean ± S.D

Table 3. Number of leaflets from second leaf of *A. muelleri* from different N and K applications

Level of N (kg ha^{-1})	Level of K_2O (kg ha^{-1})			
	0	50	100	Average
0	15.0b	43.0a	30.3a	29.4
50	14.5b	30.8a	33.4a	26.2
100	9.5b	12.5b	14.8b	12.3
150	15.0b	10.3b	9.0b	11.4
Average	13.5	24.1	21.9	

Note: Values in a column and row followed by the same letter are not significantly different after DMRT at 5% level

Leaf Size

No interaction was observed between N and K on rachis length. Application of N significantly reduced rachis length, while no discernible effect of K on rachis length was found (Table 4). However, application of 100 kg ha^{-1} K_2O enlarged rachis significantly.

Petiole diameter of the first leaf was not affected by N and K application, but no interaction between N and K was found (data not shown). Based on the observation,

Table 4. Rachis length of *A. muelleri* leaves planted on different N and K treatments

Treatment	Rachis width (cm)		
	First leaf	Second leaf	Third leaf
N (kg ha^{-1})			
0	32.63a	28.48a	-^{Z}
50	30.53a	30.88a	-
100	25.17b	21.04b	13.50c
150	23.18b	21.13b	18.00c
K_2O (kg ha^{-1})			
0	28.61a	21.38b	9.00d
50	28.38a	23.69b	16.00c
100	26.65ab	29.67a	17.50c

Note: Value in a column followed by the same letter are not significantly different after DMRT at 5% level
^{Z} no third leaf had emerged

plants with high N application was greener, but leaf collapse (bending down) increased with an increase in N levels. When 150 kg ha^{-1} N was applied, leaves collapse was found in ca. 20% plants. On the other hand, no plants showed leaf collapse when N was not applied.

Table 5 shows that there was interaction between N and K on petiole length. Petiole of the first and second leaves became shorter with an increase in N level. This is contrary to the result on taro by Singh *et al*. (1993) and *A. paeoniifolius* by Sen *et al*. (1996), where N application increased petiole length. Moreover Singh *et al.* (1993) and Sen *et al*. (1996) pointed out that K application did not affect plant height of both taro and *A. paeoniifolius*. In this experiment, however, K application increased petiole length of the second leaf when 50 and 100 kg ha^{-1} N was applied. On the contrary, K application decreased petiole length of the second leaf at the rate of 150 kg ha^{-1} N.

Based on the observation, high N levels (100 and 150 kg ha^{-1}) without K application caused severe rot in many petioles, possibly due to the infection of *Schelerotium rolfsii*. These diseases infection during leaf growth made leaves twisted, stunted and restricted. Possibly, combination of low N and high K reduces diseases severity. This in line with statement of Sugiyama and Santosa (2008) that *A. muelleri* is more tolerant to diseases such as stem rot by *Phytophthora sp* and *Schlerotium rolfsii* at lower agro-inputs. Das *et al*. (2003) stated that increasing level of N application increased disease severity in taro. However, it is still unclear how K nutrient related to diseases severity in *A. muelleri*. Visual observation in the field indicated that petiole base *A. muelleri* was sensitive to soil physical injury. It is probably that K nutrient correlates with prevention of diseases infection. Mengal and Kirkby (1987) stated that K is important as catalyst for protein and carbohydrate synthesis and involved in meristematic cell growth. Singh *et al*. (1993) and Das *et al*. (2003) stated that K is important to increase production, quality and starch content for many tuberous crops.

Plant Dry Weight

There was interaction between N and K on biomass production at 10 WAP (Table 6). The combination of 50 kg ha^{-1} N and 100 kg ha^{-1} K_2O produced the highest dry mass of canopy. Root dry mass increased with an increase in K levels. Highest root dry mass was obtained when plants were treated with 0 kg ha^{-1} N and 100 kg ha^{-1} K_2O. Root number and root length changed similarly as did number of leaves (Table 1), number of leaflets (Table 3) and plant size (Table 5).

In case of taro, Hartemink *et al*. (2000) stated that above ground biomass was not significantly different when the level of N increased up to 100 kg ha^{-1}. However, harvest index of taro (ratio marketable yield to biomass) tended to decrease with an increase in N level.

Daughter Corm

Harvest was conducted at 25 WAP when plants entered dormancy. A plant produced single depressed-globose daughter corm. There was interaction between N and K treatments on corm size and corm weight (Table 6). Control plant without either N or K treatments still produced marketable-sized corm. The highest corm yield obtained from a combination of 50 kg N and 100 kg ha^{-1} K_2O. The high yield may be supported by vigorous vegetative growth data as presented in Table 6. Field data showed that a combination of 50 kg N and 100 kg ha^{-1} K_2O produced 3.9 leaves on average, as compared to other combinations, i.e., 1.1 to 1.5 leaves.

Application of N higher than 50 kg ha^{-1} significantly reduced corm size by 20%, corm fresh weight by about 40% and corm dry weight by about 16%. Interestingly, application of N 50 kg ha^{-1} produced a little lower or similar fresh weight as compared with no application of N. It is probable that application of green manure of *Albizia falcataria* and *Casea*

Table 5. Petiole length of *A. muelleri* from different N and K combinations

Level of N (kg ha^{-1})	Level of K_2O (kg ha^{-1})	Petiole length (cm)		
		First leaf [Z]	Second leaf	Third leaf
0	0	47.7ab	- [Y]	-
	50	55.2a	-	-
	100	48.6ab	67.8a	-
50	0	40.4bc	35.3d	25.0b
	50	45.2b	55.8b	58.2a
	100	45.3b	67.4a	60.7a
100	0	37.5bc	18.0e	-
	50	32.1c	28.0d	-
	100	28.6c	43.7c	35.5b
150	0	27.9c	41.8c	-
	50	27.2c	24.5de	32.6b

Note: Value in a column followed by the same letter is not significantly different after DMRT α 5%
[Z] first leaf emerged after planting and second leaf emerged after the first leaf. Data of fourth and fifth leaves are not presented due to many missing data. [y] no leaf

Table 6. Effect of N and K applications on dry mass of *A. muelleri* (10 weeks after planting) and on corm size and weight of *A. muelleri* at harvest (25 weeks after planting)

N (kg ha^{-1})	K_2O (kg ha^{-1})	Canopy dry weight (g)			Roots			Corm yield			
		Petiole	Leaf blade	Total	Root number	Length [Z] (cm)	Dry weight (g)	Diameter (cm)	Height (cm)	Fresh weight (g)	Dry weight (g)
0	0	6.52a	13.86a	20.38a	260.3a	92.33a	9.50a	10.6a	7.2b	488.1b	79.8a
	50	6.30a	11.95b	18.25a	175.7b	78.33b	11.64a	11.0a	8.7a	559.1b	75.5a
	100	7.29a	13.82a	21.11a	283.0a	100.33a	13.64a	10.6a	7.4b	495.1b	84.7a
50	0	4.58bc	12.77ab	17.35a	234.5a	58.50b	6.61a	8.8b	6.0bc	349.5c	59.7b
	50	5.20b	12.97ab	18.18a	172.0b	69.50b	6.91a	10.6a	6.8b	494.6b	82.7a
	100	7.59a	13.44a	18.03a	152.3b	60.83b	7.88a	11.7a	7.6b	632.5a	90.8a
100	0	4.86b	8.73b	13.59b	108.7c	61.00b	2.79b	8.6b	5.6bc	282.0c	51.8b
	50	5.47ab	13.77a	19.23a	149.0b	63.50b	5.52ab	8.8b	6.1b	353.3c	39.3bc
	100	3.82c	11.57b	15.39b	145.5b	46.25c	10.47a	9.2b	5.8bc	318.2c	29.5c
150	0	5.19b	11.12b	16.31a	98.0c	59.50b	3.35b	8.9b	5.6bc	255.8c	49.6b
	50	3.63c	11.60b	15.22b	162.0b	38.50c	6.19ab	8.2b	5.6bc	273.6c	47.3b
	100	2.39c	10.64b	13.03b	58.5c	26.75c	2.53b	9.0b	5.3c	270.3c	61.7b

Note: Value in a column followed by the same letter is not significantly different after DMRT α 5%
[Z] The longest root

sp. prior to planting provided adequate nutrients including nitrogen. At the end of experiment, 25 weeks after planting, total available N was 0.13, 0.17, 0.12 and 0.14% in the level of 0, 50, 100 and 150 kg ha^{-1} N application, respectively. Moreover, available potassium at the end of experiment also increased, i.e., 45.5, 57.6 and 76.6 ppm in the level of 0, 50 and 100 kg ha^{-1} K_2O application, respectively. In taro, application of *Leucaena sp.* (Leguminoceae) biomass at the rate of 10 ton ha^{-1} gave higher vegetative growth and yield as compared to those supplemented with 90 kg ha^{-1} of nitrogen fertilizer (Escalada and Ratilla, 1998). In this experiment, available P significantly decreased by increasing level of N application, while no clear correlation with increasing level of K application (data not shown). It is probable that phosphorus absorption increase in *A. muelleri* in the high level of N, however, we did not check nutrient status in plants.

Application of K tended to increase fresh weight of daughter corm by about 23% higher than control, when level of N 50 kg ha^{-1} or higher (Table 6). Application of 50 kg ha^{-1} and 100 kg ha^{-1} K, however, did not significantly affect fresh and dry weight without application of N. It is important to note that some plants applied with high N levels (100 and 150 kg ha^{-1}) produced no corm due to rot, possibly due to the infection of *Schelerotium rolfsii*. Thus the diseases beside infected petiole, it also causing corm rot. However, some diseased plants produced a new leaf that finally produced small sized corms. This might the explanation of the decreasing corm fresh weight in high N applications.

The results showed that *A. muelleri* required a small amount of supplemented N when planted in adequate amount of compost, but K application with a small amount of N (50 kg ha^{-1}) could increase vegetative growth and yield. This research revealed that a small amount of N and K are important for growing *A. muelleri*. This finding is not in line with the result of Nair *et al*. (1990) where it is recommended at rate of $N:P_2O_5:K_2O$ = 100:50:150 kg ha^{-1}. Patel and Mehta (1984) pointed out, however, that corm yield of *A. paeoniifolius* increased by less than 10% by applying 100 kg ha^{-1} N as compared to no N application in the experiment on alluvial soil. Singh *et al.* (1993) stated that N application increase yield of taro although higher level of N than 40 kg ha^{-1} decreased dry matter content. It is not clear whether the differences in optimum rate of N and K fertilizers can be ascribed to the differences in plant species.

CONCLUSIONS

Application of N and K fertilizers significantly increased vegetative growth, i.e., number of leaves, number of leaflets and second leaf size, but did not affect harvesting time. Fresh weight and dry matter content of daughter corm were significantly affected by N and K applications. High N applications tended to increase diseases severity in *A. muelleri*. Balanced application of nitrogen and potassium is important to increase *A. muelleri* production, and recommended level of N and K for *A. muelleri* were 50 kg ha^{-1} and 100 kg ha^{-1}, respectively, when ca. 20 ton of organic manure is applied.

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