**Effect of Potassium Nitrate (KNO\textsubscript{3}) on Indonesian Konjac Productivity**

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**Abstract**

Indonesian konjac (IK in brief), also known as *Amorphophallus muelleri* Blume in Latin, is a wild plant growing in several places in Indonesian archipelago. The tuber of IK plant contains a compound called glucomannan which has high economic value since it can be used as a raw material in many industries such as medicine, cosmetic, paper, textile, synthetic rubber, and filming industries. Due to this economic value, this study was carried out in order to increase the productivity of glucomannan and bring IK into mass cultivation. For this purpose, the objective of this study is to increase the productivity of IK tubers by increasing the speed of seeds germination process and by decreasing the dormancy period. Meanwhile, bringing IK into mass plantation will be put as a package of campaign program to educate people. To speed up the germination process and to decrease the dormancy, the method used in this study period is by improving the soaking process of IK seeds using KNO\textsubscript{3} solution. Its effects were investigated using a completely randomized design (CRD) with three treatments, namely, concentration of the solution, soaking time, and plant age. Then, data were collected and analyzed statistically using general linear model, analysis of variance and Duncan’s multiple range test. The results indicate that soaking in that solution has a significant effect on shortening the time period for seeds to germinate. Its optimal effect was reached for 3,000 ppm of concentration with soaking time 3 hours at 14\textsuperscript{th} days after plantation (DAP). Moreover, in terms of dormancy period, that solution has reduced from 5-6 months to 2-4 months. These findings were significantly support the effective use of KNO\textsubscript{3} solution to answer the objective of research. The germination period has been reduced from 3-6 months to around 14 days. To the knowledge of the authors, based on the literature used in this study, these are unprecedented findings. Therefore, hopefully, it could contribute to the development of konjac-based industries and to the literature of konjac particularly Indonesian konjac.

**Keywords** Analysis of Variance, Dormancy Period, Duncan’s Multiple Range Test, Germination Rate, Soaking Process

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1. **Introduction**

1.1. **Background of the Study**

**Historical background at a glance**

This paper deals with a phenological study of Indonesia konjac (*Amorphophallus muelleri* Blume), a wild plant with promising economic potential but still mysterious in breaking the dormancy period and speeding up the germination process. For brevity, in what follows we refer to that plan as IK. As a wild plant, it is not an indigenous Indonesian plant. According to Jansen et al. (1996), it is originally from West Africa. More specifically, it was from the paleotropics West Africa. It came (more precisely, was brought) to Indonesia during the era of Dutch colonization hundreds of years ago. IK tuber has many benefits in various industries like for food and...
potassium nitrate (KNO₃) on Indonesian konjac productivity (Dwiyono and Djauhari, 2019). However, its cultivation began only when Japan occupied Indonesia. Nowadays, it grows worldwide in the tropical and subtropical zones of the paleotropical kingdom comprising the tropical areas of Africa, Asia and Oceania (excluding Australia and New Zealand). In Indonesia, in particular, it spreads out in Sumatera, Java, Madura, Bali, Celebes, Flores and Lombok.

Phenological background

IK is one of tuber plants. It belongs to the Araceae family and Monocotyledon class. The three main products of this plant (from highest to lowest economic value) are the tubers, the bulbils, and the seeds. See Figure 1 for illustration.

IK tuber contains a compound called glucomannan. It is this compound that has high economic value and since very recently it has become an export commodity to several countries such as Japan, Taiwan, Korea, China, Netherland, and other European countries. This compound has many benefits for industry as well as world food security program. In industry, such as medicine, cosmetic, paper, textile, synthetic rubber, filming industries, glucomannan is usually used as raw material for their products. For example, in Japan medical industry, it is the raw material to produce dietary food such as “konyaku” and “shirataki.” These foods contain a lot of fiber suitable to support dietary program. They may increase food digestibility, reduce blood cholesterol level and bring down obesity. Interestingly, as mentioned in Bo et al. (2013), it contains anti-human immunodeficiency virus (anti-HIV) compound. Furthermore, see Jansen et al. (1996), with appropriate processing IK tuber can be turned into a substitute to traditional food. This will be important during food crisis. Jansen et al. (1996) also mention that IK plant is also known as indigenous traditional medicine to treat some diseases such as dysentery, cholera, digestive disorder and rheumatic. These are the phenological background of this study.

1.2. Status of the Konjac Plant in the Market

For production purposes

In nature, IK plant grows well in lowland with altitude 100 meters above sea level (masl) as well as in upland (1000 masl). It has the best growth under 50 to 60 percent sunlight with (i) the soil acidity of 6 to 7.5, (ii) sandy, loose and compost soil, (iii) rainfall of 1000 to 1500 millimeters every year, and (iv) air temperature of 26 to 30°C. In this environment, Indonesian farmers have experienced the increase of yearly export value of IK tubers from 1999 to August 2003. It was consecutively 199,828 tones (267,104 USD), 181,055 tones (245,488 USD), 179,597 tones (317,675 USD), 125,747 tones (264,132 USD), and 266,719 tones (385,995 USD). Those yearly productions were still lower than foreign demand. This year 2020 alone, according to the Ministry of Agriculture, Republic of Indonesia, only 12% of demand have been fulfilled. Therefore, there is an urgent need to increase the productivity of IK tubers.

Figure 1. (a) Farmer showing 5.5 kg IK tubers harvested after 2-3 years of plantation, (b) bulbils, and (c) cob of fruits which produces seeds
For agriculture

The unbalance condition between foreign demand and local production of IK tubers offers a challenging opportunity for those who involve in the agricultural industry to invest in IK plantation. In these regards, a piece of surprising news came from a European Community agricultural research center. Very recently Dr. Alberto Forte, Director of the DASAM, Department of Sustainable Agriculture at IEMEST (https://www.iemest.eu/en/), Palermo, Italy, has mentioned in his email to the authors that konjac is one of the interests of European Community in developing and diversifying agroindustry in Mediterranean area.

As we all know, Mediterranean area is a sub-tropic region with four seasons whereas konjac is a tropical plant. This shows how konjac has become an interest of worldwide community.

1.3. Literature Review

To increase the productivity of tuber, breaking or reducing the dormancy period and speeding up the germination process becomes a priority in IK cultivation. This is a phenology-based problem. Actually, research on this problem is not new. Since the last two decades phenology is an active research. This is reported, for example, in Chmielewski, et al. (2004), Cleland, et al. (2007), Atkinson, et al. (2012), Jin, et al. (2013), Workie and Debella (2018). However, these authors’ concern is on the phenology of fruit, trees, field crops, plant, and vegetation in general. In this study the focus is on the phenology of IK. The fruit spadic of IK plant produces between 100-500 fruits and each fruit contain 2-4 seeds (Dwiyono, 2019).

The topic on how to increase the germination rate and to shorten the dormancy period has received special attention from the researchers on various types of plants. For example, Hilton and Bitterli (2006), Abdelgadir, et al. (2012) and Dostatny, et al. (2015) have reported their results on germination of *Avena fatua*. Meanwhile, Moravcová and Dostálek (1989) and Eslami (2011) have focused on germination of *chenopodium album*, and Ohadi, et al. (2009) and Derakhshan, et al. (2014) on canary grass, Gardarin, et al. (2011) and Alshallah (2018a) on that of weed, and very recently Bhatt, et al. (2019) on germination behavior of perennial halophyte of Arabian deserts. Hasan et al. (2017) stated that reduction of germination percentage and delay of wheat seed caused by the higher of salt concentration in media. Other researchers, Baskin and Baskin (1988), have described the behavior of seeds germination of herbaceous plant. Similar study on seeds germination was conducted by Ohadi, et al. (2009) on *phalaris minor* and *poa annua* and by Alshallah (2018b) on oat. Other example given in Grubišić and Konjević (1990) is about the interaction of light, nitrate and alternating temperature in promoting the germination of dormant seeds of weed species. The various physiological and biochemical processes like water stress can reduce growth and productivity of hararghe coffee in Eastern Ethiopia (Wegari and Amin, 2020).

The above literature review led to fix objective of this study. It is to increase the productivity of glucomannan. For this purpose, breaking the dormancy period and speeding up the germination process are the main concerns. Traditionally, after being harvested, IK seeds from parent tree cannot immediately germinate and then grow because they experience long dormancy period about 5-6 months Bian, et al. (2013). To accelerate the seeds growth from its formation, see Simón, et al. (2018), it needs to break the dormancy period.

In order to understand how to increase the seeds germination rate, a three-factor experiment under completely randomized design was conducted at Dramaga Research Field, Bogor Agricultural University, Indonesia. This experiment was designed under the following assumption: “Seeds germination rate is considered as a function of (i) concentration of KNO₃ solution, (ii) soaking time, and (iii) plant age.” In laboratory level, the seeds germination rate (in %) was observed using 5 levels of concentration, 4 levels of soaking time, and 8 levels of plant age.

The use of KNO₃ was inspired by the previous studies on the productivity of several plants. For example, Bian, et al. (2013) that KNO₃ treatment under 6,000 ppm concentration with 24 hours soaking time may produce unsweetened-red palm seed by 65.33% compared with control (36.00%) on 22 weeks after planting (WAP). Copeland and McDonald (1999) gave an important remark on the effectiveness of soaking pine walnut into KNO₃ solution. At 1,500 ppm concentration, it has significantly accelerated the germination. Other example was showed by Qaderi and Cavers (2000). They concluded that higher concentration level of KNO₃ up to 200 ppm may trigger the germination of seeds from *eragrotis curvula* species. Meanwhile, Gashi, et al. (2012) have remarked that the application of 500 ppm and 1,000 ppm KNO₃ concentration with 14 hours light soaking time and 10 hours dark on *onopordium acanthium* L seeds produced the germination rate of 66.6% and 88.2%. It is higher than the control (41.8%).

The previous studies mentioned above were the inspiration why in this study KNO₃ was used to fasten the IK seeds germination process and shorten the dormancy period. An advantage of this chemical is that it enables to give additional O₂ useful for accelerating the seeds respiration and trigger the conversion of seed carbohydrate compound into simple sugars that will be used as energy source for germination. Then, it will be decomposed into nitric acid and K element. Nitric acid has the role attenuate the seed shell to facilitate oxygen in the water to come into the seed while K element will speed up
Germination is a nature-made process of transforming seeds into young plants. Only by understanding this process, speeding up the germination process and shortening the dormancy period can be possible. The main objective of this research is to have a better understanding of the effect of soaking the IK seeds in KNO3 solution and soaking time on the seeds germination rate for different plant age. To answer these objectives, in this section the methods, materials, statistical design and analysis are presented.

2. Methods

First, a laboratory experiment was conducted using CRD with three treatments, namely the concentration of KNO3 solution in part-per-million (ppm), the soaking time (in hour), and the plant age in days after planting (DAP). Then, from this experiment, data were collected. This was followed by data preparation, data analysis and statistical analysis. The results are used to verify whether the objectives have been achieved or not.

2.1. Materials

During the experiment, the materials used were IK tubers and seeds collected from Dramaga Research Field, KNO3, aquades, and compost fertilizer. And, the equipment consists of calipers, analytical weighing scale, rulers, measuring cylinder, nursery tray, wool, thread, paper label and bamboo.

2.2. Statistical Design or Design of Experiment

To achieve the objective, five levels of concentration (0 ppm as the control treatment, 1000, 2000, 3000, and 4000 ppm) and four levels of soaking time (0, 3, 6, and 12 hours) were used. Then, the germination rate was observed on the 14th, 21st, 28th, 35th, 42nd, 49th, 56th, and 63rd DAP.

In this experiment the seeds used were the ones harvested 45 days before planting. They were divided into 40 lots were prepared and each lot containing 100 seeds, was put into cross stitch cloth. The seeds were then soaked in aquadest to clean. After cleaning, they were soaked in KNO3 solution. Some 800 seeds were soaked in the solution of the first level of concentration. The same number of seeds were soaked in the second, third, fourth and fifth levels. And, at each level of soaking time, 1000 seeds were soaked. After soaking process, the seeds were washed with aquadest to remove KNO3 residual on the seeds surface. Then, they were planted in plastic jar containing washed-quartz sand.

An experiment unit was defined as one plastic jar. These units were arranged randomly. The observation was...
Moreover, done at every 7 days starting from age 14 to 63 DAP. The data observed from normal germinated seeds in each experimental unit were recorded and converted into percentage. The criterion of being normal germinated seed is when radicle becomes a perfect shoot and plumule has formed perfect leaf.

2.4. Statistical Analysis

Based a CRD with several treatments mentioned above, to test whether the concentration and the soaking time have different effect or not for each DAP, a multiple range test was employed. For this purpose, first, a general linear model (GLM) and ANOVA were used to analyze the data. If different effect occurs in different DAP, based on Duncan (1955) as suggested by Gregory (1965) and Dafaallah (2019), then Duncan’s multiple range test (DMRT) was used. In these regards, all statistical computations were performed using SAS System.

The GLM for ANOVA under CRD in DAP is,

\[ Y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \delta_{ik} + \omega_l + \gamma_{kl} + (\alpha\omega)_{il} + (\beta\omega)_{jl} + (\alpha\beta\omega)_{ijl} + \varepsilon_{ijkl} \]

Here \( Y_{ijkl} \) is the germination rate using the \( i \)-th level of KNO3 concentration, \( j \)-th level of soaking time, \( k \)-th replication and \( l \)-th DAP, and,

(i) \( \mu \) is the overall mean

(ii) \( \alpha_i \) is the effect of the \( i \)-th level of KNO3 concentration

(iii) \( \beta_j \) is the effect of the \( j \)-th level of soaking time

(iv) \( (\alpha\beta)_{ij} \) is the interaction of KNO3 concentration and soaking time

(v) \( \delta_{ik} \) is the random component of KNO3 concentration, soaking time and replication

(vi) \( \omega_l \) is the effect of the \( l \)-th level of DAP

(vii) \( \gamma_{kl} \) is the random component of replication and DAP

(viii) \( (\alpha\omega)_{il} \) is the interaction of KNO3 concentration and DAP

(ix) \( (\beta\omega)_{jl} \) is the interaction of soaking time and DAP

(x) \( (\alpha\beta\omega)_{ijl} \) is the interaction of KNO3 concentration, soaking time and DAP

(xi) \( \varepsilon_{ijkl} \) is the overall random component

By using this model, the results will be presented and discussed in the next section.

3. Results and Discussion

Table 1 in the Appendix summarizes the effect of soaking into KNO3 solution on seeds germination rate (in %) for each concentration and soaking time observed in terms of DAP. The letters a, b, and c are used to indicate whether the results of DMRT are significant or not for Type I error of 5%. For a DAP, the same letter in a column means no different effect.

In our experiment, the first germination appears on 14th DAP. We learn from this table that:

1. The germination rate on the 14th, 21st and 28th DAP with concentration 4,000 ppm is in general significantly higher than the control. But, the observations on the 35th until 63rd DAP did not show significant difference. This indicates that KNO3 has been significantly served to accelerate the germination process.

2. In general, in terms of concentration, the highest germination rate occurred at 3,000 ppm but not significantly different at 4,000 ppm and beyond, except on the 14th DAP where the highest occurred at 4,000 ppm. On the other hand, in terms of soaking time, the highest germination rate occurred for 3 hours. Thus, to a certain extent, higher concentration will accelerate the germination process. However, overdoses of concentration will lead to a poisoning condition.

3. The soaking time of 6 and 12 hours did not give significant effect. In general, soaking more than 3 hours leads to lower germination rate for all concentrations. This might happen since longer soaking time will cause toxic to seed germination.

4. Observation on 21st DAP showed that there was no effect of the combined treatments concentration and soaking time. Meanwhile, the concentration of 3,000 ppm produced the highest result. Interestingly, the effect caused during the initial treatment (0 hour soaking time) was not always followed by the same result overtime. This could be caused by the effect of KNO3 compound which had been absorbed by the seed during nursery period.

5. Observation at 28th, 35th, and 42nd DAP showed relatively similar effect compared to those observed at 21st DAP where concentration of 3,000 ppm and 3 hours soaking time which tended to give the highest result.

6. Observation at 49th DAP showed that for 0 hour soaking time at all 5 levels of concentration, the same results were produced except for concentration of 2,000 ppm. This concentration has significantly produced the lowest result, while the highest result was produced with 3,000 ppm. However, there was no significant difference between the application of 0, 1,000 and 4,000 ppm.

7. Soaking time of 6 hours in 5 levels of concentration did not show significant difference on the germination rate. Similar results were obtained for 3 hours soaking time except for soaking with 1,000 ppm which produced the lowest value. Meanwhile, the highest germination rate was produced at 3,000 ppm and 3 hours.

8. From all those treatments, it can be said that 3 hours soaking time and 3,000 ppm concentration gave the
best result when the plant age was 14 days. After that day, the effect of KNO₃ decreased and disappeared after 49th DAP. The study showed that the same germination rate will be obtained after 63rd DAP no matter whether KNO₃ was used or not.

9. It seems that the use of potassium nitrate in this study was on the right way since, according to Ruttanaruangboworn, et al. (2017), nitrate compound can reduce the amount in the metabolic regulatory process involving nicotinamide adenine dinucleotide phosphate (NADP) in a particular reaction on glucose metabolism.

10. Barba-Espín (2012) stated that KNO₃ solution at concentration 2,000 ppm in dark condition and temperature 15-30°C can trigger the seeds germination of lepidium virginicum, eragrotis curvula, polypogon monspelliensis, agrostis, and sorghum halepense. This paper shows that the use of that solution to trigger the seeds germination of IK has similar effect.

11. At the concentration 3,000 ppm and soaking time for 3 hours the use of KNO₃ tends to accelerate the seeds germination process of IK since the dormancy period has been reduced to 2-4 months. This is a significant result compared with the result in Jansen, et al. (1996) which stated that the dormancy period of IK is 5-6 months.

4. Conclusions

In this research, KNO₃ was applied in soaking process to accelerate the seeds germination of IK and to shorten the dormancy period. The effect of its concentration and soaking time was significant. The germination rate increased when the concentration moved from 1000 ppm to 3000 ppm but then decreased for 4000 ppm. The highest germination rate occurred at concentration 3,000 ppm on 14th to 63rd DAP. Furthermore, in terms of soaking time, 3 hours soaking time with 3,000 ppm concentration and 14th DAP gave the best result. It is worth noting that more than 3 hours of soaking leads to lower germination rate and higher concentration will cause toxic to seed germination process.

The study in this paper indicates that KNO₃ has been significantly served to accelerate the germination process. To a certain extent, higher concentration will accelerate the germination process. However, overdoses of concentration will lead to a poisoning condition. Longer soaking time will also cause toxic to seed germination.

This study is unprecedented. If the previous researchers showed that the use of that KNO₃ solution can trigger the seeds germination of several plants, this paper shows similar effect when it was used to trigger the seeds germination of IK. More precisely, it can be said that 3,000 ppm concentration and 3 hours soaking time gave the best result when IK plant age was 14 days. Moreover, the dormancy period has been reduced from 5-6 months to 2-4 months.

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**APPENDIX**

**Table 1.** Effect of soaking into KNO₃ solution on seeds germination rate (in %) using different concentration and soaking time observed in terms of DAP

| Observation (DAP) | Concentration (ppm) | Soaking time (hours) |
|------------------|---------------------|----------------------|
|                  | 0       | 0.67b    | 1.67a    | 0.00b    | 0.00b    |
|                  | 1000    | 0.67b    | 2.67a    | 0.33b    | 0.00b    |
|                  | 2000    | 0.33b    | 6.00a    | 1.33b    | 0.00b    |
|                  | 3000    | 0.67b    | 5.33a    | 1.00a    | 0.67b    |
|                  | 4000    | 6.33a    | 0.67b    | 1.33a    | 0.33b    |
| Mean             | 17.3ab  | 2.27a    | 3.10b    | 0.80bc   | 0.20c    |
|                  | 0       | 11.00a   | 10.00a   | 1.00a    | 2.00a    |
|                  | 1000    | 4.00a    | 14.00a   | 7.00a    | 8.00a    |
|                  | 2000    | 6.00a    | 16.00a   | 8.00a    | 4.00a    |
|                  | 3000    | 15.00a   | 20.00a   | 9.00a    | 7.00a    |
|                  | 4000    | 17.00a   | 7.00a    | 6.00a    | 4.00a    |
| Mean             | 10.80a  | 13.27a   | 6.40b    | 4.87b    |
|                  | 0       | 39.00a   | 42.00a   | 16.00a   | 27.00a   |
|                  | 1000    | 37.00a   | 39.00a   | 34.00a   | 34.00a   |
|                  | 2000    | 30.00a   | 49.00a   | 36.00a   | 29.00a   |
|                  | 3000    | 50.00a   | 49.00a   | 29.00a   | 37.00a   |
|                  | 4000    | 48.00a   | 41.00a   | 30.00a   | 30.00a   |
| Mean             | 30.73a  | 43.93a   | 29.00b   | 31.47b   |
|                  | 0       | 65.00a   | 56.00a   | 40.00a   | 45.00a   |
|                  | 1000    | 59.00a   | 53.00a   | 55.00a   | 56.00a   |
|                  | 2000    | 44.00a   | 61.00a   | 55.00a   | 48.00a   |
| Mean             | 59.67a  | 61.20a   | 49.40b   | 52.60b   |
|                  | 0       | 74.00a   | 73.00a   | 53.00a   | 59.00a   |
|                  | 1000    | 71.00a   | 67.00a   | 65.00a   | 65.00a   |
|                  | 2000    | 58.00a   | 74.00a   | 66.00a   | 57.00a   |
|                  | 3000    | 78.00a   | 81.00a   | 64.00a   | 68.00a   |
|                  | 4000    | 73.00a   | 74.00a   | 61.00a   | 71.00a   |
| Mean             | 70.87a  | 73.67a   | 61.87b   | 63.93b   |
|                  | 0       | 78.33a   | 80.30ab  | 61.67a   | 69.67ab  |
|                  | 1000    | 80.67a   | 70.00c   | 71.67a   | 73.67ab  |
|                  | 2000    | 64.67b   | 79.00ab  | 69.33a   | 67.67b   |
| Mean             | 82.00a  | 84.00a   | 68.33a   | 72.00ab  |
|                  | 0       | 76.67a   | 76.67b   | 68.67a   | 77.00a   |
|                  | 1000    | 76.87a   | 70.00a   | 67.93b   | 72.00b   |
|                  | 2000    | 87.00a   | 84.67ab  | 67.33a   | 71.67b   |
| Mean             | 87.00a  | 84.67ab  | 67.33a   | 71.67b   | 72.00b   |
|                  | 1000    | 85.67a   | 75.33c   | 75.67a   | 74.33ab  |
|                  | 2000    | 65.00b   | 84.67ab  | 71.67a   | 74.00ab  |
| Mean             | 82.00a  | 88.33a   | 76.33a   | 76.67ab  |
|                  | 0       | 91.00a   | 89.00ab  | 75.67a   | 76.00b   |
|                  | 1000    | 86.67a   | 79.33c   | 77.67a   | 77.00b   |
|                  | 2000    | 70.67b   | 88.00ab  | 77.67a   | 78.33b   |
| Mean             | 85.33a  | 92.33a   | 82.00a   | 82.00ab  |
|                  | 1000    | 84.33a   | 81.33bc  | 77.00a   | 85.33a   |
| Mean             | 85.33ab | 86.00a   | 78.00c   | 79.80bc  |
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