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PHENOLOGY OF FLOWERING AND FRUITING AND EFFECT OF KNO_3 AND H_2O_2 ON GERMINATION PROCESS OF *AMORPHOPHALLUS MUELLERI* BLUME

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ABSTRACT

Amorphophallus muelleri Blume also known as Indonesian Konjac (IK, in short) is a wild plant that spreads out in Indonesia especially in the southern part. The genus *Amorphophallus* can also be found in some countries in South-East Asia. The IK tuber contains glucomannan, a compound which has high economic value as raw material in many industries such as food, drink, pharmacy, cosmetics, paper, rubber, textile, film industries and many others. The plant is easy to cultivate. Due to the economic benefit of IK tubers and to the easiness of its cultivation, this study was carried out to increase the productivity of glucomannan. The current productivity is still low compared to foreign demand. For example, in 2020 alone, according to the Ministry of Agriculture, Republic of Indonesia, only 12 % of foreign demand have been fulfilled. Therefore, there is an urgent need to increase the productivity of IK tubers. This is the main problem of this research. Its objectives were two-fold. First, was to study the effect of tuber weight on flowering percentage, flower size, and fruiting which is represented by the number of fruits and the number of seeds. Second, was to find out the right concentration of KNO_3 and H_2O_2 solutions as well as the soaking time in those solutions to break the dormancy period and to increase the germination rate. For these purposes, a laboratory experiment using completely randomized design with three treatments was conducted and the collected data were analyzed using general linear model, analysis of variance and multiple comparison test. The results indicate that the tuber weight significantly affects the flowering percentage, flower size, number of fruits and number of seeds of IK. The heavier the planted tuber, the higher the flowering percentage and the larger the flower size, number of fruits and number of seeds. The response on dormancy breaking treatment indicates that there is no significant effect of soaking treatment in KNO_3 and H_2O_2 solutions on dormancy period of the IK seeds. The KNO_3 and H_2O_2 solutions have only effect on increasing the germination rate and on shortening the time period for seeds to germinate. Moreover, unlike H_2O_2, there is no residual effect of KNO_3 on seeding growth, and on weight and shape of the IK tuber. To the knowledge of the authors, these findings are unprecedented and could thus, contribute to the literature.

Key words: dormancy period, flower, growth, germination, H_2O_2, IK-tuber, KNO_3, seeds

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ABSTRAIT

Amorphophallus muelleri Blume également connu sous le nom de Konjac Indonésien (IK en bref) est une plante sauvage qui se répand en Indonésie en particulier dans la partie sud. Le genre *Amorphophallus* peut également être trouvé dans certains pays de la région de l'Asie du Sud-Est. De la littérature, nous apprend que le tubercule IK contient un composé de glucomannane qui a une valeur économique élevée comme matière première dans de nombreuses industries telles que l'alimentation, les boissons, la pharmacie, les cosmétiques, le papier, le caoutchouc, le textile, le film, les industries et bien d'autres. La plante est facile à cultiver. En raison des avantages économiques des tubercules IK et de la facilité de sa culture, cet article traite d'une étude visant à augmenter la productivité du glucomannane. La productivité actuelle est encore faible par rapport à la demande étrangère. Selon le ministère de l'Agriculture de la République d'Indonésie, en 2020 seulement 12% de la demande étrangère ont été satisfaits. Par conséquent, il est urgent d'augmenter la productivité des tubercules IK. C'est le principal problème de cette recherche. Ses objectifs sont de deux ordres. Tout d'abord, il s'agit d'étudier l'effet du poids des tubercules sur la floraison et la fructification. Deuxièmement, il s'agit de trouver la bonne concentration de solutions KNO_3 et H_2O_2 ainsi que le temps de trempage dans ces solutions pour briser la période de dormance et pour augmenter le taux de germination. À ces fins, une expérience de laboratoire utilisant une conception complètement aléatoire avec trois traitements a été menée et les données collectées ont été analysées à l'aide d'un modèle linéaire général, d'une analyse de la variance et d'un test de comparaison multiple. Les résultats indiquent que le poids des tubercules affecte la floraison et la fructification des IK. Plus le tubercule planté est lourd, plus le pourcentage de floraison est élevé et plus la taille des fleurs, le nombre de fruits et la taille des graines sont grands. La réponse au traitement de rupture de dormance indique qu'il n'y a aucun effet du trempage de KNO_3 et H_2O_2 sur la période de dormance des graines. Les solutions KNO_3 et H_2O_2 n'ont d'effet que sur l'augmentation du taux de germination et le raccourcissement du délai de germination des graines. De plus, il n'y a pas d'effet résiduel de KNO_3 sur la croissance des semis et sur le poids et la forme du tubercule IK. À la connaissance des auteurs, ces résultats sont sans précédent et donc, espérons-le, pourraient contribuer à la littérature.

Mots-clés: croissance, fleurs-IK, germination, grains, H_2O_2, KNO3, période dormance, tubercule-IK

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INTRODUCTION

Phenology can be defined as the natural growth of vegetation without involving any treatment. Since the last two decades, it is an active research area covering fruit trees, field crops, plant, and vegetation [1-5]. This paper is focused on *Amorphophallus muelleri* Blume also known as Indonesian Konjac (IK). Indonesian Konjac is one of tuber plants which belong to the *Araceae* family and Monocotyledon class. It is a typical lowland to upland (100-1000 masl) plant that grows in the tropical and subtropical zones of the Paleotropical Kingdom (Paleotropics) comprising the tropical areas of Africa, Asia and Oceania (excluding Australia and New Zealand). However, historically, the plant is originally from West Africa [6]. Thus, this plant is very familiar to the people of Africa especially to those who live in the paleotropics of West Africa.

The product of IK plant is a tuber containing glucomannan, a compound which has high economic value and has been exported to several countries such as Japan, Taiwan, Korea, China, Netherland, and other European countries. This compound is of high economic value and has many benefits either in terms of industrial benefits or in world food security program. It is worth noting that this plant has the best growth if it is cultivated under 50 to 60 percent sunlight with the soil acidity (pH) of 6 to 7.5; in sandy, loose and compost soil; rainfall of 1000 to 1500 millimeters every year; and with air temperature of 26 to 30 Celsius degrees.

During a food crisis, with appropriate processing, the IK tuber can be consumed as a substitute to traditional foods like rice [6]. Glucomannan, besides being utilized as food material, can be used as raw material for several industries such as medicine, cosmetic, paper, textile, synthetic rubber, filming, among others. In medical industry, glucomannan is usually used as dietary food such as “konyaku” and “shirataki.” These are two types of Japanese foods served as snack or supplement and usually cooked in the form of soup. These foods contain lots of dietary fiber which are suitable for dieting. They contain high fiber which may increase food digestibility, reduce blood cholesterol level and bring down obesity. Glucomannan contained in IK tuber is 32,8 % of dry matter. Indonesian konjac plant is also known as indigenous traditional medicine to treat some diseases such as dysentery, cholera, digestive disorder and rheumatism [6].

In Indonesia, IK spreads out in Sumatera, Java, Madura, Bali, Celebes, Flores and Lombok. The yearly export value from 1999 to August 2003 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). Its production can still be increased because the demand of importing countries has not been met yet; according to the Ministry of Agriculture, Republic of Indonesia, only 12 % of demand can be fulfilled this year. Thus, this may increase the state revenue and provide job opportunities as shown by the statistics of export value from time to time. After being harvested, IK seeds from parent tree cannot immediately germinate and then grow because they experience long dormancy period about 5-6 months [7]. To accelerate the seeds growth from its formation, it needs to break the dormancy period [8]. Preliminary

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experiments conducted to study how to break the seed dormancy showed very promising results.

The quest 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, a report on germination rate of Avena fatua was given in Hilton and Bitterli [9] and Dostatny DF *et al*. [10]. A discussion on germination rate of henopodium album can be found in Moravcová and Dostálek [11] and Eslami [12]. Meanwhile, that of Phalaris minor and Poa annua was studied by Ohadi S *et al*, [13]. That of canary grass was delivered by Ohadi, Mashhadi and Afshari [13] and Derakhshan A *et al*. [14]. One can also learn that of weed in Gardarin, Durr and Colbach [15] and Alshallash [16]. Very recently, germination behavior of perennial halophyte of Arabian deserts in Bhatt, Bhat and Thomas [17]. Other examples, on the interaction of light, nitrate and alternating temperature in promoting the germination of dormant seeds of weed species, that of herbaceous plant, and that of oats were studied, respectively, in Grubišić and Konjević [18], Baskin and Baskin [19] and Alshallash [20]. All these examples illustrate the importance of increasing the germination rate and, shorten the dormancy period of plants in increasing their productivity.

In nature, the productivity of glucomannan contained in IK (*Amorphophallus muelleri* Blume) tubers is low. The cause is due to the slow formation of plants. This study was conducted to investigate the effect of KNO_3 and H_2O_2 on seed germination rate and on the dormancy period of IK plant. Besides that, since IK seeds come from the flower, it was also conducted to investigate the effect of the weight of IK tuber on flowering percentage and flower size.

MATERIALS AND METHODS

It is well known that theoretically KNO_3 that H_2O_2 can increase the seed germination rate because:

1. KNO_3 can give additional O_2 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. In nature, KNO_3 will decompose into nitric acid and K element. If acid can attenuate the seed shell to facilitate oxygen and water to enter the seed, K element will help in absorbing water so that germination proceeds more rapidly.
2. Meanwhile, H_2O_2 will decompose into H_2O and O_2. O_2 can be used to accelerate the respiration process. Thus, it will produce more energy for cells synthesis process and in the end increase the growth of embryo and shoot comes up.

The problem encountered in this study is to find an optimal concentration of KNO_3 as well as that of H_2O_2 and the soaking time to increase the seed germination rate and to shorten the dormancy period. For this purpose, an experiment was conducted using CRD with three treatments, namely, the concentration of KNO_3 and that of H_2O_2, the soaking time, and the plant age. The experiment was conducted at Darmaga Research Field, Bogor Agricultural University (also known as IPB) and the materials used were IK tubers and seeds collected from IPB Darmaga Research Field, KNO_3, H_2O_2,

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aquadest, and compost fertilizer. In this experiment, the equipment consisted of calipers, analytical weighing scale, rulers, measuring cylinder, nursery tray, wool, thread, paper label and bamboo.

It is worth noting that increasing productivity of IK plant means not only accelerating gemination process and shortening the dormancy period but also enlarging the tuber size. In other words, making the tuber heavier. The larger or heavier the tuber, the more the glucomannan content and thus the more the productivity of IK plant. Therefore, there is a need to figure out the relationship between the weight or size of the tuber produced and the number of flowers, flower size, number of fruits, and number of seeds in each flower cob.

Flowering Percentage

The first objective was to study the effect of tuber weight on the percentage of flowering, flower size, number of fruits and number of seeds. For this purpose, the IK tubers were classified into four groups (or levels) based on their weight namely, B_1 (300-500 g weight), B_2 (600-800 g), B_3 (900-1,100 g), and B_4 (1,200-1,400 g). As many as 132 IK tubers were classified: 71 tubers into B_1, 37 into B_2, 15 into B_3, and 9 into B_4. On the other hand, land preparation begins with the weeding process in the planting area followed by making a planting hole of size 50 cm x 50 cm and 30 cm depth. At each planting hole, 0.5 kg of compost fertilizer was filled inside until the top surface of the soil. Each of those 132 tubers were then planted in a prepared hole; one tuber per hole.

After one tuber was planted, observation was then done every 7 days until all the plants produced fruit. Data recorded at every observation time consisted of:

(i) Number of flowering tubers
(ii) Number of flowering tubers in each group
(iii) The flowering percentage was calculated using Equation 1. In each group, the percentage of blooming tuber is

$$\% \text{ blooming tubers} = \frac{\text{Number of blooming tubers in the group}}{\text{Total number of tubers in the group}} \text{ x } 100\% \quad (1)$$

(iv) Flower size
(v) Average length of female flowers and average length of male flowers in each flower cob
(vi) Number of fruits and seeds in each flower cob

Effect of Potassium Nitrate (KNO_3) on Seed Germination

Germination is a process of developing seeds into young plants. This process is important to study since it can shorten the dormancy period. Due to that special importance of germination process, the effect of KNO_3 concentration and soaking time on the seed germination rate was studied. In our experiment, the concentration had five levels, namely 0, 1000, 2000, 3000, and 4000 ppm. Meanwhile, soaking time had four levels: 0, 3, 6 and 12 hours. The plant age where the result of germination process was observed was on the 14th, 21st, 28th, 35th, 42nd, 49th, 56th and 63rd DAP. Seeds used were harvested 45 days before planting, which were then divided into 60 lots and each was put into cross-stitch cloth. Each lot was then soaked into aquadest (concentration of 0

ppm) and four levels concentration of KNO_3 at a pre-determined soaking time. After being soaked, seeds were washed with aquadest to remove KNO_3 residual on the seeds surface. After that, they were planted into plastic jar containing washed-quartz sand.

One experiment unit was one plastic jar and arranged randomly. The observation was done every 7 days starting from 14th to 63rd day after planting (DAP). The data collected were the normal germinated seeds from each experimental unit and converted into percentage. The criterion of being normal germinated seed of IK is when the radicle becomes a perfect shoot and the plumule has formed perfect leaf. In order to determine the negative effect of KNO_3 (if any) on the tuber, as many as 40 germinated seeds of each experimental unit were planted on the ground. Planting was done on a ground with compost fertilizer applied with planting size 15 cm x 20 cm under the albasia tree as cover crop.

The observation consists of the number of growing plants, the growing percentage, and the weight and shape of tubers. If the number of growing plants and the growing percentage were observed during the growth period, the weight and shape of the tuber were observed after the plant had completed the dormancy period and been harvested.

Effect of Hydrogen Peroxide (H_2O_2) on Seed Germination

To investigate the effect of H_2O_2 concentration and soaking time on the seed germination, a similar experiment was conducted. In this case, the concentration of H_2O_2 has four levels, namely 0, 500, 100, and 1500 ppm. And, soaking time has four levels, namely, 0, 6, 12 and 18 hours while the plant age has seven levels 30th, 36th, 42nd, 48th, 54th, 60th, and 66th DAP. The harvested seeds from "IPB Darmaga" Research Field were used. They were divided into 48 experimental units where each unit used 25 seeds and put into cross-stitch cloth. The bags containing seeds were soaked. Some were soaked in aquadest (concentration of 0 ppm) and some in each of the other three concentration levels under a pre-determined level of soaking time. After soaking, seeds were washed to remove H_2O_2 residual on the seed surface. After that, they were planted into plastic jars containing of washed-quartz sand and arranged randomly. The observation was done every 6 days starting from 30th to 66th DAP. Then, normal germinated seeds grown on each unit were counted and converted into percentage using Equation (2).

$$\text{Percentage of germination} = \frac{\text{Number of normal seeds in each jar}}{25} \text{ x } 100\% \qquad (2)$$

The data collected from the experiment related to the first objective are presented in Table 1. Meanwhile, those collected from the experiment to study the effect of KNO_3 and that of H_2O_2 on germination rate are given in Table 2 and Table 3, respectively.

Data Analysis

All statistical computations were performed using the SAS System. Data analysis was done using the generalized linear model (GLM) and Analysis of Variance (ANOVA) method suggested by Gomez and Gomez [21]. The Duncan Multiple Range Test (DMRT) was used to test which treatment levels have the same effect.

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RESULTS AND DISCUSSION

This section reports the effect of IK tuber weight on the percentage of flowering, flower size, number of fruits, number of seeds, and the effect of KNO_3 and that of H_2O_2 on germination process and dormancy period.

Flowering Percentage

Flowering percentage was computed based on the tuber population number from each flowering group and then converted into percentage. The flowering percentage on each group based on tuber weight is shown in Figure 1.

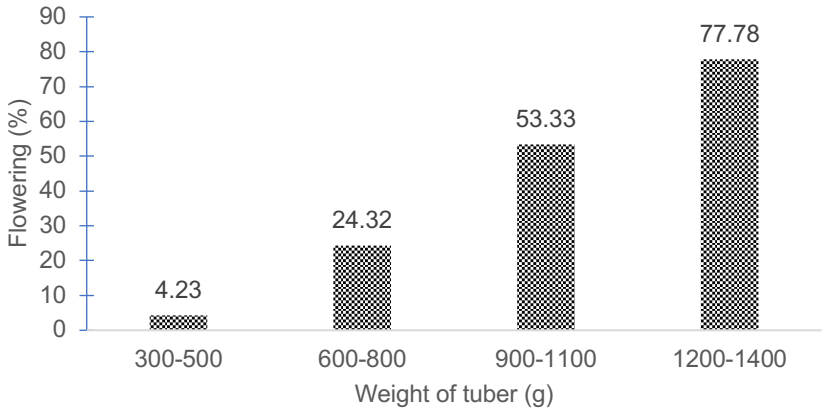

Figure 1: Effect of tuber weight on flowering percentage

Figure 1 shows that the heavier the tuber, the higher the flowering percentage. Tuber weight of 1,200-1,400 g produced the highest flowering percentage (more than 75%), while 300-500 g of weight produced the lowest flowering percentage (less than 5%). The increase of flowering percentage resulting from increasing weight of the tuber may be due to the fact that heavier tubers contain higher food reserve. In fact, heavier tuber contains more carbohydrate and thus, leads to stronger ability to flower as stated in Jansen, van der Wilk and Hetterscheid [6] and Gregory [22].

Flower Size

The flower size was measured as the length of flower. In each group, all male and female flowers were collected from all flower cobs and then the length of each flower was measured (in cm). Finally, for each group, the average length of female flowers and that of total (female and male) flowers were calculated. The results are shown in Figure 2.

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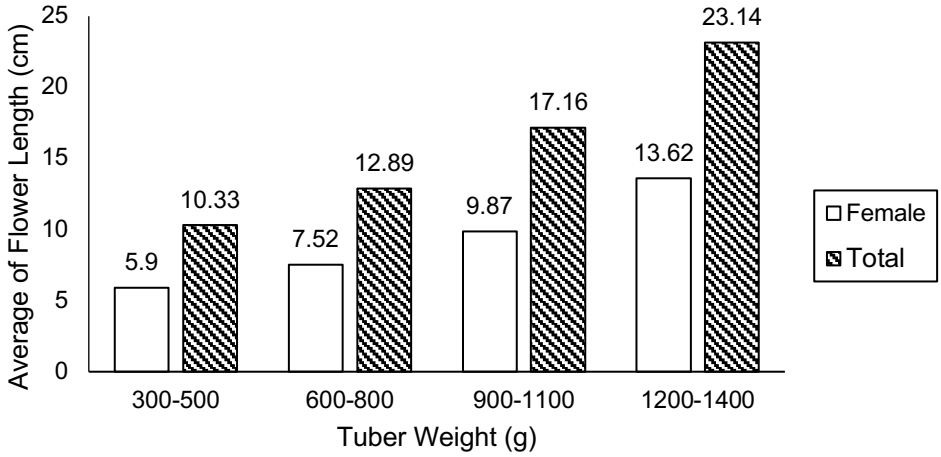

Figure 2: Effect of tuber weight on flower length

This figure shows that flower size followed a similar pattern with the flowering percentage presented in Figure 1. The heavier the tuber, the greater the length of flower especially of female flowers. The same pattern as in Figures 1 and 2 also occurs on the average number of fruits and that of seeds in each flower cob as can be seen in Figure 3.

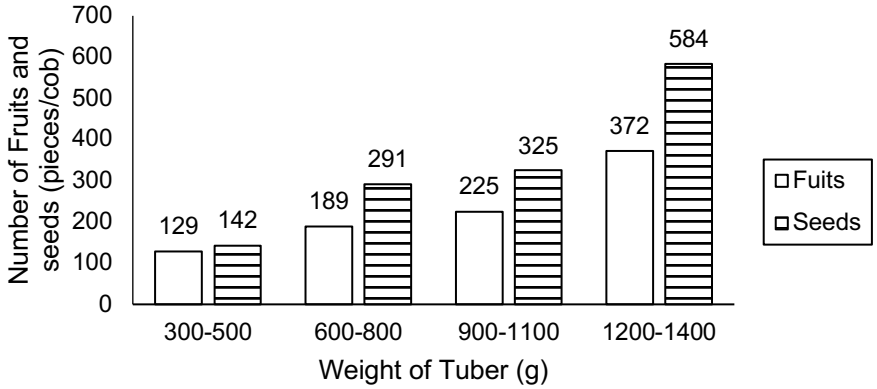

Figure 3: Effect of tuber weight on number of fruits and number of seeds

The results in these three figures show that the heavier tuber produced higher flowering percentage, longer flower size, higher number of fruits and number of seeds in each flower cob. These data, presented numerically in Table1, strongly indicate the need to enlarge the tuber size or, in other words, to make the tuber heavier. Moreover, the larger or heavier the tuber, the more the glucomannan content and thus, the more the productivity of IK plant.

Effect of Potassium Nitrate (KNO_3) concentration and soaking time

The data observed on each DAP for each KNO_3 concentration and each soaking time, together with the statistics related to those data, are presented in Table 2. This table shows that on 14th DAP the seeds germination rate under KNO_3 treatment and soaking

time did generally not show significant difference. This indicates that on 14th DAP, the seeds treated with KNO_3 or control produced the same germination rate. It means that on that observation day KNO_3 did not show the power to break the dormancy period. This table also shows that germination of seeds treated with KNO_3 at the concentration of 4,000 ppm on 14th, 21st and 28th DAP in general was significantly higher than the control. However, the observations on 35th to 63rd DAP for all levels of soaking time did not show significant difference. This indicates that KNO_3 only served to accelerate the germination for lower levels of DAP and had no influence for higher levels. In general, the effect of KNO_3 concentration for all levels of soaking time observed on all levels of DAP showed that the highest germination rate occurred at 3,000 ppm.

The effect of soaking time treatment on germination rate observed on 14th to 63rd DAP showed that the highest germination rate occurred at 3 hours soaking time. The application of KNO_3 with higher concentration to a certain extent will accelerate the germination process. However, over concentration can lead to poisoning.

According to the literature, KNO_3 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 %) at 22 weeks after planting (WAP) [7]. Previous studies have remarked that the effectiveness of soaking pine walnut in KNO_3 concentration of 500-1,000 ppm is less significant (less visible), while the 1,500 ppm concentration significantly accelerates the germination but at higher level of concentration [23]. It was also stated that the concentration level of KNO_3 up to 200 ppm may trigger the germination of seeds of *Eragrotis curvula* species [24]. And, the application of 500 ppm and 1,000 ppm with 14 hours soaking time under sunlight and 10 hours dark on *Onopordium acanthium* L seeds produces the germination rate of 66.6 % and 88.2 % [25]. It is higher than the control (41,8 %).

From Table 2 we learn that the application of KNO_3 and soaking time of 6 and 12 hours did not give significant response. Furthermore, soaking seeds for more than 3 hours leads to lower germination rate at each level of concentration. This might happen since higher concentration of KNO_3 will prove toxic to seed germination. On 21st DAP it showed that there was no effect of the combined treatment of concentration and soaking time. Meanwhile, the concentration of 3,000 ppm produced the highest result but not different when it was not soaked (0 hour). This indicates that the effect caused during the initial treatment was not always followed by same result over time. This could be due to the effect of KNO_3 compound which had been absorbed by the seed during nursery period. On 28th, 35th, and 42nd DAP the table also showed the response patterns generated by the effect of concentration and soaking time. The results were relatively similar to those observed on 21st DAP, where concentration of 3,000 ppm and 3 hours soaking period tended to give the highest result except on 28th DAP. Observation on 49th DAP showed that for 0 hour of soaking time and for all levels of concentration, the same results were produced except for concentration of 2,000 ppm. This concentration significantly produced the lowest result. Finally, soaking time of 6 and 12 hours did not show significant difference on the germination rate. And, this is true for all levels of concentration.

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From all those treatments, it can be said that 3 hours soaking time and 3,000 ppm concentration gave the best result. This result was only effective during the first 14 days. After that day, the effect of KNO_3 decreased and disappeared after 49th DAP. The study showed that the same germination percentage will be obtained after 63rd DAP, no matter whether KNO_3 was used or not. However, since the lack of oxygen is one of the reasons why seed cannot grow immediately, to increase the germination rate one can also use a nitrate compound. This compound can reduce the amount of nicotinamide adenine dinucleotide phosphate (NADP) in the metabolic regulatory process and in the particular reaction on glucose metabolism [26]. Thus, it helps to produce oxygen. This is in line with the previous studies which stated that KNO_3 associates with the activity of pentose phosphate pathways as remarked in Gashi *et al.* [26] and Ruttanaruangboworn *et al.* [27]. Hence, limited availability of oxygen causes the path of pentose phosphate to be inactive because oxygen is used for respiratory activity through other pathways.

Besides using a nitrate compound, to increase the germination rate, one can also use calcium nitrate {$Ca(NO_3)_2$}. The germination rate increases when the concentration of calcium nitrate increases until a certain level. This is in line with the experiment using KNO3 where, see Table 2, in general the rate increases from 1000 to 3000 ppm but then decreases for 4000 ppm. In this experiment, the first germination appears on 14th DAP.

To conclude, it is worth noting that KNO_3 concentration of 2,000 ppm in dark condition and temperature 15-30^{o}C have triggered the seeds germination of *Lepidium virginicum*, *Eragrotis curvula*, *Polypogon monspelliensis*, *Agrostis*, and *Sorghum halepense* [28]. Thus, Table 2 showed a similar effect of KNO_3 on seeds germination of IK where the optimal results were achieved for 3,000 ppm concentration and 3 hours soaking time. Furthermore, for 3 hours soaking time the use of KNO_3 tends to accelerate the seeds germination process of IK by reducing dormancy to 2-4 months. This is a significant result compared to the one which stated that the dormancy period of IK is 5-6 months [6].

Effect of Hydrogen Peroxide (H_2O_2) concentration and soaking time

The effects of soaking seeds in H_2O_2 solution at different concentration and different soaking time on the seeds germination rate of IK were studied on 30th to 66th DAP. The results of the experiment are presented in Table 3. This table shows that the concentration of H_2O_2 gave significant effect to seeds germination on 30th to 48th DAP. For these DAPs, the longer the DAP, the higher the germination rate. Beyond 48th DAP, the effect of H_2O_2 concentration disappeared. This also applied to the seeds used in control treatment. And, the rate then went slowly and did not significantly increase from 54th to 66th DAP. This means that H_2O_2 only accelerated the germination and did not reduce the dormancy period. In general, the treatment with several levels of H_2O_2 concentration showed that the highest germination rate was produced at the concentration 500 ppm and 1,000 ppm. On the other hand, the concentration 1,500 ppm is not recommended since the corresponding rate decreased.

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In terms of soaking time, on 30th to 42nd DAP the germination rate was significantly higher when soaked for 6, 12 and 18 hours. Beyond 42nd DAP, from 48th DAP and above, the soaking time did not give a significant effect. The highest germination rate occurred at soaking time for 18 hours except on the 30th DAP. In the latter case, the highest germination rate was obtained at 12 hours soaking.

It is interesting to note that the application of H_2O_2 concentration of 1 % (10,000 ppm) for 12 hours can increase the seeds germination of *Abies amabilis*, *Picea glauca*, and *Pinus contoria* [29]. Compared to this study, Table 3 showed that H_2O_2 can also be used to get an optimum germination rate of IK seeds by using the concentration of 500 ppm or 1,000 ppm for 18 hours soaking time.

CONCLUSION

According to the results obtained in this study, the heavier the tuber weight the larger the physical measures of flower, fruit, and seed. In terms of flowering percentage, the heavier the tuber, the higher the flowering percentage. Tubers of 1,200-1,400g weight produced the highest flowering percentage. Heavier tubers also produced higher numbers of fruits and seeds.

The effect of KNO_3 concentration and soaking time is also significant. Three hours soaking time at 3,000 ppm concentration and 14th DAP gave the best result. More than 3 hours of soaking leads to lower germination rate while higher concentration is clearly toxic to seed germination process.

Regarding the effect of H_2O_2 and soaking time on seeds germination rate, the higher the germination rate was achieved on 30th to 48th DAP. From this study, the recommended concentration was 500 ppm or 1,000 ppm. Beyond 48th DAP, from 54th to 66th, the use of H_2O_2 is not effective anymore. In addition, the use of concentration of 1,500 ppm is not recommended since at this concentration the germination rate decreased. In terms of soaking time, on 30th to 42nd DAP, the germination rate was significantly higher when seeds were soaked for 6, 12 and 18 hours. Beyond 42nd DAP, the soaking time did not give any significant effect while the highest germination rate occurred at soaking time of 18 hours except on 30th DAP. On 30th DAP, the highest germination rate was obtained at 12 hours of soaking.

Regarding the dormancy period, the use of KNO_3 has accelerated the germination process and tended to reduce the dormancy period from 5-6 months to 2-4 months. On the other hand, the use of H_2O_2 has only increased the germination rate and did not reduce dormancy period.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Table 1: Influence of tuber weight on flowering tuber, flower size, number of fruits and seeds

Tuber weight(g)	Flowering Tuber (%)	Average flower length (cm)			Number of	
		Female	Male	Total	Fruits	Seeds
300-500	4.23d	5.90d	4.43c	10.53	129c	142d
600-800	24.32c	7.52c	5.37c	12.89	189b	291c
900-1100	53.33b	9.87b	7.73b	17.60	225b	325b
1200-1400	77.78a	13.62a	9.52a	23.14	372a	584a

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Table 2: The effect of soaking into KNO_3 at different concentration and soaking time on the seeds germination rate (in %) of Indonesian konjac on 14th to 63rd DAP

Observation (DAP)	KNO_3 Concentration (ppm)	Soaking time (hour)			
		0	3	6	12
14	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	1.73ab	3.27a	0.80bc	0.20c
21	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
28	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
35	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
	3000	68.00a	71.00a	50.00a	61.00a
	4000	62.00a	64.00a	47.00a	53.00a
	Mean	59.67a	61.20a	49.40b	52.60b
42	0	74.00a	73.00a	53.00a	59.00a
	1000	71.00a	67.00a	65.00a	65.00a

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	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
49	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
	3000	82.00a	84.00a	68.33a	72.00ab
	4000	78.67a	76.67b	68.67a	77.00a
	Mean	76.87a	70.00a	67.93b	72.00b
56	0	87.00a	84.67ab	67.33a	71.67b
	1000	85.67a	75.33c	75.67a	74.33ab
	2000	65.00b	84.67ab	71.67a	74.00ab
	3000	82.00a	88.33a	76.33a	76.67ab
	4000	79.67a	79.00bc	73.00a	82.67a
	Mean	79.87ab	82.40a	72.80c	75.87bc
63	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
	3000	85.00a	92.33a	82.00a	82.00ab
	4000	84.33a	81.33bc	77.00a	85.33a
	Mean	85.33ab	86.00a	78.00c	79.80bc

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Table 3: The effect of soaking into H_2O_2 at different concentration and soaking time on the seeds germination rate (in %) of Indonesian konjac on 30 to 66 DAP

Observation (DAP)	H_2O_2 Concentration (ppm)	Soaking time (hours)			
		0	6	12	18
30	0	0.00a	1.33b	0.00b	0.00b
	500	0.00a	8.00a	13.00a	12.00a
	1000	0.00a	6.67a	16.00a	1.33b
	1500	0.00a	2.67b	0.00b	2.67b
	Mean	0.00b	4.67a	7.33a	4.00a
36	0	8.00b	10.67c	2.67d	13.33c
	500	14.67a	24.00a	38.67b	53.33a
	1000	12.00ab	29.33a	44.00a	21.33bc
	1500	6.67ab	14.67b	28.00c	26.67b
	Mean	10.33b	19.67ab	28.33a	28.67a
42	0	26.67b	25.33d	18.67c	33.33c
	500	36.00a	46.67a	54.67a	60.00a
	1000	36.00a	37.33b	52.00a	49.33b
	1500	13.33c	30.67c	45.33b	45.33b
	Mean	28.00b	35.00ab	42.67a	47.00a
48	0	60.00b	60.00b	45.33b	60.00c
	500	62.67b	69.33a	78.67a	78.67a
	1000	69.33a	66.67a	69.33b	70.67b
	1500	42.67c	61.33b	69.33b	68.00b
	Mean	58.67a	64.33a	65.67a	69.33a
54	0	83.00a	72.00c	65.33b	76.00a
	500	70.67b	77.33b	88.00a	82.67a
	1000	80.00a	74.67b	84.00a	82.67a
	1500	66.67b	80.00a	68.00b	84.00a
	Mean	74.33a	76.00a	76.33a	81.33a
60	0	85.33b	77.33b	78.67b	85.33b

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	500	72.33c	85.33a	89.33a	85.33b
	1000	90.67a	80.00ab	85.33b	82.67b
	1500	70.67c	84.00ab	81.33ab	89.33a
	Mean	80.33a	81.67a	83.67a	85.67a
66	0	90.67b	85.33d	85.33c	92.00b
	500	84.00c	89.33b	90.67a	89.33d
	1000	92.00a	86.67c	86.67b	90.67c
	1500	77.33d	94.67a	86.67b	93.33a
	Mean	86.00a	89.00a	87.33a	91.33a

https://doi.org/10.18697/ajfand.100.19425

REFERENCES

1 **Chmielewski FM, Müller A and E Bruns** Climate Changes and Trends In Phenology Of Fruit Trees And Field Crops In Germany, 1961–2000 *Agric. For. Meteorol* 2004; **121 (1):** 69-78.

2 **Cleland EE, Chuine I, Menzel A, Mooney HA and MD Schwartz** Shifting Plant Phenology In Response To Global Change *Trends Ecol. Evol* 2007; **22 (7):** 357-365.

3 **Atkinson PM, Jeganathan C, Dash J and C Atzberger** Inter-comparison of four models for smoothing satellite sensor time-series data to estimate vegetation phenology *Remote Sens. Environ* 2012; **123:** 400–417.

4 **Jin C, Xiao X, Merbold L, Arneth A, Veenendaal E and WL Kutsch** Phenology and gross primary production of two dominant savanna woodland

5 **Workie TG and HJ Debella** Climate change and its effects on vegetation phenology across ecoregions of Ethiopia *Glob. Ecol. Conserv.* 2018; **13:** 00366.

6 **Jansen PC, van der Wilk C and WL Hetterscheid** *Amorphophallus* Blume ex Decaisne . E-Prosea Detail. August 1996: 1-5.

7 **Bian L, Yang L, An Wang J and HL Shen** Effects of KNO3 Pretreatment and Temperature on Seed Germination of *Sorbus pohuashanensis J. For. Res.* 2013; **24 (2):** 309-316.

8 **Simón BE, Latorre F and C Rotundo** Study of The Reproductive Phenology of Araucaria Angustifolia in Two Environments of Argentina: Its Application to The Management of A Species at Risk. *Glob. Ecol. Conserv.* 2018; **16:** e00483.

9 **Hilton J and C Bitterli** The Influence of Light on The Germination of Avenafatua L- (Wild Oat) Seed and Its Ecological Significance. *New Phytol.* 2006; **95:** 325-333.

10 **Dostatny DF, Kordulasińska I and E Małuszyńska** Germination of Seeds of Avena fatua L. Under Different Storage Condition *Acta Agrobot.* 2015; **68 (3):** 241-246.

11 **Moravcová L and J Dostálek** Contribution to the Biology of Germination of Four Species of *Chenopodium album* agg. Under Different Condition. *Folia Geobot. - FOLIA GEOBOT* 1989; **24:** 431-439.

12 **Eslami SV** Comparative Germination and Emergence Ecology of Two Populations of Common Lambsquarters (*Chenopodium album*) from Iran and Denmark. *Weed Sci.*2011; **59 (1):** 90-97.

13 **Ohadi S, Mashhadi HR and RT Afshari** Seasonal Changes in Germination Responses of Seeds of the Winter Annual Weed Littleseed Canarygrass (*Phalaris minor*) to Light. *Weed Sci.* 2009; **57 (6):** 613-619.

14 **Derakhshan A, Gherekhloo J, Vidal RA and R De Prado** Quantitative Description of the Germination of Littleseed Canarygrass (*Phalaris minor*) **In**: Response to Temperature. *Weed Sci.* 2014; **62 (2):** 250-257.

15 **Gardarin A, Dürr C and N Colbach** Prediction of Germination Rates of Weed Species: Relationships Between Germination Speed Parameters and Species Traits. *Ecol. Modell.* 2011; **222 (3):** 626-636.

16 **Alshallash KS** Germination of Weed Species (*Avena fatua*, *Bromus catharticus*, *Chenopodium album* and *Phalaris minor*) with Implications for Their Dispersal and Control. *Ann. Agric. Sci.* 2018; **63 (1):** 91-97.

17 **Bhatt A, Bhat NR and TM Thomas** Germination Behavior of *Seidlitzia rosmarinus* Boiss., a Parenial Halophyte of Arabian deserts 2019; **53:** 348-354.

18 **Grubišić D and R Konjević** Light and Nitrate Interaction in Phytochrome-Controlled Germination of *Paulownia tomentosa* seeds. *Planta* 1990; **181 (2):** 239-243.

19 **Baskin CC and JM Baskin** Germination Ecophysiology of Herbaceous Plant Species in a Temperate Region. *Am. J. Bot.*1988; **75 (2):** 286-305.

20 **Alshallash K** Seed Germination of Rigid Ryegrass (*Lolium rigidum*) and Sterile Oat (*Avena sterilis*) Under Water Salinity Conditions at Constant or Alternating Temperatures *Egypt. J. Bot.* 2018; **58 (3)**: 539-545.

21 **Gomez, KA and A Gomez** *Statistical procedures for agricultural research, 2nd Edition*. New York, John Wiley & Sons; 1984.

22 **Gregory LE** Physiology of Tuberization in Plants. (Tubers and Tuberous Roots.) *Differ. und Entwicklung / Differ. Dev.* 1965; 1328-1354.

23 **Abdelgadir HA, Kulkarni MG, Arruda MP and J Van Staden** Enhancing Seedling Growth of *Jatropha curcas*-A Potential Oil Seed Crop for Biodiesel. *South African J. Bot.* 2012; **78:** 88-95.

24 **Copeland LO and MB McDonald** *Principles of Seed Science and Technology*. 1999.

25 **Qaderi MM and PB Cavers** Interpopulation Variation in Germination Responses of Scotch Thistle, *Onopordum acanthium* L., to Various Concentrations of GA3, KNO3, and NaHCO3. *Can. J. Bot.* 2000; **78 (9):** 1156-1163.

26 **Gashi B, Abdullai K, Mata V and E Kongjika** Effect of Gibberellic Acid and Potassium Nitrate on Seed Germination of the Resurrection Plants *Ramonda serbica* and Ra*monda nathaliae*. *African J. Biotechnol.* 2012; **11 (20):** 4537–4542.

27 **Ruttanaruangboworn A, Chanprasert W, Thobunluepop P and D Onwimol** Effect of Seed Priming With Different Concentrations of Potassium Nitrate on the Pattern Of Seed Imbibition and Germination Of Rice (*Oryza sativa* L.). *J. Integr. Agric.* 2017; **16:** 605-613.

28 **Mayer AM and A Poljakoff-Mayber** *The germination of seeds*. Oxford, New York, Pergamon Press; 1989.

29 **Barba-Espín G, Hernández JA and P Diaz-Vivancos** Role of H_2O_2 in Pea Seed Germination *Plant Signal. Behav.* 2012; **7 (2):** 193-195.