

## Immersion in 6-Benzylaminopurine for Dormancy Release and Initiation of Potato Sprouts at Various Tuber Weight and Storage Duration

### *Perendaman dalam 6-Benzilaminopurina untuk Pematahan Dormansi dan Inisiasi Tunas Kentang pada Beberapa Bobot Umbi dan Lama Penyimpanan*

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#### ABSTRACT

One of the main obstacles in providing quality potato seed tubers is the long dormancy period of the potato seeds. A study that explores this has been carried out to elucidate the response of dormancy release and initiation of potato sprouts to the differences in tuber weight and storage duration before immersion in cytokinin (6-benzylaminopurine). The study was conducted at the seed warehouse UPT Horticulture Parent Seed Kutagadung Berastagi, Department of Food and Horticulture of North Sumatra Province, from November 2018 to January 2019. The research was carried out with a factorial completely randomized design with two factors, namely (i) tuber weight, consisting of 4 levels [25-35 g, 55-65 g, 85-95g, and 115-125 g]; and (ii) tuber storage duration before immersion in 6-benzylaminopurine (BAP) solution, consisting of 5 levels [control (without immersion), 1, 15, 30, and 45 days after harvest]. Tuber weight, storage duration before immersion, and the interaction of the two factors showed significant effects in dormancy breaking time, germination percentage, germination rate, number of sprouts, and length of sprouts. The number and length of the sprouts increased with the increasing tuber weight and storage duration before immersion in BAP.

Keywords: cytokinin, germination, *Solanum tuberosum* L., tuber seeds

#### ABSTRAK

Salah satu kendala utama dalam penyediaan umbi benih kentang yang berkualitas adalah lamanya masa dormansi benih kentang. Suatu kajian yang mendalami hal tersebut telah dilakukan yaitu respon pematahan dormansi dan inisiasi kecambah kentang terhadap perbedaan bobot umbi dan lama penyimpanan umbi sebelum direndam dalam sitokinin (6-benzilaminopurin). Penelitian ini dilakukan di gudang benih UPT Benih Induk Hortikultura Kutagadung Berastagi, Dinas Tananaman Pangan dan Hortikultura Provinsi Sumatera Utara pada bulan November 2018 sampai Januari 2019. Penelitian ini menggunakan rancangan acak lengkap faktorial dengan dua faktor, yaitu (i) bobot umbi yang terdiri atas 4 taraf [25-35 g, 55-65 g, 85-95g, dan 115-125 g]; dan (ii) lama penyimpanan umbi sebelum direndam dalam larutan 6-benzilaminopurin (BAP) yang terdiri atas 5 taraf [kontrol (tanpa perendaman), 1, 15, 30, dan 45 hari setelah panen]. Bobot umbi, lama penyimpanan umbi sebelum direndam, serta interaksi kedua faktor menunjukkan perbedaan yang nyata waktu pematahan dormansi, persentase perkecambahan, laju perkecambahan, jumlah kecambah dan panjang kecambah. Jumlah dan panjang kecambah bertambah dengan bertambahnya bobot umbi dan lama penyimpanan umbi kentang sebelum direndam dalam BAP.

Kata kunci: bibit umbi, perkecambahan, sitokinin, *Solanum tuberosum* L.

#### INTRODUCTION

The tuber seeds become one of the important factors in potato (*Solanum tuberosum* L.) cultivation because the tubers

that have good quality can help increase potato productivity (Wulandari *et al.*, 2014). Basically, all potato seed tuber weights can be used as seedlings. The weight of the tubers which is usually used as seed material ranges from 30-80 g. The use of seeds with a tuber weight of less than 30 g will reduce production (Arifin *et al.*, 2014). Indonesian potato production in 2015 was 1.29 million tons with productivity

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of 18.20 tons ha<sup>-1</sup>, and this increased to 1,314,654 tons with productivity of 19.27 tons ha<sup>-1</sup> in 2019 (BPS, 2019; Ministry of Agriculture, 2021). However, this productivity is still relatively low compared to productivity in several European countries such as Belgium which can reach an average of 44.3 tons Ha<sup>-1</sup>, and the Netherlands 42.5 tons ha<sup>-1</sup> (Supit *et al.*, 2010). The target number of quality potato seeds that can be provided is 109,083 tons in 2017, and 115,193 tons for 2018 (Director General of Horticulture, 2019). The current average need for potato seeds is 108 thousand tons per year for a potato cultivation area of 72,000 hectares. Meanwhile Currently, the availability of nationally certified potato seeds has only reached 15 percent, so it is still open to meet domestic demand for potato seeds (Tempo.co, 2017).

Seed tuber size is positively correlated to seed vigor. The tuber seeds that have heavier weights tend to have better vigor. The seeds that have larger size and weight have more food reserves than the small, and it is suspected that the buds size is also larger. Food reserves stored in seeds are carbohydrates, proteins, fats and minerals (Almeida *et al.*, 2017). These materials are needed for the embryo as raw materials and energy during the germination process.

The potato tuber seeds generally take 3-3.5 months of dormancy. This condition causes the availability of seed potatoes to farmers is limited. If the potato seed dormancy period can be accelerated, the expected availability of seed potatoes can be fulfilled according to the needs of farmers. Freshly harvested seeds usually need to be stored in warehouses until the seed dormancy period ends. The length of dormancy in potatoes is influenced by several factors such as cultivar type, weather conditions, planting place, tuber age in the field and storage conditions (Jufri *et al.*, 2015).

The tuber dormancy can be broken with exogenous hormone application (Muthoni *et al.*, 2014). One of the hormones that can release the dormancy is cytokinin. Cytokines are adenine-derived compounds and play a role in the regulation of cell division and morphogenesis (Roberts and Hooley, 2013). Cytokinin of 6-benzylaminopurine (BAP) is a plant growth regulator that is widely used because it is very active in plant tissue, such as in shoots to stimulate cell division and maintain chlorophyll degradation. Nuraini *et al.* (2016) reported that G1 potato tuber seeds soaked for 1 hour in 100 mg L<sup>-1</sup> BAP (6-benzylaminopurine) showed a faster duration of dormancy breaking than without cytokinin immersion (control). Spraying the 6-Benzylaminopurine concentration which was increased up to 100 mg L<sup>-1</sup> to towards the end of tuberization phase (75 days after emergence) on several potato varieties in Kenya showed a better percentage of germination compared without the administration of 6-Benzylaminopurine (Njogu *et al.*, 2015).

Based on the description above, it is necessary to conduct a study to determine the response to dormancy breaking and the initiation of potato tuber sprouts related to differences in tuber weight and age when immersed in 6-benzylaminopurine. This study can also determine better shoot growth conditions with shorter dormancy release

times and can determine the optimal type of potato seed tuber weight for farmers' needs.

## MATERIALS AND METHODS

The study was conducted at the seed warehouse Technical Implementing Unit of Horticultural Seeds Kutagadung Berastagi, Department of Food and Horticulture, North Sumatra Province, from November 2018 to January 2019. The research was carried out with a factorial completely randomized design with 2 (two) factors. The first factor, potato tuber weight consists of 4 levels, namely: 25-35 g, 55-65 g, 85-95 g, and 115-125 g. The second factor, the storage duration of tuber seeds before immersion in cytokinin (100 mg L<sup>-1</sup> BAP), consisted of 5 levels, namely: control (without immersion), 1, 15, 30, and 45 days after harvest. This study was conducted with three replications, so that 45 experimental units were obtained. In each experimental unit plot there were 10 potato tuber seeds. The plant material used was potato seed Granola variety, seed class G1 which is equivalent to Foundation Seed of first generation.

The stages of this research consisted of (1) sterilizing the seed warehouse by spraying the insecticide of 1 mg L<sup>-1</sup> Curacron 500 EC® (the active ingredient of profenofos 500 g L<sup>-1</sup>); (2) preparation of potato tuber seeds, namely potato tubers derived from harvesting G<sub>1</sub> potato seeds of Granola variety which is harvested 90 days after planted, weighed and separated according to the treatment; (3) Immersion the seeds with 100 mg L<sup>-1</sup> BAP for 1 (one) hour according to the storage duration of the potato tuber seeds. The parameters observed were dormancy release time, germination percentage, germination rate, number of sprouts, and length of sprouts. The determination of the germination percentage and germination rate uses the following equation.

$$\text{Percentage of germination} = \frac{\text{The number of tuber germinates}}{\text{Total of tuber seeds planted}} \times 100\%$$

$$\text{Germination rate} = \frac{N_1T_1 + N_2T_2 + \dots + N_xT_x}{\text{The number of tuber germinates}}$$

Note: N<sub>x</sub> = The number of tuber germinated on a day the x, T<sub>x</sub> = The number of days between the start of the test and end at the time of the x-observation.

Observation of parameters was carried out every week until the fifth week. Furthermore, the data were analyzed using a two-way analysis of variance (ANOVA). The mean value between the variants studied was tested using Duncan's Multiple Range Test (DMRT) at α 5%.

## RESULTS AND DISCUSSION

### *Dormancy Release*

The results of an analysis of variance showed that the weight and storage duration of potato tuber seeds before immersion in BAP, as well as the interaction of both treatments, had a significant effect on the breaking time of

potato seed tuber dormancy. The fastest dormancy release time was obtained at the tuber weight of 115-125 g. While the storage duration of tuber seeds before immersion in BAP at 30 and 45 days after harvest showed the fastest dormancy release time. The treatment interaction that produced the fastest dormancy time was at tuber weight 115-125 g with the storage duration of tuber seeds before immersion in BAP of 45 days after harvest, namely 55 days after incubation and these results were significantly different from other treatments (Table 1).

Tuber weight of potato significantly affected the dormancy break time. The fastest dormancy breaking time was found in the tuber weights 115-125 g. The size of the tuber is thought to be positively correlated with greater energy reserve content so that the breaking of dormancy can be faster. Arifin *et al.* (2014) state that tubers with a larger size have a higher amount of food reserves (carbohydrates) so the tubers have large and strong sprouts. Adequate amounts of carbohydrates encourage greater translocation of carbohydrates into sprouts so that the growth of budding vegetative organs is maximal.

The storage duration of tuber seeds before immersion in BAP also significantly affected the dormancy break time. The tuber storage duration of 45 days before immersion in cytokinin showed the time to break the dormancy was 11.75 days faster than tubers that were not soaked in cytokinins. The results of this study are in line with Nuraini *et al.* (2016) that BAP administration has a significant effect on the emergence of G1 potato seed sprouts. Wróbel *et al.* (2017) also explains that the effectiveness of exogenous cytokinin treatment is influenced by the time of dormancy and is more effective when given at the end of dormancy.

Potato tuber weights 85-95 g and 115-125 g with a storage duration of 1 day before immersion in BAP can produce 100% germination with the total time needed to break dormancy (storage time + dormancy breaking time) is better than tubers with a storage duration 15, 30, and 45 days before immersion in BAP or without BAP application.

#### Percentage of Germination

The results of the analysis of variance showed that the effect of differences in weight and the storage duration of

potato tubers before immersion in BAP, and their interactions were significantly different on the germination percentage of potato tubers observed on days 7, 14, 21, 28, and 35 days after treatment. Observation data on days 7, 14, 21 after treatment showed that the tuber weights 115-125 g produced the highest percentage of germination, namely 42.00%, 70.00%, 92.67%. While observational data on 28th and 35th day after treatment showed that the tuber weights 85-95 g and 115-125 g had reached 100% germination percentage. The tubers storage duration of 45 days before immersion in BAP produced the highest percentage of germination on days 7, 14, 21, 28 namely 33.33%, 57.50%, 80.00%, 99.17%. Whereas at the age of 35 days after treatment, the difference in tuber storage duration before immersion in BAP (1, 15, 30 and 45 days) showed the percentage of germination reached 100%, significantly different from tubers that were not treated with BAP immersion, namely 91.67% (Table 2).

Table 2 shows that at 7 days of age observation after treatment, the interaction of tuber weight and BAP immersion treatment time resulted in the highest germination percentage found at the tuber weight of 115-125 g and the tuber storage duration of 45 days before immersion in BAP which was 76.67%. After 28 days after treatment, all treatment combinations did not show any tuber seeds that had not germinated. On the 35th day after treatment, almost all treatment combinations produced a germination percentage of 100%, except for the treatment combination of 55-65 g tuber weight without immersion in BAP (86.67%) and tuber weight 25-35 g without BAP immersion treatment (80%).

The results showed that the larger tuber weight resulted in a higher germination percentage than the smaller tuber weight. There is related to the sufficient energy reserves of the tubers to germinate. According to Kloosterman and Bachem (2014), the increase in tuber size is influenced by the accumulation of starch. The presence of starch was detected from the early stages of tuber swelling and initiation (Akoumianakis *et al.*, 2016). Aksanova *et al.* (2012) explained that the presence of carbohydrates (such as sucrose) is not only a substrate for starch biosynthesis but plays an important role in encouraging tuber morphogenesis. Besides, the dormancy period is related to the endogenous cytokinin levels of the seeds, and this can also be affected

Table 1. Dormancy breaking time on varying potato tuber weight and storage duration before immersion in 100 mg L<sup>-1</sup> BAP

Tuber weight (g)	The storage duration of tuber before immersion in BAP [DAH <sup>1)</sup> ]					Mean
	Control	1	15	30	45	
25-35	80.00a	75.33bc	74.67c	74.00c	69.67d	74.73a
55-65	77.67ab	70.00d	67.33de	64.67fg	64.33fg	68.80b
85-95	69.67d	65.67ef	62.33g	57.67h	59.33h	62.93c
115-125	68.00de	63.33fg	59.33h	57.67h	55.00i	60.67d
Mean	73.83a	68.58b	65.92c	63.50cd	62.08d	

Note: <sup>1)</sup>DAH = days after harvest, \*Means followed by the same letter are not significantly different by DMRT at 5%

Table 2. The percentage of germination at each observation time on varying potato tuber weight and storage duration before immersion in 100 mg L<sup>-1</sup> BAP

Days after treatment	Tuber weight (g)	The storage duration of tuber before immersion in BAP [DAH <sup>1)</sup> ]					Mean
		Control	1	15	30	45	
.....%*.....							
7	25-35	0.00d	0.00d	0.00d	0.00d	0.00d	0.00c
	55-65	0.00d	0.00d	0.00d	0.00d	0.00d	0.00c
	85-95	0.00d	0.00d	0.00d	46.67c	56.67bc	20.67b
	115-125	0.00d	0.00d	66.67b	66.67b	76.67a	42.00a
	Mean	0.00d	0.00d	16.67c	28.33b	33.33a	
14	25-35	0.00d	0.00d	0.00d	0.00d	0.00d	0.00d
	55-65	0.00d	0.00d	26.67c	23.33c	33.33c	16.67c
	85-95	0.00d	33.33c	30.00c	93.33a	96.67a	50.67b
	115-125	0.00d	53.33b	96.67a	100.00a	100.00a	70.00a
	Mean	0.00d	21.67c	38.33b	54.17ab	57.50a	
21	25-35	0.00e	33.33d	23.33d	23.33d	33.33d	22.67d
	55-65	0.00e	23.33d	76.67b	83.33b	86.67ab	54.00c
	85-95	33.33d	100.00a	86.67ab	100.00a	100.00a	84.00b
	115-125	63.33c	100.00a	100.00a	100.00a	100.00a	92.67a
	Mean	24.17d	64.17c	71.67b	76.67ab	80.00a	
28	25-35	30.00e	60.00c	70.00b	76.67b	96.67a	66.67c
	55-65	33.33d	93.33a	100.00a	100.00a	100.00a	85.33b
	85-95	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
	115-125	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
	Mean	65.83d	88.33c	92.50b	94.17b	99.17a	
35	25-35	80.00c	100.00a	100.00a	100.00a	100.00a	96.00b
	55-65	86.67b	100.00a	100.00a	100.00a	100.00a	97.33b
	85-95	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
	115-125	100.00a	100.00a	100.00a	100.00a	100.00a	100.00a
	Mean	91.67b	100.00a	100.00a	100.00a	100.00a	

Note: <sup>1)</sup>DAH = days after harvest, \*Means followed by the same letters are not significantly different by DMRT at 5%

by the administration of cytokinins. Increasing levels of seed cytokinins can accelerate the dormancy period (Panda *et al.*, 2018).

#### Germination Rate

The tuber weights of 115-125 g produce the fastest germination rate. While tuber the storage duration of 45 days before immersion in BAP produced the highest germination rate. The treatment interaction that produces the fastest germination rate is a combination of the tuber weights 115-125 g with the tuber storage duration of 45 days before immersion in BAP, but not significantly different in the tuber weight of 115-125 g with a storage duration of 30 and 15 days. Whereas tubers weighing 85-95 g with

the storage duration of 30 days immersion in BAP showed no significant difference with 45 days, and significantly different from the storage duration of 1 and 15 days and tubers that were not given BAP. Potato tuber weights 85-95 g and 115-125 g with a storage duration of 1 day before immersion in BAP showed the germination rate that were better than tubers for the control treatment (without soaking in BAP and the storage duration of 45 days). The 25-35 g tuber weight without immersion in BAP showed the lowest germination rate compared to all treatment combinations (Table 3).

The storage duration of potato tubers affects the length of time it takes to break dormancy in each variety. This is related to the level of change in tuber maturity during the storage period (Muthoni *et al.*, 2014). Mature potato tubers

Table 3. The germination rate on varying potato tuber weight and storage duration before immersion in 100 mg L<sup>-1</sup> BAP

Tuber weight (g)	The storage duration of tuber before immersion in BAP [DAH <sup>1)</sup> ]					Mean
	Control	1	15	30	45	
	.....days*.....					
25-35	35.00a	28.47c	28.47c	28.00cd	25.90e	29.17a
55-65	32.31b	26.83de	20.77g	20.53g	19.60gh	24.01b
85-95	25.67e	18.67hi	19.83gh	11.20jk	10.27kl	17.13c
115-125	23.57f	17.27i	9.57lm	9.33lm	8.63m	13.67d
Mean	29.14a	22.81b	19.66c	17.27d	16.10e	

Note: <sup>1)</sup>DAH = days after harvest, \*Means followed by the same letter are not significantly different by DMRT at 5%

have a better ability to break dormancy earlier than immature ones. Besides, the intrinsic capacity for the formation of shoots increases gradually with the longer storage duration of tuber seeds after harvest, and after exceeding a certain long storage period, this ability decreases (Deligios *et al.*, 2020).

The physiological maturity process of potato tuber seeds followed by an event of breaking of dormancy and the development of sprouts can be used to develop a suitable storage treatment before planting (Oliveira *et al.*, 2012). The initial duration of germinating until the time of planting determines the number of internodes in the main stem formed. Therefore, potato varieties that have formed normal sprouts at the end of the germination period are transferred to the field as early maturing plants, because the tubers start growing earlier and the plants will ripen early (Carli *et al.*, 2010).

#### Number of Sprouts

The analysis of variance showed that the tuber weight and the storage duration of before immersion in BAP, as well as the interaction of the two factors, had a significant effect on the number of sprouts in each observation. Table 4 shows that in the different tuber weights, the highest number of sprouts in each observation was obtained from tuber seeds with a weight of 115-125 g, and it was significantly different from other tuber weight treatments. The analysis showed that the increase in tuber weight also increased the number of shoots formed at each observation. This is related to the adequacy of energy reserves in the tubers to support shoot growth (Iseki and Matsumoto, 2020). In the observation of 35 days of age, the increase in the number of shoots was 1.90 shoots (58.64%) at a tuber weight of 115-125 g compared to the number of shoots at a tuber weight of 25-35 g.

Table 4 also showed that the tuber storage duration of 45 days before immersion in BAP showed the highest number of shoots, and was significantly different from other treatments at each observation time. In the observation of 35 days of age, the increase in the number of shoots was 30.89% at the tuber storage duration of 45 days before immersion in BAP compared to tubers that were not soaked with BAP. The

results showed that the number of sprouts increased when the older tubers were immersed in cytokinin. The onset of sprout growth is also influenced by the development stage (physiological age) of the potato tuber. The progress from physiologically young to old tubers affects yield parameters of the subsequent crop. These include dormancy release time, number of shoots, canopy growth pattern, maturity date, total tuber yield, and tuber size distribution (Oliveira *et al.*, 2017).

The treatment interaction of tuber weight and storage duration before immersion in BAP showed that the highest number of shoots for each observation time was dominated by the combination of the highest seed weight (115-125 g) with the tuber storage duration of 15, 30, and 40 days. Even for the observation time of the 28th and 35th days after treatment, tubers weighing 115-125 g and the storage duration of one day before immersion in BAP showed the number of shoots was not significantly different from the tuber storage duration of 15, 30, and 45 days. Potato tuber weights 85-95 g and 115-125 g with a storage duration of 1 day before immersion in BAP showed the number of sprouts that were better than tubers for the control treatment (without soaking in BAP and the storage duration of 45 days).

The dormancy period varies according to components, such as genotype, environmental conditions, agronomic management of the crop, storage, and endogenous hormonal dynamics of the tuber (Sonnewald and Sonnewald, 2014). During dormancy the levels of plant growth inhibitors such as abscisic acid and ethylene are high. These are the main hormones involved in dormancy initiation and maintenance (Carli *et al.*, 2010; Mani *et al.*, 2014; Deligios *et al.*, 2020). When dormancy is overcome and sprouting begins, the hormonal dynamics change and the concentrations of growth promoters such as cytokinins, gibberellins (Mani *et al.*, 2014)

Several studies have shown that exogenous cytokinins can increase the efficiency of damage to dormancy and growth of potato seed tubers. Seeds that are given cytokinins produce a higher number of shoots because cytokinins can encourage shoot emergence. Hartmann *et al.* (2011) reported that cytokinin as an essential component controlling dormancy release, and gibberellin requires cytokinin to

Table 4. The number of potato sprouts at each observation time on varying tuber weight and storage duration before immersion in 100 mg L<sup>-1</sup> BAP

Days after treatment	Tuber weight (g)	The storage duration of tuber before immersion in BAP [DAH <sup>1)</sup> ]					Mean
		Control	1	15	30	45	
.....sprouts shoot.....							
7	25-35	0.00d	0.00d	0.00d	0.00d	0.00d	0.00c
	55-65	0.00d	0.00d	0.00d	0.00d	0.00d	0.00c
	85-95	0.00d	0.00d	1.08bc	1.06c	1.04c	0.64b
	115-125	0.00d	0.00d	1.14abc	1.27ab	1.32a	0.75a
	Mean	0.00b	0.00b	0.56a	0.58a	0.59a	
14	25-35	0.00d	0.00d	0.00d	0.00d	0.00d	0.00d
	55-65	0.00d	0.00d	0.88c	0.81c	1.33bc	0.60c
	85-95	0.00d	1.00c	1.11c	1.70bc	1.69bc	1.10b
	115-125	0.00d	1.07c	1.84bc	2.40a	1.93b	1.45a
	Mean	0.00c	0.52b	0.96b	1.23ab	1.24a	
21	25-35	0.00k	1.00ij	1.00ij	0.90ij	1.00ij	0.80d
	55-65	0.00k	1.00ij	1.17ij	1.22hij	1.35ghij	0.95c
	85-95	1.48ghi	1.73def	1.22hij	2.17cd	2.17cd	1.75b
	115-125	1.67efg	1.93de	2.40bc	2.90a	2.73ab	2.33a
	Mean	0.79c	1.42b	1.45b	1.80ab	1.81a	
28	25-35	1.00f	1.00f	1.23def	1.10def	1.00f	1.07d
	55-65	1.33def	1.28def	1.28def	1.37def	1.53de	1.36c
	85-95	1.57de	2.64bc	1.60d	2.27c	2.59bc	2.13b
	115-125	2.27c	3.17a	2.99ab	3.20a	3.33a	2.90a
	Mean	1.54c	2.02a	1.78b	1.99a	2.11a	
35	25-35	1.21h	1.18h	1.53gh	1.37h	1.43h	1.34d
	55-65	1.39h	1.36h	1.90fg	1.53gh	2.37e	1.71c
	85-95	2.17ef	2.84d	2.00ef	2.99bcd	2.86cd	2.56b
	115-125	2.40e	3.32ab	3.50ab	3.25abc	3.71a	3.24a
	Mean	1.79c	2.17b	2.23b	2.29b	2.59a	

Note: <sup>1)</sup>DAH = days after harvest, \*Means followed by the same letter are not significantly different by DMRT at 5%

stimulate the resumption of meristematic activity but is sufficient to support sprout growth once bud break has occurred.

#### Length of Sprouts

The analysis of variance showed that the tuber weight and the storage duration before immersion in BAP, as well as the interaction of the two treatments significantly affected the length of potato sprouts at each observation (Table 5). The longest sprouts in each observation were at tubers weights of 115-125 g, which was 3.83 mm. In the treatment of soaking tuber seeds in a BAP solution, the longest sprouts at each observation were obtained at the tuber storage duration of 45 days. The treatment interaction that produced the longest sprouts at 35 days of observation was at tubers weights of 115-125 g with the tuber storage duration of 30 days, which was 4.74 mm. Potato tuber weights 85-95 g and 115-125 g

with a storage duration of 1 day before immersion in BAP showed the length of sprouts that were better than tubers for the control treatment (without soaking in BAP).

The dormancy release occurs simultaneously with the emergence of sprouts. Increased mobilization of sugar and respiration in tubers causes germination. The results showed that the highest shoot length was the fastest dormancy break. Breaking dormancy shows a physiological process that takes place maximally for the formation of sprouts including sufficient food reserves (carbohydrates) to support budding growth. This is related to the adequacy of energy reserves in the form of carbohydrates in the tubers which are used by the enzymes during the germination process. During the tuber development process, the presence of amylase activity is important in the starch cycle, where B-amylase activity decreases at the beginning of dormancy and then increases after initiation of sprouts (Sergeeva *et al.*, 2012).

Table 5. The length of potato sprouts at each observation time on varying tuber weight and storage duration before immersion in 100 mg L<sup>-1</sup> BAP

Days after treatment	Tuber weight (g)	The storage duration of tuber before immersion in BAP [DAH <sup>1)</sup> ]					Mean
		Control	1	15	30	45	
.....mm*.....							
7	25-35	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b
	55-65	0.00b	0.00b	0.00b	0.00b	0.00b	0.00b
	85-95	0.00b	0.00b	2.00a	2.00a	2.00a	1.20a
	115-125	0.00b	0.00b	2.00a	2.00a	2.00a	1.20a
	Mean	0.00b	0.00b	1.00a	1.00a	1.00a	
14	25-35	0.00e	0.00e	0.00e	0.00e	0.00e	0.00d
	55-65	0.00e	0.00e	2.14d	2.00d	2.00d	1.23c
	85-95	0.00e	2.00d	2.20cd	2.39bc	2.57ab	1.83b
	115-125	0.00e	2.00d	2.59ab	2.73a	2.58ab	1.98a
	Mean	0.00c	1.00b	1.73ab	1.78a	1.79a	
21	25-35	0.00e	2.00e	2.00e	2.00e	2.08e	1.62c
	55-65	0.00e	2.00e	2.27de	2.30cde	2.45cd	1.81b
	85-95	2.00e	2.33cde	2.62c	3.14ab	3.08ab	2.63a
	115-125	2.00e	2.28de	2.92b	3.34a	3.18ab	2.74a
	Mean	1.00b	2.15a	2.45a	2.69a	2.70a	
28	25-35	2.00g	2.28fg	2.53def	2.25fg	2.51def	2.31c
	55-65	2.00g	2.16fg	3.03c	2.80cde	2.93cd	2.58b
	85-95	2.25fg	2.84cde	3.13c	3.66a	3.61 a	3.10a
	115-125	2.43ef	2.79cde	3.21bc	3.90a	3.57 ab	3.18a
	Mean	2.17c	2.52b	2.98ab	3.15a	3.16 a	
35	25-35	2.12j	2.75hi	2.99fgh	2.79ghi	3.04 fgh	2.74d
	55-65	2.37ij	2.73hi	3.58de	3.58de	3.94 bcd	3.24c
	85-95	2.70hi	3.27ef	3.82cd	4.17bc	4.24 bc	3.64b
	115-125	2.74hi	3.24efg	4.31b	4.74a	4.13 bc	3.83a
	Mean	2.48c	3.00b	3.68a	3.82a	3.84a	

Note: <sup>1)</sup>DAH = days after harvest, \*Means followed by the same letter are not significantly different by DMRT at 5%

## CONCLUSION

The increasing weight and storage duration of tubers before immersion in 100 mg L<sup>-1</sup> BAP can simultaneously increase the percentage of germination, the number of sprouts, length of sprouts, and accelerate the time to break dormancy and the germination rate. Potato tuber weights 85-95 g and 115-125 g with a storage duration of 1 day before immersion in BAP resulted in a total time to break dormancy that was faster than 15, 30, and 45 days before immersing in BAP or without BAP administration.

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