การยกระดับความงอกและการเจริญเติบโตของต้นกล้าบักวีต โดยการเคลือบเมล็ดร่วมกับธาตุอาหารพืชและสารเคมีป้องกันเชื้อรา

Enhancement of Germination and Seedling Growth of Common Buckwheat (*Fagopyrum esculentum* Moench) by Seed Coating with Plant Nutrient and Fungicide

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บทคัดย่อ

บักวีตสามารถปลูกได้ดีในดินที่มีความอุดมสมบูรณ์ต่ำและเกษตรกรนิยมปลูกบักวีตด้วยวิธีการโรยเมล็ดเป็นแถวหรือหว่านกระจายไปทั่วแปลง แต่การปลูกด้วยวิธีการดังกล่าวมักจะพบปัญหาการงอกและการเจริญเติบโตของต้นกล้าไม่สม่ำเสมอ และการเข้าทำลายของโรคในระยะต้นกล้า จากปัญหาดังกล่าวจึงได้แก้ปัญหาโดยการใช้เทคโนโลยีการเคลือบเมล็ดพันธุ์มาใช้เพื่อยกระดับคุณภาพเมล็ดพันธุ์ให้ดีขึ้นและมีผลกระทบต่อสภาพแวดล้อมน้อยที่สุด งานทดลองนี้จึงมีวัตถุประสงค์เพื่อศึกษาผลของการเคลือบเมล็ดร่วมกับธาตุอาหารและสารเคมีป้องกันเชื้อราและติดตามความงอกและการเจริญเติบโตของต้นกล้าบักวีต ดำเนินการทดลองที่ห้องปฏิบัติการเทคโนโลยีเมล็ดพันธุ์และห้องปฏิบัติการสรีรวิทยาพืชไร่ สาขาวิชาพืชไร่ คณะผลิตกรรมการเกษตร มหาวิทยาลัยแม่โจ้ ซึ่งกรรมวิธีการเคลือบ 8 กรรมวิธี ประกอบไปด้วย เมล็ดไม่เคลือบ (T1), เมล็ดเคลือบ Carboxylmethyl cellulose 0.1 เปอร์เซ็นต์ (CMC) (T2), เมล็ดเคลือบร่วมกับ NH_4NO_3, NaH_2PO_4, KCl ที่อัตรา 0.384 กรัม (T3), 0.512 กรัม (T4) และ 0.104 กรัม (T5) ตามลำดับ และเมล็ดเคลือบร่วมกับ NH_4NO_3, NaH_2PO_4, KCl ที่อัตรา 0.384 กรัม ร่วมกับ Metalaxyl 2.0 g.ai. (T6), 0.512 กรัม ร่วมกับ Metalaxyl 2.0 g.ai. (T7) และ 0.104 g. ร่วมกับ Metalaxyl 2.0 g.ai. (T8) ตามลำดับ จากการศึกษา พบว่า การเคลือบเมล็ดด้วย KCl อัตรา 0.104 กรัม เพิ่มอัตราการงอกของเมล็ดขึ้น 14% เมื่อเปรียบเทียบกับเมล็ดที่ไม่ได้ผ่านการเคลือบ ส่วนการตรวจสอบในสภาพเรือนทดลองแสดงให้เห็นว่าการเคลือบเมล็ดด้วย carboxymethyl cellulose (CMC) และ NaH_2PO_4 0.384 กรัม ร่วมกับ Metalaxyl 2.0 g.ai. มีความงอกสูงที่สุดและมีแตกต่างกันในทางสถิติเมื่อเปรียบเทียบกับวิธีการอื่นๆ นอกจากนี้การเคลือบเมล็ดด้วย NaH_2PO_4 0.384 กรัม ร่วมกับ Metalaxyl 2.0 g.ai. ยังช่วยส่งเสริมให้ต้นกล้ามีความยาวรากเพิ่มขึ้นจากเดิม 13% ดังนั้นสรุปได้ว่า การเคลือบเมล็ดด้วย NaH_2PO_4 0.384 กรัม เพียงอย่างเดียวจะทำให้ต้นกล้ามีความยาวลำต้น น้ำหนักสดลำต้นต้นกล้า และน้ำหนักแห้งลำต้นต้นกล้าดีมากกว่าเมล็ดที่ไม่ได้ผ่านการเคลือบอย่างชัดเจนเมื่อตรวจสอบในสภาพเรือนทดลอง

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ABSTRACT

Common buckwheat (*Fagopyrum esculentum* Moench) grows well in nutrient-poor soil. Seed sprinkling and sowing are the most popular methods for growing buckwheat. However, with such methods, there are problems with inconstant germination and seedling growth as well as seedling diseases. Consequently, a seed coating is applied to resolve the problem and to enhance seed quality with the lowest impact on the environment. The objectives of this research were (1) to study the results of seed coating with plant nutrients and fungicide and (2) to monitor the germination and seedling growth of common buckwheat. The experiment was conducted at the Seed Technology Laboratory and Field Crop Physiology Laboratory of the Agronomy Program, Faculty of Agricultural Production, Maejo University, Chiang Mai, Thailand. Eight treatments were applied in this research consisting of non-coated seeds (T1); coated seeds + Carboxymethyl cellulose 0.1% (CMC) (T2); coated seeds + NH_4NO_3, NaH_2PO_4, and KCl at rates of 0.384 g (T3), 0.512 g (T4), and 0.104 g (T5), respectively; and coated seeds + NH_4NO_3, NaH_2PO_4, and KCl at rates of 0.384 g + Metalaxyl 2.0 g.ai. (T6), 0.512 g + Metalaxyl 2.0 g.ai. (T7), and 0.104 g + Metalaxyl 2.0 g.ai. (T8), respectively. The experimental results showed that seeds coated with 0.104 g of potassium chloride (KCl) increased the germination rate significantly by 14% relative to non-coated seeds. The greenhouse results illustrated that seeds coated with carboxymethyl cellulose (CMC) and 0.384 g of monosodium phosphate (NaH_2PO_4) mixed with 2.0 g.ai. of metalaxyl resulted in the highest germination rate, which was significantly different from that obtained from other methods. Furthermore, coating of seeds with 0.384 g of NaH_2PO_4 mixed with 2.0 g.ai. of metalaxyl lengthened the roots of the seedlings by 13%. Thus, it was concluded that seeds coated with 0.384 g of NaH_2PO_4 enhanced germination and increased shoot length in common buckwheat and resulted in higher shoot fresh and dry weight relative to non-coated seeds when tested under greenhouse conditions.

Key words: seed quality, seed vigor, seed enhancement, active ingredient

INTRODUCTION

Common buckwheat is an annual crop that grows well in nutrient-poor soil. It is widely planted in countries in the global temperate zone (Valenzuela and Smith, 2002) and in the northern region of Thailand. Common buckwheat contains various nutrients (Alvarez-Jubete *et al.*, 2009), such as protein, flavonoids, and others (Antonio *et al*., 2015). In Thailand, the Rice Department encourages agriculturists to grow common buckwheat after the rice growing season in order to earn extra income (Rice Department, 2017; Insalud *et al*., 2020). Most agriculturists use the seed sprinkling and sowing technique to grow common buckwheat at the appropriate seeding rate and distance. However, these methods experience problems with the germination rate, slow and inconstant seedling growth, dwarfing seedlings, and diseases in the seedlings in a high humidity area (Manitoba Agriculture, 2017), which lead to seed loss. As a result, the provision of seed quality in terms of germination and seed vigor is very significant to agriculturists.

In light of the above problems, a seed coating technique has been applied to enhance the quality of common buckwheat. Seed coating is a method of coating the seed skin with a solution of, for example, a polymer (Siri, 2015). Currently, the cost of seed coating is low because the coating substance can be produced or supplied within Thailand; seed coating is thus a cost-effective solution. Seed coating is a technique wherein the coating is the medium for delivery of active substance such as plant nutrients, growth regulators, or active substances for preventing diseases and insects that are necessary for germination and seedling growth (Pedrini *et al.*, 2017). Siri and Keawmaungklang (2014) revealed that coating cucumber seeds with a phosphorus solution gave greater enhancement of germination and seed vigor relative to uncoated seeds. Similarly, Kucera *et al*. (2005) reported that nitrogen was very crucial for respiration and the nutrient digestion process in the seeds. Additionally, Keawkham *et al*. (2014) discovered that coating cucumber seeds with metalaxyl improved the germination rate, while some active substances coated on the seed surface prevented diseases caused by the soil (Ren *et al*., 2019). With the lower cost of coating and the higher efficiency of growing common buckwheat, this would be an alternative for growing quality economic crops and increasing productivity in the future.

Therefore, this research aimed to study the results of coating seeds with plant nutrients and fungicide, and monitor the germination and seedling growth of common buckwheat to enhance seed quality and increase productivity.

MATERIALS AND METHODS

Common buckwheat Taiwan 01, which was provided from the Phrae Rice Research Center, Division of Rice Research and Development, Rice Department, was used in the experiment, which was conducted in the Seed Technology Laboratory and Field Crop Physiology Laboratory of the Agronomy Program, Faculty of Agricultural Production, Maejo University, Chiang Mai, Thailand during July 2019 and March 2020.

1. Coating of seeds with plant nutrients and fungicide

The study on common buckwheat seed coating used carboxymethyl cellulose (CMC) as the coating mixed with four active substances, ammonium nitrate (NH_4NO_3), monosodium phosphate (NaH_2PO_4), potassium chloride (KCl), and metalaxyl, per 15 g of common buckwheat for each substance (Table 1). Then, the seeds were coated with JK-01 seed coating equipment, and the seed moisture was minimized after coating by sitting at room temperature for 48 hours before seed quality was tested.

Table 1 Seed coating treatment formulation

Coating substance	T1	T2	T3	T4	T5	T6	T7	T8
CMC	-	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %	0.1 %
NH_4NO_3	-	-	0.384 g	-	-	0.384 g	-	-
NaH_2PO_4	-	-	-	0.512 g	-	-	0.512 g	-
KCl	-	-	-	-	0.104 g	-	-	0.104 g
Metalaxyl	-	-	-	-	-	2.0 g.ai	2.0 g.ai	2.0 g.ai

CMC = Carboxymethyl cellulose, NH_4NO_3 = Ammonium nitrate, NaH_2PO_4 = monosodium phosphate, KCl = Potassium chloride, g.ai = Grams of active ingredient, Plant nutrient
Modified from: Kangsopa (2018)

2. Seed quality testing

2.1 Germination test under laboratory conditions: Non-coated seeds and seeds coated with all substances were randomized, 50 seeds to each of four replications, to test for germination between paper (BP). Then, the seeds were placed in a seed germination incubator at alternating temperatures (30 °C for 8 hours and 20 °C for 16 hours). Germinated seeds were counted on Day 4, the (first count) and again on Day 7 (final count) of the culture by evaluating germination according to ISTA (2019).

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds sown}} \times 100$$

For the examination of dead seeds, non-germinated seeds that were fresh or had no fungi from the four replications were evaluated, and the number of dead seeds was calculated. For hard seeds, live seeds that could not absorb water were evaluated, the number of seeds in the same condition as before germination was determined for the four replications, and the percentage of hard seeds was calculated. For the examination of abnormal seedlings, the seedlings that had no potential to grow or those with unhealthy roots and shoots from the four replications were evaluated and their percentage calculated.

2.2 Germination test under greenhouse conditions: Non-coated seeds and seeds coated with all substances were randomized, 50 seeds for each of the four replications, to test germination in a nursery tray by using peat moss as a growing medium. During days 4-7, germination was evaluated as in the laboratory test.

2.3 Speed of germination test under laboratory and greenhouse conditions: Non -coated seeds and seeds coated with all substances were randomized, 50 seeds for each of the four replications, from the laboratory and greenhouse. The number of normal germinated seeds and the number of the germination days from the first culture day (first count) until the last day (final count) were counted. The speed of germination was calculated according to the following equation AOSA (1983)

$$\text{Speed of germination (Seedling/days)} = \frac{\text{No. normal seedlings}}{\text{Day of first count}} + \frac{\text{No. normal seedlings}}{\text{Day of final count}}$$

2.4 Radicle emergence test under laboratory conditions: Radicle emergence from the laboratory was randomly evaluated from the four replications. Counting began when the radicle was 2 mm and the percentage calculated according to the following equation:

$$\text{Radicle emergence (\%)} = \frac{\text{Number of germinated roots}}{\text{Total number of seeds sown}} \times 100$$

2.5 Speed of radicle emergence test under laboratory conditions: Counting was conducted daily from Day 1 to Day 3 after the culture of the four replications, 50 seeds for each method.

2.6 Cotyledon emergence and speed of cotyledon emergence test under greenhouse conditions: Cotyledon germination of emergent common buckwheat seedlings for each method for the four replications was randomly evaluated and the percent emergence calculated. To test the speed of emergence, cotyledon germination of emergent buckwheat seedlings for every day from Day 1 to Day 3 after the culture was randomly counted and the speed of emergence calculated.

2.7 Shoot and root length test under laboratory and greenhouse conditions: Shoot and root length at Day 7 of culture in the laboratory were evaluated. For those from the greenhouse, only shoot length was evaluated in the four replications, 10 seedlings for each. Then, the seedlings were randomly evaluated by measuring from the connection of the shoot and root to the tip of the leaf using a ruler with millimeter units. For root length, the measurement was conducted from the end of the root to the connection between the root and the shoot. To evaluate seedling length, the measurement was conducted from the end of root to the tip of the leaf. To evaluate the shoot length of those from the greenhouse, the measurement was conducted from the connection of the shoot to the tip of the leaf.

2.8 Shoot fresh weight and shoot dry weight test under laboratory and greenhouse conditions: Shoot weight was obtained from Item 2.7 to determine shoot fresh weight. Then, shoots were dried at 72 ^{o}C for 72 hours and weighed to obtain shoot dry weight. In greenhouse conditions, seedlings were weighed to obtain the fresh weight (in milligrams) then dried at the same temperature and duration as in the laboratory test to calculate the shoot dry weight. Of the four replicates, 10 seedlings were examined at a time.

2.9 Data analysis: Seed quality and the change in quality were analyzed using a completely randomized design (CRD). The percentage of the germination was transformed for statistical analysis using an arcsine transformation. If the data were zero, the square root $\sqrt{x+0.5}$ was applied. Means were compared using Duncan's Multiple Range Test (DMRT). Statistical analysis was performed using SAS (Version 9.3).

RESULTS AND DISCUSSION

1.1 Common buckwheat seed quality in the laboratory

After coating of seeds by different methods and quality testing, statistically significant differences were found between dead seeds and hard. Coating of seeds with NH_4NO_3, NaH_2PO_4, and KCl coupled with 2 g of metalaxyl (T6, T7, and T8, respectively) resulted in 150% more dead seeds than leaving seeds uncoated (T1). Seeds coated with NH_4NO_3 (T3) were hard and were statistically different from those treated by other methods, but similar to seeds coated with one coating substance and non-coated seeds. None of the seed coating methods resulted in abnormal seedlings, in contrast to non-coated seeds. In addition, when considering the percentage increase or decrease in hard seeds, coated seeds did not differ significantly from uncoated seeds. A declining trend in hard seeds was also found in coated kernels. The exception was seed coating with NH_4NO_3 0.384 g with hard seeds, which increased by 55% (Table 2).

The evaluation results of common buckwheat seed quality from the laboratory showed that only a few dead seeds were found from each method, but 1%-2% dead seeds were found from those seeds coated with plant nutrients mixed with metalaxyl (T6-T8). Moreover, in seeds coated with NH_4NO_3 at a ratio of 0.384 g, there were many hard seeds that were not different from those coated with one type of coating because Nitric oxide (NO•) is an uncharged, gaseous and lipophilic free radical that can readily diffuses across biological membranes. These free radicals restrict biochemical processes during germination (Arc *et al*., 2013). Consequently, common buckwheat seeds that were coated with nitrogen had more hard seeds than those coated with other substances or non-coated seeds. Furthermore, no methods of seed coating caused any abnormal seedlings. When evaluating the changes in the seeds after the culture, it was found that seeds coated with NH_4NO_3 gave the lowest rate and speed of radicle emergence, which was statistically different from the other methods. Additionally, seeds coated with KCl at a ratio of 0.104 g gave a higher rate of germination, which was statistically different from that of non-coated seeds by 14%. The evaluation results of the speed of radicle emergence showed that seeds coated with 0.104 g of KCl and 0.384 g of NaH_2PO_4 coupled with 2 g.ai. of metalaxyl had more rapid radicle emergence than non-coated seeds (Table 3).

In addition, NH_4^+ from NH_4NO_3 was the source of nitrogen that was absorbed during germination. Nitrogen plays an important role in the respiration and nutrient digestion system in seeds (Kucera *et al*., 2005) (Table 3). As a result, seed growth was better in seeds coated with NH_4NO_3 than in non-coated seeds. This concurred with the observed results of radicle emergence at 48 hours of culture, which showed that coating seeds with an active substance for all methods increased the possibility of root spread and produced a greater number of rootlets than non-coated seeds (Figure 1)

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Table 2 Dead seed, hard seed, and abnormal seedling percentage of buckwheat seeds after coating with difference types of plant nutrients and fungicide, tested under laboratory conditions.

Treatment[1]	Laboratory condition				
	Dead seed (%)[2]	**(%)[4]**	**Hard seed (%)**	**(%)**	**Abnormal seedling (%)**
T1	0 b[3]		10.0 ab		12.0
T2	0 b	(0)	9.0 ab	(-10)	7.5
T3	0.5 ab	(+50)	15.5 a	(+55)	10.0
T4	0 b	(0)	7.0 b	(-30)	10.0
T5	0.5 ab	(+50)	6.5 b	(-35)	5.0
T6	1.5 a	(+150)	4.5 b	(-55)	9.0
T7	1.5 a	(+150)	7.5 b	(-25)	6.0
T8	1.5 a	(+150)	5.5 b	(-45)	9.5
Mean	0.69		8.2		8.0
F-test	*		*		ns
CV (%)	34.29		22.9		32.41

ns, *: Not significantly different and significantly different at $p \leq 0.05$ respectively.

[1] T1 = Untreated, T2 = coating with CMC, T3 = coating with NH_4NO_3 0.384 g, T4 = coating with NaH_2PO_4 0.512 g, T5 = coating with KCl 0.104 g, T6 = coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai., T7 = coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. and T8 = coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai.

[2] Data are transformed by square root $\sqrt{x+0.5}$ before statistical analysis.

[3] Means within a column followed by the same letter are not significantly different at $p \leq 0.05$ by DMRT.

[4] The number in parentheses refer to percentage increase (+) and decrease (-) compared with the control.

Table 3 Radicle emergence, speed of radicle emergence (SRE), germination percentage, and speed of germination (SPG) of buckwheat seeds after coating with difference types of plant nutrients and fungicide, tested under laboratory conditions.

Treatment [1]	Laboratory condition							
	Radicle emergence (%)	**(%)[4]**	**SRE (roots/day)**	**(%)**	**Germinatio n (%)**	**(%)**	**SPG (plants/day)**	**(%)**
T1	82 a[2, 3]		39.50 a		77.0 bc		16.41 b	
T2	81 a	(-1)	39.08 a	(-1)	83.5 a-c	(+9)	17.00 ab	(+4)
T3	66 b	(-20)	30.33 b	(-23)	74.0 c	(-4)	14.53 c	(-11)
T4	80 a	(-2)	36.75 a	(-7)	83.0 a-c	(+8)	15.70 bc	(-4)
T5	84 a	(+2)	38.17 a	(-3)	88.0 a	(+14)	18.69 a	(+14)
T6	82 a	(0)	39.42 a	0	85.0 ab	(+10)	17.38 ab	(+6)
T7	83 a	(+1)	39.67 a	0	85.0 ab	(+10)	18.78 a	(+14)
T8	81 a	(-1)	38.67 a	(-2)	83.5 a-c	(+9)	17.38 ab	(+6)
Mean	80		37.70		82.0		16.98	
F-test	*		**		*		**	
CV(%)	6.67		7.17		7.09		6.8	

*, **: Significantly different at $p \leq 0.05$ and $p \leq 0.01$, respectively.

[1] T1 = Untreated, T2 = coating with CMC, T3 = coating with NH_4NO_3 0.384 g, T4 = coating with NaH_2PO_4 0.512 g, T5 = coating with KCl 0.104 g, T6 = coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai., T7 = coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. and T8 = coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai.

[2] Data were arcsine transformed before statistical analysis, and back transformed data are presented.

[3] Means within a column followed by the same letter are not significantly at $p \leq 0.05$ by DMRT.

[4] Numbers in parentheses refer to the percentage increase (+) and decrease (-) compared with the control.

1.2 Common buckwheat seed quality under greenhouse conditions

When buckwheat seed quality was tested with different seed coating methods and under greenhouse conditions, it was found that seeds coated with 0.512 g of NaH_2PO_4 and 0.104 g of KCl coupled with 2 g.ai. of metalaxyl (T7 and T8, respectively) gave a better result for cotyledon emergence percentage and speed of cotyledon emergence than other methods, with no statistically significant difference from seeds coated with 0.384 g of NH_4NO_3 and 0.104 g of KCl. Moreover, seeds coated with only one coating substance and seeds coated with 0.384 g of NaH_2PO_4 and 2 g.ai. of metalaxyl gave the highest germination percentage (increase 8% from non-coated seeds), which was statistically different from other methods. When the speed of germination was compared, the speed of germination of seeds coated with one coating substance, with 0.384 g of NH_4NO_3 and with 0.384 g of NaH_2PO_4 coupled with 2 g.ai. of metalaxyl, was faster than and statistically different from the non-coated seeds (Table 4).

Table 4 Cotyledon emergence percentage, speed of cotyledon emergence (SCE), germination percentage, and speed of germination (SPG) of buckwheat seeds after coating with difference type of plant nutrient and fungicide, tested under greenhouse condition

Treatment [1]	Greenhouse condition							
	Cotyledon emergence (%)	(%)[4]	SCE (plant/day)	(%)	Germination (%)[2]	(%)	SPG (plants/day)	(%)
T1	19 cd[3]		6.58 c		93 b		16.6 d	
T2	18 d	(-5)	6.25 c	(-5)	99 a	(+6)	18.4 a	(+11)
T3	29 a-c	(+53)	10.42 ab	(+58)	95 b	(+2)	17.8 a-c	(+7)
T4	16 d	(-16)	5.58 c	(-15)	97 b	(+4)	17.4 cd	(+5)
T5	33 ab	(+74)	11.75 ab	(+79)	95 b	(+2)	16.9 d	(+2)
T6	26 bc	(+37)	9.08 bc	(+38)	94 b	(+1)	17.0 cd	(+2)
T7	38 a	(+100)	14.00 a	(+113)	100 a	(+8)	17.9 ab	(+8)
T8	37 a	(+95)	13.42 a	(+104)	94 b	(+1)	17.0 cd	(+2)
Mean	27		9.64		95.88		17.4	
F-test	**		**		**		**	
CV(%)	14.75		25.41		4.11		2.97	

**: Significantly different at $p \leq 0.01$.

[1] T1 = Untreated, T2 = coating with CMC, T3 = coating with NH_4NO_3 0.384 g, T4 = coating with NaH_2PO_4 0.512 g, T5 = coating with KCl 0.104 g, T6 = coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai., T7 = coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. and T8 = coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai.

[2] Data are transformed by the arcsine before statistical analysis and back transformed data are presented.

[3] Means within a column followed by the same letter are not significantly at $p \leq 0.05$ by DMRT.

[4] Numbers in parentheses refer to percentage of increase (+) and decrease (-) compared with the control.

After buckwheat seed coating, considering the results of the experiment under laboratory conditions, it was found that seeds had a lower germination rate than those tested under greenhouse conditions. A possible explanation is that the conditions that occur in the laboratory with a number of factors as a control, such as the cultivation of treated seeds and between paper (BP), may result in various active substances; therefore, the substance adheres to the seed better than in the greenhouse test. As the germination rate was higher in the laboratory than in the greenhouse, the coated seed was subjected to a greater number of different factors, such as the substrate. Moreover, through the watering process, active substances attached to the seeds may have dissolved in the surrounding planting material. Also, fungicide chemical coatings on seeds may be able to dissolve in the substrate area. This gave the seedling roots a greater potential for utilization of the active ingredient in the greenhouse than in laboratory tests.

The experimental results showed that seeds coated with NaH_2PO_4 at a ratio of 0.512 g with 2 g.ai. of metalaxyl had a higher possibility of cotyledon emergence percentage, speed of cotyledon emergence, germination percentage, and speed of germination than other methods. Phosphorus (P) was the insufficient nutrient for the plants. In general, plants absorb P from the soil in the form of $H_2PO_4^-$ and HPO_4^{2-}, and the amount of the two substances would depend on the pH. Black (1968) reported that at pH 6-7, the amount of P was 50% of the total P, while a pH of 4-6 contained $H_2PO_4^-$ or 100% of Phosphorus in the solution. Simultaneously, at pH 8, $H_2PO_4^-$ was 20% and HPO_4^{2-} was 80% of the total P. However, most plants were unable to utilize such substances because they were separately adhered to clay (Vance *et al.*, 2003), so the seed coating delivered P to contact the seed. It could thus utilize the nutrients promptly after germination, which was useful for the seedlings'growth (Kangsopa and Siri, 2019). Moreover, P is very important to activate phytase activity in the form of orthophosphate from an inositol of phytic acid to form inorganic P together with phytase, which is useful for germination (Debnath *et al*., 2005; Azeke *et al*., 2011). With all the significances of P, some researchers had investigated this matter. For example, Rebafka *et al*. (1993) coated millet seeds with superphosphate, ammonium dihydrogen phosphate ($NH_4H_2PO_4$), monocalcium phosphate Ca $(H_2PO_4)_2$, sodium dihydrogen phosphate, and sodium triphosphate (STP) and found that coating with $(NH_4)H_2PO_4$ resulted in the best growth of the millet seeds. Karanam and Vadez (2010) also added that seeds coated with P were the optimal alternative to promoting the growth of millet seedlings and had positive effects on inflorescence and resulted in higher productivity. Furthermore, Masauskas *et al*. (2008) examined seed coating of malting barley with P and discovered that it helped with the vigor during the seedling phase and growth until the stage of productivity. Moreover, it enhanced the concentration of protein in the seeds, which increased the productivity. Additionally, Soares *et al*. (2016) discovered that P was one of the most important nutrients for soybean. The results of coating soybean with P showed that the shoot dry weight, root dry weight, yield components, and shoot height increased, as well as the root nodules that assist in nitrogen fixation. Importantly, it was noted that growth was more efficient.

2. Changes in common buckwheat seedling growth

2.1 Common buckwheat seedling growth under laboratory conditions

After testing the growth of the common buckwheat seedlings in the laboratory after coating with different methods, it was found that for all coating methods, there was no statistically significant difference in shoot length, seedling length, seedlings fresh weight or dry weight. For the test on the length of the common buckwheat root, it was found that seeds coated with 0.384 g of NaH_2PO_4 and 2 g.ai. of metalaxyl gave better results and were different from seeds coated with one coating substance. However, there was no difference when compared with other methods (Table 5).

The experimental results indicated that the shoot length, seedling length, seedlings fresh weight, and dry weight were similar. The most notable difference was in the change in the growth of the common buckwheat seedlings' roots, which were coated with 0.384 g of NaH_2PO_4 with 2 g.ai. of metalaxyl. This implied that root length was better than those of the non-coated seeds. P had the properties to activate the production of the substance that affected the root's emergence, such as glucose, auxins, ethylene, cytokinin, nitric oxide (NO), and reactive oxygen species (ROS) (Niu *et al*., 2013), so the seeds coated with 0.384 g of NaH_2PO_4 with 2 g.ai. of metalaxyl were likely to have better root growth than other methods. This result was consistent with the report of Zhu and Smith (2001), who compared the level of P of wheat seed and found that seeds with a high level of P showed enhanced root development.

Table 5 Shoot length, root length, seedling length, seedling fresh weight, and seedling dry weight of buckwheat seeds after coating with different types of plant nutrients and fungicide, tested under laboratory conditions

Treatment[1]	**Laboratory condition**					
	Shoot length (mm)	**Root length (mm)**	**(%)**[3]	**Seedling length (mm)**	**Seedling fresh weight (mg)**	**Seedling dry weight (mg)**
T1	101.38	154.33 ab[2]		255.70	1,975	115
T2	110.38	144.23 b	(-7)	254.60	2,015	117
T3	105.73	165.10 ab	(+7)	270.83	2,005	114
T4	106.28	152.68 ab	(-1)	258.95	2,020	120
T5	102.90	155.23 ab	(+1)	258.13	1,920	120
T6	107.20	169.20 ab	(+10)	276.40	1,897	111
T7	107.40	174.83 a	(+13)	282.23	1,962	115
T8	108.00	165.03 ab	(+7)	273.03	2,090	115
Mean	106.16	160.08		266.23	1985	116
F-test	ns	*		ns	ns	ns
CV(%)	6.17	11.4		7.88	8.53	9.03

ns, *: Not significantly different and significantly different at $p \leq 0.05$, respectively.

[1] T1 = Untreated, T2 = coating with CMC, T3 = coating with NH_4NO_3 0.384 g, T4 = coating with NaH_2PO_4 0.512 g, T5 = coating with KCl 0.104 g, T6 = coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai., T7 = coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. and T8 = coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai.

[2] Means within a column followed by the same letter are not significantly at $p \leq 0.05$ by DMRT.

[3] Numbers in parentheses refer to percentage increase (+) and decrease (-) compared with the control.

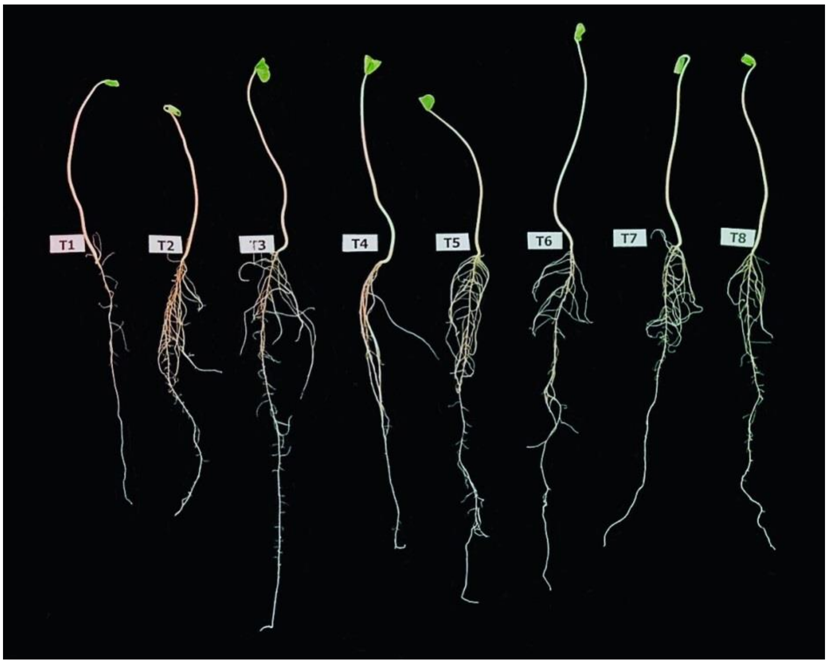

Figure 1 Effect of seed coating with different types of plant nutrients and fungicide on radicle emergence 3 days after planting tested under laboratory conditions. Untreated T1), coating with CMC T2), coating with NH_4NO_3 0.384 g T3), coating with NaH_2PO_4 0.512 g T4), coating with KCl 0.104 g T5), coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai. T6), coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. T7) and coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai. T8).

2.2 Changes in common buckwheat seedling growth in the greenhouse

When seedling length in common buckwheat was examined, it was found that seeds coated with 0.512 g of NaH_2PO_4 had the longest seedling length at 69.10 mm, which was statistically different from other methods. Regarding seedling fresh weight, it was found that seeds coated with 0.512 g of NaH_2PO_4 had higher fresh weight than those of other methods, with no statistically significant difference from coating with 0.384 g of NH_4NO_3. For seedling dry weight, seeds coated with 0.512 g of NaH_2PO_4 had a higher weight than non-coated seeds, which displayed a statistically significant difference (Table 6). Coated seeds in all treatments had a seedling dry weight 32%-67% higher than uncoated seeds.

The experimental results showed that seeds coated with 0.512 g of NaH_2PO_4 gave optimal growth of common buckwheat seedlings. Moreover, the change in shoot fresh and shoot dry weight was greater than that in non-coated seeds. Phosphorus (P) affected root growth during the seedling phase, so the seedlings grew faster (Baas *et al*., 2016) because this delivered the signal related to gibberellins, auxin, cytokinins, ethylene, and strigalactones, including the movement of microRNAs (miRNAs) that were related to the gene affecting cell expansion (White and Veneklaas, 2012). In addition, this helped the root to efficiently absorb potassium (George *et al*., 2016). These results also conformed with the study of Zelonka *et al*. (2005), who discovered that coating barley seeds with P enhanced the physiological activities of the seeds and increased productivity by 3%-91%. Moreover, the seeds absorbed P very well, which prevented them from being affected by environmental conditions. Furthermore, Kangsopa and Siri (2019) found that coating lettuce seeds with P improved seedling growth in terms of shoot length, root length, and seedling fresh and dry weight. Based on the results of seedling growth tested in the laboratory (shoot length, seedling length, seedling fresh weight, and seedling dry weight), although there were no statistically significant differences (Table 5), but the results for some seed quality parameters, including germination potential and seedling strength, were statistically significantly different. However, when considering the purpose of seed coatings combined with plant nutrients and anti-fungal chemicals in this study, metalaxyl did not affect the development of buckwheat at the seedling stage and was not different from other methods (Table 6).

Table 6 Shoot length, shoot fresh weight, and shoot dry weight of buckwheat seeds after coating with different types of plant nutrients and fungicide, tested under greenhouse conditions

Treatment[1]	Greenhouse condition					
	Shoot length (mm)	**(%)[3]**	**Shoot fresh weight (mg)**	**(%)**	**Shoot dry weight (mg)**	**(%)**
T1	46.85 d[2]		875 e		78.50 d	
T2	55.43 c	(+18)	1,230 d	(+41)	104.25 c	(+32)
T3	63.53 b	(+36)	1,502 ab	(+72)	124.50 ab	(+58)
T4	69.10 a	(+47)	1,555 a	(+78)	131.75 a	(+67)
T5	62.73 b	(+34)	1,340 cd	(+53)	119.50 b	(+52)
T6	60.90 b	(+30)	1,405 bc	(+61)	121.75 ab	(+55)
T7	63.58 b	(+36)	1,390 bc	(+59)	119.50 b	(+52)
T8	63.68 b	(+36)	1,455 bc	(+66)	126.50 ab	(+61)
Mean	60.72		1,344		116	
F-test	**		**		**	
CV(%)	4.61		6.23		6.20	

**: Significantly different at $p \leq 0.01$

[1] T1 = Untreated, T2 = coating with CMC, T3 = coating with NH_4NO_3 0.384 g, T4 = coating with NaH_2PO_4 0.512 g, T5 = coating with KCl 0.104 g, T6 = coating with NH_4NO_3 0.384 g mixed metalaxyl 2.0 g.ai., T7 = coating with NaH_2PO_4 0.384 g mixed metalaxyl 2.0 g.ai. and T8 = coating with KCl 0.104 g mixed metalaxyl 2.0 g.ai.

[2] Means within a column followed by the same letter are not significantly at $p \leq 0.05$ by DMRT.

[3] Numbers in parentheses refer to percentage increase (+) compared with the control.

CONCLUSION

The results of coating common buckwheat seeds with plant nutrients and fungicide at different ratios that were cultured to examine the quality in different environments were as follows:

1) Coating of seeds with 0.104 g of KCl increased the germination percentage by 14%

2) Tests conducted under greenhouse conditions showed that seeds coated with CMC and with 0.384 g of NaH_2PO_4 mixed with 2.0 g.ai of metalaxyl gave the best germination percentage, with a statistically significant difference when compared with other methods.

3) Coating of seeds with 0.384 g of NaH_2PO_4 mixed with 2.0 g.ai. of metalaxyl increased root length by 13%.

4) Seeds coated with 0.384 g of NaH_2PO_4 had longer shoots and higher shoot fresh and dry weights than non-coated seeds when tested under greenhouse conditions.

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