Songklanakarin J. Sci. Technol.
47 (4), 273–280, Jul. – Aug. 2025

http://www.sjst.psu.ac.th

Original Article

Effects of a new tomato organic seed coating agent on physical characteristics and seed quality of lettuce *(Lactuca sativa)*

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Received: 2 May 2024; Revised: 4 February 2025; Accepted: 21 May 2025

Abstract

Films prepared from tomato coatings have a thin, flexible, and highly elastic nature, with a non-smooth surface and high flexibility. When sodium alginate was added at 0.3, 0.6, and 0.9 v/v, the films became thinner, and the film surface was relatively smooth with moderate flexibility. When each coating formula was applied to lettuce seeds, both before and after accelerated aging, all these coatings resulted in higher germination rates compared to uncoated seeds when examined under laboratory conditions. In greenhouse conditions, tomato-alginate at all mixture proportions exhibited higher germination rates than the other methods. However, after accelerated aging, the seeds coated with tomato + alginate at 0.3, 0.6, and 0.9 v/v exhibited statistically significantly higher germination rates than the uncoated seeds. Additionally, the mentioned coating also significantly increased the shoot length compared to the other methods, both before and after accelerated aging in laboratory conditions. Therefore, preparing a coating with tomato + alginate at 0.3 v/v is recommended for coating lettuce seeds to enhance germination and seedling growth.

Keywords: polymer, organic seed coating, seed enhancement, *Lactuca sativa*

1. Introduction

Organic agriculture is of great importance to the overall environment, ensuring safety for both producers and consumers within the ecological system. Organic farming principles are an integral component of a living environmental system. Organic production relies on environmental processes and natural cycles, aiming to create suitable ecosystems for each type of production (Agricultural Research Development Agency, 2020). One crucial aspect of organic cultivation is the use of seeds produced in organic farming systems. The European Union has mandated that plant producers in organic agriculture must use seeds produced within the organic farming system (Bonina, & Cantliffe, 2004). However, seeds produced within the organic system have limitations in various aspects, especially for high-demand crops, such as organic lettuce, with a market demand of over 300 kg/day in Thailand. Seeds produced in organic farming systems have a short storage life, are susceptible to quality deterioration, and are vulnerable to diseases and pests due to their small size, limited food reserves (Kangsopa, Hynes, & Siri, 2018), and restrictions on fertilizer use in organic production systems. These factors ultimately affect the long-term quality of organic lettuce seeds.

Seed coating is a technology used to enhance seed quality with high efficiency. This involves applying a thin polymer layer around the seed surface (Pedrini, Merritt, Stevens, & Dixon, 2017). In general, commercially traded seeds are coated with seed-coating agents to maintain seed quality and promote germination and seedling growth. However, in organic farming systems, commercially available seed coating agents cannot be used on organic seeds due to the restricted use of certain chemicals in organic crop production. This limitation prevents organic seeds from undergoing

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quality enhancement to achieve the highest quality and performance for cultivation, similar to conventionally traded seeds.

Therefore, to enhance the quality of organic seeds, it is necessary to develop seed coating formulations that are acceptable for use in organic cultivation. This can be achieved by selecting important biopolymers that act as adhesive agents binding various organic active substances to the seed coat. Currently, biopolymers derived from plant sources, such as pectin, cellulose, starch, and chitosan, have been utilized. These biopolymers can be processed into a fine texture, resembling puree, by applying suitable heat and mechanical processes (Dalhatu, Khoonsap, Suwannarat, Amnuaypanich, & Amnuaypanich, 2022). The resulting material can be further shaped into seed-coating films (Albert, & Mittal, 2002; Espitia, Du, Avena-Bustillos, Soares, & McHugh, 2014; Lee, Connor-Appleton, Haq, Bailey, & Cartwright, 2004). Different plant species exhibit varying characteristics and properties in their seed coating films, influenced by their chemical components. Pectin serves as a component that binds cell tissues together, contributing to the flexibility and uniformity of the film. Cellulose fibers form the structural framework of plant cells, enhancing the film's stability. In particular, tomatoes, rich in vitamin C, vitamin K, potassium, and boron, also contain lycopene, a carotenoid compound with antioxidant properties (Ali *et al*., 2021; Thawong, Phuakjaiphaeo, Hermhuk, Inthasan, & Kangsopa, 2024). Lycopene plays a crucial role in delaying the deterioration of seed quality. Additionally, the fruit and juice of tomatoes can be shaped into films.

Therefore, the objective of this research was to develop an organic seed coating formulation using tomatoes and to monitor the physical changes in the film. Additionally, it aimed to assess the impacts on germination quality and seedling growth of coated lettuce seeds. The findings from this study provide an alternative option for using organic seed coatings to enhance the quality of seeds in organic crop production systems.

2. Materials and Methods

2.1 Preparation of tomato coating and film physical characteristics

Ripe table tomatoes were harvested after 85 days. They were washed thoroughly with distilled water, peeled, and cut into small pieces approximately 2 cm in size. The tomatoes were then simmered in boiling water for 20 minutes. Afterward, they were blended until smooth to make a puree. Finally, the recipe was prepared by combining the puree with various types of coating and seasoning agents, as indicated in Table 1.

2.2 Lettuce seed coating

This experiment utilized Red Oak lettuce seeds with a moisture content of 7%, purity of 99%, and germination rate of 96%. Subsequently, the coating agent prepared in section 2.1 was applied to the seeds using a rotary seed coater (model KSC-02D, Ceres International®). The following alternative treatments were used: T1) Uncoated seeds, T2) Tomato-coated seeds, T3) Tomato-coated seeds with 0.3 v/v alginate, T4) Tomato-coated seeds with 0.6 v/v alginate, and T5) Tomato-coated seeds with 0.9 v/v alginate. The coated seeds from each recipe were then subjected to moisture reduction using a forced-air oven model KKU40-2 at 33°C for 24 hours.

2.3 Accelerated aging of seed

The uncoated seeds and the coated seeds from section 2.2 were subjected to accelerated aging at 42°C for 48 hours. The moisture content of the aged seeds was reduced using a forced-air oven (model KKU40-2) at 33°C for 12 hours.

2.4 Data collection

2.4.1 Coating substance physical characteristics

1) pH of the coating substance

To test the acidity or alkalinity of the coating formulas listed in Table 1, a pH meter (model PH-80) was used. A glass rod probe was immersed in 50 mL of the coating solution. This process was repeated with four replications for each formula.

2) Coating substance viscosity

The viscosities of the coating formulas in Table 1 were measured using Standard Ford Viscosity Cup no. 0.4. The cup was filled with 100 mL of the coating solution, and the container was covered with a finger to prevent the coating from flowing out. When the finger was released, the timer was started, and the coating solution began to flow. The timer was stopped when the coating solution completely stopped flowing. The viscosity of the coating solution was measured at 25±1°C, and the data were recorded. This process was repeated with four replications for each formula. The recorded values were then used to calculate the viscosity of the coating solution expressed in centistokes (cSt).

Table 1. The alternative tomato coating formulations

Treatment	Tomato coating formulations				
	T1	T2	T3	T4	T5
Tomato (v/v)	-	30	30	30	30
Sodium alginate (w/v)	-	-	0.3	0.6	0.9
Talcum (w/v)	-	-	3	3	3
Water (ml)	-	70	69.7	69.4	69.1
Total (ml)	-	100	100	100	100

3) Film weight

Thirty milliliters of the coating formulas from Table 1 was poured into a clean Petri dish, ensuring there were no air bubbles present. Then, the dish was placed in an oven at 60°C for 18 hours. Afterward, the film was removed from the Petri dish, and the dish was stored in a plastic bag. The coating film was cut into 4 square centimeter pieces and weighed for each coating formula. This process was repeated with four replications (Korkasetwit, 2008).

4) Film dissolution

The solubility of the prepared film sheets, as mentioned in section 3, was tested. The grid had dimensions of 3×5 cm and holes measuring 2×1.5 mm, with a height of 1 cm. The film sheets made from various coating formulas were cut into 4 square centimeter pieces and placed on the grid. The grid with the film sheets was weighed and submerged in 100 mL of water contained in a beaker for 5 minutes. After the specified time, the grid with the film sheets was removed and dried in an oven at 60°C for 18 hours. The grid with the film sheets was weighed again. This procedure was repeated with four replications, and the solubility of the film was calculated based on a formula (Korkasetwit, 2008).

2.4.2 Seed quality

1) Seed quality examination under laboratory conditions

The quality assessment of seeds in the laboratory was conducted using the top of paper (TP) method. The experiment was repeated four times, with each repetition consisting of 50 seeds. The seeds were placed in a germination chamber at 25°C with a relative humidity of 80%, a light intensity of 180 micromoles per square meter per second, and continuous light exposure for 24 hours. Afterward, the following characteristics were examined.

1.1) Radicle emergence

In each of the four replications of all experiment methods, 50 seeds were assessed daily from day 3, when the root was at least 2 mm long (Kangsopa, & Atnaseo, 2022).

1.2) Speed of radicle emergence

Fifty seeds with radicles 2 mm in length were counted daily from day 1 to day 3 in each of the 4 replications of all experiment methods.

1.3) Germination percentage

All seeds were randomly selected for germination testing. Four replicates of 50 seeds each were tested. Normal seedlings were then evaluated after seeding days 4 and 7 (International Seed Testing Association [ISTA], 2019).

1.4) Speed of germination

The germination of normal seedlings was evaluated from the first count on day 4 to the final count on day 7 after germination. Each treatment had 4 replicates, with each repetition consisting of 50 seeds (Association of Official Seed Analysts [AOSA], 1983).

1.5) Mean germination time

The germination of normal seedlings was recorded daily from day 1 to day 7 after germination. The formula from Ellis (2022) was used to calculate the results.

1.6) Shoot length and root length

In each of the four replications, 10 seedlings were assessed on day 7 after germination. The shoot length of the seedlings was measured from the base of the epicotyl to the tip of the leaf. The root length was measured from the bottom to the tip of the taproot. The seedling length was measured from the tip of the root to the tip of the leaf (Baki, & Anderson, 1973).

2) Seed quality examination in greenhouse conditions

2.1) Germination percentage

The germination test was conducted under greenhouse conditions, where the temperature was maintained at 25±2°C with 60±5% relative humidity. Peat moss was used as the growing medium. Each treatment was carried out in 4 replicates with 50 seeds each in pit trays. Normal seedlings were assessed after the first seeding on days 4 and 7. Then, the germination percentage was calculated using the obtained data, following the same procedure as in laboratory conditions.

2.2) Speed of germination and mean germination time

The speed of germination and mean germination time were evaluated in the same manner as when determined in laboratory conditions.

2.3) Shoot length

Shoot length was assessed on 10 randomly selected plants **7** days after planting by measuring the length of the shoot. Shoots were cut at the base close to the seedling media, and shoot length was measured.

2.5 Statistical analysis

The percentage of germination was arcsine transformed to normalize the data before statistical analysis. All data were analyzed by one-way analysis of variance (ANOVA, Complete Randomized Design), and the difference between the treatments was tested by Duncan's Multiple Range Test (DMRT).

3. Results and Discussion

3.1 Physical characteristics of the coating substance

The pH testing of the coating substance is crucial to prevent a decrease in the effectiveness of moisture absorption and essential nutrient uptake during the seed germination process (Siri, 2015). The optimal pH range for the germination and growth of lettuce is between 5.5 and 6.0 (Winslow, 2023). Testing the coating substance in liquid form revealed that tomato preparation as a coating substance has a slightly acidic pH. Similarly, as reported by George (2010), tomato fruits were found to have a pH range of 4.3-4.7. When alginate was added at three alternative concentrations together with the tomato coating substance, it was observed that the coating substance exhibited a light orange color, and the components of the coating substance precipitated when left undisturbed for 5–10 minutes. The coating substances in all three formulations (F2–F4) had a neutral pH (Table 2).

Viscosity is an important property that allows seeds to bind effectively with the coating substance. From the experimental results, the viscosity of the coating substance prepared solely with tomatoes was 1.48 cSt. Subsequently, the viscosity of the coating substance increased proportionally with the addition of alginate at three concentrations (Table 2). General seed coating substances in various research studies have utilized polymers derived from natural extracts, such as hydroxypropyl methyl cellulose, with a viscosity of 289 cps at a concentration of 5% w/v for sweet corn seeds (Korkasetwit, 2008). As for commercially available coating substances commonly used in Thailand, there are two types with viscosities of 110.67 cSt (Ceres international®) and 94.62 cSt (Incotec®) (data not shown). However, commercial coating substances are often used in a coating substance-to-water ratio of 20:80, as their high viscosity may have an impact on the quality of the seeds after application (Siri, 2015). In the seed coating process, it is common to prepare the coating substance with a viscosity ranging within 30–40 cSt to facilitate its application with seed coating machines.

The weight of the film serves as an indicator of the film's density, which may impact the water and air absorption of the seeds (Siri, 2015). Film sheets prepared by incorporating alginate at three concentrations exhibited increased weight compared to tomato coating substances alone, approximately twice as much. The preparation of these film sheets revealed that, when solely prepared with the tomato coating substance, the film sheets were thin, sticky, and highly flexible, but the surface was not smooth (Figure 1). This experiment demonstrated the efficacy of the film. If utilized as a seed coating, it should be capable of maintaining its film-like properties for an extended period without compromising stability. The tomato coating substance alone and the tomato coating substance mixed with alginate at concentrations of 0.3 v/v and 0.6 v/v demonstrated high water solubility, which differed from the tomato coating substance mixed with alginate at a concentration of 0.9 v/v, where water solubility was measured as 36.24%, a lower value and distinctive from the other formulations. Nevertheless, the film sheets prepared using all methods displayed water solubility, indicating that the films prepared from tomato peels tended not to impede the seed germination process. Thus, considering the physical properties of the coating substance derived from tomato peel extracts, it can be inferred that it shows a propensity to facilitate seed germination when employed as a seed-coating substance.

Table 2. Film characteristics of coating agents, pH and viscosity of prepared solutions

Coating substance	Coating solution		Film characteristic	
	pH	Viscosity (cSt)	Film weight (mg)	Film dissolution (%)
Tomato	4.9 b[1]	1.48 d	0.3 b	56.10 a
Tomato + alginate 0.3 v/v	7.1 a	7.18 c	0.6 a	54.76 a
Tomato + alginate 0.6 v/v	7.0 a	42.32 b	0.7 a	54.84 a
Tomato + alginate 0.9 v/v	7.1 a	171.49 a	0.7 a	36.24 b
F-test	**	**	**	**
C.V. (%)	1.00	61.95	14.43	21.10

**: significantly different at P≤0.01

[1] Means within a column followed by the same letter are not significantly different at P≤0.05 according to DMRT.

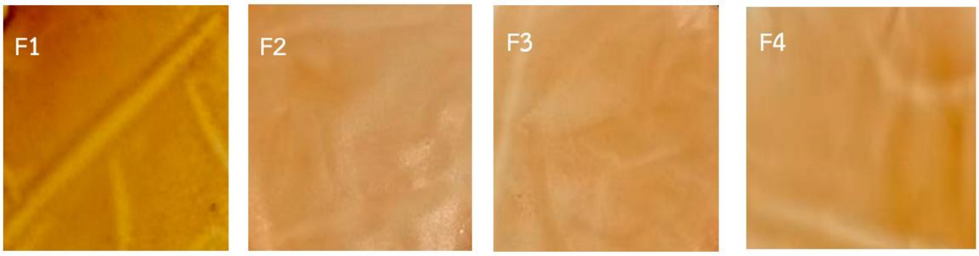

Figure 1. Films obtained from various coating solutions as follows: F1 = Tomato-coated, F2 = Tomato with alginate at 0.3 v/v, F3 = Tomato with alginate at 0.6 v/v, and F4 = Tomato with alginate at 0.9 v/v

3.2 Lettuce seed quality

In laboratory conditions, before accelerating the aging process, lettuce seed coating with tomato and alginate at all three mixture proportions did not affect germination quality. Coating the seeds with alginate included (T3–T5) showed a trend of higher germination percentages, but the differences were not statistically significant compared to the uncoated seeds. Tomato + alginate at 0.3 v/v demonstrated a significantly faster mean germination time and differed from uncoated seeds. After accelerating the aging process, tomato with alginate in all cases resulted in higher germination and speed of germination compared to uncoated seeds. Tomato + alginate at 0.9 v/v revealed that the seeds were able to germinate faster and differed from the other cases (Table 3).

In greenhouse conditions, coating the seeds with tomato extract mixed with alginate (T3–T5) resulted in a significantly higher germination percentage and speed of germination, showing clear statistical differences from uncoated seeds. After the aging process, distinct changes were observed, where tomato + alginate at 0.3 v/v exhibited a higher germination percentage and speed of germination compared to the other treatments. Furthermore, the coated seeds exhibited significantly faster germination compared to the uncoated seeds (Table 4).

Currently, there are no prior reports on the use of tomato extracts as a seed-coating material in seed production. However, this research has demonstrated that tomato extracts can create flexible films when subjected to physical testing. Furthermore, when applied as a thin coating, it did not impede the germination process of lettuce seeds, particularly in terms of water and air absorption, as observed in laboratory and greenhouse conditions (Halmer, 2008; Hill, 1994). It is important to note that the suitability of the coating material, including its type and concentration, is crucial. Unsuitable coatings may impact enzyme stimulation, cellular respiration, and slow down cell duplication, consequently affecting embryonic development and reducing the speed and germination of seeds (Abel, & Theologis, 1996). Additionally, tomato coatings, being liquid and transparent, do not interfere with the germination process affected by the photosensitivity or photo-dormancy exhibited by lettuce seeds, which prevents them from germinating in the absence of light.

Table 3. Germination percentage (GE), speed of germination (SGE), and mean germination time (MGT) of lettuce seeds with or without aging of coated seeds under laboratory conditions

Treatment[1]	Laboratory condition					
	Non-aged			Aged		
	GE (%)[2]	SGE (seedling/day)	MGT (day)	GE (%)[2]	SGE (seedling/day)	MGT (day)
T1	96 b[3]	12.42	3.18 a	88 b	10.11 b	4.48 a
T2	100 a	12.42	3.14 ab	92 ab	10.96 ab	4.06 b
T3	98 ab	12.25	3.03 b	96 a	11.76 a	3.67 c
T4	99 ab	12.36	3.13 ab	97 a	11.63 a	3.64 c
T5	99 ab	12.13	3.07 ab	96 a	11.79 a	3.27 d
F-test	*	ns	*	*	*	**
C.V. (%)	4.75	1.28	2.41	7.17	4.71	5.10

ns, *, **: non significantly, significantly different at P≤0.05 and P≤0.01, respectively
[1] T1 = uncoated seeds, T2 = Tomato-coated seeds, T3 = Tomato with alginate at 0.3 v/v, T4 = Tomato with alginate at 0.6 v/v, and T5 = Tomato with alginate at 0.9 v/v
[2] Data were transformed by arcsine before statistical analysis.
[3] Means within a column followed by the same letter are not significantly different at P≤0.05 according to DMRT.

Table 4. Germination percentage (GE), speed of germination (SGE), and mean germination time (MGT) of lettuce seeds with or without aging of coated seeds under greenhouse conditions.

Treatment[1]	Greenhouse conditions					
	Non-aged			Aged		
	GE (%)[2]	SGE (seedling/day)	MGT (day)	GE (%)[2]	SGE (seedling/day)	MGT (day)
T1	69 c[3]	8.10 b	3.71	65 b	7.61 b	4.72 a
T2	77 b	9.06 ab	3.32	57 b	6.87 b	3.84 bc
T3	82 a	9.72 a	3.03	92 a	11.39 a	3.47 c
T4	85 a	10.23 a	2.94	58 b	6.91 b	3.95 bc
T5	83 a	9.94 a	3.33	52 b	5.57 b	4.03 b
F-test	**	**	ns	**	**	**
C.V. (%)	18.98	22.79	12.21	11.41	16.51	5.03

ns, **: non significantly and significantly different at P ≤ 0.01, respectively.
[1] T1 = uncoated seeds, T2 = Tomato-coated seeds, T3 = Tomato with alginate at 0.3 v/v, T4 = Tomato with alginate at 0.6 v/v, and T5 = Tomato with alginate at 0.9 v/v
[2] Data were transformed by arcsine before statistical analysis.
[3] Means within a column followed by the same letter are not significantly different at P≤0.05 according to DMRT.

After the aging process, which is a method used to assess seed vigor (Delouche, & Baskin, 1973), it was observed that when tested under laboratory conditions, seeds treated with tomato + alginate at concentrations of 0.3, 0.6, and 0.9 v/v, as well as tomato, exhibited significantly higher germination rates and speed of germination compared to uncoated seeds when evaluated in greenhouse conditions (Siri, 2015). The protective layer formed by the coating film helps shield the seeds from unfavorable external temperature conditions. Additionally, it controls water permeability, resulting in the reorganization of phospholipids and improving the regulation of essential substances entering and exiting the cells (Bewley, & Black, 1985). These advantages contribute to enhancing the seed's germination. Furthermore, the tomato coating showed a positive effect on seed vigor, as evidenced by increased germination speed both before and after the aging process. Furthermore, when considering pH, the tomato coating material had a slightly acidic pH of 4.9. According to the recommendations of (Ağçam, Akyıldız, & Dündar, 2018), both seed germination and lettuce growth perform well within the pH range of 4.5-4.6. Therefore, the prepared coating derived from tomato extracts and mixed with alginate at the three blend proportions closely aligned with the recommended pH range. Additionally, the extremely low coating-to-seed ratio had a minimal impact on both the germination rate and speed, both before and after the aging process. pH level has a significant effect on plant nutrient availability; thus, maintaining a suitable balance is essential. If the pH is too high or too low, it may adversely affect germination and plant growth (Gentili, Ambrosini, Montagnani, Caronni, & Citterio, 2018).

When tomato extracts are considered, various important compounds accumulate in the solution, particularly sugars, antioxidants, and vitamin C (Semiarti *et al*., 2010). In this regard, vitamin C, which contains hydroxyl groups, can release hydrogen. Hence, it is classified as a water-soluble acid that functions as an antioxidant in cells and organs composed predominantly of water, thereby mitigating the cellular damage to seeds in unfavorable environmental conditions (aging test) (Delouche, & Baskin, 1973; Ellis, 2022; Mittler, 2002). Based on the experimental findings, the use of tomato coating alone and tomato + alginate at 0.3 v/v showed promising results, with no apparent negative impact on the quality of lettuce seeds when evaluated in both laboratory and greenhouse conditions.

3.3 Shoot and root length of lettuce seedlings

In laboratory conditions, prior to accelerated aging, tomato + alginate at 0.3 v/v had a longer shoot compared to the other coating treatments. However, all coating methods showed no significant difference in root length compared to the uncoated seeds. After accelerated aging, uncoated seeds exhibited decreased shoot and root lengths when compared to actual treatments (T2–T5). In greenhouse conditions, before accelerated aging, tomato + alginate at 0.3 v/v or at 0.9 v/v showed higher shoot lengths and differed significantly from uncoated seeds. After accelerated aging, all coatings (T2–T5) exhibited significantly higher shoot lengths compared to the uncoated seeds (Table 5).

The evaluation of growth changes in lettuce seedlings, both before and after coating the seeds with only tomato coating and a mixture of tomato and alginate at three alternative proportions, clearly demonstrated significantly improved shoot and root growth compared to uncoated seeds. This indicates that the tomato coating does not hinder cell expansion in lettuce seedling growth. This finding is consistent with the results of film dissolution tests, which showed that the film dissolves well in water, providing suitable conditions for seed germination and subsequent normal seedling growth. Moreover, tomato coating solutions contain accumulated sugars and antioxidants (Semiarti *et al*., 2010), particularly a high accumulation of vitamin C, which promotes seed germination. Vitamin C is a water-soluble antioxidant that can eliminate free radicals, which increase during plant stress (Babu, & Devaraj, 2008). When accelerated aging was considered, the shoot and root elongation of lettuce seedlings from coated seeds was significantly higher than that of uncoated seeds. Furthermore, the accumulated vitamin C in the coating solution may protect cells and maintain their normal state during seed aging. For instance, when lettuce plants were sprayed with a 0.5 mM vitamin C solution under 300 mM salt stress for 9 hours, the plant survival rate increased by 50% (Shalate, & Neumann,

Table 5. Shoot length (SHL) and root length (RHL) of lettuce seeds with or without aging of coated seeds under laboratory and greenhouse conditions

Treatment[1]	Laboratory conditions				Greenhouse conditions	
	Non-aged		Aged		Non-aged	Aged
	SHL (mm)	RHL (mm)	SHL (mm)	RHL (mm)	SHL (mm)	SHL (mm)
T1	9.7 b[2]	24.5	10.6 b	2.69 b	10.8 b	9.0 b
T2	10.3 ab	25.0	11.4 ab	2.85 ab	11.3 ab	10.2 a
T3	10.8 a	27.5	12.0 a	3.27 a	12.5 a	10.6 a
T4	9.5 b	25.2	11.7 ab	3.30 a	11.8 ab	10.7 a
T5	9.8 b	25.7	13.0 a	3.24 a	12.8 a	10.5 a
F-test	**	ns	**	**	**	**
C.V. (%)	4.95	13.51	5.47	33.10	7.16	8.27

ns, **: non significantly and significantly different at P≤0.01, respectively

[1] T1 = uncoated seeds, T2 = Tomato-coated seeds, T3 = Tomato with alginate at 0.3 v/v, T4 = Tomato with alginate at 0.6 v/v, and T5 = Tomato with alginate at 0.9 v/v

[2] Means within a column followed by the same letter are not significantly different at P≤0.05 according to DMRT.

2001). Additionally, vitamin C enhances seed vigor, as reported by (Burguieres, McCue, Kwon, & Shetty, 2007), who soaked *Pisum sativum* seeds in a 20 μM vitamin C solution for approximately 12-24 hours before planting, resulting in increased levels of lycene and phenolic compounds. Vitamin C also controls the process of metabolizing during germination, promoting improved seedling growth. Therefore, the application of tomato extract as a coating material for lettuce seeds did not negatively affect the shoot and root elongation of lettuce seedlings during the 7-day testing period.

4. Conclusions

The tomato coating substance mixed with sodium alginate at proportions of 0.3, 0.6, and 0.9 v/v exhibited a neutral pH and displayed excellent water solubility. The coating substance can dissolve well in water. Seed accelerated aging was tested, revealing that seeds coated with tomato + alginate at proportions of 0.3, 0.6, and 0.9 v/v demonstrated the highest germination rates under laboratory conditions. Similarly, in greenhouse conditions, seeds coated with tomato + alginate at 0.3 v/v concentration exhibited the highest germination rates. Therefore, it is recommended to employ a coating of tomato + alginate at the concentration of 0.3 v/v for enhancing the germination and seedling growth of lettuce seeds.

Acknowledgements

We would like to thank The National Research Council of Thailand (NRCT), for the financial support for this research. This project was conducted under the Research and Researcher for industries (RRI) project, 2022, [grant number: N41A650733]. The authors would like to offer particular thanks to the Division of Agronomy, Faculty of Agricultural Production, Maejo University for materials and the use of laboratories and research sites.

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