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# Preparation of Tartary Buckwheat Seed Coating Agent and Its Effect on Germination

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## ABSTRACT

To mitigate the wastage of seed resources and reduce the usage of pesticides and fertilizers, seed coating agents have gained popularity. This study employs single-factor and multi-index orthogonal experimental design methods to investigate the seed coating formula and physical properties of Tartary buckwheat. The specific effects of each component on Tartary buckwheat seed germination are analyzed. The findings reveal that the seed coating agent formulated with 1.5% polyvinyl alcohol, 0.15% sodium alginate, 0.2% op-10, 0.1% polyacrylamide, 8% colorant, 3% ammonium sulfate, 1% potassium dihydrogen phosphate, and 0.15% carbendazim exhibits the most effective coating. It demonstrates optimal physical properties and promotes seed germination efficiently. The suspension rate of this seed coating agent reaches 91.12%, with a mere 2.13% coating shedding rate and 2.5% coating seed rot rate. Furthermore, it achieves a germination percentage of 99.17%, which is 20.84% higher than the lowest group. The germination potential and index are also significantly higher than the lowest group, with an increase of 20.84% and 26.56%, respectively. Additionally, the vitality index is 553.08, a 15.75% increase compared to the lowest group. The application of seed coating agents helps reduce seed resource loss, increase plant numbers, and ultimately enhance agricultural yields. This finding holds practical significance in agricultural production.

## KEYWORDS

Tartary buckwheat; seed coating agent; formula; germination

## 1 Introduction

Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.) is an annual herbaceous plant [1]. It is rich in lysine [2], phenols [3], flavonoids [4], and D-Chiral inositol [5]. These components can improve the body's antioxidant system function, potentially lower blood sugar and lipids, and exhibit anti-cancer properties [6]. Due to these reasons, Tartary buckwheat holds significant development value and prospects. The cultivation technology to enhance its yield and quality has been gaining increasing attention. Tartary buckwheat has a short growth period and wide adaptability, making it a valuable crop with superior planting advantages. It has been extensively studied and shows potential for producing and



commercializing related products. However, buckwheat is sensitive to abiotic stress, particularly during seedling [7]. Through years of research, we have identified the urgent issue of low seed emergence rate in Tartary buckwheat. Our germination experiments revealed a high mold rate, which directly affects the seedlings' resistance, seedling rate, and yield.

Seed coating agent is a chemical pesticide preparation that can be used for coating crop seeds or plant seeds and has film-forming characteristics. It can directly deliver essential compounds (symbiotic microorganisms, micronutrients, growth regulators, etc.) and is filled with protective chemicals (pesticides, herbicides, fungicides, etc.), which is more conducive to seed germination and survival under unfavorable environmental conditions [8,9]. At present, the application of seed coating agents has been more common in the international market, and most of the agricultural and horticultural seeds sold in the market have been coated with seeds [10], especially the film seed coating agent, which was widely popularized and applied in the 1980s [11]. European and American countries have developed patented seed coating agent products for agricultural production. The research focus on coated crops in developed countries is different, but most focus on wheat, corn, cotton, flowers, seedlings, rice, vegetables, and other crops [12]. Coated seeds can also be stored for a long time without losing their characteristics [13], which has outstanding advantages and application value.

In order to apply the seed coating agent to the field of Tartary buckwheat more effectively, it is necessary to study the basic formula of conventional seed coating agents in detail. In this study, Xiqiao No. 1 was selected as the research material, and the germination of seeds was studied using different coating treatments to develop a conventional seed coating agent formula suitable for Tartary buckwheat.

## 2 Material and Methods

### 2.1 Plant Materials

This experiment was conducted from November 2021 to February 2022, and the Tartary buckwheat "Xiqiao No.1 (XQ1)" was provided by the Key Laboratory of Coarse Grains Processing of the Ministry of Agriculture and Rural Affairs of Chengdu University.

### 2.2 Seed Coating Preparation

According to the preliminary experiment, the drug-seed ratio was set to 1:40, polyvinyl alcohol and sodium alginate were used as film-forming agents, op-10, polyacrylamide, and colorant were used as auxiliaries, and ammonium sulfate, potassium dihydrogen phosphate, and carbendazim were used as active ingredients.

The film-forming agent was screened by single-factor experimental design. The concentration of the film-forming agent (all concentrations in this paper refer to mass concentration) was set as follows: polyvinyl alcohol: 0.5%, 1%, 1.5%, 2%, and 2.5%, respectively; Sodium alginate: 0.05%, 0.1%, 0.15%, 0.2%, and 0.25%.

Polyvinyl alcohol (PVA) is an excellent film-forming agent. It was found that sodium alginate not only has the film-forming ability but also has the function of increasing the viscosity of solution so that the seed coating agent can better adhere to the surface of seeds. The single factor pre-experiment in the early stage showed that the film-forming ability of polyvinyl alcohol solution with 1.5%, 2%, and 2.5% concentration was qualified; 0.15%, 0.2%, and 0.25% sodium alginate solutions are qualified for film formation. Considering that if they are compounded, the concentration of the film-forming agent cannot form a film after the two film-forming agents are compounded, so the concentration range of polyvinyl alcohol is set to 1%, 1.5%, and 2%. The concentration range of sodium alginate is set to 0.1%, 0.15%, and 0.2%, and further experiments are made, as shown in [Table 1](#).

**Table 1:** Formula of film-forming agent

Number	Polyvinyl alcohol	Sodium alginate
T1	1 (1%)	1 (0.1%)
T2	1	2 (0.15%)
T3	1	3 (0.2%)
T4	2 (1.5%)	1
T5	2	2
T6	2	3
T7	3 (2%)	1
T8	3	2
T9	3	3
Control	0	0

The selection of additives adopts a factor experimental design and multi-index orthogonal experimental design, and the factors and concentrations are set as OP-10: 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%, respectively. Polyacrylamide: 0.05%, 0.1%, 0.15%, 0.2%, and 0.25%; Colorant: 6%, 8%, 10%, 12%, and 14%. Op-10, polyacrylamide, and colorant are set at three levels, as shown in [Table 2](#).

**Table 2:** Table of factors in an orthogonal test of additives

Level	(A) Op-10/%	(B) Polyacrylamide/%	(C) Colorant/%
1	0.1	0.05	8
2	0.2	0.1	10
3	0.3	0.15	12

The active ingredients were screened by single-factor experimental design and multi-index orthogonal experimental design, and the factors and concentrations were set as follows: ammonium sulfate: 1%, 2%, 3%, 4% and 5%, respectively; Potassium dihydrogen phosphate: 1%, 2%, 3%, 4%, and 5%; Carbendazim: 0.05%, 0.1%, 0.15%, 0.2%, and 0.25%. There are three levels for ammonium sulfate, potassium dihydrogen phosphate, and carbendazim, as shown in [Table 3](#).

**Table 3:** Table of factors in orthogonal test of active ingredients

Level	(A) Ammonia sulfate/%	(B) Monopotassium phosphate/%	(C) Carbendazol/%
1	1	1	0.1
2	2	2	0.15
3	3	3	0.2

### 2.3 Plant Growth and Sample Preparation

The seed germination test adopts the filter paper germination method, and two layers of filter paper are placed in a Petri dish with a diameter of 11 cm as a germination bed to ensure that the filter paper is saturated

with water and the Petri dish is free of water at any time. Forty seeds were placed in each dish, and three replicates were set. The Petri dish was placed in a light incubator, and the culture conditions were set at 25°C and light for 12 h/day. Observe the seed germination at 6 pm daily and replenish the lost water.

Taking the seed implantation day as the first day, taking the hypocotyl length as the germination standard, measuring the germination potential on the fourth day, and ending the germination on the seventh day, randomly selecting three seedlings with similar growth and measuring the primary root length (cm) for each repetition, and calculating the germination percentage, germination potential, germination index, vigor index, and seed mildew rate.

#### 2.4 Determination

According to the quality inspection method of suspension seed coating agent in GB/T 17768-1999 [14], the following physical performance indices of seed coating agent were determined: Film-forming property: after the coated seeds were laid flat for 5 min, the surface of the seeds was stirred and observed. If all seed coating agents on the surface of the seeds had solidified into films, and the seeds did not stick or agglomerate, the film-forming agent was qualified.

$$\text{Suspension rate (\%)} = (10m_a - m_b)/m_a \times 111 \quad (1)$$

$m_a$ : the mass (g) of 25 mL suspension left at the bottom of measuring cylinder A evaporated to constant weight,  $m_b$ : the mass (g) of 25 mL suspension left at the bottom of measuring cylinder B evaporated to constant weight.

$$\text{Coating shedding rate (\%)} = (A_0m_1 - m_0A_1)/A_0m_1 \times 100\% \quad (2)$$

$m_0$ : the mass of coated seeds in preparation solution A,  $m_1$ : the mass of coated seeds in preparation solution B,  $A_0$ : the absorbance of solution A, and  $A_1$ : the absorbance of solution B.

$$\text{Uniformity of coating} = n/20 \times 100\% = 5n \quad (3)$$

$n$ : number of coated seeds with absorbance a ranging from 0.7 to 1.3,  $20$ : number of coated seeds tested.

$$\text{Germination percentage (GP)} = n/N \times 100\% \quad (4)$$

$n$ : number of seeds germinated on the 7th day,  $N$ : total number of seeds [15].

$$\text{Germination energy (GE)} = n/N \times 100\% \quad (5)$$

$n$ : the number of seeds germinated on the fourth day,  $N$ : the total number of seeds [16].

Germination index (GI) was estimated by using the formula described in the Association of Official Seed Analysts.

$$\text{Germination index (GI)} = \sum G_t/D_t \quad (6)$$

$G_t$ : number of seeds germinated on day  $t$ ,  $D_t$ : number of days in calculation [17].

$$\text{Vigor index (VI)} = \text{GI} \times h \quad (7)$$

GI: germination index,  $h$ : taproot length (cm).

$$\text{Seed mildew rate (SMR)} = n/N \times 100\% \quad (8)$$

$n$ : number of seeds mildew on the 7th day,  $N$ : total number of seeds [17].

## 2.5 Statistical Analysis

All the data were statistically sorted by Excel 2016 software and statistically analyzed by SPSS Statistics 26.0 with ANOVA analysis of variance. The data were expressed by the mean standard deviation (SD), significantly analyzed by the least significant difference method (LSD).

## 3 Results

### 3.1 Screening of Film Forming Agents

As shown in Table 4, the film-forming ability of the solution is qualified for different combinations, and the compound film-forming agent has little effect on the germination percentage of Tartary buckwheat seeds. By observing the data, compared with other treatments, the germination percentage, germination potential, germination index, and vigor index of buckwheat seeds in T5 are relatively higher, which are 97.5%, 97.5%, 70.01%, and 475.36%, respectively. Considering comprehensively, the compound concentration of T5 film-forming agent was selected, that is, 1.5% polyvinyl alcohol and 0.15% sodium alginate.

**Table 4:** Effect of film-forming agent on germination of Tartary buckwheat seeds (means  $\pm$  SD, n = 3)

Number	Film forming property	GP/%	GE/%	GI	VI
T1	Qualified	96.67 $\pm$ 1.44a	95.83 $\pm$ 2.89ab	70.78 $\pm$ 3.25a	490.56 $\pm$ 97.45a
T2	Qualified	94.17 $\pm$ 1.44a	90.83 $\pm$ 3.82b	53.56 $\pm$ 17.48b	350.71 $\pm$ 118.54b
T3	Qualified	95.83 $\pm$ 3.82a	95.83 $\pm$ 3.82ab	64.17 $\pm$ 9.33ab	412.12 $\pm$ 15.38ab
T4	Qualified	95.00 $\pm$ 2.50a	94.17 $\pm$ 3.82ab	60.11 $\pm$ 6.38ab	425.90 $\pm$ 77.93ab
T5	Qualified	97.50 $\pm$ 2.50a	97.50 $\pm$ 2.50a	70.01 $\pm$ 1.71a	475.36 $\pm$ 32.55ab
T6	Qualified	95.00 $\pm$ 4.33a	92.50 $\pm$ 6.61ab	61.61 $\pm$ 2.86ab	410.29 $\pm$ 72.36ab
T7	Qualified	94.17 $\pm$ 1.44a	93.33 $\pm$ 1.44ab	60.19 $\pm$ 8.02ab	405.26 $\pm$ 83.71ab
T8	Qualified	96.67 $\pm$ 1.44a	95.00 $\pm$ 2.50ab	61.03 $\pm$ 5.7ab	413.36 $\pm$ 48.17ab
T9	Qualified	95.83 $\pm$ 1.44a	95.83 $\pm$ 1.44ab	60.28 $\pm$ 7.73ab	409.11 $\pm$ 45.54ab
Control	/	93.33 $\pm$ 1.44a	93.33 $\pm$ 1.44ab	66.3 $\pm$ 3.22ab	449.56 $\pm$ 37.55ab

Note: GP: germination percentage; GE: germination energy; GI: germination index; VI: vitality index. Different lowercase letters indicate the significant difference ( $p \leq 0.05$ ) among the same multi-concentrations analyzed by LSD using SPSS 26.0.

### 3.2 Selection of Auxiliaries

Considering the stable physical properties, environmental protection, low cost, and other aspects, the selected auxiliaries are Op-10, polyacrylamide, and colorant, which are mixed with 1.5% polyvinyl alcohol and 0.15% sodium alginate, respectively, and the single factor test of auxiliaries is carried out.

As shown in Table 5, compared with control, 0.5% op-10 significantly reduced the germination percentage by 13.33%, and there was no significant difference under other concentrations. The appearance of the seed coating was uniform, without obvious impurities and bumps. Therefore, according to the comprehensive consideration of data and cost, 0.1%, 0.2%, and 0.3% are selected as the concentration range of op-10 in the orthogonal test. Compared with control, 0.25% polyacrylamide significantly reduced the germination percentage by 5.83%, and polyacrylamide had a uniform coating effect. According to the comprehensive consideration of data and cost, 0.05%, 0.1%, and 0.15% were selected as the concentration range of polyacrylamide in the orthogonal test. Compared with the control, different concentrations of colorant had no significant effect on the germination percentage. The coverage of 6% colorant on the seed surface was weak, and the coating was uneven. After coating it with 14% colorant, the seed surface was rough, and the coloring thickness was uneven. Therefore, the concentration range of colorant is 8%, 10%, and 12%.

**Table 5:** Effect of additives on germination percentage of Tartary buckwheat seeds (means  $\pm$  SD, n = 3)

Op-10			Polyacrylamide			Colorant		
C/%	GP/%	Uniformity	C/%	GP/%	Uniformity	C/%	GP/%	Uniformity
0.1	88.33 $\pm$ 2.89a	Uniform	0.05	85.00 $\pm$ 2.50a	Uniform	6	87.50 $\pm$ 2.50a	Uneven
0.2	90.00 $\pm$ 5.00a	Uniform	0.1	85.83 $\pm$ 3.82a	Uniform	8	85.00 $\pm$ 5.00a	Uniform
0.3	85.00 $\pm$ 5.00a	Uniform	0.15	85.83 $\pm$ 1.44a	Uniform	10	88.33 $\pm$ 2.89a	Uniform
0.4	88.33 $\pm$ 2.89a	Uniform	0.2	86.67 $\pm$ 2.89a	Uniform	12	84.17 $\pm$ 5.20a	Uniform
0.5	75.00 $\pm$ 5.00b	Uniform	0.25	82.50 $\pm$ 2.50b	Uniform	14	85.83 $\pm$ 3.82a	Uneven
0	88.33 $\pm$ 1.44a	/	0	88.33 $\pm$ 1.44a	/	0	88.33 $\pm$ 1.44a	/

Note: C: concentration; GP: germination percentage. Different lowercase letters indicate the significant difference ( $p \leq 0.05$ ) among the same multi-concentrations analyzed by LSD using SPSS 26.0.

Regardless of the interaction between factors, the optimal formula of the seed coating agent was obtained by the comprehensive balance method. Orthogonal table L9(3<sup>4</sup>) is selected to arrange the experiment. Table 6 shows the experimental scheme and results. It can be seen from Table 7 that the influence degree of different factors is different for different indicators, and the optimal scheme corresponding to different indicators is also different. The comprehensive balance is as follows:

Factor A: In terms of suspension rate and coating uniformity, A1 is the best choice. In terms of coating shedding rate and germination percentage, A3 is the best choice. In addition, factor A is the second factor for these four indicators, so the influence of which level is selected on the four indicators is relatively tiny. A1 is selected to reduce solvent consumption based on the principle of reducing consumption.

Factor B: In terms of suspension rate, coating uniformity, and germination percentage, B1 is the best choice. From the suspension rate, B1 is the most crucial factor, and from Ki(ki), we know that the suspension rates of B1 and B3 are pretty different. B3 is the best choice for the coating shedding rate, and B3 is the most crucial factor. From Ki(ki), we know little difference between the coating shedding rates when B1 and B3 are selected. So choose B1.

Factor C: From the perspective of suspension rate, C1 is the best choice. From the perspective of germination percentage, C1 is also the best choice, and C1 is the most crucial factor. It is essential to consider when determining the superior level. From Ki(ki), it can be seen that the germination percentage is much higher when C1 is selected than C2. From the perspective of coating shedding rate, C3 is the best choice, the secondary factor at the bottom. From the perspective of coating uniformity, C2 is the best choice, and C2 is the most crucial factor. From Ki(ki), it can be seen that there is little difference in coating uniformity when C1, C2, and C3 are selected. So choose C1.

**Table 6:** Test scheme and test results of additives screening

Number	A	B	C	Blank	Suspension percentage/%	Coating shedding rate/%	Coating uniformity/%	GP/%
T1	1 (0.1%)	1 (0.05%)	1 (8%)	1	91.12	2.13	63.33	94.17
T2	1	2 (0.1%)	2 (10%)	2	85.52	5.10	65.00	65.83
T3	1	3 (0.15%)	3 (12%)	3	76.56	7.45	68.33	83.33
T4	2 (0.2%)	1	2	3	89.87	2.23	68.33	81.67

(Continued)

Number	A	B	C	Blank	Suspension percentage/%	Coating shedding rate/%	Coating uniformity/%	GP/%
T5	2	2	3	1	80.69	5.02	58.33	85.83
T6	2	3	1	2	78.78	4.97	58.33	88.33
T7	3 (0.3%)	1	3	2	85.46	3.50	65.00	90.00
T8	3	2	1	3	82.10	6.60	61.67	87.50
T9	3	3	2	1	75.46	7.82	66.67	93.33

Note: GP: germination percentage.

**Table 7:** Analysis of test results of additives screening

Target		A	B	C	Blank
Suspension percentage/%	K <sub>1</sub>	253.2	266.45	252	247.27
	K <sub>2</sub>	249.34	248.31	250.85	249.76
	K <sub>3</sub>	243.02	230.8	242.71	248.53
	k <sub>1</sub>	84.40	88.82	84.00	82.42
	k <sub>2</sub>	83.11	82.77	83.62	83.25
	k <sub>3</sub>	81.01	76.93	80.90	82.84
	R	10.18	35.65	9.29	2.49
	Primary and secondary order	BAC			
	Optimal scheme	B <sub>1</sub> A <sub>1</sub> C <sub>1</sub>			
	Coating shedding rate/%	K <sub>1</sub>	14.68	7.86	13.7
K <sub>2</sub>		12.22	16.72	15.15	13.57
K <sub>3</sub>		17.92	20.24	15.97	16.28
k <sub>1</sub>		4.89	2.62	4.57	4.99
k <sub>2</sub>		4.07	5.57	5.05	4.52
k <sub>3</sub>		5.97	6.75	5.32	5.43
R		5.7	12.38	2.27	2.71
Primary and secondary order		BAC			
Optimal scheme		B <sub>3</sub> A <sub>3</sub> C <sub>3</sub>			
Coating uniformity/%		K <sub>1</sub>	196.66	196.66	183.33
	K <sub>2</sub>	184.99	185	200	188.33
	K <sub>3</sub>	193.34	193.33	191.66	198.33
	k <sub>1</sub>	65.55	65.55	61.11	62.78
	k <sub>2</sub>	61.66	61.67	66.67	62.78
	k <sub>3</sub>	64.45	64.44	63.89	66.11
	R	11.67	11.66	16.67	10
	Primary and secondary order	CAB			
	Optimal scheme	C <sub>2</sub> A <sub>1</sub> B <sub>1</sub>			

(Continued)

Target		A	B	C	Blank
GP/%	K <sub>1</sub>	243.33	265.84	270	273.33
	K <sub>2</sub>	255.83	239.16	240.83	244.16
	K <sub>3</sub>	270.83	264.99	259.16	252.5
	k <sub>1</sub>	81.11	88.61	90.00	91.11
	k <sub>2</sub>	85.28	79.72	80.28	81.39
	k <sub>3</sub>	90.28	88.33	86.39	84.17
	R	27.5	26.68	29.17	29.17
	Primary and secondary order	CAB			
Optimal scheme	C <sub>1</sub> A <sub>3</sub> B <sub>1</sub>				

Note: GP: germination percentage.

Based on the above analysis, the optimal scheme is A1B1C1, 0.2% op-10, 0.1% polyacrylamide and 8% colorant.

### 3.3 Screening of Active Ingredients

The optimal concentrations of polyvinyl alcohol, sodium alginate, op-10, polyacrylamide, and colorant were mixed with different concentrations of active ingredients, and the single-factor tests of active ingredients were carried out after coating. As shown in Table 8, compared with control, the germination percentage was significantly increased by 7.67% when the concentration of ammonium sulfate was 2%, so 1%, 2%, and 3% ammonium sulfate were selected as the concentration range of the orthogonal test. Compared with control, when the concentration of potassium dihydrogen phosphate is 2%, the germination percentage is most significantly increased by 9.17%, so 1%, 2%, and 3% are selected as the concentration range of potassium dihydrogen phosphate in the orthogonal experiment. Compared with the control, the germination percentage of Tartary buckwheat seeds was significantly improved when the concentration of carbendazim was 0.15%, 0.2%, and 0.25%, especially when it was 0.15%. The mildew rate of seeds treated with carbendazim was significantly reduced (the seeds were not disinfected in advance), and the mildew rate of seeds reached the lowest when the concentration of carbendazim was 0.2% or 0.25%. According to the germination and seed mildew rates, 0.1%, 0.15%, and 0.2% were selected as the concentration range of potassium dihydrogen phosphate in the orthogonal test.

**Table 8:** Effect of active ingredients on mildew rate of Tartary buckwheat seeds (means  $\pm$  SD, n = 3)

Ammonia sulfate		Monopotassium phosphate		Carbendazol		
C/%	GP/%	C/%	GP/%	C/%	GP/%	SMR/%
1	90.83 $\pm$ 3.82bc	1	92.5 $\pm$ 4.33ab	0.05	85.83 $\pm$ 3.82bc	5.83 $\pm$ 1.44b
2	96 $\pm$ 0a	2	97.5 $\pm$ 2.5a	0.1	89.17 $\pm$ 10.1abc	5 $\pm$ 0bc
3	94.5 $\pm$ 1.80ab	3	93.33 $\pm$ 2.89ab	0.15	96.67 $\pm$ 2.89a	2.5 $\pm$ 2.5cd
4	90.83 $\pm$ 1.44bc	4	90.83 $\pm$ 1.44c	0.2	92.5 $\pm$ 2.5ab	1.67 $\pm$ 1.44d
5	88.33 $\pm$ 3.82c	5	88.33 $\pm$ 2.89c	0.25	91.67 $\pm$ 2.89ab	0.83 $\pm$ 1.44d
0	88.33 $\pm$ 1.44c	0	88.33 $\pm$ 1.44c	0	80.83 $\pm$ 1.44c	10 $\pm$ 2.5a

Note: C: concentration; GP: germination percentage; SMR: seed mildew rate. Different lowercase letters indicate the significant difference ( $p \leq 0.05$ ) among the same multi-concentrations analyzed by LSD using SPSS 26.0.



Regardless of the interaction between factors, the optimal formula of the seed coating agent was obtained by the comprehensive balance method. Orthogonal table L9(3<sup>4</sup>) is selected to arrange the experiment. Table 9 shows the experimental scheme and results. As can be seen from Table 10, the influence degree of different factors is different for different indicators, and the optimal scheme corresponding to different indicators is also different. After the comprehensive balance, the specific balance is as follows:

Factor A: Regarding germination percentage and potential, A2 and A3 are the best choices, and their factor A is the main factor. From the germination index, A3 is the best choice, and factor A is the main factor. Judging from the vitality index, A2 is the best choice. From  $K_i(k_i)$ , it can be seen that there is little difference between A2 and A3, and from the extreme range, A is the less crucial factor. Therefore, according to the majority tendency and the importance of factor A to different indicators, A3 is selected.

Factor B: In terms of germination percentage, germination potential, and germination index, B2 is the best choice, and from  $K_i(k_i)$ , it can be seen that there is little difference in germination percentage, germination potential, and germination index when B1, B2, and B3 are selected. Judging from the vitality index, B3 is the best choice. In addition, factor B is the last factor for these four indicators, so the influence of which level is selected on the four indicators is relatively tiny. B1 is selected to reduce solvent consumption based on the principle of reducing consumption.

Factor C: For the four indicators, the best level is C2, so C2 is selected.

Based on the above analysis, the optimal scheme is A3B1C2, namely 3% ammonium sulfate, 1% potassium dihydrogen phosphate, and 0.15% carbendazim.

**Table 9:** Experimental scheme and results of active ingredient screening

Number	A	B	Blank	C	GP/%	GE/%	GI	VI
T1	1 (1%)	1 (1%)	1	1 (0.1%)	78.33	78.33	53.08	477.82
T2	1	2 (2%)	2	2 (0.15%)	95.00	95.00	64.19	581.48
T3	1	3 (3%)	3	3 (0.2%)	90.83	90.83	62.21	593.05
T4	2 (2%)	1	2	3	96.67	96.67	65.42	543.19
T5	2	2	3	1	96.67	96.67	64.76	567.58
T6	2	3	1	2	95.00	95.00	64.03	563.7
T7	3 (3%)	1	3	2	99.17	99.17	67.18	553.08
T8	3	2	1	3	94.17	94.17	64.33	495.54
T9	3	3	2	1	95.00	95.00	65.20	497.57

Note: GP: germination percentage; GE: germination energy; GI: germination index; VI: vitality index.

**Table 10:** Analysis of experimental results of active ingredient screening

Target		A	B	Blank	C
GP/%	$K_1$	264.16	274.17	267.5	270
	$K_2$	288.34	285.84	286.67	289.17
	$K_3$	288.34	280.83	286.67	281.67
	$k_1$	88.05	91.39	89.17	90.00

(Continued)

<b>Table 10 (continued)</b>					
Target		A	B	Blank	C
GE/%	k <sub>2</sub>	96.11	95.28	95.56	96.39
	k <sub>3</sub>	96.11	93.61	95.56	93.89
	R	24.18	11.67	19.17	19.17
	Primary and secondary order	ACB			
	Optimal scheme	A <sub>2</sub> C <sub>2</sub> B <sub>2</sub> or A <sub>3</sub> C <sub>2</sub> B <sub>2</sub>			
	K <sub>1</sub>	264.16	274.17	267.5	270
	K <sub>2</sub>	288.34	285.84	286.67	289.17
	K <sub>3</sub>	288.34	280.83	286.67	281.67
	k <sub>1</sub>	88.05	91.39	89.17	90.00
	k <sub>2</sub>	96.11	95.28	95.56	96.39
GI	k <sub>3</sub>	96.11	93.61	95.56	93.89
	R	24.18	11.67	19.17	19.17
	Primary and secondary order	ACB			
	Optimal scheme	A <sub>2</sub> C <sub>2</sub> B <sub>2</sub> or A <sub>3</sub> C <sub>2</sub> B <sub>2</sub>			
	K <sub>1</sub>	179.48	185.68	181.44	183.04
	K <sub>2</sub>	194.21	193.28	194.81	195.4
	K <sub>3</sub>	196.71	191.44	194.15	191.96
	k <sub>1</sub>	59.83	61.89	60.48	61.01
	k <sub>2</sub>	64.74	64.43	64.94	65.13
	k <sub>3</sub>	65.57	63.81	64.72	63.99
VI	R	17.23	7.6	13.37	12.36
	Primary and secondary order	ACB			
	Optimal scheme	A <sub>3</sub> C <sub>2</sub> B <sub>2</sub>			
	K <sub>1</sub>	1652.35	1574.09	1537.06	1542.97
	K <sub>2</sub>	1674.47	1644.6	1622.24	1698.26
	K <sub>3</sub>	1546.19	1654.32	1713.71	1631.78
	k <sub>1</sub>	550.78	524.70	512.35	514.32
	k <sub>2</sub>	558.16	548.20	540.75	566.09
	k <sub>3</sub>	515.40	551.44	571.24	543.93
	R	128.28	80.23	176.65	155.29
Primary and secondary order	CAB				
Optimal scheme	C <sub>2</sub> A <sub>2</sub> B <sub>3</sub>				

Note: GP: germination percentage; GE: germination energy; GI: germination index; VI: vitality index.

To sum up, we suggest that the best formula for seed coating agent is 1.5% polyvinyl alcohol, 0.15% sodium alginate, 0.2% op-10, 0.1% polyacrylamide, 8% colorant, 3% ammonium sulfate, 1% potassium dihydrogen phosphate and 0.15% carbendazim. At this time, the germination percentage is 99.17%.

#### 4 Discussion

Polyvinyl alcohol (PVA) is a biodegradable synthetic polymer [18] with hydrophilic characteristics approved by the FDA, which has good film-forming, adhesion, and excellent thermal stability [19]. It is also called “green polymer” because of its solubility and biodegradability [20]. Sodium alginate is a natural polysaccharide, which can also be obtained by biosynthesis [21] and has the advantages of non-toxicity, biodegradability, and easy preparation [22]. In agricultural applications, sodium alginate is mainly used as a carrier of nutrients [23] or as a component of slow-release coating [24]. Because of their excellent stability and biodegradability, polyvinyl alcohol and sodium alginate were chosen as the preferred materials for the film-forming seed-coating agent. Finally, the optimal mass concentration of their combination was 1.5% polyvinyl alcohol and 0.15% sodium alginate. Op-10 is a stable emulsifier, which avoids flocculation of all components. This experiment found that ammonium sulfate and polyacrylamide will partially flocculate into coated spheres, so adding op-10 and designing a preparation process can make them blend well. Polymer is one of the promising materials recently applied to soil stabilization. Polyacrylamide (PAM) is one of the most commonly used superabsorbent polymers (SAP), which can stabilize the soil surface by aggregating fine soil particles, thus reducing soil erosion caused by irrigation [25]. Because of its long-term water retention capacity, PAM is usually used as an agricultural water-retaining agent [26]. Other studies have reported that PAM can strengthen nutrient retention and inhibit weed growth [27].

Seeds with low germination potential lead to low competition potential of seedlings in the field [28]. Germination percentage represents seed vigor and is an important index to evaluate seed quality [29]. Studies have pointed out that nitrogen, phosphorus, and potassium, especially nitrogen, play a vital role in plants' physiological and biochemical metabolism [30]. In the single-factor experiment of this study, 2% ammonium sulfate has the best effect, and the seed germination percentage is 7.67% higher than that of the blank control; 2% potassium dihydrogen phosphate has the best effect, and the seed germination percentage is 9.17% higher than that of the blank control. According to reports, compared with applying fertilizer to soil or foliage, using limited nutrient elements can more effectively overcome the problem of crop nutrient deficiency and improve plant growth in poor soil [31]. Some studies show that applying potassium dihydrogen phosphate can reduce malondialdehyde's content and reduce plants' oxidative damage [32]. Carbendazim is a broad-spectrum fungicide used to control fungal pathogens in cereals and fruit crops [33], reducing the probability of fungal invasion of seeds during storage and germination. In the single-factor experiment of this study, carbendazim significantly improved the germination percentage of seeds, which was 15.84% higher than that of the blank control. It also significantly reduced the number of moldy seeds, and the moldy rate of seeds was at most 9.17% lower than that of the blank control, consistent with the research results obtained by the above scholars. Germination is the main characteristic that determines the maximum potential of seed quality, and it evaluates the percentage of normal seedlings under the best development conditions [34].

In good cultivation practice, seed quality is one of the main factors to be considered to establish good field seedlings and achieve good grain yield. The research results provide a technical reference for applying Tartary buckwheat in the seed coating agent industry. On this basis, some targeted functional components, such as pesticides, hormones, and beneficial fungi, are added to achieve the expected results, which expands the potential application of seed coating agents in miscellaneous grains and other fields. At the same time, further research on the subsequent growth of Tartary buckwheat-coated seeds is necessary to prove this coating agent's practicability in agricultural production.

## 5 Conclusions

The optimal formulation of the Tartary buckwheat seed coating agent is 1.5% polyvinyl alcohol, 0.15% sodium alginate, 0.2% op-10, 0.1% polyacrylamide, 8% colorant, 3% ammonium sulfate, 1% potassium dihydrogen phosphate and 0.15% carbendazim. The seed coating agent has the advantages of stable performance, good film-forming performance, short film-forming time, low shedding rate, high coating uniformity, suspension rate of 91.12%, convenient use, and good promotion effect on seed germination, with the germination percentage as high as 99.17%. The combination of various components can reduce the mildew rate of seeds, thus effectively reducing the loss of resources, and has no adverse impact on the safety of Tartary buckwheat seeds, which has a good promotion prospect.

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