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Effect of potassium fertilizer on the nutrition and physical quality of Job's tears (*Coix lacryma-jobi* L.) seeds

Abstract. Job's tears is a cereal crop that has beneficial nutrients. Potassium is known to affect the growth and yield of cereal crops, but there has been limited study on whether potassium affects the nutrition and physical quality of Job's tears seeds. This study aimed to analyze the effect of K fertilizer on the nutritional content and physical quality of Job's tears seeds. This research was conducted from January to May 2024 at Ciparanje Experimental Field, Faculty of Agriculture, Universitas Padjadjaran, Sumedang, Indonesia. This experiment used the Randomized Block Design (RBD) method with six treatments and four replications. Various doses of K fertilizer (KCl) were tested, i.e., 0, 62.5, 125, 250, 375, and 500 kg/ha KCl. The measured nutritional content was the extraction rates of carbohydrate, protein, lipid, calcium, and potassium, while the physical quality was represented by the weight of husked grain, size of seeds, and seed hardness. Results showed that potassium increased the extraction rates of carbohydrate, protein, lipid, calcium, and potassium. Potassium also increased the weight of husked grain and size of seeds. A dosage of 500 kg/ha KCl resulted in the best nutrition, weight of husked grain, and size of seeds.

Keywords: Dosage · Extraction rate · Job's tears · Nutrition · Potassium

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Introduction

Job's tears (*Coix lacryma-jobi* L.) is a cereal plant that has many health benefits and nutritional value (Wicaksono et al., 2024; Aqil et al., 2023). Nutrients such as carbohydrates, proteins, fats, and important minerals, such as calcium and potassium, are found in Job's tears seeds (Ramadhan et al., 2022). Job's tears contain less carbohydrates than rice, so it can be a healthy alternative food (Qosim & Nurmala, 2011). In addition, the high protein content makes Job's tears play a role in the formation and repair of body tissues, enzymes, and hormones, so that it can support the body's metabolic processes (Aminah et al., 2019). Job's tears have a healthy fat content, which supports cell function and body metabolism (Djaja, 2022; Devaraj et al., 2020). Calcium in Job's tears plays a role in maintaining healthy bones and teeth and supporting nerve and muscle function (De & De, 2019; Pravina et al., 2013), while potassium has an important role, especially in maintaining electrolyte balance and nerve function, excretion process and fluid balance in the human body (Aminah et al., 2019). Varieties of job's tears from different regions and habitats may show varied nutritional compounds (Rupitak et al., 2024; Biswas & Das, 2022; Devaraj et al., 2020)

To develop biofortification of Job's tears product, fertilizer is needed to make optimal photosynthesis, macromolecule synthesis, and finally produce high quality product (Wang et al., 2019). One essential nutrient that plays a role in the growth and seed development is potassium (K) (Torabian et al., 2021). Potassium is an essential macronutrient in many physiological processes in plant cells, such as enzyme activation, membrane potential maintenance, and osmotic regulation (Vijayakumar et al., 2021). Appropriate potassium dosing can promote yield formation by promoting photosynthate transport and coordinating biomass accumulation in source organs and storage organs (Wang et al., 2018; Epron et al., 2016). The important role of potassium in determining the quality of agricultural products is related to chemical compositions (Sardans et al., 2021).

Potassium regulates diverse biochemical processes associated with regulating photosynthesis, translocation, protein synthesis, and carbohydrate metabolism (Hasanuzzaman et al., 2018). The application of potassium enhances the efficiency of carbon fixation during photosynthesis by increasing photosynthetic activity. Fructose-1,6-bisphosphatase (FBpase) is a key enzyme in the Calvin cycle, and its activity is closely related to photosynthetic efficiency, as well as the accumulation and distribution of photosynthesis. FBPase has a K^+ binding site, and higher application rates of potassium fertilizer significantly increase FBPase activity, which in turn regulates carbohydrate accumulation and distribution, thereby increasing yield (Hu et al., 2015). Potassium also plays a role in balancing the charge of nitrate ions (NO_3^-) absorbed by plants, thereby facilitating more efficient nitrogen uptake (Blevins et al., 1978). This process is closely related to the role of K^+ in transporting nitrogen, a major component of protein, to the site of protein synthesis (Saktiono et al., 2021). Potassium affects plant quality by increasing lipid content by increasing the activity of enzymes related to lipid synthesis (Chen et al., 2023). Potassium helps regulate the activity of several key enzymes in the lipid biosynthesis pathway, such as Acetyl-CoA carboxylase (ACCase), fatty acid synthase (FAS), glycerol 3-phosphate dehydrogenase (3 GPD), phosphatidyl phosphatase (PPase), and glycerol 3-phosphate acyltransferase (GPAT).

In addition to affecting the chemical composition, potassium also plays a role in the physical quality of seeds in Job's tears. Sufficient potassium levels enable optimal transport of photosynthetic products from leaves to seeds, which can increase size of seeds (Jiaying et al., 2022). Potassium deficiency can result in incomplete seed filling, leading to small and shriveled seeds (Liu et al., 2011). Potassium can increase carbohydrate synthesis and translocation, thereby increasing the thickness of the cell wall, which affects the outermost layer of the seed coat and then increases seed hardness (Mutaqin et al., 2019). Seed hardness influences grain extraction rate from the dehuller machine (Blandino et al., 2010; Reichert & Youngs, 1984). Optimal potassium is expected to produce seeds with a dense structure and good physical quality (Usherwood, 1985).

However, the study of potassium fertilizer on nutritional content and physical characteristics of the local variety of Job's tears seeds is still unknown. This study aims to analyze the effect of K fertilizer dosages on the content and extraction rates of carbohydrate,

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protein, lipid, calcium, and potassium in Job's tears seeds. The research can be useful to provide the best potassium dosage in optimizing the quality of local Job's tears seeds.

Materials and Methods

This research was conducted from January 2024 to May 2024 at Ciparanje Experimental Farm, Faculty of Agriculture, Universitas Padjadjaran, Sumedang, Indonesia. The elevation of the research site is 750 m above sea level, and the agroclimate zone is C3 according to Oldeman classification. The soil has a pH of 5.9, indicating a weakly acidic condition. Nitrogen content is low, phosphorus is high, potassium is low, and the cation exchange capacity is 16.31 $cmol.kg^{-1}$ (Table 1). Analysis of nutrient content was carried out at the Laboratory of the Agency for Agricultural Assembly and Modernization for Vegetable Crops, West Bandung, Indonesia.

The materials used were Job's tears seeds from the Watani Wado variety, collected from the Laboratory of Crop Production Technology, Faculty of Agriculture, Universitas Padjadjaran; urea; SP-36; KCl fertilizer; cow manure; pesticides; and laboratory materials for nutrition analysis (filter paper, distilled water, etc). The tools used analytical scales, grain dehuller machine, laboratory equipment (oven, analytical scales, digestion tube, test tube, UV-VIS spectrophotometer, microwave digester, dropper, measuring cup, 500 ml Erlenmeyer, 100 ml Kjeldahl flask, distillation equipment, electric heater), and agricultural tools.

This experiment used the Randomized Block Design (RBD) method with six treatments and four replications, so that there were 24 experimental units. The treatment is dosages of KCl fertilizer, consisted of A = no K fertilizer (Control); B = 25% of the recommended dose of K fertilizer (62.5 kg/ha KCl = 3 g/plant); C = 50% of the recommended dose of K fertilizer (125 kg/ha KCl = 6 g/plant); D = 100% of the recommended dose of K fertilizer (250 kg/ha KCl = 11.97 g/plant); E = 150% of the recommended dose of K fertilizer (375 kg/ha KCl = 17.95 g/plant); F = 200% of the recommended dose of K fertilizer (500 kg/ha KCl = 23.94 g/plant).

Table 1. Soil chemical analysis of Ciparanje Experimental Farm

No	Parameters	Unit	Result	Criteria
1.	pH: H_2O	-	5.9	Weakly acidic
2.	pH: KCl 1 N	-	4.6	-
3.	C-organic	(%)	1.94	Low
4.	N-total	(%)	0.21	Low
5.	C/N	-	9	Low
6.	P_2O_5 HCl 25%	(mg/100g)	60.86	High
7.	P_2O_5 (Olsen)	(ppm P)	33.8	High
8.	K_2O HCl 25%	(mg/100g)	13.25	Low
9.	Al-dd	($cmol.kg^{-1}$)	0.00	-
10.	H-dd	($cmol.kg^{-1}$)	0.11	-
11.	CEC	($cmol.kg^{-1}$)	16.31	
	Base saturation	(%)	63	Medium
12.	K: Morgan Venema	(%)	44.4	High
13.	Cations:			
	K-exch	($cmol.kg^{-1}$)	0.11	Low
	Na-exch	($cmol.kg^{-1}$)	0.09	Low
	Ca-exch	($cmol.kg^{-1}$)	7.66	High
	Mg-exch	($cmol.kg^{-1}$)	2.47	Very High
14.	Texture:			
	Sand	(%)	4	
	Dust	(%)	38	
	Clay	(%)	58	

Notes: CEC was cation exchange capacity, exch was exchangeable; source from the Agency for Agricultural Assembly and Modernization for Vegetable Crops (2024)

The size of the plot was 3 x 2 m. The plant spacing was 60 x 40 cm. Basic fertilization used manure 2 t/ha, a week before planting. Seeds were planted after germinating for 4 days. Urea fertilizer 300 kg/ha was applied to the plants 3 times, namely at 3, 6, and 9 weeks after planting (WAP). SP-36 fertilizer 200 kg/ha is given once at 3 WAP, while KCl fertilizer was given twice, at 3 and 6 WAP, with the dose based on each treatment. Plant maintenance includes watering, weeding, and pest and disease control. Harvesting was done at 170 days after planting, when the plants dried, and the seeds reached physiological maturity. Job’s tears seeds are dried under the sun, which aims to reduce the water content in the job's tears seeds. Job’s tears seeds are polished using a dehuller machine.

Chemical analysis was carried out on Job's tears seeds, including protein content by the semi-micro Kjeldahl method; carbohydrate content by the Luff-Schoorl method; fat content by the Soxhlet method; calcium and potassium content by the wet soaking method (AOAC, 2019). Each nutrition extraction rate is measured by multiplying each nutrition content and weight of the husked grain. The size of the seeds is measured using calipers, while the seed hardness is measured using a penetrometer.

Nutrition content data is presented descriptively, while weight of husked grain, extraction yield, size of seeds, and seed hardness data were analyzed using Least Significant Difference (LSD) at a significant level of 5%. The data processing used the SmartstatXL program.

Results and Discussion

Results. The results showed that potassium provision starting from 50% of the recommended dose increased the weight of husked seeds compared to the control (Table 2). The 200% recommended dose gave the best yield, but was not different from 150%.

Potassium greatly affected the nutritional content of Job’s tears seeds (Table 3). Lower doses of potassium (A, B, and C) gave higher carbohydrate content. Increasing potassium doses from 25% to 100% recommended dose gave higher protein compared to the control, but higher doses decreased it. Concerning lipid, calcium, and potassium content, the KCL doses did not show a definite tendency.

Table 2. Effect of potassium dosage on the weight of husked grain of Job’s tears

Treatment	Weight of husked grain (g)
A	31.3 a
B	41.1 ab
C	43.3 b
D	44.2 b
E	51.9 bc
F	56.8 c

Note: A = Control; B = 3 g/plant; C = 6 g/plant; D = 11.97 g/plant; E = 17.95 g/plant; F = 23.94 g/plant. Mean values followed by the same lowercase letter in the same column are not significantly different based on Least Significant Difference (LSD) at a significant level of 5%.

In contrast to the nutrient content, increasing the potassium dose gave a higher nutrient extraction rate compared to the control (Table 4). Increasing the potassium dose to 200% of the recommended dose gave the best carbohydrate and protein rate, although not significantly different from the 150% recommended dose treatment. As much as 200% of the recommended dose gave the best lipid yield, but this dose did not give a significant difference with 150% or 100% in calcium extraction rate, and was not significantly different from the 50 to 150% dose in potassium extraction rate.

Table 3. Effect of potassium dosage on nutrient content of Job’s tears seeds

Treatment	Carbohydrate (%)	Protein (%)	Lipid (%)	Calcium (mg/100g)	Potassium (mg/100g)
A	57.45	14.9	4.01	80	310
B	57.95	15.86	4.27	60	270
C	57.44	16.08	3.58	60	340
D	53.3	16.14	4.14	80	340
E	53.79	15.41	3.75	70	270
F	53.79	15.18	4.14	70	310

Note: A = Control; B = 3 g/plant; C = 6 g/plant; D = 11.97 g/plant; E = 17.95 g/plant; F = 23.94 g/plant.

Table 4. Effect of potassium dosage on nutritional content of Job's tears seeds

Treatment	Carbohydrate (g/plant)	Protein (g/plant)	Lipid (g/plant)	Calsium (mg/plant)	Potassium (mg/plant)
A	18.0 a	4.7 a	1.3 a	25.0 a	97.0 a
B	23.8 b	6.5 b	1.8 bc	24.7 a	64.4 b
C	24.9 b	7.0 bc	1.6 ab	26.0 a	147.4 b
D	23.5 b	7.1 bc	1.8 bc	35.3 b	150.2 b
E	27.9 bc	8.0 cd	1.9 c	36.3b	140.1 b
F	30.6 c	8.6 d	2.4 d	39.8 b	176.2 b

Note: A = Control; B = 3 g/plant; C = 6 g/plant; D = 11.97 g/plant; E = 17.95 g/plant; F = 23.94 g/plant. Mean values followed by the same lowercase letter in the same column are not significantly different based on Least Significant Difference (LSD) at a significant level of 5%.

Tabel 5. The effect of potassium dosage on the physical quality of Job's tears seeds

Treatment	Size of seeds (mm)	Seed Hardness (kgf)
A	6.1 a	4.8 a
B	6.6 b	4.8 a
C	6.7 b	4.9 a
D	6.8 bc	4.9 a
E	6.8 bc	5.0 a
F	7.2 c	5.0 a

Note: A = Control; B = 3 g/plant; C = 6 g/plant; D = 11.97 g/plant; E = 17.95 g/plant; F = 23.94 g/plant. Mean values followed by the same lowercase letter in the same column are not significantly different based on Least Significant Difference (LSD) at a significant level of 5%.

Increasing the potassium dose could increase the seed size of Job's tears. Treatment A yielded the lowest results and was significantly different from the other treatments, while potassium doses ranging from 62.5 kg/ha (B) to 300 kg/ha (E) showed no significant differences among themselves but were significantly different from treatments A and F. The 500 kg/ha dose (F) yielded the largest seed width at 7.2 mm (Table 5). Meanwhile, the seed hardness of Job's tears did not show any significant differences between treatments (Table 5).

Discussion. Potassium is needed by plants, especially for seed formation, through its direct effect on sinks and/or indirectly on source tissue (Sardans & Peñuelas, 2021). This element plays a role in the translocation of photosynthate from leaves to seeds (Rawat et al., 2022). Potassium also helps regulate osmotic pressure and cell turgor, thereby increasing the efficiency of photosynthesis (Mostofa et al., 2022; Jhonson et al., 2022). In terms of direct effect on grain yield, potassium plays a role in increasing the rate and duration of seed filling, thereby reducing small broken grains (Lv et al., 2017; Li-Jun et al., 2011). All these reasons make potassium increase the weight of the husked seeds.

Increasing potassium to a certain limit increased carbohydrate and protein content, but higher doses decreased carbohydrate and protein content. Potassium does not affect starch synthase in seeds significantly, so the effect of potassium is limited to the flow of photosynthate (Hou et al., 2018). Perhaps, there is an interaction between potassium and nitrogen, where higher potassium will reduce nitrogen for the formation of carbohydrates and proteins (The et al., 2021).

Meanwhile, potassium cannot consistently affect lipid, calcium, or potassium content. Previous studies had shown that potassium did not affect lipid synthesis consistently, especially two different effects on the saturated and unsaturated fatty acids synthesis (Gu et al., 2024; Pande et al., 2014). The effect of potassium on calcium content and even potassium itself also did not have a clear pattern. This phenomenon needs to be studied further to ensure the effect of potassium on calcium and potassium contents in grain.

Potassium increased the extraction rate of carbohydrates, proteins, lipids, calcium, and potassium. This increase was due to the multiplier effect of the weight of husked seeds on the nutrient content. Although potassium has various effects on nutrient content, its significant effect on husked seed weight also causes the extraction yield to increase. Potassium plays a role in transporting photosynthetic products from leaves to storage organs such as seeds (Hutagalung et al., 2019).

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Larger size of seeds was influenced by increased potassium supply to the seeds (Edy et al., 2021). Potassium dose did not have a significant effect on seed hardness in each treatment. Seed hardness is more influenced by other compounds, such as silica. Previous research has shown that giving liquid silica fertilizer made the skin of Job's tears seeds harder (Nurmala et al., 2017). High doses of potassium (200% of the recommendation) are important to obtain maximum extraction yield of all nutrients.

Conclusion

The 200% recommended dose of potassium resulted in the best extraction rate of carbohydrates, proteins, lipids, calcium, potassium, and seed size of Job's tears. The effects of potassium on lipid, calcium, and potassium content need to be further studied.

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