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Research Article

Response of jack bean (*Canavalia ensiformis* (L) DC) to potassium sources and application time

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ABSTRACT

Jack bean or koro pedang is a potential source as a soybean substitute for food and feed. In production, the plant is also useful in crop rotation and intercropping to support sustainable agriculture systems. However, jack bean production in Indonesia is still challenging. One of the obstacles in the production is the flowers and pods dropping, which reduces yield markedly. This study aimed to evaluate the source and timing of additional potassium fertilizer on the generative phase and yield of jack bean. The experimental design used a randomized complete block design with two factors, i.e., the source of potassium fertilizer as the first factor consisting of five levels: no fertilizer application, base fertilizer, base fertilizer + goat manure, base fertilizer + rice husk ash, and base fertilizer + KCl. The second factor was fertilization time, i.e., at 46 and 121 days after planting. The treatment of the potassium fertilizer source and fertilization timing affected several generative characters, but did not have much effect on productivity. Future studies should identify other potassium fertilizer sources to find the optimal dose to support plants in the generative phase.

Keywords: additional potassium; flower drop; koro pedang; pod formation

INTRODUCTION

Jack bean (*Canavalia ensiformis* (L) DC), known as *koro pedang* in Indonesian, has the potential as an alternative source of vegetable food with essential amino acids that are important for humans. Jack bean has a good nutritional content, namely crude protein reaching 21-24% (Widiantara et al., 2021). Currently, the utilization of jack bean is not widely known, and its production in Indonesia is not as large as soybean because jack bean is cultivated for local needs or special markets only.

The nutritional content of jack bean seeds makes this bean a raw material for food products. Jack bean seeds are generally used as a base for flour (Wahyuningsih & Dwiati, 2016). Jack bean milk is a vegetable-based beverage similar to soy milk (Sutedja et al., 2022). In addition to flour, jack bean seeds can be processed into food products such as tempeh, tofu, yogurt, soy sauce, and various other processed jack bean products (Suryaningrum & Kusuma, 2013; Widiantara et al., 2018; Widiantara et al., 2017). Jack bean flour can be used in baked food such as brownies, with a similar taste and texture to wheat flour (Darini et al., 2021).

Jack bean is also used for intercropping culture that maximizes land use by increasing productivity per unit area (Alonso & Espinosa, 2015; de Leon et al., 2024). Its leaves or fronds are used as feed for ruminants (Indriani et al., 2017). Jack bean has the potential to be a valuable alternative, especially for areas with limited soybean production.

Jack bean is generally a seasonal crop, although it can also function as a short-lived annual crop. The maturity of jack bean varies between 130 and 158 days after planting (Nelza et al., 2016), and the formation of jack bean flowers and pods does not occur simultaneously. When the pods that form earlier are harvested, there are flowers and pods that remain developing. Early-forming pods will be harvested earlier at 47.2 to 49.9 days since the pods are formed (Sarijan et al., 2020). Therefore, the harvest period of jack bean is quite long, due to the indeterminate type of plant. Thus, it needs potassium elements that play an important role in various physiological processes, especially in flowering and seed formation. Jack bean has a relatively large number of flowers in one inflorescence series, which is 6 to 16 flowers, but the flowers that successfully bloom and form pods range from 1 to 4 (Nelza et al., 2016).

Potassium fertilizer sources can be obtained from inorganic materials and organic materials. Some organic materials reported to contain potassium include goat manure and rice husk ash. The content of phosphorus and potassium nutrients in rice husk ash plays a role in the formation of specific proteins that help flowering become more numerous, so that it can produce pods in large quantities as well (Arinong et al., 2020). Adding husk ash increased the soil's exchangeable potassium content and potassium uptake in the leaves (Rahman & Tyasmoro, 2019). The application of goat manure organic fertilizer at a dose of 20 g/polybag has the highest number of pods among other treatments (Erfina et al., 2023).

Based on the problem of the large number of flowers falling in jack beans, the effect of potassium fertilizer addition in the generative phase of jack bean plants was observed. The potassium fertilizer addition is expected to reduce the percentage of flower and pod loss, so that it can provide high production yields. This study aimed to evaluate the source and timing of additional potassium fertilizer on the generative phase and yield of jack bean.

MATERIALS AND METHODS

This research was conducted from October 2023 to July 2024 at Cikabayan Experimental Station, IPB University. The seeds used were commercial/generic seeds that are used routinely in the Jack bean Edu-Tour, which are produced for educational and production purposes, and showed uniformity in their genetic integrity. The initial soil, goat manure, rice husk ash, and total nitrogen were analyzed at the Testing Laboratory, Department of Agronomy and Horticulture, IPB University.

The experimental design used a randomized complete block design with two factors, namely the source of potassium fertilizer as the first factor consisting of 5 levels, i.e., no fertilizer, base fertilizer, base fertilizer + goat manure, base fertilizer + rice husk ash, and base fertilizer + KCl. Base fertilizer was goat manure (5 ton ha^{-1}) + NPK (Urea 50 kg + SP-36 100 kg + KCl 75 kg ha^{-1}). The second factor was the application time, i.e., at 46 and 121 days after planting (DAP). Each treatment combination was repeated 3 times. The additional fertilizer applied was considered from the half of the base fertilizer dose, i.e., goat manure 2.5 tons ha^{-1}, rice husk ash 2.5 tons ha^{-1}, and KCl 37.5 kg ha^{-1} (Table 1). The level of base fertilizer applied followed the recommendation of AKABI (2011), i.e., goat manure 5 tons ha^{-1} during cultivation, and urea 50 kg ha^{-1}, SP-36 100 kg ha^{-1}, and KCl 75 kg ha^{-1} at one week after planting (WAP). Here, the levels of potassium in each goat manure, rice husk, and KCl were 0.74%, 0.5% and 60%, respectively.

Jack bean seeds were planted manually at a spacing of 70 cm x 70 cm. Two seeds were planted in each planting hole. The germinated plants were selected after a week from planting by leaving one plant that had the best appearance. The size of the research plot was 3 m x 3.5 m, with the number of plants per plot was 20. Plant maintenance included weeding, soil hilling, watering, and controlling pests and diseases.

The fertilizer treatment was applied at 46 days after planting, considering the plants started the generative phase, indicated by the first flowering of about 50% plant population. The pod filling and maturation of the jack bean is about 10 to 20 WAP (70 to 140 DAP), and harvesting could be performed at this stage (Nurbaetun et al., 2017). Since jack bean was indeterminate, application at 121 DAP was considered to support the second harvesting phase.

Table 1. Treatment of fertilizer source, fertilization timing, and fertilizer dosage.

K source	Fertilization timing
No fertilizer	-
Base fertilizer	Goat manure + NPK at 1 WAP
Base fertilizer + goat manure 2.5 tons ha^{-1}	Additional fertilizer at 46 and 121 DAP
Base fertilizer + husk ash 2.5 tons ha^{-1}	Additional fertilizer at 46 and 121 DAP
Base fertilizer + KCl 37.5 kg ha^{-1}	Additional fertilizer at 46 and 121 DAP

Note: Base fertilizer: Goat manure 5 tons + urea 50 kg + SP-36 100 kg + KCl 75 kg ha^{-1}; WAP: weeks after planting, DAP = days after planting.

Vegetative characters observed included plant height, number of leaves, and productive branches. Statistical analysis of the vegetative characteristics of jack bean plants was conducted under two treatments: no fertilizer and with basic fertilizer. This approach was chosen because, during the vegetative phase, no additional fertilizer applications had yet been applied. Generative characters included total inflorescences, total productive inflorescences, total pods per plant, fruit set per inflorescence, weight of 100 seeds, weight of seeds by pods, weight per plot area, and productivity. In addition, soil and total nitrogen were analysed.

Protein content was estimated from N total using a conversion factor with the basic assumption that protein contains 16% nitrogen. N total was evaluated using the Kjeldahl method. Protein was estimated using the formula:

$$\text{Protein (\%)} = \text{N (\%)} \times \text{Conversion factor}$$

Data were analysed using analysis of variance (ANOVA) at $\alpha = 5\%$. Duncan's multiple range test (DMRT) was conducted on the significant effect between treatments according to the ANOVA test. Analysis was conducted using R Studio software v.4.3.3.

RESULTS AND DISCUSSION

General condition

All planted seeds germinated well, so that no replanting was conducted. Rainfall in December 2023 reached 465.1 mm per month, with an average temperature of 27.21°C and an average humidity of 79.76%, thus supporting the growth of jack bean seeds. In the early flowering phase from March to April, average rainfall reached 651.8 to 676.3 mm per month. The early harvest was conducted in April.

K-potential content on the research land was classified as medium (Table 2), according to Nurbaetun et al. (2017). The value of C-organic content was low, and the soil pH was acidic. According to Sulaiman et al. (2005), 1-2% C-organic content is classified as low.

Table 2. Soil analysis before treatment at Cikabayan Experimental Station.

Soil parameters	Unit	Results	Status	Methods
N-total	%	0.39	Low	Kjeldahl
P-potential	mg P_2O_5/100g	194.13	High	Spectrophotometry
K-potential	mg K_2O/100g	35.22	Medium	AAS
pH		4.58	Acid	pH meter
C-Organic	%	1.60	Low	Spectrophotometry

Source: Results of soil analysis at the Testing Laboratory, Department of Agronomy and Horticulture IPB in 2023.

Vegetative characters

The source of potassium fertilizer and of fertilization timing were not significant to the vegetative characteristics of jack bean plants (plant height, number of leaves, and number of productive branches) (Table 3). The planting of jack beans without fertilizer and with base fertilizer did not affect plant height (7 WAP), number of leaves (7 WAP), and number of productive branches.

Low soil pH and C-organic content in the soil (Table 2) might reduce soil nutrient retention capacity. At low pH, nutrients are leached easily, and phosphate is bound by aluminum and iron, making it unavailable for plants. In addition, cation exchange sites are filled with H^{+} and Al^{3+} ions instead of essential nutrients. Low C-organic also leads to fewer nutrient absorption sites because organic matter significantly stores nutrients. As a result, the soil becomes nutrient-poor despite fertilizer application. Phosphate availability decreases as phosphate ions bind strongly to aluminum and iron ions, forming insoluble compounds unavailable to plants (Xia et al., 2024).

In this study, the average number of productive branches ranged from 6 to 7 (Table 3). In contrast to the research by Nurbaetun et al. (2017), which does not form productive branches, and pods formation is only available on the main stem. Previously, research by Nazir (2016) showed that the number of productive branches was 1-2. Considering the plant is able to produce productive branches in the absence of fertilizer application, it is probable that jack beans can utilize available nutrients in the soil for growth without relying on additional fertilizers. As shown in Table 2, P and K levels could be adequate for jack bean growing.

Table 3. Plant height, number of leaves, and number of productive branches of jack bean at 7 weeks after planting from different fertilizer applications.

Treatment	Plant height (cm)	Number of leaves	Number of productive branches
No fertilization	75.97	26.30	7.50
Base fertilization	73.42	25.40	7.20
F-test	ns	ns	ns
CV (%)	6.69	15.30	22.70

Note: ns: non-significant effect at α = 5%.

Generative characters

The average population of jack bean plants reached the 50% flowering phase at 7 to 9 weeks after planting. In Alfiah's (2014) research, jack bean plants flowered simultaneously 8 weeks after planting. The average harvesting of the first pod was done at 20 weeks.

The source of potassium fertilizer and the timing of supplemental fertilization did not affect the generative characteristics of jack bean plants, namely the average pod length, number of pods per plant, number of inflorescences, number of productive inflorescences, and fruit set per inflorescence (Table 4). The average pod length in this study ranged from 30 to 32 cm, with an average number of pods per plant ranging from 4 to 6 pods.

An inflorescence is where a collection of flowers grows on the same stalk. In this study, the average number of inflorescences formed per plant ranged from 8 to 9, while the average number of productive inflorescences was only around 4 to 5 (Table 4). The low number of productive inflorescences is due to the many flower buds that fall off. Research by Nurbaetun et al. (2017) also obtained the average number of inflorescences formed on jack bean plants, which was around 7, but the number of productive inflorescences was very low. Flowers in one inflorescence ranged from 6 to 16 flower seeds, but in this study, the average number of flowers that became pods was around 2 pods per inflorescence.

Flower fall can be caused by natural factors of the plant itself, non-pathogens (climate and fertility), pests, and diseases. High rainfall during the flower formation period is from March to April (651.8 to 676.3 mm per month). Rainfall conditions during the flower formation period are not the optimum conditions that support the flowering of beans such as soybeans and chickpeas, which range from 400 to 600 mm per year or 33 to 50 mm per month (Khatun et al., 2021; Cole et al., 2022). High rainfall can make flowers susceptible to rotting and premature dropping.

Table 4. Pod length, total pods per plant, total inflorescences, total productive inflorescences, and fruit set per inflorescence from different potassium fertilizer sources and timing of application.

Treatment	Pod length (cm)	Total pod perd per per plants	Total inflorescences	Productiveroductive inflorescence z	Fruit set per inflorescence
Supplemental fertilizer (F)					
No fertilizer	30.4	5.6	8.7	5.0	2.0/5
Base fertilizer (BF)	31.1	4.6	8.2	4.4	2.1/4
BF+Goat manure	33.6	5.0	8.3	4.5	2.0/5
BF+Rice husk ash	31.8	4.5	10.1	5.9	2.1/5
BF+KCL fertilizer	32.7	6.1	8.3	5.1	2.2/5
F-test	ns	ns	ns	ns	ns
Timing of application (T)					
46 DAP	31.3	4.9	8.8	5.4	2.1/4
121 DAP	32.5	5.5	8.6	4.5	2.0/5
F-test	ns	ns	ns	ns	ns
FxT interaction	ns	ns	ns	ns	ns
CV (%)	4.5	16.6	12.0	17.3	10.2

Note: ns: non-significant effect at α = 5%; DAP: day after planting; z calculated from total inflorescence minus fallen whole flowers of an inflorescence

The treatment of potassium fertilizer source and fertilization time did not affect the characteristics of weight per plot area (3.36 m^2) and productivity. However, the potassium fertilizer source treatment increased the 100-seed weight and seed weight per pod (Table 5). Potassium fertilizer sources from goat manure and husk ash gave heavier 100-seed weight values (164.73 g and 167.16 g) than other treatments. The treatment of potassium fertilizer source from goat manure gave the heaviest seed weight per pod (20.26 g) compared to the treatment without additional potassium fertilizer. The increase in seed weight per pod was not in line with the rise in seedling weight and productivity. The number of pods produced is related to the number of seeds produced by the plant, and the number of pods per plant produced in this study ranged from 4 to 6 pods.

Table 5. The average weight of 100 seeds, seed weight per pod, seed weight per plot, and productivity of jack bean from different potassium sources and timing of application.

Treatment	Weight 100 seeds (g)	Weight seeds by pods (g)	Weight per plot area (kg)	Productivity (kg ha^{-1})
Supplemental fertilizer (F)				
No fertilizer	141.50b	18.15b	0.49	1,264.6
Base fertilizer (BF)	144.85b	18.03b	0.38	877.8
BF+Goat manure	164.73a	20.26a	0.42	861.4
BF+Rice husk ash	167.16a	19.38ab	0.42	1,048.4
BF+KCL fertilizer	151.25b	19.23ab	0.40	993.0
F-test	**	*	ns	ns
Timing of application (T)				
46 DAP	153.18	18.70	0.47	1,011.3
121 DAP	154.61	19.30	0.43	1,006.8
F-test	ns	ns	ns	ns
FxT interaction	ns	ns	ns	ns
CV (%)	6.10	6.48	19.30	19.15

Note: Numbers followed by the same lowercase letter in a column are not significantly different according to DMRT test at α = 5%; ns: not significant; **: significant at α= 0.001; *: significant at α = 0.05.

The nitrogen content of seeds is related to the quality of their protein content. Potassium fertilizer helps improve seed quality by supporting the formation of organic compounds such as proteins, which contain nitrogen. Although potassium increases seed protein content, it does not always affect total yield. In mung bean, potassium application at 1 tons ha^{-1} significantly increased protein content without affecting productivity (Eroglu & Önder, 2023).

Protein content

The results of the calculation of protein content in jack bean seeds in this study ranged from 30-38% (Table 6). The value is almost close to the protein content of soybeans, about 35-40% based on dry weight (Aulia et al., 2023; Guo et al., 2022; Fatkhunnisa et al., 2025).

Table 6. Conversion of protein content in jack bean seeds.

Type of fertilizer	N total (%)	Conversion factor	Protein (%)
No fertilizer	5.25	6.25	32.8
Base fertilizer (BF)	5.25	6.25	32.8
BF + Goat manure	5.19	6.25	32.4
BF + Rice husk ash	4.81	6.25	30.0
BF + KCl	6.16	6.25	38.5

Source: Results of protein analysis at the Testing Laboratory, Department of Agronomy and Horticulture IPB in 2024.

Adequate potassium supply promotes nitrogen translocation to plant tissues, including grains, enhancing nitrogen assimilation and accumulation (Yin et al., 2023; Fatkhunnisa et al., 2025). Fatkhunnisa et al. (2025) revealed balance stoichiometry between N/P/K in soybean. It is probable that K^+ ions balance the negative charge of nitrate ions (NO_3-) taken up by the roots, aiding nitrate uptake and long-distance transport within the plant, which is crucial for efficient nitrogen metabolism. Potassium supports photosynthesis and the formation of carbohydrates, which provide the energy and carbon skeleton necessary for synthesising amino acids and proteins.

CONCLUSIONS

The combination of treatment with additional potassium fertilizer source and fertilization time has not reduced the percentage of flower and pod loss of jack bean plants. The treatment of additional potassium fertilizer source and fertilization time did not have much effect on productivity. It is likely that flower and pod drop were less associated with the potassium supplement. It is necessary to further clarify the role of potassium in flower and pod drop in jack bean using quantitative source of fertilizers.

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