Vol. 15, No. 3 (2026): 1232 - 1240 http://dx.doi.org/10.23960/jtepl.v15i3.1232-1240

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)

Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Effect of Phosphorus Fertilizer Application Timing and Dosage on the Growth and Yield of Snow Pea (*Pisum sativum* L.)

Dita Widianti[1], Widiwurjani[1,✉], Agus Sulistyono[1]

[1] Department of Agrotechnology, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya, INDONESIA.

Article History:

Received : 28 July 2025
Revised : 04 August 2025
Accepted : 02 May 2026

Keywords:

Legumes,
Phosphate Fertilization,
Pods,
Productivity.

Corresponding Author:
✉ widiwurjani@upnjatim.ac.id
(Widiwurjani)

ABSTRACT

Snow pea (Pisum sativum L.) is a high-value vegetable crop with increasing market demand; however, its productivity remains relatively low due to suboptimal cultivation practices, particularly phosphorus (P) fertilization management. This study aimed to evaluate the effects of phosphorus fertilizer application timing and dosage on the growth and yield of the Taichung variety of snow pea. The experiment was conducted in Mojoroto Village, Pacet District, Mojokerto Regency, Indonesia, using a factorial Randomized Block Design (RBD) with two factors: phosphorus fertilizer application timing (at planting, 7 days after planting [DAP], and 14 DAP) and phosphorus fertilizer dosage (60, 80, 100, and 120 kg/ha). The results showed that the combination of phosphorus fertilizer applied at 100 kg/ha and 7 DAP produced the highest number of pods, pod weight per plant, and pod yield per hectare. Furthermore, phosphorus application at 7 DAP enhanced nutrient uptake efficiency during the early vegetative stage, while a dosage of 100 kg/ha significantly increased yield components, resulting in a pod weight of 99.72 g/plant. These findings indicate that optimizing both the timing and dosage of phosphorus fertilizer application can improve the productivity and yield quality of snow pea and provide a basis for technical fertilization recommendations for highland cultivation.

1. INTRODUCTION

Snow pea (*Pisum sativum* L.), locally known as *kacang kapri*, is a horticultural crop belonging to the Leguminosae family that possesses high nutritional and economic value. This crop has three primary uses: mature seeds for human consumption, seeds for animal feed, and immature pods as vegetables. Snow peas are widely used in Chinese cuisine, including fried rice, cap cay, stir-fried dishes, and soups. Fresh young pods contain 6.7 g of protein, 17.7 g of carbohydrates, 0.4 g of fat, and essential minerals, including 122 mg of phosphorus, 112 mg of potassium, and 22 mg of calcium per 100 g (Rahimi *et al*., 2023). In Indonesia, snow pea cultivation is concentrated in several regions, particularly East Java, West Java, and North Sumatra, with the major production centers in East Java located in Malang and Pasuruan.

Despite its high economic potential, snow pea production in Indonesia remains relatively low and fluctuates annually. National production is only in the range of tens of tons, which is considerably lower than that of other legume crops such as mung bean and soybean. Consequently, Indonesia continues to rely on imports to meet domestic demand, which reaches several thousand tons annually. Snow pea imports declined from 14,365 tons in 2019 to 6,913 tons in 2023 (Kementerian Pertanian, 2024), representing a 51.9% reduction over five years. Although this decline may indicate increased domestic production or reduced demand, it also highlights the continued importance of improving local snow pea production to reduce dependence on imports.

Low snow pea productivity is attributed to several factors, including unfavorable environmental conditions, declining soil fertility, land conversion, and farmers' limited knowledge of appropriate cultivation practices. Among these factors, suboptimal fertilizer management remains one of the major constraints affecting crop productivity (Sajar & Setiawan, 2023). Phosphorus (P) is an essential macronutrient required for photosynthesis, root growth and development, flower initiation, and pod formation and filling. It is particularly important during the early stages of plant growth because it promotes root development, thereby enhancing water and nutrient uptake and supporting photosynthesis and overall plant growth (Novizan, 2005). In addition, phosphorus contributes to stem, branch, and leaf development as well as chlorophyll formation. Phosphorus requirements are commonly supplied through SP-36 fertilizer, which is highly soluble and effectively increases phosphorus availability in the root zone. Therefore, applying phosphorus fertilizer at the appropriate dosage and timing can improve soil fertility and enhance snow pea growth and yield.

However, the effectiveness of phosphorus fertilization depends not only on the application rate but also on the timing of application. Phosphorus demand is highest during the early vegetative stage, when root and shoot development are most active. Therefore, phosphorus application at 7–14 days after planting (DAP) is considered more effective than earlier or later applications (Rosalyne, 2023). Application before this period may increase the risk of phosphorus loss, whereas delayed application can reduce nutrient uptake efficiency. Zhang *et al*. (2025) reported that synchronizing phosphorus application with the early growth stage significantly enhances phosphorus uptake and promotes the growth of leguminous crops.

Previous research by Nuryani (2019) demonstrated that phosphorus fertilizer applied at rates ranging from 58 to 133 kg/ha significantly affected the number and weight of green bean pods, with the optimum response obtained at 108 kg/ha. The study also reported that phosphorus application at 14 DAP produced the highest fresh pod weight per plant because it coincided with the onset of the vegetative growth stage. However, information regarding the combined effects of phosphorus fertilizer application timing and dosage on snow pea growth and yield remains limited. Therefore, further research is needed to identify the optimum phosphorus application strategy for maximizing snow pea productivity.

Based on the above considerations, this study aimed to evaluate the effects of phosphorus (SP-36) fertilizer application timing and dosage on the growth and yield of snow pea (*Pisum sativum* L.). In addition, this study sought to identify the most effective combination of application timing and fertilizer dosage for improving crop productivity and yield quality. The findings are expected to provide scientific evidence to support the development of appropriate and sustainable phosphorus fertilization strategies for snow pea cultivation.

2. MATERIALS AND METHODS

2.1. Time and Place

The study was conducted from February to May 2025 on agricultural land located in Mojoroto Petak Village, Pacet District, Mojokerto Regency, East Java Province, Indonesia, at an altitude of approximately 600 m above sea level (masl). The study site had an average daily temperature ranging from 21 to 31 °C, relative humidity of 65–97%, and annual rainfall of approximately 1,300–1,900 mm.

2.2. Tools and Materials

The equipment used in this study included hoes, hand trowels, a digital balance, measuring tape, bamboo stakes, a hand sprayer, plastic mulch, buckets, and stationery. The plant material consisted of Taichung variety snow pea (*Pisum sativum* L.) seeds obtained from Know You Seed. The fertilizers used were SP-36 phosphorus fertilizer produced by Petrokimia Gresik, urea fertilizer produced by Pupuk Kalimantan Timur, KCl fertilizer produced by Petrokimia Gresik, and goat manure obtained from a local goat farm. Water was supplied as needed for irrigation throughout the experiment.

2.3. Experimental Design

The experiment was arranged in a factorial Randomized Block Design (RBD) consisting of two treatment factors with three replications. The RBD was selected to account for field variability resulting from differences in soil fertility and topographic conditions, thereby improving experimental precision. The first factor was the timing of phosphorus fertilizer application (W), consisting of three levels, namely: W_1 (at planting), W_2 (7 days after planting, DAP), and W_3 (14 DAP). The second factor was the dosage of SP-36 phosphorus fertilizer (P), consisting of four levels, namely: P_1 (60 kg/ha), P_2 (80 kg/ha), P_3 (100 kg/ha), and P_4 (120 kg/ha)

The combination of these factors resulted in 12 treatment combinations. Each treatment was replicated three times, resulting in a total of 36 experimental units. Each experimental unit consisted of 10 plants, of which three plants were randomly selected as sample plants for observation.

2.4. Observations

The observed variables included the number of pods per plant, pod weight, pod length, pod weight per plant, and pod yield per hectare. The number of pods per plant was recorded from the first to the fifth harvest by counting all pods produced by each sample plant. Each harvest period consisted of two harvesting events. Pod weight was determined by weighing individual pods using an analytical balance immediately after harvest. Pod length was measured after harvest using a ruler. Pod weight per plant was determined by weighing the total pod yield harvested from each sample plant over five harvest periods using a digital balance. Pod yield per hectare was calculated by converting the total pod weight obtained from each experimental plot into yield per hectare.

2.5. Statistical Analysis

The experimental data were analyzed using analysis of variance (ANOVA) based on the factorial Randomized Block Design according to Gomez & Gomez (1995) using the following linear model:

$$\mathbf{Y_{ijk}} = \boldsymbol{\mu} + \boldsymbol{\delta_{ik}} + \boldsymbol{\alpha_i} + \boldsymbol{\beta_j} + (\boldsymbol{\alpha\beta})_{ij} + \boldsymbol{\varepsilon_{ijk}} \quad (1)$$

where Y_{ijk} is the observed response at the *i*-th level of factor A, the *j*-th level of factor B, and the *k*-th replication; $\boldsymbol{\mu}$ is the overall population mean; $\boldsymbol{\delta_{ik}}$ s the effect of the *k*-th block at the *i*-th level of factor A; $\boldsymbol{\alpha_i}$ is the main effect of factor A; $\boldsymbol{\beta_j}$ is the main effect of factor B; $(\boldsymbol{\alpha\beta})$ is the interaction effect between factors A and B; and $\boldsymbol{\varepsilon_{ijk}}$ is the random experimental error, assumed to be independently and normally distributed.

When significant treatment effects were detected, mean comparisons were performed using the Honest Significant Difference (HSD) test at the 5% significance level. Statistical analyses were conducted using Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1. Number of Pods per Plant

The analysis of variance showed that the interaction between phosphorus fertilizer application timing and dosage significantly affected the total number of pods per snow pea plant over five harvest periods. This result indicates that the effectiveness of phosphorus fertilization depends not only on the fertilizer dosage but also on the timing of application. The interaction between these two factors significantly influenced the total number of pods per plant at the 5% significance level, as presented in Table 1.

Table 1. Effect of phosphorus fertilizer application timing and dosage on the total number of pods of snow pea per plant

Application Time	Fertilizer Dose			
	P1 (60)	**P2 (80)**	**P3 (100)**	**P4 (120)**
W1 (0)	46.89 c	45.39 c	47.67 c	49.38 cd
W2 (7)	46.45 c	51.89 d	**63.95 e**	40.94 b
W3 (14)	40.45 b	46.22 c	40.56 b	35.55 a

Note: Mean values followed by same letters are not significant under the HSD test at $\alpha = 5\%$. Lowercase for dose, uppercase for frequency

Table 1 shows that phosphorus fertilizer applied at 7 days after planting (DAP) at a dosage of 100 kg/ha (W_2P_3) produced the highest number of pods, with an average of 63.95 pods per plant. This finding indicates that phosphorus application during the early vegetative stage promotes optimal reproductive development and enhances pod formation. In contrast, phosphorus application at 14 DAP with a dosage of 120 kg/ha (W_3P_4) resulted in the lowest number of pods (35.55 pods per plant), suggesting that delayed application combined with an excessive fertilizer dosage reduces phosphorus use efficiency and subsequently limits pod development.

The superior performance of the W_2P_3 treatment can be attributed to the availability of phosphorus during the critical early vegetative stage, when root development and vegetative growth are highly active. Adequate phosphorus availability during this period enhances nutrient uptake efficiency and promotes the accumulation of photosynthates required for flower initiation and pod development. These findings are consistent with those reported by Nuryani *et al*. (2019), who demonstrated that phosphorus application during the early growth stage of leguminous crops resulted in greater pod formation than applications made at later growth stages. Furthermore, phosphorus plays a crucial role in energy transfer through adenosine triphosphate (ATP) and in the differentiation of reproductive tissues, thereby directly contributing to improved crop productivity (Mayendra *et al*., 2019).

Conversely, the lowest pod production was observed in the W_3P_4 treatment. This result suggests that phosphorus application at 14 DAP was less effective because the critical period for root establishment and early reproductive development had already passed, reducing the plant's ability to utilize the applied phosphorus efficiently. Increasing the phosphorus dosage to 120 kg/ha also failed to improve pod production, indicating that the phosphorus requirement of snow pea had likely been satisfied at lower application rates. Excessive phosphorus application may reduce fertilizer use efficiency by creating nutrient imbalances in the soil, ultimately limiting plant response and pod formation. Similar findings were reported by Ampong *et al*. (2024), who concluded that the timing of phosphorus application has a greater influence on crop yield formation than increasing fertilizer dosage, particularly when phosphorus is applied during the early growth stage.

Overall, the significant interaction between phosphorus fertilizer application timing and dosage observed in this study supports the findings of Rosalyne (2023), who reported that synchronizing phosphorus application with the appropriate physiological growth stage, together with the optimum fertilizer dosage, is essential for maximizing yield components, particularly the number of pods per plant. Therefore, phosphorus application at 7 DAP at a dosage of 100 kg/ha can be recommended as an effective and efficient fertilization strategy for improving snow pea productivity.

3.2. Pod Weight

The analysis of variance showed that there was no significant interaction between phosphorus fertilizer application timing and dosage on pod weight. Likewise, phosphorus fertilizer application timing as a single factor did not significantly affect pod weight. In contrast, phosphorus fertilizer dosage had a significant effect on pod weight at the 5% significance level. The average pod weight for each treatment is presented in Table 2.

The non-significant effect of phosphorus fertilizer application timing indicates that differences in application timing (at planting, 7 days after planting, and 14 days after planting) did not significantly influence the plant's ability to accumulate biomass in the pods. This finding is consistent with Rosalyne (2023), who reported that the effect of fertilizer application timing on yield components such as pod weight depends largely on the synchronization between nutrient availability and the plant's physiological growth stage. The influence of application timing is generally more pronounced on early vegetative growth than on final yield components. Similarly, Assega & Tadesse (2022) explained that plant responses to nutrient application timing are often more evident in vegetative growth parameters than in final yield attributes, such as seed or fruit weight.

Table 2. Effect of phosphorus fertilizer application timing and dosage on the average pod weight of snow pea (g/pod)

Application Frequency	**Fertilizer Dose**				**Average**
	P1 (60)	**P2 (80)**	**P3 (100)**	**P4 (120)**	
W1 (0)	1.58	2.48	1.71	1.65	1.86 A
W2 (7)	1.67	2.62	2.29	1.53	2.03 A
W3 (14)	1.33	2.27	1.82	1.84	1.82 A
Average	1.53 a	2.46 d	1.942 c	1.673 b	

Note: Mean values followed by same letters are not significant under the HSD test at α = 5%. Lowercase for dose, uppercase for application timing

Although application timing did not significantly affect pod weight, phosphorus fertilizer dosage significantly influenced this parameter. The highest average pod weight was obtained with a phosphorus fertilizer dosage of 80 kg/ha, whereas the lowest average pod weight was recorded at 60 kg/ha. These results indicate that increasing the phosphorus dosage from 60 to 80 kg/ha improved the accumulation of photosynthates allocated to pod development. Phosphorus plays a vital role in energy transfer through adenosine diphosphate (ADP) and adenosine triphosphate (ATP), thereby supporting pod filling and tissue development (Wahyudin *et al*., 2015).

According to Rofik *et al*. (2025), phosphorus fertilizer applied at an appropriate dosage improves nutrient uptake efficiency and supports optimal plant growth. However, increasing phosphorus application beyond the optimum rate does not necessarily improve crop yield because phosphorus availability is limited by the soil's capacity to retain and supply the nutrient to plants. Moreover, excessive phosphorus application may induce nutrient imbalances and antagonistic interactions with other essential nutrients. Therefore, phosphorus fertilizer dosage should be determined based on soil nutrient status to achieve efficient nutrient utilization and sustainable crop production. Overall, these results indicate that a phosphorus fertilizer dosage of 80 kg/ha is the most effective treatment for increasing pod weight in snow pea. In contrast, the timing of fertilizer application had no significant effect on this parameter.

3.3. Pod Length

The analysis of variance showed that there was no significant interaction between phosphorus fertilizer application timing and dosage on pod length of snow pea (*Pisum sativum* L.). However, both factors individually had a significant effect on this parameter. Phosphorus fertilizer application timing significantly influenced pod length, and phosphorus fertilizer dosage also had a significant effect at the 5% significance level. The average pod length under each treatment is presented in Table 3.

The results showed that phosphorus fertilizer application timing significantly affected pod length. Application at 7 days after planting (DAP) produced the longest average pods, whereas application at planting (0 DAP) resulted in the shortest pods. This finding indicates that phosphorus application at 7 DAP, when root development is well established and plants are entering the early reproductive stage, is more effective in promoting pod elongation. Synchronizing nutrient application with the physiological growth stage enhances nutrient uptake efficiency and positively affects yield components, including pod length and seed development (Simorangkir & Barunawati, 2022).

Phosphorus fertilizer dosage also significantly affected pod length. The application of 80 kg/ha produced the longest average pods, whereas the lowest pod length was recorded at the dosage of 60 kg/ha. These results indicate that snow pea plants responded optimally to an appropriate phosphorus supply because phosphorus plays an essential role in energy metabolism and reproductive organ development. Similar findings were reported by Shohag *et al*. (2025), who demonstrated that increasing phosphorus application to an optimum level significantly increased pod length in snap bean compared with plants receiving no phosphorus fertilizer. However, phosphorus application beyond the optimum dosage did not further improve pod growth and may instead reduce fertilizer efficiency because of nutrient imbalance.

Excessive phosphorus application does not necessarily increase crop performance because plant nutrient uptake is physiologically limited. Furthermore, surplus phosphorus in the soil may interfere with the availability and uptake of other essential nutrients, particularly zinc and iron, thereby restricting crop growth and yield (Khan *et al*, 2023). Therefore, optimizing both the dosage and timing of phosphorus fertilizer application is essential for maximizing snow pea productivity, particularly with respect to pod length.

Table 3. Effect of phosphorus fertilizer application timing and dosage on the average pod length of snow pea (cm)

Application Time	Fertilizer Dose				Average Application Time
	P1 (60)	P2 (80)	P3 (100)	P4 (120)	
W1 (0 DAP)	4.48	7.46	5.97	5.45	5.84 A
W2 (7 DAP)	5.65	8.40	6.27	6.31	6.66 C
W3 (14 DAP)	5.22	8.05	5.77	5.13	6.04 B
Average Fertilizer Dose	5.12 a	7.97 d	6.002 c	5.630 b	

Note: Mean values followed by same letters are not significant under the HSD test at α = 5%. Lowercase for dose, uppercase for frequency

Overall, the results indicate that phosphorus application at 7 DAP combined with a dosage of 80 kg/ha provided the most favorable conditions for pod elongation by supplying sufficient phosphorus during the critical stage of reproductive development.

3.4. Total Pod Weight per Plant

The analysis of variance revealed a significant interaction between phosphorus fertilizer application timing and dosage on the total pod weight per plant over five harvest periods. This significant interaction indicates that the effect of phosphorus fertilizer dosage depended on the timing of application. The average total pod weight per plant for each treatment combination is presented in Table 4.

Table 4. Effect of fertilizer application time and dose on the total pod weight (g/plant) of snow pea over five harvest periods

Application Time	**Fertilizer Dose**			
	P1 (60)	**P2 (80)**	**P3 (100)**	**P4 (120)**
W1 (0 DAP)	71.77 d	80.66 e	63.39 c	62.58 c
W2 (7 DAP)	63.02 c	60.36 c	**99.72 f**	50.52 b
W3 (14 DAP)	66.05 cd	76.90 de	56.72 bc	41.40 a

Note: Mean values followed by same letters are not significant under the HSD test at α = 5%.

As shown in Table 4, the combination of phosphorus fertilizer application at 7 DAP with a dosage of 100 kg/ha (W_2P_3) produced the highest total pod weight, reaching 99.72 g/plant. In contrast, the lowest total pod weight (41.40 g/plant) was observed in the W_3P_4 treatment, where phosphorus was applied at 14 DAP at a dosage of 120 kg/ha. These findings indicate that the synchronization of phosphorus application timing and dosage plays a crucial role in maximizing pod yield.

The superior performance of the W_2P_3 treatment suggests that phosphorus applied during the early vegetative stage was efficiently absorbed when root development was most active and plants were preparing for the transition to the reproductive stage. Adequate phosphorus availability during this critical period promotes cell division, energy transfer through adenosine triphosphate (ATP), and reproductive tissue development, thereby enhancing assimilate allocation to developing pods. Similar results were reported by Anand *et al*. (2024), who demonstrated that phosphorus application during the early growth stage significantly increased pod weight and total crop yield by improving root development and facilitating efficient nutrient translocation to reproductive organs.

Conversely, the combination of delayed phosphorus application (14 DAP) and a high fertilizer dosage (120 kg/ha) resulted in the lowest total pod weight. This response is likely associated with the reduced synchronization between nutrient availability and crop demand, as well as the lower efficiency of phosphorus uptake during the later stages of plant development. Furthermore, excessive phosphorus application may induce nutrient imbalances in the soil, limiting the uptake of essential micronutrients such as boron and zinc that are involved in flower and pod development. Similar observations were reported by Ampong *et al.* (2024), who found that excessive phosphorus fertilization can disrupt soil nutrient balance and reduce the availability of micronutrients required for optimal fruit development.

Overall, the results demonstrate that nutrient use efficiency is strongly influenced by the synchronization between fertilizer application timing and dosage. As an essential macronutrient, phosphorus plays a central role in energy metabolism and reproductive tissue development. Therefore, phosphorus fertilizer applied at 7 DAP at a dosage of 100 kg/ha represents the most effective treatment for maximizing total pod weight per plant, whereas delayed application combined with excessive phosphorus dosage reduces crop productivity.

3.5. Pod Yield

The analysis of variance showed that there was no significant interaction between phosphorus fertilizer application timing and dosage on pod yield per hectare. Likewise, phosphorus fertilizer application timing, when evaluated as a single factor, did not significantly affect pod yield. In contrast, phosphorus fertilizer dosage significantly influenced pod yield per hectare at the 5% significance level. The average pod yield under each treatment is presented in Table 5.

Table 5. Effect of phosphorus fertilizer application timing and dosage on pod yield of snow pea over five harvest periods (t/ha)

Application Time	Fertilizer Dose				Average Application Time
	P1 (60)	P2 (80)	P3 (100)	P4 (120)	
W1 (0 DAP)	5.57	6.13	3.56	3.84	4.78 A
W2 (7 DAP)	3.67	6.21	3.94	3.77	4.40 A
W3 (14 DAP)	4.70	5.08	4.24	3.08	4.28 A
Average Fertilizer Dose	4.65 a	5.80 a	3.91 a	3.56 a	

Note: Mean values followed by same letters are not significant under the HSD test at α = 5%. Lowercase for dose, uppercase for frequency

The results presented in Table 5 indicate that phosphorus fertilizer application timing did not significantly affect pod yield per hectare. This finding suggests that the different application times (at planting, 7 DAP, and 14 DAP) did not produce sufficient differences in yield at the field scale. This response may be attributed to the ability of snow pea plants to absorb and utilize phosphorus efficiently throughout the early growth stage, provided that phosphorus is available during the period of active root development. Consequently, relatively small differences in fertilizer application timing may not substantially influence final yield. Similar findings were reported by Dikr & Abayechaw (2022), who observed that differences in phosphorus application timing did not always result in significant variation in crop yield components, provided that phosphorus availability was adequate during the critical early growth stage.

In contrast, phosphorus fertilizer dosage significantly affected pod yield per hectare. The application of 80 kg/ha produced the highest average yield (5.80 t/ha), whereas the application of 120 kg/ha resulted in the lowest yield (3.56 t/ha). These findings indicate that increasing phosphorus application beyond the optimum rate does not necessarily improve crop productivity. The dosage of 80 kg/ha was sufficient to satisfy the phosphorus requirement of snow pea without causing excessive nutrient accumulation or reducing fertilizer use efficiency.

The reduction in yield observed at the highest phosphorus dosage (120 kg/ha) may be associated with nutrient imbalance in the soil, which limits the uptake of other essential nutrients. Excessive phosphorus availability can reduce the absorption of certain micronutrients such as iron (Fe), zinc (Zn), and manganese (Mn), all of which are essential for physiological processes including pod filling and maturation (Santos *et al*., 2026;) reported that the. Furthermore, excessive phosphorus application may alter soil chemical conditions and induce physiological stress, thereby reducing reproductive biomass production and ultimately decreasing crop yield.

Overall, the results suggest that phosphorus fertilizer applied at 80 kg/ha provides the most efficient fertilizer rate for maximizing pod yield per hectare. Increasing the phosphorus dosage beyond the optimum level does not improve productivity and may instead reduce yield because of lower nutrient use efficiency and nutrient imbalance.

4. CONCLUSION

Based on the results of this study, phosphorus fertilization significantly affected the growth and yield of snow pea (*Pisum sativum* L.). Phosphorus application at 7 days after planting (DAP) produced the longest pods and contributed positively to overall crop performance. In addition, a phosphorus fertilizer dosage of 80 kg/ha was the most effective in increasing pod weight, pod length, and pod yield per hectare. A significant interaction between phosphorus fertilizer application timing and dosage was also observed. The combination of phosphorus application at 7 DAP and a dosage of 100 kg/ha produced the highest number of pods and the greatest total pod weight per plant over five harvest periods. These findings demonstrate that optimizing both the timing and dosage of phosphorus fertilizer application is essential for maximizing the productivity of snow pea. Therefore, phosphorus fertilizer applied at the appropriate timing and dosage is recommended as an effective fertilization strategy for snow pea cultivation in highland areas.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to the farmer partners and the Local Government of Mojoroto Village, Pacet District, Mojokerto Regency, for their support, guidance, and facilities provided throughout this study. The authors also thank all individuals and institutions who contributed directly or indirectly to the research activities, including field activities, data collection, and technical assistance, which enabled this study to be successfully completed.

AUTHOR CONTRIBUTION STATEMENT

Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
DW	✓	✓			✓	✓			✓	✓	✓			✓
Wid	✓	✓		✓								✓		
AS	✓	✓			✓							✓		

C: Conceptualization
M: Methodology
So: Software
Va: Validation
Fo: Formal Analysis
I: Investigation
D: Data Curation
R: Resources
O: Writing - Original Draft
E: Writing - Review & Editing
Vi: Visualization
Su: Supervision
Fu: Funding Acquisition
P: Project Administration

REFERENCES

Ampong, K., Penn, C.J., & Camberato, J.J. (2024). The timing of phosphorus availability to corn: What growth stages are most critical for maximizing yield? *Agronomy*, ***14***(11), 2731. https://doi.org/10.3390/agronomy14112731

Anand, M., C, U., & Raj, R. (2024). Effect of bio-fertilizers and phosphorus on growth and yield of garden pea (*Pisum sativum* L.). *International Journal of Research in Agronomy*, ***7***(9S), 798–802. https://doi.org/10.33545/2618060X.2024.v7.i9Sk.1603

Assega, H., & Tadesse, T. (2022). Effects of sources, rate and application times of nitrogen fertilizer on yield and yield components of upland rice (*Oryza sativa* L.) in Northwest Ethiopia. *Agriculture, Forestry and Fisheries,* ***11***(5), 186–190. https://doi.org/10.11648/j.aff.20221105.16

Dikr, W., & Abayechaw, D. (2022). Effects of phosphorus fertilizer on agronomic, grain yield and other physiological traits of some selected legume crops. *Journal of Biology, Agriculture and Healthcare,* ***12***(12), 1–13. https://doi.org/10.7176/JBAH/12-12-01

Kementerian Pertanian Republik Indonesia (2024). *Statistik Pertanian - Agricultural Statistics 2024*. Pusat Data dan Sistem Informasi Pertanian, Kementerian Pertanian Republik Indonesia, Jakarta. ISBN: 979-8958-65-9

Khan, F., Siddique, A.B., Shabala, S., Zhou, M., & Zhao, C. (2023). Phosphorus plays key roles in regulating plants' physiological responses to abiotic stresses. *Plants*, *12*(15), 2861. https://www.mdpi.com/2223-7747/12/15/2861

Mayendra, M., Lubis, K.S., & Hidayat, B. (2019). Ketersediaan hara fosfor akibat pemberian biochar sekam padi dan pupuk kandang sapi pada *Inceptisol* Kuala Bekala. *Jurnal Pertanian Tropik,* ***6***(2), 287–293.

Novizan, N. (2005). *Petunjuk Pemupukan yang Efektif*. AgroMedia Pustaka, Jakarta. ISBN: 9789793084220

Nuryani, E., Haryono, G., & Historiawati, H. (2019). Pengaruh dosis dan saat pemberian pupuk P terhadap hasil tanaman buncis (*Phaseolus vulgaris*, L.) tipe tegak. *VIGOR: Jurnal Ilmu Pertanian Tropika dan Subtropika*, ***4***(1), 14-17.

Rahimi, V., Nurwantoro, N., & Setiani, B.E. (2024). Sifat fisikokimia dan organoleptik minuman soygurt sari kedelai yang disubstitusi dengan sari kapri. *Jurnal Teknologi Pangan,* ***7***(1), 6–11. https://doi.org/10.14710/jtp.2023.26651

Rofik, G.A., Pribadi, D.U., & Dewanti, F.D. (2025). Pengaruh pemupukan P dan *green manure* leguminosa bunga telang terhadap pertumbuhan dan hasil jagung pulut Arumba (*Zea mays ceratina* var. Arumba). *Jurnal Ilmu-Ilmu Pertanian Indonesia*, ***27***(2), 77–86. https://doi.org/10.31186/jipi.27.2.77-86

Rosalyne, I. (2023). Respon pertumbuhan dan produksi tanaman kacang kapri (*Pisum sativum* L.) akibat pemberian konsentrasi POC dan dosis posfor. *Fruitset Sains: Jurnal Pertanian Agroteknologi,* ***11***(4), 269–278. https://iocscience.org/ejournal/index.php/Fruitset/article/view/4225

Sajar, S., & Setiawan, A. (2023). Soybean yield response to inoculation bacteria nitrogen fixer and fertilizer kohe chicken. *Proceedings of the National Seminar on Biology*, ***3***, 78-87.

Santos, E.F.; Silva, A.B.P.; Silva, M.d.S.; Scalon, S.d.P.Q.; Lavres, J. (2026). Kinetic parameters of phosphorus uptake as a function of cationic metal supply in cotton. *Plants*, ***15***, 1215. https://doi.org/10.3390/plants15081215

Shohag, M.J.I., Salgado, E.M., Gluck, M.C., Sriti, N., & Liu, G. (2025). Phosphorus fertilizer thresholds matching snap bean nutrient demands in Florida Spodosols. *Scientia Horticulturae*, ***350***, 114334. https://doi.org/10.1016/j.scienta.2025.114334

Simorangkir, E.K., & Barunawati, N. (2022). Pengaruh dosis dan waktu pemberian pupuk NPK majemuk terhadap pertumbuhan dan hasil buncis manis (*Phaseolus vulgaris* L.). *Produksi Tanaman,* ***10***(6), 216–327.

Wahyudin, A., Nurmala, T., & Rahmawati, R.D. (2015). Pengaruh dosis pupuk fosfor dan pupuk organik cair terhadap pertumbuhan dan hasil kacang hijau (*Vigna radiata* L.) pada ultisol Jatinangor. *Kultivasi,* ***14***(2). https://doi.org/10.24198/kultivasi.v14i2.12041

Zhang, L., Jiang, Y., Yin, M., Ling, Y., Li, H., Gan, Y., Yue, C., Ma, Y., Kang, Y., Qi, G., & Wang, Y. (2025). Optimizing phosphorus fertilization management is conducive to improving alfalfa yield and quality: A meta-analysis. *Agriculture,* ***15***(8), 797. https://doi.org/10.3390/agriculture15080797