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Growth, Yield and Fatty Acid Profile of Winged Bean (*Psophocarpus tetragonolobus*) Seeds with Shoot Pruning and Additional Fertilizer

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Abstract

Winged bean is a remarkable climbing plant, distinguished by its multiple segments that serve as growth sites for shoot, leaf and flower. Several studies have shown that the plant requires shoot pruning to increase the production of its flower buds, pods and seeds, but this practice can inhibit the generative phase. To overcome this challenge, the application of additional fertilizer is needed to provide the required nutrients. Therefore, this study aims to determine the effects of shoot pruning and additional fertilizer on the growth, yield and bioactive compounds of winged bean seeds. The determination of the proper rates of fertilization was important for plant production and to support sustainable agriculture. The study procedures were carried out at IPB experimental station in Leuwikopo, IPB University, Bogor. A Randomized complete block design (RCBD) was utilized with two factors and three replications, namely leaf pruning (without shoot pruning, 15 cm, and 30 cm from the ground) and additional fertilizer (0, 6.25, 12.5 and 18.5 g NPK (16-16-16) plant^{-1}). The parameters observed included plant height, leaf nutrient, root length, yield, leaf number, as well as protein and fatty acid profile of seeds. The results showed that shoot pruning treatment and additional fertilizer had no interaction effect on plant growth and seed yield. Shoot pruning caused an increase in leaf number, fatty acid and linoleic acid content by 17 to 20%, 10%, and 16 to 19%, respectively, compared to the control. The use of additional fertilizer at a concentration of 6.25 to 12.5 g NPK (16-16-16) plant^{-1} increased leaf number, nutrients, and seed yield. Based on the findings, the highest seed yield (2.56 tons ha^{-1}) was achieved with the application of additional fertilizer at the rates of 6.25 g NPK (16-16-16) plant^{-1}, but shoot pruning was not required.

Keywords: bioactive compounds; leaf nutrient; linoleic acid; morphological characters; protein

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INTRODUCTION

Winged bean (*Psophocarpus tetragonolobus* L.) is a native tropical legume species (Calvindi et al., 2020), cultivated for its young winged pods as vegetables or harvested as dry pods for seed production (Eagleton, 2020). In terms of nutritional content, 100 g of dry winged bean seeds contain approximately 29.8 to 39.0 g protein, 15.0 to 20.4 g fat, 0.9 to 3.1 g fiber, and 22.8 mg tocopherols (Mohanty et al., 2020). Furthermore, its protein content, ranging from 29 to 39% (Mohanty et al., 2020), was found to be similar to soybean (34 to 37%) (Ciabotti et al., 2019), suggesting its potential as an alternative. Seeds also contain bioactive

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compounds, including 105 to 112 mg QE 100 g^{-1} total flavonoids, 154 to 161 mg GAE 100 g^{-1} total phenolics (Calvindi et al., 2020), 1.7 to 2.5% tannins, and 3.27 to 9.38 mm phytat 100 g^{-1} dry seed (Adegboyega et al., 2019). This indicates that winged bean can be classified as a potential tropical commodity candidate for crop development (Bassal et al., 2020) with improved cultivation techniques (Anjos et al., 2021).

Based on previous studies, winged bean is a plant that naturally grows to a height of 3 to 4 m above ground level, and is distributed across Asia and Africa (Lepcha et al., 2017). This indeterminate plant takes more than 100 days to produce its first flowers (Eagleton, 2019) and exhibits continuous flowering (Ishthifaiyyah et al., 2021). The potential yield of its seed ranges from 2 tons ha^{-1} (Tanzi et al., 2019) and it takes 4 to 5 months to mature (Lepcha et al., 2017). Despite its potential, winged bean is often underutilized, mainly due to low productivity and long growing duration (Mohanty et al., 2020). To promote sustainable agricultural practices, the use of a determinate variety with high production and low input, such as Fairuz IPB, is considered to be significantly beneficial. The productivity of Fairuz IPB can reach up to 2.53 tons of dry seeds ha^{-1} (44.31 g of dry seeds $plant^{-1}$) at 23 weeks after transplanting (WAT), with seeds starting to develop at 65 days (Laia, 2019).

Winged bean plants are vines (Calvindi et al., 2020) and possess numerous stem segments that serve as attachment points for buds, branches, leaf or flowers (Eagleton, 2020). Furthermore, the presence of multiple shoots and components contributes to the increased growth of flowers and fruits, leading to higher production rates. One effective method to improve growth of shoots and branches is through pruning. The application of this method plays a crucial role in reducing humidity, thereby mitigating the risk of disease attacks (Kraus et al., 2022) and decreased transpiration (Li et al., 2016), as well as increasing crop production (Roosta et al., 2020). The treatment of pruning has been reported to have several benefits, such as improved development of new shoot and high-quality flower buds (Suganya et al., 2023). In walnut orchards, its application led to the highest dry matter production, as reported by Sierra-Zurita et al. (2023). Pruning can also reduce yield of storage root and increase shoot yield of sweet potatoes (Indawan et al., 2020). The treatment generally enhances canopy openness, which in turn, contributes to increased yield. Removing primary nodes during pruning reduces the number of sinks, leading to better nutrients distribution from these reserves to the remaining vegetative parts. Although shoot biomass and yield can reduce, pruned vines tend to yield products of superior quality (Williams et al., 2023). Several studies have extensively explored the benefits of pruning, but there are some drawdowns associated with this practice. One of the common issues is that it tends to prolong the duration of a plant's vegetative phase (Susanto et al., 2015). To overcome these challenges, the use of additional fertilization is required to achieve optimal growth.

Fertilizer play a crucial role in supporting plant growth and enhancing productivity (Ma et al., 2022), with the inorganic variant being the most used type (Owolabi et al., 2016). Plant fertilizer can be given in two stages, namely basic and additional. The basic type is often given at the end of land preparation, while additional variant is utilized during growth period, especially for plants with multiple harvests, such as tomatoes (Maillard et al., 2015), cauliflower (Sofian and Susila, 2018) and winged bean (Ishthifaiyyah et al., 2021). Additional fertilizer contain essential nutrients for plant growth and development, such as N, P and K, and can be provided through the use of compounds fertilizer (Pattnayak and Swain, 2018).

A continuous supply of nutrients is essential to maintain growth, fruit quality, and productivity (Kueklang et al., 2021). The use of compounds fertilizer has been reported to be more beneficial compared to single variants because they contain more than one nutrients (Betty et al., 2021). The N, P and K are essential nutrients needed by plants for optimal development. Nitrogen serves as a building block for nucleic acid and proteins, while P is needed for the development of nucleic acid, energy and sugar. Furthermore, K plays a role in photosynthesis, sugar transportation, protein formation and enzyme activation (Purba et al., 2019). Chemical fertilizer were used in this experiment because they affected plant growth and development due to rapid absorption (Liu et al., 2021). The use of fertilizer with the right dose is one of the activities involved in sustainable agricultural practices (Pagliarino et al., 2020) to ensure the sustainability of the environment.

According to previous studies, pruning treatment had been carried out on grape plants (Williams et al., 2023), jasmine (Suganya et al., 2023), orchard (Sierra-Zurita et al., 2023) and sweet potatoes (Indawan et al., 2020) but had never been utilized for winged bean. Therefore, this study aims to evaluate the effect of shoot pruning and additional fertilizer on the morphological characters, seed production and fatty acid profile of winged bean seeds.

MATERIALS AND METHOD

Field conditions and materials

The experiment was carried out at the experimental field of IPB in Leuwikopo, Bogor, Indonesia (longitude 106°43'11.7" E, latitude 6°33'45.2" S) at 250 m above sea level, from January to June 2022. The materials used included winged bean seeds of the Fairuz IPB variety, compounds fertilizer NPK (16-16-16), dolomite and chicken manure.

Based on Bogor climatic data in 2022, the rainfall climate data from January to June 2022 ranged from 113 to 463 mm. The average temperature was 23 to 26 °C, with an average relative humidity of 76 to 85%, and solar intensity of 284 to 471 Cal cm^{-2}.

Experimental design

The experiment used a Randomized complete block design (RCBD) design with two factors and three replications. The first factor was the height of shoot pruning, which consisted of without pruning (6 stems segment), pruning at 15 cm height (2 stems segment), and pruning at 30 cm height (3 to 4 stem segments) (7 WAT). The second factor was the rates of additional fertilizer consisting of 0, 6.25, 12.5 and 18.75 g NPK (16-16-16) $plant^{-1}$ at 7, 9, 11, 13 and 15 WAT.

Land preparation, planting and harvesting

After preparing the land with a plot size of 1 m x 5.7 m each, the ground was applied with 2 tons of dolomite ha^{-1} and 10 tons of chicken manure ha^{-1} three weeks before planting. Furthermore, seedlings were prepared by soaking seeds in warm water overnight to facilitate germination, and then the samples were planted in seedling trays for two weeks. Seedlings were transplanted with 50 cm x 30 cm spacing, with two samples per hole. All plots were added with 25 kg N ha^{-1}, 36 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1} as basic fertilizer (Laia, 2019) two weeks after planting. Winged bean were harvested when the pods were brown and began to dry, followed by harvest every week until 24 WAT.

Variables to observe

The observed variables were plant height, root length, leaf number (measured at 10 and 15 WAT), leaf nutrients levels (10 WAT), weight per pod, 100-seed weight, number of seeds per pod, yield production, protein content (Kjeldahl method), fat and fatty acid profile. Fatty acid analysis was carried out in three stages: a) extraction: the first stage was Soxhlet extraction for fatty acid, and 20 to 30 mg of fat in oil was weighed; b) methylation: fat or oil was mixed with 20 to 40 mg of 0.5 N NaOH in methanol and heated for 20 minutes in a water bath. A total of 2 ml of 20% BF3 was added, and the mixture was allowed to cool. After cooling, 1 ml of hexane and 2 ml of saturated NaCl were added and then shaken until homogeneous. The hexane layer was moved with a pipette into a tube containing 0.1 g anhydrous Na_2SO_4 and left for 15 minutes, followed by the injection of the liquid phase into the gas cromatography (GC); c) identifying fatty acid: methyl esters were injected into a GC with the standard fatty acid of SupelcoTM 37 component FAME Mix. The gas was N at a pressure of 20 m, which was used as the mobile phase. The combustion gas was hydrogen at a flow of 30 ml. The column utilized was a Quadrex fused silica capillary column 007 cyclopropyl methyl, 60 m long, and 0.25 mm in diameter (Moradzadeh et al., 2021).

Statistical analysis

The data were analyzed with analysis of variance, followed by Duncan's Multiple Range Test at α = 5%. Statistical analysis was carried out with the SAS software, while correlation and heatmap analysis were performed using R software.

RESULTS AND DISCUSSION

Plant growth

Shoot pruning and additional fertilizer treatments significantly affected leaf number at 15 WAT, as shown in Table 1. Shoot pruning at 15 and 30-cm heights led to a 17 to 19% increase in the number of leaves compared to the control. The findings of this study were similar to the previous studies, where the treatment facilitated growth of new shoot and leaf (Dufour et al., 2019; Shashi et al., 2022), leading to higher productivity, compared to unpruned plants (Valdes-Rodriguez et al., 2020).

The higher rates of additional fertilizer led to a significant increase in the number of leaf, as shown in Table 1. At 15 WAT, the addition of 12.5 and 18.75 g fertilizer per plant increased leaf number by 18 and 23 leaf. The fertilization in the form of NPK (16-16-16) was generally used to increase vegetative growth, especially in leaf. The ability of plants to properly absorb nutrients could facilitate plant growth, such as stem, leaf and branch (Feng et al., 2020). Furthermore, N, P and K were often classified as 'primary' macronutrients, which were needed to continue the process of morphological, biochemistry and physiology (El-Seifi et al., 2015).

Leaf nutrients content

The addition of fertilizer significantly increased the levels of leaf N, P and K, but the rate of fertilization had no significant effect, as shown in Table 2. The use of additional fertilizer from 6.25 to 18.75 g plant^{-1} increased leaf N, P, and K nutrients by 12 to 16%, 10 to 15% and 9.8 to 25%, respectively, compared to controls. The results indicated that plants could absorb nutrients provided through fertilization.

The results showed that plants responded well to additional fertilizer by absorbing soil nutrients. The availability of nutrients was supported by a suitable climate for plant growth with sufficient rainfall and sunlight in April to June 2022. The average rainfall, temperature, relative humidity and solar intensity ranged from 228 to 463 mm, 25 to 26 °C, 79 to 85% and 370 to 471 Cal cm^{-2}, respectively. The increased temperature could affect the plant reproductive phase and reduce yield of pods and seeds due to the prolonged vegetative phase, ultimately leading to an increment in biomass. Under favorable conditions, seed production was expected to be higher in winter and summer, then increase linearly with increasing groundwater availability. High availability of groundwater was likely to cause increased absorption of water and nutrients by roots, leading to enhanced photosynthetic capacity and optimal growth (Barros et al., 2023).

Nitrogen was an important nutrient in the formation of chlorophyll formation and the photosynthesis process. Furthermore, it was often used to facilitate plant growth, especially in leaf, stems and branches, during vegetative growth (Fathi, 2022). Phosphorus had been reported to play a vital role in various processes, including photosynthesis, assimilation, respiration and

Table 1. Effect of shoot pruning and additional fertilizer on the morphological characters of winged bean plants

Treatment	Plant height (cm)		Root length (cm)		Leaf number	
	10 WAT	15 WAT	10 WAT	15 WAT	10 WAT	15 WAT
Shoot pruning						
Without pruning	141.83	302.91	19.50	21.50	34.20	62.3^{b}
Pruning height 15 cm	138.50	306.16	18.00	22.16	29.90	73.1^{a}
Pruning height 30 cm	153.33	305.91	15.08	25.16	38.60	75.0^{a}
Additional fertilizer (g plant^{-1})						
0	168.22	301.66	18.88	26.77	36.20	57.6^{c}
6.25	139.44	305.77	15.44	22.00	32.30	66.5^{bc}
12.5	133.78	310.44	20.88	22.33	37.80	75.6^{ab}
18.75	136.22	302.11	14.88	20.67	30.70	80.7^{a}
CV (%)	26.70	5.50	23.68	18.45	22.25	16.70

Note: numbers with different letters in the same column significantly differ from the 5% DMRT test; WAT = Weeks after transplanting

Table 2. Effect of pruning and additional fertilizer on leaf nutrients levels at 10 WAT

Treatment	N (%)	P (%)	K (%)	C-org (%)	C/N
Shoot pruning					
Without pruning	5.15	0.53	2.38	39.23	7.77
Pruning height 15 cm	5.30	0.55	2.68	36.11	6.84
Pruning height 30 cm	5.17	0.50	2.79	35.88	7.01
Additional fertilizer (g plant^{-1})					
0	4.65^{b}	0.48^{b}	2.33^{b}	35.35	8.80
6.25	5.24^{a}	0.55^{a}	2.56^{ab}	39.98	7.64
12.5	5.41^{a}	0.53^{a}	2.61^{ab}	35.80	6.60
18.75	5.44^{a}	0.55^{a}	2.92^{a}	32.56	6.00
CV (%)	6.69	10.06	15.48	14.36	16.89

Note: numbers with different letters in the same column significantly differ from the 5% DMRT test growth (stems, roots, twigs and leaf) (Zhu et al., 2017). Potassium was found in plants in the form of K^+ cation, which played an essential role in respiration and photosynthesis. Nutrient is particularly important for plant growth, especially during the fruit ripening period, namely seed filling (Hafsi et al., 2014). The ability of plants to properly absorb nutrients could lead to increase plant growth (Feng et al., 2020) and productivity (Leghari et al., 2016) by facilitating translocation to reproductive organs (Chen et al., 2018). According to a previous study, plants could easily perform physiological processes with the availability of sufficient nutrients (Seeda et al., 2021).

Various treatments of shoot pruning and additional fertilizer doses significantly affected yield, as shown in Table 3. Pruning shoot at 15 cm height caused a lower seed yield compared to the control, while a height of 30 cm produced dry seeds and was similar to the control. Pruning at 15 cm from the ground leaf led to the development of plant stems with a height of 15 cm or consisting of two stem segments, while at 30 cm height leaf, 3 to 4 stem segments were developed. Nodes referred to spots where leaf and flower buds appeared. Therefore, the higher the number of stem segments, the higher the buds, leading to the formation of more flowers and fruit buds. Pruning at a very low height of 15 cm could reduce the plant's source and decrease sink capacity.

Additional fertilizer at a dose of 6.25 to 12.5 g plant^{-1} significantly increased pod and seed weight per plant. This study was carried out under good weather conditions to ensure the optimal

Table 3. Effect of shoot pruning and additional fertilizer on winged bean yield

Treatment	Yield per plant			Yield per 5.7 m^2			Yield per ha	
	Pod number	Pod weight (g)	Seed weight (g)	Pod number	Pod weight (g)	Seed weight (g)	Pod weight (kg)	Seed weight (kg)
Shoot pruning								
Without pruning	16.8^a	59.78	40.44	574.2^a	2,092.6	1,398.8	3,587.92	2,441.63
Pruning height 15 cm	12.8^b	60.30	35.68	448.5^b	2,110.7	1,249.0	3,703.01	2,191.19
Pruning height 30 cm	13.4^{ab}	70.23	40.72	484.6^{ab}	2,458.3	1,425.5	4,312.85	2,500.84
Additional fertilizer (g plant^{-1})								
0	12.4	53.08^b	32.88^b	435.7	1,858.0	1,151.1^b	3,259.61^b	2,019.44^b
6.25	15.3	63.35^{ab}	41.75^a	536.3	2,217.6^{ab}	1,461.5^a	3,890.48^{ab}	2,563.95^a
12.5	16.5	73.92^a	40.35^{ab}	557.8	2,587.5^a	1,390.3^{ab}	4,428.28^a	2,422.46^{ab}
18.75	13.7	63.40^{ab}	40.80^{ab}	480.0	2,219.2^{ab}	1,428.3^{ab}	3,893.33^{ab}	2,505.70^{ab}
CV (%)	28.00	25.44	20.48	28.00	25.44	20.48	25.44	20.48

Note: numbers with different letters in the same column significantly differ from the 5% DMRT test

Table 4. Effect of shoot pruning and additional fertilizer on pod length and nutrients content of winged bean seeds

Treatment	Pod length (cm)	Weight per pod (g)	Seeds number per pod	100 seed weight (g)	Protein (%)	Fat (%)	Fatty acid (%)
Shoot pruning							
Without pruning	20.70	11.89	11.4	30.06	23.46	7.93	75.67^b
Pruning height 15 cm	21.81	11.56	11.6	33.92	23.98	6.97	82.94^a
Pruning height 30 cm	21.36	11.51	11.9	33.60	25.35	6.97	80.00^{ab}
Additional fertilizer (g plant^{-1})							
0	21.35	11.40	11.4	31.11	25.67	7.12	79.20
6.25	22.00	10.97	11.6	33.67	22.15	8.14	79.14
12.5	21.24	11.55	12.0	33.63	25.32	6.66	79.57
18.75	20.53	12.01	11.7	31.38	24.10	7.26	79.81
CV (%)	8.03	30.96	3.75	3.97	14.93	21.60	7.45

Note: numbers with different letters in the same column significantly differ from the 5% DMRT test growth of plants. The results showed that the use of additional fertilization treatment increased yield of winged bean seeds. The seed yield from this experiment was relatively lower compared to the potential yield of 44.5 g plant^{-1} (Laia, 2019). This was possibly due to differences in rainfall, where this study used 113 to 463 mm of rainfall per month, while the previous study utilized 138 to 671 mm (Laia, 2019).

Shoot pruning and additional fertilizer had no effect on pod length, seeds numbers per pod, pod weight, 100-grain weight, protein content and fat content but significantly increased the level of fatty acid in dry-winged bean seeds (Table 4). Physical stress, such as pruning could induce the plant's immune system. Fatty acid were synthesized in plants through a direct relationship with the defense mechanism (Zhao et al., 2022). Furthermore, they were primarily produced in chloroplasts, and almost 95% of them consisted of plastids, such as stearic, oleic and linoleic acid. These fatty acid played an essential role in the defense system, which depended on the bonds and arrangement of carbon, such as in tomatoes and eggplants (Moradzadeh et al., 2021).

Figure 1 showed 31 types of fatty acid compounds in winged bean seeds, with the dominant variants being oleic and linoleic acid (red color). Oleic acid was a mono-unsaturated fatty acid classified as excellent or healthy and included omega-9 fatty acid. Meanwhile, linoleic fatty acid was polyunsaturated, and an example of an omega-6 type (Ciabotti et al., 2019). Based on previous studies, there were two groups of fatty acid, namely unsaturated and saturated. The unsaturated types had hydrocarbon chains with double bonds, while the saturated variants did not have double bonds. Figure 1 showed the profile of fatty acid in various treatments of shoot pruning and additional fertilizer. Pruning height of 15 cm gave higher levels of linoleic acid (darker red) compared to other treatments. This indicated that pruning could increase linoleic fatty acid (unsaturated fatty acid) levels as a defense mechanism to respond to physical

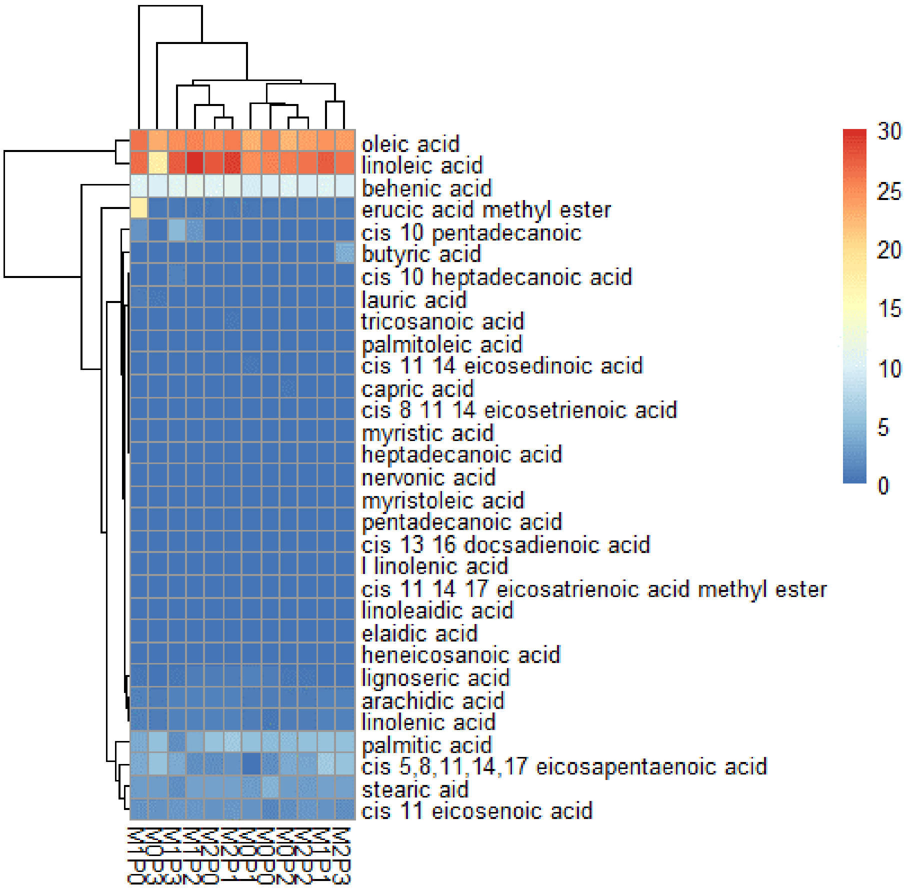

Figure 1. Heatmap of fatty acid profile for shoot pruning and additional fertilizer treatments

Note: M0 (no pruning); M1 (pruning height 15 cm); M2 (pruning height 30 cm); P0 (0 g NPK (16-16-16) plant^{-1}); P1 (6.25 g NPK (16-16-16) plant^{-1}); P2 (12.5 g NPK (16-16-16) plant^{-1}); P3 (18.75 g NPK (16-16-16) plant^{-1}). Fatty acid content is a percentage (%) of dry bean

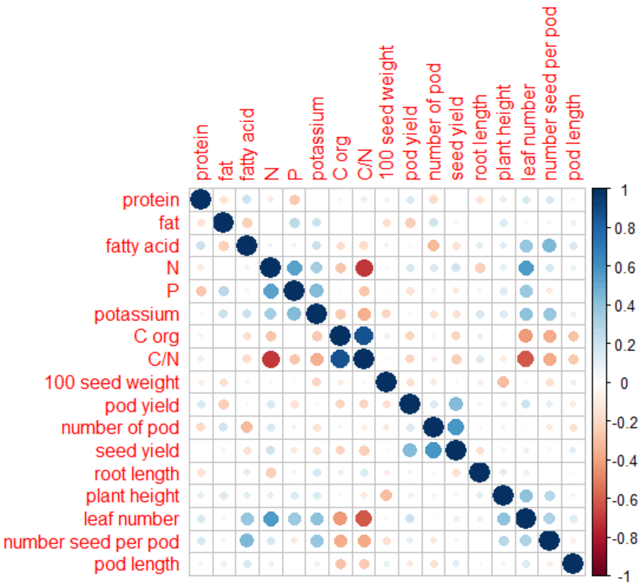

Figure 2. Correlation analysis of several observed variables

stress. The roles of fatty acid in the defense system of plants had been reported in tomatoes and eggplants (Moradzadeh et al., 2021).

Treatment without pruning combined with additional fertilizer of 18.75 g plant^{-1} caused lower linoleic acid levels, as shown in Figure 1. These low levels of linoleic acid could reduce the unpleasant smell of winged bean by decreasing the *lipoxygenase* enzyme's activity, which was a catalyst for fatty acid oxidation. The unpleasant smell of winged bean seeds was caused by the *lipoxygenase* enzyme's activity through fatty acid oxidation, especially linoleic acid (Ciabotti et al., 2019). Treatment consisting of larger doses of fertilizer could increase the excellent nutrients content, especially P, thereby lowering fatty acid levels. This was in line with previous studies that increasing the dose of P fertilizer could reduce linoleic acid levels in *Paeonia ostii* plants (Duan et al., 2022).

Based on the correlation matrix obtained in Figure 2, there was a strong positive correlation between leaf number and the N, P and K in leaf, the pod number and seed yield, the number of seeds per pod, and fatty acid content. A positive correlation was shown by leaf number and N nutrients in leaf, where the higher leaf number, the higher the N nutrients. The N, P and K were often classified as 'primary' macronutrients because deficiencies of these nutrients were more common than the 'secondary' macronutrients (El-Seifi et al., 2015; Singh et al., 2020). Nitrogen was one of the macronutrients that played an essential role in the formation of amino acid, nucleic acid, chlorophyll, proteins, and various secondary and primary metabolites. This indicated that the inadequacy of this nutrients could lead to suboptimal growth in plants (Kishorekumar et al., 2020). According to a previous study, N stimulated plant growth, especially during the vegetative phase (Fathi, 2022). Leaf number was also influenced by the levels of P and K present in the plant. Phosphorus was considered an essential nutrients and had proven to be vital for growth and yield (Khan et al., 2020). Potassium was one of the essential macronutrients and a vital factor in controlling productivity and could trigger the enzymatic antioxidant mechanisms (Adhikari et al., 2019). The N, P and K levels in leaf showed a positive correlation. The higher the N nutrients level, the higher the P and K content. This was possibly because of the type of fertilizer used in this study, namely NPK (16-16-16) fertilizer, which had equal content of these nutrients at 16%.

The pod number and seed yield also showed a positive correlation, where the presence of many pods could increase yield (weight) of seeds. This was because, in the pods, there were seeds ranging from 11 to 12 grains with a weight of 30 to 33 g 100 grains^{-1}. The results showed that there was a positive correlation between the number of seeds per pod and fatty acid content. This was in line with previous studies, where the number of seeds per pod had a significant and positive association with yield, 100 protein content and oil content (fatty acid content) (Painkra et al., 2018).

CONCLUSIONS

The interaction between shoot pruning treatment and additional fertilizer did not affect winged bean growth and seed yield parameters. As a single-factor treatment, shoot pruning increased leaf number and total fatty acid content. Furthermore, shoot pruning led to a 17 to 20%, 10%, and 16 to 19% increment in leaf number, fatty acid and linoleic acid content, respectively, compared to the control treatment. Based on the results, shoot pruning was not required to increase seed yield. Additional fertilizer increased leaf N, P and K levels, and seed yield, but reduced linoleic acid levels. The highest seed yield of winged bean (2.56 tons ha^{-1}) was achieved with the application of additional fertilizer at the rates of 6.25 g NPK (16-16-16) $plant^{-1}$.

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REFERENCES

Adegboyega, T. T., Abberton, M. T., Abdelgadir, A. A. H., Dianda, M., Maziya-dixon, B., Oyatomi, O. A., Ofodile, S., & Babalola, O. O. (2019). Nutrient and antinutrient composition of winged bean (*Psophocarpus tetragonolobus* (L.) DC.) seeds and tubers. *Journal of Food Quality*, *12*(1), 3075208. https://doi.org/10.1155/2019/3075208

Adhikari, B., Dhungana, S. K., Kim, I., & Shin, D. (2019). Effect of foliar application of potassium fertilizers on soybean plants under salinity stress. *Journal of the Saudi Society of Agricultural Sciences*, *19*(4), 261–269. https://doi.org/10.1016/j.jssas.2019.02.001

Anjos, R. A., Lisboa, C., Silva, G., Vaz, V., Teixeira, I., Eduardo, M., Corrêa, P. C., Mota, J. H., Silva, A., & Lourenço, A. (2021). Yield of common bean cultivars and castor hybrids intercropped in two cultivation sites with oxisol in the Midwest region of Brazil. *Australian Journal of Crop Science*, *15*(10), 1307–1313. https://doi.org/10.21475/ajcs.21.15.10.p3255

Barros, J. R. A., Guimarães, M. J. M., Simões, W. L., de Melo, N. F., & Angelotti, F. (2023). Temperature: A major climatic determinant of cowpea production. *Acta Scientiarum - Agronomy*, *45*, e56812. https://doi.org/10.4025/actasciagron.v45i1.56812

Bassal, H., Merah, O., Ali, A. M., Hijazi, A., & Omar, F. El. (2020). *Psophocarpus tetragonolobus*: An underused species with multiple potential uses. *Plants*, *9*(12), 1730. https://doi.org/10.3390/plants9121730

Betty, B., Aziz, S. A., & Suketi, K. (2021). The effects of different rates of chicken manure and harvest intervals on the bioactive compounds of bitter leaf (*Vernonia amygdalina* Del.). *Journal of Tropical Crop Science*, *8*(2), 80–88. https://doi.org/10.29244/jtcs.8.02.80-88

Calvindi, J., Syukur, M., & Nurcholis, W. (2020). Investigation of biochemical characters and antioxidant properties of different winged bean (*Psophocarpus tetragonolobus*) genotypes grown in Indonesia. *Biodiversitas*, *21*(6), 2420–2424. https://doi.org/10.13057/biodiv/d210612

Chen, Z., Tao, X., Khan, A., Tan, D. K. Y., & Luo, H. (2018). Biomass accumulation, photosynthetic traits and root development of cotton as affected by irrigation and nitrogen-fertilization. *Frontiers in Plant Science*, *9*, 327468. https://doi.org/10.3389/fpls.2018.00173

Ciabotti, S., Juhász, A. C. P., Mandarino, J. M. G., Costa, L. L., Corrêa, A. D., Simão, A. A., & Santos, E. N. F. (2019). Chemical composition and lipoxygenase activity of soybean (*Glycine max* L. Merrill.) genotypes, specific for human consumption, with different tegument colours. *Brazilian Journal of Food Technology*, *22*, e2018003. https://doi.org/10.1590/1981-6723.00318

Duan, X., Liu, W., Wang, X., Zhang, L., Liu, S., Guo, L., Guo, D., & Hou, X. (2022). Effects of phosphorus fertilization on growth characteristics, fatty acid composition, and seed yields of fengdan (*Paeonia ostii*). *HortScience*, *57*(6), 733–740. https://doi.org/10.21273/HORTSCI16555-22

Dufour, B., Kerana, W., & Ribeyre, F. (2019). Effect of coffee tree pruning on berry production and coffee berry borer infestation in the Toba Highlands (North Sumatra). *Crop Protection*, *122*, 151–158. https://doi.org/10.1016/j.cropro.2019.05.003

Eagleton, G. E. (2019). Prospects for developing an early maturing variety of Winged Bean

(*Psophocarpus tetragonolobus*) in Bogor, Indonesia. *Biodiversitas*, *20*(11), 3142–3152. https://doi.org/10.13057/biodiv/d201106

Eagleton, G. E. (2020). Review : Winged bean (*Psophocarpus tetragonolobus*) cropping systems. *Biodiversitas*, *21*(12), 5927–5946. https://doi.org/10.13057/biodiv/d211258

El-Seifi, S., Hassan, M., Elwan, M., & Haggag, O. (2015). Plant growth, yield, macro and micro-nutrients uptake of fennel (*Foeniculum vulgare* Mill.) positively affected by N-sources and rates as well as foliar application of micronutrients. *Hortscience Journal of Suez Canal University*, *4*(1), 7–16. https://doi.org/10.21608/hjsc.2015.6468

Fathi, A. (2022). Role of nitrogen (N) in plant growth, photosynthesis pigments, and N use efficiency: A review. *Agrisost*, *28*, 1–8. https://doi.org/10.5281/zenodo.7143588

Feng, J., Hussain, H. A., Hussain, S., Shi, C., Cholidah, L., Men, S., Ke, J., & Wang, L. (2020). Optimum water and fertilizer management for better growth and resource use efficiency of rapeseed in rainy and drought seasons. *Sustainability*, *12*(2), 703. https://doi.org/10.3390/su12020703

Hafsi, C., Debez, A., & Abdelly, C. (2014). Potassium deficiency in plants: Effects and signaling cascades. *Acta Physiologiae Plantarum*, *36*(5), 1055–1070. https://doi.org/10.1007/s11738-014-1491-2

Indawan, E., Lestari, S. U., Thiasari, N., & Sasongko, P. (2020). The pruning effect on the storage root yield and starch content of sweet potato clones planted at dry land. *Caraka Tani: Journal of Sustainable Agriculture*, *35*(2), 289–298. https://doi.org/10.20961/carakatani.v35i2.34480

Ishthifaiyyah, S. A., Syukur, M., Trikoesoemaningtyas, & Maharijaya, A. (2021). Agro-morphological traits and harvest period assessment of winged bean (*Psophocarpus tetragonolobus*) genotypes for pods production. *Biodiversitas*, *22*(2), 1069–1075. https://doi.org/10.13057/BIODIV/D220264

Khan, B. A., Hussain, A., Elahi, A., Adnan, M., Amin, M. M., Toor, M. D., Aziz, A., Sohail, M. K., Wahab, A., & Ahmad, R. (2020). Effect of phosphorus on growth, yield and quality of soybean (*Glycine max* L.): A review. *International Journal of Applied Research*, *6*(7), 540–545. Retrieved from https://www.allresearchjournal.com/archives/?year=2020&vol=6&issue=8&part=A&ArticleId=6960

Kishorekumar, R., Bulle, M., Wany, A., & Gupta, K. J. (2020). An overview of important enzymes involved in nitrogen assimilation of plants. In: Gupta, K. (eds) Nitrogen Metabolism in Plants. *Methods in Molecular Biology*, *2057*, 1–13. New York: Humana. https://doi.org/10.1007/978-1-4939-9790-9_1

Kraus, C., Rauch, C., Kalvelage, E. M., Behrens, F. H., D'aguiar, D., Dubois, C., & Fischer, M. (2022). Minimal versus intensive: How the pruning intensity affects occurrence of grapevine leaf stripe disease, wood integrity, and the mycobiome in grapevine trunks. *Journal of Fungi*, *8*(3), 247. https://doi.org/10.3390/jof8030247

Kueklang, M., Krisanapook, K., Havananda, T., Phavaphutanon, L., & Luengwilai, K. (2021). Seasonal variation of fruit yield and leaf macronutrient concentrations of Thai aromatic coconut. *Agriculture and Natural Resources*, *55*(5), 854–862. https://doi.org/10.34044/j.anres.2021.55.5.16

Laia, K. (2019). *Perbedaan keragaman, daya hasil, dan kandungan proksimat kecipir (Psophocarpus tetragonolobus* L.*). Thesis*. Bogor: IPB University. Retrieved from https://repository.ipb.ac.id/handle/123456789/100952

Leghari, S. J., Wahocho, N. A., Laghari, G. M., Laghari, A. H., Bhabhan, G. M., Talpur, K. H., Bhutto, T. A., Wahocho, S. A., & Lashari, A. A. (2016). Role of nitrogen for plant growth and development : A review. *Advances in Environmental Biology*, *10*(9), 209–218. Retrieved from https://go.gale.com/ps/i.do?id=GALE%7CA472372583&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=19950756&p=AONE&sw=w&userGroupName=anon%7E6fbd8168&aty=open-web-entry

Lepcha, P., Egan, A. N., Doyle, J. J., & Sathyanarayana, N. (2017). A review on current status and future prospects of winged bean (*Psophocarpus tetragonolobus*) in tropical agriculture. *Plant Foods for Human Nutrition*, *72*(3), 225–235. https://doi.org/10.1007/s11130-017-0627-0

Li, X., Schmid, B., Wang, F., & Paine, C. E. T. (2016). Net assimilation rate determines the growth rates of 14 species of subtropical forest trees. *PLoS ONE*, *11*(3), e0150644. https://doi.org/10.1371/journal.pone.0150644

Liu, Q., Xu, H., & Yi, H. (2021). Impact of fertilizer on crop yield and C:N:P stoichiometry in arid and semi-arid soil. *International Journal of Environmental Research and Public Health*, *18*(8), 4341. https://doi.org/10.3390/ijerph18084341

Ma, X., Li, F., Chen, Y., Chang, Y., Lian, X., Li, Y., Ye, L., Yin, T., & Lu, X. (2022). Effects of fertilization approaches on plant development and fertilizer use of citrus. *Plants*, *11*(19), 2547. https://doi.org/10.3390/plants11192547

Maillard, A., Diquélou, S., Billard, V., Laîné, P., Garnica, M., Prudent, M., Garcia-Mina, J. M., Yvin, J. C., & Ourry, A. (2015). Leaf mineral nutrient remobilization during leaf senescence and modulation by nutrient deficiency. *Frontiers in Plant Science*, *6*, 137688. https://doi.org/10.3389/fpls.2015.00317

Mohanty, C. S., Singh, V., & Chapman, M. A. (2020). Winged bean: An underutilized tropical legume on the path of improvement, to help mitigate food and nutrition security. *Scientia Horticulturae*, *260*, 108789. https://doi.org/10.1016/j.scienta.2019.108789

Moradzadeh, S., Siavash Moghaddam, S., Rahimi, A., Pourakbar, L., El Enshasy, H. A., & Sayyed, R. Z. (2021). Bio-chemical fertilizer improves the oil yield, fatty acid compositions, and macro-nutrient contents in *Nigella sativa* L. *Horticulturae*, *7*(10), 345. https://doi.org/10.3390/HORTICULTURAE7100345

Owolabi, I. O., Ashaolu, T. J., & Abayomi, Y. A. (2016). Effects of inorganic fertilizer application on plant growth and dry matter yield of physic nut (*Jatropha curcas* L.). *International Journal of Agricultural and Food Research*, *5*(1), 1–14. https://doi.org/10.24102/ijafr.v5i1.587

Pagliarino, E., Orlando, F., Vaglia, V., Rolfo, S., & Bocchi, S. (2020). Participatory research for sustainable agriculture: the case of the Italian agroecological rice network. *European Journal of Futures Research*, *8*(1), 7. https://doi.org/10.1186/s40309-020-00166-9

Painkra, P., Shrivatava, R., Nag, S. K., & Kute, I. (2018). Correlation analysis for seed yield and its attributing traits in soybean (*Glycine max* L. Merrill). *International Journal of Current Microbiology and Applied Sciences*, *7*(04), 2034–2040. https://doi.org/10.20546/ijcmas.2018.704.234

Pattnayak, S., & Swain, S. K. (2018). The importance of potassium in plant growth - A review. *Somadutta Pattnayak Int. Journal of Engineering Research and Application*, *8*(3), 44–52. Retrieved from https://www.ijera.com/papers/Vol8_issue3/Part-5/0803054452.pdf

Purba, R. S., Irwan, S. N. R., & Putra, E. T. S. (2019). The effect of spent bleaching earth filler-based NPK fertilization on proline, growth and yield of maize. *Caraka Tani: Journal of Sustainable Agriculture*, *35*(1), 44–53. https://doi.org/10.20961/carakatani.v35i1.34166

Roosta, H. R., Mohammadian, F., Raghami, M., Hamidpour, M., & Mirdehghan, S. H. (2020). Effect of nutrient solution and pruning on plant growth, yield, and fruit quality of hot pepper grown in an NFT system. *Journal of Agricultural Science and Technology*, *22*(6), 1537–1550. http://dorl.net/dor/20.1001.1.16807073.2020.22.6.3.9

Seeda, A., Yaseen, A., El-Nour, E. A. A. A., & Zaghloul, S. M. (2021). Effectiveness and fate nitrogen in plants physiology, molecular approaches for maximization and improving nitrogen use efficiency. A review. *Middle East Journal of Agriculture Research*, *10*(2), 683–769. https://doi.org/10.36632/mejar/2021.10.2.50

Shashi, Garhwal, O. P., Choudhary, M. R., Bairwa, L. N., Kumawat, K. L., Kumar, P., Basile, B., Corrado, G., Rouphael, Y., & Gora, J. S. (2022). Effects of time of pruning and plant bio-regulators on the growth, yield, fruit quality, and post-harvest losses of ber (*Ziziphus mauritiana*). *Horticulturae*, *8*(9), 809. https://doi.org/10.3390/horticulturae8090809

Sierra-Zurita, D., Santana-Espinoza, S., Rosales-Serna, R., Ríos-Saucedo, J. C., & Carrillo-Parra, A. (2023). Productivity and characterization of biomass obtained from pruning of walnut orchards in México.

Energies, *16*(5), 2243. https://doi.org/10.3390/en16052243

Singh, S. B., Singh, K., Singh Butola, S., Rawat, S., & Arunachalam, K. (2020). Determination of macronutrients, micronutrients and heavy metals present in Spilanthes acmella Hutch and Dalz: Possible health effects. *Natural Product Sciences*, *26*(1), 50–58. https://doi.org/10.20307/nps.2020.26.1.50

Sofian, M. E., & Susila, A. D. (2018). Increasing cauliflower yields through fertigation. *Journal of Tropical Crop Science*, *5*(1), 1–5. https://doi.org/10.29244/jtcs.5.1.1-5

Suganya, S., Rajamani, K., Gangga, M., Latha, M., & Jayakumar, P. (2023). Response of flower quality and physiological characters of *Jasminum sambac* (L.) to modified planting system and pruning schedule. *Journal of Applied and Natural Science*, *15*(1), 273–279. https://doi.org/10.31018/jans.v15i1.4327

Susanto, S., Aji, T. G., & Rahayu, A. (2015). The effect of apex pruning on vegetative and generative growth of roselle (*Hibiscus sabdariffa* L.). *Jurnal Hortikultura Indonesia*, *4*(3), 150–156. https://doi.org/10.29244/jhi.4.3.150-156

Tanzi, A. S., Eagleton, G. E., Ho, W. K., Wong, Q. N., Mayes, S., & Massawe, F. (2019). Winged bean (*Psophocarpus tetragonolobus* (L.) DC.) for food and nutritional security : Synthesis of past research and future direction. *Planta*, *250*, 911–931. https://doi.org/10.1007/s00425-019-03141-2

Valdes-Rodriguez, O. A., Gomez-Zuniga, I., Palacios-Wassenaar, O. M., Quintas, G. S., & Perez-Vazquez, A. (2020). Effect of pruning and organic fertilization over productive parameters of four mexican provenances of *Jatropha curcas* L. *Emirates Journal of Food and Agriculture*, *32*(8), 567–576. https://doi.org/10.9755/ejfa.2020.v32.i8.2133

Williams, H. N., Stafne, E. T., Zhang, Y., & Chang, S. K. (2023). Evaluating the effects of early pruning, leaf removal, and shoot thinning on 'MidSouth' grapes over two consecutive vintages in South Mississippi. *Agronomy*, *13*(2), 368. https://doi.org/10.3390/agronomy13020368

Zhao, Z., Fan, J., Yang, P., Wang, Z., Opiyo, S. O., Mackey, D., & Xia, Y. (2022). Involvement of Arabidopsis Acyl carrier protein 1 in PAMP-triggered immunity. *Molecular Plant-Microbe Interactions*, *35*(8), 681–693. https://doi.org/10.1094/MPMI-02-22-0049-R

Zhu, Q., Ozores-Hampton, M., Li, Y., Morgan, K., Liu, G., & Mylavarapu, R. S. (2017). Effect of phosphorus rates on growth, yield, and postharvest quality of tomato in a calcareous soil. *HortScience*, *52*(10), 1406–1412. https://doi.org/10.21273/HORTSCI12192-17