Indonesian Journal of Agronomy

ISSN 2085-2916 | e-ISSN 2337-3652
Indonesian J. Agron., *51*(1), 54-64, April 2023
DOI: https://dx.doi.org/10.24831/ija.v51i1.46034

Research Article

Pruning and additional fertilizer applications affect morphophysiological characters and flavonoid content of winged bean

Isna Tustiyani [1], Maya Melati [2*], Sandra Arifin Aziz [2], Muhamad Syukur [2], and Didah Nur Faridah [3]

[1] Agronomy and Horticulture Study Program, Graduate School of IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA

[2] Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA

[3] Department of Food Science and Technology, Faculty of Agricultural Technology, IPB University (Bogor Agricultural University), Kampus IPB Darmaga, Bogor 16680, INDONESIA

* Corresponding author (✉ maya_melati@apps.ipb.ac.id)

ABSTRACT

Excessive leaf production in winged bean may delay the flowering time and reduces the yield, therefore, shoot pruning and additional fertilizer were applied in order to improve yield. The research was carried out at Leuwikopo Experimental Station, IPB University, Bogor from January to July 2022. The study used a randomized complete block design with 2 factors and three replications. The first factor was three types of shoot pruning, namely without shoot pruning, shoot pruning at 15, and 30 cm height. Pruning was conducted at 7 weeks after transplanting (WAT). The second factor was four doses of fertilizers (0, 6.25, 12.5, and 18.75 g of NPK (16-16-16) per plant). The additional fertilizer was given every two weeks from 7 until 15 WAT. The variables observed were the morphophysiological characters, shoot auxin levels, plant nutrient levels, pod yield, pod number, and pod flavonoid content. The results showed that plant's biomass increased with additional fertilizer, lower relative growth rate and higher auxin content was from 15 cm pruning. The interaction of two factors affected flowering time and flavonoid content. Shoot pruning and 6.25 g NPK delayed flowering by 0.7-1 day. The highest flavonoid content was found in the plant without pruning and additional fertilizer. Plant yields were not significantly affected by treatments.

Keywords: auxin; flavonoid content; flowering time; leaf nutrient; young pods

Edited by:
Maryati Sari

Received:
2 March 2023
Accepted:
5 April 2023
Published online:
29 April 2023

Citation:
Tustiyani, I., Melati, M., Aziz, S. A., Syukur, M., & Faridah, D. N. (2023). Pruning and additional fertilizer applications affect morphophysiological characters and flavonoid content of winged bean. *Indonesian Journal of Agronomy*, *51*(1), 54-64

INTRODUCTION

The winged bean (*Psophocarpus tetragonolobus* (L.) is a potential leguminous vegetable plant that belongs to the Fabaceae (Handayani, 2013; Rakhmad et al., 2021). Young winged bean pods are widely used as a vegetable that can be consumed raw, boiled, or steamed (Handayani, 2013; Lepcha et al., 2017). The yield potential of young winged bean pods ranges from 2.58 to 8.94 tons per ha (Handayani et al., 2015).

Winged bean also potential as a functional food because it has a high nutritional content and contains functional components that have health benefits. A 100 g of young winged bean pods contain protein (1.9-4.3 g), total carbohydrates (1.1-7.9 g), fat (0.1-3.4 g), fiber (0.9-3.1 g), ash (0.4-1.9 g), phenol (48.4-143.5 mg GAE) and flavonoid (9.1-37.0 (Singh et al., 2019). According to Khoirunnisa & Sumiwi (2019), flavonoids are polyphenolic compounds containing 15 carbon atoms, soluble in water, rich in antioxidants that may alter toxins and disease, anti-inflammatory, antimutagenic, and anti-carcinogenic. Therefore, plants with high flavonoid content are beneficial for human health.

Winged bean is popular in the tropics (Mohanty et al., 2013), especially in Papua New Guinea and Indonesia (Krisnawati, 2010; Handayani, 2013). This plant grows vines, so it requires support, has trifoliate leaves, butterfly-shaped flowers, and root nodules, and the pods have four wings (Handayani et al., 2015). The winged bean plants can live for a long time (Gregory et al., 1980) and generally takes more than 100 days from planting to produce the first flowers (Eagleton, 2019), and harvesting young pods is up to seven times or more (Sari et al., 2018; Ishthifaiyyah et al., 2021). Besides being long-lived, this plant also has dense leaves to support its growth. This dense leaf growth allows the vegetative phase of the plant to be longer and delays the generative stage. Therefore, shoot pruning is considered to improve plant productivity.

Pruning is an effort to remove plant parts that are not productive to facilitate the more productive plant parts for supporting growth and production (Panggabean et al., 2014), reduce canopy humidity (Tsegaye & Struik, 2000; Makhubedu et al., 2022), reduce transpiration rate (Li et al., 2016), stimulates the growth of productive shoots, facilitates plant maintenance (Yuliana et al., 2017), and controls plant growth (Mudau and Mariga, 2010; Max et al., 2016; Shashi et al., 2022). Several studies have shown that the pruning treatment can support plant growth, for example, pruning treatment produced longer stem on sweet potato plants (Novianti and Setiawan, 2018), an increased shoot number and biomass (Mediene et al., 2002), an increased production (Saifuddin et al., 2010; Partey, 2011), changes in hormone concentrations in plants (Tworkoski et al., 2006), decreases proline content in shoots (Sanjay et al., 2010), changes in chlorophyll a and b content (Calatayud et al., 2007), and changes in root shoot ratio (Carrillo et al., 2011) than the without pruning treatment. Pruning is a common and constructive technique for plants under natural exposed sunlight. There are several types of pruning techniques, namely leaf pruning (Shashi et al., 2022), shoots pruning (Santhoshkumar et al., 2022), flower pruning (Saifuddin et al., 2010), and fruit pruning (Susanto et al., 2019). However, pruning usually delays the flowering time; therefore, flowering stimulation is needed, for example, through the application of fertilizers.

Fertilizer application aims to provide plant nutrients to increase crop production (Santana et al., 2021). The recommended fertilizer doses for winged bean production are 50 kg urea, 90 kg SP-36, and 150 kg KCl ha^{-1} (Laia, 2019); these fertilizers are applied as basic fertilizers applied at planting. However, as the plant has continuous flowering, additional fertilizer may be needed to support plant growth and production after the plant enters the generative phase.

Preliminary studies have been carried out in winged beans by using a combination of leaf pruning and additional fertilizer application. Nevertheless, the result was still unsatisfactory because it's have not been able to increase winged bean production yet. In the present experiment, shoot pruning as an alternative to leaf pruning is investigated to obtain the desired results. Moreover, this research is also intended to measure flavonoids as one of the important biochemical compounds of winged beans that have beneficial effect to human health. The experiment aimed to determine the effect of shoot pruning and additional fertilizing on young winged bean pods' morphophysiological character and flavonoid content.

MATERIALS AND METHODS

Trial site and experimental design

The experiment was carried out from January to July 2022 at the Leuwikopo Experimental Station, IPB University, Darmaga, Bogor. The site has an altitude of 218 m above sea level. The materials used in the experiment were winged bean seeds of the Fairuz IPB variety and NPK fertilizer (16-16-16).

The experiment used a two-factor randomized complete block design (RCBD), namely shoot pruning height and the rates of additional fertilizer (NPK 16-16-16). The three shoot pruning treatments were implemented, i.e., without shoot pruning, pruning 15 cm, and pruning 30 cm from the ground at 7 weeks after transplanting (WAT). The additional fertilization treatment consisted of four rates, i.e., 0, 6.25, 12.5, and 18.5 g NPK (1616-16) per plant. Additional fertilizer application was carried out by pouring a fertilizer solution of 250 mL per plant at 7, 9, 11, 13, and 15 WAT. All treatments were repeated three times to obtain 12 experimental units. Each unit is sized 1 m x 5.7 m.

Planting methods

After land preparation, agricultural lime at a dose of 2 tons ha^{-1} and manure at a dose of 10 tons ha^{-1} as ameliorant were applied three weeks before planting. Then, the soil bed was constructed with a width of 1 m. The bed was covered with silver-black mulch to prevent weed growth.

Planting holes were 50 cm x 30 cm. Winged bean seeds were sown in trays for 2 weeks before planting in the field. After transplanting, bamboo sticks were used to support the plants. At two weeks after planting, the basic fertilizers were applied composed of 25 kg N, 36 kg P_2O_5, and 50 kg K_2O ha^{-1} following Laia (2019). The young pods were harvested at 8 days after anthesis (DAA), and the harvest continued until 24 WAT.

Variables observed

Variables observed included morphophysiological character (plant height, leaf number, root length, fresh and dry weight per plant, leaf area, net assimilation rate (NAR), relative growth rate (RGR), shoot auxin concentration, leaf nutrient concentrations, pod yield, and number of pods, and flavonoid content young pod at 8 days after anthesis (DAA).

Data were processed with an analysis of variance at an alpha level of 0.05. The data were further evaluated using the Duncan Multiple Range Test (DMRT) for any significant effect.

RESULTS AND DISCUSSION

Morphophysiological character

In general, there was no significant interaction effect between pruning treatment and additional fertilization on the growth variables of winged bean plants. Still, the additional fertilization treatment had a different effect on plant height at 10 WAT and the leaf number at 15 WAT (Table 1). At 10 WAT, the application of 6.25 and 18.75 g NPK per plant stimulated a higher plant than those without additional fertilizer. The plant heights from 12.5 and 18.75 g NPK treatments were 10.1% and 14.6% higher, respectively than the control. Other results showed that additional fertilization significantly affected leaf number at 15 WAT, with the highest leaf number from 12.5 g NPK per plant.

The NPK doses of 6.25, 12.5, and 18.75 g per plant resulted in 15.3, 31%, and 15% higher leaf number, respectively, than the control treatment (Table 1). Table 1 also shows that plant height has increased from 5 to 10 WAT and then decreased at 15 WAT. Plant height increased during the vegetative phase, following a common growth pattern. After the plant enters the generative phase, there was no marked increase in plant height; therefore photosynthate is mainly translocated to develop generative organs (Max et al., 2016; Gunawan et al., 2021). In such a case, where vegetative growth stops after flowering and during pod formation is called a determinate growth pattern. The winged bean growth pattern is generally indeterminate (Handayani, 2013), however, the Fairuz IPB variety used in the present experiment has a determinate growth pattern (Laia, 2019).

Table 1. Plant height, leaf number, and root length of winged bean at 5, 10, and 15 WAT affected by shoot pruning and additional fertilizer rates.

Treatment	Plant height (cm)			Root length (cm)			Leaf number		
	5 WAT	10 WAT	15 WAT	5 WAT	10 WAT	15 WAT	5 WAT	10 WAT	15 WAT
Shoot pruning									
Without pruning	21.83	120.25	289.75	4.91	18.16	21.83	7.4	64.6a	61.5
15 cm	23.25	117.16	305.58	6.41	18.08	23.25	7.5	50.0b	68.8
30 cm	27.08	119.83	301.83	4.66	18.58	27.08	7.2	59.9ab	69.6
Additional fertilizer (g per plant)									
0	16.44	109.22b	290.44	3.55	18.77	26.66	6.3	55.2	57.4b
6.25	18.77	123.11a	302.33	6.22	19.33	23.22	8.0	56.8	67.4ab
12.50	17.88	117.44ab	305.22	5.66	15.44	23.44	8.2	57.3	75.6a
18.75	18.77	126.55a	298.22	5.88	19.55	22.88	7.0	63.3	66.2ab
CV (%)	14.63	7.64	7.22	22.79	8.37	18.64	25.85	24.87	22.57

Note: Numbers in a column followed by the same letter are not significantly different based on the DMRT at the level of α=5%, WAT: week after transplanting.

Shoot pruning had a significantly different effect on plant fresh weight at 15 WAT and plant dry weight at 10 WAT (Table 2). The 15 cm shoot pruning treatment had the lowest fresh weight at 15 WAT and the dry weight at 10 WAT. The additional fertilizer treatment affected plant fresh weight at 10 and 15 WAT, plant dry weight at 5 WAT, and the leaf area at 5 and 10 WAT; treatment of 18.75 g NPK per plant was the best performance. These results indicate that additional fertilizer application is needed to increase the winged bean biomass, especially fresh weight, and the leaf area. This fact is contrary to the results of a preliminary experiment conducted in the dry season (July to December 2021) where no additional fertilizer was needed to increase the plant biomass. It is probable that soil humidity might contribute to the effectiveness of fertilizer application.

Table 2. Fresh and dry weight, and leaf area of winged bean at 5, 10, and 15 WAT as affected by shoot pruning and additional fertilizer rates.

Treatment	Fresh weight per plant (g)			Dry weight per plant (g)			Leaf area (cm^2)		
	5 WAT	10 WAT	15 WAT	5 WAT	10 WAT	15 WAT	5 WAT	10 WAT	15 WAT
Shoot pruning									
Without pruning	1.29	98.22	137.39a	0.57	28.02a	71.13	229.00	5111.7	28454
15 cm	1.38	78.58	100.25b	0.76	18.81b	68.17	304.33	4016.7	28271
30 cm	1.26	89.13	136.38a	0.65	27.26a	80.54	262.33	4867.0	32216
Additional fertilizer (g per plant)									
0	0.97	66.84b	98.73b	0.54b	20.80	69.14	217.33b	3694.7b	27656
6.25	1.32	96.96ab	128.07ab	0.60b	26.45	65.41	242.22b	5274.2a	26610
2.50	1.31	84.19ab	117.52ab	0.58b	24.53	82.58	232.00b	4573.3ab	33921
18.75	1.63	106.58a	154.36a	0.92a	27.01	76.00	369.33a	5118.2a	30402
CV (%)	18.22	20.90	17.48	11.86	16.51	27.51	21.13	15.93	28.41

Note: Numbers in a column followed by the same letter are not significantly different based on the DMRT at the level of α=5%, WAT: week after transplanting.

The additional fertilizer treatment affected dry weight and leaf area, in which higher doses of fertilizer increased plant fresh weight at 10 and 15 WAT, dry weight at 5 WAT, and leaf area at 5 and 10 WAT (Table 2). The treatment of 18.75 g NPK per plant had a fresh weight of 59.4% (at 10 WAT), 59.4% (at 15 WAT), and a dry weight of 70.3% higher at 5 WAT than those the control plants.

Shoot pruning treatment affected the relative growth rate (RGR) and net assimilation rate (NAR) of winged bean plants (Table 3). Table 3 shows that at 5-10 WAT, the 15 cm pruning treatment resulted in lower RGR and NAR values than those of the 30 cm pruning treatment and the control. On the other hand, at 10-15 WAT, the 15 cm and 30 cm pruning treatments had better RGR values than the control treatment. Shoot pruning was carried out at 6 WAT, so the RGR value of the pruning treatment at 5-10 WAT might have been lower than the control due to plant adaptation to the pruning treatment itself. The leaf number at 10 WAT, which was lower in the 15 cm pruning treatment compared to other treatments (Table 1) also caused the growth rate to be lower. The net assimilation rate (NAR) of plants is the accumulation of dry weight per unit of leaf area per unit of time (Santana et al., 2021).

Generally, the RGR values measured in the 10-15 WAT period are lower than those in phase 5-10 WAT (Table 3). This indicates that the plant growth rate is slower by increasing plant age. The relative plant growth rate (RGR) shows the increase in plant biomass at each plant age in a particular land area (Santana et al., 2021). This statement is in line with the results reported by Suryaningrum et al. (2016) that the RGR value will decrease as the plant ages.

Table 3. Relative growth rate and net assimilation rate of winged bean plants affected by shoot pruning and additional fertilizer rates.

Treatment	Relative growth rate ($g\ g^{-1}\ week^{-1}$)		Net assimilation rate ($g\ cm^{-2}\ week^{-1}$)	
	5-10 WAT	10-15 WAT	5-10 WAT	10-15 WAT
Shoot pruning				
Without pruning	0.79a	0.18b	27.37a	22.75
15 cm	0.64b	0.27a	17.95b	24.94
30 cm	0.74a	0.22ab	26.58a	27.25
Additional fertilizer (g per plant)				
0	0.72	0.25	20.39	22.35
6.25	0.75	0.18	25.74	22.10
12.50	0.75	0.24	23.82	28.49
18.75	0.68	0.21	25.92	26.98
CV (%)	15.49	6.71	17.47	18.83

Note: Numbers in a column followed by the same letter are not significantly different based on the DMRT at the level of α=5%, WAT: week after transplanting.

The levels of auxin in the shoot differed among pruning treatments (Table 4). Plants pruned at 15 cm had auxin as much as 0.018% or 50% higher than the control. The growth-promoting phytohormones, such as IAA (auxin), GA_1, GA_3, and cytokinin, were significantly elevated in the plants pruned, which might be a plausible explanation for its earlier development and better growth status (Lu et al., 2022). This is consistent with previous research that the pruning treatment had increased auxin levels than the control treatment in tea (Lu et al., 2022) and tomatoes (Xu et al., 2020). Pruning causes apical dominance to stop so that more shoots and branches grow because auxin accumulation in the shooting area is channeled to lateral shoots (Srirejeki et al., 2015). Shoot-derived auxin is transported downward to roots and accounted for as the major source of auxin to drive root growth and development. For mechanisms, an appropriate extension of pruning increased indole acetic acid (IAA) concentrations in the root, which promoted the biosynthesis and upward transport of inactive cytokinins (CKs), as well as root development in tomatoes (Xu et al., 2020).

Pruning also affected the potassium, organic C, and C/N levels, with the highest value at 30 cm pruning treatment (Table 4). Higher leaf nutrients such as potassium and C organic content in heavily pruned treatment were due to less accumulation of dry matter and vigorous growth, which caused increased uptake of this element (Kaith *et al.* 2017). Potassium was higher in frequent pruning plants than in non-pruned plants, and potassium deficiency was reduced by complete pruning (Cheng and Fuchigami 2000).

Table 4. Leaf nutrient levels and auxin in winged bean shoots affected by shoot pruning and additional fertilizer rates.

Treatment	Auxin (%)	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)	C org (ppm)	C/N ratio
Shoot pruning						
Without pruning	0.012b	3.96	0.36	1.93b	33.18b	8.66b
15 cm	0.018a	4.08	0.37	2.29b	34.78b	8.54b
30 cm	0.011b	3.87	0.36	3.00a	41.68a	10.92a
Additional fertilizer (g per plant)						
0	0.015	3.68b	0.34	2.27	36.51	10.21
6.25	0.013	3.87ab	0.35	2.44	36.75	9.65
12.5	0.014	4.03ab	0.36	2.37	35.48	8.86
18.75	0.013	4.30a	0.38	2.56	37.44	8.78
CV (%)	28.00	13.73	11.87	20.05	20.90	26.59

Note: Numbers in a column followed by the same letter are not significantly different based on the DMRT at the level of α=5%.

Table 4 shows that additional fertilization treatments significantly affected leaf N content; the higher the dose of fertilizer given would increase the leaf N content with the highest value in the treatment of 18.75 g per plant. High leaf N levels can positively affect plant growth (Table 1) and leaf area (Table 2). During the growth and development of a plant, especially in the vegetative phase, such as the growth of stems and leaves, the most needed content is nitrogen (N) because nitrogen plays a vital role in forming chlorophyll, helpful in the process of photosynthesis. This photosynthesis process functions to obtain and produce assimilates for plants, with sufficient chlorophyll content to spur plant growth, especially in stimulating vegetative organs in a plant (Kim and Li, 2016; Adhikari et al., 2019; Lee et al., 2019; Simanjuntak et al., 2019). Adequate nutrients of N, P, and K are essential for plant growth (Husni and Rosadi, 2015; Kim and Li, 2016; Husnihuda et al., 2017; Adhikari et al., 2019; Lee et al., 2019). Adequate doses of NPK fertilizer will affect the availability of nutrients for plants so that their growth and development are optimal and plants can carry out physiological processes properly (Adhikari et al., 2019; Lee et al., 2019; Roosta et al., 2020).

The increasing plant weight and leaf area as shown in Table 2 were possibly due to the increased N levels in the leaves (Table 4). Nitrogen stimulates overall growth, especially in leaves, stems, and branches. Nitrogen in large quantities is needed especially during vegetative growth (Manasikana et al., 2019). Nitrogen is one of the essential elements needed to improve plant growth, including as a supporting element for soil fertility (Santana et al., 2021).

Plant yield and flavonoids content

The interaction of pruning and additional fertilization treatments affected flowering time and pod flavonoid content (Table 5). Pruning at 30 cm height and without additional fertilizer and an additional fertilization dose of 6.25 g per plant had a longer flowering date than other treatments, and higher doses of additional fertilization would speed up the flowering time.

The flavonoids content of young pods was also affected by the interaction between pruning treatment and additional fertilizer (data not shown). The combination of without pruning and additional fertilizer, and without pruning and additional fertilizer rate 12.5 g per plant showed the highest levels of flavonoids compared to the others (Table 5). In comparison, the lowest levels of flavonoids were found in the pruning treatment of 15 cm, which was fertilized with 12.5 g per plant. Pruning may have triggered the response mechanism in terms of increased flavonoid production (Hernandez et al., 2009). The number of active components in plants can be influenced by cultivation practices such as fertilizer levels. The use of fertilizers improves soil fertility, and it is a logical step toward increasing the production of medicinal plants.

Table 5. Flowering time and flavonoid content of winged bean young pods affected by shoot pruning and additional fertilizer rates.

Treatment	Rate of additional fertilizer (g per plant)			
	0	6.25	12.5	18.75
	Flowering time (WAT)			
Without pruning	12.8b	12.5b	12.6b	12.3b
15 cm	13.5a	12.8b	12.5b	12.5b
30 cm	13.8a	13.5a	12.3b	12.6b
CV (%)	2.71			
	Flavonoids (mg 100 g QE^{-1})			
Without pruning	329.60a	255.84bcd	325.06a	295.50abc
15 cm	259.24bcd	276.35abcd	224.90d	285.58abc
30 cm	307.50ab	259.74bcd	298.52abc	244.82cd
CV (%)	10.90			

Note: Numbers of particular variables followed by the same letter are not significantly different based on the DMRT at the level of α=5%, WAT: week after transplanting.

In the present experiment, flavonoid content significantly increased in plants treated with 12.5 g of additional fertilizer (Table 5). It is presumed that the chemical properties of the soil or soil fertility were improved resulting in higher nutrient absorption and finally leaf nutrient such as nitrogen increased. However, according to Jiang et al. (2007), the accumulation of flavonoids in a particular plant could be influenced by ecological conditions such as locality and harvesting period.

The additional fertilizer affects the number of flowers (Table 6). The number of flowers was observed at 15 WAT. The additional fertilizer application resulted in a higher number of flowers than the control with 7-8 flowers per plant. However, Table 6 shows that the yield of winged bean pods and pod weight in the present experiment were not significantly different between treatments.

Table 6. Yield of winged beans with pruning and additional fertilizer treatments.

Treatment	Pod length (cm)	Pod weight (g)	Number of flowers	Pod per plant		Pod per plot		Pod ha^{-1}	
				Number	Weight (g)	Number	Weight (g)	Number	Weight (kg)
Shoot pruning									
Without pruning	13.38	11.26	7.1b	15.8	179.38	554.8	6278.3	973392	11014.5
15 cm	13.38	11.32	8.3a	15.6	172.79	546.4	6047.6	958626	10609.8
30 cm	12.71	11.29	7.9ab	15.5	184.21	544.4	6447.2	955117	11311.0
Additional fertilizer (g per plant)									
0	13.42	11.32	6.5b	14.8	169.08	521.2	5917.8	914425	10382.1
6.25	13.26	11.24	7.8a	15.8	180.72	554.2	6325.3	972320	11097.0
12.50	12.97	11.26	8.5a	15.6	180.09	546.3	6303.0	958480	11057.9
18.75	12.97	11.33	8.4a	16.3	185.28	572.4	6484.7	1004288	11376.6
CV (%)	3.69	1.87	11.92	17.69	18.60	17.69	18.60	17.69	18.60

Note: Numbers in a column followed by the same letter are not significantly different based on the DMRT at the level of α=5%.

The pod weight ranged from 169-185 g per plant (Table 6). The pod weight per plant in the present experiment was higher than in a previous study which was 88.63 g per plant (Laia, 2019). One of the possible reasons for higher yield is better soil nutrient absorption by the plant. This experiment was carried out from January to July 2022, or the rainy season (106-463 mm/month), with temperature from 23-26°C and sunshine intensity from 137.74-228.44 W/m^2 or 1.14-1.90 Lux. The availability of sufficient and balanced nutrients is important for plant growth (Roosta et al., 2020). Productivity is an essential indicator of crop yield components closely related to the timing of planting activities.

Planting at the end of the rainy season can give better yields because the plants can obtain sufficient water (Santana et al., 2021). Another reason for the higher yield of the current experiment as compared to the previous study because under good weather conditions, the harvesting time in the present experiment was 13 times. The previous study harvested the pods 6-7 times (Sari et al., 2018) or 10 times (Laia, 2019; Ishthifaiyyah et al., 2021).

Pruning and additional fertilizer treatments did not increase pod yield (Table 6). Some explanations of the cause of the non-significant effect are: First, this research was conducted in optimum climatic conditions, including light intensity, rainfall, and air temperature. The previous study in winged bean experiment was rainy season with monthly precipitation of 138-671 mm (Laia 2019), and 153-583 mm (Susanti et al., 2022) but this experiment was conducted at the end of the dry season or 113-463 mm rainy per month. This caused plants to grow well, as indicated by an increase in leaf N nutrient levels in the additional fertilizer treatment (Table 4). Second, the application of basic fertilizers such as chicken manure and NPK fertilizers might improve soil nutrient facilitating best plant growth. Third, crop yields in this experiment were greater than the yield in the previous study, so fertilizer treatment could not increase yields because they had met with potential yield. Although Table 4 shows an increase in leaf N nutrient levels at the highest fertilizer dose, it probably has not been able to improve plant physiological processes resulting in a non-significant increase in crop yields. Plant physiological processes will work properly if plant nutrients, climate, and sunshine intensity are sufficient to support plant growth and development (Adhikari et al., 2019).

CONCLUSIONS

The results revealed that the interaction between pruning and additional fertilizer treatments significantly affected the flavonoid content and flowering time, but not the yield. The auxin content, leaf potassium contents, C organic, C/N ratio, and the relative growth rate increased with 15 cm pruning treatment. Treatment of fertilizer increased plant height, leaf number, dry weight, leaf area, leaf nitrogen content, and flowers. Plants treated with a combination of without pruning and without additional fertilizer, and with a combination of without pruning and additional fertilizer of 12.5 g NPK (16-16-16) flowered earlier and its pod contained higher flavonoid levels than the other treatments.

ACKNOWLEDGEMENTS

The authors thank the Ministry of Finance of the Republic of Indonesia for funding through the LPDP Scholarship.

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