

RESEARCH ARTICLE

# The Effect of Population Density and Intercropping with Tomato on the Growth and Yield of Winged Bean (*Psophocarpus tetragonolobus*)

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## Abstract

Winged bean (Fabaceae) is a tropical crop that has high nutrient content, and almost all parts of the plant are edible. The research aimed to evaluate the growth and production of winged bean in an intercropping system with tomato. The study was conducted at the Cikabayan Experimental Field of Bogor Agricultural University, Bogor, Indonesia, in a randomized block design with three replications during the rainy season of December 2017 to June 2018. Winged beans were planted in high and low population densities and intercropped with three tomato genotypes, "Tora", F70030081-12-16-3 and "Apel Belgia". Monoculture winged bean was assigned as control. Tomatoes were planted between the rows of the winged beans in the intercropping treatment. The results showed that the growth of winged bean in monoculture and intercropping systems was not significantly different. The photosynthetic activity of winged bean at three to five weeks after planting remained high, indicating that the vegetative growth was optimal in both systems. Intercropping increased the winged bean number of pods per plant by 12.66-19.52% compared to monoculture, irrespective of population density. Therefore, winged bean could be considered as suitable to grow in intercropping systems.

Keywords: population density, vegetable, net assimilation rate, winged bean

## Introduction

Winged bean (*Psophocarpus tetragonolobus* L. (DC)) has long been cultivated in several regions in

Indonesia. Winged bean has been given different names in these different regions, such as *belingbing* beans in Sumatra, *embing* in Palembang, *jaat* in Sunda, *cipir* in Javanese, *kalongkang* in Bali, *biraro* in Manado and *botor* or *kumbotor* in Borneo (Susila et al., 2012). Almost all parts of the winged plants are edible including young pods, seeds, young leaves, flowers and tubers (Singh et al., 2013; Sabtadi et al., 2016; Tanzi et al., 2019) and the beans are a good source of protein (Mohanty et al., 2013). The young leaves of winged beans contain 5240-20800 IU of vitamin A whereas the young pods contain 300-900 IU per 100 g (Krisnawati, 2010). Due to its nutritional values, winged bean becomes an important cultivated crop (Vietmeyer, 2008).

Winged bean belongs to the Fabaceae family; it is a vine with trifoliolate leaves, butterfly-shaped flowers, with pods having four wings (thus the name) (Handayani et al., 2015). Winged beans have nodules and are capable of producing tubers (Handayani et al., 2015). Winged bean is relatively easy to cultivate, but limited studies on winged bean production and culture have been conducted, therefore information pertaining to its production in the tropics is still limited. This might because winged bean is not a popular crop to cultivate extensively, but only seen as intercrops along the border plot of the rice field or in the backyards along with other vegetable crops. Some Asian countries such as Thailand, Sri Lanka, Malaysia and the Philippines have cultivated winged bean commercially (Khan, 1976).

Winged bean can grow on less fertile soil with limited water availability (Sinha, 2013), suppress weeds (Anugroho et al., 2010), preserve the ground water

(Salako and Tian, 2003), increase soil fertility (Barthes et al., 2004), tolerant of saline soils (Weil and Khalil, 1986), and can be used as a cover crop (Kitou et al., 2010). Such advantages lead to its potentials to be an important crop for semi arid regions, including in east Nusa Tenggara, Indonesia.

In the present study, winged bean is planted with tomatoes in an intercropping system. Intercropping with legumes, including winged beans, can maintain or enhance soil fertility due to their great capacity in root nodulation (Tanzi et al., 2019) and supply the nitrogen for the crops (Mucheru-Muna et al., 2010). Many authors have reported the advantage of intercropping legumes with a diverse crop species such as long bean with tomato (Farhan, 2017), cowpea with cassava (Njoku et al., 2010), cowpea with maize (Adeniyani et al., 2011) and soybean with cassava (Sundari and Mutmaidah, 2018). Intercropping systems with winged bean, however, is relatively new and is rarely reported. The purpose of this study was to evaluate the growth and production of winged bean as a major crop in a tomato intercropping system.

## Materials and Methods

The cultivar of winged bean used in this study was IPB Zaphira. Seeds of winged bean were planted in the Experimental Farm Cikabayan of Bogor Agricultural University, Bogor, Indonesia during the rainy season in December 2017 to June 2018. The experiment was arranged using a randomized block design with three

replications at low (20,000 plants per ha) and high (28,571 plants per ha) population densities grown in a 100 cm x 50 cm and 70 cm x 50 cm spacing, respectively. The beans were intercropped with three different tomato genotypes, namely “Tora”, F70030081-12-16-3 (F700) and “Apel Belgia”, planted among rows of winged bean with a population of 16,666 plants per hectare in the low population, and 20,000 plants per ha in the high population density. As a control winged bean was grown as a monoculture with either low or high population density.

Winged bean seeds were planted in a 1.2 m x 5 m beds with two parallel lines as a corresponding predefined spacing. Tomato seedlings were transplanted into the plot two weeks after planting (WAP) of the winged bean seeds. Plant replacement of winged bean was conducted two weeks after germination (WAG) by replacing the abnormal, died or non-germinated seeds. Replacement of tomato plants was carried out up to 2 WAP. Once grown, 2 m long bamboo stakes forming a triangle were used to support the winged bean crops (Figure 1).

Winged beans were fertilized according to the method by Poerwanto and Susila (2014) i.e., 100 kg of ZA (21% N), 135 kg SP-36 (36% P<sub>2</sub>O<sub>5</sub>) and 90 kg KCl (60% K<sub>2</sub>O) per hectare. All NPK fertilizers was mixed and it was splitted into four times of application at 2, 4, 6 and 8 weeks after planting. In each application, 10 g NPK mixture was diluted into one liter water and applied to each winged bean plant at a rate of 200 ml. Weed control was done manually; pest and disease

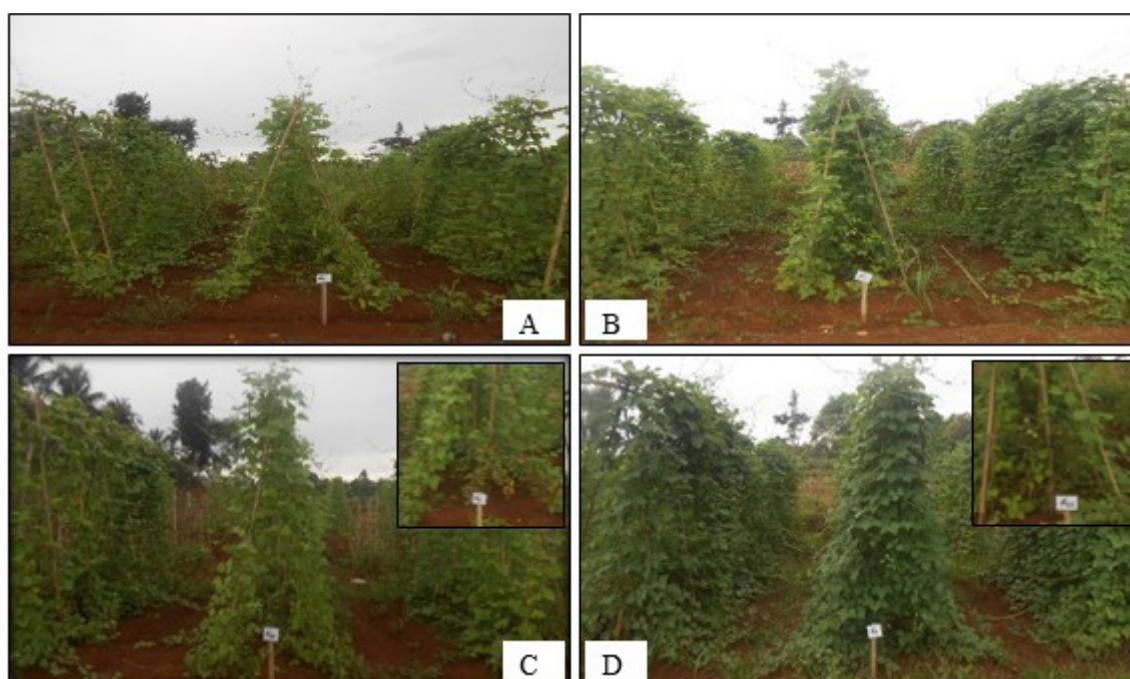


Figure 1. Monoculture wing beans at low (A) and high population (B); intercropped wing beans at low (C) and high (D) population. Inset shows the position of the tomato between the winged bean rows.

control was conducted when necessary. Unless there was rain of > 3 mm, the crops individually were watered twice a day in the morning and afternoon with about 3 L per plant for each application.

The growth parameters were measured weekly starting from second WAP, otherwise mentioned, for shoot lengths, stem diameter, leaf area, number of flowers, flowering time, harvesting time, plant dry weight, net assimilation rate, relative growth rate, number of pods, pod length and pod diameter. All plants in a bed was measured. Measurements of length, weight and diameter of pods were carried out on five pods per plant per harvest for all plants. Young bean pods were harvested at 16-25 WAP, or when the color of the pod was green and the pod size has reached its maximum size. During the course of the study, harvesting was done six times.

In order to measure growth rate and assimilation rate, destructive samples were taken at 3, 5, and 7 WAP. Each observation used three sample of each replication. The relative growth rate (RGR) and net assimilation rate (NAR) values were measured using a formula of Sunaryanti (2017):  $RGR = \frac{\ln W_2 - \ln W_1}{T_2 - T_1}$  dan  $NAR = \frac{(W_2 - W_1)(\ln A_2 - \ln A_1)}{(T_2 - T_1)(A_2 - A_1)}$ , where W1 and W2 = 1<sup>st</sup> and 2<sup>nd</sup> observation plant dry weight (g); A1 and A2 = 1<sup>st</sup> and 2<sup>nd</sup> observation leaf area (cm<sup>2</sup>); T1 and T2 = 1<sup>st</sup> and 2<sup>nd</sup> measurement.

Data was analyzed using ANOVA using SAS 9.4, followed by Duncan's Multiple Range Test (DMRT) at 5%. In the analysis, the data obtained from the average yields of the three tomato genotypes at low and high population were included.

## Results and Discussion

### *Length of shoot, Stem Diameter and Leaf Area*

Shoot length and leaf area varied between cropping systems, but they were not significantly different among the different tomato genotypes (Table 1). It is possible that there was a limited or absence of competition for the use of nutrients, water and light between crops when the wing beans were still young and small in size, as reported in Ahmed et al. (2016). The number of shoot per plant was 5 to 7. The total number of shoot tend to increase with increasing size of the main shoot, but the number of shoots was not observed further in this study.

Intercropping significantly affected the diameter of the winged bean stem (Table 1). Winged bean had smaller stem diameter (6.03 mm) when intercropped with genotype F700 at a low population, and the stem diameter (5.98 mm) was not significantly different to those intercropped with "Apel Belgia" at a low population density, but significantly larger than the control. The winged bean stems were green, cylindrical and had many segments, irrespective of population density and intercropping.

### *Flowering time, Number of Flower Arrangements and Harvesting Time*

Table 2 shows that intercropping had no effect on flowering time and the number of inflorescences per plant, but significantly affected harvest time. Flowering time for all the treatments ranged from 84.95 to 85.33 days after planting (DAP). Several factors may influence the flowering of legumes, including the environment (Boote, 1982), genetics

Table 1. Length of shoot, stem diameter and leaf area of winged bean at 8 WAP

Treatment	Shoot length (cm)	Stem diameter (mm)	Leaf area per plant (cm <sup>2</sup> )
Monoculture LP	98.21	5.67 bc	62.20
Monoculture HP	103.24	5.72 abc	86.72
Intercropping LP			
"Tora"	97.97	5.64 bc	71.53
F700	96.56	6.03 a	82.56
"Apel Belgia"	99.81	5.75 abc	67.53
Intercropping HP			
"Tora"	96.73	5.61 c	62.02
F700	97.93	5.60 c	64.33
Apel Belgia	96.97	5.98 ab	70.68
Treatment	ns	*	ns

Note: Values followed by the same letters in the same column show no significant difference based on DMRT at  $\alpha=5\%$ ; ns: not significantly different, \* significantly different; WAP: weeks after planting; LP: low population; HP: high population;



Table 2. Flowering time, number of flowers and harvesting time of the winged bean in monoculture and intercropping systems

Treatment	Flowering time (DAP) <sup>z</sup>	Number of inflorescence per plant	Harvesting time (DAP)	Duration of harvest (day)
Monoculture LP	85.0 a	51.3 a	111.3 a	1-2
Monoculture HP	85.1 a	52.8 a	110.7 ab	1-2
Intercropping LP				
“Tora”	85.2 a	45.7 a	110.2 b	1-2
F700	85.2 a	42.1 a	110.4 ab	1-2
“Apel Belgia”	85.2 a	43.2 a	110.9 ab	1-2
Intercropping HP				
“Tora”	85.1 a	42.7 a	110.1 b	1-2
F700	85.0 a	41.9 a	110.2 b	1-2
“Apel Belgia”	85.3 a	47.0 a	110.4 ab	1-2

Note: Values followed by the same letters in the same column show no significant difference based on DMRT test at 5%; DAP-day after planting. <sup>z</sup> flowering time was calculated when 50% of the population has flowered; LP=low population; HP=high population

(Sumpena et al., 2013) and pruning (Wulandari et al., 2017). Some of the accession of red beans is known to differ in the flowering time, ranging 30-35 DAP (Rizqiani et al., 2007).

The total number of inflorescence ranged from 41.9-52.8 per plant, irrespective of treatments (Table 2). The flower stalks are green; the flower petals have butterfly shape with light blue wing colors (Figure 2). Winged beans has compound flowers; one inflorescence has 3-8 flower buds which will potentially produce pods. According to Gahara (2015) an Isoflavone Bioactive Compound Characterization and Anti-oxidant Test from Tempe Extract of winged bean has 3-10 flower buds, however, Enderyani (2017) noted that only 3-5 flower buds develop into mature flower while the rest fail to bloom and drop.



Figure 2. The mature winged bean with unopened (A) and opened flowers (B)

#### *Relative Growth Rate (RGR) and Net Assimilation Rate (NAR) of Intercropped Winged Bean*

RGR value was the highest in winged bean planted intercropped with tomato F700 at low populations during the 3-5 WAP (1.36 g day<sup>-1</sup>), whereas the RGR was the lowest when intercropped with tomato genotype “Apel Belgia” (0.75 g day<sup>-1</sup>) at high

population density (Table 3). RGR and NAR values of winged bean plant at 3-5 WAP was higher than in the period of 5-7 WAP for both treatment of genotypes and cropping patterns. According to Sunaryanti (2017), RGR and NAR values may change along with the growth of plants. In present study, photosynthetic activity at 3-5 WAP was likely to be high as shown by the dry matter accumulation rate. Decreasing RGR and NAR values at 5-7 WAP could be due the plants starting to enter the generative phase. It is well known that during generative phase stored nutrients and photosynthate are allocated into generative organs, i.e. flowers, fruits, and seeds, as strong sink. As shown in Table 2, harvesting time started 110.5-111.3 DAP or about 16 WAP. It is possible that the transition stage from vegetative into generative resulted in inconsistent values of NAR at 5-7 WAP among treatments, and resulted in non-significant differences among treatments (Table 3).

Table 3 shows that the RGR values of winged bean at 3-5 WAP was higher in intercropping than in monoculture, and it was the reverse at 5-7 WAP the values. This indicates that there is an interaction between tomato plants and winged beans which explains the low NAR value with the intercropping treatment both at 3-5 WAP and 5-7 WAP. Further investigation is required to confirm this, particularly to determine the level of interaction and space occupation of the crops, which include both above and underground biomass.

#### *Winged Bean Production*

Population density and intercropping treatments did not affect the average weight per pod, pod length, and

Table 3. Relative growth rate (RGR) and net assimilation rate (NAR) of winged bean in monoculture and intercropping systems

Treatment	RGR (g.day <sup>-1</sup> )		NAR (g.cm <sup>-2</sup> .day <sup>-1</sup> )	
	3-5	5-7	3-5	5-7
	WAP			
Monoculture LP	0.93 ab	0.83 a	0.053 a	0.023 a
Monoculture HP	0.95 ab	0.74 a	0.077 a	0.037 a
Intercropping LP				
“Tora”	0.98 ab	0.60 a	0.080 a	0.040 a
F700	1.36 a	0.68 a	0.077 a	0.023 a
“Apel Belgia”	0.86 ab	0.67 a	0.077 a	0.037 a
Intercropping HP				
“Tora”	0.95 ab	0.60 a	0.083 a	0.023 a
F700	0.83 ab	0.59 a	0.053 a	0.023 a
“Apel Belgia”	0.75 b	0.69 a	0.045 a	0.037 a
Average				
Monoculture	0.67 a	0.84 a	0.080 a	0.035 a
Intercropping LP	0.89 a	0.65 b	0.065 a	0.030 a
Intercropping HP	0.84 a	0.63 b	0.060 a	0.030 a

Note: Values followed by the same letters in the same column show no significant difference based on DMRT at 5%; WAP: weeks after planting; LP: low population; HP: high population

diameter of the pod (Table 4). Harvesting was done at 16-26 WAP. After the pods in one inflorescence were harvested, new flowers appeared on the same inflorescence. Thus, in some cases, pods could be harvested repeatedly from the same inflorescence. From first to sixth harvesting time, pod number increased steadily, so the pod yield per plant will still increasing in the subsequent harvesting period.

Nevertheless, total number of pods as shown in Table 4 was not inline with total number of inflorescence as shown in Table 2. It is likely that not all inflorescence able to develop into pod. Number of pod per inflorescence ranged 1.4-2.2 pods, meaning that fruit set rated 28-47%. It is still unclear in present study, why monoculture winged bean produced lower number of pods as compared to intercropping. In cowpea, Trustinah et al. (2000) noted that only 39% of 6-12 flower buds in an inflorescence will form pods, the rest will drop or failed to form pods. According to Wulandari et al. (2017) high flower loss is common in legumes.

Young pods of winged bean harvested from both monoculture and intercropping treatments had normal shape and no abnormality was observed. Straight pods is considered as marketable. Winged beans grown at a low population density and intercropped with "Apel Belgia" produced the highest number of pods, i.e., 89.50 (Table 4). It is likely that "Apel Belgia"

genotype was a suitable companion for winged bean. Mohamadali et al. (2004) evaluated 36 winged beans genotypes revealed the average number of pods per plant from 8 times of harvests ranged from 32-188.5 weighing 0.22-1.9 kg. The use of stakes in planting winged bean can also improve the results of winged bean pods as reported by Schiavinato and Valio (1996). Mator et al. (1998) demonstrated in their study that the planting of cowpeas without stakes where the crop was left to creep on the soil surface produced lesser fresh weight of pods (0.31 t ha<sup>-1</sup>) whereas staking the crop was able to produce a higher yield (2.12 t ha<sup>-1</sup>). Nevertheless, all winged beans were planted with stake in present experiment, thus high pod production in winged beans grown in a low population density and intercropped with "Apel Belgia" could -check the space be affected by other factors. It is interesting in the future to study the factor involving in the interaction between winged beans and tomato genotypes.

The growth performance of winged bean and pod production showed flexibility of the winged beans planted as monoculture and intercropping. Figure 1 shows that morphologically winged beans plants grew over the tomato canopies, irrespective of genotypes. This fact might as the explanation the winged beans growth was less likely affected by presence of tomato as intercrop, so winged bean has high suitability for intercropping with various tomato genotypes. In

Table 4 Long pods, wide pods, average weight per pods and number of pods

Treatment	Pod length (cm)	Pod width (mm)	Average weight per pods (g)	Number of pods per plant
Monoculture LP	25.22 a	23.87 a	23.78 a	73.08 b
Monoculture HP	23.89 a	23.19 a	23.89 a	77.25 ab
Intercropping LP				
“Tora”	24.72 a	23.63 a	23.84 a	83.67 ab
F700	23.07 a	22.26 a	24.78 a	82.00 ab
"Apel Belgia"	24.30 a	22.63 a	23.72 a	89.50 a
Intercropping HP				
“Tora”	23.25 a	22.53 a	24.89 a	86.37 ab
F700	23.37 a	23.68 a	24.61 a	81.00 ab
"Apel Belgia"	23.36 a	22.64 a	23.83 a	73.17 b
Average				
Monoculture	24.56 a	23.53 a	23.83 a	71.17 a
Intercropping LP	24.03 a	22.84 a	24.11 a	85.06 a
Intercropping HP	23.29 a	22.95 a	24.44 a	80.18 a

Note: Values followed by the same letters in the same column show no significant difference based on DMRT at 5%; WAP: weeks after planting; LP: low population; HP: high population.

present experiment, we used tomatoes with different genetic backgrounds as described by Sulistyowati et al. (2016), i.e., tolerant, medium and sensitive to shading.

Here, we are confident to state that the level of species competition between tomato and winged beans is not solely due to genetic factors, but also due to the interaction with environment. Some studies have reported that crop growth in intercropping system is determined by spacing (Soetiarso and Setiawati, 2010), time of planting (Herlina et al., 2017), shading management (Santosa et al., 2006) and the varieties used (Ulinnuha, 2017). In *Solanum nigrum*, Yulianti et al. (2018) revealed that shading treatment promotes shoot elongation; and mild shading favor the plant growth and production. Thus, the winged bean plant intercropped with tomatoes in this study requires further investigation if applied in the field of production, in order to comply with local production technology. In addition, there is a need to study on how the contribution of winged bean may enhance the soil fertility by providing nitrogen to intercrop plants.

## Conclusion

The growth and yield of winged bean whether in monoculture or intercropped with tomatoes was not significantly affected by plant density nor the cropping systems, even though the yield was slightly higher in a monoculture system. There was an increase of

12.66-19.52% in the number of pods of winged beans in an intercropping system regardless of population density and tomato genotypes. Present study implies that winged bean can be intercropped with tomato with acceptable yields.

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