

Plant Growth Pattern, Forage Yield, and Quality of *Indigofera zollingeriana* Influenced by Row Spacing

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ABSTRACT

Indigofera zollingeriana is one of legumes has a great potential to be used as an animal feed having high quality nutrients and is tolerant to different environmental conditions. The objective of this experiment was to study the effect of different row spacings between individual plants on growth pattern, forage yield, and quality of *I. zollingeriana*. Field experiment was conducted at Field Laboratory of Agrostology, Faculty of Animal Science Bogor Agricultural University, during the growing season of 2015/2016. The 4 spacings levels used were 1 x 1.5 m; 1 x 1 m; 1 x 0.75 m; and 1 x 0.5 m. The treatment was arranged in a completely randomized block design, with 4 replicates. Variables in this research were plant height, number of leaves, number of branches, plant population for each plot, fresh and dry matter yields, and forage quality. The results showed that narrow plant spacing increased plant height, plant population, fresh and dry weights, dry matter yields, as well as NDF and β -carotene contents. The wider the plant spacing the greater the number of branches and leaves per plant. It was concluded that increasing plant population by narrowing plant spacing remained the most effective way to increase *Indigofera* forage yield without negative effects of it on nutritive values, i.e., crude protein, crude fat, crude fiber, ADF, and TDN.

Keywords: *Indigofera*, row spacing, plant growth, nutritive value, beta-caroten

ABSTRAK

Indigofera zollingeriana merupakan salah satu legum yang potensial untuk pakan ternak karena berkualitas tinggi dan toleran terhadap beragam kondisi lingkungan. Tujuan penelitian ini adalah untuk mempelajari pengaruh jarak tanam yang berbeda pada pola pertumbuhan, produktivitas dan kualitas hijauan *I. zollingeriana*. Penelitian ini dilaksanakan di Laboratorium Lapang Agrostologi, Fakultas Peternakan, Institut Pertanian Bogor pada musim tanam tahun 2015/2016. Jarak tanam yang digunakan adalah 1 x 1,5 m; 1 x 1 m; 1 x 0,75 m; dan 1 x 0,5 m. Penelitian ini menggunakan rancangan acak kelompok dengan 4 perlakuan dan 4 kali ulangan. Peubah yang diukur pada penelitian ini terdiri atas tinggi tanaman, jumlah cabang, jumlah daun, populasi tanaman per plot, produksi segar, bahan kering dan berat kering serta kualitas hijauan. Hasil penelitian menunjukkan bahwa jarak tanam pendek dapat meningkatkan tinggi tanaman, populasi tanaman, produksi segar, berat kering, bahan kering, NDF, dan β -karoten. Jarak tanam yang lebih lebar dapat meningkatkan jumlah cabang dan jumlah daun per tanaman. Kesimpulan penelitian ini adalah peningkatan populasi tanaman merupakan suatu metode yang efektif untuk meningkatkan produksi hijauan dengan memperkecil jarak tanam tanpa berpengaruh negatif pada nilai nutrisi protein kasar, lemak kasar, serat kasar, ADF, dan TDN.

Kata kunci: *Indigofera*, jarak tanam, pertumbuhan tanaman, kualitas, hasil panen

INTRODUCTION

Indigofera zollingeriana has a great potential to be used as a feed for ruminants, poultries, pets, and fisher-

ies. *Indigofera* contains high crude protein (27.60%-31%) (Palupi *et al.*, 2014) and produces 4,096 kg DM leaf per hectare per harvest with 68 days of cutting time with *in vitro* DM digestibility of 67%-81% (Abdullah & Suharlina, 2010). *Indigofera* has high nutrient contents that can be used as a feed supplement or as a sole forage to meet nutrient requirements and to sustain ruminant performance (Ginting *et al.*, 2010). Good protein, amino

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acid, mineral, and vitamin contents of *Indigofera* also improves egg production and quality in quail (Faradillah *et al.*, 2015).

The availability of high quality forage such as *Indigofera* plays important roles in increasing animal production and feed efficiency. This plant has a wide range of adaptation to various environmental conditions, tolerates drought, light floods, and moderate salinity (Hassen *et al.*, 2008). A common use of *Indigofera* cultivation is based on methods developed by Abdullah & Suharlina (2010) that *Indigofera* plants are planted with a row space of 1.0 x 1.5 m. The cultivation of *I. zollingeriana* in a row space of 1.0 x 1.5 m may enhance the optimum plant of *Indigofera* in varied soil conditions (Ali *et al.*, 2014). Since the efficiency of land use in producing nutrition for animal becomes an important issue in populated region, an evaluation of row spacing is needed to find an appropriate row spacing for planting *Indigofera* to produce the highest forage yield and quality. The changes in plant spacing is used as a tool to increase or decrease plant density (Murányi, 2015). New innovations in *Indigofera* production recommend the use of narrower row spacings.

Plant spacing is one of management aspects that determines the efficiency of land, light, water, and nutrients uses. A narrower row spacing increases crop's growth rate, dry matter accumulation, and seed yield (Pedersen, 2008). Plants spaced equidistantly from each other compete minimally for nutrients, light, and other factors (Agele *et al.*, 2007). The narrow plant spacing had positive effects on plant density and yield per area (Murányi, 2015), green leaf area, plant height, number of leaves, final leaf number, and final leaf size (Streck *et al.*, 2014). In addition, the narrow rows canopied more quickly, which reduced weed pressure (Grosbach, 2008) and weed biomass (Chauhan & Opeña, 2013). In other side, the wider plant spacing had a positive effect on yield per plant and root (Streck *et al.*, 2014).

The objective of this experiment was to evaluate the effect of different row spacings between plants on a growth pattern, forage yield and quality of *I. zollingeriana*, and find out an appropriate row spacing that results in a higher forage production and quality.

MATERIALS AND METHODS

The research was conducted at Field Laboratory of Agrostology, Faculty of Animal Science Bogor Agricultural University, in growing season of 2015/2016. The soil type in this field is latosol that predominantly clay loam (Baskoro & Tarigan, 2011). Forage quality was analyzed at Laboratory of University Center (PAU), Integrated Laboratory of Faculty of Animal Science, and Animal Research Institute at Ciawi.

The treatments consisted of 4 equidistant spacings between rows and between plants: 1 x 1.5 m; 1 x 1 m; 1 x 0.75 m; and 1 x 0.5 m, corresponding to the densities of 0.8 plant/m, 1 plant/m, 1.3 plants/m, and 1.5 plants/m, respectively. Each plot had a size of 3 x 5 m.

The basal fertilizer was an organic fertilizer (cattle manure) applied at the rate of 10 t/ha and was applied 2 weeks before planting, and inorganic fertilizers

(Phonska) at the rate of 50 kg/ha/yr and was applied 2 weeks after planting (surrounding the plant). The planting was performed using *Indigofera* seedling (4 weeks after sowing) with specified row spacing. Pruning was done after a month of grown in the experimental plots. The forages were trimmed approximately 100 cm above the ground using garden shears. This trimming would allow a new and uniform re-growth from where the experimental samples were later measured and harvested.

Growth attributes were measured from thirty percent of plant plots at random from the central ridges of each plot. Plant height (cm) for each plant was measured from the base of the plant to the tip of central spike tassel. The number of leaves and branches per plant were counted from each selected plant then calculated the means. Plant population was counted from each plot to obtain the number of plants in a square meter and calculated the mean in a square meter. The growth attributes of selected plants were recorded during eight weeks after pruning.

Fresh yields from each plot were cut 60 d after cultivation. The plants were cut approximately 100 cm from the ground from each plot and directly weighed to determine the fresh yield. Then a plant was separated by branch, leaves, young leaves, and weighed to obtain the fraction weight of a plant. From the same plot, forages were composited and air dried, then weighed to obtain the dry matter yield.

Chemical and Statistical Analysis

Fresh herbage samples from each plot were taken 2000 g fresh weight, air dried under sunlight for 2 x 12 h, then the samples were dried in air-forced oven at 60°C for 48 h, and ground to pass through a 1 mm sieve for chemical analyses. The dry matter (DM) and crude protein (CP) contents were determined according to the AOAC (2005) procedure. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents were estimated according to the method of Van Soest *et al.* (1991). β -Carotene contents were analyzed by HPLC method in Integrated Laboratory of Faculty of Animal Science.

The treatment was arranged in a completely randomized block design, with 4 replicates. The 4 spacings levels used were 1 x 1.5 m; 1 x 1 m; 1 x 0.75 m; and 1 x 0.5 m. Data were analyzed statistically with Analysis of Variance Test (ANOVA), and if there was a significant difference then the analyses was continued with Duncan's Multiple Range Test (DMRT).

RESULTS

Plant Height

The effect of space between plants on plant height of *I. zollingeriana* is presented in Figure 1. The results revealed that there was no significant difference in plant height between plant spacings until 3 weeks of measurement. The differences in plant height were detected between the row spacings in the fourth week of measurement. At the end of research, the narrowest plant spacing, 1 x 0.5 m (P.5), gave the tallest mean plants

height, i.e., 177.15 cm compared to 1 x 1.5 m (P1.5), 1 x 1 m (P1), and 1 x 0.75 m (P.75) of plant spacings.

Number of Leaves per Plant

The effect of space between plants on the number of leaves per plant of *I. zollingeriana* is presented in Figure 1. A significant difference ($P < 0.05$) in the number of leaves per plant between row spacings was detected at the fifth week of measurement. The highest number of leaves per plant was recorded in plant spacing of P1.5 (1186.25 ± 125.4) and P1 followed by P.75 and P.5, respectively. The pattern of leaves number per plant was fluctuate for each week. In the seventh week of measurement, the number of leaves per plant in P1.5 increased up to the highest level, i.e., 2295.0 ± 256.9 leaves.

Number of Branches per Plant

The effect of space between plants on the number of branches per plant of *I. zollingeriana* is presented in Figure 1. A significant ($P < 0.05$) difference in the number of branches per plant was detected between row spacings on the fifth week of measurement. The highest number of braches per plant was recorded in plant spacing P1.5 (208.75 cm), P1 (207.75), and P.75 (195.5) followed by P.5 (176.55).

Plant Population

The effect of space between plants on plant population of *I. zollingeriana* is shown in Table 1. A significant difference ($P < 0.05$) in plant population was detected be-

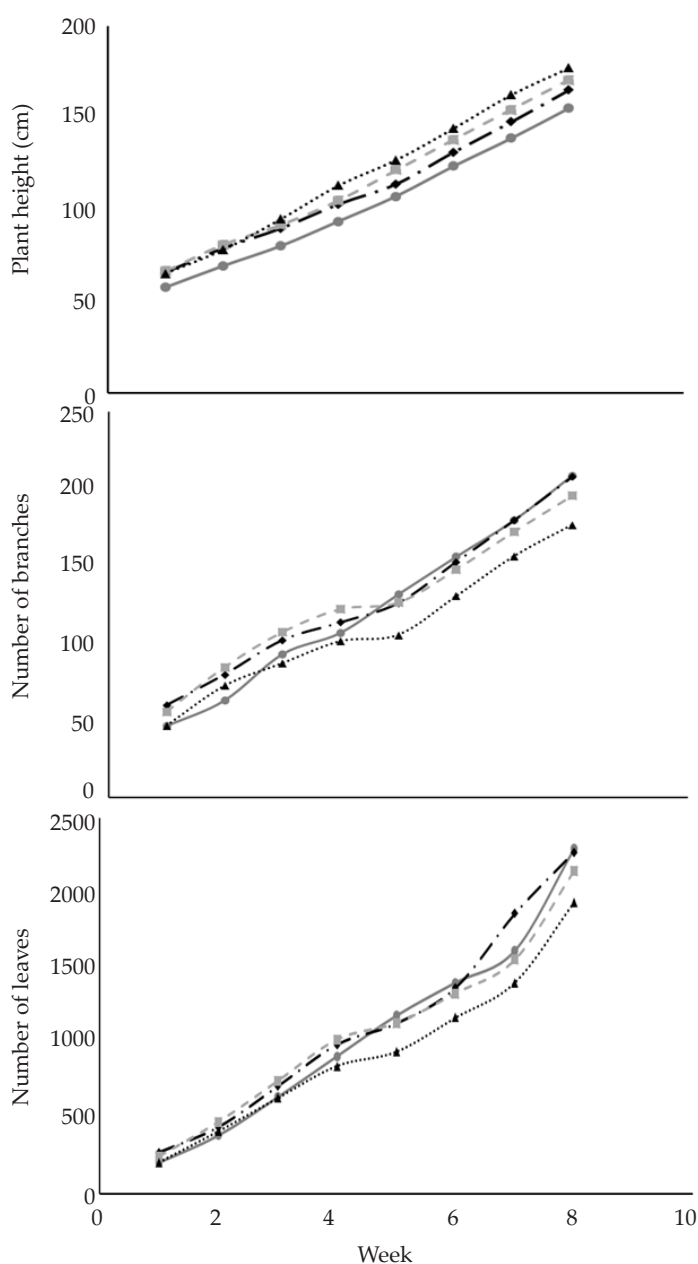


Figure 1. Plant height, number of branches, and number of leaves in different row spacings of *Indigofera zollingeriana* forage (-•- P1.5= row spacing 1x1.5 m; -◆- P1= row spacing 1x1 m; -■- P.75= row spacing 1x0.75 m; -▲- P.5= row spacing 1x0.5 m).

tween different row spacings. Narrow plant spacing (1 x 0.5 m) gave significantly ($P < 0.05$) the highest number of plants per unit area, i.e., 30 plants per plot, compared to the plant spacing of 1 x 1.5 m (12 plants), 1 x 1 m (15 plants), and 1 x 0.75 m (20 plants).

Forage Yield and Quality

Forage yield. The effect of space between plants on fresh and dry weights of forage yield is presented in Table 1. There were significant differences in fresh and dry matter forage yields between different plant spacings. The highest fresh forage yield was recorded in the narrower plant spacing (1 x 0.5 m) i.e., 10.88 kg fresh/plot and 3.56 kg dry/plot compared to those in 1 x 1.5 m, 1 x 1 m, and 1 x 0.75 m plant spacings.

Forage quality. The effect of space between plants on nutrient content is presented in Table 2. There were no significant differences in crude protein, crude fat, crude fiber, ADF, and TDN between different plant spacings. The significant effect of plant spacing was found on NDF and β -carotene content. The highest NDF content was recorded in the narrowest plant spacing (1 x 0.5 m) i.e., $30.62 \pm 0.77\%$ compared to those in 1 x 1.5 m, 1 x 1 m, and 1 x 0.75 m plant spacings. The pattern of β -carotene content was different from the other parameters: β -carotene contents on the narrowest and the widest plant spacing were higher than the other plant spacings.

DISCUSSION

Narrow plant spacing of *Indigofera* compared to standard row spacing had positive effects on whole-

plant yield. The same results of different spacings effects on whole-plant yield was reported in corn that there was no negative effect of plant spacing on plant yield and nutritive value (Baron *et al.*, 2006). Increasing plant population significantly increased the yield biomass, whereas plant spacing had a smaller effect on dry matter (Kuai *et al.*, 2015). The positive relationship between row spacing and forage yield recommends the use of narrow row spacing for optimum *Indigofera* production. Narrow rows also can reduce the crowding of plants within a row, lessening the competition between individual plants and potentially enhancing the availabilities of light, water, and nutrients (Pioneer, 2015).

Increased narrow plant spacing up to 1 x 0.5 m significantly increased plant height. The plant height curve during weeks of measurements follows a linear model (Figure 1). The increase in plant heights in a narrower spacing is probably be due to high rate of stem elongation. Stem elongation is related to the competition to get light between plants in narrow plant spacings that results in a significant taller plant compared to those in wider plant spacings (Craine & Dybzinski, 2013).

In this research, the use of narrower row spacings than conventional row spacings reduces the number of branches and leaves significantly. It is likely that the greater distance between adjacent plants within rows enhances the abilities of the plants to convert the intercepted solar radiation to leaf production (Streck *et al.*, 2014).

The changes in plant spacing in this research resulted in the increased plant population. The spacial arrangement of crop plants in a field such as row spacing and population adjustments in an attempt to improve yields and seed production (Stevovic *et al.*, 2010). On the

Table 1. Plant population, dry matter, fresh weight, and dry weight of forage

Treatments	Number of plant/m ²	Dry matter (%)	Fresh weight (kg)/plot	Dry weight (kg)/plot
P1.5	0.8	25.40 ± 3.87 ^b	5.82 ± 1.25 ^b	1.45 ± 0.20 ^b
P1	1.0	27.02 ± 4.10 ^b	6.66 ± 3.10 ^b	2.11 ± 1.26 ^b
P.75	1.3	26.66 ± 2.26 ^b	9.03 ± 1.10 ^a	2.40 ± 0.22 ^b
P.5	1.5	32.74 ± 1.28 ^a	10.88 ± 1.13 ^a	3.56 ± 0.32 ^a

Note: Means in the same row with different superscripts differ significantly ($P < 0.05$). P1.5= row spacing 1x1.5 m; P1= row spacing 1x1 m; P.75= row spacing 1x0.75 m; P.5= row spacing 1x0.5 m.

Table 2. Nutrient content of *Indigofera zollingeriana* forage

Treatments	P1.5	P1	P.75	P.5
Crude protein (%)	26.44±1.39	25.55±2.32	25.98±1.35	25.17±0.81
Crude fat (%)	1.87±0.11	1.88±0.27	1.68±0.29	1.87±0.24
Crude fiber (%)	12.83±0.34	12.90±0.20	12.09±0.17	12.57±0.39
NDF (%)	29.15±1.10 ^b	27.49±0.30 ^c	28.96±1.00 ^b	30.62±0.77 ^a
ADF (%)	27.64±1.90	25.61±0.72	25.77±1.66	26.48±0.54
β -carotene (ppm)	25.69±0.55 ^a	21.36±1.11 ^b	23.89±1.15 ^a	25.64±1.09 ^a
TDN (%)	68.99±1.98	68.27±3.84	65.48±1.78	64.63±2.25

Note: Means in the same row with different superscripts differ significantly ($P < 0.05$). P1.5= row spacing 1x1.5 m; P1= row spacing 1x1 m; P.75= row spacing 1x0.75 m; P.5= row spacing 1x0.5 m.

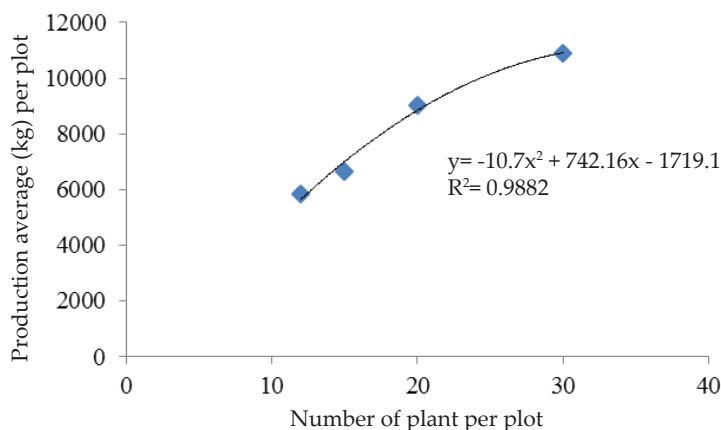


Figure 2. Correlation of plant population and production average of each plot of *Indigofera zollingeriana* forage

other hand, the increased plant population per unit area will approach an upper limit of production, plateau, and then declines (Figure 2).

Crude protein is an important parameter for forage quality. The crude protein contents of *Indigofera* in this research ranged between 25.17%-26.44% (SD 0.81–2.32). Crude protein contents of *Indigofera* in this research are in range of crude protein contents in *Indigofera* reported previously i.e., 23.1%-29.83% (Ali *et al.*, 2014; Abdullah, 2010). The low protein content might be associated with the lower ability of plants to supply N for protein synthesis due to the absence of leaf fertilizer (Abdullah, 2010) and environmental condition (Ali *et al.*, 2014).

ADF and NDF contents were found to be an important factor influencing nutritional quality of a plant. Row spacing did not affect the ADF concentration of *Indigofera* forage. ADF concentration varied from 25.61% to 27.64% that may be attributed to individual differences. This result was slightly different from previous research that reported the range of ADF content of *Indigofera* was 26.23%-45.29% (Abdullah & Suharlina, 2010). Otherwise, there was a significant difference in NDF concentrations between the different row spacings. NDF concentrations ranging from 28.96% to 30.62% were lower than 38.30%-59.57% reported previously (Abdullah & Suharlina, 2010). The NDF variation in this research correlated to the decreased row spacing. These results agree with the findings of Iptas & Acar (2006) that NDF increases by the decrease in row spacing from the highest to the lowest.

The pattern of β -carotene content was different from that of NDF i.e., β -carotene contents increased with the decreased row spacing. β -carotene content in this research varied from 21.36 to 25.69 ppm, while the highest β -carotene was found in the widest plant spacing i.e., 1 x 1.5 m (25.69 ppm). In contrast, Palupi *et al.* (2014) reported that young leaves of *Indigofera* contained β -carotene until 507.6 ppm. Ndiaye *et al.* (2016) revealed that β -carotene content accumulated in leaf area of legume despite the amount was different between species. Such differences in the results might be affected by environmental, cultural, and genetic factors (Iptas & Acar, 2006). Elgersma *et al.* (2012) reported that the dif-

ferences in β -carotene contents of legumes related to the interaction of plant species, fertilizer, and harvest time.

CONCLUSION

Increasing plant population remains the most effective way to increase *Indigofera* forage yield. Narrow row spacing had no negative effects on forage yield and nutritive value, i.e.: crude protein, crude fat, crude fiber, ADF, and TDN, while minor effects on forage nutritive value, i.e. increase β -carotene and NDF.

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