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Preliminary evaluation on morphological response of *Indigofera zollingeriana* tree legume under different cropping patterns grown at 12 weeks after planting underneath mature coconuts

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Abstract

The aims of this study was to assess the morphological response, leaf/wood ratio and dry weight yield of *Indigofera zollingeriana* to differences in cropping patterns (planting spacing) at the age of 12 weeks after planting. This study applied a Completely Randomized Design using three treatments of size areas of 1.0 m x 0.5 m (PS1), 1.0 m x 1.0 m (PS2), and 1.0 m x 1.5 m (PS3). Each treatment was repeated 6 times. The measured variables in term of morphological traits were plant height, stem diameter, the highest number of leaves and number of branches. Dry weight yield and leaf/wood ratio were also measured. The results showed that plant height and stem diameter in PS2 and PS3 treatments were significantly higher than those in PS1, while those in both PS2 and PS3 were not differ significantly. The numbers of leaves were not affected by treatments, but numbers of branches were affected significantly by treatments. Moreover, Leaf/wood ratio and total dry weight were significantly affected by treatments. Based on the results of this study, it can be concluded that the best morphological response of *Indigofera zollingeriana* in term of leaf/wood ratio and total dry weight at the age of 12 weeks after planting was obtained in the size of 1.0 m x 1.0 m (PS2) planting spacing area underneath mature coconuts.

Keywords: *coconut plantation, forage indigofera, morphology, planting spacing*

Introduction

Plant morphology can be seen and measured in several parameters including plant height, stem diameter, leaf number, branching and root development. Morphological development was observed both as a growth indicator and as a parameter used to measure environmental influences or treatments applied. Thus plant growth was an increase in size that can be known by the increase in length, stem diameter, plant covered area, volume or biomass, wet and dry weight of plants (Abdullah 2010).

Indigofera zollingeriana is a main stay plant tree legume to be alternative to *Leucaena leucocephala* tree legume which is susceptible to insect pests leucaena psyllid (*Heteropsyllacubana*) sometimes called "jumping plant lice". This kind of tree legume is one of important forage legume in Indonesia because in term of agronomical aspect, it grows well during dry season, produces fertile seeds, branch and leaves developed exponentially up to certain times due to defoliation and highly relished by livestock. However, this plant was widely studied in an open environment, while in the shading conditions such as under the coconut plantation area has never been reported. This type of legume contained relatively higher crude protein ranging from 22-29% compared to other tree legumes and low fiber content (NDF) ranging from 22- 46% (Abdullah and Suharlina 2010).

The limited land for forage planting is a common problem in the ruminant animal development. Along with the increasing of human population, participation in the availability of land for the development of extensive forage fodder was decreasing, because it was used for the development of human food agriculture and other infrastructure. Therefore, the effort would be needed to provide the efficient land use for growing forages.

Indigofera zollingeriana underneath coconuts plantation

Coconut commodity is currently still one of the economic back-bone of community development in Indonesia, as the largest copra producer in the world (FAO 2009). Farming systems applied in North Sulawesi province of Indonesia was still in form of integrated land with industrial agricultural plantations including coconut that can be used for the development of forage crops (Anis et al 2015). However, this kind of agricultural integration system is facing the competition for nutrients, water and sunlight.

Since the efficiency of land use in producing nutrition for animal becomes an important issue in populated region, an evaluation of rows pacing is needed to find suitable row spacing for planting of *Indigofera* to produce the highest forage yield and quality. Many research reports had been done and reported concerning *I. zollingeriana* grown in full sun light without shading system. Unfortunately, study to assess this plant under natural shading environment especially under coconut plantation has not well explored and documented. Therefore, this preliminary study aims to evaluate the effect of planting spacing configuration patterns and population density of *I. zollingeriana* and to measure their morphological response and dry matter yield in the coconut farming area. The purpose of the results in this preliminary research was to be a base line for the next research program to build a model of field ration formulation of integrated forage production under coconuts plantation.

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Materials and methods

Experimental Site

The study was conducted in the experimental station of Assessment Institute Agricultural Technology (AIAT) of North Sulawesi, located 12 km from Manado City. Experimental site received an average rainfall of 2700 mm, and fairly distributed even around location, except for the period of lower rainfall of 100-150 mm monthly, occurred from July to September 2018. The pH of the fertile, sandy loam soil was around 6. Light transmission at 10.00 a.m on a sunny day as PAR underneath mature tall coconuts was averaging of 73 percents. The soil color was dark brown clay. Precipitation peaks took place in January, with high rainfall intensity This condition caused high relative humidity of 80 percents. Air temperature ranged from 25 ^{0}C to 37 ^{0}C.

Experimental Design

Legume seeds of *I. zollingeriana* were obtained from the Agrostology Laboratory of the Faculty of Animal Science, Bogor Agricultural University. *Indigofera* seeds sown on land had been processed as a nursery. Plant seeds that had grown well were then moved into the 2.5 kg plastic bag already filled with soil (one plant / plastic bag). After growing of two months in a medium plastic bag, the plant was then transferred in to experimental site in a plot size of 3 m x4 m that had been processed and divided into 18 plots to accommodate the 3 treatments of planting spacing (PS) with row spacing of 1 m apart. Planting spacing varied from 0.5 to 1.5 m, labeled with PS1: 1.0 m x 0.5 m, PS2: 1.0 m x 1.0 m, and PS3: 1.0 m x 1.5 m, corresponding to the population densities of 21 plants/plot (1.75 plant/m^2), 12 plants/plot (1 plant/m^2), 9 plants/plot (0.7 plant/m ^{2}), corresponding 5714 plants/ha, 10.000 plants/ha and 13.333 plants/ha respectively. Each plot of treatment with a size of 3 m x4 m (12 m^2) was then placed individually. Since the distance between plots of treatments was 1 meter apart, causing the space of land utilized by each plot enlarged up to 4x5 m (20m^2) in each of 10x10 m square as pattern of coconut plantation. There were number of plots of treatments in each space of coconut plantation of 100 m^2 with 5 plots.

The variables measured in this study were plant height, stem diameter, leaves number, and number of branches. Ten individual plants had been selected as sample in each treatment. The total numbers of plant as sample in this experiment were 180 plants as a sum of 10 plants in 3 treatments containing 6 replications per treatment. Morphological trait data were calculated each week along 12 weeks. The consecutive observations were done before harvesting.

The samples of plants for counting the number of branches were in the middle of the experimental plot in order to avoid border effect. In facilitating observation, the samples of plants were marked with a red ribbon. Harvesting of plants was done by cutting the plant canopy, then the leaves were separated from stems. Samples of 500 g were then dried in an oven at a temperature of 105 ^{0}C for 24 hours to get dry weight. Crude protein (CP) content of leaf component varied from 33 up to 37% or an average of 35%, steam component CP content average was 17%, or the whole plant CP average was 26%.

This study used a Completely Randomized Design consists of 3 treatments of planting spacing area and 6 replications in each treatment. Data were then statistically analyzed by using analysis of variance (ANOVA) by means of MINITAB (Version 16). Honestly Significance Difference (HSD) was applied to determine the difference among treatments. Differences were considered at $p<0.05$.

Results

Plants height

The influence of planting spacing treatments on plant population and morphological traits variable measured was presented in Table 1. The highest plant height at the age of 12 weeks was obtained at the planting spacing of 1.0 m x 1.0 m (PS2) with a plant height reaching 86.57 cm. Planting at a spacing of 1.0 m x 1.0 m (PS2) differed markedly (*p* <0.05) and higher than planting spacing at 1.0 m x 0.5 m (PS1), but plants in the PS1 did not differ with plant at spacing of 1.0 m x 1.5 m (PS3).

Stem diameter

Stem diameter and number of branch were affected by planting spacing. Planting spacing at treatments of PS2 and PS3 gave higher ($p<0.05$) in stem diameter and number of branches compared to those in narrower spacing of 1.0 m x 0.5 m (PS1), but both last treatments of PS3 was not different with PS1.

Table 1. Some morphological traits of *I. zollingeriana* under difference planting spacing in coconuts plantation area

Items	**Treatments groups**			**SE**	***p* value**
	PS1	**PS2**	**PS3**		
Plant height (cm)	68.73^{b}	86.57^{a}	71.62^{ab}	0.231	0.001
Stem Diameter	0.93^{b}	1.18^{a}	1.04^{ab}	0.061	0.034
Leaves number	15.33	16.17	15.93	0.317	0.192
Number of branch	8.27^{b}	11.60^{a}	11.00^{a}	1.361	0.214

[a,b] Means in the same row with different letters show differences ($p<0.05$).
PS1: planting spacing 1m x 0.5 m, PS2: planting spacing 1m x1m, PS3: planting spacing 1m x1.5 m. DW: dry weigh, SE: standard error

Number of leaves

The highest numbers of leaves of *I. zollingeriana* at 12 weeks after planting were obtained at the planting spacing of 1.0 m x 1.0 m with the average numbers reaching 16.17 leaves per plant. Analysis of variance showed that treatments had no effects on the number of leaves.

Number of branches

The effect of space between plants on the number of branches per plant of *I. zollingeriana was* presented in Table 1. Treatment showed that the highest number of branches of *Indigofera* at the age of 12 weeks was obtained at the planting spacing of 1.0 m x 1.0 m (PS2) reaching 11.60 branches and significantly higher ($p<0.01$) than those at treatment PS1 (8.27 branches), but PS1 did not differ with those at treatment PS3 (11.00 branches). Narrow spacing in this research reduced number of branches.

The effects of treatments on biomass dry weight production

Table 2 below presented data of the treatment effects on biomass dry weight production based on population density or number of plants per hectare. Those populations were 5,710 plants, 10,000 plants and 13,333 plants, corresponding to PS1, PS2 and PS3, respectively. The ratio of leaves / wood instead was not affected by planting spacing. The highest dry weight production (24.1 kg/ ha /harvest) was resulted from the treatment of planting spacing of 1.0 m x1.0 m (PS2) and 24.9 kg/ha/harvest at planting distance of 1.0 m x 1.5 m (PS3). Both treatments were higher (*p<0.05*) compared to treatment of PS1 (21.2 kg/ha/harvest).

Table 2. Leaf (L), wood (W), L/W ratio , DW yield of *I. zollingeriana* under difference planting spacing in coconuts plantation area

Items	**Treatments groups** Number of plants/ha			**SE**	***p* value**
	PS1 5,710	**PS2** 10,000	**PS3** 13,333		
Leaf DW (t/ha)	13.6[b]	16.59[a]	15.75[a]	0.730	0.033
Wood DW (t/ha)	7.54[b]	9.31[a]	9.14[a]	0.231	0.001
Leaf/Wood ratio	1.81	1.78	1.72	0.056	0.242
Total DW (t/ha)	21.2[b]	24.1[a]	24.9[a]	0.596	0.001

[ab]Means in the same row with different letters show differences (p<0.05) PS1: planting spacing 1.0 m x 0.5 m, PS2: planting spacing 1.0 m x1.0m, PS3: planting spacing 1.0 m x1.5 m. DW: dry weight, SE: standard error

Discussion

Morphological traits at treatment PS1 in term of plant height, stem diameter and number of branches were significantly inferior compared to treatment PS2 and PS3 (Table1), where the last both treatments were not significant. Shorter plant height, smaller diameter and lower number of branches in treatment PS1 were in strong relation with the higher plant populations with almost double compared to PS2 and PS3. It means this phenomenon occurrence was probably due to strong competition of nutrient and water, which was markedly raised in crowded plant population (Craine and Dybzinsky 2013). Contrary wider spacing of PS2 and PS3 showing plant height, stem diameter and number of branch were significantly superior compared to narrower spacing PS1. The increase in plant height in equitant spacing (PS2) was probably due to high rate of stem elongation. Stem elongation was related to the light competition among plants in narrow planting spacing (Widodo et al 2016) followed with taller plant compared to those in wider spacing (Craine and Dybzinski 2013). The increasing this plant height in PS2 treatment was followed by increasing in stem diameter (1.18 cm) and number of branches (11.60 branches). This founding was in agreed with study by Kumalasari et al (2017) reporting that narrower row spacing of 1.0 m x 0.5 m (PS1) reduced the number of branches. It was likely that the great spacing between adjacent plants within rows enhanced the abilities of the plants to convert the intercepted solar radiation to leaf production (Telleng et al 2016). Nevertheless, leaf number was not affected by all plant spacing treatments. It was meant that this plant could produce same number of leaves at 12 weeks after planting for all treatments. This was probably due to the age of tree legume plant at 12 weeks still in vegetative development stages with the leave component grown dominantly (Anis et al 2016).

Parts of plant preferred by livestock and had higher nutritional quality were leaf fractions (Kaligis et al 2018). Therefore, the ratio of leaves / stems became important. From finding of this study, the highest numbers of branches of *Indigofera* at the age of 12 weeks were obtained at the planting distance of 1.0 m x 1.0 m (PS2) reaching 11.60 branches. The more numbers of branches, the higher the growing point for leave development and will be related to the availability of energy reserves (carbohydrates) sustain re-growth of forages plant (Ngo and Hao 1993; Anis et al 2016). Previous report stated that leave and branches of *I. zollingeriana* grown exponentially up to sixth pruning and then decrease gradually (Abdullah 2014). Leaf production potential of this tree legume could be expected as protein source on tropical pasture with local grasses mostly containing around 6% of crude protein which could not reach the minimum requirement for ruminant diet (Abdullah and Suharlina 2010). This research had been done under shading environment in coconut plantations. Even though the number of plant populations increased per hectare, dry weight had not increase linearly. Total dry weight, as well as leaves and wood dry weight increased up to the treatment of PS2 and then almost reached plateau at PS3. This phenomenon was probably due to the shortages light in coconuts plantation. Finding in study was not in line with result found in full sun light environment increasing plant population per unit area. This condition approached an upper limit of production linearly (Kumalasari et al 2017).

Pasture based on *Brachiaria humidicola* under coconut plantation needs to enrich protein with tree legume, since integrated herbaceous or creeping legume was not able to persists in mixed pasture due to its aggressiveness of *Brachiaria* (Anis et al 2015). Integrated *Indigofera* in pasture underneath mature coconuts was potential to enhance livestock productivity, but it had to be precisely elucidated.

Discussion about coconut plantation was still important topic in rural development since this commodity was back bone economy at farmer level (Kaligis et al 2017). The highest dry weight production of *I. zollingeriana* in this research was found at planting spacing PS2 and PS3. Forages dry matter production was contributed by leaf and stem formation, which was affected by cell division and elongation. Both physiology processing was the sites of high metabolic activity, including dry matter accumulation through photosynthetic activity utilization of CO 2 atmospheric (Schaufele and Schneider 2000). Indirectly, pasture involved to mitigate climate changes, since well managing tropical pasture systems may contain amount of soil organic carbon (SOC) equal or even superior to those under native tropical forest (Lugo and Brown 1993; Mosquera et al 2010).

Conclusion

- Based on the results of this study, it can be concluded that the best morphological response of *Indigofera zollingeriana* in term of leaf/wood ratio and total dry weight at the age of 12 weeks after planting was obtained in the size area of 1.0 m x 1.0 m (PS2) as planting spacing underneath the mature coconuts.

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