Evaluation of intercropping Indigofera and Pennisetum underneath mature coconuts based on yield and carrying capacity

by Malcky Telleng

Evaluation of intercropping Indigofera and Pennisetum underneath mature coconuts based on yield and carrying capacity

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Abstract

Intercropping can increase crop growth and yield due to resources use efficiently. The purpose of this research was determines the land equivalent ratio in coconut plantation of intercropping tree legume Indigofera zollingeriana(IZ) and tropical grass Pennisetum purpureum (PP) cv. Mott. The aims of this research was to determines the land equivalent ratio (LER) of this intercropping based on nutrient content and carrying capacity underneath coconut plantation. This experiment was conducted using Completely Randomized Design (CRD) with six treatments combination of planting space as follows: IZ with planting space at 1.0m x 0.5m, 1.0m x 1.0m and 1.0m x 1.5m, combined with PP planting space 1.0m x 0.5m, 1.0m x 0.75m. Data were analyzed using analysis of variance and HSD test. The variables measured were Land Equivalent Ratio (LER) based on carrying capacity measure for dry matter and crude protein. The results showed that treatment were significant different (P<0.01) on LER in term of carrying capacity based on crude protein and crude fiber content, but were non significant different (P>0.05) on LER based on dry matter and ash content. The HSD test showed that intercropping IZ with planting space at 1.0m x 1.0m and PP with planting space at 1.0m x 0.75m have highest LER for crude protein and lowest LER for crude fiber content. It conclusion that intercropping IZ with planting space at 1.0m x 1.0m and PP with planting space at 1.0m x 0.5m have most suitable LER based on nutrient content.

Key words: crude protein, dry matter, LER, planting space

Introduction

Intercropping is advanced as one of the integrated soil fertility management practices consisting of cultivating two or more crops in the same space at the same time, which have been practiced in past decades and achieved the goals of agriculture. Also, intercropping systems are beneficial to the smallholder farmers in the low-input and/or high-risk environment of the tropics, where intercropping of cereals and legumes is widespread among smallholder farmers due to the ability of the legume to contribute to addressing the problem of declining levels of soil fertility (Matusso et al 2012).

The main purpose of intercropping is to produce a greater yield on a land by optimizing resources that cannot be utilized in a monocropping system efficiently (Moradi et al 2014). The main advantage of intercropping is helps in utilizing the available resources efficiently and increases the productivity of the crops. Intercropping can conserve soil water by providing shade, reducing wind speed, increasing infiltration with mulch layers, and improving soil structure (Mobasser et al 2014). The success of intercropping systems and performance of component crops are governed mainly by the availability of and the competition between the components for the environmental resources (Telleng et al 2016). However, some combinations have negative effects on the yield of the components under intercropping system (Matusso et al 2012).

An important tool for the study and evaluation of intercropping systems is the Land Equivalent Ratio (LER). LER providing that all other things being equal measure of the yield advantage obtained by growing two or more crops or varieties as an intercrop compared to growing the same crops or varieties as a collection of separate monocultures (Yancey and Cecil 1994).

Materials and methods

Experimental Site

The study was conducted in the experimental station of Asassement Institute of Agriculture Technology (AIAT) of North Sulawesi, located 12 km from Manado City. Experimental site received an average rainfall of 500 mm, and fairly distributed even around location, except for the period of lower rainfall of 50-100 mm monthly, occurred from July to September 2020. 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 86 percents. Air temperature ranged from 23.1 ^{0}C to 32.7 ^{0}C.

Experimental Design

Grass of Pennisetum purpureum cv Mott (PP) were obtained from Asassement Institute of Agriculture Technology (AIAT) of North Sulawesi. Legume seeds of Indigofera zollingeriana (IZ) 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 with 6 treatments of planting spacing (PS) with row spacing of 1 m apart. Three planting space Iz : (i) 1.0 m x 0.5 m, (ii) 1.0 m x 1.0 m, and (iii) 1.0 m x 1.5 m. After two months Indigofera grown in experimental plots, PP was planted. Two Planting space PP : (i) 1 m x 0.5 m, and (ii) 1 m x 0.75 m. Intercropping having six combination and each was planted in three plot. The plot combination were: I_1= 1 m x 0.5 m IZ & 1 m x 0.5 m PP; I_2= 1 m x 0.5 m IZ & 1 m x 0.75m PP; I_3= 1 m x 1 m IZ & 1 m x 0.5 m PP; I_4= 1 m x 1 m IZ & 1 m x 0.75m PP; I_5= 1 m x 1.5 m IZ & 1.0 m x 0.5 m PP; I_6= 1 m x 1.5 m IZ & 1 m x 0.75 m PP.

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 $p<0.05$.

Variable Observations

Harvesting Indigofera was done + 90 days after planting, defoliated at 100 cm above ground level. Pennisetum were defoliated at height level of 10 cm above ground. Samples were dried at 60^0C for about 48 hours to determine the dried weight. The samples were analyzed for dry matter, crude protein, and crude fiber according to the standard procedure of Association of Official Analytical Chemists (2005).

The variables include potential dry weight yield (ton/ha) and crude protein yield (ton/ha), land equivalent ratio (LER) based on carrying capacity for dry matter and protein production. Dry matter yield of each plot was calculated through the value of green forage production and dry-weight precentage. Combining the dry matter yield with crude protein data allowed us to calculate the mean crude protein yield. Carrying capacity was determined by the information obtained from the forage harvested; it was collected from productivity estimation of each plot and converted to one ha. Available forage was calculated based on 70% of the total used as factor. It is assumed that animal consumes 6.29 kg DM of forage/day/head (Indonesian condition). The amount of dry matter required to provide 6.29 kg of digestible nutrients based on available forage (70% of the total used as factor) was 9.0 kg.

Land Equivalent Ratio

Land equivalent ratio (LER) is the most common index adopted in intercropping to measure the land productivity. It is often used as an indicator to determine the efficacy of intercropping (Brintha and Seran 2009). The LER is a standardized index that is defined as the relative area required by sole crops to produce the same yield as intercrops (Mead and Willey 1980). The LER is the ratio of land required by pure (sole) crop to produce the same yield as that of intercrop was determined according to the following formula:

$$LER = \frac{Yiz \text{ in mixed stand}}{Yiz \text{ in pure stand}} + \frac{Ypp \text{ in mixed stand}}{Ypp \text{ in pure stand}}$$

Where : LER = Land equivalent ratio,

Yiz = nutrient content of Indigofera zollingeriana,

Ypp= nutrient content of Pennisetum purpureum

Results

Potential Yield

Intercropping improve the soil's micro-environment (Salau et al 2011). Soil microorganisms have an important role in maintaining soil function and involving in mineralization and mobilization of nutrients required for plant growth. Due to differential rhizodeposition, the microbial community structure in the rhizosphere may vary with plant species, nutritional status of the plant, manganese availability, soil type, and mycorrhizal colonization. Increasing N in the soil is the most efficient method to increase the yield of plant dry matter. Dantata (2014) suggests that intercropping affects vegetative growth of component crops depending on the adaptation of planting pattern and selection of compatible crops. Intercropping with legume is a desirable agronomic practice to boost crop production. Planting space affects plant growth stage. Decreasing plant density with increasing spacing causes plants to have a longer chance to develop their roots and accumulate photosynthetic (Telleng et al 2020). It is well shown in Table 1 that intercropping at different spacing had highly significant effects on dry matter and crude protein yield.

Dry matter yield of intercropping have about 30.9 ton/ha/year until 50.1 ton/ha/year. Dry matter yield was highly significant effects, there was that intercropping at different spacing had highly significant effects on dry matter yield. Combination planting space 1mx0.5m IZ and 1mx0.75m PP have highest dry matter yield. It is well shown in figure 1.

Crude protein yield of intercropping have about 5.91 kg/ha/harvest until 9.75 kg/ha/harvest. Crude protein yield was highly significant effects, there was that intercropping at different planting space had highly significant effects on crude protein yield. Combination planting space 1mx0.5m IZ and 1mx0.5m PP have highest dry matter yield. It is well shown in Figure 1.

Land Equivalent Ratio

The LER with value greater than 1 indicates that intercropping is advantageous while the LER less than 1 shows that intercropping is disadvantageous (Mohammed 2011). For instance, a LER 1.25 indicates that an area planted sole crop or monoculture, would require 25% more land to produce the same yield as the same area planted in an intercrop (Dariush et al 2006). Statistical analysis of the data showed that combination of intercropping systems had significant effects on LER based on crude protein and crude fiber content, but had non significant effects on LER based dry matter and ash content (Table 1).

Table 1. Land Equivalent Ratio of Intercropping *I. zollingeriana dan P. purpureum* cv Mott Based on Carying Capacity

Planting Spacing		**Intecrop Potential Yield (ton/ha/year)**		**Land Equivalent Ratio (based carrying capacity)**	
I. zollingeriana	*P. purpureum*	**Dry Matter**	**Protein**	**Dry Matter**	**Protein**
1m x 0.5m	1m x 0.5m	50.1^{a}	9.75^{a}	1.55^{b}	1.44^{c}
	1m x 0.75m	47.2^{ab}	9.6^{ab}	1.57^{b}	1.57^{b}
1m x 1m	1m x 0.5m	42.7^{bc}	7.99^{bc}	1.63^{a}	1.66^{a}
	1m x 0.75m	41.1^{bc}	7.96^{c}	1.69^{a}	1.65^{a}
1m x 1.5m	1m x 0.5m	39.4^{c}	7.23^{cd}	1.63^{a}	1.63^{ab}
	1m x 0.75m	30.9^{d}	5.91^{d}	1.65^{a}	1.65^{a}
***p* Value**		<0.001	<0.001	<0.001	<0.001
MSE		1.41	0.367	0.0125	0.0156

^{a,b} *Means in the same row with different letters show differences ($p<0.05$)*

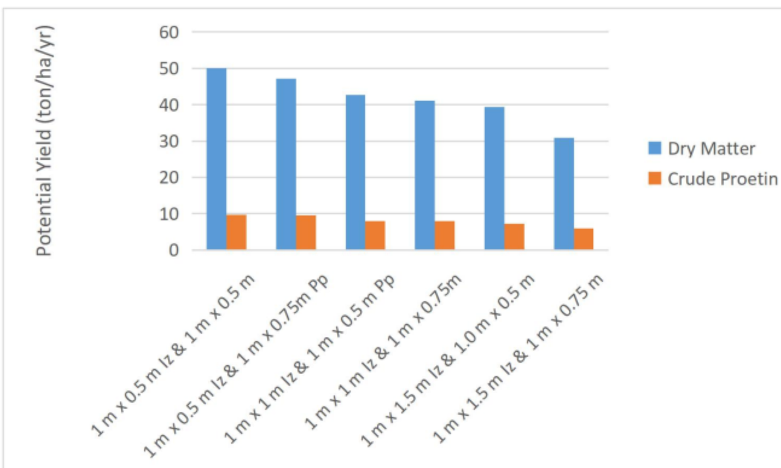

Figure 1. Effect of planting space on dry matter and crude protein yield

I1= 1 m x 0.5 m Iz & 1 m x 0.5 m *Pp*; **I2**= 1 m x 0.5 m *Iz* & 1 m x 0.75m *Pp*; **I3**= 1 m x 1 m Iz & 1 m x 0.5 m *Pp*;
I4= 1 m x 1 m Iz & 1 m x 0.75m *Pp*; **I5**= 1 m x 1.5 m *Iz*& 1.0 m x 0.5 m *Pp*; **I6**= 1 m x 1.5 m *Iz* & 1 m x 0.75 m *Pp*

A LER based on carrying capacity of dry matter have about 1.55 to 1.69 indicates that an area planted an intercrop would have higher 55% to 69% carrying capacity of dry matter more than carrying capacity of dry matter as the same area planted in sole crop or monoculture. A LER based on carrying capacity of dry matter hgihly significant effects, there was that intercropping at different spacing had highly significant effects on carrying capacity of dry matter. Combination planting space 1mx1m IZ and 1mx1m PP have highest carrying capaity of dry matter. It is well shown in Table 1.

A LER based on carrying capacity of crude protein have about 1.44 to 1.66 indicates that an area planted an intercrop would have higher 44% to 66% carrying capacity of crude protein more than carrying capacity of crude protein as the same area planted in sole crop or monoculture. A LER based on carrying capacity of crude protein highly significant effects, there was that intercropping at different spacing had highly significant effects on carrying capacity of crude protein. Combination planting space 1mx1m IZ and 1mx0.5m PP have highest carrying capaity of dry matter. It is well shown in Table 1.

Discussion

Potential Yield

The main reason for adoption of intercropping is to produce higher yield than a pure stand of same land area in a given period. intercropping as an economic method for higher production with lower levels of external inputs (Wiley 1991). This increasing use efficiency is important, especially for small-scale farmers and also in areas where growing season is short (Altieri, 1995) and in rainfed areas (Maitra et al 2001a; Maitra et al 2001b). Production more in intercropping can be attributed to the higher growth rate, more biomass production and efficient use of space and resources (Telleng 2017). Moreover, in any intercropping system if there are complementary effects among the component crops, production increases due to less competition among crops (Willey 1991)

Intercropping can be a solution to diversify agroecosystems by using more leguminous crops and also applying less mineral fertilizers (Neugschwandtner and Kaul 2015). Reasonable intercropping could increase crop growth and productivity (Cecilio et al 2011), efficient use of the resources water, nitrogen and radiation (Lithourgidis et al 2011), macronutrients (Salehi et al 2018) and micronutrients (Neugschwandtner and Kaul 2016), yield quality (Klimek-Kopyra et al 2017) and lower the damage caused by diseases and pests (Hauggaard-Nielsen et al 2001). Advantages of intercropping legumes with non-legumes are explained by the complementary use of resources due to non-competition for the same resource niche (Bedoussac and Justes, 2010).

Increased nutrient uptake in intercropping systems can occur spatially and temporally Spatial nutrient uptake can be increased through the increasing root mass, while temporal advantages in nutrient uptake occur when crops in an intercropping system have peak nutrient demands at different times (Anders et al 1996). The improvements in digestibility were reflected in feed intake, live weight gain and feed conversion which were all improved when the tree legume leaves were a part of the diet. Combine dwarf elephant grass,Gliricidia sepium, Leucaena leucocephala and Indigofera zollingeriana, for all criteria, the goats fed the tree legume Indigofera zollingeriana recorded the best performance (Anis et al 2020).

Advantages of intercropping are attributed to a more efficient utilization of finite resources such as light, nutrients and water (Musa et al 2010). The nutrient composition of plants influenced by fertility rate of the growing media and some factors of the biotic environment. Short distance (increased density) increases nutrient requirement and sunlight competition. Planting space affected microenvironment (temperature, humidity and light) and expanded the rod to uptake nutrient (Telleng et al 2020). Because light is supplied from above plants, individuals that situate their leaves above those of neighbours benefit directly from increased photosynthetic rates and indirectly by reducing the growth of those neighbours via shade (Craine and Dybzinski 2013). Narrower row spacing of 1.0 m x 0.5 m reduced the number of branches (Kumalasari et al 2017). 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 2015). Planting space Indigofera zollingeriana in coconut plantation had effect leaf protein content, leaf crude fiber content and stem crude fiber content (Telleng et al 2020).

The land equivalent ratio

The land equivalent ratio (LER) is a widely used relative indicator of economic reliability of an intercrop, unlike yield as an absolute one. It is calculated on the basis of the yield of each component in an intercrop and in its pure stand; if surpassing 1.00, an intercrop is considered economically reliable. A LER greater than 1 for crude protein content can often be attributed to enhanced nitrogen fixation and nitrogen uptake in intercropping (Salehi et al 2018).

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 (Anis et al 2016). Research under shading environment in coconut plantations, even though the number of plant populations increased per hectare, dry weight had not increase linearly. This phenomenon was probably due to the shortages light in coconuts plantation (Anis et al 2019). 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).

Reduction in number of pods of okra intercropped with maize stating the reason being the effects of nutrient and light completion (Ijoyah and Jimba 2011). Shading of maize plants reduced photosynthetic capacity of cotton in mixed intercrop pattern (Metwally et al 2012). Furthermore, a reduction of common bean yield in intercropping compared with pure stand due to the effect of shading (Santalla et al 2001). 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). Tree legumes such as Indigofera since this species has high content of protein and grown well in coconut plantation (Anis et al, 2019), increased protein content of complete ration based on tropical grass (Anis et al, 2020), and previously reported by Suharlina and Abdullah (2010) that feed efficiency was high in complete rations with utilization of this species. 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 as backbone economy at farmer level (Kaligis et al 2017). 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 Schnyder 2000). Indirectly, pasture involved to mitigate climate changes, since well managing tropical pasture systems may contain amounts of soil organic carbon (SOC) equal or even superior to those under native tropical forest (Mosquera et al 2010).

The positive effects of tree legume leaves can be ascribed to their high levels of protein and has condensed tannins content, which is known to form complexes with dietary protein helping their escape from the rumen and efficient digestion in the intestines (Preston and Leng 1987). Recent result from in vivo trials showed that methane production decreased up to more than 60% when the majority of diet content tree legume leaves especially leucaena, reduction rumen methane in turn result more rumen propionate followed by better glucogenic status of the diets and good animal performance (Pineiro-Varquez et al 2018).

Conclusion

Based on the results of this study, it can be concluded that the most suitable Land Equivalent Ratio based on carrying capacity in term of dry matter was obtained combination in the size area of 1m x 1mIndigofera zollingeriana and 1m x 0.75m Pennisetum purpureum cv Mott and carrying capacity in term of crude protein was obtained combination in the size area of 1m x 1mIndigofera zollingeriana and 1m x 0.5m Pennisetum purpureum cv Mott as planting spacing underneath the mature coconuts.

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Received 13 October 2021; Accepted 20 October 2021; Published 1 November 2021

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