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Research article

The Influence of Planting Density on Maize-Soybean Intercropping Inoculated with Organic Fertilizer

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Abstract.
Mycorrhizae and organic fertilizers play a critical role in nutrient availability and absorption, soil texture development, and hormone production to promote plant growth. The aim of this research was to determine the influence of planting density on intercropping maize and mycorrhizal soybeans, and the impact of organic fertilizers on maize and soybean yields in dry lands in North Lombok. The experiment was conducted using a randomized block design with five intercropping treatments: P1 = 2 maize lines: 2 soybean lines, P2 = 3 maize lines: 2 soybean lines, P3 = 3 maize lines: 3 soybean lines, P4 = 4 maize lines: 2 soybean lines, and P5 = 4 maize lines: 3 soybean lines. The data were then analyzed using two-way ANOVA and Tukey's significant difference test with a significance level of 5%. It was found that the P3 density showed the highest yield compared with the other intercropping treatments; the number of spores and mycorrhizal infection rate were also increased. The P3 treatment, with the addition of 15 tons of cow manure per hectare and inoculation with AMF, enhanced the yield and promoted the development of mycorrhiza.

Keywords: Intercropping; maize; plant density; soybean

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1. Introduction

Maize and soybeans are food commodities whose needs in Indonesia are increasing every year. According to the Central Statistics Agency maize production reached 19,611 million tons, while in 2015 it reached 963,099 thousand tons, while the annual demand for soybeans was around 2.5 million tons [1]. The increasing demand for maize and soybeans is not matched by an increase in regional and national production. Efforts to fulfill the need for maize and soybean consumption can be done by increasing the planted area through the use of dryland.

The dryland development business is the best solution considering the large number of them. The area of dryland in Nusa Tenggara Barat (NTB) reaches 1.8 million ha (84.19%)

of the total area and there are about 33,069 ha that have the potential to be developed for food crops [2]. Of the dryland potential in NTB, North Lombok district has a dryland potential of 38,000 ha that can be used for food crop development [3].

However, the management of dry lands has specific limitations, which are mainly related to the biophysical limiting factors of infertility soil, indicated by low nutrient utilization, low organic matter and limited of water for plants [4]. These factors are often said to be the main causes of poor dryland harvests and low crop productivity, as well as declining soil fertility quality and increasing soil vulnerability to degradation**.** [5].

Therefore, a new concept is needed to overcome the biophysical constraints of dryland where irrigation is highly dependent on rainfall. The choice of maize is very appropriate because it can adapt well to dry conditions, has a fairly high economic value and is cultivated regularly by farmers. Meanwhile, soybean protein sources and high demand for tofu and tempeh production, on the other hand, soybeans can increase the N content through N fixation from the air with the help of Rhizobium bacteria which can increase the weight up to the root and nodules, as well as the activity of N-fixing bacteria when compared with non-legume growing methods [6].

The effective land use of intercropping model is a new method towards sustainable agriculture in dry land. The intercropping mode can initiate symbiosis with legumes and supply nutrient in soil through nitrogen fixation [7]. Development of maize and soybean intercropping depends on the availability of soil nutrients, especially elements N and P availability compared to the single crop model.

Arbuscular mycorrhizal inoculation on maize and soybeans in dryland was proven to increase P uptake and plant yields which were significantly different from controls in dryland [8]. Arbuscular mycorrhizal inoculation gave better growth, P uptake and yield in plants treated with phosphate rock fertilizer and arbuscular mycorrhizal inoculation on upland rice plants [9]. The inoculation of arbuscular mycorrhizae can increase the weight of dry maize cobs, the nutrient status is much higher than without mycorrhizae [10, 11].

Addition of organic material has a positive impact on soil improvement, increasing yields and grain maize and soybeans. Low organic material content cause damaged soil structure, low water soil, low soil buffering capacity, and low nutrient exchange and supply efficiency [12]. Organic matter has the effect of increasing the water retention of the soil, because can absorb 20 times its weight in water. It can increase effectiveness of organic matter decomposition, stabilize soil aggregates, act as a buffer for soil pH changes, and increase capacity. Cationic Soil Exchange (CEC).), and is used as an energy source for soil microbial activities. [13].

Studies on the effect of maize-soybean intercropping added mycorrhizae and organic matter on crop yields in the dryland of North Lombok have not been carried out. Therefore, a study of ”The Influent of Planting Density on the Intercropping Maize-Soybean Inoculated with Organic Fertilizer modified Mycorrhizae on the Yield in Dry Land in North Lombok, Indonesia” was conducted to understand the plant density effect on maize-soybean intercropping that modified with mycorrhizal and organic matter on crop yields.

2. Methodology

2.1. Experimental design

The experiment started from March to July 2020 and observed of mycorrhizal and soil nutrients in the Laboratory of Soil Microbiology and Chemistry, College of Agriculture, Mataram University. Randomized Block Design (RBD) was used with 5 intercropping models, that is ; P 1 = 2 lines of maize : 2 lines of soybeans, P 2 = 3 lines of maize: 2 lines of soybeans, P 3 = 3 lines of maize: 3 lines of soybeans, P 4 = 4 lines of maize : 2 lines of soybeans, P 5 = 4 lines of maize : 3 lines of soybeans. Three replicate times was applied for each treatment.

2.2. Mycorrhizal inoculum

The Indigenous mycorrhizal inoculum used in this research sourced from the private collection of Dr. Ir. Wahyu Astiko MP called M AA01.

2.3. Planting of Maize and Soybean

Planting maize and soybean seeds were conducted by inserting seeds into soil appropriate the intercropping treatment. Two seeds of maize and soybean were applied in each hole. The plant density and layout for each treatment can be seen in Table 1 and Figure 1 to Figure 5.

Table 1: Planting density and population of maize and soybeans.

Plant density (Maize : Soybean)	Spacing and intercropping population		
		Maize	Soybean
P1(2:2)	Planting distance Plant population/plot	60cm x 40cm 6x11=6675	30cm x 20cm 14x4=5616
P2(3:2)	Planting distance Plant population/plot	60cm x 40cm 6x11=6675	30cm x 20cm 14x4=5616
P3(3:3)	Planting distance Plant population/plot	60cm x 40cm 6x11=6675	30cm x 20cm 14x4=8425
P4(4:2)	Planting distance Plant population/plot	60cm x 40cm 6x11=88100	30cm x 20cm 14x4=288
P5(4:3)	Planting distance Plant population/plot	60cm x 40cm 6x11=88100	30cm x 20cm 14x4=4212

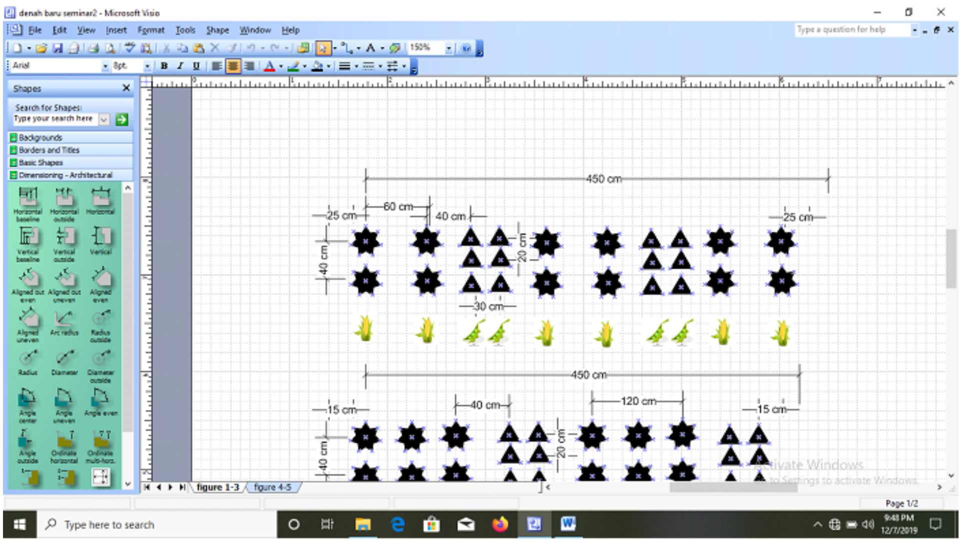

Figure 1: Crop layout in 2 lines of maize intercropping: 2 lines of soybeans.

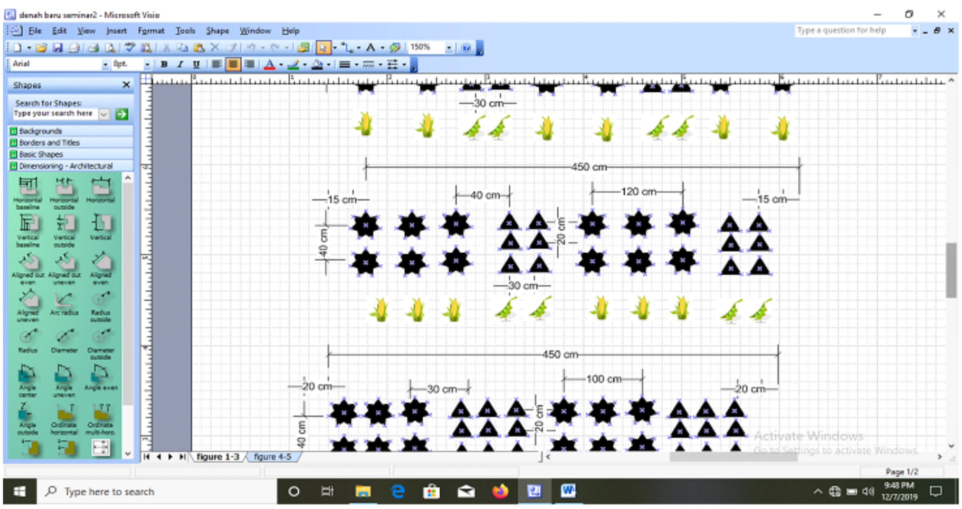

Figure 2: Crop layout in 3 lines of maize intercropping: 2 lines of soybeans (P_2).

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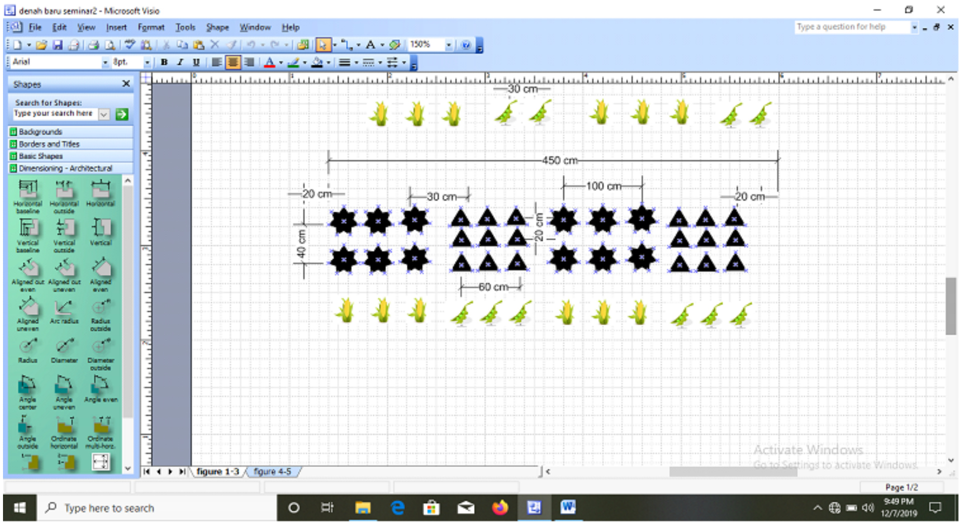

Figure 3: Crop layout in 3 lines of maize intercropping: 3 lines of soybeans (P_3)

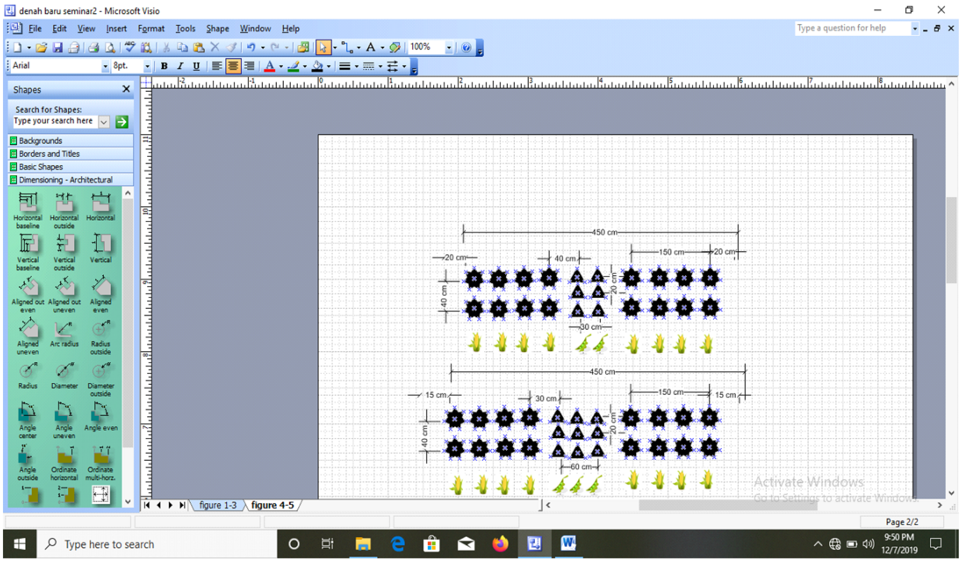

Figure 4: Crop layout in 4 lines of maize intercropping: 2 lines of soybeans (P_4).

2.4. Plant replacements

Plant replacement is replacing dead plants or abnormal growth by replanting maize and soybean seedlings 7 days after planting (dap). Once the plants have grown, a thinning is performed, leaving a plant 14 days after planting.

2.5. Fertilization and plant protection

The amount of organic fertilizer applied is 360 grams/hole for maize and 180 grams/hole for soybeans. The maximum application of inorganic fertilizers for maize is 180 kg/ha for urea and 120 kg/ha for Phonska, while soybeans are 120 kg/ha for urea and 60 kg/ha

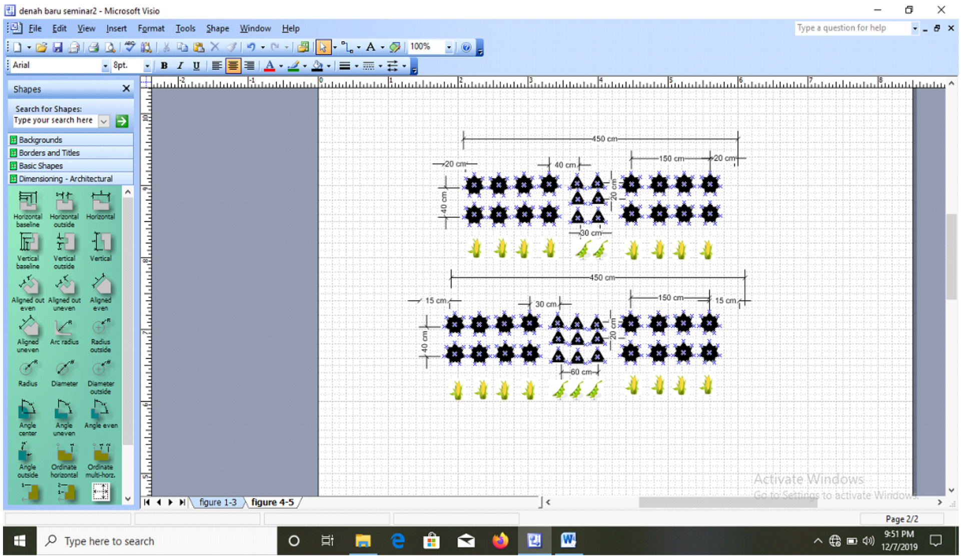

Figure 5: Plant layout in intercropping 4 lines of maize: 3 lines of soybeans (P_5).

for Phonska. The organic pesticide azadirachtin under the trade name OrgaNeem is used for plant protection by 5 ml/liter with 7 days spraying interval.

2.6. Parameters of observation

The parameters observed in this study are the wet and dry weight of shoots and roots, the ears and dry pods weight per plant, the dry shell pods and seed pods weight per plot, and the weight of 1000 seeds.

2.7. Statistical analysis

Data analysis uses analysis of variance (ANOVA). If there is a significant difference, continue by least significant difference (LSD) test with significance error 5%.

3. Result and Discussion

3.1. Maize and Soybean Yield

The results of 3 lines of maize: 3 lines of soybean plant density treatments yield the highest, indicated significantly different from other treatments. The weight values of 1000 grains and maize seeds are 303.33 g and 7.37 kg/plot, while soybeans are 183.33 g and 0.635 kg/plot (Table 2).

Table 2: Mean yield of seed weight (kg/plot) and 1000 dry seed weight of maize and soybeans (g) at 92 days after planting.

Treatmen	Maize Weight		Soybean Weight	
	1000 dry seed	Seed weight	1000 dry seed	Seed weight
P1 (2M: 2S)	236.7^{c}	5.7^{cd}	148.3^{b}	0.17^{c}
P2 (3M: 2S)	235.0^{c}	5.9^{bc}	146.7^{b}	0.27^{bc}
P3 (3M: 3S)	303.3^{a}	7.4^{a}	183.3^{a}	0.64^{a}
P4 (4M: 2S)	231.7^{c}	6.7^{bc}	160.0^{ab}	0.23^{c}
P5 (4M: 3S)	261.7^{b}	6.7^{b}	168.3^{ab}	0.29^{b}
LSD 5%	9.91	0.65	18.01	0.228
Notes:	The followed same letter behind the average value in each column didn't differ significantly between the plant density treatments.			

Based on Table 2, 3 lines of maize: 3 lines of soybeans for the initial plant density, and then add 1 row of maize to 4 maize : 3 soybeans (P5), the weight percentage has decreased by 1,000 kernels and maize weight. They were down 15.93% and 10%, while soybeans were down 8.91% and 11.97%.

The yield of treatment 3 lines of maize seeding density treatment: 3 lines of soybean was increased. This showed that N, P, organic and plant nutrients have also increased their nutrient uptake and therefore the yields are also higher. The nutritive component has important role in increasing yield is P element. This element plays significant role in filling pods of plants, thus increasing the maize yields and soybeans. In addition, 3 lines of maize: 3 lines of soybeans density give rise to environmental conditions that allow sustaining the availability of nutrients to increase crop yields in the best way.

Plant density affects ear length, ear weight, and weight of 100 seeds. To a certain extent, increasing plant density per unit area can increase yield. On the other hand, a decrease in maize plant density per hectare will cause microclimate changes that affect growth and yield, because the spacing is too wide, causing a large amount of water to evaporate in the soil, thereby interrupting growth and yield. Humidity level, temperature, and genetic factors also have a great influence on plant growth and performance [14].

3.1. Maize Cobs and Pods Yield - Soybean

The yield of cob biomass weight in the 3-row maize: 3 soybean intercropping density treatment showed the significant and highest yield from the other treatments. This can be seen in the wet maize biomass weight per plot (WW), the cobs weight per plant (WCp), the cobs weight per plot (WCpt) and soybean biomass weight per plot (WW), soybean pods weight per plant (WPp), pods weight per plot (WPpt) with a value of 26.78 kg/plot, 295.38 g/plant, 34.57 kg/plot and 5.92 soybean plants. kg/plot, 47.83g/plant 9.31 kg/plot while dry weight 20.94 kg/plot, 278.93 g/plant, 18.31 kg/plot, 1.21 kg/plot, 11.83 g /plant and 3.78 kg/plot (Table 3).

Table 3: Average weight of plant biomass per plot (kg / land), soybean ear and ear per plot weight (kg / land), and the ear and ear of soybean weight per plant (g / plant) at 92 days from planting.

Treatment	Maize			Soybean		
	WW	WCp	WCpt	WW	WPp	WPpt
Wet Weight (Maize : Soybean)						
P1 (2: 2)	20.7^{c}	195.5^{c}	31.7^{b}	2.7^{c}	33.4^{d}	3.8^{ab}
P2 (3: 2)	19.1^{d}	163.8^{d}	22.2^{e}	3.9^{b}	30.6^{e}	4.5^{ab}
P3 (3: 3)	26.8^{a}	295.4^{a}	34.6^{a}	5.9^{a}	47.8^{a}	9.3^{a}
P4 (4: 2)	22.7^{b}	227.0^{b}	28.3^{c}	1.2^{e}	42.8^{b}	4.6^{ab}
P5 (4: 3)	25.9^{ab}	143.0^{d}	25.4^{d}	1.9^{d}	37.3^{c}	2.3^{ab}
LSD 5%	1.1	7.2	1.8	0.1	0.8	7.1
Dry Weight (Maize : Soybean)						
P1 (2: 2)	15.3^{b}	144.3^{c}	14.7^{cd}	0.5^{bc}	5.4^{b}	0.9^{b}
P2 (3: 2)	14.3^{c}	146.6^{c}	12.2^{cd}	0.8^{b}	3.5^{c}	1.7^{ab}
P3 (3: 3)	20.9^{a}	278.9^{a}	18.3^{a}	1.2^{a}	11.8^{a}	3.8^{a}
P4 (4: 2)	18.1^{ab}	227.1^{b}	15.8^{ab}	0.3^{cd}	10.2^{ab}	1.3^{b}
P5 (4: 3)	19.3^{a}	87.3^{c}	14.3^{bc}	0.4^{cd}	10.3^{ab}	0.8^{b}
LSD 5%	1.6	25.3	1.9	0.3	1.3	3.6
Notes:	The followed same letter behind the average value each column has no significant difference between plant density treatments; wet biomass weight per plot (WW), weight per plant (WCp), weight per plot (WCpt), and the weight of soybean biomass per plot (WW), soybean pods weight per plant (WPp), and soybean pods weight per block (WPpt)					

Based on Table 3, If initially it is 3 lines of maize: 3 lines of soybeans, then add 1 row of maize to 4 maize: 3 soybeans in (P5), the wet weight of biomass per plot and the weight percentage of each ear of maize will decrease. The maize cob weight, the soybean pod per plot weight, The soybean pod per plant weight and The pod per plot weight were 3.19%, 10.65%, 36, 43%, 20.35%, 28.360.47%, respectively, and the percentage of dry weight decreased was 8.49%., 21.96%, 28.22%, 14.85%, 36.09%

The above facts showed, there is a symbiotic coincidence between the intercropping pattern of 3 lines of maize and 3 lines of soybeans and addition of fertilizers (inorganic and organic plus mycorrhiza) as a nutrients addition, which are necessary for increasing crop yield. This has correlation to the role of nutrient sources other than the nutrient source that provides the nutrient elements required by plants and the energy and nutrient sources required for the growth of biological fertilizers. Due to the presence of growth hormone produced by biological fertilizers, both are necessary to promote plant growth [15].

The regulation of planting density is one way to optimize the utilization of nutrients needed by plants so that they are easily available for each plant so that plants can grow well. Increasing plant population per unit area to some extent can increase crop yields. On the other hand, a reduction in maize density per hectare can lead to changes in the availability of micronutrients that affect plant growth and yield [16].

3.2. The Wet and Dry of Roots and Shoots Weight

The wet and dry biomass weight of intercropping in 3 lines of maize: 3 lines of soybeans density treatment showed significant and the highest yield from the others. This can be seen in the wet roots and shoots weight of maize at the age of 40 days after planting which were 49.22 g/plant and 310.69 g/plant, while soybean plants were 1.49 g/plant and 18.62 g/plant, at 92 days after planting were 191.88 g/plant and 624.68 g/plant, while for soybean it was 0.65 g/plant and 3.32 g/plant. The dry biomass weight of maize roots and shoots aged of 40 days after planting was 17.45 g/plant and 88.93 g/plant respectively, while soybean plants were 0.54 g/plant and 3.88 g/plant at 92 days after planting for maize was 56.26 g/plant and 381.19 g/plant, while for soybean it was 1.81 g/plant and 12.26 g/plant (Table 4).

TABLE 4: Mean weight of plant root and shoot biomass at different plant densities (g/plant).

	Maize				Soybean			
Treatment	Root (dap)		Shoots (dap)		Root (dap)		Shoots (dap)	
	40	92	40	92	40	92	40	92
Wet Weight (Maize : Soybean)								
P1 (2: 2)	35.2^{c}	136.1^{b}	273.3^{c}	249.3^{c}	0.7^{bc}	0.8^{b}	11.5^{ab}	15.3^{cd}
P2(3: 2)	30.6^{d}	63.2^{c}	220.0^{d}	166.3^{d}	0.9^{ab}	1.6^{b}	10.7^{b}	11.9^{de}
P3(3: 3)	49.2^{a}	191.9^{a}	310.7^{a}	624.6^{a}	1.5^{a}	3.4^{a}	18.6^{a}	36.2^{a}
P4(4: 2)	47.9^{a}	89.7^{c}	292.0^{b}	369.8^{b}	1.2^{ab}	1.1^{b}	14.5^{ab}	20.4^{b}
P5(4: 3)	40.2^{b}	35.8^{d}	283.6^{bc}	148.6^{d}	1.3^{ab}	1.3^{b}	15.0^{ab}	19.2^{c}
LSD 5%	1.8	12.4	7.5	29.3	0.22	0.65	3.63	3.3
Dry Weight (Maize : Soybean)								
P1 (2: 2)	16.6^{a}	46.7^{b}	31.6^{c}	117.4^{c}	0.4^{ab}	0.6^{ab}	2.2^{b}	6.6^{bc}
P2 (3: 2)	11.8^{b}	41.8^{b}	47.5^{b}	136.7^{c}	0.1^{ab}	0.9^{ab}	3.2^{ab}	4.6^{bc}
P3 (3: 3)	17.5^{a}	56.3^{a}	88.9^{a}	381.2^{a}	0.5^{a}	1.8^{a}	3.9^{a}	12.3^{a}
P4 (4: 2)	15.5^{a}	26.1^{b}	56.8^{b}	250.1^{b}	0.4^{ab}	1.2^{ab}	3.6^{ab}	7.2^{bc}
P5 (4: 3)	12.4^{b}	12.5^{c}	47.7^{b}	69.0^{c}	0.4^{ab}	0.8^{ab}	1.7^{c}	8.8^{ab}
LSD 5%	1.7	5.3	7.2	14.5	0.11	0.69	0.4	2.5

Notes: The followed same letter behind the average value each column means has no significant difference between plant density treatments.

Based on Table 4, if initially 3 lines of maize: 3 lines of soybeans were added 1 more row of maize so that it became 4 maize: 3 soybeans (P5), there will be a decrease in the percentage of wet weight of roots and shoots of maize plants at 40 days after planting 22.52% and 9.55% for soybeans were 14.61% and 24.14%, while at 92 days after planting for maize were 43.59% and 32.02%, while soybeans were 15.37% and 8.85%. The weight of dry biomass of maize roots and shoots aged 40 days after planting were 41.29% and 86.51% while soybean plants were 4.59% and 12.42%, at 92 days after planting maize were 35.0%, respectively and 42 days while for soybeans it was 14.13% and 36.28%.

The good result was showed in 3 lines of maize: 3 lines of soybeans treatment. Especially on yield of plant crown wet biomass weight in 3 lines of maize: 3 lines of soybeans treatment was increased than the other treatments. When processing 3 lines of maize: 3 lines of soybeans, the increase in wet ear weight is due to the good photosynthesis process of the plant. The leaves function are place of photosynthetic process, so in addition to being used as growth indicators and necessary to observe [17].

Spacing settings with lower population densities increased dry weight yield and leaf area index in maize, but decreased light transmission for soybeans Increasing population decreased soybean production but increased maize production [18]. Population density in the intercropping of maize and soybeans causes soybean production to be depressed due to competition with maize plants with soybean yields 59-75% lower than monocultures. Intercropping of maize and soybeans at a ratio of 3:3 suppresses soybean growth production due to the dominance of maize over soybeans [19].

4. Conclusion

The highest yield in terms of single plant corn ear and dry and wet weight showed by 3 lines of maize : 3 lines of soybeans treatment result, while biomass maize ear, dry and wet weight soybean ear and dry weight per plot, weight of 1000 seeds and other intercropping treatments was significant difference in comparison.

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