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Submission date: 24-Feb-2022 04:02PM (UTC+0700)

Submission ID: 1769812405

File name: Sci_712_2021_012025-The_comparative_analysis_of_row_Tunitin.pdf (466.02K)

Word count: 4704

Character count: 22796

The comparative analysis of row proportions and the effect on nutrient status maize and soybean intercropping in sandy soil of North Lombok, Indonesia

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Abstract. Competition is the main problem of application intercropping cultivation in sandy soil, such as water absorption, nutrients, sunlight, and growing space. Plant density and distribution are the primary roles to consume nutrient supply in the sandy soil during intercropping. The study was aimed at determining the nutritional status of maize and soybean intercropping in the sandy soil areas of North Lombok, Indonesia. The experiment was performed at Akar-Akar village in Bayan district of North Lombok and was designed with Randomized Block Design and five treatments, i.e., P1 (2 rows of maize + 2 rows of soybean), P2 (3 rows of maize + 2 rows of soybean), P3 (3 rows of maize + 3 rows of soybean), P4 (4 rows of maize + 2 rows of soybean), P5 (4 rows of maize + 3 rows of soybean). Each treatment was replicated three times. The variables observed were the nutritional status of the soil (N-total and P availability) and nutrient uptake (N and P). The result shows that intercropping patterns of 3 rows of maize and soybean (P3) with the addition of 15 tons of cattle manure per hectare and the inoculation of AMF can increase the nutritional status of soil in nitrogen and phosphorus absorption of plants' nutrients. It is recommended for farmers to obtain high yields using an intercropping pattern of three rows of maize and three rows of soybeans. This research recommended that nutrient improvement can be achieved by intercropping three rows of maize and three rows of soybean. Further research is needed on the response to yields of various varieties of maize and soybean intercropped on sandy soil.

1. Introduction

Maize is generally grown together with soybeans for the intercropping system in the sandy soils of North Lombok. Intercropping is defined as planting two or more plants at the same time and place [1]. The intercropping system is more beneficial compared to the monoculture system due to its high productivity. Besides, various commodities are produced, efficient in production cost, and less risk of crop failure. The intercropping system can also reduce erosion and maintain soil fertility. In intercropping systems, there is a very complex interaction between two or more plants using water, light, and nutrients [2].

If plant density can be managed properly, the two intercropped plants will complement each other in the use of resources [3]. However, some factors must be considered in intercropping, such as differences in root systems, plant height, family and host plants of different pests, population, and planting density [4]. Planting maize with wide spacing significantly decreases the dry weight of seeds compared to



narrow spacing and medium spacing; although planting with wide spacing has a higher dry weight of seeds per cob, the population is smaller, so the number of cobs is also less [5].

The intercropping system is included in a diversified agriculture approach that can be applied to maize and soybean plants. The maize consists of C₄ that prefers direct sunlight [6] and requires nitrogen in quite high amounts, too [7]. Soybeans are included in C₃ plants, which are quite tolerant of shade [8]; besides that, soybean roots can fix nitrogen through symbiosis with *Rhizobium japonicum* bacteria [9]. Furthermore, the intercropping system of maize with soybean had a positive influence on maize production [10]. Based on the results can be seen that the intercropping system of soybean and maize is more efficient compared to the intercropping system of soybean and upland rice [11].

Competition is the main problem of application intercropping cultivation in sandy soil, such as water absorption, nutrients, sunlight, and growing space. Plant density and distribution are the main roles to consume nutrient supply in the sandy soil during intercropping. Shades can cause changes in the reception of solar radiation by plants, both intensity, and quality so that it affects a variety of plant activities [12, 13]. Therefore to obtain the best results from maize intercrops with soybeans, it is necessary to adjust the proportion of planting density so that the use of resources is more efficient and does not interfere with the intercropped soybean plants. Adjustments of plant density proportion are to provide better growth space for plant growth and development. Intercropping production is a function of the management of aquaculture and the environment, which involves the interaction between soil and microclimate around the plant. Good management of these two factors will result in high crop production [14]. The proportion of planting density suitable for intercropping cotton with soybeans is 1 row of cotton (1 plant/hole) and three rows of soybeans [15]. However, the proportion of density appropriate for intercropping maize with soybeans in the sandy soil of North Lombok has not been revealed. This study aims to examine the effect of the proportion of density of maize and soybeans planted with intercropping systems on nutrient status of soil and nitrogen and phosphorus absorption of plants in the sandy soil of North Lombok.

2. Materials and methods

2.1. Experimental design

The experiment was conducted in Akar-Akar village in the Bayan district of North Lombok from April to July 2019. The land is located at a geographic position of -8°21'650, 116.350283. Randomized Block Design was used in this experiment with five treatments, i.e., P1 (2 rows of maize: 2 rows of soybean), P2 (3 rows of maize: 2 rows of soybean), P3 (3 rows of maize : 3 rows of soybean), P4 (4 rows of maize: 2 rows of soybean), P5 (4 rows of maize : 3 rows of soybean). Each treatment was replicated three times.

2.2. Conduct of experiments plants cultivation

Soil tillage was done using a tractor to remove the weeds from the land. The land was then divided into 15 plots of 5 m x 4.5 m size. A composite sample of 200g was taken (Soil Survey Staff, 2014). An indigenous AMF inoculum, *Glomus mosseae* (the MAA01 mycorrhizal isolate including the hyphae and the mycorrhizal spores), was used propagation results of culture pots for three months with soil media and manure (1: 1) sterile with maize host plants. It was isolated from the dryland area (1,500 spores per 20 g of soils) in Akar-Akar village of North Lombok. AMF inoculation and organic matter from cattle manure (1 ton/ha and 15 tons/ha) for all maize and soybean plots were used as treatments simultaneously and placed under the seeds as much as 20 g per planting holes at a depth of 10 cm. The cattle manure applied was measured with 3.08% total Nitrogen, pH 6.66, 17.70 mg/kg of available P, 2.31 cmol/kg of available K, 10.45 C/N ration, and 32.2% C-organic. Maize or soybean seeds ("Bima-Uri 20" variety and "Anjasmoro" varieties) are planted by planting two seeds per planting hole for each treatment of planting density.

At the time of planting, fertilization is carried out with cattle manure (a dose of 15 tons/ha) given to the planting hole (equivalent to 360 g per maize plant and 180 g per soybean plant). Inorganic fertilization for maize plants done three times, namely at the age of 7 days after seeding (DAS), age 21 DAS after the plant is 28 DAS after planting. Fertilization of maize given with a dose of 180 kg/ha Urea

(equivalent to 4.3 g per plant) and NPK Phonska (15:15:15) at an amount of 120 kg/ha (equivalent to 2.8 g per plant). Which is 60% of the recommended dose, and for soybean plants, is given with 60 kg/ha Urea (equivalent 0.79 g per plant) and 120 kg/ha Phonska (equivalent 1.49 g per plant). The fertilizer is the best dose to increase growth, yield, and uptake of N and P in the planting patterns of maize - sorghum, and soybeans in the dry land of North Lombok. The first fertilization is done at 7 DAS with a dose of 60 kg/ha Urea and 60 kg/ha NPK Phonska fertilizer. The second fertilization with Urea and Phonska fertilizer is given at 21 DAS after a dose of 60 kg/ha. The third fertilizing with Urea fertilizer is offered at a dose of 60 kg/ha at 28 DAS. For soybean, Urea and Phonska fertilizers are given at 1/3 dose at the age of 7 DAS, and the remaining 2/3 are offered at 28 DAS after planting. NPK fertilizer was applied in a 5 cm groove beside a row of maize and soybean plants at a depth of 5-7 cm before being covered with soil.

2.3 Plant protection

Plant protection was done by spraying "OrgaNeem" (an organic pesticide of plant origin containing Azadirachtin extracted from neem leaves) at a concentration of 5 mL OrgaNeem per Liter of water. Planting is done in the rainy season (April - July) so that the plants' irrigation is sufficient from the rainfall in the test site. Weeding is done at intervals of 10 days until the plants are 40 das by cleaning the growing weeds. Weeding is done at intervals of 10 days until the plants are 40 das by cleaning the growing weeds. The OrgaNeem solution was applied to both crops (maize or sorghum) from 10 to 60 DAS at a 3-day interval. Harvesting of maize and soybean crops was done at 92 DAS.

2.4. Observation of parameters

Observations were made on research variables: soil nutrients (total N and P available) at 40 DAS and 92 DAS, plant nutrient concentration (N and P) at 40 and 92 DAS. Laboratory analysis was carried out at the Soil Chemistry Laboratory, Faculty of Agriculture, Mataram University, Indonesia. Soil pH and textures were measured by standard procedures [16]. Determination of total N in the soil was carried out using (NH₄)₂SO₄ extractor and distillation with NaOH where NH₄⁺ was determined by the blue indophenol colorimetry method and NH₃ then titrated with 0.05N H₂SO₄ solution [17]. Total N in plants was measured using the blue indophenol spectrophotometry method with a wavelength of 636 nm after extracting with (NH₄)₂SO₄ and distillation with NaOH following the Conway procedure [18]. The available phosphorus in the soil and plants was measured using a spectrophotometer ($\lambda = 693$ nm) after the extraction process using Bray and Kurt I solution (0.025 N HCl + NH₄F 0.03 N) [19].

2.5. Statistical analysis

Data were analyzed using analysis of two-way ANOVA and Tukey's HSD (Honestly Significant Difference) means-tested at a 5% level of significance.

3. Results and discussion

3.1. Soil Nutrient Status

There were significant effects of the different row proportions of maize and soybean on soil nutrient status (N and P contents of the soil) of the rhizosphere of both maize and soybean crops at 40 and 92 das (Table 1). In general, there is a tendency that the highest values of the soil nutrient status, measured either at 40 or 92 das, are highest under the P₃ (3 rows of maize : 3 rows of soybean). N and P concentrations in shoots of maize and soybean were also highest in the three rows of maize:3 rows of soybean treatment (Table 2).

Table 1 shows the row proportion of intercropping in 3 rows of maize:3 rows of soybeans, the concentration of total N and available P increased with time. For instance, the total N concentration in the maize rhizosphere is relatively high at 92 das. This is due to the characteristic of maize plants, which have more N rather than other elements. This characteristic may be supported by an increase in mineralization of soil organic matter at high temperatures. This fact is consistent with field conditions where high sunlight intensity reaches the experimental plot's ground surface. Another possibility is the

increase in the total N concentration of the soil due to decreased plants' absorption at the end of the crop cycle. On the other hand, the decomposition of the organic matter becomes perfect over time, which causes the N concentration to remain high at the end of the maize crop cycle. The results of the initial analysis of the chemical content of cow manure used in this experiment have a high total N content. It is remarkable that in measuring the total N concentration of maize plants at the age of 92 das, N concentrations remain high. This fact makes it possible to suggest the regulation of maize intercropping density in the proportion of 3 rows of maize:3 rows of soybeans to increase complementarity in soil N absorption because this is relevant to high N concentrations at high temperatures by administering 15 tons/ha of cow manure at the beginning of planting. It also appears that differences in root types that differ between maize and soybeans [20] can lead to a more efficient exploration of soil volume in the proportion of crop intercropping in 3 maize rows:3 rows of soybeans.

Table 1. Mean concentration of total N and available P of soil in the rhizospheres of maize and soybean for each treatment of intercropping pattern, measured at 40 and 92 DAS

Intercropping pattern	Total N (g.kg ⁻¹) at 40 DAS		Available P (mg.kg ⁻¹) at 40 DAS		Total N (g.kg ⁻¹) at 92 DAS		Available P (mg.kg ⁻¹) at 92 DAS	
	maize	soybean	maize	soybean	maize	soybean	maize	soybean
P ₁ (2m:2s)	0.54 ^d	0.54 ^d	20.70 ^e	24.69 ^d	1.43 ^b	1.21 ^b	21.93 ^c	26.70 ^b
P ₂ (3m:2s)	0.57 ^{cd}	0.60 ^{bcd}	21.40 ^d	24.50 ^d	1.45 ^b	1.23 ^b	25.06 ^b	26.36 ^b
P ₃ (3m:3s)	0.80 ^a	0.73 ^a	25.69 ^a	42.14 ^a	1.62 ^a	1.35 ^a	36.38 ^a	45.43 ^a
P ₄ (4m:2s)	0.64 ^c	0.57 ^{cd}	24.40 ^c	27.71 ^c	1.41 ^b	1.21 ^b	25.43 ^b	28.94 ^b
P ₅ (4m:3s)	0.71 ^b	0.65 ^b	24.73 ^b	31.71 ^b	1.36 ^{bc}	1.28 ^{ab}	26.15 ^b	27.43 ^b
HSD 5%	0.04	0.04	0.14	0.98	0.08	0.06	1.27	8.06

Mean values in each column followed by the same letters are not significantly different between treatments of intercropping pattern

The facts above are in line with the results of the study of which concluded that among the mycorrhiza-based fertilization packages tested on the maize-sorghum cropping sequence system at the drylands in North Lombok of Indonesia, the package consisting of 60% NPK recommended dose, 12 t/ha cattle manure, and the indigenous AMF inoculation was found to be the best fertilization package to improve crop yield and soil nutrient availability. This study noted that the AMF development was higher in the sorghum at the second cropping cycle compared to the growth in the maize at the first cropping cycle. This condition is led to the higher NP-uptake, and soil nutrient availability in subsequent crops, both at the sandy dryland, with no additional fertilization and mycorrhizal propagules applied [21].

Table 2. Mean N and P concentration (mg g⁻¹ plant dry weight) by each crop at 40 DAS for each treatment of intercropping pattern.

Intercropping pattern	N and P concentration (mgg ⁻¹ plant dry weight) by each crop at 40 DAS			
	Maize		Soybean	
	N	P	N	P
P ₁ (2m:2s)	13.54 ^b	3.66 ^{bc}	20.05 ^c	3.06 ^d
P ₂ (3m:2s)	13.62 ^b	3.73 ^b	22.14 ^c	3.04 ^d
P ₃ (3m:3s)	13.98 ^a	4.77 ^a	23.16 ^a	3.98 ^a
P ₄ (4m:2s)	13.92 ^a	3.53 ^c	22.35 ^b	3.64 ^b
P ₅ (4m:3s)	13.56 ^b	3.63 ^{bc}	19.97 ^c	3.56 ^c
HSD 5%	0.12	0.10	0.05	0.05

1 Mean values in each column followed by the same letters are not significantly different between treatments of intercropping pattern

2 3.2. Nutrient Concentration in Plant Tissues

The concentration of N and P in plant tissues was different between treatments (Table 2). The data in table 2 shows that the highest concentration of both elements in plant tissue was found in the treatment P3, which was intercropping of 3 rows of maize:3 rows of soybeans. This value was significantly different compared with other treatments. If the content of N and P was expressed based on dry weight, then it was found the concentration of N per total dry weight per plant (shoot and root) was 1517.11 mg at the age of 40 das and increased to 6115.55 mg at the age of 92 das. However, when the plants in this treatment were supplied with 180 kg/ha Urea and 120 kg/ha Phonska, the concentration of N in tissue was only 1188,005 mg N/plant. Even Though the N total in soil media tends to increase from 800 mg/kg at age 40 das to 1620 mg/kg at age 92 das. These facts indicate that N was not absorbed maximally by the plants. This might be due to the total N uptake status of maize, which improved with increasing plant and root growth over time.

Another possible argument deals with the characteristic of soybean, which is legume producing root nodule to uptake N_2 and convert into NH_3 and NH_4 . In this case, soybean did not absorb N from soil media. As a result of this, the concentration N in soil media increases, which can be used by maize plants. However, a certain level of N in the media could inhibit the absorption of N by the root system. Soybean plants are C_3 plants that can form nodules in the soil. Root nodules producing plants, if given sufficient N (urea), will inhibit the formation of root nodules. This root nodule, when fixating N_2 and converting it to NH_3 , requires a considerable amount of energy (12 ATP). However, if N is not available in the soil, then the root system chooses to absorb N directly from the soil rather than forming nodules. This makes it possible for N produced by soybean plants to be absorbed by maize plants so that maize has a high N content [22].

Since soybean plants are classified as C_3 plants, they fix CO_2 from the atmosphere using ribulose phosphate carboxylate and catalyze by rubisco. However, the fixation can occur when CO_2 in the atmosphere is available in quite high amounts. On the other hand, maize plants are categorized as C_4 plants that require CO_2 at a rate that does not have to be high because they can fix CO_2 with the help of the PEP enzyme (Phosphoenolpyruvate carboxylase). Therefore, the condition of agroclimatic, which could support mutualistic symbiosis, is an important task to support maximal carbon assimilation by both plants. Competition in obtaining sunlight in the maize-soybean intercropping system is one of the critical factors that have more influence on the growth of soybean plants compared to maize plants. This condition is caused by maize plants' growth, which is relatively faster than soybeans, thus inhibiting light penetration into the canopy of soybean plants. It is estimated that the average light intensity above the soybean canopy aged 40 das is lower than that received by maize plants. The difference in light intensity shows that the shading capacity of maize plants in the proportion of 4 rows of maize: 3 rows of soybeans is greater than the proportion of plant density of 3 rows of maize: 3 rows of soybeans. This also shows that the level of the shade of maize at a density of 3 rows of maize: 3 rows of soybeans can still be tolerated, and environmental conditions such as water availability, nutrients, and microclimate are still optimum, both for the growth of maize and soybean plants [23].

N_2 binding bacteria can convert N_2 to ammonia (NH_3). N-binding bacteria and plants further metabolize ammonia into protein as one of its body constituents. Plant diversity largely determines the N cycle [24]. Plant diversity can affect total N uptake due to synergistic or competitive use of resources. If nutrients are obtained from different available sources (other spaces, times, and forms), the total N uptake by plants will increase so that the chances of leaching are smaller [25]. Maize plants are plants that do not need too much N. Plants with different N content will have dry biomass with additional N content so that the time and type of microbes necessary for the decomposition process will also be added so that ultimately affects the N cycle [26].

The presence of soybean plants in maize intercrops generally causes an increase in levels of N (nitrate and total) soil. Increased levels of soil nitrate are due to the supply of N from N_2 , which is fixed by

soybean plants [27, 28]. N supply by soybean plants can increase yields and weights of maize biomass from nearby plants [29].

Nitrogen that is fixed through soybean plants can be directly transferred to the maize plants that grow next. The process of nitrogen transfer by soybean plants can go through several mechanisms. The most massive N transfer can be made after mineralization of organic N into inorganic N. With the N transfer process is one of the supporting factors for the formation of associations of soybean plants with maize plants that grow next to it.

Nitrogen transfer (N) transfers N from soybean plants to non-legume crops such as grass or maize. The term transfer is used to describe N residues of dead soybean plants [30]. The proportion of N in grass plants derived from intercropping soybeans varies greatly depending on the time of observation, plant species, age of the plant, the methodology used, and environmental conditions. Other research found that 68% of nitrogen contained in canary grass (*Phalaris arundinacea* L.) originated from alfalfa (*Medicago sativa* L.) and 79% nitrogen from *Lotus maizeiculata* L. plants [31]. This amount is 17 and 13% of total N fixed by alfalfa and *Lotus maizeiculata* L. Other facts proved the transfer of N as much as 6-12% from white clover to ryegrass (*Lolium perens* L.) [32]. The amount of nitrogen transferred by alfalfa plants to bromegrass is 14 kg/ha/yr with a proportion of 5 kg/ha/yr derived from the soil and 9 kg/ha/yr derived from N₂ fixation. The supply of N by soybean plants to none-Leguminosae (maize) plants causes an increase in the growth and production of maize plants. One example is the production of fodder from intercropping with legume crops as much as the production of 15 monocultures with fertilization of more than 100 kg N/ha [33].

4. Conclusion

The result shows that intercropping patterns of 3 rows of maize and three rows of soybean (P3) with 15 tons of cattle manure per hectare and the inoculation of AMF can increase the nutritional status of soil in nitrogen and phosphorus absorption of plants' nutrients. Setting the intercropping density of maize in the proportion of 3 rows of maize: 3 rows of soybeans can increase the complementarity in soil N absorption by administering 15 tonnes/ha and of cattle manure and inoculation of AMF 1 tonnes/ha at the beginning of planting. This research recommended that nutrient improvement can be achieved by intercropping three rows of maize and three rows of soybean. This study noted a higher N, P uptake and availability of soil nutrients in the intercropping cultivation of 3 rows of maize and three rows of soybeans on sandy soil with an environmentally friendly fertilizer application to environmental sustainability. Further research is needed to respond to yields of various varieties of maize and soybean intercropped on sandy soil.

3. Acknowledgment

The authors would like to thank the Directorate of Research and Community Service, the General Directorate of Research and Development at the Ministry of Research, Technology and Higher Education (DRPM RISBANG KEMRISTEKDIKTI), and to the University of Mataram for the research grants with the number of 182/SP2H/LT/DRPM/2019.

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