Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

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OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2023.269.276

Research Article
Land Efficiency of Functional Food Sweet Corn Intercropped with Vegetable Soybean in Application of Integrated Fertilizers

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Abstract

Background and Objective: The need for functional food is increasing along with the increase in population. Meanwhile, Indonesia experiences the conversion of agricultural land into non-agricultural land reaching 120,000 ha per year. Therefore, one of the cultivation methods for the development of functional food crops is the intercropping system. To support soil fertility, various organic fertilizers are used, namely cow manure, chicken manure and municipal compost. The purpose of this study was to evaluate the efficiency of the intercropping system of sweet corn and vegetable soybeans in the application of the combination of different organic fertilizer sources and dosage of NPK fertilizer. **Materials and Methods:** The research was carried out from June to August, 2022 in the Giwangan Umbulharjo Village, special region of Yogyakarta. The study was arranged in a factorial randomized complete block design with three replications. The first factor was the source of organic fertilizer consisting of three sources (cow, chicken manure and municipal compost) and the second factor was dosages of NPK consisting of three levels 200, 300 and 400 kg ha^{-1}, so that obtained 27 unit of experimental plots. The observation variable includes components of growth, yield and efficiency of land. The Analysis of Variance (ANOVA) at a significant level of 5% was used to analyze the significant differences between treatments, followed by Duncan's Multiple Range Test at a significant 5%. **Results:** The application of a combination of chicken manure with a dosage of 300 kg ha^{-1} NPK fertilizer in the best growth and the highest yield of intercropping sweet corn and vegetable soybeans and the component efficiency land showed the value of land equivalent ratio, competition index, crop system efficiency and actual yield total. **Conclusion:** The intercropping system of sweet corn and soybeans could increase the productivity of both crops and improve land efficiency, including land equivalence ratio, competition index, crop system efficiency and total yield. Cow manure or municipal compost combined with NPK fertilizer at 300 kg ha^{-1} could improve the yield of corn and soybean.

Key words: Cropping system efficiency, land equivalent ratio, municipal compost, sweetness level

Citation: Darini, M.T., S. Widata, E. Setiawati and A. Astuti, 2023. Land efficiency of functional food sweet corn intercropped with vegetable soybean in application of integrated fertilizers. Asian J. Plant Sci., 22: 269-276.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Currently, Indonesia's population reached 273.51 million and is the fourth largest population in the world, this population has increased compared to 2017 the population reached 263.99 million[1]. Various needs of the population to meet the sustainability of life other than land, clothing as well as food. An increase in knowledge, welfare and health. Therefore to meet the needs of life not only food in quantity but also quality. To support the quality of life, functional food is needed besides acting as a source of energy as well as health because it contains building blocks in the form of minerals, vitamins and phytochemicals[2]. Different types of functional food crops that have recently an increased in demand are sweet corn and vegetable soybeans.

Sweet corn is widely popular in the community, has a high economic value and has a high nutritional and sugar content[3]. Sweet corn hybrid variants have a sugar level of 16-18%, compared to 9-11% for local varieties[4]. Therefore, sweet corn is recognized as a quality and delicious food. The seeds are delicious and full of sugars that are balanced with amino acids, minerals and B vitamins and corn is a good source of fiber. Moreover, sweet corn contains phytochemicals that can improve health such as carotenoid, tocopherol and phenolic acid[5,6]. In Indonesia, sweet corn was first known in the form of imported cans. In the 1980s this maize variety was cultivated in Indonesia commercially on small scale. The higher the level of public awareness, the more priority is given to healthy food and the higher the demand for sweet corn. Sweet corn productivity in Indonesia is still low with average productivity of under 10 tons ha^{-1}. Likewise, Subaedah *et al.*[7] reported that sweet corn productivity only reached 8.31 tons ha^{-1} or only one-third of the potential yield. Srdić *et al.*[6] reported the potential yield of sweet corn reached 13.33 tons ha^{-1}, while according to Subaedah *et al.*[8], the twin-row system produces a cob weight of 22.33 tons ha^{-1}.

Besides sweet corn as functional food, fresh vegetable soybeans also contain (10-14%) protein, rich in essential amino acids, dietary fiber, minerals and vitamins. This type of nut from Japan also contains isoflavone compounds that have a number of potential health benefits in the human body, including increasing antioxidant activity, preventing cancer and reducing Low-Density Lipoprotein (LDL) bad cholesterol that contributes to cardiovascular disease. This is what distinguishes a type of legume from japan as a source of functional food that is able to provide consumers with many additional benefits beyond basic nutritional needs[9]. These plants are also capable of binding atmospheric nitrogen, given to plants and facilitating soil nutrient circulation and water storage. Based on these benefits, legumes have a high potential for the conservation of agricultural soil soils[10].

Organic fertilizers from plants and animals applied directly or after composting or other processes can supply significant nutrients for growing sweet corn. Organic fertilizers are mandatory in organic farming and are often used in conventional agriculture as a complement to fertilization or to improve soil properties. The potential value of animal faeces as fertilizer and soil enhancer depends on the rate and rate of decomposition of organic matter to release nutrients or build organic soil in ponds of matter. In maize production systems, simply increasing the species richness cover crop will have little impact on agroecosystem services, but designing polycultures that maximize functional diversity can lead to multifunctional agroecosystems[11].

Based on the report by El-Negar and Mohamed[12], cow manure contains the mineral N. This process depends on the type of manure and its nutrient content, soil temperature and humidity among other factors. The chicken manure contains N (6.99-7.78%), P (0.89-099%), K (4.88-5.70%), organic matter (37.80-38.09%), bulk density (0.39-0.86%) and total porosity (31.00-60.40%), while the mineral nutrient content of compost (agricultural waste) contains N (0.51-0.53%), P (0.21-0.23%) and K (0.60-0.65%)[13].

Nitrogen (N) is an essential element that is required both in terms of influencing plant productivity and negative environmental effects. The main source of N in organic systems can come from growing N-fixing legumes alternately with sweet corn>research on land application of combined manure with NPK and its effects on crop production is even rarer[14]. Nitrogen fertilizers have been widely used to increase crop yields, but inadequate N inputs result in low yields and food shortages. In modern intensive agricultural production systems, up to 50% of the N fertilizer applied to agricultural soil is lost to the environment[15].

Intercropping systems with legumes in a symbiotic manner can provide nitrogen nutrients that are able to potentially increase environmental resources and crop yields[16]. Intercropping is beneficial in many ways as it ensures greater use of resources, a reduced population of harmful biotic agents, higher resource conservation and soil health as well as more production and sustainable system outputs. In an intercropping system, more than one plant is planted together on the same soil and utilizes its soil nutrients, soil moisture, atmosphere and sunlight. Intercropping has a strong potential to increase yields and thereby reduce global climate impacts such as greenhouse gases. Barriers to the locking effect for increased use of intercropping in organic farming and suggest a roadmap for innovation and strategy

implementation in organic farming[17]. In the intercropping system, complementarity between the types of the cultivated plant is very important to increase the yield of both crops[18]. Several reports are available on cereal-based intercropping such as corn-bean, corn-potato, corn-cassava, corn-yam, corn-soybean and corn-peanut, among many others. Recent studies on intercropping have focused on cereal-vegetable mixtures[19]. Based on the description above, it is a hypothesis that the application of municipal compost and dosages of 300 kg ha^{-1} NPK fertilizer can increase the yield and efficiency of intercropping sweet corn and vegetable soybean.

MATERIALS AND METHODS

The research was carried out from June to August, 2022, in the Giwangan Sub-District Umbulharjo Yogyakarta. The research location is at an altitude of 115 meters above sea level, soil type grumusol, temperature (18-16°C), rainfall 200 cc monthly, high light intensity, humidity (50-90%) and soil pH 5.6-6.6.

Experimental design: Experiment design, the field research was arranged in factorial randomized completely block design with three replications. The first factor was the source of organic fertilizer namely chicken, cow manure and municipal compost at a dosage of 20 tons ha^{-1}, the second factor was the dosage of NPK compound fertilizer, namely 200, 300 and 400 kg ha^{-1}. Control treatment with cow manure, urea, TSP and KCl fertilizers. The implementation of the research includes the making of experimental plots, soil preparation and basic fertilization with the application of organic fertilizer according to the dosage and source of organic fertilizer. Seed selection and planting with sweet corn spacing 75×25 cm and vegetable soybean 25×25 cm, so that between two rows of sweet corn plants there are two rows of vegetable soybean. Embroidery was done one week after planting. Watering until the condition it is not raining. Control of plant pest organisms manually pest by picking, killing and burying and weeds by weeding/pulling and then burying. Observation of growth variables by destruction on plants ages 1 month, followed by generative growth until harvest. Variables observed for sweet corn and vegetable soybean include fresh weight and dry weight per plant, fresh weight of cobs and pods per plant, fresh weight of corn cobs and vegetable soybean pods per ha, chlorophyll content, sweetness level of sweet corn seeds and vegetable soybean, cropping system efficiency, land equivalent ratio and competition index. Data analysis used variance at a significance level of 5% and continued with Duncan's Multiple Range Test at a significant level of 5%.

RESULTS AND DISCUSSION

The effect of types of organic and dosages of NPK fertilizers on plant growth. There was an interaction between sources of organic fertilizer and dosage of NPK on plant dry weight and chlorophyll content, while other variables did not interact, namely fresh weight of the plant, sweet corn cob weight per ha, sweetness level and fresh weight of vegetable soybean pod per ha.

Figure 1 showed that there is an interaction between various source organic fertilizer and the dosage of NPK fertilizer (significant p<0.05%). The dry weight of sweet corn obtained from the combination of chicken manure with a dosage 400 kg NPK fertilizer was not significantly and the highest with the combination of chicken manure and dosage

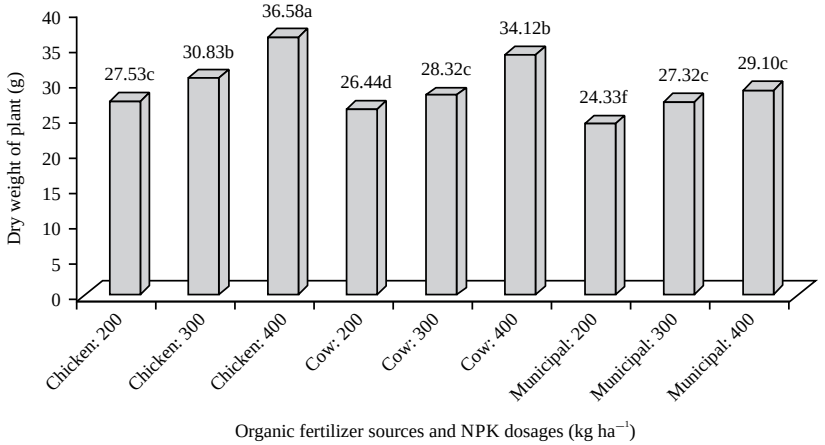

Fig. 1: Interaction between organic sources and NPK fertilizer on dry weight of plant

Number followed by different letters in columns for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

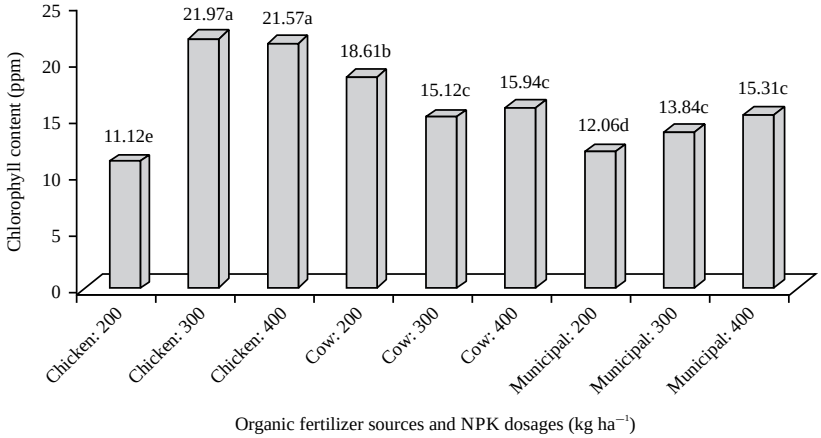

Fig. 2: Interaction between organic sources and NPK fertilizer on leaf chlorophyll content

Number followed by different letters in columns for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

NPK 300 kg ha^{-1} fertilizer and higher with the application with cow manure and NPK dosage 400 kg ha^{-1}. The lowest dry weight was obtained in the combination municipal compost with 200 kg NPK dosages fertilizer. In accordance with the report of Pangaribuan *et al.*[20], the combination of chicken organic manure and urea fertilizer at a dosage of 300 kg ha^{-1} increased the growth, yield and quality of vegetable soybean. Ahmed *et al.*[14] reported combining compost increased dry matter yield compared to control by 17-53% and increased grain yield by 1.8-3.1 times in both varieties of sorghum. Grain yield from plots treated with NPK, single similar for both varieties in both seasons. Likewise, Ngosong *et al.*[21] reported that the application of chicken manure increased the dry weight of climbing bean.

There was an interaction between the sources of organic manure with the dosage of NPK fertilizer (significant p<0.05) as shown in Fig. 2. The highest leaf chlorophyll content was obtained in a combination of chicken manure and NPK dosages of 300-400 kg ha^{-1} fertilizer. Lower chlorophyll content was obtained in the combination of cow manure with NPK fertilizer at dosages of 300-400 kg ha^{-1} which was no different with municipal compost and NPK dosages of 300-400 kg ha^{-1} fertilizer. The lowest leaf chlorophyll content was obtained in the combination of municipal compost with NPK fertilizer dosage of 200 kg ha^{-1} supported[22].

An interaction between various source organic fertilizer and the dosage of NPK fertilizer (significant p<0.05%) as shown in Fig. 3. The fresh weight of sweet corn obtained from the combination of chicken manure with a dosage 400 kg NPK fertilizer was not significantly and the highest with the combination of chicken manure and dosage NPK 300 kg ha^{-1} fertilizer and higher with the application with cow manure and NPK dosage 400 kg ha^{-1}. The lowest dry weight was obtained in the combination municipal compost with 200 kg NPK dosages fertilizer. The accordance report Pangaribuan *et al.*[20] stated that the combination of chicken organic manure and urea fertilizer at a dosage of 300 kg ha^{-1} increased the growth, yield and quality of vegetable soybean. Ahmed *et al.*[14] reported combining compost increased dry matter yield compared to control by 17-53% and increased grain yield by 1.8-3.1 times in both varieties of sorghum. Grain yield from plots treated with NPK, single similar for both varieties in both seasons.

There is not an interaction between various source organic fertilizer and the dosage of NPK fertilizer (significant p<0.05%) (Fig. 4). The highest fresh weight of sweet corn cob obtained on chicken manure than cow manure and municipal compost. Whereas, high fresh weight of sweet corn cob obtained on dosage 300-400 kg NPK fertilizer. Meanwhile, fresh weight and dry weight of tubers in the administration of cow manure tend to be obtained at the administration of a dose of 30 ton ha^{-1} [23]. Whereas, Ahmed *et al.*[14] reported that, the application of NPK similar chicken manure similar with chicken manure NPK toward yield grain sorghum.

Figure 5 showed there was no interaction between sources of organic manure with NPK fertilizer dosages 200-400 kg ha^{-1} on fresh weight of vegetable soybean pot (significant p<0.05). Fresh weight of the plant, fresh weight of cob and sweet corn sweetness level showed that there was significant. Fertilizer was compared to cow manure and municipal compost and both no significant different. This is not in accordance with Sulaiman and Mohammed[24], who reported that the application organic and inorganic fertilizers

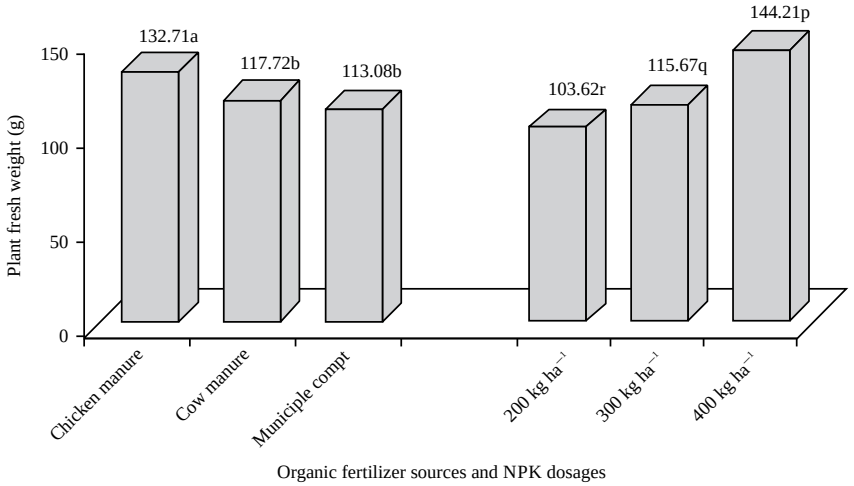

Fig. 3: Effect of different organic fertilizer sources or NPK dosage of fertilizer to fresh weight plant
Number followed by different letters in graphic (a, b and p, q, r) for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

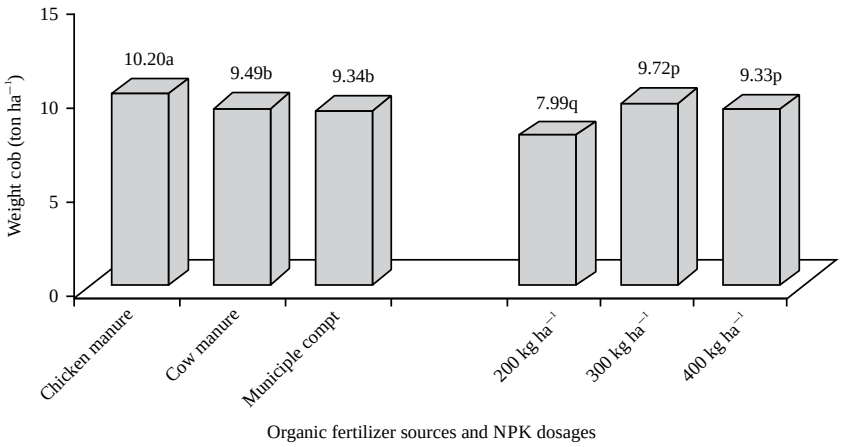

Fig. 4: Effect of different organic fertilizer sources or NPK dosage to weight cob
Number followed by different letters in graphic (a, b and p, q) for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

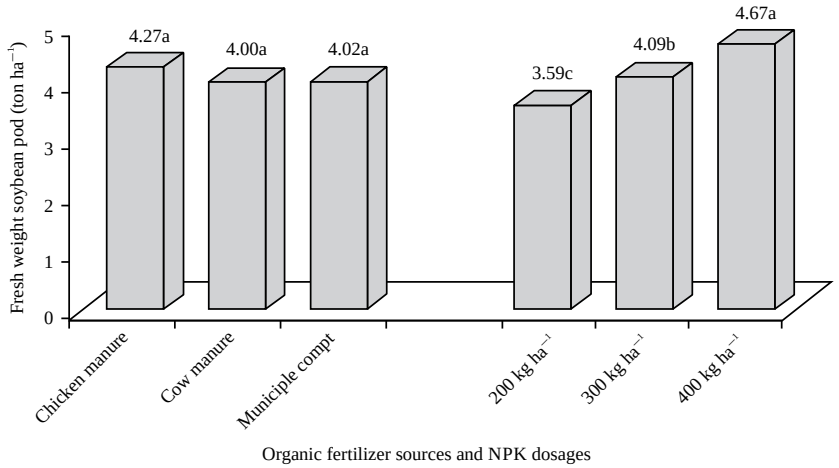

Fig. 5: Effect of different organic fertilizer sources or NPK dosage to weight of vegetable soybean pod
Number followed by different letters in graphic (a, b, c) for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

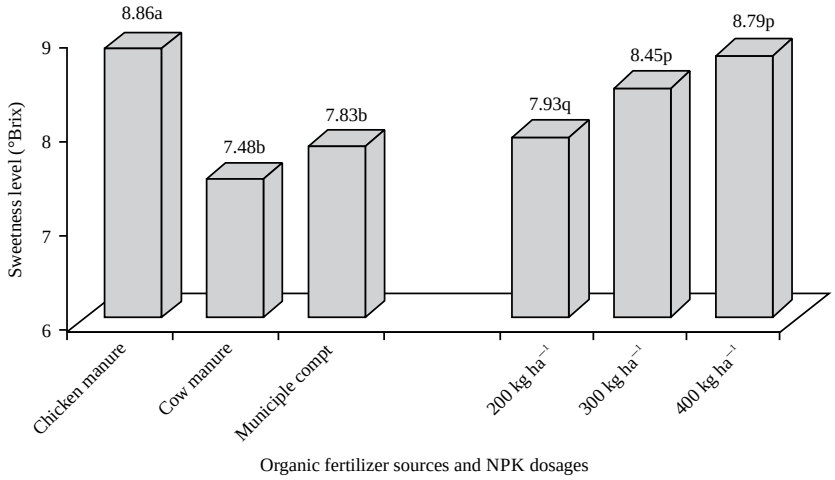

Fig. 6: Effect of different organic fertilizer sources or NPK dosage to the sweetness level of corn

Number followed by different letters in graphic (a, b and p, q) for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

Table 1: Effects of different organic fertilizer sources and NPK dosage on the land efficiency

Combination of organic sources/NPK dosages (kg ha^{-1})	Land equivalent ratio	Relative crowding coefficient	Crop system efficiency	Aggressiveness	Competition index
Chicken-200	1.21^{b}	9.31^{c}	1.35^{b}	0.02^{b}	0.85^{a}
Chicken-300	1.56^{a}	15.07^{a}	1.59^{a}	0.15^{b}	0.92^{a}
Chicken-400	1.66^{a}	19.12^{a}	1.71^{a}	0.05^{b}	0.90^{a}
Cow-200	1.33^{b}	6.38^{d}	1.28^{b}	-0.27^{b}	0.79^{a}
Cow-350	1.44^{b}	9.59^{c}	1.41^{a}	-0.07^{b}	0.81^{a}
Cow-400	1.60^{a}	12.46^{b}	1.53^{a}	0.10^{b}	0.85^{a}
Municipal-200	1.27^{b}	4.61^{e}	1.22^{b}	1.27^{a}	0.71^{a}
Municipal-300	1.43^{b}	6.80^{d}	1.37^{b}	0.10^{b}	0.79^{a}
Municipal-400	1.56^{a}	9.58^{c}	1.49^{a}	-0.18^{b}	0.82^{a}

Number followed by different letters in row for each variable are significantly different based on Duncan's Multiple Range Test α = 0.05

increased the growth and yield of peanuts. The current findings indicate that the integrated use of agriculture compost and gypsum under field conditions can increase crop productivity, crude protein, oil content and moisture percentage and reduce soil density thereby improving overall soil health. Darini *et al.*[25] reported that the application of a combination of cow manure at a dosage of 10 ton ha^{-1} with ammonium sulphate fertilizer 200 kg dosages increases the growth and yield of vegetable soybean pods on volcanic soil. With a dosage of nitrogen fertilizer of 200 kg ha^{-1} and a corn plant density of 8.25 million. A maximum yield of 9321.21 kg ha^{-1} can be achieved[26].

Likewise, the dosage of NPK fertilizer showed significantly different fresh weight plant, fresh weight of cob ha^{-1} sweetness level was obtained at dosages of 400 kg ha^{-1} and lower dosages also produced lower yield (Fig. 6). The higher of the sugar content, the better the quality. Organic fertilizer gives a greater sugar content to sweet corn. The potential sugar content of sweet corn cultivar jamboree is 13.5°Brix, while the average of sweet corn sugar content produced in the research for application without organic fertilizer is 13.89°Brix and the application of organic manure is 15.30°Brix. This is in accordance with Sulaiman and Mohammed[24], who stated that application organic and NPK fertilizers increased the sweetness level of grapes. Likewise, Latif *et al.*[13] reported that, the combined application of gypsum and compost increased pod yield by 67 and 65% during 2018 and 2019, respectively compared to the controls. Crude protein of 21% and oil content of 9.0% also increased substantially in the combined application. In addition, the combined application of gypsum and agriculture compost significantly retains soil moisture and reduces soil density.

Table 1 showed that the and efficiency in the intercropping of sweet corn with vegetable soybean is very high, this indicates the land equivalent ratio value of 1.56-1.66, other efficiency values are relative crowding coefficient, crop system efficiency and competition index. This was supported by the result of various studies. Based on the report by Bantie *et al.*[26], the intercropping of lupine and barley crop increase land efficiency by increasing the land equivalent

ratio (LER) and area time equivalent ratio (ATER) and reducing the Competition Index. Dhonde *et al.*[27] reported that, the intercropping system of maize and long bean in arrow ratio of 2:2 increased the land equity ratio to 1.15. The LER value is generally higher indicating a higher yield advantage over monoculture. The relative crowding coefficient shows that legume members are more dominate than corn[28]. Likewise, Aswe and Maimela[29] reported that intercropping the pathway system between cowpea and corn increased the yield, grain yield, LER and net yield. Not influenced by cropping pattern LER, ATER, A and CR were higher than sesame. In addition, planting cotton among sesame has higher monetary benefits than sesame sole monoculture[30]. The highest seed yield was obtained in intercropping through 2 rows of cowpea plants between maize plants. The land equivalent ratio is greater than for each intercropping[31]. Increasing the yield of long beans and corn in the intercropping system by giving a dosage of P fertilizer of 30 kg ha^{-1} and increasing the land equivalent ratio[32].

CONCLUSION

Based on the description above, it can be concluded as follows:

- There was an interaction between the source of organic fertilizer and the dosage of NPK fertilizer of 200-400 kg ha^{-1} on the dry weight of the plant and the chlorophyll content of the leaves of sweet corn, while other variables did not interact
- The best growth of sweet corn intercropping with vegetable soybean was obtained from a combination of chicken manure or cow manure and 300 kg of NPK fertilizer. The growth of the sweet corn plant with cow manure was not significantly different from that of municipal compost
- The highest yield of sweet corn cobs was obtained from the application of chicken manure and the lower yield was obtained from the application of cow manure and was not different from that of municipal compost
- The highest efficiency of intercropping was obtained in the combination of chicken or cow manure with NPK fertilizer dosage of 300 kg ha^{-1} with a LER value of 1.66, lower efficiency was obtained in the combination of cow manure and 300 kg of NPK not different from the combination of municipal compost and NPK dosage 400 kg ha^{-1} with a value of reaching a LER of 1.56. Likewise, the efficiency component includes RCC, CSE, A and CI

SIGNIFICANCE STATEMENT

The research was carried out because the need for functional food every year always increases along with the increase in population. With the decreasing fertile land available for agriculture, intercropping system becomes an option to improve crop yield in limited land area. The intercropping system of sweet corn and soybeans is expected to increase the productivity of both crops, land efficiency includes land equivalence ratio, competition index, crop system efficiency and total yield. Thus, the efficiency of the intercropping system is needed to be evaluated and the application of integrated fertilizer application should be studied further to optimize the intercropping system to improve crops yield.

ACKNOWLEDGMENT

The author would like to thank Ministry of Research Technology and Higher Education for providing financial support for this study through No. PDUPT.DIKTI.01/UST/LP2M/K/VI/2022.

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