Asian Journal of Plant Sciences

ISSN 1682-3974

OPEN ACCESS Asian Journal of Plant Sciences

ISSN 1682-3974
DOI: 10.3923/ajps.2020.107.113

Research Article

Maize-coconut Intercropping System in the Humid Tropics Dry Land of Indonesia

[1]Sofyan Abdullah, [2]Risma Neswati and [3]Nasruddin

[1]Hasanuddin University, Indonesia
[2]Department of Soil Science, Hasanuddin University, Indonesia
[3]Department of Agronomy, Hasanuddin University, Indonesia

Abstract

Background and Objective: Land productivity can be increased by optimizing land use and applying environmentally friendly technologies to achieve sustainable agriculture and one of them is intercropping. This study aims to analyze the growth and production of maize in the tropics of Indonesia's humid regions that utilize space under the coconut canopy. **Materials and Methods:** This study was carried out using a Randomized Block Design (RBD) where the treatment was given the combination of packages. The condition of the shade as the main plot consists of 3 levels namely; K0: Without coconut plants, K1: Shade of coconut plants aged 10-15 years and K2: Coconut plants >15 years. Plots were maize varieties namely; V1: Composite and V2: Hybrid. While plot children are fertilizing carried out in 3 stages, namely; F1: Fertilizing 100 kg urea ha^{-1}+200 kg NPK, F2: 150 kg urea+300 kg NPK and F3: 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1}. **Results:** The results showed that the age treatment of coconut plants had a very significant effect on plant height, number of rows per cob, production per hectare and weight of 1000 seeds. Variety treatment significantly affected the weight of 1000 seeds. **Conclusion:** Cultivation of maize in dry land intercropping with coconuts over 15 years old shows the economic feasibility with an average R/C ratio of 1.75 and monoculture maize cultivation (without coconut) has the best level of economic feasibility with an average R/C ratio of 1.94.

Key words: Intercropping, maize, coconut canopy, dry land, humid tropics, monoculture

Citation: Sofyan Abdullah, Risma Neswati and Nasruddin, 2020. Maize-coconut intercropping system in the humid tropics dry land of Indonesia. Asian J. Plant Sci., 19: 107-113.

Corresponding Author: Risma Neswati, Department of Soil Science, Hasanuddin University, Indonesia

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

Optimal use of natural resources is one way to increase the land productivity[1]. One of the environmentally friendly agricultural technologies that can support the program is intercropping[2], which includes the regulation of planting systems or cropping patterns, to achieve efficient water use, utilizing the canoe land or under the canopy which will increase farming capacity. The advantage of intercropping system is because the total yield of plant components is higher per unit area of land compared to monoculture on the same land area, suppression of disturbing organisms, protecting the soil against erosion and fertility stability[3]. Although there can also be a decrease in yield from one of the plants due to competition for the growth factor of CO_2, light, water and nutrients. Competition will increase if the available growth factors are in a limited state. Competition for light is the most important factor compared to competition for water and nutrients[2,4].

The effect of shade or the percentage of light received by low ethanol plants on the inter-culture system will be increasingly apparent in the regulation of planting spacing or population that is not optimal[4]. To increase acceptable light interception, double row arrangement and spacing in rows can be sought to reduce etiolation problems, as well as increase water and nutrient absorption. The distance from the main plant with high habitat in the inter-planting system can also be done, so that it can improve farming efficiency without having to add excessive seed input because of the optimal population achievement and prevent the influence of plant competition that may arise from overlapping roots and canopies.

Land use in new coconut plantations ranges from 15-20%, so monoculture exploitation of coconut plants is inefficient in terms of land use and solar energy utilization for the purpose of converting energy into plant biomass[5]. Gorontalo province is an area that has a wide area of coconut plantations and most of them are plantations with a monoculture system. For this reason, it is necessary to analyze the potency of space under the coconut canopy can be used for the development of maize as a superior commodity, taking into account the age of the coconut plant, plant spacing or broad unity population so that the growth of maize interrupted plants can be optimal and provide high production. This study aims to analyze the growth and production of maize in the humid tropics of Indonesia's dry land that utilize space under the coconut canopy.

MATERIALS AND METHODS

Study area: This study was carried out in the Gorontalo District of Indonesia from March-August, 2018 (Fig. 1).

Materials and research tools: Materials used in this activity include: Composite maize (Lamuru), hybrids maize (NK 33), NPK fertilizer. The equipment used consists of a solarimeter, a set of measurement equipment in the field including weather cage, dry and wet thermometer.

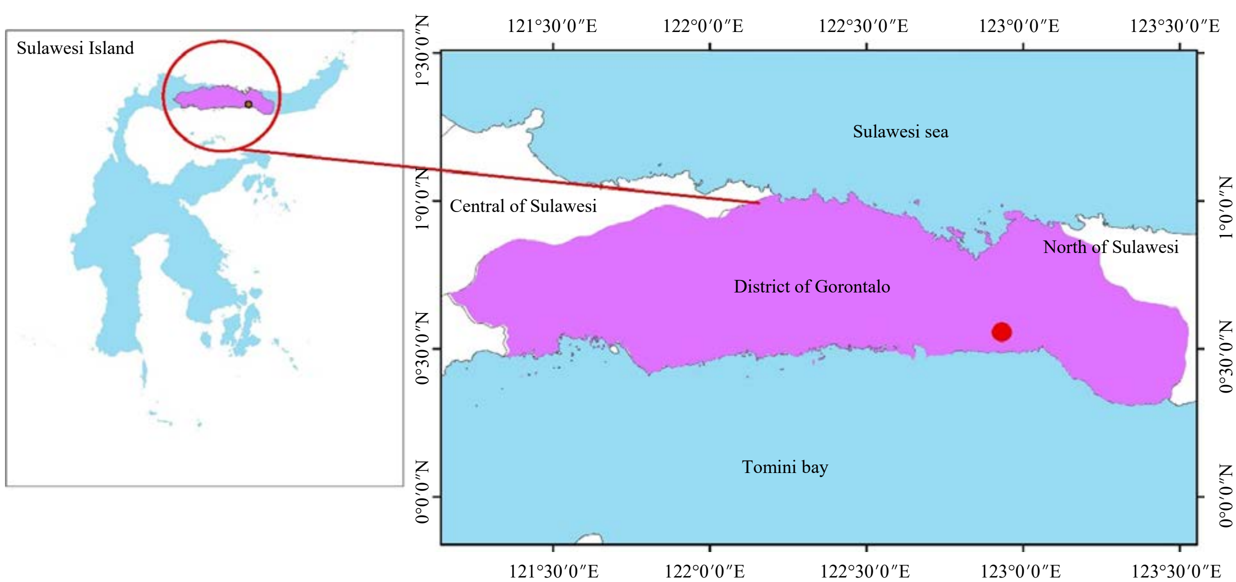

Fig. 1: Research location map by using Geographical Information System (GIS)

Research procedure: The research was carried out using a plot plan divided into Randomized Block Design (RBD) where the treatment was given a combination of packages: The condition of the shade as the main plot consisted of 3 levels i.e., K0: Without coconut, K1: Shade of coconut plants aged 10-15 years and K2: Coconut plants >15 years. As subplots are maize varieties namely; V1: Composite and V2: Hybrid. While plot children are fertilizing carried out in 3 stages namely; F1: Fertilizing 100 kg urea ha^{-1}+200 kg NPK, F2: 150 kg urea+ 300 kg NPK and F3: 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+ 50 kg KCl ha^{-1}. The 18 treatment combinations are as follows:

- K1V1F1, K1V1F2, K1V1F3, K1V2F1, K1V2F2, K1V2F3, K2V1F1, K2V1F2, K2V1F2, K2V2F1, K2V2F2, K2V2F3, K3V1F1, K3V1F2, K3V1F3, K3V2F1, K3V2F2, K3V2F3

Each treatment was repeated three times, so there were 54 experimental units. The selection of research sites is based on the condition of coconut plantations of various ages according to the existing cropping conditions. Furthermore, plots are made consisting of at least 3 rows of coconut planting. Maize planting is carried out in accordance with the standard planting distance and recommended cultivation techniques.

Observation of different parameters:

- **Agro-ecological data:**
  - Measurement of growth factors that affect main crops and intercropping plants are measured at: Initial planting, 30, 60 DAP and before harvest. The factors to be observed are:
  - Photosynthesis active radiation (PAR) with Licor-301 PS
  - Air temperature
  - Relative air humidity
- **Components of growth:**
  - The height of the crop (cm) are measured one day before harvesting, starting from the ground level until the last book of panicle stems
  - Number of leaves, counted all the leaves that are formed until the release of male flowers
- **Component yield:**
  - Dry weight of 1000 seeds at 14% moisture content, observed at the end of the experiment.
  - Dry shell production at 14% moisture content per plot and per hectare, observed at the end of the experiment
- **Economic analysis:**
  - Economic analysis can be calculated at the end of the activity by calculating the R/C (Revenue/Cost) ratio[6] of each treatment by using Eq. 1:

$$\text{R/C ratio} = \frac{\text{Total revenue}}{\text{Total cost}} \quad (1)$$

Statistical analysis: This study was carried out using a separate plot design in a random group and for statistical data analysis was using a SPSS software version 24. To know the significance difference between treatments, a Least Significance Different (LSD) test was performed.

RESULTS AND DISCUSSION

The results of the statistical analysis in Table 1 show that the age treatment of coconut plants significantly affected plant height, number of leaves, production per plot, weight of 1000 seeds and production per hectare. Variety treatment significantly affected the weight of 1000 seeds, but no significant effect on other parameters. Fertilization treatment did not significantly affect all parameters observed. All interactions of coconut age treatment with varieties and fertilization did not significantly affect all parameters measured.

Plant height: Table 1 shows that the age treatment of coconuts has a very significant effect on the height of maize. Variety and fertilization treatments and their interactions have no significant effect.

Figure 2 shows that maize plants under coconut aged 10-15 years (K1) are higher and significantly different than maize plants without coconut plants (K0) and maize plants under coconut age above 15 years (K2). Hybrid varieties (V2) tend to be higher than composite varieties (V1) and fertilization with a dose of 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3) tends to be higher than fertilization with dose of 100 kg urea ha^{-1}+200 kg NPK (F1) and 150 kg urea+300 kg NPK (F2). Growth and development of vegetative parts of plants on the ground is largely determined by the activity of the apical meristem[7]. The development of stem elongation is generally included in maize plants depending on the new stem tissue formed at the tip which is controlled by phyto-hormone activity originating from the end meristem tissue and young leaves. The test results showed that the maize planted under coconut plants aged 10-15 years showed a higher plant height and was significantly different from the plants that had maize without coconut plants and maize under coconut plants aged over 15 years. This growth condition is mainly due to the shade of maize which tends to lead to etiolation. In shaded plants, especially in C4 plants such as maize, elongation of the stems will increase and leaf thickness decreases due to changes in the quality of light towards the distant red[8].

Table 1: Parameters observed for intercropping of maize-coconut

	F-calculate of treatments						
Parameters	Ages of coconut (K)	Maize variety (V)	Fertilizer (F)	KV	KF	VF	KVF
Plant height	112.0562**	1.9869^{tn}	0.0003^{tn}	1.4484^{tn}	0.00026^{tn}	0.0001^{tn}	3.0131^{tn}
Number of leaves	71.3193**	0.6212^{tn}	1.4112^{tn}	3.0008^{tn}	0.00017^{tn}	0.0004^{tn}	1.6317^{tn}
Weight of 1000 seeds	14.6114*	11.8326*	0.0001^{tn}	2.4355^{tn}	0.0005^{tn}	0.0002^{tn}	0.0001^{tn}
Maize yield per plot	19.9762**	0.0794^{tn}	0.0001^{tn}	4.9909^{tn}	0.0001^{tn}	0.0001^{tn}	0.0003^{tn}
Maize yield per ha	19.9762**	0.0794^{tn}	0.0001^{tn}	4.9909^{tn}	0.0021^{tn}	0.0003^{tn}	0.0001^{tn}
F. Table 0.05	6.94	5.99	3.40	5.14	2.78	3.40	2.78
F. Table 0.01	18.00	13.74	5.61	10.92	4.22	5.61	4.22

tn: Not significant, *Significant at level 5%, **Significant at level 1%, KV: F calculate of coconut x maize variety, KF: F calculate of coconut×fertilizer, VF: F calculate of maize variety×fertilizer, KVF: F calculate of coconut×maize variety×fertilizer

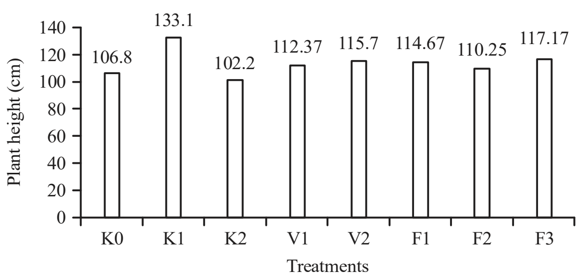

Fig. 2: Average plant height of each intercropping treatment, varieties (V1, V2) and fertilizer dosage (F1, F2, F3)

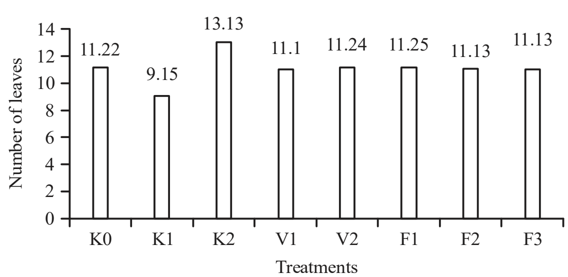

Fig. 3: Average number of leaves of maize in each intercropping treatment, varieties and fertilizer dosage

Number of leaves: Table 1 shows that the age of coconut treatment has a very significant effect on the number of leaves. Variety and fertilization treatments and their interactions have no significant effect. Figure 3 shows that maize plants under coconut age more than 15 years (K2) have more leaves and are significantly different compared to maize plants under coconut age below 15 years (K1) and maize plants without coconut plants (K0). Hybrid varieties (V2) tend to have more leaves than composite varieties (V1) and fertilization with a dose of 100 kg urea ha^{-1}+ 200 kg NPK (F1) tends to have more leaf counts than fertilizing with a 150 kg urea+300 kg dose NPK (F2) and fertilizing with a dose of 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3). Under shaded plants conditions will cause phyto-hormone activity at the end meristem will increase and encourage elongated growth, on the contrary it will suppress growth to the side so that growth and leaf size decreases and will result in the number of plant leaves formed and the total leaf area of the plant decreases. A low total leaf area will result in a low total photosynthesis rate as a result of the low total leaf area that can photosynthesize so that the formation of plant organs will decrease[9-11].

Seeds weight: Table 1 shows that the coconut age treatment had a very significant effect, while the variety and fertilizer dosage as well as all interactions did not significantly affect the weight of 1000 seeds (14% of water content). Figure 4 shows that maize grown under coconuts over 15 years (K2) has an average weight of 1000 seeds were heavier and significantly different than the weights of 1000 produced on maize planted under coconut aged 10-15 years (K1), but not significantly different with the weight of 1000 seeds in maize planted without coconut shade (K0), hybrid varieties (V2) tend to have an average weight of 1000 seeds heavier than the composite variety (V1). Maize plants fertilized at a dose of 100 kg urea ha^{-1}+200 kg NPK (F1) tend to have an average weight of 1000 KA seeds heavier than seeds of maize plants fertilized at a dose of 150 kg urea+300 kg NPK (F2) and fertilizing with a dose of 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3).

Maize yield per plot and per hectare: Table 1 shows that the coconut age treatment has a very significant effect, while the variety and dosage of fertilization as well as all interactions have no significant effect on the dry grain yield per plot and per hectare.

Figure 5 shows that maize grown without shade (K0) has an average of dry grain maize yield per plot which is higher and significantly different from average of dry grain maize yield per plot produced on maize plants grown in under coconut aged over 15 years (K2) and maize plants planted below coconut age 10-15 years (K1), composite varieties (V1) tend to have higher average of dry grain maize

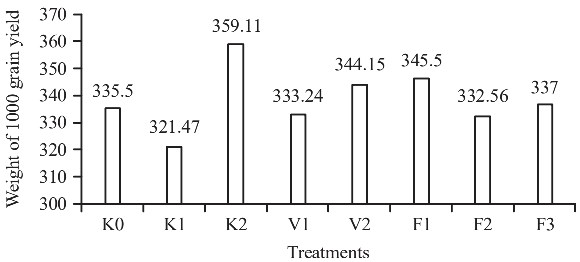

Fig. 4: Average weight of 1000 grain yield of maize in each intercropping treatment, varieties and fertilizer dosage

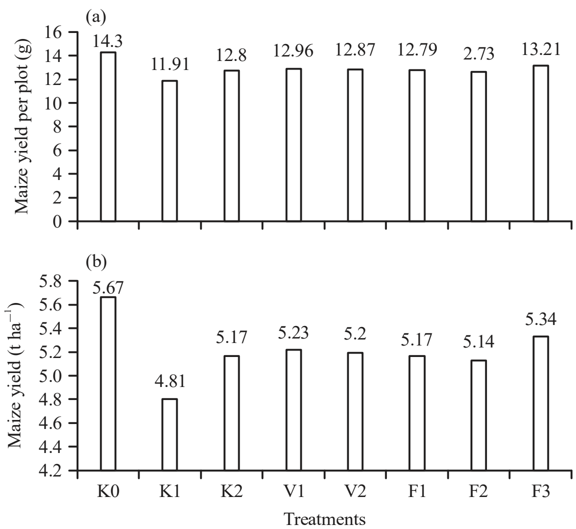

Fig. 5(a-b): Average of (a) Dry grain maize yield per plot and (b) Per hectare, for each maize-coconut intercropping treatment, varieties and fertilizer dosage

yield per plot (Fig. 5a) compared to hybrid varieties (V2). Maize plants fertilized at a dose of 150 kg urea+300 kg NPK (F2), tend to have an average of dry grain maize yield per plot (Fig. 5a) higher than seeds of maize plants fertilized at a dose of 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3) and fertilizing with a dose of 100 kg urea ha^{-1}+200 kg NPK (F1). Figure 5 shows that maize planted without shade (K0) has an average of dry grain maize yield per hectare (Fig. 5b) which is significantly higher than average of dry grain maize yield per hectare (Fig. 5b) produced on maize planted below coconut aged 10-15 years (K1), but not significantly different from the average of dry grain maize yield per hectare (Fig. 5b) produced on maize planted under coconut aged over 15 years (K2), composite varieties (V1) tend to have average of dry grain maize yield per hectare (Fig. 5b) is higher than that of hybrid varieties (V2). Maize plants that are fertilized with a dosage of 200 kg urea ha^{-1}+100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3), tend to have an average of dry grain maize yield per hectare (Fig. 5b) more height of maize seeds fertilized with a dose of 100 kg urea ha^{-1}+200 kg NPK (F1) and a dose of 150 kg urea+300 kg NPK (F2).

The LSD test results showed that the treatment of coconut shade has a very significant effect on the components of maize production. Maize plants grown under coconut plants aged 10-15 years show a lower component of production and are significantly different compared to maize plants under coconut plants aged over 15 years and without shade. Maize plants under coconut plants aged over 15 years show almost the same production as maize plants without coconut plants. This is due to the fact that maize plants are plants that belong to the C4 group which have optimum temperatures for photosynthesis that are relatively high. In maize plants, the optimum photosynthesis rate occurs at temperatures[12-14] between 30-33°C.

The average of air temperature without coconut shade is around 33.2°C, under coconut aged 10-15 years 31.6°C above 15 years around 32.2°C (Table 2). The results of observations with the portable photosynthesis system CID-301 PS show that the lowest photosynthesis rate occurs in maize under coconut aged 10-15 years which is 15.32 μmol m^{-2} sec and the highest occurs in maize plants without shade with the rate of photosynthesis an average of 20.98 μmol m^{-2} sec, while in maize plants under coconut age over 15 years reached an average of 20.68 μmol m^{-2} sec (almost the same as a maize plant without shade) (Table 2). Differences in the rate of photosynthesis of maize plants planted under coconut trees that have different shading rates result in the amount of assimilate that can be utilized for the formation and filling of panicles on maize plants without coconut plants and maize plants under coconut more than 15 years of age. These results in the formation of grains on maize plants without coconut shade and maize plants under coconut aged over 15 years higher than maize plants under coconut aged 10-15 years.

Economic analysis: Economic analysis that calculates R/C ratio values shows R/C>1. According to Dhakal *et al.*[15], Bwala and John[16] and Branca *et al.*[17] that the cultivation with an R/C value >1 indicates that the business is profitable. Table 3 shows that the use of composite varieties under a coconut tree is more beneficial than the use of hybrid varieties. Likewise, the use of a single fertilizer dose with a dose of 200 kg urea ha^{-1}+ 100 kg TSP/SP 36 ha^{-1}+50 kg KCl ha^{-1} (F3) was more beneficial compared to the use of compound fertilizers (F1 and F2).

The feasibility level of maize farming from the calculation of R/C ratio is obtained the highest in the treatment of planting composite maize with the use of fertilizer 100 kg urea+200 kg NPK that is 2.35 (K0V1F1). In Table 3, the

Table 2: Data of licor system CID-301 PS measurements

Treatments	T. air (°C)	T. leaf (°C)	RH (%)	CO_2 out (ppm)	PAR (µmol m^{-2} sec)	CO_2 (mmol m^{-2} sec)	P (µmol m^{-2} sec)	E (mmol m^{-2} sec)	C (mmol m^{-2} sec)
K0V1F1	33.13	35.33	56.85	498.33	1184.60	296.15	19.48	5.57	118.46
K0V1F2	33.72	35.92	57.13	482.77	1325.60	331.40	21.80	6.23	132.56
K0V1F3	33.15	35.35	57.32	510.12	1296.39	324.10	21.32	6.09	129.64
K0V2F1	33.27	35.47	53.75	492.72	1335.55	333.89	21.97	6.28	133.56
K0V2F2	33.15	35.35	55.92	489.28	1175.55	293.89	19.33	5.52	117.56
K0V2F3	32.98	35.18	57.08	492.87	1335.70	333.93	21.97	6.28	133.57
Average	33.23	35.43	56.34	494.35	1275.57	318.89	20.98	5.99	127.56
K1V1F1	31.91	34.11	58.88	502.33	950.66	475.33	18.28	3.39	135.81
K1V1F2	32.08	34.28	59.87	510.35	724.44	362.22	13.93	2.58	103.49
K1V1F3	32.19	34.39	58.92	518.39	898.07	449.03	17.27	3.20	128.30
K1V2F1	30.05	32.25	59.12	525.91	954.15	477.07	18.35	3.40	136.31
K1V2F2	31.35	33.55	58.92	533.74	601.75	300.87	11.57	2.14	85.96
K1V2F3	32.05	34.25	58.63	541.76	650.63	325.32	12.51	2.32	92.95
Average	31.61	33.81	59.06	522.08	796.62	398.31	15.32	2.84	113.80
K2V1F1	32.56	34.76	57.93	496.35	1067.63	355.88	21.31	5.20	118.63
K2V1F2	33.05	35.25	58.75	508.14	1025.02	341.67	20.46	4.99	113.89
K2V1F3	31.98	34.18	56.97	498.49	1097.23	365.74	21.90	5.34	121.91
K2V2F1	32.82	35.02	58.37	510.94	1144.85	381.62	22.85	5.57	127.21
K2V2F2	31.96	34.16	56.93	516.58	888.65	296.22	17.74	4.33	98.74
K2V2F3	31.89	34.09	56.82	518.79	993.17	331.06	19.82	4.84	110.35
Average	32.38	34.58	57.63	508.21	1036.09	345.36	20.68	5.04	115.12
Average V1	32.64	34.84	58.07	502.81	1063.29	366.84	19.53	4.73	122.52
Average V2	32.48	34.68	57.80	506.42	1089.03	374.08	19.98	4.85	125.21
Average F1	32.29	34.49	57.48	504.43	1106.24	386.66	20.37	4.90	128.33
Average F2	32.55	34.75	57.92	506.81	956.83	321.04	17.47	4.30	108.70

T. air: Total average air, T. leaf: Total average leaf, RH: Relative humidity, PAR: Photosynthesis active radiation, P: Light intensity, E: Stomatal conductance, C: Transpiration

Table 3: Economic analysis of maize-coconut intercropping

Treatments			R/C	Average R/C
K0	V1	F1	2.35	1.94
		F2	1.82	
		F3	2.24	
	V2	F1	1.73	
		F2	1.59	
		F3	1.92	
K1	V1	F1	1.75	1.64
		F2	1.64	
		F3	1.74	
	V2	F1	1.43	
		F2	1.52	
		F3	1.72	
K2	V1	F1	1.81	1.75
		F2	1.75	
		F3	1.73	
	V2	F1	1.79	
		F2	1.60	
		F3	1.82	

K0: Plant without coconut, K1: Coconut plant aged 10-15 years, K2: Coconut plants >15 years, V1: Compost varieties, V2: Hybrid varieties

R/C ratio calculation shows that in general maize farming without coconut is more profitable than planting maize under coconut with an R/C ratio of 1.94. However, land use under coconut plantations over the age of 15 years is still quite feasible to be cultivated with an R/C ratio of 1.75 and under a coconut plant aged 10-15 years with an R/C ratio of 1.64. The composite varieties are more feasible to use compared with hybrid varieties. Likewise, the use of a single fertilizer is more feasible than the use of compound fertilizers.

CONCLUSION

Maize cultivation without coconut shade, hybrid varieties with a single fertilizer have higher maize yield compared to other treatments with coconut shade with compound fertilizer. Cultivation of maize intercropping with coconut plants over 15 years of age results in fairly good growth and maize yield, while in intercropping maize aged 10-15 years, the lowest growth and production is obtained. Monoculture maize cultivation (without coconut) provides a higher level of feasibility of farming than intercropping systems.

SIGNIFICANCE STATEMENT

This study shows the growth and production of maize under the canopy of coconut with intercropping systems in the humid tropics of Indonesia area. These results can be used as a reference for other researchers to verify this model in areas with different agro-ecology. This study will show to other researchers that the utilization of the space under shades/canopy can be one of the alternatives to increase the land productivity.

ACKNOWLEDGMENT

The author would like to thank Gorontalo district government of Indonesia for the support of the data needed in this study. In addition, thanks were extended to the Faculty of Agriculture, Hasanuddin University, Indonesia, who supported this research by providing tools and materials for the analysis of this research data.

REFERENCES

1. FAO., 2017. The future of food and agriculture: Trends and challenges. Food and Agricultural Organization of the United Nations. Rome. http://www.fao.org/3/a-i6583e.pdf
2. Ennin, S.A., B. Banful, E. Andoh-Mensah, R.N. Issaka and J.N. Lamptey *et al*., 2009. Food crop intercropping alternatives for replanting coconut farms destroyed by lethal yellowing disease. J. Food Agric. Environ., 7: 581-587.
3. Mousavi, S.R. and H. Eskandari, 2011. A general overview on intercropping and its advantages in sustainable agriculture. J. Applied Environ. Biol. Sci., 1: 482-486.
4. Braconnier, S., 1998. Maize-coconut intercropping: Effects of shade and root competition on maize growth and yield. Agronomie, 18: 373-382.
5. Gunathilake, H.A.J., 2019. Technological developments on coconut crop improvement, coconut agronomy/nutrition and coconut based farming system in Sri Lanka. https://library.apccsec.org/paneladmin/doc/20180404063426Dr.%20H.A.J.%20Gunathilake.60.pdf
6. Soekartawi, 1995. Ilmu Usaha Tani. UI Press, Jakarta.
7. Brukhin, V. and N. Morozova, 2011. Plant growth and development-basic knowledge and current views. Math. Modell. Natl. Phenomena, 6: 1-5.
8. Fan, Y., J. Chen, Y. Cheng, M.A. Raza and X. Wu *et al*., 2018. Effect of shading and light recovery on the growth, leaf structure and photosynthetic performance of soybean in a maize-soybean relay-strip intercropping system. PloS One, Vol. 13, No. 5. 10.1371/ journal.pone.0198159.
9. Weraduwage, S.M., J. Chen, F.C. Anozie, A. Morales, S.E. Weise, T.D. Sharkey, 2015. The relationship between leaf area growth and biomass accumulation in *Arabidopsis thaliana*. Front Plant Sci. 10.3389/fpls.2015.00167.
10. Koester, R.P., J.A. Skoneczka, T.R. Cary, B.W. Diers and E.A. Ainsworth, 2014. Historical gains in soybean (*Glycine max* Merr.) seed yield are driven by linear increases in light interception, energy conversion and partitioning efficiencies. J. Exp. Bot., 65: 3311-3321.
11. Gifford, R.M., J.H. Thorne, W.D. Hatz and R.T. Giaquinta, 1984. Crop productivity and photoassimilate partitioning. Science, 225: 801-808.
12. Benomar, L., M.T. Moutaoufik, R. Elferjani, N. Isabel and A. DesRochers *et al*., 2019. Thermal acclimation of photosynthetic activity and RuBisCO content in two hybrid poplar clones. PloS One, Vol. 14, No. 2. 10.1371/journal.pone.0206021.
13. Hatfield, J.L. and J.H. Prueger, 2015. Temperature extremes: Effect on plant growth and development. Weather Clim. Extremes, 10: 4-10.
14. Winter, S.R. and J.W. Pendleton, 1970. Results of changing light and temperature regimes in a corn field and temperature effects on the apparent photosynthesis of individual leaves. Agron. J., 62: 181-184.
15. Dhakal, S.C., P.P. Regmi, R.B. Thapa, S.K. Sah and D.B. Khatri-Chhetri, 2015. Productivity and profitability of maize-pumpkin mix cropping in Chitwan, Nepal. J. Maize Res. Dev., 1: 112-122.
16. Bwala, M.A. and A.U. John, 2018. Profitability analysis of paddy production: A case of agricultural zone 1, Niger State Nigeria. J. Bangladesh Agric. Univ., 16: 88-92.
17. Branca, G., A. Arslan, A. Paolantanio, R. Cavatassi, N. McCarthy, N. VanLinh and L. Lipper, 2018. Economic Analysis of Improved Smallholder Paddy and Maize Production in Northern Viet Nam and Implications for Climate-Smart Agriculture. In: Climate Smart Agriculture, Natural Resource Management and Policy, Vol. 52, Lipper, L., N. McCarthy, D. Zilberman, S. Asfaw and G. Branca (Eds.)., Springer, Cham, pp: 563-595.