RADIATION USE EFFICIENCY AND SOIL WATER CONTENT ON MAIZE-MUNGBEAN INTERCROPPING

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Abstract

Mungbean is traditionally intercropped with maize by small-scale farmers which do widely in the tropics, including Southeast Sulawesi. This study aims to assess the radiation use efficiency (RUE) and soil water content (SWC) in maize intercropped with mungbean. The research was arranged on Split-Plot Design of two factors, i.e. dose of "komba-komba" compost as the main plot consists on 5 t ha^{-1} and 10 t ha^{-1} and planting time of mungbean as a subplot, consists on planting mungbean with maize at the same time, delayed planting of mungbean 7 and 14 days after planting (DAP) of maize. The results shown that the highest RUE of maize 2.69 g MJ^{-1} and 3.15 g MJ^{-1} obtained on komba-komba compost dose 10 t ha^{-1} and planting mungbean 7 DAP of maize, while highest RUE of mungbean 0.31 g MJ^{-1} and 0.60 g MJ^{-1} obtained on komba-komba compost dose 10 t ha^{-1} and planting mungbean and maize at the same time, respectively. The soil temperature has negatively correlated with (SWC) that at the komba-komba compost with r_{xy} = - 0.7422 and at the time planting of mungbean in intercropping with maize with r_{xy} = - 0.7922.

Keywords: intercropped, RUE, SWC, komba-komba, delayed planting.

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INTRODUCTION

Cropping system is defined as a combination of some of the plants grown in a particular area and at the same time. Forms of farming and cropping systems is varies and can be found throughout the world, as a result of variations in climate, soils, economic and social structures (Seran and Brintha, 2010). Solar radiation, water balance, temperature and soil conditions are the main factors that determine the ability of a plant to grow and evolve as well as the success of cropping systems developed. Therefore, the design of cropping systems must be tailored to the capacities and advantages of regional resources that can be adapted by farmers in increasing productivity and secure of production stability.

Intercropping is one form of the cropping system of planting two or more types of crops which done simultaneously on the same land during the growing season. Verdelli *et al*. (2012) stated that intercropping is basically a merger of two or more crops are grown on the land and the same time. This is a cheap and simple way which has been recognized as a technology of cultivation, especially in dry climates that aims to increase production and profits of both types the intercropped plants compared with monocultures.

Some of the advantages obtained in intercropping compared with monoculture crops such as; (a) optimize the utilization of land resources (Shafiq *et al*., 2003; Ogindo and Walker, 2005; Adeniyan *et al*., 2007), (b) minimizing crop failure, (c) maximize production per unit area (Pandita, 2001; Ciftci *et al*., 2006), (d) produce a variety of food, (E) deciding the life cycle of the pest, (f) improving economy and income of farmers (Suresha *et al*., 2007; Seran and Brintha, 2009) and (g) support the establishment of sustainable agriculture (Ciftci *et al*., 2006).

Intercropping maize with mungbean farmers generally done in such dry areas in Southeast Sulawesi not only in the dry season but also during the wet season. Productivity obtained in the dry season generally lower than the productivity in the wet season. Koesmaryono *et al*. (2005) stated that low production during the dry season due to lack of effective rainfall on the other hand and the high flux density of solar radiation on the other side so the rate of water loss through evapotranspiration is increased.

Solar radiation is an important component of the climate relation to phenological development, plant growth and production. Koesmaryono and Sabaruddin (2005); Worku and Skjeivag (2006) state that as the elements of climate that affecting photosynthesis, amount of radiation absorbed by the plants depends on the intensity of radiation which arrives at the surface of plant and type of crops were cultivated. Therefore, maize (C4 type) that has a high levels of light saturation can be intercropped with mungbean (C3 type) which has a low level of light saturation. Other climate elements such as soil water content also plays an important role in supporting the growth rate of plants, primarily in the leaves formation, reproductive organ initiation and grain filling. The study aims to assess the solar RUE and SWC in intercropping maize with mungbean.

MATERIAL AND METHODS

Place and Time Research

The experiment was conducted in the field trial to assess the RUE of the radiation use and soil water content in maize intercropped with mungbean held in Experimental Farm, Faculty of Agriculture Halu Oleo University, Kendari. Research site is located at an altitude of 25 m above sea level at coordinates 4^0 00’ 46” SL and 122^0 31’ 06” east longitude. The experiment lasted for five months i.e. from July to November 2009.

The Design of Experiment

The research was arranged on Split-Plot Design consisting of two factors, i.e. dose of “komba-komba” compost as the main plot consists on 5 t ha^{-1} (B_1) and 10 t ha^{-1} (B_2) and planting time of mungbean as a subplot, consists on planting mungbean with maize at the same time (W_0), delayed planting of mungbean 7 (W_1) and 14 (W_2) DAP of maize.

Implementation of the Experiment

Before tillage, soil samples were taken prior to analyze its properties. Soil sampling includes soil sample intact (undisturbed soil samples) for analysis of physical properties such as moisture content and texture and disturbed soil samples for determination of chemical properties of the soil. Land clearing of grass and the remains of plant roots is done before making of the experimental plots.

The first processing with in turn the soil and left for a week to remove gases and toxic substances contained in the soil. The first tillage is done by reversing the ground and left for one week to remove acidic substances contained in the soil. Secondary process includes the destruction of soil masses and tilling the soil surface becomes flat. The second tillage aim to control weeds, improve soil porosity, breaking up the soil and soil aeration and air system is better so that more extensive root cruising breaking up the soil to improve soil aeration and air system to extend the cruising range of the roots. Next step is preparation of experimental units each with a size of 2.5 m x 3 m.

Organic matter of "Komba-Komba" collected from around of the experiment. Komba-Komba in the form of fresh-cut into pieces along 1 cm, then composted into the sack, after two weeks in a sack and then aerating removed and dried before applied. Application of "Komba-Komba" compost on experimental plots given two days before planting with appropriate treatment dose. Whereas inorganic fertilizer application (75 kg ha^{-1} urea, 100 kg ha^{-1} superphospate-36 and 50 kg ha^{-1} potassium) consists of two times: a day before planting (40% urea and potassium and 100% phospate-36 per hectare) and during vegetative growth of maize (35 days) with 60% urea and potassium dose per hectare. Maize and mungbean were planted at each planting distance i.e. 75 cm x 50 cm and 37.5 cm x 25 cm.

The maintenance plants includes watering, replanting, while weed, pest and disease control. Watering is using by the "hype", is done every day if not rainy on afternoon, given on each plot with the same volume is 6 mm (equivalent amount of evaporation). Stitching on plants that not grow is done a week after planting. Weed control is done by pulling weeds or to clean it by using a hoe.

Data Collection and Analysis

Components of solar radiation are measured include radiation intensity arriving at the top of maize plants (Rg_m as global radiation in maize) and transmission radiation of maize ($R\tau_m$) and under maize or on top of mungbean canopy (as global radiation of mungbean, Rg_b) and radiation at the bottom as the transmission radiation of mungbean ($R\tau_b$). Radiation use efficiency (RUE) is calculated using the formula (Koesmaryono and Sabaruddin, 2005;

Verdeli *et al.*, 2012; Worku and Demisie, 2012), as follows;

$$RUE = \frac{Y}{R_{\text{int}}}$$

where: Y : production (t ha^{-1}) and R_{in} : radiation interception (MJ m^{-2})

Radiation intensity observations is done every day from 7:30 pm to 15:30 am by using *digital light meters*. The amount of interception radiation in plants (maize and mungbean) was calculated from the difference between the amount of radiation at the top of canopy to the amount of radiation to below the plant as transmission radiation. Interception radiation on maize and mungbean on the plant can be calculated by the equation as follows; (Keating and Carberry; 1993; Sabaruddin *et al.*, 2004; Verdeli *et al.*, 2012; Worku and Demisie, 2012).

Intercepted radiation on maize is

$R_{int;m} = R_{gm} - R\tau_m$; and

Intercepted radiation on mungbean is

$R_{int;b} = R_{g\,b} - R\tau_b$;

where: Rg: the amount of radiation arriving at the top of the canopy (cal cm^{-2} s^{-1}); $R\tau$: the amount of radiation transmitted on the bottom surface of the canopy (cal cm^{-2} s^{-1}); m: maize; b: mungbean; $R\tau m = Rgb$

The observations of soil water content performed using soil moisture tester (model PMS-714) were conducted once in three days. The observation data of the soil water content were analyzed with using the correlation test. To determine closeness and direction of the relationship between two variables were tested and followed by t-test to determine whether the correlation between two variables were tested real or not real.

RESULTS AND DISCUSSION

Intercepted Radiation

The results of radiation interception calculation, yield of maize and mungbean and radiation use efficiency (RUE) of maize and mungbean are presented in Table 1 and Table 2. Total radiation interception due on maize and mungbean increases began to enter the stage of flower initiation or when plants having active vegetative growth stage until the grain filling. Active vegetative growth stage characterized by an increased rate of growth of the vegetative parts of plants such as the number of branches, number of leaves and leaf area.

Table 1 it appears that the highest R_{int} of maize is 3.14 MJ^{-2} d^{-1} obtained at planting mungbean 7 DAP of maize, followed by planting maize and mungbean at the same time 3.10 MJ^{-2} d^{-1} and the lowest at delayed planting time of mungbean 14 DAP of maize. The differences are thought to be caused by the active growth rate of mungbean at planting delays 7 DAP of maize, coincided with the active growth of maize, so nitrogen fixation results of mungbean can be used by maize to spur its growth. While the delay planting of mungbean 14 DAP of maize produce lower R_{int} of maize 3.08 MJ^{-2} d^{-1}.

In mungbean plants, the highest of R_{int} is 2.12 MJ^{-2} d^{-1} is occurred when planting mungbean and maize at the same time and the lowest is 1.78 MJ^{-2} d^{-1} on delayed planting of mungbean 14 DAP of maize. The mungbean were planted simultaneously with maize, the growth rate both in tandem so that produce a perfect canopy and withstand the maximum radiation. Koesmaryono and Sabaruddin (2005) states that the difference in the amount of radiation received by the plants in intercropping system is determined by the amount of radiation received by the canopy, the optical characteristics of the plant and the geometrical structure of plants (stems and leaves).

Table 1 Radiation interception, radiation use efficiency and production on maize and mungbean in intercropping system

Planting time of Mungbean	R_{int} (MJ m^{-2} d^{-1})		Yield (t ha^{-1})		RUE (g MJ^{-1})	
	Maize	Mung-bean	Maize	Mung-bean	Maize	Mung-bean
Planting maize and mungbean simultaneously	3.10^{ab}	2.12^{a}	8.15^{b}	0.89^{a}	2.92^{b}	0.60^{a}
Planting mungbean 7 DAP of maize	3.14^{a}	1.95^{b}	8.91^{a}	0.60^{b}	3.15^{a}	0.44^{b}
Planting mungbean 14 DAP of maize	3.08^{b}	1,78^{c}	7.99^{c}	0.57^{b}	2.88^{c}	0.46^{ab}
LSD-0.05	0.05	0.13	0.07	0.11	0.04	0.14

Remarks: Number followed by the same letter in the same collum are not significantly different at 95% test level

The RUE of maize is highest 3.15 g MJ^{-1} occurs at a delayed planting time of mungbean 7 DAP of maize and for mungbean is 0.60 g MJ^{-1} occurs in planting time of mungbean maize at same time. The radiation use efficiency that occurs at mungbean is very low allegedly because since the beginning of its growth, mungbean plants stressed by maize. These results indicate that the amount of radiation received by maize was higher than mungbean so produced different RUE values. The difference of RUE between maize and mungbean are caused by differences in the level of light saturation, wherein maize plants as C4 type have a higher saturation level than mungbean (as C3). Black and Ong (2000), stating the RUE crops ranged between 1.05 g MJ^{-1} to 2.3 g MJ^{-1} for groups of C4 plants and between 1.0 g MJ^{-1} to 1.5 g MJ^{-1} for C3 plants. The results of RUE of local maize varieties "Muna" which intercropped with mungbean Kijang varieties, respectively for maize ranged between 0.76 - 0.87 g MJ^{-1} (Rainy Season) and 0.63 - 0.75 g MJ^{-1} (Dry Season) and mungbean 12:35 - 0:36 g MJ^{-1} (rainy season) and 0.19 - 0.38 g MJ^{-1} (Dry Season) (Koesmaryono and Sabaruddin, 2005).

In Table 2 it appears that the application of komba-komba compost 10 t ha^{-1} resulted R_{int} 3.21 MJ^{-2} d^{-1} (maize) and 3.10 MJ^{-2} d^{-1} (mungbean) is higher than 5 t ha^{-1}. The difference is caused by differences in the amount of plant nutrients derived from komba-komba compost. The amount of radiation that is retained by the plants into energy that used for metabolic processes, due for vegetative growth (formation and leaf expansion and stem elongation) or generative components (flower initiation and grain filling). These conditions have implications for the value of the RUE, which is dose of "komba-komba" compost 10 t ha^{-1} produced RUE 2.69 g MJ^{-1} (maize) and 0.31 g MJ^{-1} (mungbean) is higher than the rate of 5 t ha^{-1}.

Table 2. Radiation interception, radiation use efficiency and production in maize and mungbean intercropped

Dose of Komba-Komba Compost (t ha^{-1})	R_{int}		Yield (t ha^{-1})		RUE (g MJ^{-1})	
	Maize	Mung-bean	Maize	Mung-bean	Maize	Mung-bean
5	3.10	2.16	7.38	0.61	2.38	0.28
10	3.21	2.47	8.65	0.76	2.69	0.31

Soil water content is one of the components of soil physical properties plays an important role in the process of growth and crop production. The water content in the soil varies according to soil type, soil texture, climate, especially precipitation and soil temperature, season and cultivation system used. Differences cultivation system can affect the soil physical properties and soil temperature which further affect the ability of the soil holds water (water holding capacity).

The results indicated that soil temperatures were observed in the rooting depth (20 cm) shows a close correlation or relationship with soil water content (Figure 1).

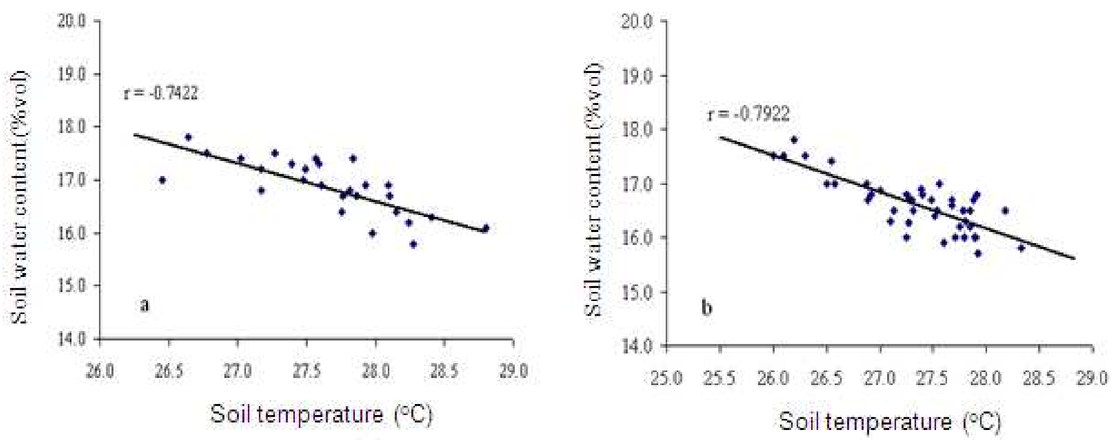

Figure 1 Correlation between soil temperature with soil water content; (a) on the provision of komba-komba compost and (b) planting time of mungbean in intercropping with maize (b).

Figure 1 shows that the soil temperature was negatively correlated with soil water content, namely the provision of "komba-komba" compost with r_{xy} = - 0.7422 and at planting time of mungbean in intercropping systems with maize with r_{xy} = - 0.7922. Based on the results of statistical analysis, the t-test result greater than the value -5.6477 $t_{0.025}$ = 2.086 and -8.2131 greater than the value $t_{0.025}$ = 2.021 on composting of "komba-komba" and planting time of mungbean, respectively. The relationship between soil temperature with soil water content showed a negative significant correlation. The implications of these relationships is an increasing of soil temperature at a depth of rooting resulted the decreasing the soil water content or vice versa. Irianto *et al*. (1997) stated that the relationship of soil temperature with soil water content is inversely proportional, i.e if the soil water content increases the soil temperature is decreases and vice versa if the temperature of the soil increases soil water content is decreases. Jong *et al*. (2011) stated that water loss in the root zone due effected to evaporation and transpiration to increased soil temperatures and low rainfall.

CONCLUSION

The highest of RUE on maize is 3.15 g MJ^{-1} if the mungbean is planted 7 DAP of maize and the RUE of mungbean highest 0.60 g MJ^{-1} occurs at planting mungbean with maize at the same time. Soil water content in the rooting depth and varies according to temperature and correlates both real and negative. The correlation between soil temperature and soil water content on "komba-komba" compost with planting time of mungbean with maize each with r_{xy} = - 0.7422 and r_{xy} = - 0.7922.

ACKNOWLEDGEMENTS

We gratefully thanks to the Rector of the Halu Oleo University that has provided research funding through DIPA of UNHALU with Number: 76-3/PK/UPT/ UNHALU/2009, May 5, 2009.

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