Land Use Efficiency in Maize and Legume Under Intercropping System

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Abstract- Intercropping is an agricultural system where on one land there are two or more plants. Intercropping is an alternative cultivation technology to increase land productivity. Apart from that, intercropping provides benefits in managing soil erosion, controlling weeds and improving soil fertility and contributing to biodiversity, thereby reducing the risk of failure. The existence of differences in morphological characteristics between two or more plants in one field simultaneously at the same time is one of the efforts to increase plant production and agricultural land productivity. However, the intercropping system directly creates competition between the constituent plants, namely light, water and nutrients. To minimize competition between plant constituents, it is necessary to carry out careful planning, including types of plants that have different morphologies and the need for environmental factors, planting distance and planting time. Intercropping corn and legumes is an alternative in an effort to increase production and land productivity. To determine whether the combination of plants that make up intercropping is appropriate or not, it can be estimated based on the Land Equivalent Ratio (LER). Intercropping corn and legumes with planting time settings showed a LER value of 2.20 when corn was planted 40 days after soybeans. Then, intercropping corn and peanuts with plant population settings shows that with population settings of 75% peanuts and 25% corn, it can provide a LER of 1.26.

Keyword- Intercropping system, Land productivity, Legume, LER, Maize

I. Introduction

One way to increase food crop production and farmers' income by intensifying land use is by cultivating various types of crops (multiple cropping) on the same land. A form of multiple cropping farming is planting two or more plants simultaneously in one area of land, this method is better known as intercropping or intercropping [1]. The objectives and benefits of the intercropping system according to Mushagalusa et al. [2], the intercropping system provides benefits in managing soil erosion, controlling weeds and improving soil fertility and contributing to biodiversity, thereby reducing the risk of failure.

The differences in characteristics between plant types in the use of environmental factors and various other advantages encourage the planting of two or more plants simultaneously at the same time and on the same land in an effort to increase production. High habitus plants will form a canopy that uses sunlight more efficiently. Especially if plants with low habitus are tolerant of shade, this will guarantee higher production increases than monoculture [2]. Plant growth and production results from an intercropping system are closely related to root distribution, which determines the absorption and utilization of water and nutrients. Root distribution plays a major role in interactions between species in the soil [3]. In the intercropping model, this will directly lead to competition between the constituent plants [4]. The intercropping system directly creates competition for several components, namely light, water and nutrients [5; 6]. Competition is one of the factors that influences the growth rate and yield of cultivated plants in the intercropping system. Therefore, to reduce competition in intercropping, careful planning must be done, such as selecting suitable plant types, planting distance and planting time.

Almost all regions in Indonesia are familiar with corn plants and some regions make corn a staple food. Corn production has fluctuated every year for the last five consecutive years from 2009-2013, namely 17,629,748, 18,327,636, 17,643,250, 19,387,022, and 18,511,853 tons [7]. Apart from corn, legume plants are also really needed by Indonesian people in general to meet nutritional needs, for example soybeans. Soybeans are a source of vegetable protein for humans and are needed as industrial raw materials and animal feed. However, production of legumes such as peanuts and soybeans has decreased over the last five years. Peanut production in 2009-2013 was 777,888, 779,228, 691,289, 712,857 and 701,680 tons. Meanwhile, soybean production in 2009-2013 was 974,512, 907,031, 851,286, 843,153 and 779,992 tons [7]. The decline in soybean and peanut production is influenced by the decrease in land area for soybean and peanut crops. The Ministry of Agriculture [7] stated that there was a decrease in land area for legume crops in 2009, namely 722,791 ha (soybeans) and 622,616 ha (peanuts) to 550,793 ha (soybeans) and 519,056 ha (peanuts) in 2013.

One solution to increase legume production is maize-legume intercropping. Maize is the main crop and legumes are the second crop.

The maize-legume intercropping system provides benefits that have the potential to increase high productivity and increase soil fertility through legume plants, because legume plants are able to provide N nutrients through N fixation by their root nodules [8; 9]. Apart from that, legumes have a definite opportunity to become secondary crops because their requirements for water resources, nutrients and sunlight are relatively low, they are adaptable to various environmental conditions, and they are able to sequester atmospheric N_2, the content of which is around 78% [10]. Therefore, the maize and legume intercropping system can be used as an alternative to increase maize and legume yield through efficient use of available land.

II. INTERCROPPING SYSTEM

Intercropping is the cultivation of two or more plants on the same land and growing season [1; 11; 12]. Meanwhile, according to Sharma and Banik [13], intercropping is the cultivation of two or more plant species simultaneously on the same land, has the potential advantage of higher productivity and is able to overcome weed problems. According to Kiswantoro and Hermanto (2013), intercropping of food crops has advantages, namely: utilizing empty spaces, saving on land cultivation, utilizing excess fertilizer given to staple crops, increasing income per unit area of land and providing income before staple crops. harvested.

Several things that need to be considered in designing an intercropping system are minimizing competition, maximizing mutually beneficial effects, improving soil fertility and equalizing the absorption of soil nutrients by plants. For example, intercropping between green beans and sugarcane produces a land equivalent ratio (LER) of 1.35, which indicates that intercropping between these two crops is more profitable than a monoculture system. It is also hoped that the combination of plants in the intercropping system will provide benefits in overcoming or reducing the presence of plant pests, both pests and weeds, for the constituent plants, for example Plutella pests on cabbage plants will be reduced if intercropped with tomatoes, the growth of weeds on corn plantations can be reduced if intercropped with green bean plants [14].

A. Aspects that need to be considered in the Intercropping System

The success of the intercropping system requires some careful planning before implementing the intercropping system cultivation. Silwana and Lucas [15] found the effect of intercropping on plant vegetative growth. The intended effect is that there are obstacles to plant growth which are influenced by competition between plants in the intercropping system. Therefore, to gain economic benefits from the intercropping system is determined by the planting pattern and selection of plants that are suitable for the intercropping system [16]. However, selecting plants that are suitable for the intercropping system is important in intercropping [17]. Selection of suitable plants for intercropping depends on plant growth patterns, land use, light, water and nutrients [16]. Apart from selecting suitable plants, Seran and Brintha [17] stated that in an intercropping system you must pay attention to several aspects when planning, namely:

a. Plant compability

   Selection of plants that will be intercropped is a basic thing that must be considered. Population density, shade and competition for nutrients between plants will reduce crop production. Kassam [18] reported that peanuts are usually intercropped with corn in East Asia and Africa, because corn is easy to maintain and peanuts are tolerant of shade from corn. Intercropping of corn and legumes is generally carried out in Asia, Africa and South America [19]. Legume plants such as calopo (*Calopogonium tnuconoides*), peanuts (*Arachis hypogaea*), cowpea (*Vigna sinensis*), and green gram (*Phaseolus aureus*) are shade tolerant of corn plants [17].

b. Plant density

   The low population of cultivated plants means that the results obtained will be small. However, if the population is too large, production results will also decrease due to the close spacing of plants, thereby increasing competition between plants. According to Maluleke et al. [19], there was a decrease in the dry weight of corn plants along with an increase in the number of corn populations on the land. In corn and okra intercropping, dense populations reduce the number of plant leaves due to competition for light and other sources.

c. Planting time

   Planting time greatly influences the level of competition between intercropping plants. There are some plants that are planted together that will give good results, but there are also those that give less good results. Mongi et al. [20] stated that planting cowpea and corn together in an intercropping system can provide good results. Planting corn and sweet potatoes simultaneously does not affect corn yields, but when sweet potatoes are planted after corn plants result in corn yields decreasing [21].

B. Root interactions in intercropping systems

Several studies have shown good results in intercropping systems. Good LER and ATER results are obtained from increasing production yields from each plant. This increase in production was due to a positive response from the intercropping plant components. Visually, intercropping plants have a large level of competition so that it can inhibit the growth of the constituent plants. However, the yield data shows that the existing competition does not really suppress production yields, but actually increases crop production yields. Inal et al. [22] reported that the intercropping system for corn and peanuts has mutually beneficial root interactions. The intercropping system causes mobility of nutrients in the root area and contributes to the efficiency of nutrient reception. Plant roots have a physiological response when there is a nutrient deficiency in the intercropping system. In P-deficient soils, legume plant roots secrete and activate enzymes such as phosphoric acid and phytase, thereby helping to increase P absorption in the root area [22]. Apart from macro elements, if there is a deficiency of micro elements, plant roots also have a physiological response in the form of releasing phytosiderophores from the roots and activating the enzyme ferric reductase from the roots. The activation of this enzyme causes an increase in the absorption of

Fe and Zn in plant tissue.

C. Feasibility Assessment of the Intercropping System

The combination of plants from an intercropping system is said to be feasible or not, determined by several indicators such as:

a. Land Equivalent Ratio (LER)

The land equivalent value (LER is a description of efficiency in land use. If the land equivalent value obtained after harvesting is >1 then the intercropping system is considered profitable. Calculation of the NKL value can be done according to the equation:

$\text{LER} = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$; where:

Yab = yield of plant a in intercropping system a and b;
Yba = yield of plant b in intercropping systems a and b;
Yaa = monoculture results of plant a;
Ybb = results of plant monoculture b.

b. *Area Time Equivalent Ratio (ATER)*

The Time Equivalent Ratio (ATER) area is a description of the equality value based on time. This means that the longer a type of plant is in the land, the smaller the yield advantage in terms of time. The formula that can be used to calculate the ATER value is the equation as follows:

$$ATER = \left(\frac{\text{Yab}}{\text{Yaa}}\right) \text{x} \left(\frac{\text{Ta}}{\text{T}}\right) + \left(\frac{\text{Yba}}{\text{Ybb}}\right) \text{x} \left(\frac{\text{Tb}}{\text{T}}\right)$$

Yab =yield of plant a in intercropping system a and b;
Yba =yield of plant b in intercropping systems a and b;
Yaa =monoculture results of plant a;
Ybb =monoculture yield of plant b;
T = time

III. MAIZE AND LEGUME UNDER INTERCROPPING SYSTEM

Plant height is a factor that must be observed in determining which plants will be intercropped. Based on research results, plants that have lower stem sizes should be planted first, followed by plants that have higher stem sizes and are more mature, this is to minimize competition between similar and different types of plants. By planting simultaneously directly, maize plants benefit more because maize has taller stem characteristics so that the plants are not directly outmatched by the soybeans that are planted. This condition causes differences in the growth rate and production of maize plants [23]. Selection of plants in an intercropping system needs to be done so that the plants can optimize space and time during the growth process with minimum competition. The constituent plants that have a higher plant size should be plants that require higher sunlight intensity than the lower constituent plants that require less light intensity during their growth process [14]. The presence of legumes in maize plantations causes the plants to be encouraged to grow faster due to competition for sunlight and the contribution of free N in the soil resulting from the fixation of legume plants causes nutrient availability for maize plants to also increase. According to Seran and Brintha [16], intercropping between plants that are capable of N fixation and plants that are not capable of N fixation (maize and legumes) provides better productivity results than monoculture. Because legume plants can fix N from the atmosphere and do not compete with maize for nitrogen sources [24].

Based on research by Darnawi et al. [25], that intercropping of maize and soybeans based on planting time has a significant influence on soybean and maize yields. The yield of soybean plants in the treatment when planting soybeans 20 days and 40 days after maize was lower compared to monoculture. This is related to the ability of plants to capture sunlight for photosynthesis activities. Delaying soybean planting 20 days and 40 days after maize causes relatively long shade, because the maize plants have grown tall and have enough leaves to shade the area around the plants so that the maize plants are superior in competition for sunlight, nutrients and water [25]. According to Anderson and Vasilas [26] in soybean plants, planting time influences the vegetative and reproductive phases as well as the speed of filling dry matter into the seeds. Shading of soybeans by maize can affect carbohydrate production in the photosynthesis process which will ultimately reduce the weight of the seeds planted so that it will reduce plant production.

The results of the maize planting time treatment together with soybeans, 20 days, 40 days, and 60 days did not show a significant effect compared to the maize monoculture treatment. This is because maize has faster growth and a higher habitus than soybeans, so maize is superior in getting sunlight, nutrients and water [25]. Land equivalency ratio (LER) in maize and soybean intercropping research based on planting time by Darnawi et al. [25]. The highest LER value that could be achieved in this study was in the treatment when planting maize 60 days after soybeans (LER = 2.20) and when planting soybeans 60 days after maize (LER = 2.15). The next LER results were in the simultaneous planting treatment (LER = 1.91), when planting maize 20 days after soybeans (LER = 1.80) and 40 days after planting soybeans (LER = 1.84). A LER value >1 means that land use in this study is more efficient even though there is competition between maize and soybeans.

The highest ATER value can be achieved in the treatment when planting simultaneously between maize and soybeans at 1.830. The

ATER value is closely related to the length of time required for double planting, in addition to the yield of each plant. When planting maize and soybeans in intercropping is done together, it will provide a relatively shorter double planting time compared to other planting time treatments. Other research on intercropping of maize and legumes is intercropping of maize and peanuts based on planting time carried out by Pinem et al. [27]. Pinem et al. [27] explained that the treatment when planting maize and peanuts together was able to produce good LER and ATER values compared to other planting time treatments, namely 1.39 and 1.35. Intercropping of maize and peanuts based on the proportion of maize and peanut populations was carried out by Pasau et al. [28]. In the research of Pasau et al. [28] used 4 population proportion treatments for maize and peanuts, namely monoculture of maize and peanuts, 75% peanuts + 25% maize, 50% peanuts and 50% maize, and 25% peanuts and 75% maize. In the research of Pasau et al. [28] the highest LER and ATER values that could be achieved were 1.26 (75% peanuts + 25% maize) and 1.17 (50% peanuts + 50% maize).

IV. CONCLUSION

Land use efficiency in intercropping maize and legumes can be achieved by cultivating maize and legumes in intercropping with simultaneous planting times based on its ability to provide better land and time equality (ATER) values from different planting times between constituent plants. Simultaneous planting provides good land and time equivalency (ATER) values in maize-soybean intercropping and maize-peanut intercropping.

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