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Effects of Soil Tillage on the Agronomic Performance of Maize-Soybean Intercropping in Dry Land North Lombok, Indonesia

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Abstract:- If land processing techniques on dry land are not carried out correctly, it can cause soil erosion and poorer soil fertility. Therefore, one way that can be done to prevent the soil from becoming sour is through proper soil processing accompanied by the addition of bio-ameliorants to the soil. This research aims to determine the effect of soil tillage on the agronomic performance of corn and soybean intercropping on dry land in North Lombok, Indonesia. The research was conducted from May to July 2023 in Pemenang Barat Village, Pemenang District, and North Lombok Regency. The study used an experimental method in the field using a randomized block design by testing five tillage techniques, i.e., Oo: without tillage; O1: without tillage, only sprayed with pre-growth herbicides before planting; O2: minimum tillage is only hoeing; O3: simple tillage and leveling; and O4: intensive tillage by hoeing, loosening, and leveling. The results showed that treatment-intensive and complete processing can increase the growth performance and biomass yield of maize and soybean intercropping. Treatment-intensive and complete processing can improve the performance of intercropping maize and soybeans in the dry land of North Lombok. To improve the agronomic performance of maize-soybean intercropping in the dry land of North Lombok, the best results are obtained using intensive and complete processing accompanied by the addition of bio-ameliorant at a dose of 15 tons per ha.

Keywords:- *Bio-Ameliorant, Mycorrhiza, Soil Fertility*.

I. INTRODUCTION

Maize and soybeans are food commodities whose demand in Indonesia increases every year. According to maize production in 2022, it will reach 19.611 million tons, while the annual need for soybeans is around 2.58 million tons [1]. The increasing demand for maize and soybeans has not been matched by increased production regionally or nationally. Therefore, one effort to fulfill the consumption needs for maize and soybeans can be made by increasing the planting area through the use of dry land.

Dry land development efforts are the best solution considering the large number. The area of dry land in Nusa Tenggara Barat (NTB) reaches 1.8 million ha (84.19%) of the land area, and there are around 749,000 ha that have the potential to be developed for food crops [2]. From the dry land potential in NTB, North Lombok district has a dry land potential of around 38,000 ha for the development of food crops [3].

However, dry land management has various obstacles, including the uneven distribution of rainfall and the low quality of soil fertility, which can affect yield reduction and even crop failure [4]. This can become worse if the soil processing techniques on dry land are not appropriate, which can cause soil erosion and cause the soil to become more marginal. Therefore, one of the efforts made is proper soil cultivation, accompanied by adding bio-ameliorant materials to the soil.

Tillage is the mechanical manipulation of soil to create good soil conditions for plant growth. Various soil processing systems will affect soil compaction and soil organic matter content [5]. Soil processing can be done using several methods, depending on the level of soil density and the desired level of soil porosity. Herbicide application is also an inseparable part of soil processing activities, which will affect the activity of soil microorganisms, especially if the mixture of compounds is applied repeatedly over many years. Most of the herbicides applied to plants will eventually fall into the soil, undergo changes, and over time will be absorbed by clay fractions and organic matter in the soil, which are generally known as herbicide residues. Toxic herbicide residues in the soil can kill soil microbes that are not their targets *(*nontarget microorganisms*)*, thereby disrupting the activity of soil microorganisms, which can ultimately affect the nutrient cycle in the soil [6].

Soil processing to improve soil aeration is good for root development and plant growth. In general, in food crop farming on dry land, intensive tillage is carried out from the start of planting without using plant residues, which is also called conventional tillage. Apart from requiring a lot of time and energy, conventional tillage can accelerate damage to the structure and composition of soil organic matter, which in turn will increase the rate of erosion, especially on sloping land [7].

However, dry land management has specific obstacles, especially those related to the biophysical limiting factors of land, which are low-quality soil fertility, which is characterized by low nutrient availability, poor soil organic matter (SOM), and limited water availability for plants [8]. This factor is often identified as the biggest contributor to the phenomenon of crop failure and low plant productivity in dry

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land, as well as the decreasing quality of soil fertility and the increasing vulnerability of land to degradation processes [9].

Therefore, it takes effort to overcome the biophysical constraints of dry land, bio-meliorant, whose irrigation is very dependent only on rainfall. One effort is to carry out intensive soil processing accompanied by the addition of bio-ameliorant, which is a mixture of biological agents such as mycorrhiza and soil improvers (ameliorant), such as compost, cuttle manure, and rice husk charcoal. Organic ameliorant materials have an important role in improving the physical, chemical, and biological properties of soil [10] [11]. Its role in soil physics includes, amongothers, acting, as an adhesive between soil particles to unite into soil aggregates, improving soil structure, increasing soilporosity, and, increasing the soil's ability to hold water [12]. Apart from that, the addition of native mycorrhiza to ameliorant can increase nutrient availability for plants, which can increase the efficiency of plant roots to absorb nutrients by two to three times [13] [14]. Adding bio-ameliorants to the soil is one way that can increase plant resistance to drought and climate change. Bio-ameliorants enriched with organic extracts and nutrients can improve soil health and soil fertility continuously [15].

On the other hand, land use efficiency can be increased by intercropping maize with soybeans on dry land. This intercropping pattern can improve soil fertility levels through nitrogen fixation in legume plants [16]. The success of intercropping between maize and soybeans is determined by the availability of nutrients in the soil, especially the availability of N and P elements compared to monoculture patterns.

However, how much soil processing with added bio-ameliorant can increase the growth and yield of maize-soybean intercropping in dry land in North Lombok has not yet been widely reported. Therefore, this research needs to be carried out, which will find out. This research aims to determine the effect of soil tillage on the agronomic performance of corn and soybean intercropping on dry land in North Lombok, Indonesia.

II. MATERIALS AND METHOD

A. *Experimental Design*

The experimental design used was a randomized block design with five soil processing technique treatments, namely: O_0: without tillage; O_1: spray with a pre-emergent herbicide before planting; O_2: minimum tillage is just hoeing; O_3: simple tillage, hoeing, and leveling; and O_4: intensive soil cultivation by hoeing, loosening and leveling.

B. *Plants Cultivation*

Soil processing is carried out using a hoe and spraying herbicide according to the soil processing treatment to remove weeds from the soil. The land was then divided into 20 plots measuring 5 m x 5 m. The maize-soybean intercropping pattern used is 3 rows of maize and 3 rows of soybeans. Each hole is filled with 2 seeds, with the maize planting distance being 60 cm by 40 cm and the soybean planting distance being 30 cm by 20.

Give 40 g of bio-ameliorant per hole by inserting it 5 cm deep and at a distance of 7 cm from the planting hole. Meanwhile, inorganic fertilizer is given at 50% of the recommended dose in the form of urea and phonska (maize: urea 150 kg/ha and phonska 100 kg/ha, & soybeans: 30 kg/ha urea and 60 kg/ha phonska). Embroidery is carried out by replanting maize and soybean seeds at the age of 7 days after planting (DAP).

C. *Observation of Parameter*

The parameters observed in this study were: plant height and number of plant leaves at 14, 28, 42, 56, 70 and 84 days after planting (DAP), plant biomass weight and yield per plot at 92 DAP.

III. RESULTS AND DISCUSSION

A. *Performance of Plant Height and Number of Leaves*

The results of the analysis variance showed that intensive soil processing was carried out by hoeing, loosening and leveling (O_4) had a significant effect on plant height compared to the control (without tillage) when the plants were 14 – 84 DAP (Table 1).

Table 1:-Height Growth Rates for Maize and Soybean Plants in Tillage Treatments

Tillage	Plant Height (cm)					
	14 dap	28 dap	42 dap	56 dap	70 dap	84 dap
Maize						
O0	15.50^{b}	35.16^{b}	69.00^{b}	125.5^{b}	128.01^{d}	160.50^{d}
O1	21.33^{a}	65.16^{a}	87.33^{a}	161.83^{a}	154.01^{cd}	171.50^{cd}
O2	22.33^{a}	66.83^{a}	102.50^{a}	165.83^{a}	181.66^{bc}	195.33^{bc}
O3	22.83^{a}	68.66^{a}	104.66^{a}	165.16^{a}	190.66^{ab}	202.50^{b}
O4	27.50^{a}	71.00^{a}	116.50^{a}	175.16^{a}	216.50^{a}	237.16^{a}
HSD 5%	4.85	21.08	27.55	15.25	19.01	19.80
Soybean						
O0	12.16^{b}	19.83^{b}	28.00^{b}	42.16^{a}	46.33^{a}	53.83^{a}
O1	16.50^{ab}	26.16^{a}	33.66^{ab}	40.16^{a}	50.83^{a}	52.83^{a}
O2	17.00^{a}	28.50^{a}	33.83^{ab}	40.83^{a}	49.50^{a}	50.16^{a}
O3	17.66^{a}	30.16^{a}	38.83^{a}	44.66^{a}	50.83^{a}	52.16^{a}
O4	18.50^{a}	31.33^{a}	39.00^{a}	45.5^{a}	51.50^{a}	63.01^{a}

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HSD 5%	4.64	5.21	9.96	5.72	8.97	11.84

Table 2:- Growth Rates for the Number of Maize and Soybean Leaves in Soil Processing Treatments

Tillage	Number of Leaves					
	14 dap	28 dap	42 dap	56 dap	70 dap	84 dap
Maize						
O0	3.83^{b}	7.30^{b}	9.33^{c}	10.50^{c}	12.50^{b}	14.50^{b}
O1	5.33^{a}	9.00^{a}	10.16^{bc}	11.66^{abc}	13.50^{ab}	15.50^{ab}
O2	5.50^{a}	9.10^{a}	10.50^{bc}	11.01^{bc}	13.33^{ab}	15.33^{ab}
O3	5.50^{a}	9.30^{a}	10.83^{b}	12.50^{ab}	14.50^{a}	16.50^{a}
O4	5.50^{a}	9.50^{a}	11.33^{a}	13.01^{a}	15.01^{a}	17.01^{a}
HSD 5%	0.75	1.45	1.32	1.15	1.28	1.28
Soybean						
O0	1.00^{b}	3.00^{b}	7.16^{b}	8.50^{c}	9.66^{b}	11.83^{c}
O1	1.16^{ab}	4.00^{ab}	8.16^{ab}	9.50^{abc}	9.83^{ab}	13.33^{abc}
O2	1.33^{ab}	4.16^{ab}	8.33^{a}	9.66^{abc}	11.50^{a}	14.00^{ab}
O3	1.66^{b}	4.16^{ab}	8.66^{a}	9.83^{ab}	12.50^{a}	14.33^{ab}
O4	2.00^{a}	4.83^{a}	9.83^{a}	10.66^{a}	12.66^{a}	15.00^{a}
HSD 5%	0.58	1.40	2.50	1.31	1.76	1.93

As time goes by, table 2 shows the development of the number of leaves showing a trend of high development in intensive tillage treatment by hoeing, loosening and leveling (O4) was the highest at 84 DAP and was significantly different compared to the control, without tillage (Table 2).

Intensive tillage (O_4) provides an average growth in plant height and a greater number of leaves. This is because intensive soil processing makes the soil crumbly and loose so that plant roots can more easily enter the soil and more easily absorb the nutrients contained in the soil which are used by plants for their growth. The plant root system is controlled by the genetic characteristics of the plant and is influenced by soil conditions or plant growing media. Soil conditions with intensive tillage will affect root distribution patterns, which can improve aeration, water availability, and nutrient availability for plants [17].

Tilling the soil will produce loose soil conditions that are good for root growth, thereby forming better soil structure and aeration than without tilling [18]. Good structure and aeration will provide space for the roots to move more easily and freely so that the roots' ability to absorb nutrients, water, and oxygen is greater and the photosynthesis process can run smoothly.

Apart from absorbing nutrients, plant roots that enter the soil will also absorb water which is used for plant growth and development. Apart from being a raw material for photosynthesis, water also functions as the main compound that forms protoplasm, maintains cell turgidity acts as a mechanical force in cell enlargement and cell elongation and regulates plant movement mechanisms such as opening and closing stomata, opening and closing flowers and folding plant leaves [19]. This is what causes the number of leaves to be significantly different for each treatment in this study. Plant height and number of leaves are influenced by genotype and environmental factors. Environmental factors that influence are soil, water, light and nutrients. Intensive tillage can provide height and number of leaves that continue to increase at all ages of plant observation [20].

Increasing the number of leaves will ultimately affect height, which can be seen in the results of this research that the best plant height and number of leaves were obtained in the O treatment$_4$ (intensive tillage). Plants that have more leaves at the beginning of their growth will grow faster because of their ability to produce higher photosynthesis than plants with a lower number of leaves. The number of plant leaves will influence the growth of other plant tissues [21].

B. Plant Biomass Weight Performance

The results of analysis variance and HSD test at the 5% level show intensive soil tillage treatment by hoeing, loosening, and leveling (O4) had a significant effect on the weight of plant biomass per plot (kg/plot), the weight of maize cobs and dry soybean pods harvested per plot (kg/plot) and the weight of maize cobs and soybean pods per plant (g/plant) aged 92 days compared to with control treatment (Table 3).

Perfect tillage accompanied by the addition of bio-ameliorants has great potential in improving the agronomic performance of maize-soybean intercropping on dry land. The application of bio-ameliorant is an effective strategy to improve soil health, increase nutrient availability, and reduce water stress in plants, thus contributing to increasing biomass weight and plant productivity. Perfect tillage generally involves the use of mechanical equipment to till the soil deeply and thoroughly before planting, to create optimal soil conditions for plant growth. This perfect tillage can increase soil aeration and water infiltration capacity. This allows plant roots to grow deeper and spread wider, seeking more nutrients and water, which directly contributes to higher plant

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biomass growth. By cultivating the soil properly, weed seeds and soil pest habitats can also be disturbed, reducing competition for the use of nutrients and other resources. This allows the planted plants to use those resources more efficiently, potentially increasing the plant's biomass weight. Perfect tillage can also improve soil structure and increase the mineralization of organic matter, thereby increasing the availability of nutrients for plants. Well-cultivated soil has a more even distribution of nutrients, which supports healthy plant growth and increased biomass weight. However, it is important to balance short-term benefits with long-term sustainability considerations, including the potential for soil erosion and degradation of soil structure. Therefore, soil management must be adapted to local conditions and specific agronomic production goals [22] [23].

Table 3:- Plant Biomass Weight per Plot (BW) (kg/plot), Weight of Harvested Maize Cobs and Soybean Pods per Plot (WHM) (kg/plot), and Weight of Maize Cobs and Soybean Pods per Plant (WHS) (g/plant) in the Tillage Treatment at 92 Days After Planting.

Tillage Treatment	Maize			Soybean		
	BW (kg/plot)	WHM (g/plant)	WHM (kg/plot)	BW (kg/plot)	WHS (g/plant)	WHS (kg/plot)
Harvest dry weight						
O0	24.10^{d}	84.03^{e}	18.6^{a}	3.62^{d}	11.81^{e}	1.61^{d}
O1	27.90^{abc}	120.86^{d}	17.5^{a}	4.14^{cd}	13.64^{d}	2.21^{cd}
O2	29.50^{abc}	149.84^{c}	21.2^{a}	4.79^{bc}	15.28^{c}	2.86^{bc}
O3	29.96^{ab}	162.34^{b}	22.16^{a}	5.64^{b}	17.95^{b}	3.52^{b}
O4	30.80^{a}	213.29^{a}	25.3^{a}	6.75^{a}	19.39^{a}	4.22^{a}
HSD 5%	3.53	2.75	5.74	0.63	0.87	0.45
Dry Weight in sun						
O0	12.05^{d}	60.75^{e}	11.2^{b}	1.81^{d}	8.81^{e}	1.31^{d}
O1	13.95^{bc}	83.67^{d}	12.4^{ab}	2.07^{cd}	10.64^{d}	1.91^{cd}
O2	14.75^{ab}	121.47^{c}	12.4^{ab}	2.39^{bc}	12.28^{c}	2.56^{bc}
O3	14.98^{ab}	132.47^{b}	13.96^{ab}	2.81^{b}	14.95^{b}	3.22^{b}
O4	15.40^{a}	184.23^{a}	19.03^{a}	3.37^{a}	16.39^{a}	3.92^{a}
HSD 5%	1.26	2.66	5.05	0.31	0.87	0.45

C. Plant Yield Performance

In Table 4 can be seen the results of the analysis variance and HSD test at the 5% level showing intensive soil treatment by hoeing, loosening, and leveling (O4) had a significant effect on the weight of harvested dry shelled seeds (kg/plot) and the weight of 100 dry seeds of maize and soybeans (g) aged 92 DAP compared to the control treatment.

In Table 5 it can also be seen the results of the analysis variance and HSD test at the 5% level showing the treatment of intensive soil treatment by hoeing, loosening, and leveling (O4) had a significant effect on cob length, maize cob diameter, pod length and soybean pod width compared to the control treatment.

Table 4:- Weight of Harvested Dry Shelled Seeds (kg/plot) and Weight of 100 Dry Seeds of Maize and Soybeans (g) in the 92 DAP Tillage Treatment.

Tillage Treatment	Maize Weight		Soybean Weight	
	100 seed	Shelled Seeds	100 seed	Shelled Seeds
O0	157.01^{d}	4.33^{d}	43.66^{d}	1.64^{e}
O1	168.01^{cd}	5.43^{c}	58.66^{c}	2.26^{d}
O2	173.33^{bc}	6.22^{bc}	68.66^{c}	2.69^{c}
O3	180.66^{ab}	6.66^{b}	86.33^{b}	3.16^{b}
O4	188.66^{a}	8.06^{a}	117.66^{a}	3.52^{a}
HSD 5%	7.36	0.67	9.26	0.15

Table 5:- Mean Cob Length, Maize Cob Diameter, Pod Length, and Soybean Pod width in Tillage Treatments.

Tillage	Cob length (cm)	Cob diameter(cm)	Pod length(cm)	Pod width(cm)
O0	15.36^{d}	3.10^{e}	3.20^{e}	0.56^{e}
O1	15.66^{d}	3.45^{d}	3.46^{d}	0.69^{d}
O2	16.34^{c}	3.75^{c}	3.78^{c}	0.81^{c}
O3	17.01^{b}	3.90^{b}	4.23^{b}	0.94^{b}
O4	17.84^{a}	4.18^{a}	4.52^{a}	1.35^{a}
HSD 5%	0.32	0.09	0.09	0.01

Based on Table 3, Table 4 and Table 5, treatment Intensive tillage by hoeing, loosening and leveling (O4) produce weight of harvested dry biomass, dry dry biomass weight, dry dry cob/pod weight of maize, soybeans per plot, weight of dry harvested shelled beans, weight of 100 dry seeds of maize and soybeans, as well as cob length, maize cob diameter, pod length and pod width soybeans higher compared to the control treatment. Complete soil processing can change the aggregate composition and soil porosity to make it looser and the soil pores are more filled with macropores [24]. Apart from that, there is a decrease in the weight of soil particles caused by changes that occur in soil that is completely processed so that the soil is turned over to a certain depth and air exchange occurs in the soil [25]. The weight of soil particles plays a very important role in plant cultivation because volumetric weight and porosity are used to determine the ability of the soil to absorb and store water, the dynamics of the water in it and the availability of water in the soil for plant growth. The decrease in soil particle weight is related to water holding capacity which is useful for plant growth. The smaller the weight of the soil particles, the more micro pore spaces are formed so that the soil will have an increasing moisture retention capacity [26]. Soil moisture will fill the soil pore spaces, usually the first soil pore spaces to be filled are the macro pores, then the micro pores. The need for water for plant growth comes from the availability of water in macro pores, followed by micro pores [27] [28]. The higher the value of soil particles can cause plant growth to be hampered because the soil becomes denser so that it is difficult for the roots to penetrate the soil, as a result the roots cannot absorb the water available in the soil micropores [29] [30]. Providing organic material can improve soil physical properties such as increasing soil aggregate stability, porosity, soil water content and reducing soil bulk density. This causes wider root distribution and penetration, resulting in greater nutrient and water uptake and an impact on increasing plant growth and production [31] [32].

IV. CONCLUSION

Treatment-intensive tillage and complete can increase the growth performance and biomass yield of maize and soybean intercropping plants. Treatment intensive and complete processing can improve the performance of intercropping maize and soybeans in the dry land of North Lombok. To improve the agronomic performance of maize-soybean intercropping in the dry land of North Lombok, the best results are using intensive and complete processing accompanied by the addition of bio-ameliorant at a dose of 15 tons per ha.

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