Impact of different soil tillage added bio-ameliorant on nutrient concentration and growth maize-soybean intercropping adaptive to climate change in dry land

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Abstract. Climate change hurts the production of food crops, especially maize, and soybeans, on dry land. This climate change affects the concentration of nutrients and the growth of maize-soybean intercropping on dry land. This study aimed to determine the impact of different soil tillage added with bio-ameliorant on nutrient concentrations and the growth of climate change adaptive maize-soybean intercropping in the dry land of North Lombok, Indonesia. The research was conducted from May to July 2023 in West Pemenang 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., O_o: without tillage, O_1: without tillage, only sprayed with pre-growth herbicides before planting, O_2: minimum tillage is only hoeing, O_3: simple tillage and leveling, O_4: intensive tillage by hoeing, loosening, and leveling. The results showed that the intensive processing technique, complete with the addition of bio-ameliorant, significantly affected the nutrient concentration and growth of the maize-soybean intercropping that was adaptive to climate change in dry land. Plants can be improved to be more adaptable to climate change through intensive tillage and adding bio-ameliorants.

1. Introduction

Tillage is a land preparation activity for plant cultivation. The tillage system is divided into intensive tillage and conservation tillage. Land preparation commonly used by farmers is intensive tillage. Farmers often use intensive tillage because it is more cost-effective, labor and time efficient. Intensive tillage is a system carried out twice to loosen the soil so that plant roots can grow well and the soil surface is clean without weeds or grass covering the soil surface [1, 2].

Global warming, on the other hand, has altered global, regional, and local climate conditions. This global climate change is produced, among other things, by an increase in

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greenhouse gas emissions due to various activities that cause the earth's temperature to rise. Because climate is the most critical factor in plant metabolism, physiology, and ecosystem systems, global climate change will severely influence agricultural sustainability [3]. One of the consequences of global climate change is a drop in crop yield, which can impact food availability in Indonesia [4].

One strategy for increasing crop yield is to use heavy tillage with bio-ameliorant, a combination of biological agents like mycorrhizae, and soil additives, including manure, compost, and rice husk charcoal. Organic material ameliorants are essential in enhancing soil's physical, chemical, and biological qualities [5, 6]. The role of physical soil, among other things, as an adhesive material between soil particles to join into soil aggregates, enhance soil structure, increase soil porosity, and promote soil water retention [7]. Furthermore, adding indigenous mycorrhiza to the ameliorant can boost nutrient availability for plants, increasing the efficacy of plant roots to absorb nutrients by two to three times [8, 9]. This is one way to increase plant resistance to drought and climate change. This study aimed to determine the impact of different soil tillage added with bio-ameliorant on nutrient concentrations and the growth of climate change adaptive maize-soybean intercropping in the dry land of North Lombok, Indonesia.

2. Materials and method

2.1. Experimental design

The experimental method utilized was a randomized block design with five tillage technique treatments, notably O_0: without tillage, O_1: no without-tillage, only pre-growth herbicides applied before planting, O_2: only hoeing, O_3: simple tillage hoeing and leveling, O_4: intensive tillage with a hoe, loosened, and flattened. Each treatment was replicated four times.

2.2. Plants cultivation

The experiment was conducted in Telaga Wareng Hamlet, West Pemenang Village, Pemenang District, North Lombok Regency, Indonesia, from May to August 2023. Tillage removes weeds from the soil by using a hoe and spraying herbicides according to the tillage treatment. The area is then divided into 20 plots in 5 m by 5 m portions. The intercropping design employed is three rows of maize (NK212 variety) and three rows of soybeans (Dega 1 variety). With a maize spacing of 60 cm by 40 cm and a soybean spacing of 30 cm by 20 cm, each hole was filled with two seeds.

They give 40 g of bio-ameliorant per hole by placing it as deep as 5 cm and 7 cm away from the planting hole. At the same time, inorganic fertilizers are applied at 50% of the prescribed dosage in the form of Urea and Phonska (maize: 150 kg/ha Urea and 100 kg/ha Phonska, and soybeans: 30 kg/ha Urea and 60 kg/ha Phonska). Stitching is accomplished by replanting maize and soybean seeds seven days after planting (dap).

2.3. Observation of parameter

At 42 dap, soil nutrient concentrations and plant N and P uptake were measured, as were the weight of wet and dry stover roots and shoots and the number of spores and percentage of root infection.

3. Results and discussion

3.1. Wet and dry plant biomass weights

When the plants reached 42 DAP, the results of the analysis variance revealed that intense tillage by hoeing, loosening, and leveling (O_4) had a significant effect on the weight of wet and dry biomass of roots and plant shoots compared to the control (without-tillage) (Table 1).

Table 1. Average weights of wet and dry biomass of maize and soybean roots and shoots at some tillage, ages 42 DAP.

Soil Tillage	Maize		Soybean	
	Roots	Shoots	Roots	Shoots
Wet Biomass				
Oo : without tillage	5.53^{b}	47.35^{e}	1.62^{c}	3.37^{d}
O_1 : only herbicides	8.81$^{a.}$	53.18^{d}	1.77^{c}	5.59^{c}
O_2 : only hoeing	18.76^{ab}	148.48^{c}	1.89^{c}	1..75^{b}
O_3 : simple tillage	62.12^{ab}	192.80^{b}	3.51^{b}	13.83^{b}
O_4 : intensive tillage	65.32^{a}	368.57^{a}	4.52^{a}	32.60^{a}
HSD 5%	39.10	2.47	0.32	1.38
Dry Biomass				
Oo : without tillage	1.12^{d}	10.85^{e}	0.18^{d}	1.02^{e}
O_1 : only herbicides	2.72^{d}	18.28^{d}	0.22^{d}	1.94^{d}
O_2 : only hoeing	5.78^{c}	71.33^{c}	0.34^{c}	3.21^{c}
O_3 : simple tillage	32.43^{b}	78.55^{b}	1.65^{b}	4.66^{b}
O_4 : intensive tillage	44.58^{a}	189.14^{a}	2.68^{a}	8.26^{a}
HSD 5%	1.42	1.74	0.038	0.026

*Mean values in each column followed by the same letters are not significantly different between treatments.

Maize and soybean wet and dry weight yields were highest and most significant were obtained on intense tillage (O_4) compared to control, no-tillage. This is generated by intense tillage, which causes the soil to become loose, crumbly, and weed-free so that roots and plant shoots can grow and flourish. Maize and soybean plants require loose soil to grow and develop properly. The intensive tillage treatment (O_4) had the largest dry biomass weights of maize and soybean roots and shoots, substantially different from no-tillage (O_O). The low weight of wet and dry root and shoot biomass in the no-tillage treatment was attributable to plant-weed competition.

The wet and dry weight yields of maize and soybean gave the highest and most significant results in intensive tillage (O_4) compared to control without tillage. This is caused by intensive tillage, causing the soil to become loose and crumbly and clean of weeds to support the growth and development of roots and plant shoots [10, 11]. Maize and soybean plants require loose soil so that the roots grow and develop optimally. The highest dry biomass weights of maize and soybean roots and shoots were found in the intensive tillage treatment (O_4), significantly different from no-tillage (O_O). The low weight of wet and dry root and shoot biomass in the no-tillage treatment was attributable to early-growth competition between plants and weeds. Weeds are more fertilizer and water responsive than maize and soybean plants [12]. Furthermore, intense tillage affects the process of nutrient absorption and the availability of water for plants to provide water in the soil, which might alter the wet and dry weight of roots and plant shoots to better [13-15].

3.2. Soil Nutrient Concentration and Plant Nutrient Absorption

The HSD test results at the 5% level showed that intensive tillage with hoeing, loosening, and leveling (O_4) could increase N, P, and K concentrations, soil-organic C uptake, and plant nutrient uptake of N, P, K, and Ca at 42 DAP and is significantly different from the control (Table 2).

Table 2. Average N, P, K, C-organic, and pH contents in the rhizospheres of maize and soybean plants at 42 DAP soil treatments.

Treatment	N (g kg^{-1})		P (mg kg^{-1})		K (cmol kg^{-1})		C-organic (g kg^{-1})		pH	
	Maize	Soybear	Maize	Soybean	Maize	Soybean	Maiz	Soybear	Maize	oybean
Without tillage	1.21^{e}	1.18^{e}	12.16^{e}	12.76^{e}	0.64^{d}	0.62^{c}	7.27^{e}	6.64^{e}	6.37^{d}	6.71^{d}
Only herbicides	1.33^{d}	1.27^{d}	16.34^{d}	15.37^{d}	0.69^{c}	0.72^{bc}	7.61^{d}	7.23^{d}	6.63^{c}	6.76^{cd}
Only hoeing	1.42^{c}	1.33^{c}	20.62^{c}	17.29·	0.75^{b}	0.76^{b}	8.65^{c}	7.75^{c}	6.73^{b}	6.80^{c}
Simple tillage	1.61^{b}	1.42^{b}	23.72^{b}	20.2^{b}	0.78^{b}	0.83^{ab}	9.77^{b}	8.51^{b}	6.88^{a}	6.87^{b}
Intensive tillage	1.95^{a}	1.49^{a}	32.53^{a}	24.65^{a}	0.86^{a}	0.94^{a}	10.65^{a}	9.55^{a}	6.94^{a}	6.97^{a}
HSD 5%	0.050	0.027	2,010	0,861	0.026	0.084	0.044	0.193	0.044	0.040

*Mean values in each column followed by the same letters are not significantly different between treatments.

At 42 dap, the same thing happened to the plant nutrient absorption parameters N, P, K, and Ca (Table 3). Compared to the control (O_O), the intense tillage treatment by hoeing, loosening, and flattening (O4) produced the most significant and significantly different increase.

Table 3. Plant nutrient uptake (N, P, K, and Ca) concentration (mg/g) at 42 DAP aged soil treatment.

Treatment	Nutrient uptake (mg/g plant)							
	Maize				Soybean			
	N	P	K	Ca	N	P	K	Ca
Without tillage	28.2^{e}	1.87^{e}	25.41^{e}	2.38^{d}	35.25^{e}	1.91^{e}	17.54^{d}	5.68^{d}
Only herbicides	29.4^{d}	244^{d}	26.48^{d}	2.58^{cd}	36.73^{d}	2.26^{d}	22.80^{c}	6.62^{c}
Only hoeing	30.60^{c}	2.76^{c}	27.15^{c}	2.74^{bc}	40.47^{c}	2.80^{c}	23.65^{b}	6.78^{bc}
Simple tillage	31.81^{b}	3.32^{b}	27.73^{b}	2.83^{ab}	45.45^{b}	3.49^{b}	23.75^{b}	6.92^{b}
Intensive tillage	33.36^{a}	3.91^{a}	28.53^{a}	$2,98^{a}$	46.95^{a}	3.90^{a}	24.76^{a}	7.60^{a}
HSD 5%	0.65	0.13	0.12	0.15	0.25	0.12	0.21	0.17

*Mean values in each column followed by the same letters are not significantly different between treatments.

In the results of soil pH analysis on intensive tillage with additions of bio-ameliorant plus mycorrhiza (O_4), the highest pH was obtained, close to normal pH, and the lowest was in the treatment without tillage (O_O), which was 6.71. The addition bio-ameliorant plus mycorrhizae to the soil during intensive tillage can increase soil pH. The organic compounds released by bio-ameliorant organic matter can increase cations in the soil complex [16, 17].

A bio-ameliorant is a substance that can be applied to soil to enhance its physical, chemical, and biological qualities. Soils in North Lombok's dry land generally have a very low C-organic content. Cow dung, rice husk charcoal, compost, and mycorrhiza significantly boosted soil pH, N, P, K, and C-organic content, as well as N, P, K, and Ca nutrient uptake by maize and soybean plants grown on sandy soil [18]. Organic matter as an ameliorant can boost C-organic in the soil, allowing nutrients such as N, P, K, Ca, Mg, and S to be available for maize and soybean plants during growth and plant tissue formation [19]. pH is a key determinant in phosphorus availability in soil. Suspected the planting medium has increased accessible P levels. In that case, this is because the majority of phosphorus in the soil originates from weathering of natural mineral rocks, with the remainder coming from weathering of organic mineral components. The phosphorus ions in the soil are similarly impacted by soil pH [20].

3.3. Number of Spores and Root Colonization

The 5% HSD test findings revealed that intensive tillage using hoed, loosened, and flattened (O_4) was significantly different from the control treatment (O_O) on the parameters of spore count (per 100 g of soil) and root colonization (%) at 42 dap (Table 4).

Table 4. At 42 DAP, the average number of spores (per 100 g of soil) and root colonization (%) of maize and soybean plants.

Soil Tillage	Spores on Maize	Spores on Soybean	%-Maize Colonization	%-Soybean Colonization
Oo : without tillage	383.00^{d}	800.00^{c}	31.66^{c}	27.66^{d}
O_1 : only herbicides	628.00^{c}	1172.56^{b}	66.00^{b}	58.33^{c}
O_2 : only hoeing	641.00^{c}	1194.66^{b}	74.33^{b}	61.66^{c}
O_3 : simple tillage	1288.33^{b}	1220.00^{b}	84.33^{a}	78.33^{b}
O_4 : intensive tillage	1438.33^{a}	1381.66^{a}	89.33^{a}	86.66^{a}
HSD 5%	10.53	45.84	5.808	5.016

*Mean values in each column followed by the same letters are not significantly different between treatments.

Improving the fertility of sandy soil in the arid region of North Lombok can be accomplished through intense processing combined with bio-ameliorant additives containing mycorrhiza. Mycorrhizal spores and colonization percentage increased more in the heavy tillage treatment than in the non-tillage treatment. To carry out their metabolic functions and to grow and develop, mycorrhizal fungi require specific organic substances as a source of carbon and nutrients [21]. According to the total quantity of spores and mycorrhizal colonization results, heavy tillage appears to be associated with bio-ameliorant organic output of higher value than non-tillage. Intensive tillage with the addition of a bio-ameliorant can boost mycorrhizal effectiveness on plant root infection. Organic substrates provide energy to mycorrhizal fungi, whereas growth hormones, which are also found in organic matter, stimulate the growth and regeneration of plant roots and create root exudate, accelerating the symbiotic interaction between mycorrhizal fungi and plants [22].

4. Conclusion and suggestions

The results showed that the intensive processing technique, and the addition of a bio-ameliorant had a substantial effect on the nutrient content and growth of the climate-adaptive maize-soybean intercropping in a dry field. Plants can adapt more to climate change by using intense tillage and adding bio-ameliorants.

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