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# Mungbean-maize rotation improved soil properties and maize yield in dryland

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**Abstract**. One of the conditions to improve maize yield in dryland areas is by improving soil properties. This paper reports on the improvement of soil properties and maize yield resulted from rotating mungbean and maize in two consecutive years. In the first year, mungbean was grown as a cover crop at different population densities (250,000, 375,000, and 500,000 plants ha$^{-1}$) combined with desiccation times of 21, 28 and 35 days after planting in April 2019. Two weeks after the desiccation, maize seeds were planted at a density of 7 plants per m$^2$. In those cover crop plots and a control treatment without a cover crop. All the treatments were replicated three times and were arranged in a Randomized Block Design. Following the maize crops, mungbean was grown again (except in the control plots) from October to December 2019 at the same population densities as before, combined with two seed classes; stock seeds and extension seeds. The mungbean was harvested in mid-December 2019 and after biomass determination, the residue was incorporated into the treatment plots. In mid-January 2020, maize seeds were planted at the same population density as before in all plot treatments, including control plots. Soil properties were determined at 60 days after maize planting. The results revealed that nitrogen, phosphorous, and potassium in the soil increased substantially by 52.6, 282.9, and 110%, respectively after two years of the rotation. There was an average of 44.7% increase in maize yield resulted from the highest mungbean population density plots as compared to the control treatment. It is concluded that mungbean-maize rotation is an effective way to improve maize yield in dryland areas.

## 1. Introduction

Dryland is currently receiving serious attention to be developed as food-producing area. This is due to the increasing need for food as a result of the increase in population. The area of dryland is estimated at 6.15 million hectares or 47.2% of the land area worldwide [1]. In Indonesia, the percentage of dryland is about 75.6% of the land area or around 144.47 hectares and 29.39 hectares of which have the potential to be developed as food-producing lands [2]. Considering this fact, dryland in Indonesia is very potential to be developed as a food producer since the prediction from Food and Agriculture Organization (FAO), that in 2050 the need for food, especially from grains, will increase by around 30% [3].

Maize is one of the grains food sources which is also used as the main source of animal feed ingredients. Currently, most maize crops are cultivated on dryland to avoid competition with rice in paddy fields. However, most dryland soils have low C-organic resulted in low fertility and productivity [4]. Moreover, the dryland soils mainly have coarse textures, low nutrient content and low water holding capacity to make the plants growing on it are prone to stress, especially drought stress [1]. These conditions have resulted in low productivity of maize grown on drylands. In the province of Nusa Tenggara Barat (NTB), the productivity of maize in dryland areas is only 5.3 ton/ha [5]. Meanwhile, the overall maize productivity in NTB in 2018 reached 6.7 ton/ha [6]. At the research level, the yield of maize grown on dryland can reach a range of 8.2 to 9.7 ton/ha [7]. These results were achieved with high inorganic fertilizers (urea 500 kg/ha and NPK Phonska 380 kg/ha) inputs and an optimum light interception by the plant canopy.

The use of high inorganic fertilizers input, especially in sandy dryland soils such as in North Lombok Regency, is needed because of the very poor soil nutrients content. In the previous study it was reported that in sandy soil of dryland in North Lombok, the soil organic carbon content is low [8]. Meanwhile, the use of high input inorganic fertilizers with intensive crop cultivation practices can rapidly reduce the C-organic content in the soil [4]. This means that the level of soil fertility in dryland will continue to decline so that the plant productivity will also continue to decline. Therefore, it is necessary to make efforts to increase soil fertility in dryland.

Several methods to increase the soil C-organic content and soil fertility in dryland have been widely applied. One of the methods reported was to include organic matter because organic matter can improve soil physical, chemical, and biological properties [9]. Organic materials can be obtained by rotating the crops and the common practice is to rotate grain crops, such as maize with legume crops, such as chickpeas [10]. The residue from mungbean crops that have been harvested, was reported to have a positive effect on rice yield due to its high contribution of nitrogen [11]. However, how effective is this organic material to increase soil fertility depends on several factors, such as the source of organic matter, the minimum amount of application, the right application method, and the stability of the applied organic matter in the soil [12].

Organic material derived from mungbean residue incorporated into the soil was reported to increase the yield and yield components of barley [13]. Furthermore, it was reported that the mungbean plant residue that was incubated at different times could increase soil C-organic, cation exchange capacity, P and K content, and exchangeable Mg but decreased the N content and soil pH [14]. This study aimed to examine soil properties and yield of maize in a mungbean-maize crop rotation system on a dryland.

## 2. Materials and methods

### 2.1. Materials and site description
Mungbean cv. Vima-1 (produced by BALITKABI Malang) and maize varieties of NK7328 (produced by PT. Syngenta) and Bisi18 (PT. BISI International) were the main materials for this study. Series of field experiments were carried out on a dryland in Gumantar village, Kayangan subdistrict, North Lombok, Indonesia, from April 2019 to April 2020. Soil properties at the experimental site were as follows: pH 6.6, C-organic (Walkley-Black) 0.92%, N-total (Kjeldhal) 0.07%, available P (Spectro) 7.36%, and exchangeable K (Ammonium acetate) 0.49 meq%. The soil class was Entisol with a sandy loam texture.

### 2.2. Methods

*2.2.1. Treatment and crops establishment.* From April to June 2019 mungbean was grown as a cover crop at various population densities (250,000, 375,000, and 500,000 plants/m$^2$) combined with two desiccation times, 28 and 35 days after sowing (DAS) to form six treatments plus one control treatment. The size of each treatment plot was 17.5 m$^2$. The treatments were allocated randomly in a Randomized Block Design and were replicated three times. Following the mungbean cover crop desiccation, maize seeds were sown at a population density of 9 plants/m$^{2,}$ and the crops were

harvested in September 2019. The results of the experiment have been submitted for publication elsewhere. In October 2019, mungbean was again planted at the same population densities in the same plots as before combined with two classes of mungbean seeds, namely stock seeds and extension seeds. The control plot with three replications was left uncultivated. The mungbean seeds then were harvested in the second week of December 2019 and the biomass residue of each treatment was determined. The mungbean residue from each treatment then was incorporated into the soil along with soil preparation. The three control plots were also prepared to make them ready for the new maize crops. The maize seeds were sown on the 11th January 2020 at the same population density as the previous maize crops and the crops were harvested on the 25th April 2020.

*2.2.2. Crops management*. All water required to support plant growth was provided by the rainfall. Fertilizers applied for the maize crops were the same as the previous year, started with basal fertilizers, consisted of urea and NPK (nitrogen, phosphor, potassium) Phonska (15-15-15) at doses of 150 and 190 kg/ha, respectively. The first supplementary fertilizer was applied when the plants were at 35 days after planting (DAP) with 200 and 190 kg/ha doses of urea and Phonska, respectively. The last fertilization was at tasselling (56 DAP) by using urea at a rate of 150 kg/ha. Mechanical weeding was done once a day before the first supplementary fertilization. No pesticide was applied during the experiment because there was no significant pest attack. A systemic fungicide (Tebukonazol + Trifloksistrobin) was applied at 75 DAP to prevent the spread of an unidentified fungus that caused discoloration of the lower leaves. The harvest time was at 110 days after planting.

*2.2.3. Measurements of variables*. Variables measured were grouped into three. First was mungbean biomass at harvest and soil properties (N, P, and K), second was maize crops measurements that included plant height, and N, P, K contents in leaves tissue at tasselling, and third, yield and yield components at harvest. All the collected data were analysed using Analysis of Variance (ANOVA) in Minitab15 continued with Duncan's Multiple Range Test for those showing significant differences.

## 3. Results and discussion

### *3.1. Crops performance*

The rainfall intermittent from the sowing time (11th of January) to the first supplementary fertilizers application (figure 1), resulted in the slow growth of the crops. Very little rainfall was received during the period of tasselling to kernels filling (from 10th of March onward) that resulted in the underperformance of the Bisi18 variety. Earlier, in the rainy season of 2015/2016, maize crops that were grown in the same location received more than double of rainfall than the crops reported in here, their yields were also poor (Jaya et al., 2020). This means that sufficient rainfall is needed during the tasselling to kernels filling stage to ensure a good yield [15].
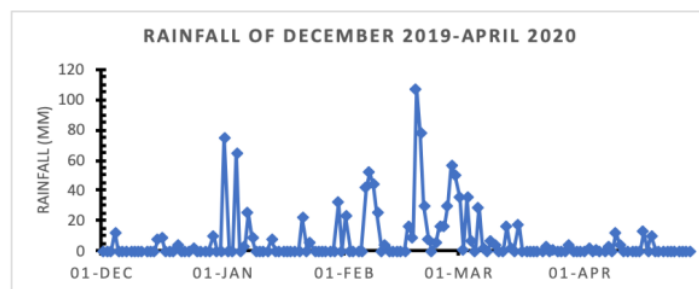


**Figure 1**. Rainfall pattern at the experimental site during the period of the experiment.

### *3.2. Mungbean biomass and soil properties*

The mungbean biomass from various population densities combined with two seed classes is presented in table1. The higher the population densities, the higher the biomass, and no difference was

observed in the two seed classes planted in high densities. Both the two seed classes of mungbean still able to tolerate the high population density for biomass production, even though its optimum population density was at 250,000 plants/ha [16]. The extension seeds outperformed stock seeds in producing biomass only when it was grown in the lowest population density of 250,000 plants/m$^2$. The extension seeds had been well adapted to the location because they were produced locally from stock seeds at the experimental site by a certified local breeder. The stock seeds were imported from Malang, East Java that has a moderately different agro-climate to the experimental site for this study.

**Table 1**. Mungbean biomass, total N, available P, and available K in the soil as affected by mungbean residues from two classes of seeds planted at various densities.

| Treatment | Mungbean biomass (g/m$^2$) | N Total (%) | Available P (ppm) | Available K (meq%) |
|---|---|---|---|---|
| Control | | 0.057a | 0.047a | 0.030a |
| SS 250,000 plants/ha | 646.7a* | 0.063ab | 0.105b | 0.044b |
| ES 250,000 plats/ha | 700.0b | 0.067ab | 0.125c | 0.047bc |
| SS 375,000 plants/ha | 1255.7c | 0.077bc | 0,131cd | 0.052bcd |
| ES 375,000 plants/ha | 1273.3c | 0.080bc | 0.143de | 0.053bcd |
| SS 500,000 plants/ha | 1540.7d | 0.087c | 0.150e | 0.055cd |
| ES 500,000 plants/ha | 1561.0d | 0.087c | 0.180f | 0.063d |

*Values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confidence interval. SS= stock seeds, ES= extension seeds.

Total N, available P, and available K in the soil improved with mungbean–maize rotation. The results revealed that nitrogen, phosphorous, and potassium in the soil increased substantially by 52.6, 282.9, and 110%, respectively after two years of the rotation (Table 1). These results agree with the earlier findings that mungbean residue improved soil chemical properties, such as exchangeable K, available P, and soil organic carbon [14] and total N [10]. Both studies suggested further use of mungbean residue to improve soil fertility or to reduce the inorganic fertilizer inputs as well as to improve maize yield. The improvement in available P and K increased with the increase of mungbean residues resulted from the increase in population density. In the case of total N in the soil, the improvement was started to occur at mungbean residues resulted from 375,000 plants/ha. These findings showed that the lowest population density for mungbean as a rotation crop, to be able to give an effect on soil nitrogen, should be at 375,000 plants/m$^2$. For available P and K, residues resulted from population density as low as 250,000 plants/ha have had already a significant effect.

*3.3. Maize crops measurements*

**Table 2**. Total N, P, and K in maize leaves tissue, maize plant height at tasselling, and maize biomass at harvest as affected by mungbean residues from two seeds classes planted at various densities.

| Treatment | Total N Tissue (%) | Total P Tissue (%) | Total K Tissue (%) | Plant height (cm) | Maize biomass (kg/m$^2$) |
|---|---|---|---|---|---|
| Control | 2.617a* | 0.195a | 0.113a | 178.7a | 1.67a |
| SS 250,000 plants/ha | 2.753b | 0.194a | 0.174b | 184.0ab | 1.70ab |
| ES 250,000 plats/ha | 2.850c | 0.216ab | 0.1747b | 187.7bc | 1.71abc |
| SS 375,000 plants/ha | 2.913c | 0.239bc | 0.177b | 193.0c | 1.90bcd |
| ES 375,000 plants/ha | 2.937cd | 0.243bc | 0.179bc | 195.7c | 1.97cd |
| SS 500,000 plants/ha | 3.040d | 0.268c | 0.187c | 201.0c | 1.97cd |
| ES 500,000 plants/ha | 3.190e | 0.329d | 0.208d | 200.3c | 2.10d |

*Values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confidence interval. SS= stock seeds, ES= extension seeds

The total N, P, and K in the leaf tissue significantly higher in the maize that had been rotated with mungbean than that maize without mungbean rotation (control treatment). It appeared that the higher mungbean biomass residue from a higher population density, the higher the total N, P, and K in the leaf tissue (Table 2). These results showed that the mungbean residues incorporated into the experimental site had met the effective doses as one of the requirements to make residue application from previous crops to be useful for the following crops [12]. In contrast to P availability in soil, the total P in leaf tissue of maize plants planted without mungbean rotation (control treatment) was not significant to those plants rotated with mungbean at 250,000 plants/ha. The possible explanation for this result is that BISI 18 variety, grown at the experimental site with a lack of rainwater, might not perform a high P absorption efficiency. An earlier study reported that the P absorption by maize crops depends on the maize genotype [17].

Maize plants height at tasselling and their biomass (without ear) at harvest are presented in table 2. The results showed that the tallest maize crop was recorded at the highest mungbean residues resulted from the highest population density in both seed classes, and the shortest was recorded in the control treatment. There was a close ($r^2$=0.76) and significant ($p$<0.05) correlation between N in the leaf tissue with plant height. This result showed that the photosynthetic capacity of maize plants increased with the increase of N concentration in the leaf [18] that resulted in taller plants in the higher mungbean biomass residues treatments. The maize biomass at harvest also increased with the increase of mungbean residues resulted from the higher population densities. However, the plant height in the control treatment was not significantly different to those plants with mungbean residue treatments resulted from stock seeds and extension seeds planted at 250,000 plants/ha. The maize biomass pattern data was similar to total P in leaf tissue data. The possible reason for this condition was that the low P content in plant tissue reduced the maize growth, especially leaf growth, resulted in lower plant biomass [19].

### 3.4. Yield and yield components of maize

Mungbean-maize rotation resulted in an average of 44.7% increase in maize yield (kernel weight/plot) compared to control treatment. The highest increase was resulted from the highest mungbean population density for both stock and extension seed treatments (Table 3). The increase in maize yield reported in here was much less than the one reported earlier on chickpea (*Cicer arietinum* L) – maize rotation in North-Western Pakistan based on four years rotation study. It was reported that maize yield increased by 122% and stover yield (biomass) increased by 133% [10].

**Table 3**. Yield and yield components of maize as affected by mungbean residues from two seeds classes planted at various densities.

| Treatment | Ear weight per plant (g) | Kernel weight per Ear (g) | Weight of 1000 kernels (g) | Kernels weight per plot (kg) |
|---|---|---|---|---|
| Control | 107.08a | 88.4a | 256.33a | 8.33a |
| SS 250,000 plants/ha | 115.43ab | 95.33ab | 264.67a | 8,5ab |
| ES 250,000 plats/ha | 121.37b | 100.07abc | 273.00ab | 9.00b |
| SS 375,000 plants/ha | 127.33bc | 104.6bc | 279.67ab | 9.00b |
| ES 375,000 plants/ha | 136.20c | 112.4c | 290.67bc | 9.167b |
| SS 500,000 plants/ha | 139.73c | 115.33c | 291.67bc | 10.50c |
| ES 500,000 plants/ha | 141.73c | 116.2c | 293.15c | 11.03c |

*Values followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confidence interval. SS= stock seeds, ES= extension seeds

Lack of rainfall, both during the early growth stage and kernel filling stage (Figure 1), was the main reason for the low yield of maize in the current study. For yield components, such as ear weight per plant, kernel weight per ear, and weight of 1000 kernels, were very much increased with the increase of mungbean population density. The pronounced maize yield components increased

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however, was started from mungbean population density of 375,000 plants/ha for both stock and extension seeds. This might due to the contribution of nutrients by mungbean residues, such as total N, available P and available K in the soil that started to increased significantly at that population density (Table 1).

## 4. Conclusion

Incorporating mungbean residue in mungbean-maize crop rotation system improved soil chemical properties, such as total nitrogen, available phosphorous, and available potassium by 52.6, 282.9, and 110%, respectively. These improvements were achieved when the mungbean crops were planted at 500,000 plants/ha. Fewer improvement values for soil chemical properties were recorded from the lower mungbean population densities. The improvement in soil chemical properties led to an improvement in maize yield up to 44.7%. The 44.7% in yield improvement after two consecutive years of the study is considered low because of the sub-optimal growing conditions due to lack of rainfall, both during the initial growth and kernel filling stages. The practice of mungbean-maize rotation system and incorporating the mungbean residues to the soil needs to be continued to improve soil properties, to sustain environmental quality, and to increase maize yield in dryland areas.

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