

# Mung bean cover crop improved soil organic

*by I Wayan Sudika*

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## Mung bean cover crop improved soil organic carbon and maize yield in a semiarid area

I K D Jaya<sup>1,2\*</sup>, Sudirman<sup>2</sup> and I W Sudika<sup>2</sup>

<sup>1</sup> Dryland Agriculture Study Programme, Postgraduate University of Mataram, Jl. Pendidikan 37 Mataram 83125, Lombok, West Nusa Tenggara, Indonesia

<sup>2</sup> Faculty of Agriculture, University of Mataram, Jl. Majapahit 62 Mataram 83125, Lombok, West Nusa Tenggara, Indonesia

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Corresponding author: ikdjaya@unram.ac.id

**Abstract.** The study aimed to know the potential use of mung bean (*Vigna radiata* L. Wilzeck) as a cover crop and its effect on soil organic carbon and maize yield were studied. Six cover crop treatments; 250,000, 375,000 and 500,000 plants/ha combined with desiccation times at 28 and 35 days after sowing (DAS) and one control treatment (without cover crop), were tested in a semi-arid area of North Lombok. Maize at a density of 98,000 plants/ha was planted two weeks following the desiccation time. The treatments were arranged in a Randomized Block Design with three replications. The results revealed that the higher cover crop population density with later desiccation time, produced higher above ground biomass, being the highest at 8.3 Mg/ha and the lowest at 2.6 Mg/ha. The highest cover crop biomass improved soil organic carbon by 60%, nitrogen, phosphorous and potash concentrations in plant tissue by 54%, 54% and 63%, respectively, compared to the one in the control treatment. Maize yield also increased by 24% at the highest cover crop density desiccated at 35 DAS. The use of mung bean as a cover crop sounds promising and further studies are needed to explore more of its potential benefits.

### 1. Introduction

Statistic Indonesia in 2018 showed that maize (*Zea mays* L.) productivity in West Nusa Tenggara (WNT) in 2018 was 6.71 tons / ha, far higher than the average national maize productivity, which was only 5.24 tons / ha in the same year. There have been several factors that contribute to increasing the productivity of maize in NTB, including the use of hybrid varieties and fertilization. Hybrid varieties of maize planted on a dry land could increase productivity (reaching 17 tons / ha) if the population density was increased to close to 100,000 plants per hectare [1]. When the maize crops were planted in a double-row pattern that resulted in population density of approximately 100,000 plants/ha, the sunlight captured by the canopy of maize plants during the tasseling phase was 95% [2]. Earlier study showed that a maximum yield of maize was achieved when the canopy of maize plants able to capture sunlight by 95% during tasseling until the grains filling phase [3].

The high yield of maize in a dryland reported earlier [2] was a result of high fertilizers application rate. The fertilizers applied were N-P-K Phonska, that contained nitrogen, phosphorous and potassium (15-15-15) as much as 600 kg / ha and 300 kg/ha Urea. Besides being expensive, the use of too much inorganic fertilizer in a long period of time could have negative impacts on soil. Inorganic fertilizers or other inorganic inputs, such as pesticides and herbicides, can directly or indirectly affect



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microorganisms (biota) in the soil and have a negative impact on the environment [4,5]. Soil biota which plays an important role in the process of recycling nutrients in the soil and also plays a role in the process of nitrification, is threatened by the use of continuous inorganic agricultural inputs [6] and decreasing soil organic matter content.

In the long term, the use of chemical fertilizers, especially fertilizers containing nitrogen (N) in maize plants can be reduced by planting cover crops that are able to fix N from the air and to add organic material to the soil [7]. Cover crop is defined as any type of living ground cover that is planted together with the main crop or after the main crop and is generally killed before the next crop is planted [8]. The cover crops can be a source of organic material in the soil and this organic material, in addition to being a source of soil nutrition in the short term, can also maintain soil fertility in the long term [9]. Other studies also reported that cover crops were able to reduce nitrate leaching from maize plantations by 40% compared to the conventional maize planting systems without the use of cover crops [10]. Cover crops can also improve soil structure, increase soil capacity to retain water to increase the effectiveness of nitrogen fertilization [11].

Legume crops, such as mung bean has been already as an integrated part of the agricultural system in semi-arid areas, especially as an adaptation strategy to climate change by means of crop diversification [12]. Growing mung bean together with maize crops in a strip intercropping system was reported to increase land use efficiency, and was economically feasible to be carried out by farmers on drylands because the system can provide additional income to maize farmers [13]. In the dryland of North Lombok, 'Kenari', a superior mung bean variety, when planted at a population density of 500,000 plants / ha could produce more than 2 tons of seeds [14]. However, information on the use of mung bean as cover crops in maize plants, especially the management technology of mung bean cover crops that related to biomass production, has not been reported. Biomass production of cover crops is determined by population density and growing period [15]. This study aimed to study the contribution of mung bean as a cover crop, grown at various population densities and growing periods, on soil organic carbon and yield of maize in a semi-arid area.

## 2. Materials and methods

### 2.1. Site description and experimental design

A field experiment was carried out in a semi-arid area of Gumantar village, Kayangan subdistrict, North Lombok (8,253654 S, 116,285695 E), Indonesia, from April to September 2019. In the area, maize is the main crop grown by farmers during the rainy season. In the dry season, most of the time the lands are left fallow due to the difficulty to access water. 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 (Spectro) 14.96%. The soil order was Entisol with sandy loam texture.

The experiment design was a randomized block design with three replications. The treatments were: (A). Control (without mung bean cover crops); (B). Mung bean population of 250,000 plants/ha and was desiccated at 28 days after planting (DAP); (C). Mung bean population of 250,000 plants/ha and was desiccated at 35 DAP; (D). Mung bean population of 375,000 plants/ha and was desiccated at 28 DAP; (E). Mung bean population of 375,000 and desiccated at 35 DAP; (F). Mung bean population of 500,000 and was desiccated at 28 DAP; and (G). Mung bean population of 500,000 and desiccated at 35 DAP.

### 2.2. Mung bean cover crops preparations and management

Seeds of the cover crops (mung bean cultivar Vima-1) were planted soon after the main crop (maize, that had been planted during the rainy season of December 2018 to March 2019) was harvested. Treatment plots were made and the size of each plot was 350 × 500 cm. Before the seeds were sown, soil preparations were conducted by cleaning, ploughing and harrowing, except in the control plots (without cover crop treatment), no ploughing and harrowing were done. The cover crop populations

were adjusted according to the treatments. For those cover crops that were desiccated at 35 DAP had been planted a week earlier than those desiccated at 28 DAP.

The mung bean cover crops were fertilized with 100 kg / ha of NPK (15-15-15) Phonska. Furthermore, the cover crops were maintained until they were desiccated. Desiccation of all the cover crops was done at the same day by spraying using a mixture of contact (paraquat) and systemic (glyphosate) herbicides (according to treatment). Two weeks after the desiccation of the cover crops, maize seeds (cultivar NK212 produced by Syngenta) were planted (without tillage) in plots that already contained biomass of cover crops according to the treatments. For control treatment, the plots were prepared (ploughed and harrowed) according to the maize planting standards.

### 2.3. Maize management

Maize crops were planted in the 70 × 35 × 20 cm double-row planting pattern, where the distance between two double rows was 70 cm, the distance within the double row was 35 cm, and the spacing in a double row was 20 cm. The plot size of each treatment was 500 × 350 cm<sup>2</sup>, and with such a plot size, five double rows of maize were planted in each plot with one single row in each edge of the plot. The planting orientation was east-west.

The crops were fertilized with basic urea fertilizer and NPK (nitrogen, phosphor, potassium) Phonska (15-15-15) at doses of 150 and 190 kg/ha, respectively. Furthermore, 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. A 150 kg/ha dose of urea was applied for the third time at tasseling (56 DAP). Weekly irrigation water was obtained from a deep-well pump located nearby the experimental site. The maintenance of the crops, such as mechanical weeding, was done before the first supplementary fertilizer application. A systemic fungicide (Tebukonazol + Trifloksistrobin) was applied at 70 DAP to prevent the spread of an unidentified fungus that caused discoloration of the lower leaves.

### 2.4. Measurements and data analysis

Above ground biomass of the cover crops were measured before the herbicides were sprayed to desiccate the mung bean. A one square meter sample from each plot were taken by cutting the crops on the soil surface then was weighed. For maize, the variables measured at the end of the vegetative stage (at tasseling) were height of the plants, number of leaves, interception of sunlight by the plant canopy and nutrients content included nitrogen (Kjeldhal), phosphorous (Spectro) and potassium (AAS) of the plant tissue (a mix of stems and leaves). Light interception was measured using AccuPAR/LAI Ceptometer LP-80, METER Group, Inc. USA at midday (at 60 DAP). Soil organic carbon at the maize crops rhizosphere from each treatment plot was also measured (Walkley-Black).

Maize biomass at harvest was measured soon after the cobs were removed from the plants. A one square fresh sample were cut above the ground and then weighed. The crop yield (weight of kernels per plot) and its components, such as cob weight and weight of 1,000 seeds were measured after the cobs were sundried 2 days without husk and shank. Analysis of variance for all collected data was run on Minitab 15 followed by Duncan Multiple Range Test (DMRT) for the significantly different data. Correlation analyses for some variables were performed in Microsoft Excel.

## 3. Results and discussion

The results of the study showed that the higher cover crops population density followed by the later desiccation time, the higher cover crops biomass produced (Table 1). The highest increase in biomass (51%) as a result of delaying desiccation time was obtained at cover crops population density of 375,000/ha. In the other two population densities, a week delay in desiccation time resulted only 34 and 10% increased of biomass for 250,000 and 500,000 cover crops/ha respectively. The results were obvious because the higher population density and the older the cover crops mean the more carbon accumulated into biomass. The 375,000 plants/ha might be the most optimum population for mung bean to grow. Earlier study showed that plant height and leaf area index of mung bean increased with



the increased of population from 200,000 to 300,000 plants/ha [16]. The percentage of biomass increased with the delay of desiccation time at the population density of 500,000 plants/ha was not as large as in the population density of 375,000 and this might due to an intra-specific competition in the highest population density.

**Table 1.** Above ground of cover crops biomass, soil C-organic, total N, P and K in plant tissue as affected by mung bean cover crops treatments

Treatments	Variables measured				
	Cover crops biomass (Mg/ha) <sup>a</sup>	Soil C-organic (%)	Total N in tissue (%)	Total P in tissue (%)	Total K in tissue (%)
Control	0.0 <sup>a</sup>	0.92 <sup>a</sup>	0.033 <sup>a</sup>	0.32 <sup>a</sup>	0.014 <sup>a</sup>
250,000 plants, desic. at 28 DAS	2.6 <sup>b</sup>	0.96 <sup>ab</sup>	0.043 <sup>b</sup>	0.34 <sup>ab</sup>	0.015 <sup>a</sup>
250,000 plants, desic. at 35 DAS	3.5 <sup>bc</sup>	1.02 <sup>ab</sup>	0.053 <sup>cd</sup>	0.36 <sup>bc</sup>	0.016 <sup>a</sup>
375,000 plants, desic. at 28 DAS	4.3 <sup>c</sup>	1.14 <sup>bc</sup>	0.053 <sup>cd</sup>	0.37 <sup>cd</sup>	0.016 <sup>a</sup>
375,000 plants, desic. at 35 DAS	6.5 <sup>d</sup>	1.23 <sup>bcd</sup>	0.057 <sup>d</sup>	0.40 <sup>d</sup>	0.017 <sup>ab</sup>
500,000 plants, desic. at 28 DAS	7.5 <sup>e</sup>	1.32 <sup>cd</sup>	0.060 <sup>d</sup>	0.41 <sup>d</sup>	0.018 <sup>ab</sup>
500,000 plants, desic. at 35 DAS	8.3 <sup>e</sup>	1.47 <sup>d</sup>	0.063 <sup>d</sup>	0.49 <sup>e</sup>	0.023 <sup>b</sup>

<sup>a</sup> Mean values in the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confident interval

Soil organic carbon <sup>31</sup> increased with the increased of population density and desiccation time (Table 1) and there was a strong and significant correlation between the two variables ( $r^2 = 0.96$ ;  $p = 0.00074$ ). This result agrees with a previous research, that cover crops improved soil organic carbon [17] and a suggestion to increase the amount of biomass cover crops in order to get more soil organic carbon [18]. Along with soil organic carbon, the percentage of total nitrogen (N), phosphorous (P) and potassium (K) in the maize plant tissues, that were measured at 60 days after planting (DAP) also increased (table 1). There were strong and significant correlations between soil organic carbon and N ( $r^2 = 0.79$ ;  $p = 0.0074$ ), soil organic carbon and P ( $r^2 = 0.94$ ;  $p = 0.00029$ ) and soil organic carbon and K ( $r^2 = 0.86$ ;  $p = 0.0026$ ). Leguminous cover crops improve nutrients availability in the upper layer of the soil by absorbing the low availability nutrients in the soil profiles [19]. The decomposed biomass of cover crops released N and contributed more N in the soil-plant system to make more N and P available to maize plant [20]. The available nutrients in the upper layer of the soil were also made more available to be absorbed by the maize plants with the increase of soil organic matter content [21].

Increasing cover crops population density and delaying the desiccation time did not have significant effect on the height of maize crops at tasseling stage (Table 2). According to the description of the variety, the height of NK212 variety is 190cm. In this study, all of the treatments, including control, produced plants that higher than 190cm. Unlike plant height, number of leaves of the maize crops was affected by increasing the cover crop population density and delaying desiccation time. However, the cover crop started to have effect only when there grown at 375,000 plants/ha with desiccation time at 35 DAP or at 28 DAP, when the population density was 500,000 plants/ha as seen in table 2. <sup>43</sup> There were at least 33% increase in soil carbon as a result of cover crops application with population density of 375,000 plants/ha or more and desiccated at 35 DAP (Table 1). The mung bean cover crop might enrich the humic substance in the soil as reported for rye and vetch [22]. Humic substance has been reported to have a positive effect on plant growth and can increase the number of leaves of maize crops [23]. This finding is in agreement with the result of this study that the number of maize leaves improved with the cover crops treatments at a certain level.

Light interception by the maize crops canopy at tasseling increased with the increased of cover crop population density and delaying desiccation time (Table 2). The highest light interception was recorded at cover crop population density of 500,000 plants/ha but there was no significant difference between those cover crop treatments desiccated at 28 and 35 DAP. In these two treatments, the light interception by the maize plant canopy at tasseling was at around 95%. This value is suggested by

Puntel [3] to be the most optimum light interception by maize canopy during tasseling up to grain filling stage. Furthermore, Puntel elaborated that the ability of maize canopy to intercept sunlight was improved when nitrogen applied was sufficient to improve nitrogen content in the plant tissue, especially in the leaves. In this study, it was a strong and significant relationship ( $r^2=0.82$ ;  $p=0.0047$ ) between total nitrogen maize in plant tissue and light interception. As it has been discussed earlier, the total nitrogen content in the plant tissue increased with the increased of cover crop biomass.

**Table 2.** Maize plants height, number of leaves and light interception by the canopy at tasseling stage as affected by mung bean cover crops treatments

Treatments	Variables measured		
	Plant height (cm) <sup>a</sup>	Number of leaves	Light interception (%)
Control	192.0 <sup>a</sup>	15.2 <sup>a</sup>	88.7 <sup>a</sup>
250,000 plants, desic. at 28 DAS	197.1 <sup>a</sup>	15.2 <sup>a</sup>	89.2 <sup>ab</sup>
250,000 plants, desic. at 35 DAS	202.5 <sup>a</sup>	15.6 <sup>ab</sup>	92.4 <sup>c</sup>
375,000 plants, desic. at 28 DAS	199.0 <sup>a</sup>	15.2 <sup>a</sup>	90.2 <sup>b</sup>
375,000 plants, desic. at 35 DAS	199.7 <sup>a</sup>	15.9 <sup>b</sup>	93.5 <sup>cd</sup>
500,000 plants, desic. at 28 DAS	239.4 <sup>a</sup>	16.1 <sup>b</sup>	95.0 <sup>d</sup>
500,000 plants, desic. at 35 DAS	209.1 <sup>a</sup>	16.1 <sup>b</sup>	95.2 <sup>d</sup>

<sup>a</sup> Mean values in the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confident interval

Table 3 shows that yield (weight of kernels per plot), yield components (cob weight and weight of 1,000 kernels) and maize biomass at harvest increased with the increase of cover crops population density and the delay of desiccation time. The highest yield (15.7 kg/plot or equal to 8.97 ton/ha) and its components was recorded at population density of 500,000 plants/ha with desiccation time at 35 DAP. However, the yield produced from treatment of 500,000 cover crops/ha and desiccated at 28 DAP did not significantly different yield resulted from 375,000 cover crops/ha at both desiccation times. Relatively the same pattern of cover crops effect on yield was found in the weight of maize biomass at harvest. The cob weight and weight of 1000 kernels produced from the highest cover crops population density was not significantly different to the cobs produced by maize crops in the treatment of 250,000 cover crops/ha desiccated at 35 DAP as well as at 375,000 cover crops/ha with both desiccation times.

**Table 3.** Yield, yield components and above ground fresh biomass of maize at harvest as affected by mung bean cover crops treatments

Treatments	Variables measured			
	Weight of cob (g)	Weight of 1,000 kernels (g)	Weight of kernels/plot (kg)	Biomass of maize (kg)
Control	158.0 <sup>a</sup>	256.3 <sup>a</sup>	12.7 <sup>a</sup>	5.4 <sup>a</sup>
250,000 plants, desic. at 28 DAS	160.2 <sup>ab</sup>	264.7 <sup>ab</sup>	13.0 <sup>a</sup>	5.8 <sup>ab</sup>
250,000 plants, desic. at 35 DAS	169.5 <sup>bc</sup>	273.0 <sup>abc</sup>	13.3 <sup>ab</sup>	6.1 <sup>bc</sup>
375,000 plants, desic. at 28 DAS	172.7 <sup>bc</sup>	279.7 <sup>bc</sup>	14.2 <sup>bc</sup>	6.0 <sup>bc</sup>
375,000 plants, desic. at 35 DAS	180.1 <sup>c</sup>	290.7 <sup>cd</sup>	14.3 <sup>bc</sup>	6.4 <sup>bc</sup>
500,000 plants, desic. at 28 DAS	182.9 <sup>c</sup>	291.7 <sup>cd</sup>	14.7 <sup>cd</sup>	6.7 <sup>cd</sup>
500,000 plants, desic. at 35 DAS	188.9 <sup>c</sup>	312.0 <sup>d</sup>	15.7 <sup>d</sup>	7.3 <sup>d</sup>

<sup>a</sup> Mean values in the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test at 95% confident interval

The higher yield and yield components of maize grown in higher cover crops population densities treatment mostly attributed to the higher ability the maize canopy to intercept sunlight. The correlation between light interception and maize yield (weight of kernels per plot) was strong and significant ( $r^2=0.72$ ;  $p=0.016$ ). Higher sunlight interception by the maize plants' canopy resulted in higher photosynthate produced by the leaves. Leaves photosynthetic capacity increases with the increase of nitrogen in the plant tissue, especially in the leaves [3,24], as well as with potassium [25]. On the other hand, high phosphorous concentration in the plant tissue improved the number of leaves that led to the improvement in light interception and plant biomass [26]. Table 2 shows that total N, P and K in the plant tissue increased with the increase of cover crops population densities and delaying the desiccation time.

#### 4. Conclusions

The higher population density of the mung bean followed by the later desiccation time, the higher the above ground biomass of cover crop was produced. The degraded cover crop biomass improved soil organic carbon in the soil up to 60% and resulted in higher yield of the maize. The best yield of maize (up to 15.7 kg/plot or equal to 8.97 ton/ha) was resulted from the treatment of 500,000 plants/ha of mung bean cover crop that was desiccated at either 28 or 35 days after planting. Maize yield in the control treatment (without mung bean cover crop) was 12.7 kg/plot or equal to 7.26 ton/ha. Since the use of mung bean cover crop could improve maize yield by up to 23%, this practice needs to be considered in developing a sustainable maize production system, especially in arid areas.

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