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Research Article

Conservation farming in rain-fed agriculture: can biogeotextile, cover crop residues, and soil tillage application improve the growth and the yield of maize (*Zea mays* L.)?

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Abstract: Market demand for maize (*Zea mays* L.) in Indonesia is increasing from time to time along with the increasing demand for food and livestock for fodder. However, current farming practices in the upland area where maize usually cultivated, threaten the sustainability of maize production. Conservation farming could be an alternative to reduce land and soil degradation caused by current farming practices. A factorial randomized block designed field experiment was conducted to determine the combined effect of biogeotextile with cover crop residues and soil tillage on growth and yield of maize. The treatments included utilization of Mendong plant's mat (*Fimbrystilis globulosa*) as biogeotextile material and four cover crop species: Sunn hemp (*Crotalaria juncea*), Cowpea (*Vigna unguiculata*), Pigeon pea (*Cajanus cajan*), and Mucuna (M*ucuna spp*). The results showed that the biogeotextile mat and cover crop residues, but not soil tillage, increased maize height and the number of leaves, and yield of maize. Biogeotextile mulch increased maize yield up to 43% compared to control. The highest yield (8.0 t/ha) was shown by the combination of biogeotextile application with cowpea residues. Conservation farming is prospective for improving plant production and protecting land from degradation.

***Keywords**: biogeotextile, conservation farming, cover crop residue, soil tillage, Zea mays*

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Introduction

Maize is the second highest food commodity in Indonesia after rice. Maize usually planted in the upland area where potentially vulnerable to degrade. Since the 1990s until 2015, maize production in Indonesia tends to increase from year to year. In 2014, national maize production reached 19 million tons or increased by 2.6% compared to the previous year. In general, the domestic maize production increased by 1.11% in the period 2010-2015. On the contrary, the harvested area decreases about 1.77% yearly (Ministry of Agriculture, 2015). The sustainability of maize production is becoming a national concern, considering the increasing demand for maize.

Increasing the yield and productivity of maize are closely related to farming practices. Current farming practices on sloping upland potentially cause erosion and hence reduce soil quality. This consequently will inhibit maize growth and yield. Therefore, proper farming practices by applying conservation techniques - what so-called conservation farming - can be an alternative solution. Conservation farming using crop rotation, ground cover and minimum tillage practiced in Malawi, Southern Africa increased maize yield by 35% (Ngwira et al., 2012) until 40% (Thierfelder et al., 2013).

Conservation farming is developed from three basic principles: minimum soil disturbance, organic soil cover and crop diversification (rotation). Previous studies showed that no-till farming or zero tillage as part of minimum soil disturbance generally reduce sensitivity to run off and soil erosion. Zero tillage farming in 4 years decreased runoff to 3 times compared to conventional tillage (Williams et al., 2009). Minimum tillage may reduce soil erosion by 95% depending on the slope and ground cover (Dickey et al., 1983).

As part of conservation farming, the use of legume cover crops to replace fallow season may improve soil quality, through providing organic materials, nutrient supply and preventing erosion by covering soil surface. As an example, mucuna (*Mucuna spp.*) was reported to provide 68% to 92.63% soil coverage in the first six months (Adiele et al., 2014) and useful to reduce soil erosion. Pigeon pea (*Cajanus cajan*) cover crops in combination with minimum soil tillage reduced soil erosion up to 200 kg/ha (Contreras et al., 2014). Besides, to protect soil from erosion, legume cover crop and its residue serve to provide essential nutrient for plants. Sunn hemp (*Crotalaria juncea*) produces 7 t/ha of organic material and 150-165 kg/ha of nitrogen (Rotar and Joy, 1983). A similar report has been reported by Horst and Härdter (1994) that rotating maize and cowpea (*Vigna unguiculata*) increased the yield of maize and nutrient accumulation.

Conservation farming implements the use of organic soil cover as one of its components, which in this study used biogeotextile. Biogeotextile is considered as a potential contribution to the land protection and soil conservation. Biogeotextile is a biodegradable geotextile that uses natural fibres to cover the soil and stabilize the soil (Ogbobe et al., 1998). Geotextile is a favourite material in civil engineering construction activity to strengthen the soil and protect the soil from erosion. Subedi et al. (2012) found that the use of palm leaves as geotextiles and Buriti palm on the fallow area could reduce the height of splash up to 31% and erosion up to 42%. A similar finding was reported by Jankauskas et al. (2012b) that palm-mat biogeotextile effective to decrease soil erosion up by 94% and gave multiple effects on soil conservation, plant growth improvement, and earthworm population.

This study was aimed to identify the impacts of the combination of biogeotextile, cover crop residue, and minimum tillage application, especially concerning plant growth and yield. Maize was selected because of its sensitivity to environmental changes in the soil.

Materials and Methods

This research was conducted in the Agro Techno Park of Brawijaya University in Jatikerto, Kromengan sub district, Malang Regency, East Java, Indonesia from October 2016 until August 2017. The latitude of the area is ± 330 m above the sea level with a temperature range of 27-29°C and an annual rainfall of 2,339 mm. This research was divided into two stages. The first stage was planting of legume cover crop in the fallow period followed by the planting of maize. This research used a randomized block design factorial that consisted of three factors: 1) biogeotextile [with (B_I) and without (B_O)]; 2) type of cover crop residues (4 types); and 3) soil tillage application [(conventional (T_C) and minimum tillage (T_M)]. There were twenty treatments in total (Table 1), with three replications. Legume cover crops used in this study were Sunn hemp (*Crotalaria juncea* L.), Cowpea (*Vigna unguiculata* (L.) Walp), Pigeon pea (*Cajanus cajan* (L.) Millsp.), and Mucuna (*Mucuna spp.*). The material used as biogeotextile was a two-layer mendong leaf (*Fimbristylis globulosa* (Retz.) Kunth) mat with straw in between (Figure 1) that was applied at the rate of 10 t/ha. All cover crops were planted and harvested after two months. Maize was planted two weeks afterwards.

Figure 1. Biogeotextile installation

At land preparation, cover crop residues were incorporated into the soil and cultivated in ridges (conventional tillage application), others were simply flattened without ridges (minimum tillage application). After which, it was covered with biogeotextile following the experimental design. Plant growth parameters (height and number of leaves) were measured every two weeks, started from three weeks after planting (WAP). To determine the yield of maize, this study calculated the oven dry weight of the seeds from the sample in each plot at harvest time to be converted to hectare unit (t/ha). Significance effect of the treatments was analyzed using ANOVA, and continued with Duncan Multiple Range Test at 5% level using GENSTAT 4.0 Discovery Edition program.

Table 1. Biogeotextile, cover crop residue, and soil tillage treatment combinations

Treatments	Description
$B_OC_OT_C$	No Biogeotextile + No cover crop residue + Conventional tillage
$B_OC_MT_C$	No Biogeotextile + Mucuna residue + Conventional tillage
$B_OC_PT_C$	No Biogeotextile + Pigeon pea residue + Conventional tillage
$B_OC_ST_C$	No Biogeotextile + Sunn hemp residue + Conventional tillage
$B_OC_CT_C$	No Biogeotextile + Cowpea residue + Conventional tillage
$B_OC_PT_M$	No Biogeotextile + No cover crop residue + Minimum tillage
$B_OC_MT_M$	No Biogeotextile + Mucuna residue + Minimum tillage
$B_OC_PT_M$	No Biogeotextile + Pigeon pea residue + Minimum tillage
$B_OC_ST_M$	No Biogeotextile + Sunn hemp residue + Minimum tillage
$B_OC_CT_M$	No Biogeotextile + Cowpea residue + Minimum tillage
$B_IC_OT_C$	Biogeotextile + No cover crop residue + Conventional tillage
$B_IC_MT_C$	Biogeotextile + Mucuna residue + Conventional tillage
$B_IC_PT_C$	Biogeotextile + Pigeon pea residue + Conventional tillage
$B_IC_ST_C$	Biogeotextile + Sunn hemp residue + Conventional tillage
$B_IC_CT_C$	Biogeotextile + Cowpea residue + Conventional tillage
$B_IC_OT_M$	Biogeotextile + No cover crop residue + Minimum tillage
$B_IC_MT_M$	Biogeotextile + Mucuna residue + Minimum tillage
$B_IC_PT_M$	Biogeotextile + Pigeon pea residue + Minimum tillage
$B_IC_ST_M$	Biogeotextile + Sunn hemp residue + Minimum tillage
$B_IC_CT_M$	Biogeotextile + Cowpea residue + Minimum tillage

Results and Discussion

The effects of biogeotextile, cover crop residue, and soil tillage on the yield of maize

Yield is an indicator of dryland farming management impact. Genetic and environmental factors influenced the yield. Biogeotextiles, cover crop residues and soil tillage are part of the modified environmental factors which support soil quality for maize growth. The result of the ANOVA test continued with the Duncan test showed that the biogeotextile of mendong mat (B_I) influenced significantly ($p<0.001$) the yield of maize (Table 2). The use of biogeotextile mendong mat (B_I) increased about 43% the yield of maize from 4.32 t/ha without biogeotextile (B_O) to 6.18 t/ha. Cover crop residue (C_I) significantly affected the grain yield of maize. Planting maize after a legume cover crop obtained the average grain yield of 5.53 t/ha or increased by 34% compared to no cover crop of 4.14 t/ha. Soil tillage (T) did not affect the yield of maize because this research was conducted in the first year. It was probably due to the short time of tillage application which takes a longer time to see the response of soil tillage to plant production and plant growth. The average grain yield in conventional tillage application (T_O) of 5.17 t/ha tended to be no different with minimum tillage application (T_I) of 5.37 t/ha.

The effect of biogeotextile application on maize growth

To determine the vegetative growth of maize, the number of leaves and plant height were measured. The result of plant height (Figure 2) and number of leaves (Figure 3) measurements showed that there was a significant effect of biogeotextile treatment. At 21 day after planting (DAP), the average height of maize plant was higher under the application of biogeotextile (38 cm) than the control (27 cm) ($p<0.001$). At the last measurement of plant height at 65 DAP, the average height of maize plant was higher under biogeotextile treatment (160 cm) than control (98 cm). The average number of maize leaves at first observation under biogeotextile treatment was 6 folds higher than the control with 4 folds. At the last observation at 65 DAP, biogeotextile treatment showed a higher value of 12 folds compared to the control of 9 folds (p<0.001). Some leaf died during maize growth processes.

Table 2. Analysis of variance of biogeotextile, cover crop residue and soil tillage

Source of variation	d.f	s.s	m.s	v.r	F pr.
Block Stratum	2	20.49	10.24	3.16	
Block *Unit* Stratum					
Biogeotextile (B)	1	51.76	51.76	15.99	<.001
Cover crop residue (C)	4	32.63	8.16	2.52	0.06
Soil tillage (T)	1	0.78	0.78	0.24	0.63
Biogeotextile. Cover crop residue (BC)	4	5.92	1.48	0.46	0.77
Biogeotextile. Soil tillage (BT)	1	0.31	0.31	0.10	0.76
Cover crop residue.Soil Tillage (CT)	4	15.96	3.99	1.23	0.31
Biogeotextile. Cover crop Residue. Soil Tillage (BCT)	4	8.27	2.07	0.64	0.64
Residual	38	123.04	3.24		
Total	59	259.15			

Remarks: d.f for the degrees of freedom; s.s for the sum of square or the total amount of variability; m.s for mean squares or the sum of squares divided by the corresponding degrees of freedom; v.r for variance ratio; and F pr. for P-value that $\alpha<0.05$ value was significantly affected.

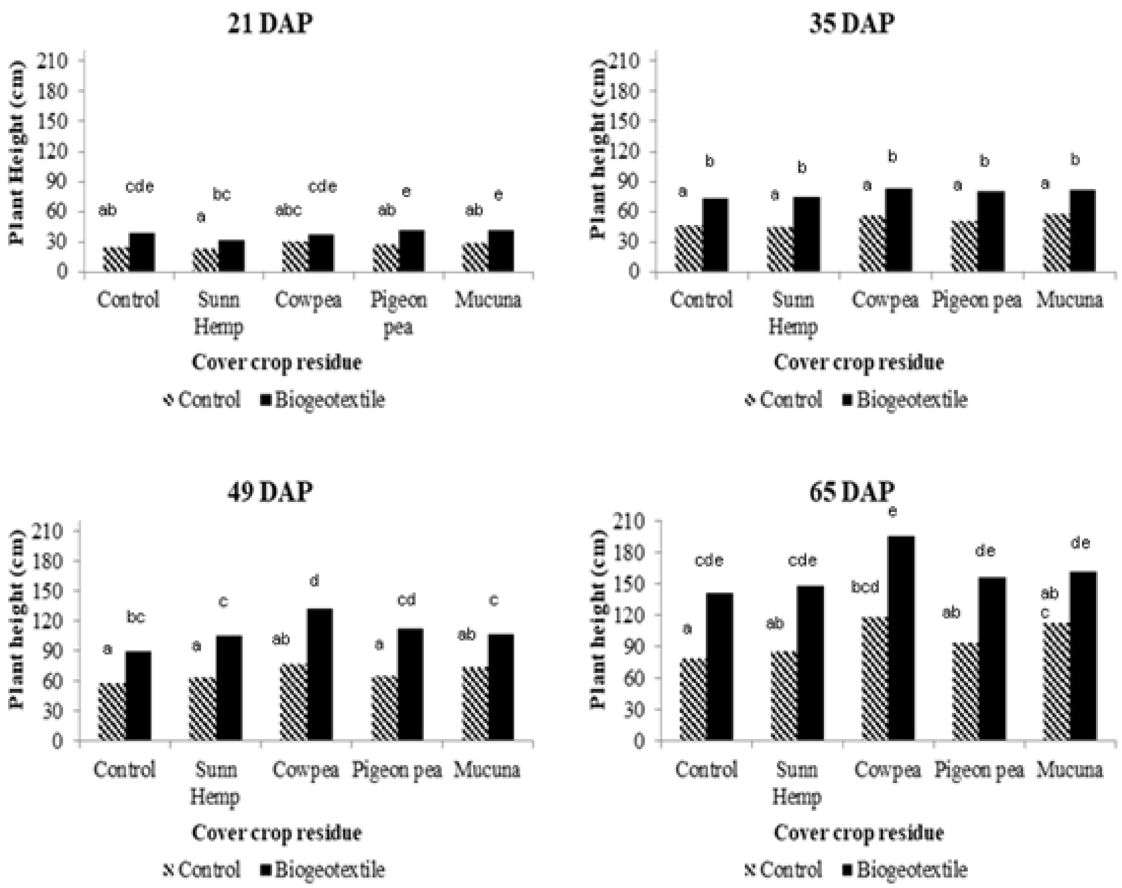

Figure 2. The effect of biogeotextile and cover crop residue on plant height

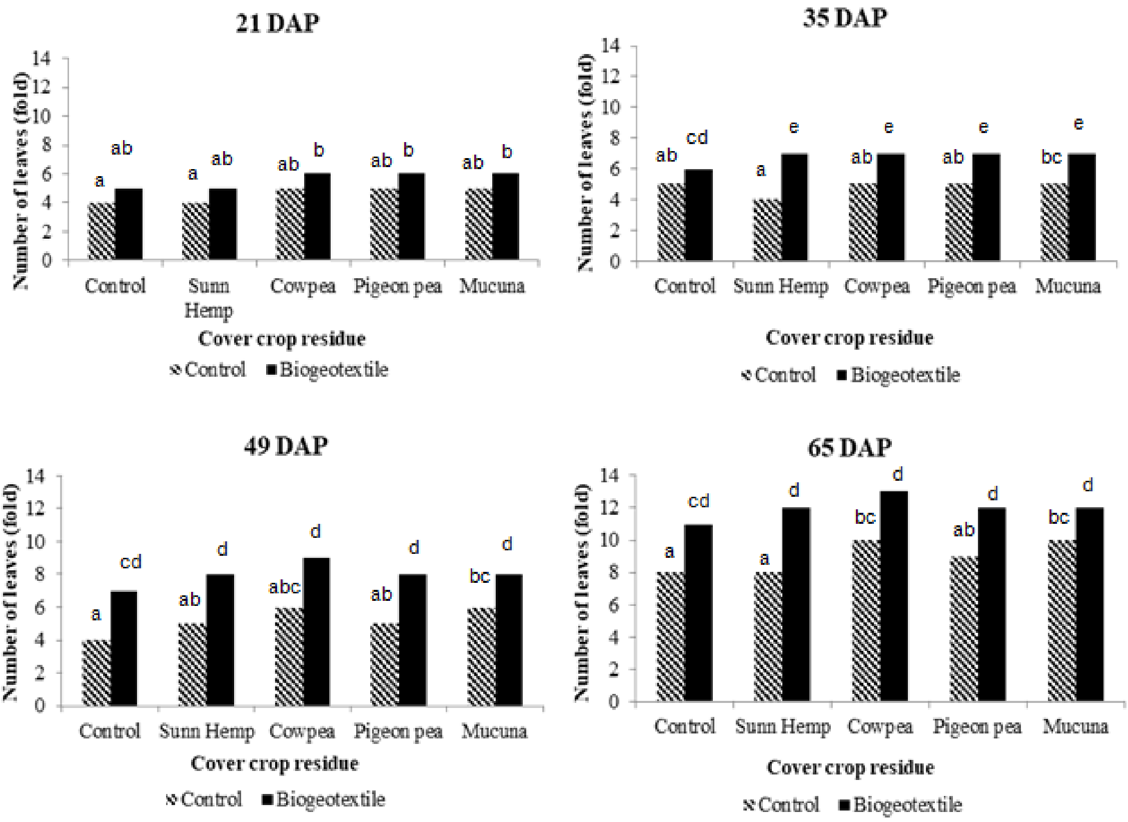

Figure 3. The effect of biogeotextile and cover crop residues on the number of leaves

The environment strongly influenced the number of leaves and plant height. The number of leaves is a response to soil microclimate in the form of temperature and soil moisture. Biogeotextile as well as mulch improved soil physical properties including organic matter contents (Khurshid et al., 2006), increased soil moisture content (Jankauskas et al., 2012a; Li et al, 2013), maintained soil temperature at surface soil at conducive level to the growth of young plants (Sidhu et al., 2007; Subedi et al., 2012; Pradana et al., 2015), and supported root growth (Gajri et al., 1994). It was in line with the finding of this study that soil temperature and soil moisture stayed conducive in the biogeotextile application. High soil moisture on the soil surface covered with biogeotextiles indicates higher soil water content (Prasetyo et al., 2014). Water is essential for plant growth because of its function as a medium for distribution of assimilates from leaves to the meristems that affect plant size (Suminarti, 2011). Dieleman and Heuvelink (1992) also reported that differences in the number of leaves were commonly affected by the total amount of assimilates in the plant during the first inflorescence which depended on light intensity and temperature.

The effect of cover crop residue application on maize growth

Application of cover crop residue, as well as biogeotextile application, significantly affected maize plant growth at all growing periods. At 21 days after planting (DAP) ($p<0.05$), the plant height of maize under cover crop residue application (33 cm) was higher than control treatment (32 cm). At the following measurement, cover crop residue also significantly affected plant height of maize at 35 DAP ($p<0.05$), 49 DAP ($p<0.05$) and 65 DAP ($p<0.05$) (Figure 2). Based on the Duncan Multiple Range Test, there was no significant difference on plant height of maize among application of cover crop residue types at 21 DAP. However, at 35 DAP, 49 DAP, and 65 DAP, there was significantly different. At 35 DAP, cowpea residue resulted in the highest average of maize height among the other type of cover crop residue of 70 cm which was significantly different with sunn hemp of 60 cm. A similar result was found at 49 DAP and 65 DAP. Cowpea residue and sunn hemp contributed the highest and the lowest one respectively of 104 cm and 85 cm at 49 DAP, and at the 65 DAP of 157 cm and 116 cm, respectively. Similar findings were obtained in the number of leaves observation. A significant effect of cover crop residue application on the number of leaves were found at 21 DAP (p<0.01), 35 DAP (p<0.05), 49 DAP (p<0.05) and 65 DAP (p<0.05) (Figure 3). Mucuna residue application contributed the highest average number of maize leaves, and sunn hemp produced the lowest one at 21 DAP. However, at the following measurement, cowpea application always gave the highest one, and sunn hemp application obtained the lowest one on the average number of maize leaves. At the last observation, cover crop residue contributed an average number of leaves of 11 folds which was more than control of 9 folds. Cover crop residues played essential roles for maize growth from their decomposition process which led to nitrogen uptake and other nutrients. Legume cover crops planted in this research represented the amount of N supplied to the soil for giving high input of nitrogen to improve the growth of maize and grain yield of maize. Cowpea presented the highest nitrogen content based on the laboratory analysis conducted before planting maize (Table 3).

Table 3. N content in different cover crops

Cover crops	**N content (%)**
Cowpea (*Vigna unguiculata*)	2.77 b
Mucuna spp.	1.81 a
Pigeon pea (*Cajanus cajan*)	1.77 a
Sunn hemp (*Crotalaria juncea*)	1.69 a

Notes: number followed by the same letters showed no significant differences based on the Duncan Multiple Range Test at 5% (p<0.05).

Nitrogen applied before planting stimulated root growth and increased the absorption capacity of phosphorus which contributed to the plant height and total dry weight (Fahmi et al., 2010). Based on the result on analysis of variance, there was significant (p<0.05) effect of cover crop types on N content. Duncan Multiple Range Test result showed that cowpea provided the highest N-content of 2.8% that was significantly different to *Mucuna spp.*, pigeon pea and sunn hemp with 1.8%, 1.8%, and 1.7%, respectively (Table 3). This finding was in line with the previous study which found that cowpea produced N higher than sunn hemp (Jeranyama, 2000). Mangaravite (2014) reported that the N content of sunn hemp was higher than pigeon pea and mucuna.

The effect of biogeotextile application on yield of maize

The average yield of maize was significantly higher under biogeotextile application (BI) than control (p<0.001). Biogeotextile (BI) application contributed the average yield of maize of 6.18 t/ha, or 43% higher than control (BO) of 4.32 t/ha Biogeotextile application effectively maintained soil temperature and stored soil moisture and water content. Biogeotextile as well as mulch reduced soil temperature by 2°C (Kader et al., 2017) and increased soil moisture content which affected the higher yield (Teame et al., 2017) during the hot summer days of rain-fed condition which potentially caused adverse impact on the growth and the yield of the crop. This finding proved that biogeotextile application improved soil microclimate condition. Fullen et al. (2007) found that biogeotextile mulch conserved soil moisture and reduce soil temperature by 11.4% under palm material and 14% under wheat straw. Soil temperature and soil moisture played an important role in the growth and the yield of crops by affecting soil microbial activity, decomposition rate, and N mineralization. It is in line with the result of the previous experiment which found that decomposition rate is not only influenced by the C/N ratio of the cover crops but also influenced by soil temperature and moisture (Ruiz-Vega et al., 2010). The stable, maintained soil temperature and moisture can enhance the decomposition of cover crop residue and biogeotextile material. Soil temperature also affected soil organic carbon (Qi et al., 2016). Boechori and Suprayogo (2018) found that a combination of mendong leaf and straw produced soil organic carbon of 3.08% which was advantageous to plant growth and production. All the descriptions above proved that temperature and soil moisture increase the yield of maize because of their influence on creating a good condition for the decomposition process.

The effect of cover crop residue on the yield of maize

The results showed that the use of cover crop residues (CI) significantly increased maize yield. The average yield of maize under cover crop residue application reached 5.53 t/ha that was higher than control of 4.14 t/ha. Cover crop residue might provide nutrients for plant production through the process of decomposition by soil microorganisms. The decomposition process was influenced by the organic material content found under cover crop residue. Cover crop biomass increases the content of soil organic matter (Haque et al., 2015) which leads to nutrient supply for plant growth and plant production. The calculation of the cover crop biomass value returned entirely to the land prior to maize planting showed that the sunn hemp contributed the highest amount of biomass of 5.18 t/ha (Figure 4), followed by the cowpea of 4.60 t/ha, mucuna of 4.49 t/ha and pigeon pea of 3.11 t/ha. There were no significant differences in biomass production between different types of legume cover crops except between pigeon pea and sunn hemp. Based on the Duncan Multiple Range Test, the yield of maize under the cowpea residue application was significantly different with control, but it was not significantly different compared to other types of cover crop. The yield of maize under cowpea residue application reached 6.47 t/ha, followed by *Mucuna spp.* of 5.28 t/ha, sunn hemp of 5.21 t/ha, and pigeon pea of 5.17 t/ha, respectively. Nitrogen plays an essential role in increasing maize production. Muhamman et al. (2014) found that maize consumed a tremendous amount of nitrogen. The higher nitrogen added in the soil, the higher the maize yield is produced (Hammad et al., 2011). Nitrogen and phosphorus and other nutrients released from the decomposition of legume cover crop residue may be useful for plant growth and stimulate the grain yield. Rusinamhodzi et al. (2011) reported that conservation agriculture requires high input especially nitrogen for improving yield, but mulch cover leads the lower yield because of waterlogging. It was different with the result of this research that biogeotextile increased the maize yield. The different value of N content is commonly caused by the various number of N_2 fixation of each cover crop which is ready to be absorbed. Yuliana et al. (2015) stated that optimal adsorption of nutrient would increase the yield of maize. It was assumed that high nitrogen content in cowpea residue was optimally adsorbed by maize plant for its growth and grain yield, so cowpea residue combined with biogeotextile (BICC) presented the best result for maize yield. The Duncan Multiple Range Test showed that biogeotextile mendong mat combined with cowpea residue (BICC) produced the highest average maize yield of 7.99 t/ha (Figure 5) followed by biogeotextile and mucuna residue (BICM), biogeotextile and sunn hemp residue (BICS), and biogeotextile and pigeon pea residue (BICP) of 6.16 t/ha, 5.96 t/ha, and 5.77 t/ha, respectively. Biogeotextile material decomposition and high N content of cowpea reflected how the combination produced the best result for maize yield.

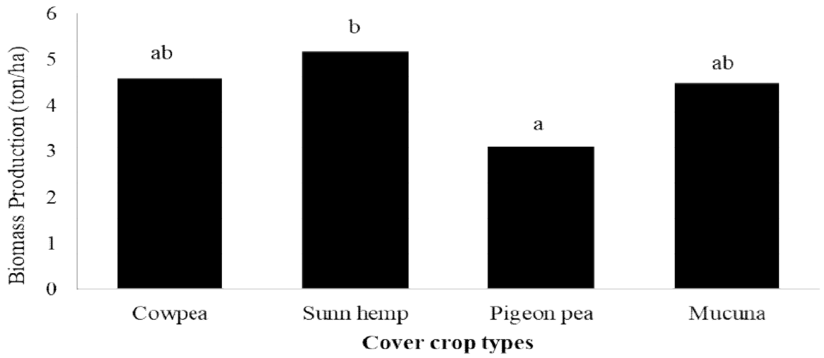

Figure 4. Biomass production of different types of cover crops

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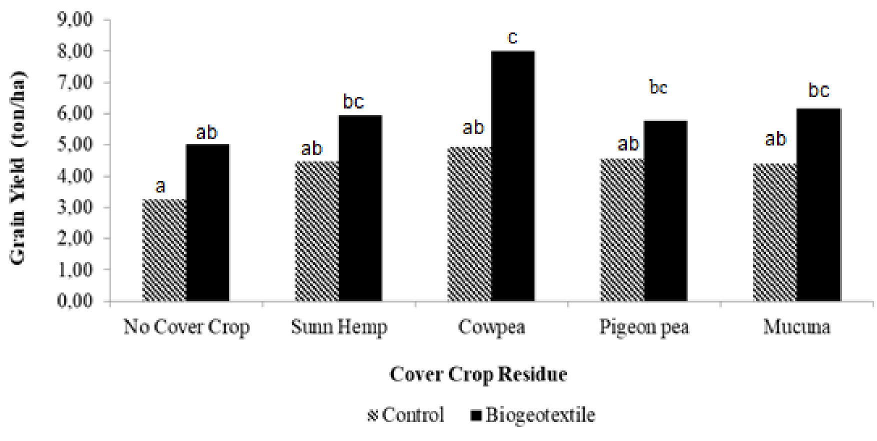

Figure 5. The effect of biogeotextile and cover crop residue on the yield of maize

Conclusion

Biogeotextile application significantly increased the yield of maize by 43% higher than control. Biogeotextile application significantly contributed plant height of maize and number of maize leaves. Cover crop residue application gave higher grain yield of maize by 34% than control. This study also found that cover crop residue application increased the plant height of maize and the number of maize leaves. Cowpea residue application contributed the highest yield of maize, plant height of maize and number of maize leaves. Soil tillage did not affect any changes in the yield and the growth of maize. The conservation farming with this combination is prospective for giving multiple benefits to plant production and protecting land from degradation.

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