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Nitrogen Dynamics in the Corn-Soybean Intercropping Pattern Due to Applications Residue of Corn, Soybean and Biochar

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Abstract

The aim of this research was to study the dynamic of N in the intercropping pattern of maize and soybeans given residues of maize and soybeans and their biochar. Information on the use of plant residues from crop residues and biochar as amendments and sources of organic matter in different cropping patterns against nitrogen dynamics in the field is still lacking. The experiment was arranged in a divided plot design with five residual treatments as subplots and five cropping patterns as the main plots. Measurement of the dynamics of N, pH and C-soil organic was carried out to study the interaction effect of the two treatments. The results showed that residues of corn, soybeans or those containing soybeans residues and their biochar in different intercropping patterns significantly affected levels of Nitrogen, C-organic, and soil pH, where the increase in total N levels was highest in corn and soybean residues and biochar in corn intercropping and soybean (1:2), and (2:4), and for soil organic content increase to 1.93% when the plats were 15 DAS, increased to 3,22% at 30 DAS and then decreased to 1,19% at plant age 45 DAS. Thus, giving corn and sobean residues and biochar to corn-soybean intercropping can increase the total N and C-organic soil levels

Keywords: Nitrogen Cycle; Plant Residue; Cropping System; Cerealia and Leguminosae; Sustainable Agriculture.

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1. Introduction

Nitrogen is an element that severely limits growth and productivity in many agricultural systems [1,2]. because of its role as a constituent of amino acids and proteins [3]. Plants absorb N in 2 main forms, namely; ammonium (NH_4^+), and nitrate (NO_3^-), where each form has its own uniqueness. Ammonium has a positive charge and binds to the negative charge of soil particles. Nitrogen mineralization and immobilization are important processes in the N cycle [4]. Another source of N comes from organic matter which undergoes a decomposition process. Where decomposition is a very important process in the nutrient cycle of a soil ecosystem [5,6]. The decomposition process is vital, because plant production in natural ecosystems depends on natural nutrient recycling [7]. Through the process of decomposition of biomass (litter), a process of releasing nutrients will occur to meet plant needs, and also determine soil organic C stores in an ecosystem. Meanwhile, biochar is a carbon compound that is resistant to decomposition [8,9], can improve soil quality [10,11,12], able to retain the N released from urea fertilizer in the form of N-NH_4^+ [13], as well as absorb NO_3^- [14] and increase maize yield [12], soybean [15]. Apart from being sourced from organic matter and fertilizers, N can also be obtained from N fixation of soybean plants (legumes), both in soybean monocultures and in the intercropping system with soybean plants. Biological N fixation by legume plants has the potential to add N to the intercropping system and is a low external input technology in agriculture (LEIA) [16]. The presence of soybean plants in corn-soybean intercropping can improve mineral N and the efficiency of N use of corn plants [2]. In the N_2 intercropping system, which occurs in the atmosphere and released through the decomposition of organic matter, it is converted to ammonia through the biological N fixation process, where ammonia is converted through oxidation or reduction processes to form NH_4^+ and NO_3^- which are available for plants [17]. Compared to monocultures, the cereal-legume intercropping system is 30-40% more efficient in utilizing all N resources. In the intercropping system, the competitiveness of cereal crops for soil N was stronger than that of legumes [18], affecting the N uptake of maize and soybean plants, but did not affect soil organic C [19]. The NO_3^- content in maize straw treatment was lower than the biochar as well as organic C [20]. The importance of understanding the relationship between the quality of plant residues and biochar in crop cultivation systems to the dynamics of N, soil organic C content and changes in soil pH is due to limited publications related to N dynamics in intercropping systems that use plant residues and biochar from intercropping plants. We want to test that hypothesis; 1) the intercropping pattern will affect the dynamics of N and; 2) that the immersion of corn-soybean litter and its biochar in the soil in the intercropping system will further increase the N content and C content of soil organic. Therefore, this research was carried out for; 1) assessing the role of corn-soybean litter and its biochar on the dynamics of N and C in different intercropping patterns 2) studying the interaction between corn-soybean residue and its biochar in different intercropping systems against the dynamics of N and C.

2. Material and Methods

2.1 Experimental Area

This research has been carried out in the science garden of Sidondo BPTP Central Sulawesi which is located at an altitude of 90 m above sea level and is at latitude 01^o.06 ".. 35.68" and longitude 119^o.56'.34.93 ". The soil properties in the field were evaluated according to [21] including pH (1: 2.5 v / v method) of organic matter (Walkey & Black method), N (KCl and Kjedahl analysis methods) , P (Olsen method) Ca, K (absorption method via ammonium acetate extraction), CEC (estimated based on pH and ammonium acetate extraction) and soil texture (hydrometer method).

Table 1: Soil characteristics in the study area before intercropping and giving corn-soybean residue

Soil characteristics (soil samples depth 15 cm)	Value	Unit	Information
pH H_2O (1:2.5)	7.21	-	Neutral
pH KCl (1:2.5)	6.68	-	Neutral
Soil texture			
Sand	29.8	%	
Dust	60.4	%	Dusty loam
Loam	9.8	%	
C-Organic	1.44	%	Low
N-Total	0.07	%	Very low
KTK	10.30	cmol kg^{-1}	Low
P_2O_5 (Olsen)	12.46	ppm	Middle
K_2O (HCl 25%)	28.35	$mg.100g^{-1}$	Hight
Calsium (Ca)	5.58	$cmol.kg^{-1}$	Low
Kalium (K)	0.47	$cmol.kg^{-1}$	Middle
Natrium	0.42	$cmol.kg^{-1}$	Middle

Source: Soil Laboratory of the Faculty of Agriculture, Tadulako University, 2016

2.2 Residue preparation

The residue comes from the stovers from the corn and soybean crops resulting from the farmers' crops, then cut using a mechanical cutting tool with a size of ± 2-5 cm, dried under the hot sun. Before to application, an analysis of the content of N, C and the C / N ratio was carried out

Table 2: Characteristics of corn litter, soybeans, corn + soybeans and biochar corn + soybeans before immersing them in the planting location

Residues	C	N	C/N
Corns	19.6	0,29	84,48
Soybeans	14.37	0,57	39,82
Corns+Soybeans	18.16	1,66	13,67
Corns+Soybeans Biochars	15.57	0,14	139,02

Source; Agriculture Faculty, Tadulako University Agrotechnology Laboratory

2.3 Experiment Design and Treatment

The experiment was arranged based on a randomized block design with a split plot design with three replications. The main plot is the intercropping pattern, namely; corn monoculture (T1), soybean monoculture

(T2), corn / soybean intercropping (1: 1) T3, corn / soybean intercropping (2: 1) T4 and corn / soybean intercropping (2: 4) T5 and corn-soybean residues, namely ; without residue (R1), corn residue (R2), soybean residue (R3), corn + soybean residue (R4), corn + soybean biochar (R5) as subplots. Total land area size 42.5 m x 14 m (595.0 m2) Each replication (block) has 25 plots, each measuring 3.5 m x 4.5 m (13.25 m2) The distance between replicates is 1 m and between plots is 0.5 m. The time of application of the treatment to the subplots was 10 days after application. Plant litter is given between rows of plants immersed 20 cm from the soil surface at a dose of 2 t.ha-1 or equivalent to 3.25 kg.petak-1, while the dose of urea fertilizer is 50 kg.ha-1, SP 36 100 kg.ha-1 and KCl 75 kg.ha-1. Spacing for maize is 100 x 40 cm (between 100 rows and 40 cm in rows) while soybeans are 40 x 20 cm);

2.4 Soil and Plant Samples

Soil samples for N analysis were taken from five points then bulkied, on each plot at a depth of 0 -15 cm and 15-30 cm using a drill at intervals of 15, 30 and 45 days after immersion or 15 30 and 45 days after planting (DAS), while plant samples were taken on dextructive plots at intervals of 15, 30 and 45 DAS

2.5 Laborotory Analisis Methods

Determination of total N using the Kejdahl method, measurements were made at the age of 15, 30 and 45 DAS. Weighing 1 g of soil, put it into the kejdahl then add 25 ml of H2SO4, let stand for 30 minutes, add 0.5 g of Na2S2O5H2O, put it in the tube, shake it, 15 minutes then add 200-300 mg of catalyst. Transfer to digestion, then heat carefully and gradually increase the temperature. Cool then distillate previously added 25 ml of 40% NaOH. Put in an Erlenmeyer containing 10 ml of indicator borate solution. After distillation the borate indicator turns light green. Then titrated with 0.01 N HCl, the green end point becomes pink. The determination of C-organic (%) was carried out by the Walkey & Black method.

2.6 Staistical Analysis

To determine the effect of treatment, the analysis of variance (ANOVA) was used. To test the differences between treatments, the 5% DMRT test was used [21]. To determine the relationship between parameters, correlation and regression analysis were carried out. Data analysis was performed by applying Excel and SPSS 17.0 software

3. Results and Discussion

3.1 Mineralization of N

The total of nitrogen in the soil at a depth of 0-15 cm which was applied with biochar in the monoculture pattern tended to be higher, whereas in the intercropping pattern, the 1: 1 intercropping pattern, the accumulated N amount was higher in the control, and in the 1: 2 pattern the amount of N accumulated the highest was in the biochar treatment, while in the 2: 4 pattern, the residual treatment of a mixture of corn and soybeans. However, this number decreased on average at a depth of 15-30 for all treatments (Table 2).

Table 3: Effect of interactions between cropping patterns and residues of corn-soybean and biochar on total N content of soil at depths of 0-15 and 15-30cm, age 15, 30 and 45 DAS

Time	Treatments	Corn monuculture		Soybean monoculture		Intercropping corn+soybean (1:1)				Intercropping corn+soybean (2:4)	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
15DAP	No residue	$0,07^{bc}$	$0,04^{abc}$	$0,07^{bc}$	$0,07^{de}$	$0,10^{bc}$	$0,04^{abc}$	$0,09^{bc}$	$0,05^{bcd}$	$0,13^{d}$	$0,04^{abc}$
	Corn residue	$0,08^{bc}$	$0,01^{a}$	$0,03^{a}$	$0,04^{abc}$	$0,20^{e}$	$0,03^{abc}$	$0,10^{bc}$	$0,05^{bcd}$	$1,07^{e}$	$0,05^{bcd}$
	Soybean residue	$0,07^{bc}$	$0,02^{ab}$	$0,08^{bc}$	$0,06^{cde}$	$0,08^{bc}$	$0,03^{abc}$	$0,09^{bc}$	$0,05^{bcd}$	$1,00^{e}$	$0,07^{de}$
	Corn+soybean residue	$0,07^{bc}$	$0,02^{ab}$	$0,06^{b}$	$0,04^{abc}$	$0,07^{bc}$	$0,02^{ab}$	$0,07^{bc}$	$0,04^{abc}$	$0,07^{bc}$	$0,05^{bcd}$
	Biochar corn+soybean	$0,09^{bc}$	$0,05^{bcd}$	$0,09^{bc}$	$0,06^{cde}$	$0,09^{bc}$	$0,09^{f}$	$1,00^{bc}$	$0,07^{de}$	$0,09^{bc}$	$0,06^{cde}$
30 DAP	No residue	$0,07^{a}$	$0,04^{a}$	$0,10^{bcd}$	$0,05^{ab}$	$0,09^{abc}$	$0,08^{de}$	$0,11^{cd}$	$0,13^{h}$	$0,09^{abc}$	$0,13^{h}$
	Corn residue	$0,08^{ab}$	$0,04^{a}$	$0,09^{abc}$	$0,07^{cd}$	$0,11^{cd}$	$0,06^{bc}$	$0,10^{bcd}$	$0,08^{de}$	$0,12^{de}$	$0,09^{ef}$
	Soybean residue	$0,09^{abc}$	$0,06^{bc}$	$0,10^{bcd}$	$0,09^{ef}$	$0,10^{bcd}$	$0,17^{i}$	$0,10^{bcd}$	$0,13^{h}$	$0,12^{de}$	$0,07^{cd}$
	Corn+soybean residue	$0,08^{ab}$	$0,06^{bc}$	$0,08^{ab}$	$0,08^{de}$	$0,08^{ab}$	$0,07^{cd}$	$0,10^{bcd}$	$0,07^{cd}$	$0,08^{ab}$	$0,06^{bc}$
	Biochar corn+soybean	$0,10^{bcd}$	$0,08^{de}$	$0,10^{bcd}$	$0,12^{gh}$	$0,11^{cd}$	$0,10^{f}$	$0,11^{cd}$	$0,12^{gh}$	$0,10^{bcd}$	$0,08^{de}$
45 DAP	No residue	$0,03^{bc}$	$0,02^{ab}$	$0,05^{de}$	$0,03^{bc}$	$0,05^{de}$	$0,04^{c}$	$0,08^{fg}$	$0,06^{de}$	$0,08^{fg}$	$0,03^{bc}$
	Corn residue	$0,02^{ab}$	$0,02^{ab}$	$0,03^{bc}$	$0,10^{hi}$	$0,06^{e}$	$0,08^{fg}$	$0,06^{e}$	$0,13^{k}$	$0,13^{j}$	$0,08^{fg}$
	Soybean residue	$0,01^{a}$	$0,01^{a}$	$0,04^{cd}$	$0,02^{ab}$	$0,08^{fg}$	$0,04^{c}$	$0,09^{gh}$	$0,09^{gh}$	$0,09^{gh}$	$0,07^{ef}$
	Corn+soybean residue	$0,01^{a}$	$0,01^{a}$	$0,02^{ab}$	$0,02^{ab}$	$0,02^{ab}$	$0,02^{ab}$	$0,04^{cd}$	$0,12^{jk}$	$0,13^{j}$	$0,10^{g}$
	Biochar corn+soybean	$0,08^{fg}$	$0,02^{ab}$	$0,09^{gh}$	$0,11^{g}$	$0,10^{h}$	$0,11^{g}$	$0,11^{ih}$	$0,10^{hi}$	$0,12^{i}$	$0,09^{gh}$

Note: the numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

The use of corn, soybeans and biochar litter in the area around plant roots can reduce the loss of N from the absorption zone, and this is influenced by the quality of the litter. From the results of laboratory analysis, biochar and maize have higher C / N than soybeans and a mixture of corn and soybean litter so that they have the ability to inhibit the rate of nitrification. This is in line with [3] that the provision of organic matter which has a higher C: N ratio can inhibit the process of N loss through nitrification. Meanwhile [22] stated that residues with high N concentration and low C / N ratio can accelerate mineralization compared to low residues with high N concentration and high C / N ratio. In contrast to plant residues, biochar can reduce N loss through the adsorption process of NH3 + which reacts with acid functional groups on the biochar surface or directly forms bonds between cations and NH4 +. Decomposed corn and soybean litter will produce a number of proteins and amino acids which break down into ammonium (NH4 +) or nitrate (NO3-) which can contribute to total N in the soil. As [23] states that the increase in total N-soil is obtained directly from the decomposition of organic matter which will produce ammonium (NH4 +) and / or nitrate (NO3-), while organic matter itself is a source of the elements N, P, and S. The dynamics of N in the soil are not only absorbed by plants but also due to the mineralization process of N from the residue, the fixation activity of soybean plants which results in additional N in the system and also infiltration in the layer below the Rhizhosphere zone (30 cm) which results in reduced N uptake by plants. The increase in soil N concentration can also come from the decomposition of litter, especially litter with a C; N ratio of less than 20. The maize / soy litter mixture has a lower C / N ratio than corn and soybean litter and biochar. Thus plant residues have the potential to affect N dynamics in both monocultures and intercropping systems. Besides the residual factor, the intercropping pattern also indirectly affects the N content in the soil. The results showed that the cropping pattern could positively affect the total N concentration in the soil. The presence of soybean plants intercropped with corn plants can increase the N concentration in the soil. The increase in the total N of soil in the corn-soybean intercropping pattern was derived from the N fixation of soybean plants, while in soybean monocultures through biomass from root nodules or dead bacteria. Or in other words, the N content in the soil in this study can be influenced by the presence of soybean plants in the cropping system, either directly or indirectly.

3.2 C-Organic (%) and soil pH

Soil organic C levels increased due to the application of residual mixtures of corn, soybeans and biochar, before use of the residues, the soil organic C content was 1.44%, (Table 1) then increased to 1.93% when the plants were 15 or 25 days after planting. days after application. At the age of 30 days of plants, it increased to 3.22%, then decreased to 1.19% at the age of 45 days after planting. The application of Soya litter and biochar at a depth of 0-15cm tends to lower the soil pH one status from alkaline to neutral (pH 7.0), both at the age of 15, 30 and 45 DAP and the best is in the 1: 1 and 1: 2 intercropping systems. The decrease in soil pH from alkaline to neutral pH in this study is temporary and closely related to the decomposition process of organic matter. Whereas at a depth of 15-30, the pattern of plant composition in different intercropping systems tends to affect soil pH, especially at the age of the plant entering active vegetative, namely up to the age of 45 DAS, where the interaction between the intercropped plants is higher, especially in the use of resources such as light, water and nutrients (Table 3) The decrease in soil productivity and fertilizer efficiency is due to reduced soil resilience due to decreased organic matter content. Therefore, the availability of organic matter in the soil can function as nutrients, stimulate the activity of soil microorganisms, and improve soil physical, chemical and biological properties [24].

Table 4: The effect of intercropping patterns and residues of corn / soybean and biochar on changes in pH and C-Organic (%) Soil at 15, 30 and 45 days after planting (DAS) at a depth of 15-30 cm

Time	Treatments	Monoculture corn		Monoculture soybean		Intercropping corn + soybean (1:1)		Intercropping corn + soybean (1:2)		Intercropping corn + soybean (2:4)	
		pH	C-Organik	pH	C-Organik	pH	C-Organik	pH	C-Organik	pH	C-Organik
15 DAP	No residue	7.95^{c}	0.93^{a}	7.42^{bc}	0.98^{ab}	7.31^{bc}	1.58^{abc}	7.63^{bc}	0.95^{ab}	7.35^{bc}	1.77^{cd}
	Corn residue	7.68^{bc}	1.37^{ab}	7.60^{bc}	1.88^{ef}	7.60^{bc}	2.04^{hi}	7.52^{bc}	1.11^{ab}	7.25^{bc}	2.33^{kl}
	Soybean residue	7.36^{bc}	1.37^{ab}	7.24^{bc}	1.17^{ab}	7.16^{bc}	1.94^{ef}	7.16^{bc}	1.08^{ab}	7.21^{bc}	2.53^{l}
	Corn+soybean residue	7.62^{bc}	1.11^{ab}	7.07^{ab}	1.98^{fgh}	7.37^{bc}	1.93^{ef}	7.25^{bc}	1.83^{de}	7.44^{bc}	2.21^{ij}
	Biochar corn+soybean	7.45^{bc}	1.77^{cd}	7.37^{bc}	0.95^{ab}	7.01^{a}	1.92^{ef}	7.28^{bc}	1.34^{ab}	7.56^{bc}	2.12^{ej}
30 DAP	No residue	7.52^{de}	0.65^{ab}	7.86^{ij}	0.16^{a}	7.88^{ij}	1.11^{ab}	7.72^{gh}	0.88^{a}	7.41^{bc}	1.48^{bc}
	Corn residue	7.53^{de}	1.25^{ab}	7.97^{jk}	1.09^{ab}	7.49^{de}	1.65^{bc}	7.50^{de}	1.52^{bc}	7.45^{cd}	2.32^{de}
	Soybean residue	7.26^{a}	1.23^{ab}	7.47^{de}	1.47^{bc}	8.19^{l}	1.43^{ab}	7.38^{ab}	1.35^{ab}	7.40^{ab}	3.20^{gh}
	Corn+soybean residue	7.30^{ab}	1.19^{ab}	7.75^{hi}	1.32^{ab}	7.26^{ab}	1.55^{b}	7.51^{de}	2.06^{cd}	7.84^{ij}	2.83^{fg}
	Biochar corn+soybean	8.57^{m}	1.37^{bc}	7.88^{ij}	1.01^{ab}	7.65^{fg}	1.47^{bc}	8.02^{kl}	2.54^{ef}	7.90^{ij}	3.27^{h}
45 DAP	No residue	8.28^{l}	1.24^{ab}	7.98^{jk}	1.84^{ab}	7.47^{bc}	1.85^{ab}	7.72^{ef}	1.52^{ab}	7.60^{de}	1.80^{ab}
	Corn residue	8.37^{l}	1.65^{ab}	8.04^{jk}	1.23^{a}	7.60^{de}	1.81^{ab}	7.34^{ab}	1.93^{ab}	7.98^{jk}	2.75^{ef}
	Soybean residue	8.04^{jk}	2.11^{ab}	8.05^{jk}	2.41^{cd}	8.02^{jk}	2.21^{ab}	7.89^{gh}	2.13^{ab}	7.39^{bc}	2.77^{fg}
	Corn+soybean residue	8.02^{jk}	1.56^{ab}	7.73^{ef}	1.55^{ab}	7.50^{cd}	2.35^{bc}	7.76^{ef}	2.17^{ab}	7.51^{cd}	3.15^{hi}
	Biochar corn+soybean	7.92^{ij}	2.78^{fgh}	7.50^{cd}	3.17^{hi}	7.27^{a}	3.22^{ij}	7.45^{bc}	3.61^{j}	7.89^{fg}	2.59^{de}

Note: the numbers followed by the same letter in the same column are not significantly different according to the 5% DMRT test.

The results (Table 3) also showed that giving of soybean litter and biochar significantly reduced the soil pH from alkaline to neutral (pH 7.0) both at the age of 15, 30 and 45 DAP and the best was in the 1: 1 intercropping system and 1: 2. The decrease in soil pH from alkaline to neutral pH in this study is temporary and closely related to the decomposition process of organic matter. The decomposed organic material can increase the activity of OH^- and H^+ ions derived from organic acid compounds produced from the decomposition of organic matter, including amino acids which will undergo ammonification and nitrification processes from nitrogen to ammonium and nitrate. Thus the change in pH value due to the provision of organic material is due to the presence of COOH and OH functional groups on the surface of the organic material.

Relationship between Total N of Soil and Organic C due to Residue Application in the Corn-Soybean

Intercropping System

The availability of nitrogen in the soil from organic matter is closely related to the soil organic C content which comes from the decomposition of organic matter associated with the soil. The results of the regression analysis regarding the relationship between C-organic levels and total N are as shown in Figure 1.

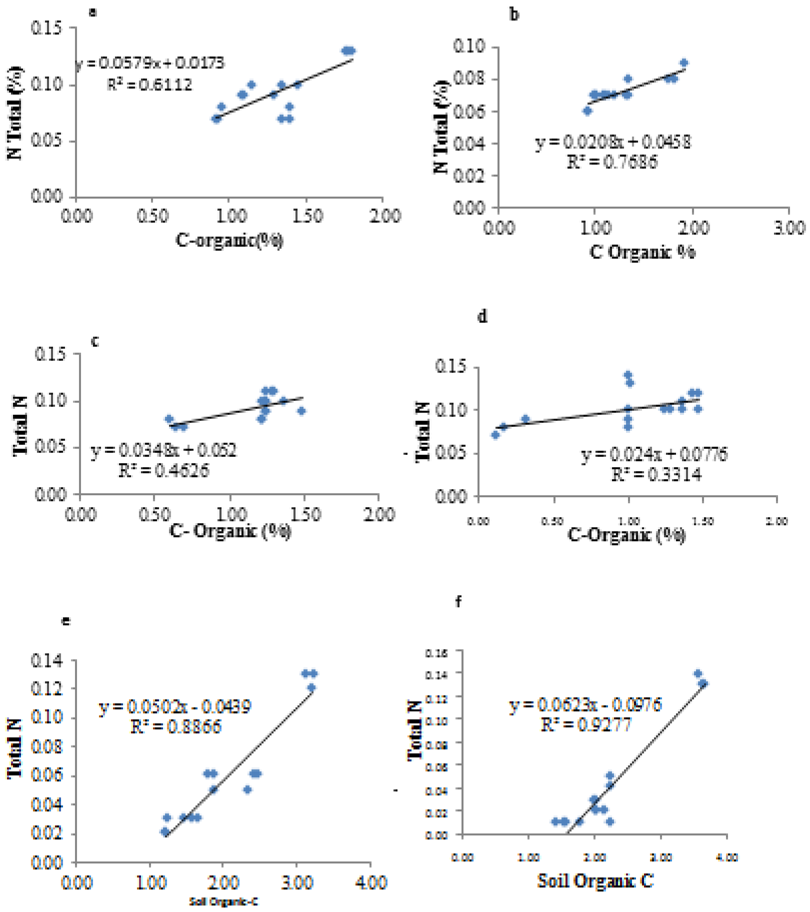

Figure 1: Regression graph of the relationship between soil organic C and total soil N in monoculture (a) and intercropping (b) aged 15 DAS, 30 DAS (c, d) and 45 DAS (e, f)

The results of the regression analysis (Figure 1) show that the total N content of the soil is influenced by the soil organic C content, where the total N of the soil increases linearly with the increase in soil organic C content or it can be interpreted that the higher the soil organic C content, the N value. contained in the soil is also increasing. From the results of the correlation analysis, it shows that the coefficient of determination is the strongest at the age of 45 days after planting in the intercropping pattern (R2 = 92%). This is because during this period the decomposition of corn and soybean litter was close to optimal so that the soil organic C content and total N release increased and the relationship between organic C and total soil N was very strong (R2 > 50%) along with the increase in decomposition time until to some extent. Thus it can be said that the contribution of N to the accumulation of N in the corn and soybean intercropping system does not only come from N transfer (the result of N fixation) but also from other sources, including the result of decomposition of organic matter immersed in the cropping system (monoculture and intercropping).

4. Conclusion

The results of this study revealed that there was positive interspecific facilitation between corn-soybean intercropping. Application of plant residues contributes to interspecific facilitation. The residual mixture of corn and soybeans and biochar can increase soil N and C-organic soil levels and reduce soil pH from alkaline to neutral pH, especially in the 2: 4 intercropping pattern.

5. Conflict of Interest

Authors declare no conflict of interest

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Figure 2: Performans of plant in intercropping system

a. Residue of corn b Residue of soybean c. Biochar corn+soybean

Figure 4