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To cite this article: ,O Purwaningsih *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **215** 012029

IOP Conf. Series: Earth and Environmental Science **215** (2018) 012029 doi:10.1088/1755-1315/215/1/012029

Paddy straw compost application to increase nitrogen fixation on soybean cultivars

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Abstract. Soybean is leguminous crop requiring large quantity of N nutrient. The N requirement in soybean crops can be fulfilled through N_2 fixation by root nodules. Root nodules can develop through the symbiosis of soybean crops with Rhizobium bacteria. This study aimed to identify the effects of paddy straw compost application on nitrogen fixation and physiological character in Baluran, Tanggamus, Seulawah, Grobogan cultivars of soybean crops.The study was conducted at regosol soil in Banguntapan, Yogyakarta.Result has showed that paddy straw compost dosage may increase soybean capabilityto perform nitrogen fixation,indicated by the variables of total root nodules, root nodule dry weight, andnitrogenase activity. Paddy straw applicationhas not provided significant effect on total chlorophyl content, leaf greeness, water content in leaf, transpiration rate and CO_2 content in leaf, but has given significant effect on net assimilation rate of the crops.

1. Introduction

Soil serves as media for crop growth. Nutrient content in soil will affectcrop growth. The advantages of soil organic matter (SOM) have been long known for crop growth and soil fertility. Since long time ago, farmers have utilizedorganic matter residue to increasesoil fertility. These organic matters return into soil, both through natural and human-engineered systems as well. The application of organic matters has been proved to develop soil fertility and soil ecosystem health; and hence, it prevents possible environment pollution. In LEISA (low external input sustainable agriculture) system, external input usage is limited by optimizing the exploitation ofavailable local resources; andthe exploitation of external inputsis only needed to complement nutrient shortagein the ecosystem. The basic principle of LEISA are (1) to securesoil condition that supports crop growth, particularly through organic matter management andincreasing soil microorganism; (2) to optimize nutrient availability andbalance of nutrient flow, particularlythroughnitrogen fixation, recycleand external fertilizer application as complement; (3) to minimize loss due tosolar radiation, air and waterthrough microclimate management, water management and erosion control; (4) to minimize pest and disease invasion; (5) to perform mutual completion and synergy in exploitinggenetic resources including the combination of integrated farming with higher level of functional diversity [1].

The addition of organic matters into soil, either through compost application,crop residue returning into soil, andsoil cover cropsmay improve total stock of soil organic matters. Continuous farming practice will reduce total-C and total-N stocks; however,organic fertilizer application maymaintain the balance oftotal-C and total-N stocks. Amongthe nutrients which crop requires,N turns out to be the mostonethat crops require.But, since the availability is lower due to its higher mobility,N nutrient is easilylost through leaching and volatilization. Nitrogen fixation is important to supply N demand in sustainable farming system. The advantegous microbial availability in rhizospheres will increase soil fertility. Mycorrhiza is an example of microorganisms increasing water and nutrient absorbability in some crops. It also oocurs with rhizobium, azotobacter, azospirillum which may serve as organic fertilizer and alternatives to chemical fertilizer. The symbiosis of soybean–mycorrhiza and soybean-rhizobium may improve crop growth, nodulation and biomass accumulation; therefore, it provides farmers with advantages due its reduced price ofN and Pfertilizers[2].

Nitrogen serves as factor limiting crop growth, particularly in soybean crop requiring a great deal of N for its growth. To supply this N demand, soybean has symbiotic relationship with bacteria developing root nodules, so that N_2 fixation may occur. Nitrogen fixation supplies more or lessa quarter till a half of total nitrogen that legumes need [3]. In general, soybeans are cultivated following paddy harvesting time based onpaddy-paddy-*palawija* or paddy-*palawija* soybean cropping patterns. Soybean that is directly cultivated after paddy may get nutrient residual advantages from paddy fertilization. In addition,paddy straws may be utilized as mulches or applied as compost andexploited as an organically fertilizing source. Paddy straws have not been optimally exploited asorganic mass source in farming. Most of paddy straws are frequently burnt or exploited aslivestock feed, material in paper industry or in mushroom farming,toenablesoilfortillage in the next cropping. Returning paddy straws into soil may restore some of nutrient to be transported during harvesting time. The straws to be used as the organic matter sourceswillbe better if they are composted firsttopreventnutrientcompetitionbetweenthecompostingmicroorganism and the crops.

Organic matters influence crop growth through its effects onnutrientavailability for crop growth. In addition toserve as N, P, S nutrient sources throughsoil microorganism-created mineralization process,organic matters also functionasenergy source for N-fixing bacteriafrom the air [4]. Humate acid is known to increaselegume's root nodulation that is inoculated with*Rhizobium trifolii*, *R. meliloti*, *R. leguminosarum*, and *R. japonicum*[5]. Rhizobium inoculation in soybean crop andmanure application at coastal land may improvethe growth andyield of soybean crops [6]. The paddy straw compost exploited insoybean croppinginoculated with*R.japonicum* is expected to be able in increasingroot nodule development so that it also may improve the capability of soybean in nitrogen fixation. Compost yield (*rendement*) made from paddy straws shows more or less60%of initial weight of the straws. The straw compost exploiting organic microbialdecomposers contains the following nutrients: organic-C:22.06 %; organic-N:1.51 %;N-NH_4:0.05 %;N-NO_3:0.08 %; total-N:1.64 %;P_2O_5:0.53 %; K_2O: 2.23 %; water content:10.14% and C/N: 15 % [7].

2. Materials and Methods

The study was carried out in Banguntapan area, Bantul,Yogyakarta Special Province containing regosol soil. Materials involved composted-paddy straws,soybeanlegin(legume inoculant),Baluran, Tanggamus, Seulawah, Grobogancultivars soybean seeds, and chemical substances utilized in plant tissue analysis. Instruments adopted were digital scale, ruler, thermohygrometer, lux meter, area meter, spectrophotometer, thermometer, microscope, oven, caliper, SPAD, chromatography and Photosynthetic analyzer LI-COR 6400.

The study consisted of two factors in Randomized Complete Block Design (RCBD) with three blocks. The first factor involved soybean cultivars (Baluran, Tanggamus, Seulawah, Grobogan). The second factor was paddy straw compost, consisting of four treatments, i.e.without paddy straw compost, with paddy straw composts of 15 tons$\cdot$ha^{-1}, 20 tons$\cdot$ha^{-1} and 25 tons$\cdot$ha^{-1}. Before planted, the soybean seeds were inoculated with soybean legin. The activity ofnitrogen fixation by root nodules was observed according to the reduction ofacetylene toethylene bynitrogenase enzyme. The observation result was analyzed by usingAnalysis of Variance (ANOVA) at5% significance level. To identify the significanceof the treatments, the Duncan's Multiple Range Test (DMRT) was adoptedat5% significance level.

3. Results and Discussion

3.1. Analysis on N_2 Fixation Capability

Identifying soybeancultivar infixing N_2 can be seen from variablestotal nodules, nodule dry weight,nitrogenaseactivity,shoot N absorption.Result of variance analysis ontotal root nodulesshowed that nointeraction was found between soybean cultivar and paddy straw compost dosage; however,paddy straw compostprovided significant effect to increasetotal root nodules of soy bean crop.

Table 1. The root nodules and dry weight of root nodules (g) of soybean cultivardue to the effects ofvarious paddy straw compost dosages.

Cultivar	Total root nodules	Dry weight of root nodules
Baluran	20,25 a	0,24 a
Tanggamus	23,50 a	0,24 a
Seulawah	14,75 b	0,13 b
Grobogan	15,58 b	0,18 ab
Paddy straw compost dosages (ton/ha)		
0	8,58 r	0,11 r
15	16,67 q	0,18 q
20	25,25 p	0,28 p
25	23,58 p	0,23 pq

Note: MAP= The values ended by similar letter in similar column shows insignificant result in Duncan's Multiple Range Test (DMRT) at significance levelof 5%.

The increase ofpaddy straw compostdosage mayalso increasethe average of total root nodulesfollowing regression equationy = 0.666x + 8,519 (R^2 = 0.898) as seen on figure1.

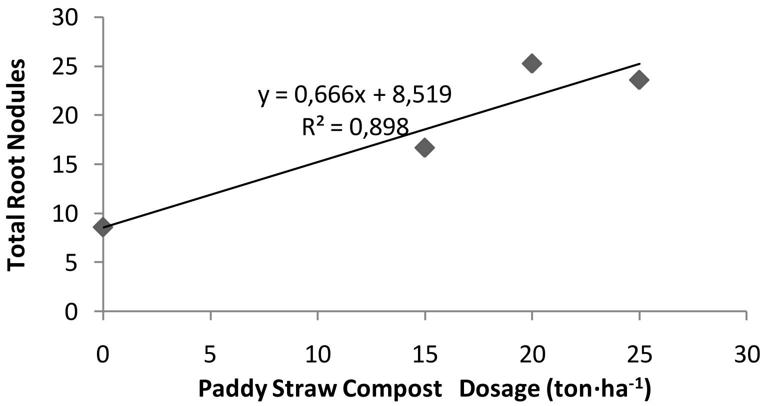

Figure 1. The average of total root nodules in various paddy straw compost dosages.

The increase of paddy straw compost dosage also significantly may linearlyincrease the dry weight of soybean root nodulesanditisindicated by regression equationy = 0.005x + 0.112 (R^2 = 0.759). Result of correlation analysis showed that there was positive and highly significant correlationbetweenthe dry weight of soybean root nodule and total root nodules (r= 0.80**). Total root nodules and the dry weight of soybean root nodule serve as indicators of nitrogen fixation capability. Soybean cultivar with greater number ofroot nodules and higher dry weight of soybean root nodule has higher nitrogen fixation capabilitycompared tothat with fewer root nodules.

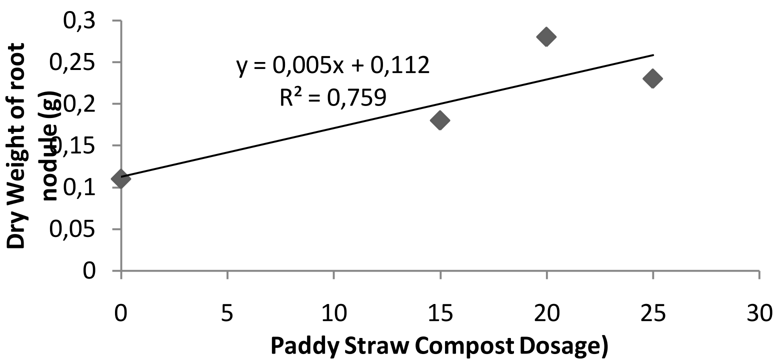

Figure 2. The average of the dry weight of soybean root nodule (g) in various paddy straw compost dosages.

The activity ofnitrogenase enzymeindicates the capability of soybean cultivarinfixing nitrogen. The nitrogen fixation occurs in bacteroid-containing root nodules. The synthesis of nitrogenase enzyme is done by bacteroid; this enzyme serves as catalyst reducing nitrogen to amonnium. The greater nitrogenase enzyme activity is, the greater soybean cultivar's capability in fixing nitrogen.Nitrogenase enzyme activity may be identified fromthereduction activity of acetylene toethylene in root nodules. The reduction ofacetyleneto ethylene is catalyzed by nitrogenase. The formed ethyleneshows the activity of nitrogenase enzyme [8].

Table 2. The nitrogenase enzyme activity (mmol/crop/hour) of soybean cultivardue to the effects ofpaddy straw compost dosages.

Paddy StrawCompost Dosage	Cultivar				Average
	Baluran	Tanggamus	Seulawah	Grobogan	
0	0.017 c	0.018 c	0.025 c	0.024 c	0.021
15	0.021 c	0.025 c	0.019 c	0.028 c	0.023
20	0.119 a	0.058 bc	0.039 bc	0.017 c	0.058
25	0.077 b	0.032 c	0.024 c	0.023 c	0.039
Average	0.059	0.033	0.027	0.023	(+)

Note: The values ended by similar letter shows insignificant result in Duncan's Multiple Range Test (DMRT) at significance level of 5 %. (+): interaction is available.

Based on nitrogenase enzyme activity per crop (table 2) it is seen thatorganic matter, i.e. paddy straw compostmay increasenitrogenase enzyme activity.Baluran cultivar applied with paddy straw compost of 20 ton·ha^{-1} has showedhighestand significant nitrogenase enzyme activity compared to Baluran, Tanggamus, Seulawah and Grobogan cultivars in variouspaddy straw compost dosage applications. Compost application on soybean crop may increase acetylene reduction activity (ARA) as compost capability in improvingroot nodule formation. Compost application provides direct effect onsymbiotic fixation throughroot nodule formation [9].

The capability ofnitrogen fixation, among others, is indicated by shoot N content. The weight ofshoot N content is closely related to crop capability in fixingnitrogen and root capability innutrient absorption, among other,N nutrient.Crops withbetter root nodules and root system also havebetter nitrogen fixation capability and good nutrient absorption; hence,shoot N content is also higher. In this study,although total root nodules,root nodule dryweight, and nitrogenase activityincrease due topaddy straw compost application,theincreaseis not followed bycrop capability in absorbingN. Paddy straw compost dosage does not provide significant effectoncrop's shoot N content. Crop's shootN content is more determined bysoybean cultivar characteristics. Cultivarswith positive response toRhizobium inoculation (Baluran and Tanggamus cultivars) show higher shoot N content [10].

Table 3. The shoot N weight (g/crop) of soybean cultivardue to the effects ofvarious paddy straw compost dosages.

Paddy StrawCompost Dosage	Cultivar				Average
	Baluran	Tanggamus	Seulawah	Grobogan	
0	0.38	0.49	0.44	0.41	0.43 p
15	0.55	0.48	0.39	0.34	0.44 p
20	0.57	0.58	0.32	0.46	0.48 p
25	0.51	0.47	0.31	0.46	0.44 p
Average	0.50 a	0.50 a	0.37 b	0.42 b	(-)

Note: The values ended by similar letter shows insignificant result inDuncan's Multiple Range Test (DMRT) at significance level of 5 %. (-): no interaction available.

The application of paddy straw compostincreases soil porosity, andso that it produces better the balance ofair and soil humidity. Such a balanceenablefixed-N and allnutrients from organic matter decompositionare more availableas microorganism requireshumidity and O_2 for maximum efficiency. Organic matters serve as energy sources to make N_2symbiotic and non-symbiotic fixationpreviously unavailableto be availablefor crops.

3.2. Physiological character analysis

The applications of paddy straw composton four soybean cultivarsdo not provide effects on the physiological character of soybean crop. Observation were conducted on chlorophyl content, leaf greeness level,CO_2 content in leaf, transpiration rate andphotosynthesis rate.

Table 4. Total chlorophyl content (leaf $mg \cdot g^{-1}$), leaf greeness level, water content in leaf (mmol $H_2O \cdot mol^{-1}$), transpiration rate (mmol H_2O $dm^{-2} \cdot s^{-1}$),CO_2 content in leaf(µmol $CO_2 \cdot mol^{-1}$), net assimilation rate (leaf area $g \cdot dm^{-2} \cdot week^{-1}$).

Compost Dosage ($ton \cdot ha^{-1}$)	I	II	III	IV	V	VI
0	0.97 p	42.09 p	37.40 p	7591 p	277.6 p	0.51 r
15	0.93 p	42.97 p	34.98 p	9958 p	433.4 p	0.59 qr
20	0.98 p	43.24 p	37.29 p	8785 p	286.1 p	0.87 p
25	0.91 p	42.99 p	36.45 p	6565 p	278.7 p	0.80 pq

Note: The values ended by similar letter in similar column shows insignificant result inDuncan's Multiple Range Test (DMRT) at significance levelof 5%.

I: total chlorophyl content (leaf $mg \cdot g^{-1}$)
II: leaf greeness level
III: water content in leaf (mmol $H_2O \cdot mol^{-1}$)
IV: transpiration rate (mmol $H_2O \cdot dm^{-2} \cdot s^{-1}$)
V: CO_2 content in leaf (µmol $CO_2 \cdot mol^{-1}$)
VI: net assimilation rate (leaf area $g \cdot dm^{-2} \cdot week^{-1}$)

The application of paddy straw compost may increase crop's net assimilation rate. Result of correlation analysis indicated positive and significant correlation between net assimilation rate and total root nodules (r=0.35*), the dry weight of soybean root nodule (r=0.32*) and nitrogenase enzyme activity (r=0.28*). This shows that the increasing capability of nitrogen fixation will be followed by increasing net assimilation rate. Crops with higher capability in nitrogen fixation indicate better net assimilation rate.

4. Conclusion

The application of paddy straw compostinRhizobium-innoculatedsoybeans may increase soybean crops' in fixingnitrogen. This is seen from increasing totalroot nodules, the dry weight of soybean root nodule and nitrogenase activitydue tothe application of paddy straw compost. The application of paddy straw compostdoes not provide significant effects on total chlorophyl content, leaf greeness level, water content in leaf, transpiration rate andCO_2 content in leaf, but has given significant effect on net assimilation rate of the crop.

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