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Composition of planting media and biological agents to improve physical and chemical properties of soil

Composition of planting media and biological agents to improve physical and chemical properties of soil

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Abstract. This research aims to study the effect of various compositions of soil organic matter, zeolite, husk charcoal and biological agents on physical and soil chemical properties of planting media. This research was done in a pot experiment in a greenhouse. The experiment was designed as randomized complete block design (RCBD) factorial. The first factor was type of biological agent consisting of control or without, PGPR and Trichoderma sp. The second factor was composition of media with combination of 50% soil and 50% soil enhancers consisting of goat manure, zeolite and husk charcoal with a combination of 11 combinations. In total there were 33 treatment combination with 3 replications each. Result showed that composition of soil media gave influence on water retention, bulk density, porosity, pH, DHL, C/N ratio, N-total, N-available, P_2O_5, K_2O, C-organic. Planting media with the proportion of goat manure, zeolite and husk charcoal at 3: 1: 2 gives best result when compared to other planting media. It was represented by the highest value of 5.81% C-organic and 0.69% N total. As biological agents, PGPR gives better influence on electrical conductivity at value 291.58 пS cm^{-3}.

1. Introduction

The development of plants cultivation using pots to meet the need of plants consumption, making the planting media is very important to support the success of plants cultivation. The use of planting media using a combination of soil, inorganic and organic natural ameliorant materials, and biological agents will provide a better physical and chemical properties of planting media in order to get a maximum production of plant. Composition of soil, manure and husk charcoal can support the growth and development of plant. These materials have a function as soil conditioner since these materials can be used to accelerate the recovery / improvement of soil quality, especially improvement of soil properties such as physics, chemistry and biology [1]. Husk charcoal has an important role as substitute for soil because it is porous, light, and sufficient to hold water. Sutono and Agus [2] showed that a combination of organic and inorganic soil conditioner had a better effect on improving land productivity, compared with organic soil conditioner. Biological agents such fungi or bacteria are inoculums microbial that have ability to improve the use of soil microbes in planting media by providing nitrogen (N), phosphorus (P), and potassium (K) elements to improve plants quality, nutrient remnants in the soil, microbes and the quality of soil aggregation [3, 4].

2. Materials and Methods

This research was carried out in Windhu Jaya Village, Kedung Banteng Subdistrict, Banyumas Regency with altitude of 360 m above sea level, starting from August to December 2017. This research was a pot experiment in a greenhouse. An experimental design using factorial complete randomized block design (RCBD) with two factors and three replications was used. The first factor was the application of biofertilizer, namely P0 = Control or without application of biological agents, P1 = PGPR, P2 = *Trichoderma* sp. The second factor was the composition of planting media, with a combination of 50% soil and 50% soil conditioner consisting of manure, zeolite and husk charcoal. In total there were 3 x 11 = 33 treatment combinations, with 3 blocks as replications and each consisting of 2 experimental units. The composition for manure, zeolite and husk charcoal is as follows: M1 = 1: 1: 1, M2 = 1: 1: 2, M3 = 1: 2: 1, M4 = 1: 2: 2, M5 = 2: 1: 1, M6 = 2: 1: 2, M7 = 2: 2: 1, M8 = 3: 1: 1, M9 = 3: 1: 2, M10 = 3: 2: 1 and M11 = 3: 2: 2. The Data were analyzed using ANOVA at the level of 5%.

3. Results and discussion

3.1. Soil chemical properties

3.1.1. Cation exchange capacity (CEC). The results in **Table 1** showed that the composition of soil conditioner significantly increased the CEC of planting media. Media M4 (1: 2: 1) gives better CEC values compared to other treatments. It is due to the high amount of zeolite on M4 media, which is 1.25 kg and the high CEC value in zeolites which is 37.16 $cmol^{(+)}kg^{-1}$ (**Table 1**), the addition of zeolites with a greater amount will help increase the value CEC planting media. Sugiarto [5] said that the more zeolites are given, the more CEC increase. Increasing the amount of organic material and husk charcoal on M8 media (2: 1: 2) with a smaller amount of zeolite gives a smaller CEC value compared to other planting media which is 20.73 cmol (+) kg^{-1}.

Table 1. Effect of Soil conditioner and biofertilizer on CEC, pH and C/N ratio planting media

Treatment	CEC ($cmol^{(+)}kg^{-1}$)				pH				C/N Ratio			
	P0	P1	P2	average	P0	P1	P2	average	P0	P1	P2	average
M1	29,30	31,79	26,73	29,27b	7,40	7,42	7,34	7,39cde	8,57	8,89	9,19	8,88b
M2	28,92	28,32	26,03	27,76c	7,59	7,51	7,46	7,52a	8,23	7,74	8,18	8,05fg
M3	21,95	28,72	29,74	26,80c	7,49	7,51	7,53	7,51a	7,92	8,40	8,41	8,24e
M4	30,35	28,10	33,00	30,49a	7,42	7,39	7,27	7,36def	8,49	8,97	8,21	8,56d
M5	25,69	22,86	25,97	24,84d	7,46	7,43	7,36	7,42bcd	8,11	7,77	8,02	7,97gh
M6	24,34	24,39	24,62	24,45de	7,53	7,46	7,46	7,48ab	7,12	8,25	8,09	7,82h
M7	23,41	25,06	25,22	24,56de	7,35	7,36	7,33	7,34ef	8,75	8,05	9,13	8,64cd
M8	19,75	18,57	23,87	20,73g	7,39	7,43	7,32	7,38cde	8,07	8,21	8,24	8,17ef
M9	26,75	25,99	28,77	27,17c	7,48	7,55	7,40	7,47ab	8,36	9,22	8,80	8,79bc
M10	25,57	21,21	24,34	23,70e	7,28	7,25	7,36	7,30f	8,81	9,97	9,93	9,57a
M11	22,71	20,37	22,73	21,94f	7,46	7,46	7,40	7,44bc	8,09	7,77	8,09	7,98gh
	25,34A	25,04A	26,46A	(-)	7,44A	7,43A	7,38A	(-)	8,23A	8,478A	8,57A	(-)

*value followed by the same letter are not significantly different, using DMRT test (<00,5)

The biological agents did not significantly affect the CEC of planting media. This is due to limited time of biological agent incubation in planting media, resulting not sufficient time to decompose the organic material.

3.1.2. Potential hydrogen. The results of analysis showed that the composition of soil conditioner significantly increased the pH of the planting media. pH value of all planting media compositions gave pH between 7.30 - 7.52 (**Table 1**) when compared to the initial media (original soil) with a pH of 5.55. Application of goat manure and zeolite is thought to be the cause of an increase in pH in the planting media. Nariratih et al. [6] stated that the application of manure is able to increase soil pH, because of its ability to bind with Al3+ metals, therefore no available Al3+for hydrolysis reaction which is able to acidify the soil. Furthermore, Nazari et al. [7] stated that the result of organic matter decomposition, among others, is in the form of base cations, such as Ca, Mg, K and Na. The release of alkaline cations into the soil solution causes the soil to saturate with these cations and ultimately increase the soil pH. Zeolite has capability to increase pH of planting media. Arafat et al. [8] showed that zeolite 9.3 t ha-1 doses compared with no zeolite had an effect on increasing soil pH from slightly acidic conditions to becomes a neutral condition.

3.1.3. C/N Ratio. Results showed that the composition of soil conditioner affected the C/N ratio in the planting media. Better composition of planting media C/N ratio value is M6 media (3: 2: 1) (**Table 1**). This is due to goat manure contains various microorganisms that help the decomposition of organic matter. According to Ibrahim *et al*. [9] the decomposition process in composting materials increases as the number of short-composer microorganisms increases. Results, showed from biological agents did not significantly affect the C/N ratio because the organic media have undergone almost perfect decomposition. This can be seen from the C/N ratio of planting media which are stable (7.82 - 9.57) so that the influence of biological agents is limited. Djajakirana [10] stated that C/N ratio of around 9-12 indicated that the decomposition reactions have been completed because the process of changing complex organic matter into simpler organic bonds has already completed.

Table 2. Effect of Soil conditioner and biofertilizer on C organic content, Total N and available P planting media.

Treatment	C Organic content (%)				Total N (%)				available P (ppm/100 g)			
	P0	P1	P2	average	P0	P1	P2	average	P0	P1	P2	average
M1	4.31	4.17	4.33	4.31ef	0.50	0.47	0.47	0.48e	362.26	318.28	340.52	340.35g
M2	5.00	4.70	5.18	5.00b	0.61	0.61	0.63	0.62b	527.41	568.32	584.15	559.96b
M3	5.29	5.09	4.58	5.29b	0.67	0.61	0.55	0.61b	620.44	545.24	615.99	593.89a
M4	2.97	3.38	3.22	2.97h	0.35	0.38	0.39	0.37h	294.41	309.11	316.53	306.68i
M5	3.57	3.29	3.99	3.57g	0.44	0.43	0.50	0.45f	378.77	366.78	408.60	384.72f
M6	4.70	4.50	4.80	4.70c	0.67	0.55	0.59	0.60b	518.96	501.60	447.15	489.23c
M7	4.42	4.20	4.52	4.42de	0.51	0.52	0.49	0.51d	331.82	309.57	329.04	323.48h
M8	4.55	5.10	5.16	4.55b	0.56	0.62	0.63	0.60b	420.17	415.89	474.30	436.79e
M9	5.81	6.09	6.28	5.81a	0.70	0.66	0.71	0.69a	581.90	534.45	559.10	558.48b
M10	4.02	4.29	4.18	4.02f	0.46	0.43	0.42	0.44g	255.78	201.35	219.81	225.65j
M11	4.64	4.55	4.18	4.64d	0.57	0.59	0.52	0.56c	476.52	463.81	451.62	463.98d
	4.48A	4.49A	4.58A	(-)	0.55A	0.53A	0.54A	(-)	433.49A	412.22A	431.53A	(-)

*value followed by the same letter are not significantly different, using DMRT test (<00,5)

The composition of soil conditioner affected the organic C content in the planting media. Organic C levels were better in the M9 treatment with the composition of goat manure: zeolite: husk charcoal (3: 1: 2) (**Table 2**). This is because the level of goat manure on M9 media is higher compared to other media. The composition of M4 (1: 2: 1) gives a lower organic C than other planting media due to the lower the amount of organic material in the media. Soepardi [11] stated that the content of soil organic C is influenced by the amount of organic matter. Utami and Handayani [12] stated that giving organic matter is able to increase soil organic C content which in turn affect to the soil properties both physically and chemically. Carbon is a food source for soil microorganisms, the presence of organic C in the soil will stimulate the activities of microorganisms thus it will be able to improve the process of soil decomposition.

3.1.4. Total N. The results showed that the composition of soil conditioner affected the total N content of the planting medium. The mean total N value is better in the composition of M9 (3: 1: 2) (**Table 2**) with the addition of higher organic matter than other planting media. Meanwhile on media M4 (1: 2: 1) with less organic matter giving a lower total N percentage that is equal to 0.37%. Junita *et al*. [13] stated that, the more organic matter given to the soil the more soil nitrogen is available. M10 (1: 2: 2) media with a smaller amount of organic material gives the lowest total N value compared to other planting media. Alhadad [14] stated that the main source of soil nitrogen is organic material, which will then undergo a process of mineralization, namely the conversion of nitrogen by microorganisms from organic nitrogen (in proteins and amino compounds) into inorganic forms available to plants. Biological agents have no effect on total N levels because the degree of root infection by Trichoderma and PGPR in this study is likely to be low so that the symbiotic efficiency of Trichoderma and PGPR is low [15].

3.1.5. Available P. The results of analysis showed that the composition of soil conditioner affects the availability of P in the soil. A higher available P value is found in M3 media with a composition of 3: 1: 1 (**Table 2**), meanwhile on M10 media with a composition of 1: 2: 2 with fewer organic ingredients gives lower P levels available compared to other planting media. This is due to the addition of more organic matter in M3 media when compared to other planting media. The organic matter given to the soil through the decomposition process will produce many organic acids containing derivatives of phenolic acids and carboxylic acids, humic acid and fulvic acid so that P-bound can be released and become available in the soil [16, 17].

Table 3. Effect of Soil conditioner and biofertilizer on available K and EC planting media.

Treatment	Available K (mg/100g)				EC (µS cm^{-3})			
	P0	P1	P2	average	P0	P1	P2	average
M1	4.31	4.17	4.33	4.31ef	0.50	0.47	0.47	0.48e
M2	5.00	4.70	5.18	5.00b	0.61	0.61	0.63	0.62b
M3	5.29	5.09	4.58	5.29b	0.67	0.61	0.55	0.61b
M4	2.97	3.38	3.22	2.97h	0.35	0.38	0.39	0.37h
M5	3.57	3.29	3.99	3.57g	0.44	0.43	0.50	0.45f
M6	4.70	4.50	4.80	4.70c	0.67	0.55	0.59	0.60b
M7	4.42	4.20	4.52	4.42de	0.51	0.52	0.49	0.51d
M8	4.55	5.10	5.16	4.55b	0.56	0.62	0.63	0.60b
M9	5.81	6.09	6.28	5.81a	0.70	0.66	0.71	0.69a
M10	4.02	4.29	4.18	4.02f	0.46	0.43	0.42	0.44g
M11	4.64	4.55	4.18	4.64d	0.57	0.59	0.52	0.56c
	4.48A	4.49A	4.58A	(-)	0.55A	0.53A	0.54A	(-)

*value followed by the same letter are not significantly different, using DMRT test (<00,5)

The results of analysis showed that the composition of soil conditioner significantly affected the available K planting media. The higher available K is found in the composition of M3 (3: 1: 1) and media M9 (3: 1: 2) (**Table 3**). This is due to the addition of more organic material in the planting media when compared to other planting media. Safuan and Bahrun [18] stated that the application of organic matter can increase the availability of K nutrients for plants. Potassium is easily available for plants in a variety of pH conditions, but it will easily disappear from the solution due to tapping. The total K in the soil will decrease, as well as the amount of K available to plants in the acidic soil and leachable soil [19].

3.1.6. Electrical Conductivity (EC). The results of analysis showed that the composition of soil conditioner and biological agents significantly affected on EC. A lower mean value of EC is found in the composition of M10 (**Table 3**). Lower EC is very necessary thus plants are easily absorbing nutrients contained in the media. Meanwhile the M3 and M9 media have greater DHL than other planting media. This is caused by the application of more organic matter which causes the accumulation / sediment of salt at the bottom of the planting media which is not able to be absorbed [20]. The M3 and M9 media have higher CEC values compared to M10 media. Growing media with a high level of organic matter has the ability to hold positively charged ions (Ca, Mg, K, Na). The presence of these ions in the pores that contain water will increase the value of EC growing media. The results showed that biological agents had an effect on EC. A better respond was obtained in the treatment of PGPR biological agents, this is caused by PGPR's function in increasing nitrogen fixation and plant tolerance to environmental stress, i.e. naturally specific root exudates released by plants act as pullers of PGPR [21].

3.2. Soil physical properties

3.2.1. Soil water content. The results of analysis showed that the composition of soil enhancers had no effect on soil water content (**Table 4**), although there was an increase in water content in the planting medium when compared with the moisture content of the initial media by 15%.

Table 4. Effect of Soil conditioner and biofertilizer on soil water content, bulk density and soil porosity

Treatment	Soil water content (%)				Bulk density (g/cm^3)				Soil porosity (%)			
	P0	P1	P2	average	P0	P1	P2	average	P0	P1	P2	average
M1	0.14	0.17	0.17	0.16a	0.79	0.84	0.96	0.86abc	0.45	0.41	0.37	0.41de
M2	0.32	0.26	0.26	0.28a	1.03	0.93	0.94	0.97abc	0.52	0.44	0.39	0.45cd
M3	0.29	0.26	0.35	0.30a	1.00	1.01	0.85	0.95abc	0.60	0.26	0.60	0.49b
M4	0.20	0.28	0.28	0.25a	0.95	0.98	1.21	1.05ab	0.38	0.39	0.40	0.39e
M5	0.34	0.21	0.29	0.28a	1.00	1.11	1.10	1.07a	0.25	0.27	0.31	0.28f
M6	0.28	0.25	0.23	0.25a	0.87	0.97	1.05	0.97abc	0.49	0.48	0.40	0.46bc
M7	0.19	0.18	0.26	0.21a	0.84	0.60	0.97	0.81abc	0.44	0.53	0.43	0.47bc
M8	0.13	0.22	0.26	0.21a	0.72	0.84	0.77	0.78bc	0.61	0.47	0.62	0.57a
M9	0.17	0.21	0.22	0.20a	0.85	0.65	0.74	0.75c	0.51	0.61	0.53	0.55ab
M10	0.22	0.13	0.23	0.19a	0.80	0.63	0.86	0.76c	0.53	0.64	0.46	0.54abc
M11	0.18	0.19	0.31	0.23a	0.82	0.89	0.88	0.86abc	0.48	0.32	0.45	0.42de
	0.23A	0.21A	0.26A	(-)	0.88A	0.86A	0.94A	(-)	0.48A	0.44A	0.45A	(-)

*value followed by the same letter are not significantly different, using DMRT test (<00,5)

3.2.2. Bulk density. The results showed that the composition of soil conditioner significantly affected to the bulk density. The higher bulk density values were shown in the composition of the media with the addition of less husk charcoal, while the M8, M9 and M10 media, with higher organic matter and higher husk charcoal, had a lower bulk density than other planting media (**Table 4**). Animal manure can provide lower soil density and higher organic C content for the soil structure. This condition will provide a benefit for growing root to increase the capability of plant in absorbing the nutrients from the soil [22]. The bulk density of mineral soils is generally range from 1.0 to 1.6 gr / cm3. While the bulk density of organic soils is in the range of 0.1 - 0.9 gr/cm^3. Bulk density or particle density affects a lot of physical properties of soil, such as porosity, strength, carrying capacity, ability of soil to store drainage water and others.

3.2.3. Soil porosity. The results of analysis showed that the composition of soil conditioner significantly affected the planting media porosity. Composition of planting increase soil porosity in the composition of M8 (2: 1: 2), M9 (3: 1: 2) and M10 (1: 2: 2) (**Table 4**). This is due to the addition of more husk charcoal in these 3-growing media. Putri [23] stated that husk charcoal has crumb properties so that air, water and roots easily enter the soil fraction and can bind water. Soil porosity is closely related to the level of soil bulk density. The denser the soil means the harder it is to absorb water, the smaller porosity. On the contrary, the easier the soil absorbs water, the soil has a large porosity.

4. Conclusions

Planting media with the composition of goat manure: zeolite: husk charcoal in a proportion of 3: 1: 2gives the better effect of organic C content 5.81% and total N 0.69%. Planting media with the composition of goat manure: zeolite: husk charcoal in a proportion of 1: 2: 1 gives the better effect of CEC of planting media in amount of 30.49 cmol$^{(+)}$ kg^{-1}. Soil conditioners of goat manure, zeolite and husk charcoal were able to increase the pH of planting media which was originally 5.69 to 7.30 - 7.52 (neutral). Planting media with the composition of goat manure: zeolite: husk charcoal (3: 1: 2) gives better effect of bulk density (0.75 g cm^3 and soil porosity (55%). PGPR biological agents gives better influence on electrical conductivity with value of 291.58 пS cm^{-3}.

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