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Application of Starter Solution Increased Yields of Chili Pepper (*Capsicum annuum* L.)

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ABSTRACT

Chili pepper (*Capsicum annuum* L.) was grown with polyethylene mulched on Inceptisol soil with low pH (5.5), low organic-C (1.54%), very low total N (0.12%), low K content (0.29 me (100 g)$^{-1}$), but very high soil P_2O_5 concentration (19.2 ppm) to evaluate the best crop management practices with starter solution. Seven starter solution combinations (1 = No Starter Solution + No CM + No SI, 2 = CM + SSVC, 3 = CM + SSG, 4 = SI + SSVC, 5 = SI + SSG, 6 = SI + CM+ SSVC, and 7 = SI + CM + SSG) were arranged in a randomized completely block design with four replications. Whereas CM = cow manure, SSVC = organic starter solution, SSG = inorganic starter solution, and SI=standard inorganic fertilizer. The results showed that inorganic, as well as organic, starter solution increased chili pepper growth and yield in less fertile soil. The highest marketable yield was obtained with application of standard inorganic (SI) + cow manure (CM) + inorganic starter solution (SSG). Inorganic starter solution application resulted in a better plant growth than organic starter solution, being evident at 1 week until 7 weeks after transplanting. However, inorganic starter solution did not significantly increase total marketable yields. Application of cow manure, standard inorganic fertilizer, or addition of organic starter solution reduced total unmarketable yield, improved fruit qualities and increased marketable yield.

Keywords: cow manure, crop management, fertilization, liquid fertilizer, vermi-composting

INTRODUCTION

Chili pepper (*Capsicum annum* L.) is one of the most important vegetable crops in Indonesia. Total chili pepper production area in Indonesia is 109,178 ha in 2008, and it is the highest among vegetables crops. More than 50% of the total chili production areas are located in Java island. Indonesian chili production is 695,707 tons with productivity of 6.37 tons ha^{-1} in 2008 (Pusat Data dan Informasi Pertanian, 2010). The main reasons of low chili pepper productivity are genetic and unfavourable environmental factors. Flower and young fruit drop is a major problem that is considered to be influenced by environmental factor.

Previous studies have shown that liquid NPK (nitrogen, phosphorus, potassium) supplements as starter solutions can boost early growth of cherry tomatoes and cabbages grown with organic fertilizers. Application of starter solutions of soluble nutrients in addition to inorganic fertilizer application is an effective technique to increase plant dry weight and N, P and K uptakes, and to promote rapid early growth of crops, especially crops with fast early growth rates (AVRDC, 2004). These studies indicated that one of the effects of the starter fertilizer was to accelerate root development, hence increasing the plant's capacity to absorb more nutrients from the soil. Starter solutions might therefore also promote increased uptake of nutrients from organic fertilizers. Gordon and Pierzynski (2006) reported that starter fertilizer containing N and P consistently increased grain yields, reduced the number of thermal units required from plant emergence to maturity, decreased grain-moisture content at harvest, and increased total P uptake of corn.

The initial N availability in soil may contribute to the fast early growth, which subsequently affects the plant establishment and plant yields. Result from study of Ma and Kalb (2006) showed the importance of maintaining nutrient concentrations in the soil solution high to boost plants early growth. The beneficial effects of the starter solution application indicated that an application of 7.2N-6.2P-6K kg ha^{-1} starter solution could substitute for about 50% of composted chicken manure (CM) applied or 30-50% of inorganic fertilizers applied as basal in the standard inorganic treatment. Chili pepper yields were the highest in treatments with CM and one starter supplemented with four additional applications of liquid fertilizers at 12, 25, 36 and 72 days after transplanting (DAT). Although the boosting effects of starter solution on initial growth were extremely significant, their influences on yield varied with crop and season. These facts indicate that the starter solution technology can be a good practice to substitute for conventional basal fertilization practices. However, the proper amount and timing of side dressings used in combination with starter solutions must be developed according to the crop and local conditions.

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Vermicompost is the product of a non-thermophilic biodegradation of organic materials through interactions between earthworms and microorganisms (Arancon *et al*., 2004). Certain species of earthworms fragment organic material residuals rapidly into much finer particles by passing them through a grinding gizzard (Ndegwa *et al*., 2000). Additionally, earthworms reduce numbers of human pathogens, an effect obtained in traditional composting by increases in temperature (Contreras-Ramos *et al*., 2004), but vermicomposting is generally faster. There is a growing tendency to use vermicompost in the production of diverse vegetables (Atiyeh *et al*., 1999; Arancon *et al*., 2004).

The pH of the sheep-manure vermicompost was 8.6 and greater than values reported for vermicompost derived from other organic sources. Vermicompost derived from cattle manure had pH 6.0 (Jordao *et al*., 2002) and 6.7 (Alves *et al*., 2001), whereas that derived from pig manure had pH 5.3 (Atiyeh *et al*., 2002) and 5.7 (Atiyeh *et al*., 2001). Vermicompost derived from sewage sludge had pH 7.2 (Masciandaro *et al*., 2000). These differences in pH are presumably related to difference in the raw material used for vermicomposting (Alves *et al*., 2001).

The vermicompost had an organic C content of 233 g kg^{-1}, an electrical conductivity (EC) of 8 mS cm^{-1}, a humic-to-fulvic acid ratio (HA/FA) of 1.7, total N content of 11.8 g kg^{-1}, cation exchange capacity (CEC) 43 cmolc kg^{-1}, a respiration rate of 152 mg CO_2-C kg^{-1} compost-C day^{-1}, a NO_3 content of 234 mg N kg^{-1}, a NO_2 content of 2.17 mg N kg^{-1}, and a NH_4 content of 9.14 mg N kg^{-1} (Llaven *et al*., 2008).

Vermicompost has been successful, among other things, in the processing of sewage sludge (Dominguez 2004; Dominguez and Edwards 2004). Vermicompost has a large potential in horticulture and agriculture (Edwards *et al*., 2004) for its physical, chemical and biological characteristics (Atiyeh *et al*., 2002), nutritional characteristics (Orozco *et al*., 1996), and characteristics related to the elimination of plant diseases.

Dilution of vermicompost in water may become a potential starter solution comparable to inorganic starter solution. Llaven *et al.* (2008) reported that the productivity and qualities of chili peppers from plants cultivated in soil supplemented with vermicompost were generally higher and better than those from plants grown in soil only. The addition of vermicompost to soil increased soluble solids in pepper fruits > 2 ^{o}Brix compared to fruits from plants cultivated in unamended soil (Llaven *et al.,* 2008). Hashemimajd *et al*. (2004) showed that tomato transplant's obtain higher biomass with tretament of mixture between vermicompost and compost than the control (soil and sand).

The application of starter fertilizer has been a common practice worldwide (Stone, 2000). The objective of this study was to determine the effect of organic and inorganic starter solution supplements in combination with organic and inorganic fertilizers on chili pepper growth and yield.

MATERIALS AND METHODS

Starter solution and fertilizer effects on chili pepper (*Capsicum annuum* L. C.V. Prabu) were evaluated at the Cikarawang Experimental Station of the University Farm, Bogor Agricultural University, Bogor, Indonesia from February to July 2006. The elevation of the experimental site is 250 m asl with average rainfall of 271. 7 mm $month^{-1}$ and average daily temperature of 28 ^{o}C.

Pre-fertilizer soil samples were taken with a soil probe from the top 15 cm of a Inceptisol soil type. Fertilizer was applied at 117-40-131 kg N-P_2O_5-K_2O ha^{-1} using Urea (45% N), SP-36 (36% P_2O_5), and KCl (50% K_2O). All the P and 50% of N and K were applied pre-plant, and 25% of N and K were applied two times at 3 and 6 weeks after transplanting (WAT). Combination of starter solution treatments and time of application are presented in Table 1.

The experiment used a randomized complete block design with four replications. Pre-plant fertilizers were

Table 1. Combination of starter solution treatments

Treatment	Formulation[1]	Time of application (DAT)[2]
1	No Starter Solution + No CM + No SI	
2	CM + SSVC	0, 12, 25, 36, 72
3	CM + SSG	0, 12, 25, 36, 72
4	SI + SSVC	0, 12, 25, 36, 72
5	SI + SSG	0, 12, 25, 36, 72
6	SI + CM+ SSVC	0, 12, 25, 36, 72
7	SI + CM + SSG	0, 12, 25, 36, 72

[1]See legend below for description
[2]DAT-Days after transplanting

CM = Cow manure applied at 20 tons ha^{-1}

SI = Standard inorganic fertilizer at 117-40-131 kg N-P_2O_5-K_2O ha^{-1} broadcast at 100% P pre-plant, 50% N and K pre-plant, 50% P and K 2x at 25% each at 3 and 6 WAT

SSVC = Starter solution vermicompost + Growth Promoter Rhizo Bacteria (GPRB); vermicompost starter solution was prepared by diluting 5 kg $liter^{-1}$ vermicompost and applied at the rate of 50 mL $plant^{-1}$ at 0, 12, 25, 36, and 72 DAT. GPRB was applied as seed treatment and 2x transplant application at 2 and 4 weeks after sowing

SSG = Starter solution prepared by diluting 30 g L^{-1} inorganic liquid compound fertilizer (14% N-12% P-14% K) and applied at a rate of 233 N-200 P_2O_5-233 K_2O mg in 50 mL water for each plant (equivalent to 6.2-5.3-6.2 kg N- P_2O_5-K_2O ha^{-1}) at 0, 12, 25, 36 and 72 DAT broadcasted and mixed into raised bed approximately 0.9 m wide and 20 cm high. The bed was covered with black polyethylene mulch (silver black with 0.0038 cm thickness). Chili pepper (*Capsicum annuum* L. C.V. Prabu) was planted at 0.5 m within row and 0.6 between rows (double rows). The irrigation was applied 2 times per day at 9 a.m. and 2 p.m. each of about 20 L (5 m^2 plot)$^{-1}$. Irrigation was applied if there was no rain.

Observations were taken on plant height, plant diameter, days to anthesis (number of days from transplanting to 50% open flower at the first node), days to maturity (number of days from transplanting to 50% fruit ripening at the first node), fruit weight, total marketable and unmarketable fruit yields, and incidence of fruit rot caused by anthracnose disease. The effects of the treatments on measured variables were determined using a two-factor ANOVA. The values that significantly affected the variables were analyzed using a Duncans multiple range test at the 95% and 99% confidence level (significance was defined as $P < 0.05$, and $P < 0.01$).

RESULTS AND DISCUSSION

Pre-plant Soil Analysis

Soil analysis showed that soil pH (water) at the experimental area was low (5.5). Organic-C content was 1.54% (low), Total N of 0.12 % (very low), and C/N ratio of 13 considered very low according to Pusat Penelitian Tanah (1983). Soil P_2O_5 concentration (Bray-1) was very high (19.2 ppm) and K (NH_4Ac 1 N, pH 7) was 0.29 me (100 g)$^{-1}$ (low). This soil analysis indicated that the soil fertility status in experimental site was low.

Plant Growth

The averages of plant height and plant diameter with the multiple comparison are shown in Table 2 and 3, repectively. Application of starter solution combined with basal application of chicken manure and standard inorganic fertilizer significantly increased plant height from 3 to 9 WAT and plant diameter from 7 to 9 WAT. Height of the plants treated with inorganic starter solution (SSG) with basal fertilizer of cow manure (CM) and with organic starter solution (SSVC) were similar at 3, 6, and 9 WAT. Similar results were obtained after application of inorganic or organic starter solution with basal fertilizer of standard inorganic (SI), or combination betwen SI and cow manure fertilizer (Table 2).

The highest plant height at 9 WAT (61.02 cm) was obtained by application of organic starter solution combined with standard inorganic and chicken manure. However, there was no significant differences between basal treatment of organic and inorganic stater solution plant height at 9 WAT.

Application of inorganic starter solution (SSG) with basal fertilizer of cow manure (CM) had a higher plant diameter than organic starter solution (SSVC) at 3 and 6, but not at 9 WAT. Similar result was obtained by application of inorganic starter solution with basal fertilizer of standard inorganic (SI), or combination betwen SI and cow manure fertilizer (Table 3). The effect of starter solution on plant diameter was evident as early as 1 to 9 WAT. The boosting effects of starter solution on initial growth were extremely significant, however, their influences on yields may vary with crops and seasons (Ma and Kalb, 2006).

Days to Maturity and Yield

Application of organic or inorganic starter solution with basal fertilizer of standard inorganic, cow manure, or combination between standard inorganic and cow manure had no effect on number of days from transplanting to anthesis and to maturity. The number of days from transplanting to anthesis occurred between 42 to 43 days, whereas, days to maturity occurred between 77 to 83 days (Table 4). In general, plants without fertilizer and starter solution (check or control treatment) took a longer time to reach anthesis and maturity.

The highest total marketable yield of chili pepper was obtained with application of inorganic starter solution at 0,

Table 2. Average plant height of chili pepper at 1 to 9 WAT under different treatments of starter solution

Treatments	Plant height (cm)								
	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT	8 WAT	9WAT
No Starter Solution + No CM + No SI	12.13b	13.71d	15.51c	19.06c	23.94c	29.56b	34.01b	37.24b	39.16b
CM + SSVC	14.47ab	16.70dc	19.44b	25.18b	32.90b	41.11a	48.44ab	51.78ab	53.41ab
CM + SSG	13.27b	17.70bc	21.22ab	30.39ab	40.24ab	49.38a	56.55a	58.22a	59.06Ab
SI + SSVC	17.10a	20.83ab	23.11a	29.19ab	37.64ab	45.48a	50.31a	52.88ab	54.69ab
SI + SSG	14.24ab	18.18abc	20.75ab	27.85ab	37.14b	46.33a	52.68a	57.90a	60.80A
SI + CM+ SSVC	17.08a	21.28a	22.58ab	30.14ab	36.71b	44.91a	52.78a	57.07a	61.02 a
SI + CM + SSG	13.86b	19.36abc	23.04ab	31.56a	44.41a	52.17a	57.12a	58.84a	59.09 a

Note: CM, SSVC, SSG, SI, see Table 1; Numbers followed by the same letter in the same columns are not significantly different based on DMRT at level $\alpha = 5\%$; WAT = Weeks After Transplanting

12, 25, 36, and 72 DAT with basal fertilizer application of combitanion between cow manure and standard inorganic fertilizer (7.09 tons ha^{-1}). The effect of organic starter solution with all basal fertilizers (CM, SI, CM + SI) on marketable yield was not significantly different with that of inorganic starter. However, the application of starter solution obtained higher marketable yield than control. Marketable yield of the plants applied with inorganic starter solution were higher than those applied with organic starter solution (Tabel 4). With inorganic starter solution, chili plant received equal to 233 mg N $plant^{-1}$. Llaven *et al*. (2008) reported that vermicompost had NO_3, NO_2, and NH_4 content of 234 mg N kg^{-1}, 2.17 mg N kg^{-1}, 9.14 mg N kg^{-1}, respectively. Application of 250 g vermicomposting per plant (SSVC) in this experiment chili plant received equal to 60.79 mg N $plant^{-1}$ and this amount was lower than the N applied in organic starter solution (SSG). Therefore, in term of marketable yields, chili plants responded better to inorganic starter solution than organic starter solution.

The highest total unmarketable yield of chili pepper was obtained with application of inorganic starter solution at 0, 12, 25, 36, and 72 DAT with basal fertilizer application of standard inorganic fertilizer (5.368 tons ha^{-1}). Similarly, application of inorganic starter solution obtained higher relative unmarketable yield than with organic starter solution.

Table 3. Average plant diameter of chili pepper at 1 to 9 WAT under different treatmentas of starter solution

Treatments	Plant diameter (cm)								
	1 WAT	2 WAT	3 WAT	4 WAT	5 WAT	6 WAT	7 WAT	8 WAT	9 WAT
No starter solution + No CM + No SI	2.04c	2.29c	2.60d	3.61 c	3.82d	4.51c	5.49c	6.08 b	6.62b
CM + SSVC	2.21bc	2.43c	3.09c	4.50b	5.25c	6.47b	7.17bc	8.59a	9.04a
CM + SSG-	2.44ab	3.40ab	4.47a	6.04a	7.12a	8.52a	9.46a	10.07a	10.10a
SI + SSVC	2.47ab	3.18b	3.80b	4.72b	5.78bc	6.77b	8.02ab	8.29a	8.90a
SI + SSG-	2.60a	3.34ab	4.30a	5.56a	6.64ab	8.12a	9.54a	10.25a	10.50a
SI + CM+ SSVC	2.41ab	3.03b	3.65b	4.70b	5.67bc	6.70b	8.14ab	9.77a	10.10a
SI + CM + SSG	2.56b	3.74a	4.66a	5.89a	7.40a	8.72a	9.33a	9.80a	10.56a

Note: CM, SSVC, SSG, SI, see Table 1; Numbers followed by the same letter in the same columns are not significantly different based on DMRT at level $\alpha = 5\%$

Table 4. Number of days from transplanting to anthesis and maturity, total yield per hectare, of chili pepper under different treatments of starter solution

Treatments	Day to anthesis	Days to maturity	Total fruit yield (ton ha^{-1})			
			Marketable (% relative yield)		Unmarketable (% relative yield)	
No stater solution + No CM + No SI	43.5	83.0	0.606c	(1)	0.810 d	(15)
CM + SSVC	43.5	81.8	2.996bc	(42)	2.102 cd	(39)
CM + SSG	42.0	77.0	4.600ab	(65)	4.090 ab	(76)
SI + SSVC	43.5	85.5	4.469b	(63)	2.467 bcd	(46)
SI + SSG	42.0	75.5	6.499ab	(91)	5.368 a	(100)
SI + CM+ SSVC	42.8	81.0	4.905ab	(69)	2.963 bc	(55)
SI + CM + SSG	42.8	82.0	7.093a	(100)	3.221 bc	(60)

Note: CM, SSVC, SSG, SI, see Table 1; Numbers followed by the same letter in the same columns are not significantly different based on DMRT at level $\alpha = 5\%$

CONCLUSION

Application of inorganic and organic starter solutions at 0, 12, 25, 36, and 72 DAT with basal fertilizer, application of cow manure, standard inorganic, or a combination between cow manure and standard inorganic fertilizer increased plant growth and yields of chili pepper compared to control treatment. Application of inorganic starter solution resulted in higher relative marketable and unmarketable yields than organic stater solution from vermicompost. These results will be beneficial to improve cultural practices and management of chili pepper in soil with low fertility status.

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