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Impact of starter solution technology on the use of fertilizers in production of chilli (*Capsicum frutescens* L.)

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Abstract. This paper examines application of starter solution technology –an efficient method of fertilizer application— in chilli production. Chilli production is one of the important sub-sectors of agricultural in Indonesia. However, the use of inorganic fertilizers is inefficient and to large extents of fertilizers were not absorbed by the production system resulted in contaminates the environment. It is not too late to conserve our earth from being contaminated by agrochemicals by using a starter solution technology. Two field trials of starter solution technology were conducted to see the impacts on production and fertilizer use. A randomized complete block design with four treatments and five replications was used to test the technology. The treatments were based on current farmers' practices and soil condition in Kediri areas. A hybrid chilli (*Capsicum frutescens* L.) called Bhaskara was used in these trials. The results show that using this technology was able to reduce the use of fertilizers by 50% of the current level without a significant reduction in yield. This means that application of the technology increased efficiency of fertilizer use. This leads to an increase in net income gained by farmers. Further challenges are to improve and disseminate such technology to other crops.

1. Introduction

The agricultural sector is very important in Indonesia. The sector provides jobs in both rural and suburban areas through value chain of the products. The sector provides significant contributions to employment and national income. One of the main sub-sectors is horticulture that includes chilli production. Chilli production has increased substantially after the development of agribusiness infrastructures, conducive market environment and adoption of improved agronomical technologies [1]. Chilli provides significant revenue for the farmers [2]. Globally, Indonesian production of chilli is ranked four after China, Mexico and Turkey, and it has been able to fulfill domestic market for both household and food industry consumption.

There is an emerging pollutant in the environment in agriculture and a threat coming from soil and water contamination of agrochemicals [3]. Chilli is not produced in a sustainable manner. In intensive chilli farming in Central Java, the use of agrochemicals is three times higher than in rice farming [4,5].



Since the Green Revolution, the use of agrochemicals has increased substantially as amplified farmers' dependency on such compounds. Initially, the role of agro-chemical input was significant in economic development [6]. However, the use of inorganic fertilizers has been excessive, and in intensive farming of high valued crops, such as chilli, and even, the situation is more severe. As the use of agrochemicals (including inorganic fertilizers) is inefficient, to a large extent of agrochemicals is not captivated by the production system and these spills will contaminate soil and water resources. This condition is different from agriculture in Africa, where farmers still apply fertilizers at a lower rate [7].

Further adverse impacts include soil degradation, the rapid growth of invasive aquatic weeds and eutrophication resulting in depletion of oxygen in the water, which causes a reduction in specific fish and other animals. The monetary values of such impacts are considerably high [8; 9]. However, it is not too late to conserve our earth from being contaminated by agrochemicals using starter solution technology. Conservation of agriculture can help us to improve long-term productivity, profitability and soil quality.

Therefore, it needs a technology that can be applied to reduce the use of fertilizers to an optimal rate. Based on balanced fertilizer application, soil nutrients are needed by plants at appropriate stages. If the supply of adequately assessed based on the soil analysis, it is not necessary to added nutrients excessively. Balanced fertilizer application should not be interpreted as granting of macro-nutrients of Nitrogen, N; Phosphate, P; Potassium, K; and other nutrients as it has been often interpreted by many farmers. Balanced fertilizer application in the real sense is the use of fertilizers according to soil nutrient supply and crop requirements.

It has been reported that to address these problems need to be fixed with NPK fertilization experiment in the locations of the planting, and then analyze the correlation between fertilization and harvest, recommended a fertilizer for the plants determine the level of soil fertility and implement fertilizer-based fertility ground. Starter solution technology (SST) is a mixture of soluble fertilizers and water used to get young plants off to a good start. The fertilizer material easily dissolves in water and the nutrients are readily available for plant uptake. The technology is developed by World Vegetable Center and has been disseminated to Thailand, Indonesia, China, India, and Taiwan. SST is an innovative technology to reduce fertilizer and simultaneously increase the productivity of fertilizer application. SST is certainly very influential to accelerate plant growth at a young age [10].

Application SST also minimizes physical stress because of transplanting. When the plants were transferred from a protected environment to the open fields, an interruption in the normal growth has affected absorption of nutrients in the soil. Rapid nutrient uptake will help the plant recover quickly from the stress and form new roots. The technology has been disseminated to Indonesian farmers in East Java and Bali trough farmer field school, and it has been successful to increase chilli productivity [11]. Since the technology is claimed to be more efficient than farmers' practices in terms of fertilizer use, there is a need for technical study of the technology. The objective of this study is to examine the advantage of the application of starter solution technology –an efficient method to apply fertilizers— for chilli farming and analyze its economic benefit.

2. Materials and methods

This study conducted two field trials in District of Kediri East Java. This region was selected because of some major constraints as follow: soils are sandy that accounted for sand more than 70%, the level organic material is low; the level of macro-nutrients is high in K. Farmers tend to overuse and unbalanced fertilizers, and inappropriate timing of fertilization. The first trial was conducted in June-August 2013 and the second one was conducted in July-September 2014.

Chilli variety of Bhaskara®, a hybrid variety commonly grown by local farmers in the areas; and complex-NPK fertilizers Mutiara® as sources of N, P and K were used in this study, as well as organic fertilizer called “Bokasi”, which was obtained from a local producer and commonly used by local farmers. There were three treatments and farmers' practices as control treatment. The hybrid variety of Bhaskara® has relatively shorter growth compared to the other varieties and relatively easy to

maintain. This variety has a short, fast harvest, and high yield. Every trial was about three months long.

The study used randomized complete block design (RCBD) with four treatments and five replications. The treatments consist of four different dosages of fertilizers. The details of treatments are provided in Table 1.

Table 1. Details of treatments.

Treatments*	Description	Total fertilizers (kg/ha)		
		N	P ₂ O ₅	K ₂ O
T1-(farmer's practice)	Bokasi+Basal, SP-36 +Side-1 +Side-2+Side-3+Side-4 +Side-5	370	379	273
T2-(farmer's rate)	Bokasi+Basal, SP-36 +ST-0 +ST-1 +Side-2+ST-3 +Side-4 +Side-5	370	379	273
T3-(medium rate)	Bokasi +ST-0 +ST-1 +Side-2 +ST-3 +Side-4 +Side-5	230	149	149
T4-(low rate)	Bokasi +ST-0+ST-1 +Side-2 +ST-3 +Side-4 +Side-5	185	137	137

Note: *RCBD with 5 replications. Bokasi was cattle manure in 2.4 t/ha for T1 and T2, 1.2 t/ha for T3 and T4
ST was applied as liquid solution, and Side was applied as solid side-dress.

Plant growth and yield of chilli were selected as variables of interest in this study. Economic analysis was conducted to see the advantage of using SST. Since all aspects were the same in all treatments, except the dosages of fertilizers and yield, partial budgeting analysis was used as an economic tool. The partial budgeting analysis is formulated as:

$$\begin{aligned}\pi_T - \pi_F &= (R_T - R_F) - (C_T - C_F) \\ \Delta\pi &= \Delta R - \Delta C\end{aligned}\tag{1}$$

Where π denotes profit, R is revenue, C is total cost related to fertilizer application, Δ denotes incremental change, subscript T and F indicate treatment and farmers' practice respectively. The higher $\Delta\pi$ represents the better treatment.

Field observation and maintenance were conducted twice a week during three months. These include weeding, watering, spraying pesticides to control pests and diseases. Agronomic data were collected several days after transplanting (DAT), and economic data were collected during harvesting at prevailing farm-gate prices. Statistical tests were conducted using F-test of ANOVA.

3. Results and Discussion

The agronomic aspects resulting from four different treatments are provided in Table 2. There are two trials. For the trial-2, plant height after 14 DAT was not significantly different among T1 to T4. Similarly, for the growth in the next stages at up to 64 DAT, the growth was not significantly different. For the trial-1, the different plant height appeared at 63 DAT. Chilli crops treated with SST did not show significantly different to farmers' practices.

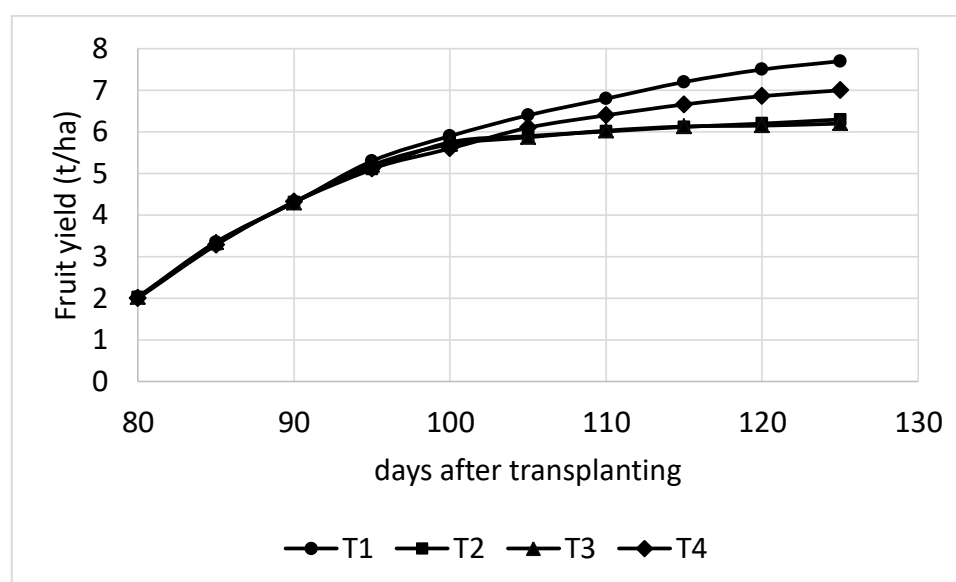
Despite the 50% reduction in fertilizer application (T4), there is no significant difference in growth performance of plants from 14 up to 64 DAT. The second trial showed that plant height was just a half of the first one. The second one was attacked by the viruses, and this led to the growth of plant height was not optimal. As a result, that fertilizer application and SST might be ineffective. Foliar fertilizers and organic fertilizers by farmers in the yellow-virus endemic areas cannot prevent the plants from infection with the virus. Plants that are already infected cannot recover back into healthy condition.

Table 2. Plant height of chilli (cm).

Treatments	Trial-1				Trial-2			
	21 DAT	35 DAT	49 DAT	63 DAT	14 DAT	28 DAT	42 DAT	64 DAT
T1	19.4a	33.7a	47.4a	57.1 a	8.5a	18.19a	23.5a	25.8a
T2	20.5a	33.1a	42.9a	51.2ab	9.9a	16.99a	24.3a	24.0a
T3	20.0a	33.5a	44.4a	53.7ab	10.49a	17.6a	21.6a	22.8a
T4	21.1a	34.1a	41.5a	45.4 b	9.59a	18.0a	23.10a	24.2a

Note: a number followed by the same letter means no significant difference. DAT=day after transplanting.

The production level of chilli in the trial-1 is presented in Figure 1. Up to 95 DAT, the production of chilli in all treatment still was almost similar, and statistically was not prominent. By 105 DAT, the chilli production shows differences. However, the difference in such production was not statistically significant until the final harvest. The trial-2 also shows similar results in terms of the insignificant difference in production. The yield of chilli on treatments of T1 to T4, which was carried out every 2 weeks starting the first harvest to the fifth harvest, is presented in Table 3.

**Figure 1.** Production of chilli for different treatments.**Table 3.** Harvest of chilli on T1 to T4 (g/20 plant).

Treatment	Average harvest of Chilli				
	1 st	2 nd	3 rd	4 th	5 th
T1	740 a	410 a	350 a	365 a	640 a
T2	565 a	325 a	230 a	320 a	455 a
T3	510 a	295 a	230 a	255 a	515 a
T4	905 a	435 a	325 a	305 a	620 a

Note: a number followed by the same letter means no significant difference at $P > 0.05$.

Both trials show that the production of chilli did not significantly decrease when the fertilizer level was reduced. This suggests that the SST treatments effectively and efficiently work in supplying enough fertilizers to chilli crops. This is due to the early availability of nutrients absorbed by young plants before the roots become strong during transplanting. The nutrients have a direct impact on stimulating plant growth and more efficiency in the use of fertilizers. Fertilizers applied in SST to the

soil are more readily available than that of the solid fertilizers applied conventionally. Enough and balanced nutrients and also available to plants have increased activity of plant physiology. The higher the yield of photosynthesis, the greater the accumulation of food reserves are translocated to the network storage of food reserves when other factors are kept in optimal condition. In this study, unfortunately, planting conditions were not optimal as expected. This is because 100% of chilli crops were infected by viruses resulting yellow and up-normal leaf. This will certainly affect the plant leaf area index. When the leaf is lower in area index and chlorophyll content is also lower, the amount of photosynthetic process for plant growth will decrease. Consequently, the average yield was low compared to healthy ones. Since the level of production is statistically not different between farmers' practice and SST treatments, analysis of economic aspect is required. Based on the prevailing market price of NPK Mutiara®=IDR6500/kg; compost=IDR100/kg; SP36=IDR1000/kg; labor wage=IDR25000/man-day; and chilli (at farm-gate)=IDR5000/kg, the different of additional net income resulting from the application of SST is provided in Table 4.

Table 4. Economic aspects of SST of trial#1 (IDR000/ha).

	T1	T2	T3	T4
Δ Cost	0	-260	-1,613	-3,173
Δ Revenue	0	-1,500	-1,500	-500
Δ Net income	0	-1,240	113	2,673

It can be seen that treatment T4 showed the highest additional net income. This means that if farmers apply T4, they will get additional net income about IDR 2.67 million higher than if they apply usual practices. This additional net income resulted from saving of fertilizer-related costs. For the trial-2, the economic analysis was not conducted because the plants at early stages were severely attacked by viruses, despite routine sprays with pesticides. The plant did not grow normally and the production was very low. If the economic analysis was insisted, the results would be very misleading.

The economic analysis of the trial-1 is expected to convince farmers to adopt the technology. The technology has been disseminated to more than 1500 vegetable farmers in Kediri and Blitar East Java, where intensive vegetable farming exists. It is expected that direct benefits can be gained by farmers as additional income because chilli is one of income-generating farming [12].

A further positive impact of this application is a reduction in the amount of agrochemical waste. Soil and water are expected to be less contaminated, the agricultural land becomes more productive and water resource becomes healthier [13]. Conservation of agriculture is required [14]. One of the impacts of improvement in better conservation is that total emissions of nutrients from agricultural production to the environment decrease [15]. However, analysis of the further benefits conservation should be properly formulated to get correct outcomes.

With respect to the balanced fertilizer management, this study suggest to consider the following points: 1: supply of readily available nutrients through starter solution to seedlings immediately after transplanting; 2: reduce the portion of basal fertilizers in sandy soil to reduce fertilizer loss by leaching; 3: split fertilizers into side-dress and apply side-dress in solid form in sandy soil, so that fertilizers will be kept near roots for longer time; 4: apply side-dress later in growing stages to improve nutrient supply during fruiting period; 5: and balanced fertilization approaches will be able to increase fertilizer efficiency and reduce fertilizer inputs.

4. Conclusion

The problem of intensive chilli farming in current practices is its sustainability. The excessive use of agrochemical is one of the culprits. Inorganic fertilizers have environmental impacts. By using SST, the potential adverse impact can be mitigated. Without jeopardizing the production of chilli, SST is able to reduce the need for fertilizers by about 50 percent, by mean that more efficient and effective use of fertilizers. In economic aspects, using SST can save the cost of fertilizers, and this is captured

by farmers as additional income. Socially, the reduction of fertilizers has a broader economic impact because soil and water resources can be saved from contamination. It is quite difficult to count exactly the economic benefit of SST of every farmer apply SST. To sum up, SST provides a hope to conserve our earth from being contaminated by unnecessary agrochemical waste. Increasing efficiency of fertilizer use reduces the amount waste discharged into the environment. A further challenge is to improve and disseminate such technology to intensive farming of other crops.

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