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Research Article

Estimating The Optimum Dose of Fertilizer to Enhance Soybean Productivity Under Kayu Putih (*Melaleuca cajuputi*) Stands

Roni Ismoyojati[1]*, Priyono Suryanto[2], Tohari[3], Fajrin Pramana Putra[4]
[1]Departement of Plantation Production Technology, Politeknik Lamandau, Lamandau, Indonesia
[2]Departement of Silviculture, Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta, Indonesia
[3]Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia
[4]Department of Agriculture, Faculty of Animal and Agricultural Science, Universitas Diponegoro, Semarang, Indonesia

*Corresponding author: ismoyojatironi@gmail.com

ABSTRACT

Optimum doses of nitrogen, phosphorus and potassium obtained through fertilizing are necessary to increase crop productivity. An excess of or lack of nitrogen, phosphorus and potassium obtained through fertilizing will cause plants responsiveness to decrease. This research estimated the response surface, i.e. a step to determine the optimum doses of urea, SP-36, and KCl fertilizers. It employed a split-split plot design. The main plot was intended for the urea dose while the subplot and sub-subplotwere intended for SP-36 and KCl, respectively. Theadministration of urea was divided into two categories, i.e. 0 kg. ha^{-1}, 25 kg. ha^{-1} and 50 kg. ha^{-1}, while the administration of SP-36 and KCl was divided into three categories, i.e. 0 kg. ha^{-1}, 150 kg. ha^{-1}, 300 kg. ha^{-1}; and 0 kg. ha^{-1}, 75 kg. ha^{-1}, and 150 kg. ha^{-1}, respectively. Based on the response surface, it is revealed that the optimum combined dose for ureais equal to 26.64 kg. ha^{-1} while for SP-36 and KCl, the optimum combined doses are 292.61 kg. ha^{-1} and 97.71 kg. ha^{-1}, respectively. The combination of these three substances can produce a maximum weight of soybean by 2.07 ton. ha^{-1}.

Keywords: *Nitrogen, Phosphorus, Potassium, Soybean Productivity, Kayu Putih Stands.*

INTRODUCTION

Soybean *(Glycine max (L.) Merr.)* is a popular crop widely cultivated by Indonesian farmers because of it vital role forthe life of society. A great number of processed foods are made from soybean as the primary ingredient, such as tempe, soya sauce, tauco and others. A greater variety of processed foods made from soybeanas the primary ingredient is expected to causesoybean demandsamong society to increase in the next few years.

The projected average soybean demand issued by the *Badan Perencanaan Pembangunan Nasional* (2013) in 2012 to 2019 is approximately 2.85 million ton and this amount is still very high as the projected domestic soya production is only 924.250 ton in 2012 to 2019, thusthere is a shortage by 1.922 million ton. Among the factors that affect the low domestic production of soybean are: 1) decreased availability of landto grow soybeanand, 2) low productivity of soybean grown by farmers. Reduced agricultural land is caused by changes in the use of land potential for agriculture to non-agricultural activities, and land use conversion from land which is originally used to grow soybeaninto land used to grow other crops. *Badan Pusat Statistik Indonesia* (2015) reveal that the average national soybean productivity between 1993 to 2015 ranged between 1.1-1.5 ton. ha^{-1}. Land intensification and balanced fertilization can be implemented to cope with such problems.

The intensification of land can be undertaken by planting soybean using the agroforestry system, for example. An example of the agroforestry system application that has been implemented by farmers can be found in Gunung Kidul Regency. Here, the system is implemented by planting soybean under kayu putih*(Melaleuca cajuputi.)*stands. The farmers use fertilizer to increase crop productivity per unit of area. However, farmers,whilst using the fertilizer, sometimes do not refer to the dose recommended by the local agricultural service, rather they use their own estimation which is often unbalanced. The use of fertilizer with a dose which is either too high or too low will result in plants' decreased responsiveness.

Nitrogen, phosphorus and potassium are macronutrients contained in fertilizer and absolutely necessary for plants. Gardner *et al*., (1991) describeseveral symptoms shown by plants in an excess of nitrogensuch asa greener leaf color, too dense leaves, decreased flower production and prone to pests and diseases. On the other hand, nitrogen deficiency will inhibitgrowth processes, such as stunted growth, yellowing leaves and reduced yield and dry weight of the plant. Ad forphosphorus, if it is given excessively it will inhibit absorption of micronutrients such as iron (Fe), copper (Cu) and zinc (Zn). Conversely, phosphorus deficiency can cause old leaves's color to turn into greyish purple, brown-colored edges of the leaves, small-sized leaves, as well as slow and stunted growth. Potassium is the third nutrient required by plants, an excess of potassium in plants will inhibit absorption of calcium (Ca) and magnesium (Mg) while potassium deficiency in plantsis shown by several symptoms such as flowers fall easily, leaves at the lowest partturn dry or contain spots, the edge of leaves gets scorched and leaves curl downward. This balanced fertilization is expected to increase soybean productivity and provide information to farmers. Thus, this research aims to determine the optimum doses of nitrogen, phosphorus and potassium to increase soybean productivity under kayu putih stands.

RESEARCH METHOD

This research was conducted in the Forest Police District Command Menggoran, Part of Forest Playen, Forest Management Unit in Yogyakarta, Gunung Kidul Regency, Yogyakarta Special Region at an altitude of 177 meters above sea level and used soybean of Grobogan variety. It research estimated the Response Surface (i.e. the surface and response analysis) of the doses of urea, SP-36, and KCL, i.e. a step to determine the optimum doses of urea, SP-36, and KCl fertilizers.

It employed a split-split plot design. 1) The main plot was intended for urea given in two doses, i.e. 0 kg. ha^{-1}, 25 kg. ha^{-1} and 50 kg. ha^{-1}; 2) the subplot was intended for SP-36 given in three doses, i.e. 0 kg. ha^{-1}, 150 kg. ha^{-1}, and300 kg. ha^{-1};3) the sub-subplot was intended for KCl given in three doses, i.e. 0 kg. ha^{-1}, 75 kg. ha^{-1}, and 150 kg. ha^{-1}. The dose used referred to the recommendations of *Badan Pengkajian Teknologi Pertanian* (2008) of Yogyakarta Special Region.

The observation included 1) components of growth: leaf area, roots dry weight and shoot dry weight were observed at the age of 21, 42 and 63 days after planting. 2) Yield components: the number of beans/plant, the number of beans/pod, the weight of beans (g. $Plant^{-1}$), the weight of 100 beans (g) and the weight of beans (ton. ha^{-1}) were observed at the time of harvesting.

RESULTS AND DISCUSSION

Based on the response surface analysis, it is revealed that there was no interaction between the doses of urea, SP-36 and KCl with the leaf area, roots dry weight and shoot dry weight of soybean. The combined fertilizer applicationusing urea at a dose of 1 kg. ha^{-1} and SP-36 at a dose of 1 kg. ha^{-1}can insignificantly reduce the leaf area at the age of 21, 42 and 63 days, by 0.0008cm^2, 0.07cm^2 and 0.06 cm^2 (Table 1), respectively. Meanwhile, the utilization of SP-36 at a dose of 1 kg. ha^{-1}can insignificantly reduce the shoot dry weight of soybeanat the age of 21, 42 and 63 days by 0.00004 g, 0.001 g and 0.002 g (Table 2), respectively. Nitrogen given at an inappropriatedose is assumed to inhibit absorption of phosphorus by the roots, causing the supply of phosphorus in the leaves to reduce followed by decreased of shoot dry weight. Gardner *et al.* (1991) state that decreases in the leaf area and the dry weight of canopies of the plants are due to the competition in absorbing nutrients, particularly nitrogen deficiency which causes decreases in the leaf area and the shoot dry weight of the plants. Inappropriate dosing of nitrogen application will result in less optimal plant growth and development because if the amount of nitrogen given is less than the optimum dose, it will become a constraintfor phosphorus and in such a condition, plants' response to the applicationof phosphorusis significantlydetermined by the availability of nitrogen in soil (Havelin et al., 2005).

Table 1. Regression coefficient of the relationship between the leaf area (cm^2) and doses of urea fertilizer, SP-36 fertilizer and KCl fertilizer based onthe response surface

Leaf Area	$\beta 0$	$\beta_1 X_1$	$\beta_2 X_2$	$\beta_3 X_3$	$\beta_{11} X_1^2$	$\beta_{12} X_1 X_2$	$\beta_{22} X_2^2$	$\beta_{13} X_1 X_3$	$\beta_{23} X_2 X_3$	$\beta_{33} X_3^2$
21 days	1295.32**	-1.82^{ns}	3.42^{ns}	3.33^{ns}	0.05^{ns}	-0.0008^{ns}	-0.0007^{ns}	-0.009^{ns}	0.003^{ns}	-0.023^{ns}
42 days	5586.95**	73.50^{ns}	-8.32^{ns}	-7.17^{ns}	-0.88^{ns}	-0.07^{ns}	-0.10^{ns}	0.03^{ns}	0.03^{ns}	0.06^{ns}
63 days	4005.64**	56.15^{ns}	4.91^{ns}	-17.02^{ns}	-0.67^{ns}	-0.06^{ns}	0.12^{ns}	0.008^{ns}	0.010^{ns}	0.11^{ns}

Description: Figures followed by (ns) and (*) indicate that they are not significantly different and significantly different at a 5% degree, respectively, while figures followed by (**) indicate that they are significantly different at a 1% degree. X1 = Urea Fertilizer; X2 = SP-36 Fertilizer; X3= KCl Fertilizer.

Table 2. Regression coefficient of the relationship between the shoot dry weight (g) and doses of urea fertilizer, SP-36 fertilizer and KCl fertilizer based on the response surface

Shoot Dry Weight	$\beta 0$	$\beta_1 X_1$	$\beta_2 X_2$	$\beta_3 X_3$	$\beta_{11} X_1^2$	$\beta_{12} X_1 X_2$	$\beta_{22} X_2^2$	$\beta_{13} X_1 X_3$	$\beta_{23} X_2 X_3$	$\beta_{33} X_3^2$
21 days	0.27**	-0.002^{ns}	0.0005^{ns}	-0.00004^{ns}	0.00004^{ns}	0.000006^{ns}	-0.000001^{ns}	0.000003^{ns}	-0.0000002^{ns}	0.000001^{ns}
42 days	1.80**	0.03^{ns}	-0.003^{ns}	-0.001^{ns}	-0.0003^{ns}	-0.00002^{ns}	0.00001^{ns}	-0.00005^{ns}	-0.000001^{ns}	0.00002^{ns}
63 days	1.03**	0.02^{ns}	0.002^{ns}	-0.002^{ns}	-0.0002^{ns}	-0.00006^{ns}	0.000004^{ns}	0.000006^{ns}	0.000003^{ns}	0.00003^{ns}

Description: Figures followed by (ns) and (*) indicate that they are not significantly different and significantly different at a 5% degree, respectively, while figures followed by (**) indicate that they are significantly different at a 1% degree. X1 = Urea Fertilizer; X2 = SP-36 Fertilizer; X3= KCl Fertilizer.

Fertilizer application using urea at a dose of 1 kg. ha^{-1} can significantly enhance the roots dry weight of soybean by 0.000009 g at the age of 21 days. Meanwhile, the combination of urea fertilizer at a dose of 1 kg. ha^{-1} and SP-36 fertilizer at a dose of 1 kg. ha^{-1} can significantly enhance the roots dry weight of soybean by 0.01 g at the age of 63 days (Table 3). Nitrogen given in the appropriate amount will improve the growth of plant roots. Wilkinson *et al.*, (1999) *cit* Fageria, (2001) report that the administration of nitrogen can promote the growth and development of roots, followed by an increase in the roots dry weight. The increasing root growth will also increase the ability of roots to absorb and translocate phosphorus to all plant organs. Andrews and Newman, (1970) *cit* Goldsworthy and Fisher, (1996) find out the correlation between the uptake of phosphorous in the soil and thelength of roots that in turn affects the dry weight of plant roots.

The application of fertilizers urea, SP-36, and KCl shows no interaction in terms of the number of beans/plant, the number of beans/pod, the weight of beans (g. $plant^{-1}$), the dry weight of 100 beans (g) and the weight of beans (ton. ha^{-1}). The application of urea at a dose of 1 kg. ha^{-1} can significantly increase the number of beans per plant, the weight of beans (g. $plant^{-1}$) and the weight of beans (ton. ha^{-1}) by 0.46, 0.08 g. $plant^{-1}$ and 0.02 ton. ha^{-1}, respectively. The application of SP-36 at a dose of 1 kg. ha^{-1} can significantly increase the number of beans per plant by 0.06 (Table 4).

Table 3. Regression coefficient of the relationship between the roots dry weight (g) and doses of urea fertilizer, SP-36 fertilizer and KCl fertilizer based on the response surface

Roots Dry Weight	$\beta 0$	$\beta_1 X_1$	$\beta_2 X_2$	$\beta_3 X_3$	$\beta_{11} X_1^2$	$\beta_{12} X_1 X_2$	$\beta_{22} X_2^2$	$\beta_{13} X_1 X_3$	$\beta_{23} X_2 X_3$	$\beta_{33} X_3^2$
21 days	0.25**	0.001^{ns}	-0.0001^{ns}	0.001^{ns}	-0.00002^{ns}	0.000009*	0.00000008^{ns}	-0.000001^{ns}	0.0000002^{ns}	0.000005^{ns}
42 days	0.94**	0.006^{ns}	-0.002^{ns}	-0.001^{ns}	-0.0001^{ns}	0.000006^{ns}	0.000005^{ns}	-0.00002^{ns}	0.0000007^{ns}	0.00001^{ns}
63 days	0.70**	0.01*	-0.0001^{ns}	-0.001^{ns}	-0.00001^{ns}	-0.00002^{ns}	0.000003^{ns}	0.00001^{ns}	-0.000001^{ns}	0.000006^{ns}

Description: Figures followed by (ns) and (*) indicate that they are not significantly different and significantly different at a 5% degree, respectively, while figures followed by (**) indicate that they are significantly different at a 1% degree. X1 = Urea Fertilizer; X2 = SP-36 Fertilizer; X3= KCl Fertilizer.

Table 4. Regression coefficient of the relationship between yield components and doses of urea fertilizer, SP-36 fertilizer and KCl fertilizer based on the response surface

Yield Component	$\beta 0$	$\beta_1 X_1$	$\beta_2 X_2$	$\beta_3 X_3$	$\beta_{11} X_1^2$	$\beta_{12} X_1 X_2$	$\beta_{22} X_2^2$	$\beta_{13} X_1 X_3$	$\beta_{23} X_2 X_3$	$\beta_{33} X_3^2$
∑ beans /plant	28.83**	0.46*	0.06*	0.0009^{ns}	-0.005^{ns}	-0.0005^{ns}	-0.0001^{ns}	-0.0003^{ns}	0.00002^{ns}	0.0002^{ns}
∑ beans /pod	1.85**	-0.0006^{ns}	0.0006^{ns}	-0.001^{ns}	0.00003^{ns}	-0.0000007^{ns}	-0.000001^{ns}	-0.00001^{ns}	-0.000001^{ns}	0.00001*
Bean weight(g. plant^{-1})	4.48**	0.08*	0.008^{ns}	0.007^{ns}	-0.0008^{ns}	-0.00007^{ns}	-0.000007^{ns}	-0.00008^{ns}	0.000008^{ns}	-0.00002^{ns}
Weight of 100 dry beans (g)	14.76**	0.009^{ns}	-0.0003^{ns}	0.01^{ns}	0.00004^{ns}	-0.00002^{ns}	0.00001^{ns}	0.00002^{ns}	0.00002^{ns}	-0.0001*
Weight of beans(ton. ha^{-1})	1.12**	0.02*	0.002^{ns}	0.0003^{ns}	-0.0002^{ns}	-0.00002^{ns}	-0.000003^{ns}	-0.00002^{ns}	0.000003^{ns}	-0.000009^{ns}

Description: Figures followed by (ns) and (*) indicate that they are not significantly different and significantly different at a 5% degree, respectively, while figures followed by (**) indicate that they are significantly different at a 1% degree. X1 = Urea Fertilizer; X2 = SP-36 Fertilizer; X3= KCl Fertilizer.

In addition to the growth and development at the vegetative stage, crop yields are also affected by the provision of plant nutrients. Nitrogen is an essential element for soybean, which is contained in large quantities, especially in the beans (Gaydou *et al.*, 1983). Nitrogen will enhance the level of protein, resulting in beans with better quality, in addition to slight increases in the yield (Rosmarkam dan Yuwono, 2002). Moreover, the level of soybean yields is affected by the concentration of phosphorus in the bean. The higher the concentration of phosphorus in the bean, the larger the size of the bean yielded (Gaydou *et al.*, 1983). The sufficient availability of nitrogen and phosphorus to assist in the formation of soya pods and beans. The number and quality of beans in a pod will determine the total dry weight of the beans. In general, nitrogen and phosphorus are very influential on the growth and yield of soybean.

Based on the response surface analysis, it is revealed that the optimum combined doses of urea, SP-36, and KClby 26.64 kg. ha^{-1}, 292.61 kg. ha^{-1}, and 97.71 kg. ha^{-1}, respectively, are necessary. The combination of these three substances can produce a maximum weight of soybeanby 2.07 ton. ha^{-1}.

CONCLUSION

The optimum combined dose for urea is equal to 26.64 kg. ha^{-1} while for SP-36 and KCl, the optimum combined doses are 292.61 kg. ha^{-1} and 97.71 kg. ha^{-1}, respectively. The combination of these three substances can produce a maximum weight of soybean by 2.07 ton. ha^{-1}.

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