# Response of Soybean on the Application of Lime and Green Manure Derived from Velvet Bean Planted in An Ultisol

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## ABSTRACT

**Response of Soybean on the Application of Lime and Green Manure Derived from Velvet Bean Planted in An Ultisol (D. Budianta):** This research is a field experiment, which was conducted to know the response of soybean (*Glycine max* L. (Merr.) on the application of lime and green manure planted in an Ultisol from Sembawa Rubber Research Station, South Sumatra. This experiment was arranged using a randomized complete block design with two factors which are dolomite applied at the rate of 0 and 4.14 tons $ha^{-1}$ and green manure derived from velvet bean ranged from 0, 3.42 and 6.84 tons $ha^{-1}$. Variables observed were plant height, shoot and root dry matters, grain yield and nutrient contents. The results showed that application of lime and green manure affected growth and yield of soybean. A dolomite at the rate of 4.14 tons per ha and green manure amounting to 3.42 tons per ha resulted statistically in a maximum yield with a value of 2.79 tons per ha. The effect of green manure to improve soybean growth and yield was less effective than that of lime. Moreover, the application of green manure did not affect N and P contents, while liming influenced K, Ca and Mg significantly. Content of Ca was highly correlated with the grain yield.

**Keywords**: Green manure, lime, soybean, Ultisol and velvet bean

## INTRODUCTION

Among the grain legumes, soybean is the most important leguminous crop in Indonesia. It is used for food and fodder and plays an important role in the Indonesian diet as a source of cheap proteins, as compared to animal protein sources (Ismunadji and Makarim, 1989). Up to 1984, soybean import reached 300,000-400,000 tons per year, since then it steadily increased up to 628,159 tons in 1994 (Central Bureau of Statistics, 1996), and 743,532 tons in 1996 (Indonesia Department of Agriculture, 1997). The increase of soybean demand is due to the increase of soybean needs for human and animal consumption, and for raw material industry as well. In fact, domestic production of soybean was limited to 1.87 million tons in 1992, and decreased down to 1.51 tons in 1996 (Central Bureau of Statistics, 1996; FAO, 1997). Meanwhile the consumption of soybean in the 1992 went up to over 2.0 million tons, whereas the soybean demand increased to 2,32 million tons in 1993 (Oka et al., 1993). When the average of soybean production and consumption are maintained at the rate of 766,980 and 941,740 tons per year respectively (Central Bureau of Statistics, 1991), the projection of soybean demand will reach about 3,495 million tons up to 2010 year, while World Bank predicts it about 4,905 million tons up to the same year (Nasution, 1990). In this respect, in the future, it is clear that an imbalance of soybean supply will show up in Indonesia.

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To fulfil this need, Indonesian government promoted a strong effort to increase soybean yield towards self-sufficiency through intensification and expansion of planted areas. As a consequence of this policy, new areas are considered on planting soybean in and outside Java which are mainly characterized as Ultisols. Unfortunately, soybean is not able to grow properly in these rather infertile acidic soils as it is highly sensitive to acidic conditions (Reddy et al., 1991). Among the most limiting factors, besides high acidity, there are P-, Ca-, Mg deficiencies, Al toxicity and low organic matter content (Burmester et al., 1988; Hakim et al., 1989; Ismunadji and Makarim, 1989). According to Munns and Fox (1977), soybean is classified as sensitive to soil acidity compared to other plant species. At highly acidic conditions with a pH value below 4.38, coupled with high Al levels, reduced growth of soybean (Ritchey and Carter, 1993). The principle factor responsible for delayed emergence in the high Al content in acidic soils was not delayed radicle initiation, but delayed initiation of hypocotyl elongation. The latter was highly associated with the rate of tap root growth of soybean (Ritchey and Carter, 1993).

Due to a negative effect of Al toxicity for crops grown in acidic soils, led Kamprath (1970) to propose that liming of highly weathered soils such as Ultisols and Oxisols is the primary step to improve the poor nutrient properties of these soils based on the amount of exchangeable Al obtained in the top soil. In this respect, exchangeable Al was eliminated by liming to pH 5.2 (Fox et al., 1991). Moreover, there is considerable evidence to support this view that the critical Al saturation should not exceed 20% for soybean (Kamprath, 1970; Sartain and Kamprath, 1975).

In relation to that, Indonesia has launched a liming program in acidic areas during the last few years to effectively promote soybean production. Indeed, this program is still controversial, because over liming has a negative impact on the status of micronutrients (Farina et al., 1980; Adams et al., 1981). The current recommendation for lime application for soybean growth on a red yellow podzolic soil (or Ultisol in USDA soil classification system) is estimated at one and half times the exchangeable aluminum content, expressed in term of tons of lime per hectare, when aluminum saturation is exceeding 20% (Ismunadji and Makarim, 1989). A priority for liming program has been given to those soils, which acquire not more than 3 tons lime per ha. Experimental evidence was obtained confirming the beneficial effect of lime on soybean growth, but no data on Mucuna growth as precursor for soil fertility improvement are available.

In fact, commercial liming product are relatively expensive and may not be readily available on various Indonesian Islands. Hence, an alternative could be sough using locally available organic matter resources. The objective of this study was to determine the effect of lime and green manure addition on growth and yield of soybean in this Ultisol.

## MATERIALS AND METHODS

A field experiment of eighteen plots with a 3 x 3 $m^2$ size was conducted on a bare Ultisol to evaluate the effect of lime and green manure addition on growth and yield of Galunggung soybean variety during the rainy season of 1997/1998. The general characteristics of this variety are an annual erect crop with a high plant about 50 cm, green leaves and shoots, white flowers, yellow seeds, mature at around 85 days and yield of seed about 1.5 tons per ha (Suprapto, 1994).

This field experiment was located at Sembawa Rubber Research Station, South Sumatra. The acidic soil of Ultisol with the soil pH of 4.94 was amended with dolomite at a rate of 4.14 tons $ha^{-1}$, and with dry green manure derived from Velvet bean (*Mucuna pruriens* L.) at the rate of 3.42 and 6.84 tons $ha^{-1}$ (the former rate of green manure, which was added, based on the Velvet bean dry matter production per ha as obtained by Hairiah, 1992). Commercial N and K fertilizers at the rate of 110 kg N and 50 kg KCl containing micronutrients at 200 g $(NH_4)_6Mo_7O_{24}.4H_2O$, 5 kg $CuSO_4.5H_2O$, 5 kg $ZnSO_4.7H_2O$ and 450 g $H_3BO_3$ per ha were applied to the control and amended soils at the same time after application of lime and green manure. The amendments and basic fertilizers were applied once at two weeks prior to sowing.

The green manure which was chopped around 2 cm size, and a powder form of dolomite were broadcasted to the soil surface and mixed thoroughly with the soil into the arable layer by plowing around 15 cm depth. Furthermore, after 2 weeks of soil treatments, three seeds of soybean were sown per hole with 20 x 20 cm plant spacing on the four objects in the three replication consisting of the control, the limed plot in presence and absence of green manure and the unlimed with green manure at the rate of 3.42 and 6.84 tons per ha. When necessary, weeds were removed by hand. Poor grown plants or ungerminated seeds were removed and replaced after one weeks, subsequently, two plants per plant hole were left throughout the experiment.

After two months of sowing, shoots and roots were harvested 10 plants per plot to determine biomass production and plant height. Grain yield was harvested at mature condition after three months of sowing. Shoots, roots and grain were then cleaned, oven-dried at 70°C for 48 h and dry weights determined. Oven-dried shoots were ground and burnt at 650°C for 5 h in a muffle furnace; the residues were oxidized with 1N $HNO_3$ on a hot plate and filtered into a 50 ml flask after filtration. Then, each aliquot was diluted using deionized water for P, K, Ca and Mg analyses. N total was digested by micro Kjeldahl method (Bremner and Mulvaney, 1982).

The data obtained were analyzed using ANOVA procedure for statistical analysis. Mean separation was accomplished by multiple comparison tests of least significant difference (LSD) at $\alpha = 0.05$ for each data set when the initial F-tests were significant. A simple linear regression analysis and correlation coefficient was also performed on relationship between dry grain yield and nutrients content.

## RESULTS AND DISCUSSION

### Plant growth

Plant growth data expressed as plant height, shoot and root dry weight, shoot to root ratio per plant displaying the means of three replications are presented in Table 1. The effect of a single dolomite dose at 4.14 tons per ha on plant height was positively significant: in the absence of green manure average plant height increased from 26 to 38 cm. This result is comparable to the findings of Ismunadji and Makarim (1989) showing that an application of 4.4 tons of lime per ha to an Ultisol from Sitiung, West Sumatra, increased soybean plant height by 50%. In this current experiment it was also evident that an addition of a single dolomite dose to this rather infertile Ultisol in combination with 3.42 and 6.84 tons per ha of green manure resulted in an additional insignificant increase of plant height from 38 to 44 cm. It follows that liming is a main limiting factor for plant height. From a statistical point of view, a dolomite dose at 4.14 tons and green manure at 3.42 tons per ha yielded a plant height amounting to 42 cm. This result is nearly close to the ideal plant height of soybean var. Galunggung used in this study with a value of 50 cm (Suprapto, 1994).

Table 1. Effect of lime and green manure application on soybean growth.

| Treatment | | Plant height | Shoot | root | Shoot:root |
|---|---|---|---|---|---|
| Dolomite (ton $ha^{-1}$) | Green manure (ton $ha^{-1}$) | (cm) | (g/plant) | | Ratio |
| 0 | 0 | 26.15a | 1.69a | 0.39a | 4.43a |
| | 3.42 | 32.67b | 3.10b | 0.51b | 6.03b |
| | 6.84 | 34.45b | 4.05c | 0.64c | 6.28b |
| 4.14 | 0 | 37.68bc | 4.70d | 0.70cd | 6.69b |
| | 3.42 | 42.48c | 5.44e | 0.72cd | 7.57c |
| | 6.84 | 43.77c | 6.31f | 0.78d | 8.12c |

Mean values followed by the same letter in a column are not significantly different from each other at 0.05 level of LSD test.

Application of green manure at the rate of 3.42 tons per ha without liming significantly increased plant height by about 25%; doubling the amount of green manure did not bring any additional significant contribution to this variable. From this study, it is obvious that the effect of a single or double green manure dose and a single dolomite rate when applied separately to this soil had statistically a similar effect with regard to plant height. To that respect, it is interesting to refer the beneficial effect of stable manure in relation to plant height of soybean that this manure added in an Ultisol From Sitiung, West Sumatra also increased plant height as reported by Ismunadji and Makarim (1989).

Due to the poor rooting system in the control to which only a basic fertilization was applied, the plants shoot weight and height of control plots were very underdeveloped. The main cause of poor plant growth of soybean in this Ultisol without amendments is probably attributed to high exchangeable Al which was 2.7 Cmol(+) $kg^{-1}$. According to Evans and Kamprath (1970), this value is largely exceeding the critical exchangeable Al value amounting to 0.48 Cmol(+) $kg^{-1}$ for maximum plant growth for soybean.

In fact, the beneficial effect of liming on soybean growth was not only limited to plant height, but extended also to shoot and root weight. Due to the effect of lime, dry root weight per plant went up from 0.39 to 0.70 g, and from 1.69 to 4.70 g for shoots. A further important weight increase especially of shoots was achieved when a double rate of green manure at the rate of 6.84 tons per ha was applied. It is also obvious that the effect on shoots was much more pronounced than on root development especially when a combination of lime and green manure at highest rate was applied, representing an almost four times increase of shoot whereas only doubled increase of root with reference to the control plot.

Moreover, application of green manure without lime showed the same trend: a shoot and root increase as obtained in the limed soil, but at a lower value amounting to 4.05 and 0.64 g per plant, respectively at the highest level. With regard to these results, it can be concluded that addition of green manure at both rates in the absence of lime was not very effective to increase these variables. These results also meet the findings of Ismunadji and Makarim (1989) that application of 5 tons of stable manure per ha to an Ultisol from Sitiung increased dry matter of root only by about 22% which is far below the yield obtained in limed soil amounting to roughly 65%.

Concerning the shoot to root ratio, this variable was significantly affected by both lime and green manure application. Shoot to root ratio significantly increased from 4.43 to 6.69 representing 1.5-fold increase versus the control when lime was applied. An additional increase of the ratio was obtained due to green manure, but doubling the rate of the latter had not additional significant effect (Table 1).

Application of 3.43 tons green manure per ha without lime significantly increased the shoot to root ratio by about 36%, but doubling the rate did not bring any beneficial effect. However, green manure effect is not significant compared to lime treatment only, because the latter always resulted in the higher value. The low value of shoot to ratio obtained in soils applied by green manure can mainly be caused by the lower amount of above-ground biomass produced in amended soils with green manure than in soil supplied with dolomite. From a statistical point of view, a combination of dolomite at 4.14 tons and green manure at 3.42 tons per ha resulted in a maximum shoot to root ratio.

**Grain Yield**

Effect of lime and green manure application on grain yield of soybean is presented in Table 2. From these results it is clear that an application of lime is effective in increasing soybean yield. The significant increase of grain yield due to liming at a single rate of 4.14 tons dolomite per ha is from 0.31 to 1.70 tons per ha. A further increase, exceeding 60% was recorded when green manure at a single rate of 3.42 tons per ha was added, but no additional effect was observed when doubling the rate. From a statistical point of view, the first combination yielded a maximum grain production amounting at 2.79 tons per ha. To that respect, Ismunadji and Makarim (1989) found that lime application at a single rate 4.4 tons per ha in an Ultisol from Sitiung increased grain yield by almost a factor three as compared to the unlimed Ultisol.

Application of 3.42 tons green manure per ha in the absence of lime did not bring any significant effect on grain yield, but doubling the rate apparently also doubled the yield. From a practical point of view, the addition of green manure at 3.42 tons per ha in combination with a single lime dose at the rate of 4.14 tons per ha will result in a maximum grain yield. In relation to the beneficial effect of manure to enhance soybean growth, Ismunadji and Makarim (1989) already reported that application of stable manure at 5 tons per ha to an unlimed Ultisol From Sitiung, West Sumatra increased grain yield from 0.55 to 0.77 tons per ha.

**Nutrient Content**

In Table 3, the mean of three replications of nutrient content in dry matter of soybean is displayed. From the statistical analysis, it is shown that liming only affected K, Ca, and Mg contents, while green manure administration did not improve the N, P, K and Ca contents, except for the combined lime and green manure treatment. Green manure alone only affected Mg content.

Table 2. Effect of lime and green manure application on soybean yield.

| Treatment | | |
|---|---|---|
| Dolomite ($ton\ ha^{-1}$) | Green manure ($ton\ ha^{-1}$) | Grain yield ($ton\ ha^{-1}$) |
| 0 | 0 | 0.31a |
| | 3.42 | 0.46a |
| | 6.84 | 0.72b |
| 4.14 | 0 | 1.70c |
| | 3.42 | 2.79d |
| | 6.84 | 3.13d |

Mean values followed by the same letter in a column are not significantly different from each other at 0.05 level of LSD test

Nitrogen content of soybean, which varied from 2.01 to 2.71%, was obtained as the highest content. A significant increase of N amounting to 35% was induced only by the application of a single lime dose of 4.14 tons per ha in combination with the highest level of green manure. These N values, however, are still very low when compared to the averaged range of 4.1-5.5% N for soybean (Jones et al., 1991). Comparable results were observed for P content: application of lime tended to decrease P content, except in limed soils combined with green manure at the rate of 6.84 tons per ha which significantly increased the P content from 0.28 to 0.32% P.

With regard to the K content, this nutrient decreased remarkably from 0.95 down to 0.48-0.50% either due to liming combined with lowest level of green manure. In an experiment conducted by Hunter et al. (1995) it was found that liming at 5 tons per ha decreased K content in sweet corn grown in an acidic Oxisol whereas application of cowpea green manure at a rate of 7.5 tons significantly increased K. According to the same author, when 6.84 tons per ha of green manure derived from velvet bean, was added to the limed Ultisol, the K content when up to 0.8% which was still below the content in the unlimed soil.

Content of Ca significantly increased due to liming treatment. Further increase but not on significant basis was observed when green manure at both rates was added. However, Ca content which ranged from 1.30 to 1.98% in all treatments including the control is in the sufficient range as found by Jones et al. (1991).

In relation to the Mg content, this nutrient significantly increased either by lime or green manure in the presence or absence of lime. It is clear that application of dolomite at 4.14 tons per ha increased Mg content by more than 100%. However, application of lime combined with green manure did not increase Mg content when compared to only on lime treatment.

To recognize the effect of nutrient content in the grain, the following linear fits between dry grain yield and nutrient content were performed:

Dry grain yield (tons $ha^{-1}$) = $-6.43 + 3.64$ N (%) $r = 0.80^{*}$

Dry grain yield (tons $ha^{-1}$) = $0.24 + 4.42$ P (%) $r = 0.08^{ns}$

Dry grain yield (tons $ha^{-1}$) = $4.15 - 3.36$ K (%) $r = -0.66^{ns}$

Dry grain yield (tons $ha^{-1}$) = $-4.02 + 3.62$ Ca (%) $r = 0.97^{**}$

Dry grain yield (tons $ha^{-1}$) = $-0.55 + 8.01$ Mg (%) $r = 0.55^{ns}$

Table 3. Effect of lime and green manure application on nutrient content of soybean.

| Treatment | | Nutrient content (based on a dry matter basis) | | | | |
|---|---|---|---|---|---|---|
| Dolomite (ton $ha^{-1}$) | Green manure (ton $ha^{-1}$) | N(%) | P(%) | K(%) | Ca(%) | Mg(%) |
| 0 | 0 | 2.01a | 0.28ab | 0.95a | 1.30a | 0.15a |
| | 3.42 | 2.03a | 0.30ab | 0.95a | 1.19a | 0.16a |
| | 6.84 | 2.08a | 0.30ab | 1.02a | 1.25a | 0.32b |
| 4.14 | 0 | 2.04a | 0.26a | 0.48b | 1.69b | 0.35b |
| | 3.42 | 2.22a | 0.27a | 0.50b | 1.79b | 0.28b |
| | 6.84 | 2.71b | 0.32b | 0.80b | 1.98b | 0.29b |

Mean values followed by the same small letter in a column are not significantly different from each other at 0.05 level of LSD test

From these equations, it is shown that the highest linear correlation ($P<0.05$) was observed between grain yield and Ca content. It is not clear what could be the major reason why almost no linear relationship occurred between the percentage of P content and the grain yield ($r = 0.08$). The possible reason for this non significant linear relationship is that this crop only required P in small amount compared to N, K, and Ca contents. In addition, P did not play important role in nitrogen fixation for leguminous crop as compared to Ca effect (Tisdale et al., 1990), whereas percentage of N derived from fixation during soybean growth was not influenced by P addition (Gunawardena et al., 1993). According to Jungk et al. (1990), a maximum plant growth of soybean was only affected by low P concentration present in soil solution with a value of 1 $\mu mol\ L^{-1}$. In this respect, application of P at a rate of 7 kg per ha only increased weight of soybean nodules, but did not improve the proportion of $N_2$ fixation (Sanginga et al., 1996).

## CONCLUSIONS

Plant growth and grain yield of soybean were significantly influenced either by lime or green manure addition. A single dolomite dose of 4.14 tons per ha and green manure amounting to 3.42 tons per ha resulted statistically in a maximum yield. The effect of green manure to improve soybean growth and yield was less effective than that of lime. The application of manure did not affect N and P content, while liming influenced K, Ca and Mg significantly. Content of Ca was highly correlated with grain yield.

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