Response of determinate and semi-determinate soybean on dolomite liming

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Abstract. This paper presents results of a study aimed to determine the effect of dolomite calcification on growth and production of the determinate and semi-determinate type of soybean (*Glycine max* L.). The study was designed in a 2-factor factorial experiment in a randomized block design. The first factor consisted of two growing types of soybean: variety of Baluran as a determinate type, and variety of Orba as a semi-determinate type. The second factor consisted of five levels of dolomite lime applications, namely: 0 kg ha^{-1}, 500 kg ha^{-1}, 1,000 kg ha^{-1}, 1,500 kg ha^{-1}, and 2,000 kg ha^{-1}. The results showed that the semi-determinate soybean type of Orba variety produced the highest average plant height (49.97 cm), the highest number of branches (3.29), the highest number of pods per plant (44.95), heaviest weight of pods per plot (671.80 g), the lowest percentage of empty pods (5.60%), the heaviest weight of seeds per plot (501.87g) and the heaviest weight of seeds per hectare (1,206.40 kg). Application of 2,000 kg ha^{-1} dolomite lime at the age of 56 dap produced the highest plants (52.13 cm), the highest number of leaves (13.00 strands), the earliest flowering age of 50% (36 days), the highest number of productive branches (3.08), highest number of pods per plant (53.33), widest leaf canopy after flowering (45.38 cm), heaviest pod weight per plot (761.32 g), lowest percentage of empty pods (3.90%), heaviest seed weight per plot (630.12 g) and highest seed weight per hectare (1,514.71 kg). The Semi-determinate type Orba variety gave the heaviest weight of 1,000 seeds at a dose of 1,500 kg ha^{-1} dolomite.

1. Introduction

Soybean is an essential commodity in Indonesia for food, feed, and industrial raw materials. For the international market, soybean is an export commodity for various countries in the world [1,2]. Despite being the 6th largest producer of soybean [3], the rate of Indonesian soybean exports experienced an average decrease of 5.92% per year during the period 1961 - 2012, while imports experienced an average rate of increase of 0.05% per year [4]. One effort to increase productivity for reducing the productivity gap is by the optimization of existing superior variety. In Indonesia, there is a number of various superior varieties of soybeans released by the government through adaptation and observation tests by various related agencies.

There are several reasons behind the development of these superior varieties. Among the targets are to increase the potential yield of seeds, improve seed quality, especially protein and fat content [5].

1.1. Superior varieties of soybean in Indonesia

Superior varieties are those that have been officially released by the government, and have advantages in terms of potential yields as well as other characteristics [6]. Among leading characteristics are high vigor, high level of purity, and high productivity [7]. Rukmana & Yuniarsih [1] added the criteria for superior varieties such as high production; short-lifespan; resistant to dangerous diseases; and has broad adaptability to various conditions of the growing environment. Until 2016, the Indonesian government has released 83 superior varieties of soybeans [8], this number is still increasing with the introduction of new types of technology to improve soybean genetics, including through the evaluation of germplasm, increasing diversity through mutation, crossing, and selection [9]. In 1995-2004, there was a surge in the release of high yielding varieties, including variety of Baluran, which had quite prominent yield potential of 2.5-3.5 t ha^{-1} [10].

Varieties play an important role in increasing soybean yields since high productivity is primarily determined by the potential of superior varieties planted. One of the efforts in increasing soybean production is by cultivating varieties whose growth types are limited (determinate) but have high yield potential. Determinate types have a shorter lifespan, hence earlier harvesting, in addition to high production of dried soybeans. In contrary, indeterminate types require a longer time to harvest, therefore despite some advantages they might have, they might not be preferable by farmers. Alternatively, high yield potential of soybean whose growing type is in-between (semi-determinate) might be preferable [11].

Although new varieties have been introduced, some old varieties found to be still planted by farmers. One of the old variety that according to Krisdiana [12] and Heriyanto [13] still preferable was Orba variety – a semi-determinate type - which was second most used in West Java. Variety of Orba was considered superior for its high productivity, short lifespan, and pest and disease resistance [14]. Old superior varieties such as Davros, Orba, and Wilis still dominated soybeans in West Java, in addition to local varieties. High yielding varieties of large soybean seeds have the opportunity to be adopted if the seeds price is affordable, and they are capable of producing higher yields than local soybean varieties commonly used by farmers [13]. This study intended to test the growth of this variety in South Sulawesi. It has been widely planted in Java and also tested in Papua with satisfying results [15].

The other variety tested in this study was a determinate Baluran variety. This variety was released in 2002, has a short life of 80 days harvesting with a potential yield of 2.5 – 3.5 t ha^{-1} [16]. Baluran is one of the superior soybean varieties produced by University of Jember; it has big seeds (13-17 g/100 grains) and short-lived [17].

1.2. Liming

Soybean requires soil with a certain pH. An acid dry land with a soil pH of 4.5 - 5.5 is less suitable. To overcome various obstacles, especially the lack of nutrients in the soil will increase production costs [18]. Soil with pH lower than the optimum can be overcome by liming the soil, to increase the pH near or following the plant's requirement [19]. Factors that determine the amount of lime necessary for the soil are: current soil pH; soil texture; soil organic matter content; lime quality and type of plant [19]. Improvement of soil pH means solving 50% of soil fertility problems. The most effective way to neutralize acidic soils is by the application of dolomite lime. Application practice by sowing and mixing dolomite lime evenly into the soil, let stand for 7-14 days before planting [20].

Agricultural lime is a natural material containing compounds of Ca and Mg that can neutralize the unfavorable effects of soil acidity. Most of them can be found around us, in the form of lime, wall lime, carbonate lime (Calcite, Dolomite), seashells and steel slag. Carbonate lime is limestone that is directly ground without going through a combustion process. These materials are now being used also for liming plots of land with the acidic condition [19]. Lime carbonate is obtained by grinding calcite

limestone ($CaCO_3$) or dolomite [$CaMg(CO_3)_2$)] to a certain fineness. This material is common as agricultural lime. The purity of this limestone varies from 75-99% or an average of 94% [21].

Apart from improving the chemical properties of the soil, another effort for improvement of soybean planting environment is by improving the biological quality of the soil. Application of organic fertilizer and bio-slurry has given a good effect for the soybean growth [22]

2. Methodology

An experiment was carried out in the Experimental farm of the Faculty of Agriculture, Hasanuddin University, Makassar at an altitude of 14 meters above sea level. A previous experiment in various elevation has shown that Baluran variety is suitable to be cultivated at altitudes from 18 m asl to 306 m asl [17]. Hence this study location in Makassar is suitable for soybean.

The method of the experiment was a two-factor factorial experiment in a Randomized Group Design. The first factor was two types of soybean varieties, namely: v1: Baluran; v2: Orba. The second factor was the dose of dolomite lime [$CaMg(CO_3)_2$] (d) which consisted of five levels: d0: 0 kg dolomite lime per hectare (0 g dolomite lime/plot); d1: 500 kg dolomite lime per hectare (300 g dolomite lime/plot); d2: 1,000 kg dolomite lime per hectare (600 g dolomite lime/plot); d3: 1,500 kg dolomite lime per hectare (900 g dolomite lime/plot); d4: 2,000 kg dolomite lime per hectare (1,200 g dolomite lime/plot). Each treatment combination was repeated three times so that there were 30 experimental units in a plot measuring 3 m × 2 m

3. Results and discussion

3.1. Effects on vegetative growth components

The results showed that the two soybean varieties: the determinate Baluran (v1) and the semi-determinate Orba (v2) had no significant effect on the parameters of the number of leaves, number of productive branches, width of leaf canopy after flowering, leaf canopy width before harvest.

The varieties had a significant effect on plant height (table 1) and number of branches (table 2), In general, the results depicted the growth of Orba variety is better than the Baluran variety.

Dolomite lime application at a dose of 2,000 kg ha-1 (d4) gave the best results on plant height, number of leaves, number of productive branches, leaf canopy width after flowering. These are better compared to other dolomite lime doses and without lime application.

Table 1. Average plant's height at 56 dap (cm)

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	41.14	47.61	49.17	51.65	52.17	48.35^{b}	1.49
Orba (v_2)	44.78	49.73	51.56	51.72	52.09	49.97^{a}	
Average	42.96^{c}	48.67^{b}	50.36^{ab}	51.68^{ab}	52.13^{a}		
$LSD_{\alpha=0.01}$	3.68						

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$

Table 2. The average number of branches at 56 dap

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	2.55	2.88	3.24	3.09	3.33	3.02^{b}	0.24
Orba (v_2)	3.12	3.24	3.27	3.45	3.36	3.29^{a}	

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$

3.2. Effects on generative growth components

The results showed that the two soybean varieties i.e. the determinate Baluran (v1) and the semi-determinate Orba (v2) had no significant effect on the weight of 1,000 seeds. However, the varieties had a significant effect on the age of 50% flowering (table 3), number of pods per plant (table 4), pod weight per plot (table 5), percentage of empty pods (table 6). Meanwhile, the use of varieties gave a very significant effect on the weight of seed per plot and per hectare (table 7).

Dolomite lime application at a dose of 2,000 kg ha-1 (d4) gave the best results on the variables of number of pods, pod weight per plot, percentage of empty pods, and seed weight per plot and per hectare

Table 3. The average age of 50% flowering

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	37.00	37.33	37.00	36.00	35.33	36.53^{b}	0.68
Orba (v_2)	38.00	38.00	37.67	36.33	36.67	37.33^{a}	
Average	37.50^{b}	37.67^{b}	37.33^{ab}	36.17^{a}	36.00^{a}		
$LSD_{\alpha=0.01}$	1.4						

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$

Table 4. The average number of pods per plant

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	25.73	42.12	44.30	45.45	51.94	41.91^{b}	3.03
Orba (v_2)	32.24	41.09	45.39	51.30	54.73	44.95^{a}	
Average	28.98^{d}	41.61^{c}	44.85^{bc}	48.38^{ab}	53.33^{a}		
$LSD_{\alpha=0.01}$	6.5						

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$

Table 5. Average pods' weight per plot

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	486.09	539.67	624.89	692.43	727.66	614.15^{b}	45.41
Orba (v_2)	570.36	591.13	676.03	726.71	794.98	671.80^{a}	
Average	528.23^{d}	565.40^{cd}	650.46^{bc}	709.57^{ab}	761.32^{a}		
$LSD_{\alpha=0.01}$	98.3						

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$

Table 6. Average percentage of empty pods

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	12.33	6.48	5.63	5.52	4.15	6.82^{b}	0.98
Orba (v_2)	8.73	5.90	5.53	4.16	3.66	5.60^{a}	
Average	10.53^{c}	6.19^{b}	5.58^{ab}	4.84^{ab}	3.90^{a}		
$LSD_{\alpha=0.01}$	2.1						

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$

Table 7. The average weight of seeds per plot and per hectare

Varieties	Dolomite application dose (kg ha^{-1})					Average	$LSD_{\alpha=0.05}$
	0 (d_0)	500 (d_1)	1,000 (d_2)	1,500 (d_3)	2,000 (d_4)		
Baluran (v_1)	293.03 (704.41)	331.47 (796.81)	447.68 (1.076.15)	519.16 (1.247.99)	611.76 (1.470.57)	440.62^{b} (1.5059.19^{b})	53.45 128.48
Orba (v_2)	360.38 (866.29)	468.42 (1.126.01)	454.33 (1.092.13)	577.72 (1.388.75)	648.48 (1.558.85)	501.87^{a} (1.206.40^{a})	
Average	326.71^{c} (785.35^{c})	399.95^{bc} (961.41^{bc})	451.00^{b} (1.084.14^{b})	548.44^{a} (1.318.37^{a})	630.12^{a} (1.514.71^{a})		
$LSD_{\alpha=0.01}$	84.51	203.15					

Notes: The numbers followed by the same letters were not significantly different from the LSD Test $\alpha = 0.05$ and LSD $\alpha = 0.01$.
Numbers inside the brackets are the result of conversion from plot to hectare.

There is an assumption that determinate variety has a lower yield potential than the semi-determinate type. It is due to the growth of the determinate indicates the flowering phase which takes place simultaneously and is characterized by vegetative growth which will stop after flowering. Not all flowers can become pods; about 60% of the flowers fall before forming the pods. While in the semi-determinate type, the flowering phase occurs gradually; i.e. after the formation of pods, flowering continues although the number of flowers is not the same as in the initial flowering period.

Figure 1. The appearance of the determinate type of soybean (Baluran variety), flowering starts from the top continues to the bottom.

Figure 2. The appearance of the semi-determinate type of soybean (Orba variety), flowering starts from the bottom and continues to the top.

Figure 3. The appearance of the determinate type of soybean (Baluran variety), flowering stops after the formation of pods

Figure 4. The appearance of the semi-determinate type of soybean (Orba variety), flowering continues even though pods have formed

Soybeans can grow in slightly acidic soils, but too low pH can cause plants poisoning [23]. Suitable soil pH values range from 5.8-7.0. Application of dolomite lime at the dose of 2,000 kg ha-1 gave the best results. The lime application can influence soil reaction which resulted in soil pH increase. Consequently, it can directly increase the content of calcium (Ca) and magnesium (Mg) in the soil. Pods forming plants require relatively high Ca and Mg [24].

The influence of lime on plant growth and production can be viewed from two aspects, namely the direct effect of lime as a source of nutrients for Ca and Mg and the indirect impact on the form of improvements in physical, chemical and biological properties of the soil [19]

The status of calcium in pods-producing plants is closely related to the acidity level. Ca affects the availability of other nutrients and soil microflora growth; especially bacteria. If the pods-producing plants grow on acidic soil, they will experience chlorosis and disturb pods formation [25]

4. Conclusion

Under the application of various dosages of dolomite liming, the semi-determinate soybean of Orba variety gave the best results on most vegetative and generative variables. The results are in terms of highest plants, most branches, most pods per plant, heaviest pod weight per plot, lowest percentage of empty pods, heaviest weight of seeds per plot and heaviest weight of seeds per hectare. These results are better compared to determinate type of Baluran variety.

Application of 2,000 kg dolomite lime per hectare resulted in highest plants, most leaves, the earliest 50% flowering, most productive branches, most pods per plant, lowest percentage of empty pods, widest leaf canopy after flowering, heaviest pod weight per plot, heaviest seed weight per plot and heaviest seed weight per hectare.

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