

# The Effects of Foliar Boron and Silica Through the Leaves on Soybean Growth and Yield

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This study was aimed to determine the effect of the increasing silica and boron concentration and their interaction on plant growth and soybean yield. This research was conducted from April-September 2017 in the integrated field of the experiment at the University Lampung. The

treatments were 0 and 5 ppm Boron (B) fertilizer and Silica (Si) concentrations in 6 levels (0, 25, 50, 75, and 100 ppm). The difference between the means of B were calculated by using Orthogonal Contrast and response of Si was used Polynomial at  $\alpha$  0.05. The results showed that application of 5 ppm of B foliarly produced higher of soybean growth and production than without B treatment through variables of the dry weight and grain weight. Application of up to 125 ppm of Si foliarly was improved of soybean growth and production through variables of plant height, number of leaf, leaf area, dry weight and number of productive branch, number of pods, filled pod, and grain weight, but it didn't affect the percentage of empty pods. The response of soybean growth and production to the increasing Si didn't depend on the foliar B which was showed in all variables.

**Keywords:** Boron; Soybean; Silica.

## 1. Introduction

Soybean (*Glycine max* (L) Merrill) is a food plant which has high source of nutrition. In Indonesia, soybean is the raw material for making drinks and foods stuff such as milk soy, “tempe”, tofu, soy sauce, etc. According to FAOSTAT (2014), United States was the biggest country produced of soybean and its production was 82.054.800 ton, followed by Brazil, Argentina, India and Paraguay. Indonesia was on the twelfth of its soybean production, that was 843.153 tons, while the needs of soy consumption in Indonesia were increased in every year since 2010 and it reaches 2.2 million tons for each year (CSA, 2015).

According to Sudaryono *et al.* (2007), the low of soybean production, which is faced until now is caused by the readiness of good quality of soybean seed is still low and less fertilization. A good quality seed is a seed which has a high viability and vigor. One of the ways to increase the quality of seed is, by fertilizing through the leaf and the readiness of ideal micronutrient for the growth and production of seeds. The effort to increase soybean production can be done by fixing the fertilizing technique.

Fertilizing is done to give additional nutrients which are needed by plants because the readiness of nutrients is limited. Fertilizing through leaf can give an effect faster and real than applying through the soil because the nutrient which is given through leaf can be absorbed directly as nutrients of nutrient. Nutrient gets into plants' tissue through cutin lining and cell wall, after that interacts directly with protoplasm, then translocated to cells which need it.

Based on the amount needs of nutrients which are needed by the plant, an essential nutrient is divided into two big groups, they are the macro and micro nutrient. Boron is one of 16 important nutrients for plants' growth. Boron is used for cell fission, pollination, fruit formation, translocation, sugar and core, synthesis amino acids, and to control metabolism carbohydrate. The readiness of boron in soil is 0,10-5,0 ppm while normal needs of boron for monocotyledon plant is 6,0-18,00 ppm and dicotyledon plants are 20,0-60,00 ppm (Heckman, 2009).

Silica (Si) is the second nutrient which is much in the earth's crust (Sommer, *et al.* 2006). According to Yukamgo and Yuwono (2007), the ability of dicotyledon plants and leguminous to absorb silica (SiO<sub>2</sub>) is about 0.5%. Plants which lack silica loses much water from plants

(the transpiration is high) because the leaf surface is not protected by silicate so that the plants will dry easily. Silica functions to strengthen the epidermal tissue wall, tissue vessels, and to reduce lack of water (Makarim *et al*, 2007).

Based on the background which has been explained, so giving boron and silica through leaf are needed to increase the growth of soybean production. This research was done to answer these research questions:

1. How is the response of foliar boron concentration through the leaf to the growth and production of soybean plants?
2. How is the response of foliar silica concentration through the leaf to the growth and productions of soybean plants?
3. Is there any response of soybean plants in the different growth and production on giving silica concentration depends on the foliar boron concentration through leaf?

## 2. Materials and Methods

The research was conducted in the Integrated Area Laboratory and the Seed and Plant Breeding Laboratory, Universitas of Lampung from April-September 2017. The materials used were Wilis soybean variety, urea, TSP, KCl, distilled water, Silica ( $\text{Na}_2\text{SiO}_3$ ), and Boron ( $\text{H}_3\text{BO}_3$ ). The laboratory instruments used were electronic scale with 0,01 grams sensitivity, measuring cups, polybag, hand sprayer, Konica Minolta SPAD 502 series chlorophyll meter, oven, and seed blower.

In order to answer the question of research questions and to find hypothesis testing, the treatment design was arranged factorially (2x6) and there was triple in every regulation. The first factor was boron's dose which consisted of 2 concentration levels they are 0 ppm (B0), 5 ppm (B1). The second factor was Silica's dose which consisted of 6 concentration levels, they are 0 ppm (S0), 25 ppm (S1), 50 ppm (S2), 75 ppm (S3), 100 ppm (S4) and 125 ppm (S5). The micronutrient B and Si was applied three times started on day 21 after planting with a 4-week interval. The boron application was done in the morning from 7:00-9:00 pm, and silica applied in the evening from 3:00-5:00 pm. The treatments were applied to the entire surface of the leaves of soybean plants. The B and Si was applied on the same day, and B was first applied to the soybean leaves, followed by Si.

Sand media were used for planting medium. Sand was washed 7 times to remove mineral content and dried. Sand was filled into a 10 kg of polybag. Boron and Silica applied 3 times during the 3, 6, 9 weeks after planting (WAP). Concentration of B in form of  $\text{H}_3\text{BO}_3$  were 0 and 5 ppm, while the Si concentration in form of  $\text{Na}_2\text{SiO}_3$  were 0, 25, 50, 75, 100, and 125 ppm. The initial steps to prepare a solution B and Si is to calculate the concentration of B and Si in  $\text{H}_3\text{BO}_3$  and  $\text{Na}_2\text{SiO}_3$  by:

$$\text{Element ppm (mg / l)} = \frac{\text{weight of the molecule (Mr)}}{\text{weight of atom (Ar)}} \times \text{concentration in ppm}$$

SPAD value observations made when the plant enters the generative phase. Samples were taken from the greenness leaf. There were three points for measuring the greenness (base, middle,

and tip of the leaf). The position of the leaf was a third leaf from the tip shoot or the youngest with fully expanded. Data was automatically saved in the memory of SPAD. The principle of this tool is to determine the chlorophyll concentration by measuring the absorbance of leaf area red and near-infrared. Light emitted by the two LEDs with a peak wavelength at 650 NM and 940 NM (Sub *et al.*, 2015).

SPAD has no units of SPAD value is used as the value (x) for the comparative correlation of core variables such as leaf area, dry weight of the plant, filled pods and grains weight. Observed variables on the plant growth and yield of soybean were plant height, number of leaf, leaf area, dry weight, number of productive branch, number of pods, filled pods, the percentage of empty pods, and grain weight. Data were then analyzed using Orthogonal Polynomial for B and Si. The entire test was done at the level  $\alpha = 0.05$ .

### 3. Result and Discussion

The results of study showed that soybean plants were responsive to the increasing concentration levels of B and Si polynomial analysis on the level  $\alpha$  of 0.05 presented in Table 1 and 2 show that there was an interaction between the concentration of B and Si on soybean growth and yield.

Table 1. Recapitulation effect of an increase in the concentration of Si and the addition of B on the soybean growth.

Comparison	Variable			
	PH	NL	LA	DW
----- %difference----				
<b>Boron (B)</b>				
<b>P1: B0 VS B1</b>	ns	ns	ns	6,78*
<b>Silica (Si)</b>				
<b>P2: Si-Linier</b>	*	*	*	*
<b>P3: Si-Quadratic</b>	ns	ns	ns	*
<b>nteraction</b>				
<b>P4: P1 x P2</b>	ns	ns	ns	ns
<b>P5: P1 x P3</b>	ns	ns	ns	ns

Remarks: B0= 0 ppm Boron; B1= 5 ppm Boron; PH= plant height; NL= number of leaf; LA= leaf area; DW= dry weight. \* significant at  $\alpha = 5\%$ , ns= not significant at  $\alpha = 5\%$ .

Table 2. Recapitulation of the effect of an increase in the concentration of Si and the addition of B on soybean yield.

Comparison	Variable				
	NPB	NP	FP	EP	GW
---- % difference ----					
<b>Boron (B)</b>					
<b>P1 : B0 VS B1</b>	ns	ns	ns	ns	5,99*
<b>Silika (Si)</b>					
<b>P2 : Si-Linier</b>	ns	ns	ns	ns	*
<b>P3:Si-Quadratic</b>	*	*	*	ns	*
<b>Interaction</b>					
<b>P4 : P1 x P2</b>	ns	ns	ns	ns	ns
<b>P5 : P1 x P3</b>	ns	ns	ns	ns	ns

Remarks: B0= 0 ppm Boron; B1= 5 ppm Boron; NPB= number of productive branch, NP= number of pods, FP= filled pod, EP= the percentage of empty pods, and GW= grain weight \* significant at  $\bar{\alpha} = 5\%$ , ns= not significant at  $\bar{\alpha} 5\%$ .

Table 3. Correlation analysis SPAD value with a variable vegetative and generative soybean plant.

Variable	R-hit	R-table
<b>Leaf Area (LA)</b>	<b>0,598*</b>	<b>0,576</b>
<b>Dry Weight (DW)</b>	<b>0,891*</b>	<b>0,576</b>
<b>Filled Pods (FP)</b>	<b>0,597*</b>	<b>0,576</b>
<b>Grain Weight (GW)</b>	<b>0,764*</b>	<b>0,576</b>

Remarks: LA= leaf area; DW= dry weight; FP= filled pods; GW= Grain weight. \* significant at R = 0,576, ns= not significant at R= 0,576.

Foliar of Si up to 125 ppm concentration with B 5 ppm did not show any interaction either in growth phase (vegetative) or production (generative). This was presumably because the provision of boron and silica through the leaves have different nutrient absorption mechanisms such as crosslink / apoplast pathways and channel transporters. Boron (B) in the form of  $B_3(OH)_4$  which was absorbed into the leaves through stomata using a simple cross path. Boron itself is actually immobile in the plant, but boron can still be easily absorbed due to the presence of alcoholic sugar (polyol). Polyols bound to B are carried by water to the bundle sheath and phloem. On the phloem tissue B brings photosynthate results to be translocated to the sink to another growing point. This is in line with the opinion of Brown and Barry (1997) that boron can be mobile as long as the plant contains sugar alcohol in the form of polyol.

Boron is absorbed through the stomata, but it cannot pass through the cell wall just because B is immobile and therefore needs a transporter. Transporter B in the plant is thought to be the genes NIP6, NIP5, and BOR1. The transporter is thought to help B through the cell membrane to mesophyll tissue, chloroplasts, vascular spaces, phloem, and sinks, and transit to other growing plant tissues. According to Tanaka *et al.* (2008) NIP6 is a channel transporter B for plant growth. This is in accordance with the opinion of Miwa and Toru (2010) that NIP and BOR are believed to help transport boron in plants.

Silica itself has a cross-path apoplast that cannot penetrate the endodermis directly except through the casparian strip. Silica is also the same as the immobile boron in plants that require transporter and alcoholic sugar in the form of polyol to be absorbed by the plant. According to Ma and Yamaji. (2006) Lsi1 is the gene responsible for the Si transporter to the root cell of the plant. The same is stated in the research da Silva Lobato *et al.* (2013) that there are at least two transporters involved in the absorption of silica in the root of the rice. One lies in the plasma membrane that helps transport the silica to the cortex or planted a mesophyll called SIT1. Both lie in the plasma membrane of the parenchymal xylem cell that helps release Si into the xylem called SIT2.

This was thought to result in the absence of B and Si interactions, due to the different absorption mechanisms of B and Si. Different B and Si absorption results in different results. According to Savic and Marjanovic (2013) that there is no interaction on the foliar of B and Si on the growth of sunflower. This is in line with Prihartini (2013) research that there is no interaction effect between B and Si on all growth variables, physiological activity, as well as structural strength of the epidermal tissue root of the yellow banana plant. The same result is in line with Timotiwiu *et al.* (2016) stated in his research that there is no interaction between giving B and Si to rice plants.

The results showed that an increase of Si up to 125 ppm could improve all the growth variables better than without Si (Fig. 1-4). This is in accordance with the research Sukkaew *et al.* (2016) that different silica foliar has a better effect on plant height variables and dried seedlings than Si. The increase in plant height as a result of Si increase is thought to affect the number of leaves. The results showed that the response of plant to Si up to 125 ppm increased number of leaf (Fig. 3). This is in line with the research of Costa *et al.* (2016) that foliar of Si with concentrations of 0.28 and 0.55 g pot<sup>-1</sup> gives the effect of the number of leaves better than without Si.

Increased plant height (Fig. 2) and number of leaf (Fig. 3) indirectly resulted in a better leaf area with Si (Fig. 4). This is in accordance with the opinion of Ahmad *et al.* (2012) that the maximum leaf area of the Chakwal-50 cultivar grain plant reaches 201.67 cm at a concentration of <10% Si. This is in line with research of Ahmad *et al.* (2011) that an increase of Si up to 200 mg L<sup>-1</sup> under water tolerant conditions causes an increase in the area of the sorghum leaf area.

Foliar Si could improve the leaf angle of plant crops so efficiently in the absorption of sunlight for photosynthesis.. As a result, it would increase the dry weight of plant (Fig. 5). Any increase of Si concentration of 1 ppm will increase 0.022 g of dry weight of the plant.

Also, based on SPAD value (Table 3 and Fig. 11), there was relationship between the greenish of leaf and dry weight of plant with  $r = 0.891$ . It means there was a high correlation between greenish of leaf and dry weight of the plant. According to Locarno *et al.* (2010) that Si absorbed by plants will accumulate in the epidermis so that it is beneficial for better crop structure changes and better sunlight capture. Increasing the efficiency of sunlight absorption allows the activity of photosynthesis to run smoothly so as to affect the concentration of chlorophyll content in leaf tissue. The process of soybean photosynthesis with the foliar of Si is expected to produce more photosynthates, in the form of carbohydrates, starches, lipids, and proteins. The result of the photosynthate will be translocated in the plant so that the dry weight of plant also increases. Result of research show that the increase of Si can still increase dry weight of soybean crop. According to Rambo *et al.* (2011) that giving of 100 and 200 kg ha<sup>-1</sup> of Si can increase the dry weight of rice crop due to the accumulation of organic material in the photosynthesis process. The results also showed that the foliar of B with a concentration of 5 ppm was able to produce dry weight of plant compared than without B. This is in line with the study of Davis *et al.* (2003) that leaf B through concentration of 95.6 mg kg<sup>-1</sup> resulted in dry weight of tomato-tomatoes of 3.11 grams higher than without B.

The greater the chlorophyll absorbance of leaves the greater the SPAD value, so it is predicted the level of green leaves will be greater. Jiang *et al.* (2017) states that SPAD-502 could be an effective tool used to estimate the leaf chlorophyll content in tomatoes quickly and nondestructively. The same is expressed by Rostini *et al.* (2003) that the chlorophyll content measured by SPAD 502 chlorophyll meter correlates with the weight of the soybean seed per plant. The longer the chlorophyll survives in the constant conditions supported by the amount of chlorophyll contained in the leaves, the higher the soybean yield.

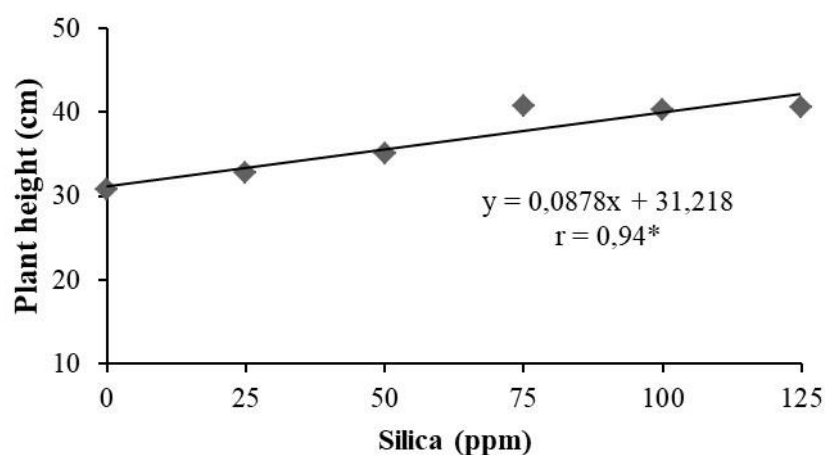


Figure 1. Response of the increasing concentration

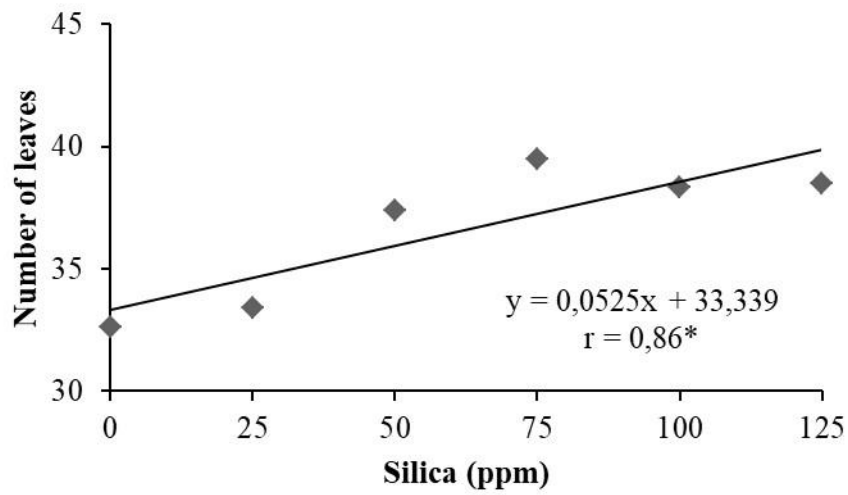


Figure 2. Response of the increasing concentration of Si on number of leaves.

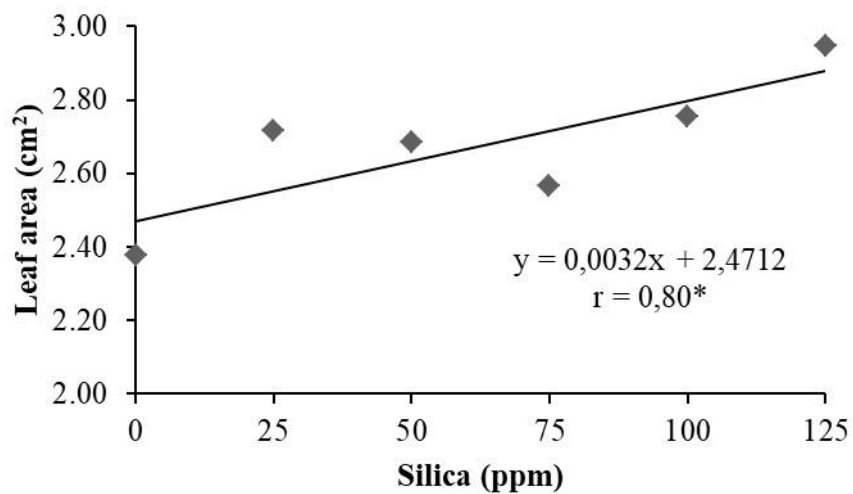


Figure 3. Response of the increasing concentration of Si on leaf area



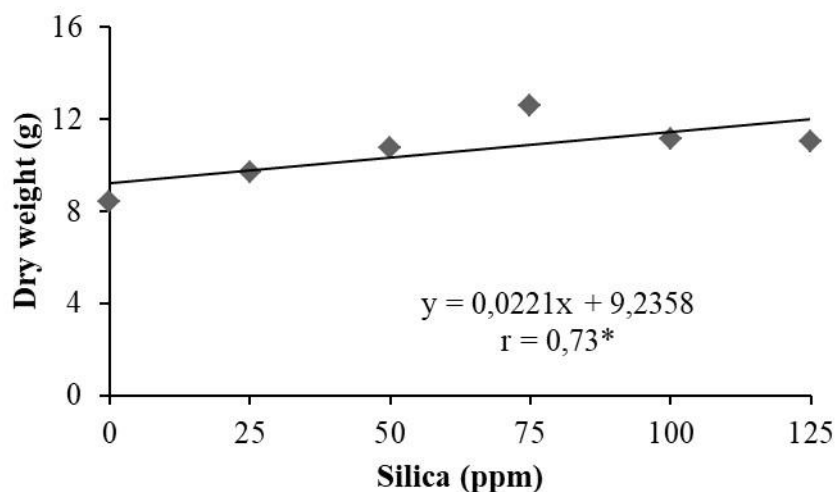


Figure 4. Response of the increasing concentration of on dry weight.

Good vegetative growth will produce high production. Makarim *et al.* (2007) explains that Si's benefits in gramminae plants, i.e. making upright leaves form efficiently capture solar radiation that will produce photosynthesis. The increase in Si concentration is expected to affect the number of productive branch (Fig. 6), number of pods (Fig. 7), and filled pods (Fig. 8), and grain weight (Fig. 9). The results showed that the number of productive branch, number of pods, and filled pods has a maximum point 71.68, 68.80, 66.86 ppm, respectively. It is suspected that the Si element entering the plant tissue accumulates in the endodermis. The accumulators in the endodermis cause Si to be an accumulator for the very important macro elements required by plants such as N, P, and K. The macro element is blocked by the accumulation of Si in the endodermis so that it cannot be absorbed completely by the plant tissue.

According to Epstein (1994) Si has some of the following partial roles: (1) the availability of both ground and dissolved Si added to plant tissue is proportional to some macro element elements such as N, K, Mg, Ca, S, and P, (2) large Si is absorbed in the form of amorphous,  $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ , or opal, the most important morphology and stockpiling of Si differ depending on the genotype of plants and environmental conditions, (3) Si sometimes reduces and eliminates the effects of excess P, heavy metals, salinity in the medium term. This is in accordance with the opinion of Sahebi *et al.* (2014) that Si's role in influencing growth, metabolism is not yet known, but the physiological role cannot be ignored because it can indirectly increase rice production.

According to Heckman (2009) one of the functions of B (Boron) is to assist the distribution of photosynthesis. This is in line with Makarim *et al.* research. (2007) that adequate supply of photosynthate can store food reserves in the grain of rice. Increasing the supply of photosynthates will increase the amount of available food reserves so as to increase the number

of pithy seeds. Increasing of pithy seeds will produce weight of 1000 seeds more heavier. Similar results are expressed by Bellaloui *et al.* (2013), showed that foliar of B through the leaves was able to increase the weight of seed (weight of 100 seeds) by 16.1 g higher than without B by 13.2 g in soybean treated crops.

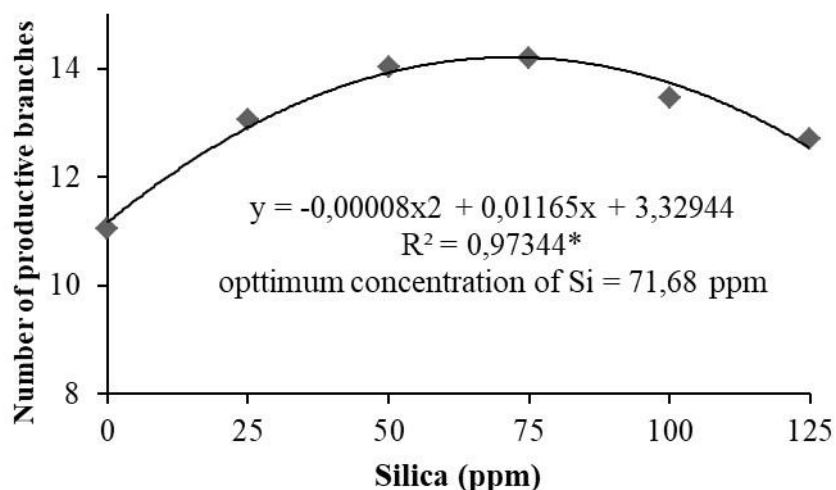


Figure 5. Response of the increasing concentration of Si on productive branches

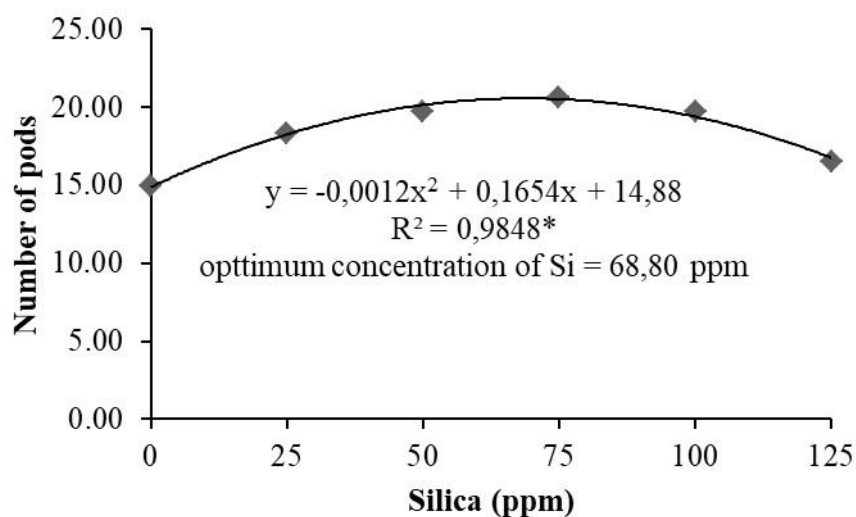


Figure 6. Response of the increasing concentration of Si on number of pods.

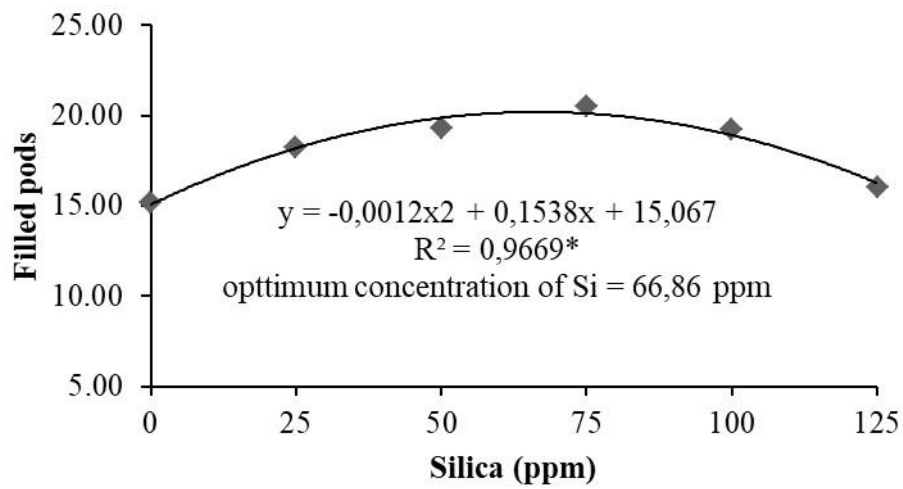


Figure 7. Response of the increasing concentration of Si on filled pods

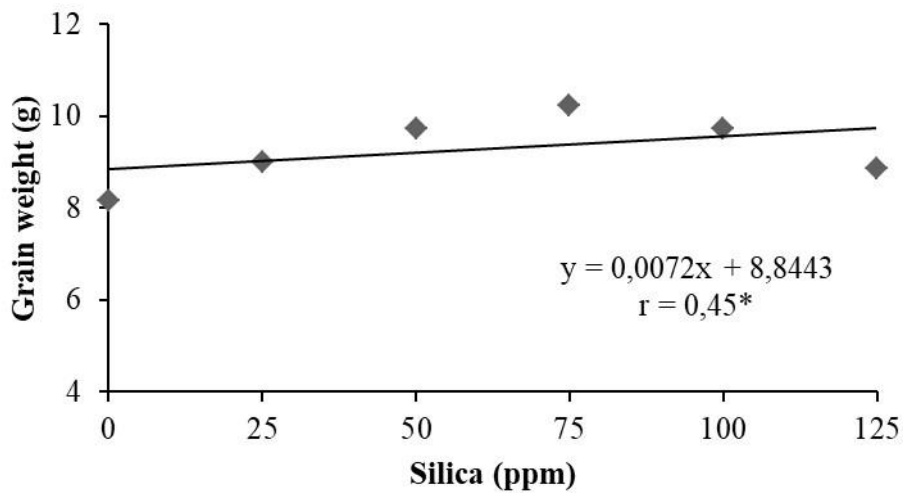


Figure 8. Response of the increasing concentration of Si on grain weight.

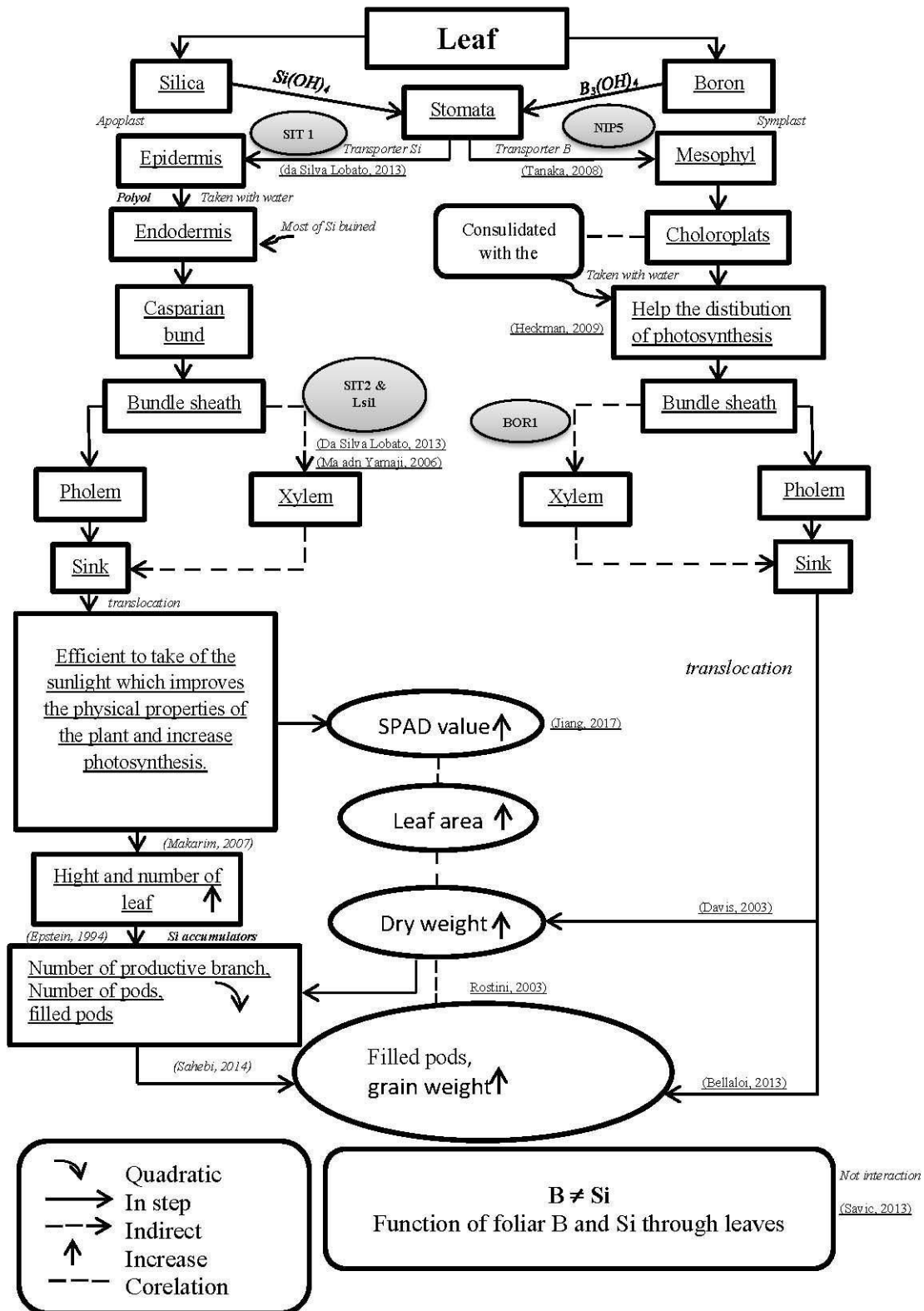


Figure 9. Proposed mechanism foliar B and Si through leaves in this research.

#### 4. Conclusion

Based on the research that has been done, then obtained the following conclusion: B foliar of 5 ppm resulted in higher growth and soybean production compared to non-B through dry weighted variables (6.78%) and grains weight (5.99%). Foliar of Si up to 125 ppm concentration can increase the growth and still increase the production of soybean crops through plant height, number of leaf, leaf area, dry weight; number of productive branch, number of pod, filled pods and grain weight of soybean, but no effect on percentage of empty void. The response of growth and production of soybeans to Si increase is independent of the foliar of B shown in all variables.

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