Effect of boron on flowering, yield components and grain yield of two prolific maize (Zea mays L.) hybrids

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Abstract. Maize is one of the strategic commodities in economic development in Indonesia. The need for maize in Indonesia continues to increase. Adequacy of nutrients affects the physiological process, where Boron (B) is one of the essential nutrients for optimal plant growth, development, yield, and quality. Nutrition B is important in the development of reproductive organs, components of corn and grain yield. This study aims to examine the effect of B on growth and flowering and its effect on yield components and grain yields of prolific maize hybrid. The study was conducted using Separate Plot Design, as the main plot was Bisi 2 variety and Nasa 29 while subplot was level B: 0 kg B ha⁻¹, 0.25 kg B ha⁻¹, and 0.50 kg B ha⁻¹, by foliar application. The results showed that There is no significant difference between Bisi 2 Variety and NASA 29 in flowering parameters, yield components and yield of seeds except for the number of tassel branches and 1000 grains weight. application B up to 0.50 kg B ha⁻¹ showed the highest results and significantly increased the number of tassel branches 5.10%, tassel length 8.62%, and silk dry weight of 29.54%, cob length 6.89%, grain weight per plant 15.69%, 1000 grains weight 8.36% and grain yield (moisture content 15%) 15.80% of 0 kg B ha⁻¹. Application B 0.50 kg B ha⁻¹ can be recommended in the Bisi 2 and Nasa 29 especially in low soils B.

1. Introduction

Corn (Zea mays L.) is one of the most important agricultural commodities because in addition to meeting food and feed needs, it is also to meet the needs of bioenergy and other industries. The need for maize in Indonesia continues to increase, so efforts are needed to increase its productivity.

Increasing maize productivity can be done through optimally providing nutrients through fertilization. the availability of nutrients N, P, K and micro elements are determinants of corn productivity [1]. Micro elements are elements that are needed in small amounts but are essential for plant growth. Micronutrients are needed in small amounts and they affect photosynthesis directly or indirectly, vital processes in plants such as respiration, protein synthesis, and the reproductive phase [2].

Boron (B) is one of the essential micro nutrients in corn [3]. B is an important trace element required for the physiological functions of higher plants. B deficiency is considered a nutritional disorder that affects metabolism and plant growth. B is involved in the structural and functional integrity of cell walls and membranes, ion fluxes (H⁺, K⁺, PO₄³⁻, Rb⁺, Ca²⁺) across membranes, cell division and elongation, nitrogen and carbohydrate metabolism, and sugar transport [4].
important role in the production of grains, pollen germination, flowering and fruiting processes. Boron also plays an important role in the storage of assimilation in corn. B deficiency in maize plants can cause pollen not viable so that fertilization is interrupted and seed filling is not perfect, thus reducing yield. Some research results show that boron increases corn yield by 10 to 26% [5-6].

Boron requirements for plant growth vary greatly among plant species. The optimal quantity B for one species can be toxic or insufficient for other species [7]. The range of concentration of soil B solution between deficiency and toxicity is smaller than other nutrients. Corn has a low B requirement, but can be very sensitive to excess B. The adequacy range of B for corn is 4 to 25 ppm in cob leaves [8]. more detailed information about the requirements of prolific hybrid corn B is still lacking.

One type of hybrid corn that has a higher yield potential is prolific corn. Prolific corn is corn that can produce more than one productive ear in one plant. The size of the second cob produced in prolific maize will determine the level of production. The Bisi-2 and Nasa-29 varieties are prolific hybrid corn varieties. The purpose of this study was to study the effect of B on the growth and development of the reproductive organs and their effect on yield components and grain yields of prolific maize hybrid.

2. Materials and Methods
This research was conducted at the Institute Cereals Research (Balitsereal) Maros Regency, South of Sulawesi Province, in 2017. Soil sampling at the research site was carried out before planting to a depth of 20 cm using a composite method. Furthermore, it was analyzed in the Soil Faculty of Agriculture Unhas laboratory. Plant analyses was carried out in the laboratory of the Center for agricultural assessment and technology. The research location has a clay texture with N (Kjeldahl) content of 0.10%, P2O5 (Olsen) 21.5 ppm, K2O (HCl 25%) 12 mg / 100 g, pH 5.8, CEC 19.62 cmol / kg , C-organic 1.72%, and B (MP-AES) 0.1 ppm.

The experimental design was a Split Plot Design with three replications. As the main plots were varieties Bisi 2 and Nasa 29. Where as for sub-plot was application B at the level of 0 kg B ha\(^{-1}\), 0.25 kg B ha\(^{-1}\) (0.57 g L\(^{-1}\) ), and 0.50 kg B ha\(^{-1}\) (1.15 g L\(^{-1}\) ). main plots size was 16m x 3m and each main plot was divided into three sub-plots with a size of 5m x 3m. Bisi 2 varieties and Nasa 29 were planted with a spacing of 75 cm between rows and 20 cm in width. Each plot consists of 100 plants. Fertilization is carried out by using a urea and NPK of 300 kg ha\(^{-1}\) each. Urea application is carried out twice, namely 50% of the dose at the age of 7 and the rest at the age of 30 days after planting, while the application of NPK fertilizer is carried out simultaneously with urea fertilizer application. Application B by foliar at V5-V7 (21 days after emergence). Land irrigation is done every week by flowing water in the area between plots.

Sampling on cob and leaf was done during silking to determine silk dry weight and leaf B content. The samples were taken from 5 plants in each plot and every silk replication was taken and then roasted for two days at 80°C or until the weight was constant. Whereas the analysis of cob leaf tissue was performed using the Microwave Plasma Atomic Emission Spectrometry (MP-AES) method. A total of ten samples were taken from each plot and each replication for parameters of the leaf number, stalk diameter, day from the emergence to anthesis, tassel length, number tassel branch and yield components.

The data obtained were analyzed using the F test for each parameter at the 0.05 and 0.01 level. If the effect of the treatment on the observed parameters shows a significant effect then the analysis is continued by using the LSD test at the level of 0.05 to find out the statistical difference between the level of treatment being tried.

3. Results and Discussion

3.1. Effect B on growth
The results of this study indicate that the effect of application B on the number of leaves, stem diameter, and age of the anthesis was not significant both in bisi-2 varieties and in NASA-29 (Table 1). However, application B tends to increase the number of leaves, stem diameter and accelerate the
time of anthesis in both varieties. No significant effect on the number of leaves and stem diameter by application B is thought to be caused by the role of B itself which has more influence on the reproductive phase compared to the vegetative phase. As explained by Piland et al. (1944) in [7] that treatment B increased the grain yield of alfalfa by 600%, while the yield of straw only increased by 3%.

Table 1. The effect B to leaf number, stalk diameter and days from emergence to anthesis on varieties Bisi-2 And Nasa-29.

| Treatment | Leaf Number (plant⁻¹) | stalk Diameter (cm) | Day from the emergence to anthesis (d) |
|-----------|------------------------|---------------------|----------------------------------------|
| Variety   |                        |                     |                                        |
| Bisi-2    | 20.41                  | 35.50               | 54.11                                  |
| Nasa-29   | 19.83                  | 37.81               | 55.00                                  |
| F test    | ns                     | ns                  | ns                                     |
| Level B   |                        |                     |                                        |
| (kg B ha⁻¹) | 0                     | 19.75               | 2.45                                   |
|           | 0.25                   | 20.19               | 2.52                                   |
|           | 0.50                   | 20.42               | 2.54                                   |
| F test    | ns                     | ns                  | ns                                     |

*ns = non significant*

This shows that the need for B is more important and is more responded to in the reproductive phase than in the vegetative phase. Nevertheless it seems that the application of 0.50 kg B ha⁻¹ produced a higher number of leaves and stem diameters of 20.42 and 2.54 compared to without B which were only 19.75 and 2.45 (Table 1). This is thought to be caused by the effect of B on cell division and photosynthetic activity and better root development. The results of research [9] on cotton plants that without giving B decreased stomatal conductance so that it affects the rate of transpiration and photosynthetic activity. In addition, B is considered important for actively growing plant areas, such as root tips, leaf development and new shoots [10].

The difference in the responses of the two varieties to the day from emergence to anthesis was not significant. Although Bisi-2 varieties require an average time of 54.11 days after planting tends to be faster than Nasa-29 which requires an average time of 55.00 days.

3.2 Effect of B on flowering

Flowering conditions of Bisi-2 and Nasa-29 varieties basically did not show any significant difference in tassel length and silk dry weight, but the number of tassel branches differed significantly where Nasa-29 produced 22.30 tassel branches per plant higher than in Bisi-2 which is only 20.34. Similarly tassel length of 37.81 cm in NASA-29 was higher than 35.50 cm in Bisi-2 but was not statistically significant (Table 2). This indicate that Nasa-29 produces more spikelet which means it has the potential to produce more amount of pollen compared to Bisi-2. Thus that different prolific hybrid maize varieties produce variations in the number of spikelets. An non significant difference was shown in silk dry weight with 0.73 g of plant⁻¹ on Nasa-29 higher than 0.72 g of plant⁻¹ on Bisi-2.
Tabel 2. Effect of B to the Numbers tassel branch, tassel length, Silk Dry Weight on Bisi-2 and Nasa-29 Varieties.

| Variety   | Level B (kg B ha⁻¹) | Treatment | Number tassel branch (plant⁻¹) | Tassel length (cm) | Silk Dry Weight (g plant⁻¹) |
|-----------|---------------------|-----------|--------------------------------|--------------------|-----------------------------|
|          |                     | Bisi-2    | 20.34ᵇ | 35.50 | 0.72 |
|          |                     | Nasa-29   | 22.30ᵃ | 37.81 | 0.73 |
|          |                     | F test    | *      | ns    |     |
|          |                     | LSD₀.₀₅  | 1.87   |       |     |
|          | 0.25                |           | 20.67ᵇ | 25.11ᵇ| 0.62ᶜ |
|          | 0.50                |           | 21.53ᵃ | 27.37ᵃ| 0.78ᵇ |
|          |                     | F test    | *      | *     | 0.88ᵇ |
|          |                     | LSD₀.₀₅  | 0.66   | 1.52  | 0.05 |

Note: average values followed by the same letters in rows (a,b,c) are not significantly different
* , ** = significant LSD test at 0.05 and 0.01 level of probability respectively
ns = non significant

These results explain that the size of silk formed is not determined by the differences in the two varieties tested. However, B supply of 0.25 and 0.50 kg B ha⁻¹ gave significant results compared to 0 kg B ha⁻¹ for the number of tassel branches, tassel length and silk dry weight both on Bisi-2 and on NASA-29. The 0.50 kg B ha⁻¹ level increased the number of tassel branches per plant from 20.66 to 21.77 (5.10%), tassel length from 25.11 cm to 27.48 cm (8.62%), and silk dry weight from 0.62 to 0.88 g plant⁻¹ (29.54%) (Table 2). An increase in the number of tassel per plant, tassel length and silk dry weight are inseparable from the role of B itself in improving the quality of tassel and silk in corn. An increase in the number of tassel branches and tassel length due to supply B indicates a potential increase in the amount of pollen contained in each spikelet. As stated by [11] that the morphological characteristics of the tassel such as tassel size can reflect the production of pollen quantitatively. Nutrition B plays an important role in the formation of pollen [5]. The increase in tassel size and dry weight of silk is presumed by the presence of B levels in panicles and silk that affect the development of panicles and silk. This is an indicator of the response of these organs to supply B. According to [3] that corn which is deficient in B, its tassel development is inhibited, becomes deformed and sterilization occurs. This statement is supported by [5] that the symptoms of B deficiency in corn are low tassel dry weight and silk dry weight per plant, number of silk per cob and silk length, tassel appear smaller and some branches die, thinner and white.

3.3. Effect of B on grain component and grain yield
The yield components of Bisi-2 and Nasa-29 varieties, namely ear diameter, ear length, seed weight per plant, 1000 grain weight and grain yield are shown in Table 3. The difference in response between Bisi-2 and Nasa-29 to ear diameter, ear length, grain weight per plant, and grain yield was not significant. Nasa-29 produces ear diameter and ear length respectively 4.12 cm and 18.45 cm higher than Bisi-2 which only produces ear diameter 3.79 cm and ear length 16.62 cm. This fact illustrates that Nasa-29 has the potential to have a higher number of grains per cob which will have an impact on grain production. Likewise in grain weight per plant, Nasa-29 produced 149.22 g of plant⁻¹ that non significant with Bisi-2 which was only 134.44 g of plant⁻¹. Number of grain per ear and the weight of grains per plant is a component of the yield that is directly positively related to yield.
Table 3. Effect of variety and level B to ear diameters, ear length, grain weight, 1000 grain weight, and grain yield on Varieties Bisi-2 and Nasa-29.

| Treatment | Ear Diameters (cm) | Ear length (cm) | grain weight (g plant\(^{-1}\)) | 1000 grain weight (g) | Grain yield (t ha\(^{-1}\)) |
|-----------|--------------------|-----------------|---------------------------------|-----------------------|-----------------------------|
| Variety   |                    |                 |                                 |                       |                             |
| Bisi-2    | 3.79               | 16.62           | 134.44                          | 294.91\(^{b}\)        | 7.94                        |
| Nasa-29   | 4.12               | 18.45           | 149.22                          | 308.19\(^{a}\)        | 8.87                        |
| F test    | ns                 | ns              | *                               | ns                    |                             |
| LSD\(_{0.05}\) |                |                 |                                 |                       |                             |
| Level B (kg B ha\(^{-1}\)) | 0 | 3.89 | 16.76\(^{b}\) | 127.17\(^{b}\) | 287.42\(^{c}\) | 7.57\(^{b}\) |
|          | 0.25              | 3.95            | 17.86\(^{a}\) | 147.50\(^{a}\) | 303.58\(^{b}\) | 8.65\(^{a}\)    |
|          | 0.50              | 4.03            | 18.00\(^{a}\) | 150.83\(^{a}\) | 313.66\(^{a}\) | 8.99\(^{a}\)    |
| F test    |                     |                 | *                               | *                     | *                           |
| LSD\(_{0.05}\) |                |                 | 1.00                           | 14.86                | 9.44                         | 1.03                        |

Note: average values followed by the same letters in rows (a,b,c) are not significantly different based on the LSD level of 0.05
*,**, = significant LSD test at 0.05 and 0.01 level of probability respectively
ns = non significant

The length of the ear has a high correlation (\(r = 0.871\)) with grain yield [12] and grain weight and number of kernel explain 29% and 75% of the variation in grain yield [13]. Meanwhile, the 1000 grain weight produced by Nasa-29 was significantly higher by 308.19 g compared to that of Bisi-2 which was only 294.91 g which was thought to be caused by a larger stem diameter on Nasa-29 so as to contribute to the assimilation of the enlargement seed. In addition, it is likely caused by the nature of stay green owned by Nasa-29 where the leaves remain relatively green until the ears are harvested so that photosynthetic activity is still active and continues to contribute sufficient assimilation until the seeds reach physiological maturity. According to [12] that grain yield is positively correlated with the number of green leaves during kernel filling. Grain yield was tend to be higher in Nasa-29 at 8.87 t ha\(^{-1}\) compared to Bisi-2 with production of 7.94 t ha\(^{-1}\) but the difference was not significant. Higher production in Nasa-29 is contributed by a number of yield components (ear diameter, ear length, ear weight per plant and 1000 grain weight) generally higher in Nasa-29 than in Bisi-2.

Table 4. The results of the analysis of tissue on the leaf ear on Bisi-2 and Nasa 29 varieties that have been fertilized with various concentrations of B.

| Variety | level B application (kg B ha\(^{-1}\)) | Content of B in ear leaf (ppm) | Testing method |
|---------|---------------------------------------|--------------------------------|----------------|
| Bisi-2  | 0                                     | 0.01                           | AAS            |
|         | 0.25                                  | 1.00                           |                |
|         | 0.50                                  | 1.30                           |                |
| Nasa-29 | 0                                     | 0.30                           | MP-AES         |
|         | 0.25                                  | 1.70                           |                |
|         | 0.50                                  | 2.90                           |                |

Application B through leaves produces a statistically insignificant difference in ear diameter, but the diameter of ear has increased from 3.89 cm at level 0 kg B ha\(^{-1}\) to 4.03 cm at level 0.50 kg B ha\(^{-1}\). The parameters of ear length, grain weight per plant, 1000 grain weight and grain yield per hectare were significantly increased by application B to the 0.50 kg B ha\(^{-1}\) level. Level 0.50 kg B ha\(^{-1}\) increased the ear length, grain weight per plant, and 1000 grain weight each by 6.89%, 15.69%, 8.36% of 0 kg B ha\(^{-1}\). The increase in grain weight per plant is due to the lack of abortion seeds due to the
influence of B through the addition of length and number of tassel branches and silk dry weight. The influence of B on the increase in silk dry weight is expected to occur because the results of the analysis of the B content of the ear leaves also increased with the increasing level of B which was applied, reaching 2.90 ppm and 2.30 ppm at the 0.50 kg B ha\(^{-1}\) level respectively in NASA-29 and Bisi-2 (Table 4). [5] suggested that B deficiency in maize plants adversely affects female flowers by producing abnormal ears with much shorter or lesser silk, thus the silk fails to carry out its functions properly in seed formation. In addition, B deficiency causes the failure of silk to receive pollen so that the formation of bad grains and cob becomes seedless [5]. The other role of B is important in the storage of assimilates so that it influences the formation of grains [6]. Grain yield obtained from the results of this study reached 8.99 t ha\(^{-1}\) at a rate of 0.50 kg B ha\(^{-1}\) significantly higher than that of 7.57 t ha\(^{-1}\) at 0 kg B ha\(^{-1}\). These results indicate that the high grain yield obtained in maize plants is related to the higher number of tassel branches and dry silk weight which causes better pollination and fertilization to take place followed by optimal kernel set due to the role of B. The role of B is also shown by the length cob, seed weight per plant, and 1000 grain weight which affect the high grain yield.

4. Conclusion
1. There is no significant difference between Bisi 2 Variety and NASA 29 in flowering parameters, yield components and grain yield except for the number of tassel branches and 1000 grains weight.
2. Application B to 0.50 kg B ha\(^{-1}\) shows the best results and significantly increases the number of tassel branches 5.10%, tassel length 8.62%, and silk dry weight of 29.54%, cob length 6, 89%, grain weight per plant 15.69%, and 1000 grains weight 8.36% of 0 kg B ha\(^{-1}\).
3. Effect of B on better flowering quality causes an increase in yield components and grain yield on Bisi-2 and Nasa-29, but to the growth parameters by effect B are not visible.
4. Application B 0.50 kg B ha\(^{-1}\) can be recommended in the Bisi 2 and Nasa 29 prolific maize plants especially in low B soils because it can significantly improve flowering quality, yield components and seed yield.

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