The effect of sulphur and lime dosage application on grain yield of hybrid maize

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Abstract. The preparation of the Method for Determining Fertilizer S Recommendations for Maize based on Soil Analysis and Yield has been carried out at the Bontobili Installation, Gowa Regency, South Sulawesi, from February 2020 to May 2020. The purpose of this experiment is to find out S fertilizer recommendations based on soil analysis. The pH of the study site was <6.5, and to make a difference in soil pH, it was incubated with lime 2 t/ha to raise the pH to neutral and 4 t/ha to obtain a pH >7.5. For each soil pH condition treatment was made using a split plot group design. The main plots were given agricultural lime at a rate of 0, 200kg/ha, 400 kg/ha and 600 kg/ha. While the sub-plots were fertilized with S, namely: 0.20,40,60,80, kg S with 3 (three) replications. All treatments will be fertilized with N and P based on soil analysis. The highest yield was obtained with lime and S fertilizer at the dose of K3S60 (600 kg/ha lime and 60 t/ha S fertilizer) showing the highest yield of 10.81 t/ha and not significantly different from the K3S80 treatment (600 t/ha lime) and fertilizer S 80 kg/ha) which is 10.64 t/ha.

1. Introduction
Fertilizers for food crops, especially urea, ZA, phonska, and other compound fertilizers are mainly subsidized by the government, although these subsidies are gradually being reduced and may eventually be eliminated. On the other hand, most of the recommendations for fertilizer dosages on maize used by farmers are not specific, while the agro-ecosystem of maize development in Indonesia is very diverse so that fertilization is less efficient. Site-specific fertilization (is one part of precision agriculture) in addition to increasing fertilization efficiency, productivity, and farmers’ income. Site-specific fertilization can also support the sustainability of the production system, environmental sustainability, and saving energy resources. Provision of adequate and balanced fertilizers is a key factor in increasing productivity and sustainable maize production [1], [4], [11].

IAARD has produced a rapid method for analyzing nutrient availability with qualitative results (low, medium, and high), named PUTK and PUPS. In the manual for the use of PUTK/PUPS, the recommendation for fertilizer dosage for maize is only based on the results of soil analysis in accordance with the criteria (low, medium, and high), without linking it to the yield target/opportunity of achievable yields.

The recommendation for N fertilizer is obtained, for every increase in the target yield of 1 t /ha from the target yield of at least 6 t /ha, an additional N fertilizer of 25 kg /ha is required. The standard of fertilization to obtain a minimum yield of 6 t /ha is 60 kg N /ha for the low C-organic content of the soil, 33 kg N /ha for the moderate C-organic content of the soil, and 5 kg N /ha for high soil organic
matter content. Each increase in yield of 1 t/ha requires an average additional 10 kg P2O5/ha for low P, and 5 kg P2O5 for medium and high P [16]. Each increase in seed yield response of 1 t/ha between those given N, P, or K and without N, P or K requires additional fertilizers per hectare of 20 kg N, 20 kg P2O5, and 30 kg K2O/ha [5].

To produce 1 t of corn, the plant will absorb 1.78 kg of S nutrients [2]. Soils with high pH often experience S deficiency [3]. Besides, in the PUTK/PUTS instructions there are only recommendations for N, P, and K fertilization, but there is no S fertilization. Therefore, it is necessary to guide recommendations for N, P, K, and S fertilization based on soil analysis by considering the target yield.

2. Materials and Methods

2.1. The research consisted of 2 stages.

2.1.1. Stage 1. Correlation of nutrient availability S with soil pH
A total of 10 -20 types of soil from acid to alkaline soil (Kalkareous) were collected from various regions. Soil samples were analyzed for S content and pH using PUTK/PUTS and laboratory analysis. The results of the analysis will be correlated through statistical analysis.

2.1.2. Stage 2. Field research to prepare recommendations
The research was carried out from February to May 2020 in dry land IP2TP, Bontobili. The pH of the study site was <6.5, and to make a difference in soil pH, it was incubated with lime 2 t/ha to raise the pH to neutral and 4 t/ha to obtain a pH >7.5. For each soil pH condition treatment was made using a split plot group design. The main plots were given agricultural lime with doses of 0 (K0), 200kg/ha (K1), 400 kg/ha (K2) and 600 kg/ha (K3). While the sub-plots were using S fertilization, namely: 0 (S0),20 kg S/ha(S1),40 kg S/ha (S2),60 kg S/ha (S3),80 kg S/ha (S4). with 3 (three) replications. All treatments will be fertilized with N and P based on soil analysis. JH -29 maize seeds were planted in 2 seeds/hole with a spacing of 70 x 20 cm, at the age of <7 DAP, they were thinned so that 1 (one) plant/hole was grown.

The application of N fertilizer is carried out in 2 stages of application. The first stage was given a half of the dose at the same time as giving all doses of P and K at the age of < 7 days after thinning (after thinning). The second stage of giving the rest of the dose is given at the age of 40 days after planting (DAP). Plant management (watering, weed control, and pests/diseases) is carried out optimally (according to conditions).

The data collected include soil analysis before the experiment was taken randomly and analyzed using PUTK and the laboratory, agronomic components (plant height, cob height, leaf length and leaf width, Leaf area index was obtained from 10 plant samples randomly in each plot), yield components (cob length and diameter, number of rows and seeds in rows, seed yield, moisture content, weight of 100 seeds) were obtained from 10 ears at random in each plot at harvest, Grain yield was calculated on a harvested area of 2.8 m (4 rows) x 4 m converted at a moisture content of 15%. The seed yield data will be analyzed by regression and will be grouped with the level of crop yields with a dose of S fertilizer.If there is a significant effect of the observed treatment, a further test analysis is carried out using the Duncan method (DMRT) at a level of 0.05.

3. Results and Discussion
The experimental soil in Bontobili can be classified as Ultisol soil type, the soil reaction is acid and the nutrient status of N, P, K, Ca, Mg and Na is low. The results of the analysis of variance showed that the interaction effect between lime application and S fertilization on plant height at the age of 50 and 80 DAP ranged from 54.33 cm to 198.05 cm (Table 1).

Table 1. Effect of combination of lime treatment and several doses of S fertilizer on plant height at 50 and 80 days after planting (DAP), Bontobili 2020.

| Lime (t/ha) | S Fertilizer |
|------------|--|----------------|----------------|----------------|----------------|----------------|
|            | S0 | S20 | S40 | S60 | S80 |
| K0         | 54,33 h | 62,25 gh | 61,84 gh | 56,75 h | 49,13 h |
| K200       | 83,92 f | 75,34 fg | 81,46 f | 74,50 fg | 74,59 fg |
| K400       | 106,75 de | 98,17 e | 101,34 e | 107,38 cde | 105,09 de |
| K600       | 117,75 bcd | 122,30 abc | 122,50 abc | 133,92 a | 125,42 ab |

Leaf height 50 (DAP)

| Lime (t/ha) | S Fertilizer |
|------------|--|----------------|----------------|----------------|----------------|
|            | S0 | S20 | S40 | S60 | S80 |
| K0         | 170,52 f | 182,81 bcd | 181,42 cdef | 179,68 def | 179,09 ef |
| K200       | 184,76 abcde | 189,13 abcede | 187,76abcde | 190,05 abcde | 188,76 abcede |
| K400       | 191,62 abcede | 188,38 abcde | 188,57 abcde | 188,57 abcde | 193,80 abcede |
| K600       | 194,76 abc | 198,05 a | 195,43 abc | 198,24 a | 196,09 ab |

Leaf height 80 (DAP)

| Lime (t/ha) | S Fertilizer |
|------------|--|----------------|----------------|----------------|----------------|
|            | S0 | S20 | S40 | S60 | S80 |
| K0         | 44,26 d | 46,55 cd | 46,50 cd | 40,72 e | 44,09 d |
| K200       | 48,33 abc | 48,78 abc | 49,41 abc | 48,86 bcd | 48,36 abc |
| K400       | 48,78 abc | 49,49 abc | 50,64 ab | 48,78 abc | 49,71 abc |
| K600       | 49,90 abc | 51,63 a | 50,30 abc | 50,87 a | 51,38 a |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT level.

The average plant height in K3S60 treatment showed the highest yields at the age of 50 and 80 days after planting (DAP), 133.92 cm and 198.05 cm, respectively, and the lowest at K0S0 treatment, which was 54.33 cm and 170.52 (Table 1). [15]. The availability of nutrients for plants is determined by factors that affect the ability of the soil to supply nutrients and factors that affect the ability of plants to use these nutrients. [24]

Table 2. The effect of the combination of lime treatment and several doses of S fertilizer on leaf chlorophyll of plants aged 50 and 80 days after planting (DAP), Bontobili 2020.

| Lime (t/ha) | S Fertilizer |
|------------|--|----------------|----------------|----------------|----------------|
|            | S0 | S20 | S40 | S60 | S80 |
| K0         | 43,40 b | 47,72 ab | 45,02 ab | 47,89 ab | 46,23 ab |
| K200       | 42,67 b | 42,60 b | 42,70 b | 42,86 b | 46,59 ab |
| K400       | 46,71 ab | 47,19 ab | 47,36 ab | 48,06 ab | 49,80 a |
| K600       | 47,23 ab | 49,43 a | 47,44 ab | 47,97 ab | 50,39 a |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT level.

The content of chlorophyll in the leaves is an indicator of the physiological response of corn plants to the given nutrient supply. In general, it can be said that the treatment of nutrient supply from fertilization can increase the chlorophyll content of plants. The results of the analysis showed that lime application and S fertilization did not significantly affect leaf chlorophyll, but still gave different results where lime treatment with K600S80 treatment at the age of 50 DAP and 80 DAP gave the...
highest yields of 51.38 units and 50, respectively. 39 units (Table 2). These results indicate that the physiological response of plants to fertilization is not the same, but there is a tendency that fertilization can increase leaf chlorophyll. This is because fertilizers have a role in the process of opening and closing stomata which are influenced by CO2 content and the process of photosynthesis [7].

**Table 3.** The effect of the combination of lime treatment and several doses of S fertilizer on the leaf area index (LAI) of plants aged 50 and 80 days after planting (DAP), Bontobili 2020

| Lime (t/ha) | LAI 50 (DAP) Unit S Fertilizers | LAI 80 (DAP) |
|------------|----------------------------------|-------------|
|            | S0 | S20 | S40 | S60 | S80 | K0 | K200 | K400 | K600 |
| K0         | 3.78 f | 5.28 cdef | 4.08 ef | 4.29 def | 4.25 def | 6.13 ab | 7.04 ab | 6.54 ab | 6.03 ab | 5.58 b |
| K200       | 5.62 bcde | 5.18 cdef | 5.71 bcd | 4.96 def | 5.71 bcd | 6.95 ab | 6.96 ab | 6.50 ab | 7.47 a | 7.59 a |
| K400       | 6.54 abc | 6.68 abc | 6.61 abc | 6.99 ab | 7.09 ab | 6.92 ab | 6.21 ab | 6.76 ab | 6.47 ab | 6.84 ab |
| K600       | 6.87 ab | 6.96 ab | 6.95 ab | 7.47 a | 7.59 a | 6.59 ab | 7.32 a | 6.94 ab | 6.39 ab | 7.48 a |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT level. According to [22], better leaf growth will allow plants to be able to receive maximum light for the plant growth process. The wider the leaves of corn plants, the ability of maize plants to receive light increases. [14] stated that the wider the leaf area of the maize plant, the more CO2 added for photosynthesis will increase so as to increase plant growth. The ability of maize plants to receive light is influenced by plant population density. In an optimal population, the light received by the plant will be optimal so that it produces leaves with a wider surface. The LAI results obtained ranged from 3.38 to 6.82 (Table 3), according to [5] as a way of calculating the ability of plants to photosynthesize. The LAI value was treated to increase the absorption of solar energy, resulting in an increase in maize productivity. The productivity rate according to [14] will increase in line with the increase in LAI due to an increase in total light capture. Leaf area is a determining factor for leaf area index. The wider the leaf area, in this case the area of the land shaded by each plant is the same, the greater the Leaf Area Index, the more active a plant is in the process of photosynthesis. Leaf area index also has a fairly close relationship with plant height and leaf area. By knowing the LAI of a plant, the biomass content of the plant can also be known.
Table 4. The effect of the combination of lime treatment and several doses of S fertilizer on the length of the ear and the diameter of the ear (cm), Bontobili 2020

| Lime (t/ha) | Ear Length (cm) | S Fertilizers | | | |
|---|---|---|---|---|---|
| | | S0 | S20 | S40 | S60 | S80 |
| K0 | 14.53 b | 14.98 ab | 15.03 ab | 14.83 ab | 15.67 ab |
| K200 | 15.18 ab | 15.55 ab | 14.83 ab | 15.47 ab | 15.85 ab |
| K400 | 14.16 b | 15.13 ab | 15.93 ab | 15.47 ab | 14.88 ab |
| K600 | 14.83 ab | 15.12 ab | 15.93 ab | 16.42 a | 15.88 ab |

| Ear Diameter (cm) | | | | | |
|---|---|---|---|---|---|
| K0 | 4.82 abc | 4.80 abc | 4.74 bc | 4.66 cd | 4.85 ab |
| K200 | 4.89 ab | 4.75 bc | 4.82 abc | 4.72 bcd | 4.75 bc |
| K400 | 4.56 d | 4.90 ab | 4.85 ab | 4.75 bc | 4.71 bcd |
| K600 | 4.80 abc | 4.85 ab | 4.82 abc | 4.98 a | 4.82 abc |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT. level

Table 5. The effect of the combination of giving gifts and several doses of S fertilizer on the number of seeds and number of rows, Bontobili 2020

| Lime (t/ha) | Number of seeds | S Fertilizers | | | |
|---|---|---|---|---|---|
| | | S0 | S20 | S40 | S60 | S80 |
| K0 | 31.87 b | 31.91 ab | 31.73 ab | 32.00 b | 33.60 ab |
| K200 | 32.30 ab | 33.93 ab | 33.13 ab | 33.23 ab | 35.15 a |
| K400 | 33.63 ab | 33.57 ab | 34.30 ab | 33.93 ab | 34.00 ab |
| K600 | 33.73 ab | 33.37 ab | 34.80 a | 33.87 ab | 34.67 ab |

| Number of Rows | | | | | |
|---|---|---|---|---|---|
| K0 | 15.53 abc | 15.60 abc | 14.93 c | 15.47 abc | 15.40 abc |
| K200 | 15.87 abc | 15.67 abc | 15.93 abc | 15.13 bc | 15.60 abc |
| K400 | 15.33 abc | 15.73 abc | 15.67 abc | 15.67 abc | 15.33 abc |
| K600 | 16.07 ab | 16.07 ab | 16.13 ab | 16.20 ab | 16.33 a |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT. level

The treatment of giving lime and S fertilizer was not significantly different from one treatment to another. However, in general the K600 S80 treatment had the best effect on the diameter of the cob, the number of rows of seeds, the number of seeds/rows (Table 4, 5).
Table 6. Effect of combination of lime treatment and several doses of S fertilizer on H t/ha maize JH29, Bontobili 2020

| Lime (t/ha) | Yield (t/ha) | S Fertilizer |
|------------|--------------|--------------|
| K0         | S0 | 9.39 f    | 9.43 f    |
| K200       | S20| 10.13 abcd| 10.06 abcd|
| K400       | S40| 9.91 abcdef| 9.72 cdef |
| K600       | S60| 10.49 abc | 10.81 a   |
| K0         | S80| 9.85 bcdf |
| K200       | S20| 9.24 f    |
| K400       | S40| 10.44 abcd|
| K600       | S60| 10.64 a   |

Note. The numbers in the same column followed by the same letter are not significantly different at the 0.05 DMRT. level

The average research results ranged from 9.03 t/ha – 10.81 t/ha. The highest yield was obtained by giving lime and S fertilizer at the K3S3 dose (600 kg/ha lime and 60 t/ha S fertilizer) showing the highest yield of 10.81 t/ha and not significantly different from the K3S4 treatment (600 t/ha lime), and S fertilizer 80 kg/ha) which is 10.64 t/ha (Table.6). Sulfur is absorbed by plants in the form of sulfate ions SO42-. Soil with low pH contains low sulfate ions, with the application of S 60 kg/ha and lime at 600 kg/ha can overcome soil acidity and provide more optimal results due to the availability of micro nutrients in relatively high soil solution at low pH [17].

4. Conclusion
The application of lime at 600 kg/ha and S fertilizer at a rate of 60 kg S/ha (K3S3) gave the highest yield of 10.81 t/ha, the lowest was in the K0S2 treatment (without lime with a dose of S fertilizer of 40 kg/ha).

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