Determination of potassium fertilizer requirement of maize hybrid with high K availability in the soil

Herawati and Syafruddin
Indonesian Cereal Research Institute
Jl. Dr. Ratulangi No. 274 Maros, Sulawesi Selatan
Email: herawati.serealia@yahoo.com

All authors are the main contributors to this paper

Abstract. Fertilization of K is to be required to increase the productivity of maize besides fertilization of N and P. Therefore, it must be given potassium with the right dosage to fill up the requirement of potassium for maize. This objective of this study was to determine the requirement of K fertilizer of maize hybrid at high K availability in the soil. This research was conducted at the Experimental Farm of Bontobili, Gowa from February – June 2017. This research was arranged in a split-plot design with three replication. The main plot was varieties of hybrid maize i.e. Nasa-29, Bima-4, and Bima-20. The subplots were the dose of potassium fertilizer that consisted of 0, 20, 40, 60, 80, and 100 kg K₂O ha⁻¹. The results of this research showed that optimal K fertilizer for better plant growth and yield attribute was found 20–100 kg K₂O ha⁻¹. Recommendation of K fertilizer depending on yield attainable. If attainable yield ≥ 11 t/ha, recommended K fertilizer was 55 – 66 kg K₂O ha⁻¹, a, but if attainable yield ≤10 t/ha it was not needed K fertilizer. We suggested to preventing a decrease in the availability of potassium nutrients in the soil, prevented decreasing productivity, and to kept sustainability productivity was requires maintenance of K fertilizer.

1. Introduction
Potassium requirement to increase the productivity of maize in large quantities after N and P. Potassium activates of enzyme catalyst in plant photosynthesis and plant metabolism, controls stomatal opening, protein synthesis, translocation of starch and water, and increasing yield and plant resistance to disease [1], [2], [3]. Potassium has a significant effect on leaf chlorophyll in corn plants [4]. Potassium deficiency can reduce the amount of leaf chlorophyll [5]. Leaf chlorophyll greatly influences the process of photosynthesis.

Potassium fertilization is expected to overcome the limitations of potassium elements for maize plants. Various studies have shown that fertilization of K to improves plant growth so that maize yields also increase. The addition of K to the optimum dose can improve the growth and productivity of maize [6]. Potassium can reduce chlorosis and yellow spots on maize leave up to 59.52% [5], increasing grain weight by 8%, yield increased from 7.81 t ha⁻¹ without K fertilizer application to 11.14 t/ha with of 60 kg K₂O ha⁻¹[7].

Maize hybrid varieties have a different response to fertilizer application. Maize varieties have different responses to N fertilization [8], P fertilization [9] and K fertilization [10], [11], due to differences in absorption, translocation, accumulation, plant utilization for growth and yield potential.
The determination of fertilizer dosage is often based on nutrient availability. The results of the study by [12], [13] analysis of soil with K nutrient classified as high > 325 ppm (using 5% KCl extract) and [14] argued that K nutrient was classified as high > 190 ppm (using NH4OAc extract). The maize plants were not responsive to K fertilizer application if yield obtained without K ≤ 9 t ha⁻¹, so K is not needed if the yield target ≤ 9 t ha⁻¹. But now, there are many hybrid maize varieties that have the yield potential > 11 t ha⁻¹[15], therefore an evaluation of potassium fertilizer on high availability in soil for several varieties with different productivity is needed. Determining the amount of fertilizer in addition to adjusting for nutrient availability, as well as the yield potential of the varieties being developed or attainable yield that might be achieved [16], [17], [18], [19].

This study aims to determine the potassium requirement of hybrid maize varieties with different yield potential on high K availability in soil.

2. Materials and Methods
This research was conducted at the Experimental Farm of Bontobili, Gowa (South Sulawesi) from February – June 2017. The soil of this research was site loam, pH 5.6, low in C-organic (2.83 %), low in nitrogen (0.11 %), high phosphorus (28.7 ppm), and high in potassium extract HCl (96 me/100g).

2.1 Experimental design and procedure
The research was arranged in a split-plot design with three replication. The main plot was varieties of hybrid maize i.e. Nasa-29, Bima-4, and Bima-20. The subplot was the dose of potassium fertilizer that consisted of 0, 20, 40, 60, 80, dan 100 kg K₂O ha⁻¹. The subplots it an area 5.6 m x 5m. The seed was planted with twin rows (90-50 cm) and was established to accommodate 8 rows and 20 cm plant distance. Recommended basal dose of nitrogen at the rate of 210 kg N ha⁻¹ and phosphorus at the rate of 90 kg P₂O₅ ha⁻¹. The whole of the phosphorus and potassium along with half of the nitrogen fertilizer were applied at the 7 days after planting. While remaining half of nitrogen was applied at 40 days after planting. All of the agronomic practices were kept normal and uniform for all the experimental units.

2.2 Analisis Data
The data were recorded on plant height (cm), stem diameter (cm), leaf chlorophyll (using SPAD-Unit)), leaf area index, length and diameter of cob, 1000-grains weight (g), grains-cob weight ratio, harvest index, and grain yield (t ha⁻¹). The data were analyzed statistically using SAS 9.0. Means were separated using DMRT to differentiate the treatment at a 5% level of probability.

3. Results and Discussion
3.1 Vegetative growth
The data presented in Table 1 showed that plant height was not differedenced between each K treatment in Nasa-29 and Bima-20 varieties, but there were significant differences in Bima-4 varieties. In general, the Nasa-29 variety was relatively higher than the Bima-4 and Bima-20 varieties on the same K treatment. Nasa-29 had a plant height of 190.1 - 202.8 cm and the highest plant was obtained at a treatment of 20 kg K₂O ha⁻¹, while the Bima-4 variety had a plant height of 174.1 - 192.9 cm and the Bima-20 was 182.7 - 192.0 cm which has the highest plants obtained at treatment 60 and 40 kg K₂O ha⁻¹ respectively for Bima-4 and Bima-20. This shows that Nasa-29 was more efficient in utilizing K fertilizer to increase plant height compared to Bima-4 and Bima-20 varieties. Potassium can increase the intermodal length so that the plant height was increased and more accumulation of photosynthesis took place [20].

Stem diameter, leaf chlorophyll, and leaf area index did not significant differences between each variety, K fertilizers, or their interactions. Nasa-29 variety has a stem diameter of 2.35 - 2.72 cm, leaf chlorophyll 49.91 - 52.22 units, and leaf area index 5.79 - 6.41. Bima-4 has a diameter stems from 2.30 until 2.58 cm, leaf chlorophyll 48.20 - 5.89 units, and leaf area index 5.25 - 5.79, and Bima-20 had a stem diameter of 2.35 - 2.53 cm, leaf chlorophyll 51.79 - 53.52 units, and the leaf area index 5.08 - 6.09.
Table 1. Average of plant height, stem diameter, leaf chlorophyll, and leaf area index of hybrid maize in various dosages of K fertilizer

| Potassium Rate (kg K₂O ha⁻¹) | Nasa-29 | Bima-4 | Bima-20 |
|-----------------------------|---------|--------|---------|
| 0                           | 190.11 a q | 174.30 a p | 184.78 a pq |
| 20                          | 202.87 a q | 174.11 a p | 184.00 a p |
| 40                          | 199.39 a p | 188.96 ab p | 192.00 a p |
| 60                          | 197.17 a p | 192.86 b p | 186.89 a p |
| 80                          | 197.69 a q | 178.06 ab p | 182.72 a pq |
| 100                         | 196.39 a p | 184.67 ab p | 187.61 a p |

CV (%) 7.6

| Potassium Rate (kg K₂O ha⁻¹) | Nasa-29 | Bima-4 | Bima-20 |
|-----------------------------|---------|--------|---------|
| 0                           | 2.58 tn | 2.30   | 2.39   |
| 20                          | 2.60    | 2.44   | 2.53   |
| 40                          | 2.72    | 2.53   | 2.39   |
| 60                          | 2.35    | 2.49   | 2.40   |
| 80                          | 2.42    | 2.43   | 2.35   |
| 100                         | 2.42    | 2.58   | 2.51   |

CV (%) 7.8

| Potassium Rate (kg K₂O ha⁻¹) | Nasa-29 | Bima-4 | Bima-20 |
|-----------------------------|---------|--------|---------|
| 0                           | 50.16 ns | 50.21  | 52.66   |
| 20                          | 52.22   | 48.20  | 51.79   |
| 40                          | 51.33   | 52.61  | 53.52   |
| 60                          | 50.54   | 52.89  | 51.81   |
| 80                          | 49.91   | 50.24  | 51.97   |
| 100                         | 50.88   | 52.33  | 53.01   |

CV (%) 7.4

| Potassium Rate (kg K₂O ha⁻¹) | Nasa-29 | Bima-4 | Bima-20 |
|-----------------------------|---------|--------|---------|
| 0                           | 5.96 ns | 5.25   | 5.08    |
| 20                          | 6.41    | 5.58   | 6.00    |
| 40                          | 5.98    | 5.75   | 5.17    |
| 60                          | 5.79    | 5.71   | 5.75    |
| 80                          | 6.40    | 5.79   | 5.32    |
| 100                         | 6.20    | 5.33   | 6.09    |

CV (%) 12.1

Noted: the numbers followed by the same letter (a-c) in the same column mean between the treatments of K in the same variety and the numbers followed by the same letters (p-q) in the same line means that the treatments of varieties in the same K are not significantly different according to DMRT = 0.05, ns = not significantly different.

a. Yield Attributes

The statistical analysis of the length, diameter cob, and grains-cob ratio showed that significant differences, whereas the 1000-grains weight and harvest index did not significantly different between treatments (Table 2). The average length of cob and the grains-cob ratio between each of K treatment in the three varieties did not significantly different, but there were significant differences in the response of the varieties to the same K treatment. Nasa-29 variety, especially the application of 40-80 kg K₂O ha⁻¹ has a higher significance of cob length and grains-cob ratio compared to the Bima-20 variety, but it was not significant compared to the Bima-4 variety. Cob length of Nasa-29 variety was 17.14-18.0 cm with grains-cob ratio was 0.78-0.81, Bima-4 was 15.4-17.34 cm with grains-cob ratio was 0.73-0.82, and Bima-20 was 14.63-15.82 cm with grains-cob ratio was 0.73-0.76 (Table 2).

Fertilization of K had no significant effect on the cob diameter of Nasa-29 and Bima-20 varieties but had a significant effect on Bima-4 varieties. The Bima-4 variety has a bigger cob diameter than the Nasa-29 variety when the application of 40-100 kg K₂O ha⁻¹. Bima-4 had a diameter of 4.69 – 4.98 cm,
while Nasa-29 was 4.64 – 4.42 cm. In general, Nasa-29 variety had more than one cob per plant and Bima-4 had one cob per plant so that at the same amount of assimilation, translocation of assimilating by potassium in Nasa-29 was divided while translocation assimilates in Bima-4 just focused on one cob. The research by Dhake [21] and Zhen [21] found that potassium exhibited significantly cob diameter.

Table 2. Average cob length, cob diameter, the weight of 1000 grains, grains-cob ratio, and harvest index of hybrid maize in various dosages of K fertilizer

| Potassium rate (kg K₂O ha⁻¹) | Nasa-29 | Bima-4 | Bima-20 |
|-----------------------------|---------|--------|---------|
| Cob length (cm)             |         |        |         |
| 0                           | 17,22 a p | 16,57 a p | 15,82 a p |
| 20                          | 17,76 a q | 15,64 a p | 14,63 a p |
| 40                          | 18,00 a q | 17,09 a q | 14,91 a p |
| 60                          | 17,14 a q | 16,36 a pq | 15,19 a p |
| 80                          | 17,68 a q | 17,34 a q | 15,22 a p |
| 100                         | 17,24 a p | 17,27 a p | 15,80 a p |
| **CV (%)**                  | 6,0     |        |         |
| Cob Diameter (cm)           |         |        |         |
| 0                           | 4,50 a p | 4,95 ab q | 4,85 a q |
| 20                          | 4,64 a p | 4,69 a p | 4,63 a p |
| 40                          | 4,54 a p | 4,98 b q | 4,66 a p |
| 60                          | 4,42 a p | 4,92 ab q | 4,85 a q |
| 80                          | 4,43 a p | 4,91 ab q | 4,70 a pq |
| 100                         | 4,48 a p | 4,94 ab q | 4,62 a p |
| **CV (%)**                  | 3,0     |        |         |
| 1000-grains weight (g)      |         |        |         |
| 0                           | 410,21 tn | 394,14 | 380,50 |
| 20                          | 390,64 | 408,90 | 376,07 |
| 40                          | 386,67 | 422,00 | 387,62 |
| 60                          | 390,76 | 426,39 | 394,72 |
| 80                          | 405,60 | 426,73 | 382,68 |
| 100                         | 396,82 | 425,15 | 368,96 |
| **CV (%)**                  | 6,4     |        |         |
| Grains-cob ratio            |         |        |         |
| 0                           | 0,78 a p | 0,74 a p | 0,74 a p |
| 20                          | 0,78 a p | 0,73 a p | 0,73 a p |
| 40                          | 0,81 a q | 0,82 a q | 0,76 a p |
| 60                          | 0,80 a q | 0,78 a pq | 0,74 a p |
| 80                          | 0,79 a q | 0,74 a p | 0,76 a p |
| 100                         | 0,80 a q | 0,73 a p | 0,75 a p |
| **CV (%)**                  | 3,4     |        |         |
| Harvest index               |         |        |         |
| 0                           | 0,37 tn | 0,34 | 0,35 |
| 20                          | 0,34 | 0,32 | 0,33 |
| 40                          | 0,34 | 0,38 | 0,33 |
| 60                          | 0,35 | 0,34 | 0,31 |
| 80                          | 0,34 | 0,30 | 0,32 |
| 100                         | 0,36 | 0,33 | 0,32 |
| **CV (%)**                  | 9,2     |        |         |

Noted: the numbers followed by the same letter (a-c) in the same column mean between the treatments of K in the same variety and the numbers followed by the same letters (p-q) in the same line means that the treatments of varieties in the same K are not significantly different according to DMRT = 0,05; ns = not significantly different.

Nasa-29 variety had a weight of 1000 grains was 386.67 g and the harvest index was 0.34-0.36, the Bima-4 had weighed 1000 grains was 394.14 - 4226.73 g and the harvest index was 0.32 - 0.38,
while Bima-20 has a weight of 1000 grains was 368.9 - 394.72 g with a harvest index was 0.31 - 0.35. Based on vegetative growth and yield attribute components, the optimal of K fertilization for maize in high K availability in the soil to better vegetative growth and yield attribute was 20-100 kg K₂O/ha. Generally, the recommendation of potassium in low K availability in the soil was 40-120 kg K₂O ha⁻¹. However, recommendation potassium in soil potassium condition approximately 38.22-41.33 mg/kg was 40-120 kg ha⁻¹ [21].

b. Potassium Fertilization Recommendations

Varieties have a different response to grain yield responses by potassium fertilization. Potassium fertilization was significantly quadratic regression in Nasa-29 and Bima-4 varieties, but it was not significant in Bima-20 varieties. Based on the equation in Figure 1, it shows that the application of K on Nasa-29 variety up to a dose of 66 kg K₂O ha⁻¹ will be increasing grain yield, without fertilizing K will produce 10.42 t ha⁻¹ and application of 66 kg K₂O ha⁻¹ will increasing of grain yield until the maximum is 11.29 t/ha. While K fertilization on Bima-4 variety up to a dose of 51 kg K₂O ha⁻¹ the grain yield will be increase, without K fertilization in the Bima-4 variety had grain yield was 9.79 t ha⁻¹, if done K fertilization was 51 kg K₂O ha⁻¹ will produce a maximum grain yield was 11.09 t ha⁻¹. Whereas the Bima-20 variety does not respond to K fertilization, without K or even with K fertilization, the yield will be ± 8.80 t/ha.

The results of this study can recommend that the yield attainable or yield target >11 t ha⁻¹ in soil with high K availability still needs fertilization > 51 kg K₂O ha⁻¹ if the yield target <10 t ha⁻¹ does not need to be fertilized K. In soils with high K availability was not required K fertilization [13]. In soils that have high potential K nutrient availability with yields of 8-9 t ha⁻¹, it was not necessary to apply potassium fertilizer [12]. Even though there was no response K fertilizer with target/attainable yield of maize was 8-10 t ha⁻¹, to prevent a decrease in the availability of potassium nutrients in the soil, to prevent decreasing productivity and to keep sustainability productivities is requires maintenance of K fertilizer. We suggestion that maize planting in dry land was needed maintenance 10-20 kg K₂O ha⁻¹ for every two times planting seasons (cropping pattern maize-maize), and in the low land after rice planting (cropping pattern rice-maize), K fertilization maintenance was carried out on rice planting (K fertilizer according to recommendations for rice plants).

![Figure 1. Correlation of K fertilizer with grain yield](image-url)
4. Conclusion
Hybrid maize with attainable yield ≤ 10 t ha\(^{-1}\) and high K nutrient availability status in the soil is not a response to K fertilization. Recommendation for fertilizing K on soil with high K nutrient availability depends on the attainable yield to be obtained. The attainable yield of ≥11 t ha\(^{-1}\) requires K fertilizer as much as 51 - 66 kg K\(_2\)O ha\(^{-1}\), for the attainable yield is ≤10 t ha\(^{-1}\) no K fertilization was needed.

References
[1] Prajapati K and Modi H A 2012 Indian J. Plant Sci. 1 177–86
[2] Patil R B, Kadam A S and Wadje S S 2011 Int. J. Pharma Bio Sci. 2 242–6
[3] Zare, Vazin F and Hassanzadehdelouei M 2014 Cercet. Agron. Mold. 47 39–47
[4] Zhao X, Du Q, Zhao Y, Wang H, Li Y, Wang X and Yu H 2016 Agric. Sci. 7 44–53
[5] Lin C Y and Yeh D M 2008 HortScience 43 146–8
[6] Amanullah, Iqbal A, Irfanullah and Hidayat Z 2016 Sci. Rep. 6 1–12
[7] Koca Y O, Kaptan M A, Erekul O and Alkan U 2016 Sci. Pap. Ser. A. Agron. 58 232–8
[8] Ahera T, Debele T and Wegary D 2017 Int. J. Agron. 2017 1–13
[9] Wasonga C, Sigunga D and Musandu A 2010 African Crop Sci. J. 16 161–73
[10] Ali T, Anwar S, Shah W A and Ahmad B 2004 J. Agron. 3 201–7
[11] Gomaa M, Radwan F I, Kandil E E and Challabi D H H A. 2017 ALEXANDRIA Sci. Exch. J. 38 506–14
[12] Sutriadi M T, Setyorini D, Nursyamsi D and Murni M 2008 J. tanah Trop. 13 179–87
[13] Subiska I G. and Sabiham S 2009 J. Tanah dan Iklim 30 17–24
[14] Biljon J J Van, Fouche D S and Botha A D P 2008 s. Afr. J. Plant Soil 25 64–70
[15] Aqil M and Arvan R Y 2016 Balai Penelitian Tanaman Serealia. Badan Penelitian dan Pengembangan Pertanian
[16] Syafrudin 2015 J. litbang Pertan. 34 105–16
[17] Syafrudin 2016 J. Pengkaj. dan Pengemb. Teknol. Pertan. 19 119–33
[18] Syafrudin 2018 Pangan 27 165–78
[19] Murni A M 2008 J. Tanah dan Lingkung. 10 46–9
[20] Ali A, Hussain M, Habib H S, Kiani T T, Anees M A and Rahman M A 2016 Turkish J. F. Crop. 21 36–43
[21] Dhake P R, Kale V S, Nagre P K, Bondre S V and Wankhade R S 2016 The Bioscan 11 1697–702