Growth and production of purple waxy corn (*Zea mays ceratina* Kulesh) on the application of NPK fertilizers and humic acid

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**Abstract.** The research aims to study the effect of various doses of NPK fertilizer and humic acid on the growth and production of purple waxy corn. The study was conducted in Bilonga Village, Bontonompo District, Gowa Regency, from September to December 2018. The method used was a two-factor factorial experiment and a randomized block design as the environmental design. The first factor was NPK fertilization consisting of four levels, namely Control, 250, 300, and 350 kg ha\(^{-1}\). Meanwhile, the second factor was humic acid which consists of three levels, namely 0, 15, and 20 kg ha\(^{-1}\) resulted in total of 12 treatment combinations that are repeated three times. The results show that NPK fertilization of 350 kg ha\(^{-1}\) resulted in the highest production of the purple waxy corn of 2.95 ton ha\(^{-1}\). The application of humic acid had no significant effect on the growth and production of the purple waxy corn, but the humic acid affected the increase in soil pH and cation exchanges capacity.

1. **Introduction**

   Indonesia is an agrarian country whose agricultural land area reaches around 107 hectares from the land area of Indonesia which reaches 192 million hectares. From the area of agricultural land, the area of corn is around 5.73 million hectares in 2018. Corn as a food crop in Indonesia ranks second after rice, but corn has an equally important role compared to rice. Its position as the main source of carbohydrates and protein after rice makes corn has an economic value and has a high enough opportunity to be developed as a raw material for the food processing industry [1]. Corn has a great influence on economic stability. This is because of the increasing needs in the manufacture of food ingredients, as well as animal feed and industrial raw materials. Stems, leaves and husks of the plant are used as organic mulch or compost fertilizer. Along with the increasing science and technology, corn plants are currently being developed as a producer of energy because corn produces bioethanol in large quantities [2].

   Corn production in Indonesia in 2018 amounted to 30.05 million tons, or increased by 3.91 million tons compared to 2017. Maize productivity increased by 0.27%, ie 52.27 ku / ha in 2017, rising to 52.41 ku / ha in 2018. Corn production in South Sulawesi Province in 2018 was 2.34 million tons or increased 0.01 million tons compared to 2017. Corn demand in 2018 was 16.14 million tons with consumption level 1.64 kg / capita / year [3].
According to Juhaeti et al. [4], South Sulawesi is the best waxy corn producing region in Indonesia, due to the high amylopectin content (> 90%) so that when compared to waxy corn from other regions, the taste is more savoury, fluffier and soft. In the outer layer of corn seeds there is lycopene, an antioxidant that can prevent various types of cancer. According to Iriani [5], waxy corn is a local corn that has a low yield potential, which is less than 2 tons / ha, small cob with a diameter of 10-11 mm and very sensitive to downy mildew. The purple waxy corn is one of the food commodities that is still less well known because it has not been widely cultivated in Indonesia. One of the reasons for the lack of recognition of the purple waxy corn because it has not received serious attention. Purple corn seeds are difficult to obtain because they are rarely cultivated by farmers. Nutrient composition of corn is not much different from the yellow sweet corn and white waxy corn. The constraints of purple waxy corn production are not much different from the constraints on the yellow or white waxy corn, which are less optimal cultivation techniques, inappropriate dosage fertilization, and planting of local varieties continuously.

The initial stage of developing the purple waxy corn can be started by utilizing available seeds and fertilizing them with the right dosage. Fertilization is one of the important activities in cultivation to increase crop productivity. Cultivated plants generally require macro or micro nutrients [6]. The use of fertilizers for unfertile land is one way to increase plant growth and production. According to Novizan [7], fertilizer is defined as material added to the soil or to the canopy of plants with the aim of completing the availability of nutrients. Fertilizers used in the form of organic and inorganic fertilizers. To achieve optimum results, corn plants require adequate nutrient input. Nutrient is an important factor that influences plant growth and development. The availability of nutrients in the soil decreases due to intensive crop cultivation, especially macro nutrients such as nitrogen, phosphorus, and potassium due to transported by crops.

NPK fertilizer is a compound fertilizer that contains elements of N, P and K in a balanced proportion and can be used as a basic fertilizer and supplement in the growth and production of a plant. In addition to providing NPK elements at once, the NPK fertilizer types usually also contained other elements, both macro and micro elements. Inorganic fertilizers have a large role to fulfil the nutrients for plants, because organic fertilizers provide more limited nutrients. The elements N, P, and K are essential nutrients that must be available for plant metabolism. The function of N for plants is as a constituent component of amino acids, proteins, enzymes, vitamin B complex, hormones and chlorophyll [8]. The phosphate functions in energy transfer, cell membrane formation, metabolism, carbohydrates and protein. On the other hand, potassium functions as an enzyme activator, triggering the translocation of carbohydrates from leaves to other organs, an important component in the mechanism of osmotic regulation in cells [9].

One alternative that can be used to help the absorption of nutrients in plants is humic acid. Humic acid can affect directly and indirectly. Indirectly, namely improving soil fertility status both in physical, chemical, and biological soil properties [10]. Increasing the fertility status of the soil will result in increased nutrient uptake in plants, hence plant growth and production will be more optimal. The effect of humic acid directly is to improve metabolic processes in plants, such as increasing the rate of plant photosynthesis. Humic acid affecting corn plants is seen by increasing the growth of the plant's upper parts and roots.

Humic acid is an organic soil conditioner. Testing the effect of a combination of NPK fertilizer and humic acid has been carried out on corn plants in Gowa Regency. The results showed the addition of 0.15% humic acid reduced the use of NPK fertilizer by 25%. The dosage of NPK fertilizer 350 kg / ha only can produce 10.14 tons / ha while the use of NPK fertilizer 257.5 kg / ha and 0.15% humic acid can produce higher yield (10.21 tons / ha) [11]. Based on the description that has been stated, then research on growth and production of purple waxy corn on NPK fertilizer and humic acid is carried out.

2. Methodology
2.1. Experimental design
The study was conducted in Bilonga Village, Bontonompo District, Gowa Regency. The study was carried out from September to December 2018. The study employed a two-factor factorial design using a randomized block design as the experimental design. The first factor was NPK fertilizer consisted of four levels namely 0, 250, 300 and 350 kg ha\(^{-1}\) equivalent to 150, 180 and 210 g per plot, respectively. The second factor was the application of humic acid consisted of three levels, namely 0, 15 and 20 kg ha\(^{-1}\). Based on the number of treatments tested, 12 combination trials were repeated three times to produce 36 experimental plots.

2.2. Planting
Prior to planting, soil tillage was performed using a hand tractor to obtain loose soil texture that will improve soil aeration. Subsequently, a 3 m × 2 m with a height of ± 30 cm were made and the distance between the beds was set to 100 cm. Seeds of local purple waxy corn were soaked in warm water for ± 30 minutes. Two seeds were planted in planting holes with plant spacing of 60 cm × 20 cm.

2.3. NPK application
The NPK fertilizer treatment was carried out twice according to the dosage treatment by making a hole with planting stick between planting holes. The first fertilization was conducted at 10 days after planting (DAP) with NPK fertilizer dose of 150 kg ha\(^{-1}\) (p1), 200 kg ha\(^{-1}\) (p2) and 250 kg ha\(^{-1}\) (p3). The second fertilization was carried out at 30 DAP with NPK fertilizer dose of 100 kg ha\(^{-1}\) for each NPK dose treatment (p1, p2 and p3).

2.4. Humic acid application
The application of humic acid was conducted by split application at planting and at 15 DAP. Humic acid was spread on the surface of the ground. The first application was 10 kg ha\(^{-1}\) (h1) and 15 kg ha\(^{-1}\) (h2) and the second application was 5 kg ha\(^{-1}\) for each humic acid treatment dosage (h1 and h2).

2.5. Data analysis
Data were analysed using two way analysis of variance based on randomized block design. A further test of least significant difference (LSD) at level of 5% was conducted if there was a significant effect of the treatments.

3. Results

3.1. Effect of NPK fertilizer and humic acid on the growth of purple waxy corn
Variance analysis results show that NPK fertilization treatment significantly affected plant height, number of leaves, and leaf area but did not significantly affect the stem diameter of the purple waxy corn plants. Humic acid treatment and its interactions with the NPK treatments did not have significant effect on the growth parameter of the purple waxy corn. The average values of the purple waxy corn growth parameters on different application of NPK fertilizer and humic acid are presented in table 1.

Table 1 shows that the growth of purple waxy corn increased with the dosage of NPK given. As general, the application of NPK fertilizer at higher dose increase the plant height, number of leaves and leaf area of the purple waxy corn. Plant treated with the 350 kg ha\(^{-1}\) NPK fertilizer, resulted in the highest plant, widest leaf area and plant with biggest number of leaves. However, the values of these parameters seems to be not different significantly with the other NPK fertilizer dosages (250 and 300 kg ha\(^{-1}\)). No significant differences were found between the humic acid treatments on the growth parameters of the purple waxy corn. In the recent study, application of this compound did not necessarily increase the plan height, number of leaves, and leaf area of the waxy corn variety.

Similarly to the response of the purple waxy corn on the humic acid application, none of the treatment applied had significant effect on the stem diameter of the waxy corn. Nevertheless, biggest stem diameter was observed in the application of NPK fertilizer of 350 kg ha\(^{-1}\), and 15 kg ha\(^{-1}\) of
humic acid and the smallest stem diameter shown by the control treatment without application of NPK fertilizer and humic acid.

**Table 1.** Effect of different dosages of NPK fertilizer and humic acid on the growth of purple waxy corn.

| Humic acid | NPK fertilizer | Plant height at 50 DAP (cm) |   |   |
|------------|----------------|-----------------------------|---|---|
|            | Control (p0)   | 250 kg ha\(^{-1}\) (p1)    | 300 kg ha\(^{-1}\) (p2) | 350 kg ha\(^{-1}\) (p3) |
| Control (h0) | 132.94         | 134.44                      | 137.17                     | 140.44                    |
| 15 kg ha\(^{-1}\) (h1) | 133.10         | 136.44                      | 138.72                     | 141.00                    |
| 20 kg ha\(^{-1}\) (h2) | 132.33         | 136.61                      | 135.78                     | 141.56                    |
| **Average** | **132.79b**    | **135.83ab**                | **137.22ab**               | **141.00a**               |
| **LSD\(_{0.05}\)** | **5.58**       |                             |                            |                            |

| Humic acid | Number of leaves (leaves) | Leaf area (cm\(^2\)) | Stem diameter (mm) |
|------------|---------------------------|-----------------------|--------------------|
|            | Control (h0)              | 6.22                  | 191.97             | 13.00              |
|            | 15 kg ha\(^{-1}\) (h1)   | 6.22                  | 194.88             | 13.20              |
|            | 20 kg ha\(^{-1}\) (h2)   | 6.17                  | 190.61             | 13.50              |
| **Average** | **6.20b**                 | **6.62ab**            | **224.35b**        | **13.70**          |
| **LSD\(_{0.05}\)** | **0.63**                 |                       | **23.96**          |                    |

Numbers followed by different alphabets in a same row mean significantly different based on LSD test at \(\alpha=5\%\). DAP = Days After Planting.

3.2. **Effect of NPK fertilizer and humic acid on the production parameters**

Application of NPK fertilizer significantly increased production of purple waxy corn such as number of row per cob, number of kernels per row (figure 1), weight of 1000 kernels, rendement and productivity (table 2). Figure 1 shows that application of NPK fertilizer increase the quality of the purple waxy corn kernels indicated by higher number of row per cob and kernels per row. Even though there was no significant effect of the NPK fertilizer on the ear diameter, the average values of the parameter increased with the dose of NPK fertilizer. This caused higher number of row and kernels per cob at higher dose of NPK fertilizer.

Table 2 reveals that application of NPK fertilizer increased the productivity of the purple waxy corn. The higher the dose of NPK fertilizers applied, the higher the size of the kernels, the rendemen and the productivity of the purple waxy corn. Although no significant differences between the humic
Acid doses applied, the weight of 1000 kernels, rendemen and productivity of the purple waxy corn increased with the humic acid dose. Highest productivity was shown by the application of NPK fertilizer of 350 kg per hectare and 25 kg per hectare humic acid (3.05 ton per hectare).

Figure 1. Average of ear length and diameter, number of row per cob, and number of kernels per row of purple waxy corn on different dosages of NPK fertilizer. Numbers followed by different alphabets in a same row mean significantly different based on LSD test at α=5%.

Table 2. Effect of different dosages of NPK fertilizer and humic acid on the average of 1000 kernels weight (g), rendemen (%), and productivity (ton/ha) of purple waxy corn.

| Humic acid | NPK Fertilizer | Weight of 1000 kernels (g) | Rendemen (%) | Productivity (ton/ha) |
|------------|----------------|-----------------------------|--------------|-----------------------|
|            | Control (p0)   | 250 kg ha⁻¹ (p1) | 300 kg ha⁻¹ (p2) | 350 kg ha⁻¹ (p3) | Average | Control (h0) | 15 kg ha⁻¹ (h1) | 20 kg ha⁻¹ (h2) | Average | Control (h0) | 15 kg ha⁻¹ (h1) | 20 kg ha⁻¹ (h2) | Average |
| Control (h0) | 159.73 | 152.98 | 165.90 | 179.97 | 164.65 | 62.09 | 67.06 | 69.70 | 73.04 | 67.97 | 2.15 | 1.95 | 2.15 | 2.87 | 2.28 |
| 15 kg ha⁻¹ (h1) | 155.83 | 152.27 | 165.40 | 176.27 | 162.44 | 56.44 | 66.60 | 64.68 | 71.06 | 64.69 | 1.65 | 1.99 | 2.24 | 2.92 | 2.20 |
| 20 kg ha⁻¹ (h2) | 160.67 | 171.67 | 164.60 | 192.13 | 172.27 | 63.46 | 69.38 | 68.21 | 73.82 | 68.72 | 1.96 | 1.90 | 2.51 | 3.05 | 2.36 |
| Average | 158.74b | 158.97ab | 165.30ab | 182.79a | | 60.67c | 67.68b | 67.53b | 72.64a | | 1.92b | 1.95b | 2.30b | 2.95a | |
| LSD₀.₀₅ | 18.69 | | | | | 4.42 | | | | | 0.43 | | | | |
4. Discussion
The results of the experiment show that NPK fertilization treatment had a very significant effect on the observed growth and production parameters of the purple waxy corn. The application of NPK fertilizer produced higher plants compared to the control treatment or without application of NPK fertilizer. This is due to increase in the availability of N nutrient which is needed for vegetative growth of plants. This is in accordance with the opinion of Law-Ogbomo & Law-Ogbomo [12] which states that the administration of NPK compound fertilizer significantly increases plant height, plant dry weight and yield of corn kernels.

In addition to plant height, the number of leaves is one important aspect for plants and the growth and yield of plants is influenced by the number of leaves as a place for photosynthesis to produce the energy needed for plant growth [13]. The number of leaves is influenced by the availability of Nitrogen (N), N nutrients absorbed by plants then play an important role in increasing chlorophyll in the leaves, with increasing chlorophyll also increases the rate of photosynthesis which affects the formation of the number of leaves in the corn plant [14].

Some balanced fertilization research can be achieved if we pay attention to soil nutrient status, soil nutrient dynamics, and plant requirements to achieve optimum production. According to Hardjowigeno [1], NPK fertilizer application has the advantage that a one-time application of fertilizer can include several elements so that it is more efficient than using a single fertilizer. The application of 350 kg per hectare of NPK fertilizer resulted in higher plant height and leaf area, highest weight of 1000 kernels and produced the highest production per hectare. Thus, this dose is the best potential fertilizer dose to be used based on the level of production and other parameters.

Humic acid treatment did not significantly affect all growth and production parameters observed. Several studies have shown that the application of humic acid had an effect on increasing growth, nutrient uptake, and production in various plants [16]. Despite this, the application of humic acid showed an increase in soil cation exchanges capacity (CEC) values in the plot with of the 25 kg per hectare humic acid (figure 2). This is consistent with the opinion of Stevenson [17] which states that the addition of humic acid can increase CEC and improve the chemical properties of the soil.

![Figure 2. Effect of humic acid application on soil pH and Cation Exchanges Capacity (CEC).](image)

The non-significant effect of the humic acid in the recent study might due to the event of high rainfall following the application of humic acid, which is applied on the surface of the soil. Rainfall in Gowa Regency was 205.25 mm with a temperature of 27.1 °C, the highest rainfall monitored by
several observation stations, in December which reached an average of 617 mm (data not shown). According to Novizan [7], the efficiency of fertilizer application or things that support growth and production can consider soil conditions, dosage, time and placement.

5. Conclusions

Based on the results of the recent study, it can be concluded as follows:

- NPK fertilization with a dose of 350 kg ha\(^{-1}\) produces the highest production of purple waxy corn (2.95 tons ha\(^{-1}\)).
- The application of humic acid did not give the best results on the growth and production of purple waxy corn, but application of 20 kg ha\(^{-1}\) humic acid and 350 kg ha\(^{-1}\) NPK fertilizer tended to produce the highest production of purple waxy corn (3.05 tons ha\(^{-1}\)) and influenced the increase in soil pH from 5.8 to 6, and CEC to 25.8 Cmol(+)/kg.

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