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# Role of phosphate fertilizer on growth and yield of hybrid maize (*Zea mays* L.)

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**Abstract.** Maize (*Zea mays* L.) is a strategic commodity because its high productivity and diverse uses. This study aims to obtain a dose of phosphate fertilizer which increases growth and yield of hybrid maize. The research was conducted on the acid dry land, Faculty of Agriculture, UNS, Jumantono in June-September 2019. The research method used was an experimental method with a Randomized Completed Block Design one factor with four dose and was repeated six times. The dose is 0; 100; 150; 200 kg. ha<sup>-1</sup> P fertilizer. The observed variables namely plant height, number of leaves, stem diameter, leaf area index, fresh stover weight, dry stover weight, weight of cobs with husks, weight of cobs without husks, average of cobs per plant, number of seeds per plant, weight of seeds per plant, weight of seeds per hectare, and weight of 100 seeds. Application of 150 kg.ha<sup>-1</sup> of phosphate fertilizer SP-36 increases growth variable on the leaf area index (LAI). The application of 150 kg.ha<sup>-1</sup> of phosphate fertilizer SP-36 increases yield variable on the weight of 100 seeds. But seen from the average dose of 100 kg.ha<sup>-1</sup> has a higher yield than the control because it increases yield per hectare (5.91%) to 2.15 tons.ha<sup>-1</sup>.

## 1. Introduction

Maize (*Zea mays*) is the second most important food crop after rice. Maize has a protein content (9.5%), higher than rice (7.4%). Maize has a higher carbohydrate content (73–75%) compared to wheat and millet (64.0%) and is equivalent to 76.2% rice, [1] also maize can produce 172 l. ha<sup>-1</sup> of oil. Maize kernels are not only consumed but can also be processed into feed, and various types of food and drinks.

Demand for maize commodities in Indonesia continues to increase from year to year. The national maize production in 2016 amounted to 23.58 million tons while the national maize demand was 16.30 million tons [2]. Indonesia should have a maize surplus of 7.28 million tons, but Indonesia still imports maize of 2.40 million tons, due to the need of maize for the feed industry of 8.90 million tons. The area of national maize plantations over the past five years (2010-2016) tends to be stagnant.

The use of superior varieties plays an important role in efforts to increase maize production and productivity. Hybrid varieties have higher yield potential compared to local varieties and free-range [3]. An increase in productivity through hybrid maize can reach 10-13 t. ha<sup>-1</sup>, far different from the seeds only <3 t.ha<sup>-1</sup>[4]. One way to increase maize yield is through fertilization.



Fertilization can increase maize yields both qualitatively and quantitatively. This is because fertilizers increase the availability of nutrients, plant health and suppress disease growth. The element of phosphorus (P) plays an important role in the transfer of energy in plant cells. It encourages root development and early fertilization, strengthens the stem to prevent fall, and increases N uptake at the beginning growth. Phosphate is also known play a role in the formation of flowers, fruits and seeds, cell division, root development which in turn improves the quality of plants. The use of phosphate fertilizer in the field often does not pay attention to the appropriate dosage. To achieve optimal fertilizer efficiency, fertilizer must be given in sufficient quantities to meet crop needs, not too much and not too little [5]. Therefore it is necessary to conduct research on the dose of phosphate fertilizer on the growth and yield of hybrid maize.

## 2. Materials and methods

This research was conducted in June 2019 until September 2019 in the Latosol acid dry land of the Faculty of Agriculture, UNS, Jumantono, Karanganyar, 110.9483 EL dan 7.63052 SL, 195 m ASL. Laboratory analysis was carried out at the Ecology and Management of Plant Production Laboratory and the Chemical and Soil Fertility Laboratory of the Faculty of Agriculture, Universitas Sebelas Maret. The materials used in this research are hybrid maize seeds Bisi-2, P fertilizer (SP36), N fertilizer (Urea), K fertilizer (KCL), and Rojokoyo manure.

This research was conducted using a Randomized Completely Block Design one factor with four dose and repeated six times. The intended dose: P0 = 0 kg. ha<sup>-1</sup> P or 0 kg. ha<sup>-1</sup> SP36 fertilizer, P1 = 100 kg. ha<sup>-1</sup> P or 277 kg. ha<sup>-1</sup> SP36 fertilizer, P2 = 150 kg. ha<sup>-1</sup> P or 417 kg. ha<sup>-1</sup> SP36 fertilizer, P3 = 200 kg. ha<sup>-1</sup> P or 556 kg. ha<sup>-1</sup> SP36 fertilizer. The observed variables namely plant height, number of leaves, stem diameter, leaf area index, fresh stover weight, dry stover weight, weight of cobs with husks, weight of cobs without husks, average of cobs per plant, number of seeds per plant, weight of seeds per plant, weight of seeds per hectare, weight of 100 seeds. Data from observations were analyzed using analysis of variance based on the F test with alpha 5%, if there were real significant differences followed by Duncan's Multiple Range Test (DMRT) 5%.

## 3. Results and discussion

### 3.1. General condition of land

Maize can grow optimally in the dry land of Agriculture Faculty, UNS, Jumantono, Karanganyar. Land including lowlands with a height of 195 meters above sea level. The geographical location of this area is located between 110.9483 East and 7.63052 South Latitude. Research field have latosol soil types. Results of soil chemical analysis on dry land (Table 1).

**Table 1.** Results of initial soil analysis

Variable	Value	Explanation
N total	0.29 %	Medium
P total	247.24 ppm	Very high
K total	0.20 %	Low
C-organic	1.45 %	Medium
Organic matter	2.50 %	Medium
C/N ratio	5.00	Low
pH	5.26	Acid

Source: Results of analysis from soil chemistry laboratory FP UNS, Surakarta 2019. Basis of scaling according to BALITTANAH 2009.

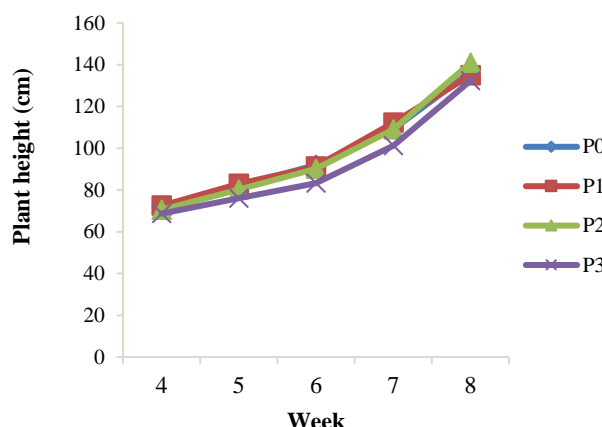
### 3.2. Maize growth

**Table 2.** Effects of phosphate fertilizer doses on growth parameters

Variable	P0	P1	P2	P3
Plant height (cm)	136.39 <sup>a</sup>	134.87 <sup>a</sup>	140.82 <sup>a</sup>	132.26 <sup>a</sup>
Number of leaves	13.17 <sup>a</sup>	12.50 <sup>a</sup>	13.00 <sup>a</sup>	12.61 <sup>a</sup>
Diameter (mm)	24.66 <sup>a</sup>	24.78 <sup>a</sup>	26.94 <sup>a</sup>	24.77 <sup>a</sup>
Leaf area index (LAI)	3.03 <sup>a</sup>	3.17 <sup>a</sup>	4.22 <sup>b</sup>	3.57 <sup>ab</sup>
Fresh stover weight (g)	115.27 <sup>a</sup>	126.50 <sup>a</sup>	165.64 <sup>a</sup>	113.49 <sup>a</sup>
Dry stover weight (g)	50.95 <sup>a</sup>	55.48 <sup>a</sup>	61.61 <sup>a</sup>	50.26 <sup>a</sup>

Note: P0 = 0 kg. ha<sup>-1</sup> P fertilizer, P1 = 100 kg. ha<sup>-1</sup> P fertilizer, P2 = 150 kg. ha<sup>-1</sup> P fertilizer, P3 = 200 kg. ha<sup>-1</sup> P fertilizer. Numbers followed by the same letter on the same line show no difference based on Duncan's multiple range test at 5% significance level.

**3.2.1. Plant height.** Plant height is measured and observed to determine the vegetative growth process of a plant associated with the addition of the size and number of cells in a plant. Plant height growth is influenced by several factors, such as the environment, physiological and genetic conditions of the plant. Based on the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in plant height. Based on Table 2, it appears that all doses provide almost the same range. This is presumably because the efficiency of P fertilization is generally very low, which is less than 10%. The role of P in the vegetative growth of plants is only around 0.3–0.5%. This is caused by P fixation in the soil so that the P element given is not entirely available to plants.

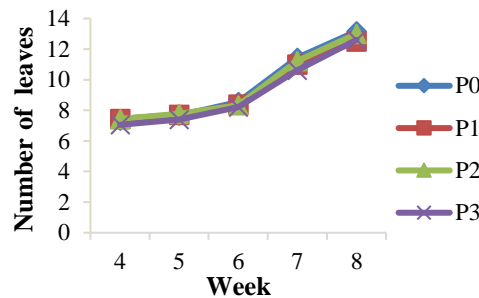


**Figure 1.** Effect of phosphate fertilizer dose on plant height of hybrid maize

The growth rate of maize plant height can be seen in Figure 1. The height growth of hybrid maize plants continues to increase every week. After 5 weeks the plants grow and accumulate dry matter rapidly. The need for nutrients and water in this phase is very high. The application of inorganic fertilizer can stimulate overall growth, especially branches, stems, leaves, and play an important role in the formation of green leaves.

**3.2.2. Number of leaves.** The number of leaves will affect the photosynthates produced in the photosynthesis process. Photosynthates will be circulated by phloem tissue to plant cells that are still experiencing growth, so it can be seen that the number of leaves will affect plant growth and yield. Based on the varying degrees of P dosage levels showed no significant difference in the variable number of leaves. This happens because of the high P fixation in the soil, which causes the accumulation of P in the soil from time to time during the administration of P. P fertilizers that are not

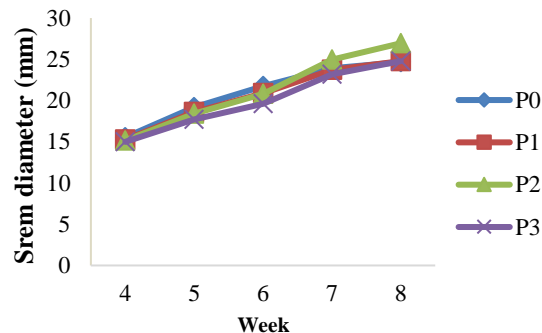
absorbed by plants are not washed away but become non-labile P which is not available for plants [6].



**Figure 2.** Effect of phosphate fertilizer doses on the number of leaves

Based on the Figure 2, leaf growth in hybrid maize is increasing every week. Giving a dose of p fertilizer is sufficient for the growth needs of maize leaves, this can be seen from the average yield of the number of leaves that shows the difference in numbers not significantly different. Entering 5 WAP/weeks after planting, maize plants experience the phase of the number of leaves that open from 8 to 12 strands with the characteristics of root development and spread in the soil very quickly, and elongation of stems increases rapidly, at this stage will be male flowers (tassel) and cob development begins. Plants will absorb nutrients in greater amounts, therefore nutrients in the soil must always be available for plants.

**3.2.3. Stem diameter.** Stem diameter is the most easily measured plant dimension especially at the bottom. The diameter of the stem affects the establishment of the plant so that it does not collapse easily when the plant gets taller. The stems of maize plants can grow bigger with a diameter of about 3–4 cm. Based on the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in stem diameter.



**Figure 3.** Effect of phosphate fertilizer doses on hybrid maize stem diameter

Observation of stem diameter in plants for 5 weeks can be seen in Figure 3 which shows the dose of phosphate fertilizer does not significantly affect the observed diameter of maize stem diameter, but shows the increase in stem diameter each week. Nutrient uptake by plants cannot be absorbed all at once for stem diameter growth. At the beginning of nutrient plantations, it will focus on plant height growth and when approaching the vegetative end, nutrients will be absorbed for stem diameter growth.

Provision of phosphate fertilizer at planting time will improve the onset of growth. The results of the measurement of the stem diameter showed that plants given a dose of phosphate fertilizer had a larger diameter than without phosphate fertilizer. This shows the addition of diameter associated with the absorption of nutrients by plants.

**3.2.4. Leaf area index (LAI).** Leaves have an important role in the absorption of solar radiation and

variations in their effects on growth can be assessed through LAI, leaf angle, and leaf density. Leaf area index is a factor that affects plants in the process of photosynthesis. The wider leaf area shows the high leaf area index value. Leaf Area Index of 11 tropical maize cultivars varied from 1.50 to 5.01 [7]. If LAI is greater than 3.0 then 95% of sunlight can be absorbed well, but if the leaf area index value is greater than 5.0 then the absorption decreases because the leaf strands cover each other.

Based on the results of the analysis of variance, it can be seen that the administration of phosphate fertilizers showed significant differences in the leaf area index (LAI). Based on the results of analysis of the various treatment dosages of P0 and P1 showed significantly different results with treatments P2. Whereas P2 treatment was not significantly different from P3 dose. Dose of phosphate fertilizer can increase the LAI value of maize. The dose of phosphate fertilizer 150 kg / ha produced the highest average LAI of 4.22. [8] this is thought to be caused by sufficient amounts of NPK so that the assimilates formed can be transplanted for canopy growth.

The control treatment gave the lowest result, because the control (P0 = 0 kg / ha) was used as a comparison in this study and was not given a dose of phosphate fertilizer. [9] that the growth of a plant cannot be maximized if the nutrient content is less than what is desired by a plant. The optimum leaf area index supports photosynthesis in plants. The optimum leaf area provides a broader leaf surface as a place for photosynthesis, so that sunlight penetration is more optimum and photosynthetic results obtained are more optimal [10].

**3.2.5. Fresh stover weight.** The fresh stover weight of a plant is strongly influenced by water status. The water status of a network or the whole body of a plant can change as the plant ages and is influenced by an environment that is rarely constant. The increase in fresh weight is related to the results of metabolism that occur in plants. N uptake was significantly correlated to the yield of wet and dry maize stover. Most of the N is absorbed by plants for stover growth. Nutrient uptake is very fast occurring in the vegetative phase of plants, where in this phase the N elements are brought to the growing point, leaves, stems.

Based on the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of fresh stover. This is due to the increased weight of fresh stover elements Nitrogen (N) is more important. Nitrogen will increase root growth and development so that plants can absorb P more effectively [11]. If a deficiency of Nitrogen (N) causes protein compound deficiency, causes an increase in the C / N ratio, and this excess carbohydrate increases the cellulose and lignin content, the cell membrane thickens and increases lignin tissue, resulting in early maturation, and the plant will appear small and dry.

**3.2.6. Dry stover weight.** Dry weight measurement is part of the measurement of plant biomass. Plant biomass is a measure that is often used to describe and determine the growth of a plant because plant biomass is relatively easy to measure and is a combination of almost all events experienced by a plant during its life cycle. Dry stover weight indicates the rate of absorption of water and nutrients for plant metabolism that affects plant growth and production. The existence of leaves is useful as a food source because the leaves are producing photosynthesis which is formed will accumulate in the dry weight of plants [12].

Based on the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of dry stover. The amount of P nutrients contained in the soil is quite high. The P nutrient in the soil is assumed to be sufficient to meet the nutrient requirements of maize plants. Therefore, giving different doses of fertilizer do not give significant results. The difference in the dose of inorganic fertilizer does not affect the increase in dry maize stover.

### 3.3. Yield of maize

**Table 3.** Effects of phosphate fertilizer doses on yield of maize parameters

Variable	P0	P1	P2	P3
Weight of cobs with husks (g)	224.35 <sup>a</sup>	253.96 <sup>a</sup>	272.64 <sup>a</sup>	202.46 <sup>a</sup>
Weight of cobs without husks	139.83 <sup>a</sup>	154.32 <sup>a</sup>	157.23 <sup>a</sup>	124.31 <sup>a</sup>
Average of cobs per plant	1.39 <sup>a</sup>	1.50 <sup>a</sup>	1.50 <sup>a</sup>	1.44 <sup>a</sup>
Number of seeds per plant	419.94 <sup>a</sup>	488.39 <sup>a</sup>	469.39 <sup>a</sup>	383.28 <sup>a</sup>
Weight of seeds per plant (g)	117.19 <sup>a</sup>	129.22 <sup>a</sup>	128.58 <sup>a</sup>	102.52 <sup>a</sup>
Weight of seeds per hectare (ton)	2.03 <sup>a</sup>	2.15 <sup>a</sup>	1.95 <sup>a</sup>	1.89 <sup>a</sup>
Weight of 100 seeds (g)	26.20 <sup>a</sup>	27.05 <sup>ab</sup>	28.78 <sup>b</sup>	25.38 <sup>a</sup>

Note: P0 = 0 kg. ha<sup>-1</sup> P fertilizer, P1 = 100 kg. ha<sup>-1</sup> P fertilizer, P2 = 150 kg. ha<sup>-1</sup> P fertilizer, P3 = 200 kg. ha<sup>-1</sup> P fertilizer. Numbers followed by the same letter on the same line show no difference based on Duncan's multiple range test at 5% significance level.

**3.3.1. Weight of cobs with husks.** [13] the increase in cob weight is closely related to the amount of photosynthate that is transplanted to the cob. The greater the photosynthate that is transplanted to the cob, the more the fresh weight of the cob increases. Giving phosphate fertilizer can increase the fresh weight of cob with cob.

Based on the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of cob with cob. Based on the measurement of weighted cob ear obtained the highest fertilizer dose of 200 kg / ha showed the lowest results. The administration of excess P (above the optimum requirement), will cause a decrease in yields that are increasingly reduced and even if too excessive tends to be toxic to plants [14]. The dose of P fertilizer must be balanced with other fertilizer doses.

**3.3.2. Weight of cobs without husks.** Maize cob weight is influenced by photosynthesis. Photosynthesis will increase if the absorption of sunlight energy takes place to the maximum, so that the production of seeds in maize will also increase and increase in weight. Increased weight of the cob is also influenced by the availability of nutrients in the soil [14]. The nutrient element which has the most role in increasing the weight of cob is phosphorus. Supply of phosphorus elements plays a very important role in the formation of maize cobs related to the weight of the cobs. The element P plays a role in generative growth, especially the formation of cob.

Based on the results of the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of the cob without husks. This is presumably because in each treatment nutrient conditions are sufficiently available for plants to support plant growth. The nutrients available for plant growth will cause nutrient absorption and photosynthesis to proceed well so that the accumulated photosynthate will also increase and will have an impact on the weight of the cob.

**3.3.3. Average of cobs per plant.** Provision of phosphate can increase production, namely production of cob with sample paddle, cob production without knots per plot because the phosphate element is an important element in seed growth. An increase in maize productivity can be achieved by increasing the use of modern production techniques such as the application of hybrid maize varieties and fertilizer applications [15]. In addition, phosphorus functions as a raw material for the formation of certain amounts of protein, helps assimilation and breathing, and accelerates flowering, ripening of seeds and fruit.

Based on the results of the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference to the average number of cob per plant. P element supports supporting the development of young roots which in turn will support plants in absorbing nutrients.

Phosphorus for plants is useful for stimulating root growth, especially the roots of young plants. Increased nutrient uptake in roots will optimize the photosynthesis process in plants, thus increasing the formation of assimilates in the form of carbohydrates and proteins which will then be transplanted to the food reserves, namely seeds, this will further affect the number of cob per plant. But in this study the addition of phosphate fertilizer had no significant effect on the average cob of plants per plant. This means that the uptake of element P in the roots has not been efficient.

*3.3.4. Number of seeds per plant.* The availability of nutrients can not be separated from the process of filling the seeds. The nutrients absorbed will be accumulated to the leaves into proteins that make up the seeds. The accumulation of metabolic material in the formation of seeds will increase, so that the seeds formed have the maximum size and weight, this happens when the nutrient needs are met which causes the metabolism to run optimally. P functions as a source of energy in a variety of plant metabolic reactions that plays an important role in increasing yields and provides a lot of photosynthates which are distributed into seeds so that the yield of maize seeds increases [16].

Based on the results of a variety of analyzes it can be seen that the administration of phosphate fertilizer showed no significant difference in the number of seeds per plant. Nutrient demand for maize is influenced by the response of the results to fertilization and the efficiency of fertilizer use. The number of seeds per cob increased at certain fertilizer doses [17].

*3.3.5. Weight of seeds per plant.* Weight of dry maize seeds is a component that is closely related to the production and distribution of dry matter. Swelling done to separate the maize kernels attached to the cob. Dry seed weight is related to the magnitude of photosynthate translocation into the seeds. The increase in dry weight of seeds is related to the amount of photosynthate translocation into seeds and the better root system of plants to be able to absorb nutrients from the soil [18]. The considerable translocation of photosynthates to the reproductive organs causes the formation of cob and seed filling to take place properly and the seeds which are formed with a larger size.

Based on the results of the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of seeds per plant. Adding a dose of P fertilizer will only increase the yield to the optimal point. Application of fertilizer with large doses will result in concentrated soil solution and will not be able to be absorbed by plants [19]. If P levels are excessive, then the absorption of other elements in the soil will be disturbed so that it will inhibit plant growth.

*3.3.6. Weight of seeds per hectare* Increased seed weight is thought to be closely related to the amount of photosynthate that is transplanted to the cob. The greater the photosynthate allocated to the cobs, the greater the accumulation of food reserves that are transplanted into seeds, thereby increasing the weight of the seeds. Conversely the lower the photosynthate allocated to the cob, the lower the stockpiling of food reserves that are transplanted into seeds, thereby reducing the weight of seeds. Based on the results of the analysis of variance, it can be seen that the administration of phosphate fertilizer showed no significant difference in the weight of seeds per hectare. The treatment of P1 (100 kg. ha<sup>-1</sup> of P fertilizer) has the highest average seed weight per hectare of 2.15 tons. ha<sup>-1</sup>

Acid soils can lead to inefficient fertilizer doses. Inefficiency in fertilizer application can be caused by acidic soil conditions, so it needs to be given continuously [20]. Acid soil conditions cause Al poisoning problems and low availability of P, Ca, Mg, and Mo nutrients.

*3.3.7. Weight of 100 seeds.* Weight of 100 dry seeds can indirectly affect the yield of plants in the form of dry shell weight. Endosperm is the largest part of the seeds which is a place to store food reserves. The Bisi-2 variety weighs 100 seeds higher than the other varieties [21] hybrid maize of Bisi-2 variety has a higher adaptability than other varieties.

Based on the results of a variety of analysis, it can be seen that the administration of phosphate fertilizer showed a significant difference to the weight of 100 seeds. The treatment of P3 and P0 doses



showed significantly different results from the P2 treatment. Whereas P2 treatment was not significantly different from P1 dose. P2 treatment (150 kg. ha<sup>-1</sup> P fertilizer) had the highest average weight of 100 seeds, 28.78 g. The results obtained indicate that the dose of phosphate fertilizer can increase the weight of 100 seeds. Magnitude of influence on P solubility or increase in plant growth / yield is influenced by several factors including phosphate sources [22]. High availability of P in the soil due to the application of P fertilizer can stimulate plant growth and yield. The higher the dry weight value of 100 seeds, the higher the quality of the seeds. Weight of 100 seeds illustrates the large size and pithiness of seeds and is one indicator of seed quality [18].

#### 4. Conclusion

Based on the results of research and discussion conclusions can be drawn as follows: the application of 150 kg.ha<sup>-1</sup> of phosphate fertilizer SP-36 increases growth variable on the leaf area index (LAI). The application of 150 kg. ha<sup>-1</sup> of phosphate fertilizer SP-36 increases yield variable on the weight of 100 seeds. But seen from the average dose of 100 kg. ha<sup>-1</sup> has a higher than the control because it increases yield per hectare (5.91%) to 2.15 tons. ha<sup>-1</sup>.

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