Production potential of sweet corn (Zea mays Linn. var. Saccharata Sturt) ‘Bonanza’ to different planting pattern and phosphorus sources

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Abstract. Planting pattern factors that regulate population density of plant greatly determine optimal plant growth and production. The “Jajar legowo” system adopted from rice plants was applied to corn plants to obtain the effect of marginal plants. The study wanted to know sweet corn (Zea mays Linn. var. Saccharata Sturt) ‘Bonanza’ production based on planting patterns on various phosphorus sources. The study used factorial experiments which were arranged based on a randomized block design which was repeated three times with the planting pattern factor including conventional planting 70 cm × 20 cm, jajar legowo (2:1) with 20 cm × 50 cm × 100 cm and dense planting 105 cm × 12.5 cm. Source factor P consists of SP-36, mycorrhiza plus, and biofertilizer. The results showed that there was a significant interaction effect between the planting pattern and source of P on the dry weight of the plant, mostly in the combination treatment of the conventional system with SP 36 was 123.51 g. The weight cobs and corn cobs with cornhusk have the highest weight on the dense planting pattern which is no different significantly from conventional planting pattern.

Keywords: Biofertilizer, jajar legowo, marginal land, mycorrhiza, SP-36.

1. Introduction
Maize (Zea mays L.) is the primary cereal crop in the world follow the important cereal crop such as rice and wheat. In Indonesia, maize is an important alternative carbohydrate source after rice. It is cultivated for food, feed and also as a source of raw materials for various industrial products [1–3]. Sweet corn (Zea mays L. var. saccharata or var. rugosa Sturt) is one type of maize which is morphologically no different from corn for food or feed because it is the development of flint type corn (pearl corn) and dent type (horse tooth corn). The difference is only in the higher sugar content when the stadia immature grains/milk stage [4] with a sugar content of about 13 % to 15 % [1].

Sweet corn is food commodities in high demand because in addition to sweet with high contains sugar, vitamins A and vitamin C higher than corn also low fat [5]. Sweet corn is harvested at soft dough stage with succulent grains so favourable for fresh consumption, developed as an alternative dish namely boiled corncob, roasted corncob, or vegetables in the form of corn seeds added to soups or other foods. The increasing variety of food menus that use sweet corn cause enhancement the demand for sweet corn. Therefore, efforts are made to increase the yield of sweet corn through...
improving the practices cultivation. Among the factors which influence the yield, plant population and fertilizer are important. It is an established fact that higher corn yield depends on optimum plant density and N, P fertilizer application [1, 6].

The preceding research has been conducted on plant competition to specify the optimum plant density for corn yield. There is no specific optimum population density for all the weather. It differs depending on environmental and controlled conditions. Increasing density of plant population can be done by regulating the spacing. Grain weight per cob was significantly affected by varying planting densities [7]. *Jajar legowo* is a method of planting that is designed to increase crop productivity through increasing plant populations by adjusting the spacing [8] and to utilise the effects of edge plants; where planting is done by reduce the distance of the plant in a row and widen the range between the plants. In planting pattern of *jajar legowo* 2:1, every two rows of plants interspersed with an empty row with a width of twice the range of the row and spacing in the row is narrowed to half the original spacing [9]. This planting pattern is already entirely developed in paddy plant, and the results are better than conventional systems. This model can be applied to other commodities, for example in corn. In different to rice, the application of the *legowo* system in maize is more directed at increasing the acceptance of sunlight intensity to optimize photosynthesis and assimilation and facilitate plant maintenance, especially weeding both manually and with herbicides, fertilization, and water. The results of the research [10] that on plant growth parameters sweet corn (plant height, stem diameter, leaf number and leaf area) and sweet corn yield parameters show that *jajar legowo* pattern on Bonanza cultivar is best while the best sugar content in Jamboree varieties.

Phosphorus (P) is an element that is needed in large quantities. The P nutrient is an anion that has mobility and low availability in the soil. The sources of P in the soil include apatite, plant remains and dead animals. Currently, the source of P which is widely used in agriculture is generally chemical fertilisers such as SP-36. Excessive application of P fertiliser causes the accumulation of P in the soil, due to the very stable nature of the phosphorus so that the solubility of P in the soil is very low. Efforts to increase the availability of phosphorus in the soil can use biofertilizers. This experiment was therefore carried out with an objective to know the effect of different P fertiliser sources on the yield of sweet corn maintained at different planting pattern. It was expected that the application of this biofertilizer as P sources on different planting pattern could increase the production potential of sweet corn crops.

2. Materials and methods

2.1. Location of the experimental site
This research was carried out in a field at the Klumutan, Saradan, Madiun, Indonesia from April to July 2017. The location geographically situated at an altitude of 65 m above sea level. The soil texture was clay loam and irrigated by canal and rainwater.

2.2. Experimental design
The experiment was arranged in a randomized complete block design (RCBD) with split plot design having three replications. The main plots were P-fertilizers sources namely SP-36 (S1), mycorrhiza plus (S2), and biofertilizer (S3), whereas planting pattern allotted to subplots that are conventional planting (P1), *jajar legowo* 2:1 (P2), and dense planting (P3). Three planting pattern have different plant spacings. Conventional planting at a spacing 70 cm × 20 cm, *jajar legowo* 2:1 with 20 cm × 50 cm × 100 cm and dense planting at 105 cm × 12.5 cm. SP-36 containing 36 % P₂O₅. Mycorrhiza plus was used in this experiment as inoculum consist mycorrhiza, *Trichoderma* sp., *Pseudomonas* sp., and *Basilus subtilis*. Biofertilizer content that is C-organik, N, P, K, micro nutrient (Fe, Mn, Zn, Pb), *Trichoderma* sp., Phosphate Solubilizing Bacteria and N-fixing bacteria. Sweet corn of Bonanza cultivar was used in the present study. Data were recorded on growth and yield analysis.
2.3. Statistical analysis

The observations data obtained were analysed statistically by applying the technique of analysis of variance for randomized complete block design with split plot design and significance was tested by F-test. Analysis of variance of experimental data was performed using SPSS software (version 22). The difference in examining treatment average for their significance was calculated at 5% level of probability undertaken using Duncan’s multiple range test (DMRT) procedures. The difference in interaction is presented only wherever there is a significant difference between the treatments.

3. Result and discussion

The interaction between planting pattern (P) by P sources (S) had significant effects on fresh weight of plant (data not shown) and the dry weight of the plant (figure 1).

Figure 1. Dry weight of plant as influenced by planting pattern on the varying P fertilizers sources.

The highest plant dry weight in conventional planting pattern with SP 36 (P1S1) although not significantly different from the dense planting pattern with mycorrhizal (P3S2) and dense systems with biofertilizers (P3S3). These results indicate that the cropping pattern with a dense system has a root system that is needed for microbes to associate. The biofertilizers used are enriched with N-fixing bacteria and phosphate-solubilizing bacteria with a formula that can improve the development and activity of soil microbes. N-fixing bacteria were binding nitrogen (N2) from the air to microbial biomass so that N nutrients are easily absorbed by plants that affect vegetative growth. Phosphate solubilizing bacteria can release nutrients that are bound to soil minerals (complex phosphate compounds) into available P forms. These results are in confirmation with the results obtained by [11] who reported that P-solubilizing Pseudomonas tolaasii IEXB showed great potential for use as bioinoculant and the application of this bacterial strain had beneficial effects on growth, yield and P nutrition on maize plants.

Mycorrhiza plus is an organic fertilizer as a development of mycorrhizal fertilizer which is added with biological agents and functions to improve the ability of plants to absorb nutrients and water. Mycorrhizae plus applied with Trichoderma sp., Pseudomonas sp., Bacillus subtilis. Without mycorrhiza, nutrient uptake is only at the tip of the hair root and the nutrients absorbed are only in the available form. While mycorrhizal fertilizer was added with mycorrhizal hyphae which grew widely with plant root tissue, nutrients absorbed by tissue hyphae are brought to the tips of root hairs to be exchanged with polysaccharides. The level of hyphae in absorbing nutrients is much broader than root tissue without mycorrhizae. Nutrients that are still not available for plants or in the form of complex organic and inorganic compounds are broken down by phosphate solvent bacteria in mycorrhizae and biofertilizers.
The sugar content and leaf area index (LAI) were not influenced by planting pattern and P-fertilizer source (table 1) but has different significantly on chlorophyll content (table 1), the weight corn cobs with and without husk (table 2).

**Table 1.** Sugar content, LAI, chlorophyll a, chlorophyll b, and total chlorophyll content of sweet corn plants in planting patterns with vary P-fertilizer sources

| Treatment            | Sugar content (%) | LAI      | Chlorophyll a (mg kg⁻¹) | Chlorophyll b (mg kg⁻¹) | Total chlorophyll (mg kg⁻¹) |
|----------------------|-------------------|----------|-------------------------|-------------------------|-----------------------------|
| Conventional         | 14.67 a           | 266.91 a | 537.50 a                | 501.72 a                | 1038.45 a                   |
| *Jajar legowo 2:1*   | 14.69 a           | 270.89 a | 549.52 b                | 521.09 b                | 1069.81 b                   |
| Dense                | 14.75 a           | 271.16 a | 560.81 c                | 539.04 c                | 1099.04 c                   |
| SP-36                | 14.78 a           | 278.20 a | 537.90 a                | 501.99 a                | 1039.13 a                   |
| Mycorrhiza plus      | 14.74 a           | 263.59 a | 551.77 b                | 524.65 b                | 1075.82 b                   |
| Biofertilizer        | 14.59 a           | 267.18 a | 558.15 c                | 535.20 c                | 1092.55 c                   |

Same letter within each column indicates no significant difference between treatments (*P > 0.05*).

The effect of planting patterns and P-fertilizer source in this study results sugar content of sweet corn are not significantly different, which might be due to the sweet corn plant harvested during the milking stage. In this phase, the process of changing the sugar to starch has not maximized so that the sugar content determined by time of harvest [4] and total sugar contents were higher in sweet corn from the late harvests compared to the early harvests [12]. The levels of sugars in vegetative tissues at various developmental stages are interdependent with levels of sugars in kernels. Factors affecting the development of plants before anthesis may affect sugar levels in kernels [13]. Although there was no significant effect, the highest sugar content on the dense planting pattern (P3) and the maximum leaf area index was recorded with SP-36 (S1).

Chlorophyll content was affected by planting pattern and P-fertilizer source. Dense planting led to the content of chlorophyll a, chlorophyll b, and total chlorophyll was the highest, as well as was reached by the biofertilizer application. Increase in chlorophyll content by mycorrhiza plus and biofertilizer inoculated on sweet corn agrees with results reported [14] that plants inoculated with Arbuscular Mycorrhizal fungi, either alone or in combination with Rhizobium, brought about significant changes in chlorophyll a, chlorophyll b and total chlorophyll content. The amount of solar radiation absorbed by a leaf is a function of the photosynthetic pigment content. Chlorophyll content can be influenced by the biosynthesis of chlorophyll, interconversion and degradation of chlorophyll a and chlorophyll b [15]. It can directly determine photosynthetic potential or primary production and is an indicator of crop growth and development [16]. According to [17] the quantification of chlorophyll provides important information about the effects of environments on plant growth. Chlorophyll content has also been suggested as the most directly relevant to the prediction of productivity [18].

Weight cobs and weight of cobs with husk was significantly affected by varying planting patterns and P-fertilizer sources (table 2). Maximum weight of cobs with husk was recorded in dense planting (17.48 t ha⁻¹) and SP-36 (17.33 t ha⁻¹). Maize depends on fertilizer P at its early stages of growth and this might have stimulated root proliferation and acquisition of nutrients for growth [19]. Phosphorus is essential in the process of filling sweet corn seeds. It is important for seed and fruit formation and crop maturation. The element P will be absorbed by the plant continuously until it approaches the maturation period of the grain. This element can also increase crop production, increase yields and accelerate the maturation of seeds and fruit. High plant growth will improve photosynthesis. Photosynthates can be translocated to fill grain, causing the weight of the cob to be higher.
Table 2. The effect of planting patterns and P-fertilizer sources on weight corn cob with husk and weight corn cob

| Treatment         | Weight cobs with husk (t ha\(^{-1}\)) | Weight cobs (t ha\(^{-1}\)) |
|-------------------|--------------------------------------|-----------------------------|
| Conventional      | 17.14 b                               | 10.60 b                     |
| Jajar legowo 2:1  | 13.61 a                               | 8.61 a                      |
| Dense             | 17.48 b                               | 11.65 b                     |
| SP-36             | 17.33 b                               | 10.83 a                     |
| Mycorrhiza plus   | 15.74 ab                              | 9.81 a                      |
| Biofertilizer     | 15.17 a                               | 10.21 a                     |

Same letter within each column indicates no significant difference between treatments (\(P > 0.05\))

4. Conclusion
It can be concluded from this study that P-fertilizer sources applied each has suitability with the planting pattern. The highest potential of sweet corn production was reached by conventional planting pattern that is given SP 36 fertilizer. Application of SP 36 fertilizer in jajar legowo 2:1 system or on dense planting pattern will decrease the dry weight of the plant. Whereas the dense system will yield the highest dry weight of plant on biofertilizer application. The dense planting pattern can produce the highest levels on the weight of corn cob with or without corn husk, also for SP-36 fertilizer application.

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