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The Effect of Mycorrhiza and Plant Growth-Promoting Rhizobacteria Supplementation on *Zea mays saccharata* Sturt. Growth and Productivity Grown on Low Nutrients Soil

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ABSTRACT

Marginal land has low nutrient content (nitrogen, phosphorus, potassium). Addressing nutrient deficiencies on marginal land requires a strategic approach. Biological fertilizers like Arbuscular Mycorrhizal Fungi (AMF) and plant growth-promoting rhizobacteria (PGPR) enhance nutrient availability through symbiotic interactions. In addition, organic fertilizers such as compost could provide organic matter and improve soil structure to increase plant growth and productivity. Combining these three fertilizers with the addition of low doses of NPK fertilizer can increase the growth and productivity of maize crops on sub-marginal land. This study aims to determine the effect of AMF, consortium of PGPR, and a low dose of NPK on the growth and productivity of maize and soil nutrients on sub-marginal land by measuring plant growth up to 8 WAP (week after planting) (parameters: plant height, stem diameter, number of leaves, leaf area, chlorophyll content, stomatal density) and productivity (parameters: cob length, cob weight with husk, fresh weight, dry weight) and levels of N, P, and K elements at 8 WAP in the soil after planting. All treatments showed an increase in the level of N and K elements, while the P element showed a decrease compared to the control (soil without treatment). Moreover, each parameter did not show a significant difference, but the P2 (Compost + PGPR consortium + AMF + 50% of NPK) treatment showed the best growth and productivity. Overall, the data showed the utilization of PGPR and AMF combination was able to reduce the usage of chemical fertilizer by 50%.

INTRODUCTION

Maize is the second staple commodity in Indonesia, with increasing demand over the years. However, due to over-farming, the low nutrient of soil becomes a problem, which leads to a decrease in maize productivity (Ng et al. 2022, Sprunger et al. 2019). The overuse of pesticides and non-organic fertilizers such as NPK ((Nitrogen Phosphorus Potassium) causes land and soil degradation and eventually lowers land productivity (Nunes et al. 2020).

Utilizing organic fertilizer and biofertilizer becomes an alternative to recover the nutrients in the soil and increase crop productivity. One example is compost, an organic fertilizer that provides organic matter and improves soil amendments (Assefa & Tadesse 2019). Biofertilizer is also reported to be able to improve soil nutrients by mobilizing and increasing the nutrient availability in soil (Mitter et al. 2021). Mycorrhiza is often combined with the Plant Growth-Promoting Rhizobacteria (PGPR) to be used as a biofertilizer. The symbiosis between them improves the growth and productivity of crops (Raklami et al. 2019).

As soil degradation becomes more frequent while the demand for maize keeps increasing, exploiting the symbiosis of mycorrhiza and PGPR as a biofertilizer on maize can be an alternative. In this study, we investigated the effects of mycorrhiza and PGPR supplementation together with compost on maize's (*Zea mays* Saccharate Sturt.) growth and productivity.

MATERIALS AND METHODS

Preparation of Mycorrhizae Propagule

The tools and materials are hoes, shovels, scales, hoses, plant shears, soil, compost, arbuscular mycorrhizal fungi (AMF), water, polybags, and sweet corn seeds. Then, soil and Dewi Fortuna Compost were prepared to be mixed in a ratio of 1:1, which was then placed in 100 polybags measuring 40 cm. Before planting corn, conventional AMF

MycoVir (Bogor) was first sprinkled with AMF Genera *Acaulospora, Gigaspora, Glomus,* and *Scutellasporra*, with sterile sand and vermiculite as much as 50 grams/polybag. Sweet corn is planted in polybags containing a mixture of soil and compost and a sprinkling of mycorrhizae. Watering was carried out once a day until the plants were 14 DAP (days after planting). At the age of 15 DAP, maize plants were given stress treatment by cutting the plant crown and not watering for 14 days. At the age of 29 DAP, the plants were watered again once a day until the age of 60 DAP. Harvesting was carried out at 61 DAP by cutting the base of the stem and taking the root part for further chopping ± 1 cm. The chopped results are put in a plastic bag.

Purification and Rejuvenation of Bacteria Isolate

PGPR bacterial isolates in K1, P1, and P2 treatment from the collection of the Microbiology and Biotechnology Laboratory, Department of Biology, Sepuluh Nopember Institute of Technology, were purified on a Nutrient Agar (NA) medium (Shovitri et al. 2021). The isolates were rejuvenated on NA medium using the streak plate method with 16 streaks to obtain a single colony, then incubated for 24 h at room temperature. After that, the pure colonies were re-cultured in NA agar slant and stored at 4°C.

Preparation of Application Inoculum

A consortium of three bacterial isolates with codes K1, P1, and P2 was used in this study. Each bacterial isolate was inoculated into Nutrient Broth (NB) medium and then incubated for 24 hours at room temperature. A 25 mL sample of previously prepared NB media was suspended in sterile distilled water after the inoculation. Using a rotary shaker, three 25 mL Erlenmeyer bottles with bacteria K1, P1, and P2 were cultured for 24 hours. Following cultivation in 25 mL Erlenmeyer, 225 mL of sterile distilled water is prepared previously and poured into 500 mL Erlenmeyer. Using a rotary shaker at room temperature, the consortium's results were recultivated for 24 hours.

Preparation of Maize Media

The application inoculum (bacteria consortium suspension) contained 1.5% molasses, 82.5% tap water, and 16% bacterial consortium with a total volume of 5000 mL. 1.5% molasses (75 mL), 82.5% well water (4175 mL), and a consortium of 16% bacteria (750 mL) were poured into a 25 L jerry can. After the three were mixed, they were allowed to stand for 90 minutes before being applied to plants.

Preparation of Experiment Plant

The soil was taken from citrus Batu, East Java, which was used for planting and was taken 300 g first for initial NPK testing. Then, soil and conventional compost (Dewi Fortuna) were mixed in a ratio of 1:1, which was then put into 45 cm × 45 cm (10 kg) polybags and watered with 300 mL of suspension of the rhizosphere bacteria P1, P2, and K1 consortium (biological fertilizer). The consortium watering was carried out for two consecutive days and allowed to stand for three days. Next, the soil pH is measured, and when the soil pH is around 7, it can be continued in the next stage. If the soil is acidic, dolomite is given with a sowing system of 66 grams/polybag, then left for 3 days. Soil that has been in a neutral pH state is ready to plant sweet corn. Then, the corn seeds are soaked in distilled water for about 3 h and selected, which are submerged and then drained. The planting media for sowing is 1 kg of soil and 1 kg of compost, which is then prepared on a tray. The selected seeds are sown at a depth of approximately 1 cm from the top surface of the soil.

Furthermore, it was grown until the age of 9 DAS (Days After Seedling) until growing 2 leaves. Seedlings were transferred to polybag planting media as deep as 3 cm from the soil surface. After the transfer, watering, weeding, and pest control are carried out. Water the plant every day using water with a small discharge. Weeding is done manually by pulling weeds that grow around the plants. Pest control is done by giving insecticide sow, which is sprinkled around the plants (5 grams/polybag). After 7 DAP, the plants were ready to be given treatment.

Application of Mycorrhizae, PGPR, and NPK to Sweet Corn

The application of rhizobacterial consortium biofertilizers and NPK fertilizers was carried out at 5 and 26 DAP. The suspension of the rhizobacteria consortium was sprinkled on the plants as much as 300 mL per polybag. NPK fertilizer was sprinkled according to the dose of each treatment (K2 = 4.8 g, P1 = 1.2 g, P2 = 2.4 g). The PGPR consortium was applied at 3 DAP (days after planting), 7 DAP, 21 DAP, 35 DAP, and 49 DAP. Mycorrhizae were applied at 0 DAP. The NPK application was carried out at the age of 5 DAP and 26 DAP.

Measuring Growth and Productivity of Plant

During the planting period, measurements were done once per week, with the Observation of research results, including plant height, stem diameter, number of leaves, and leaf area index. After harvesting, sweet corn plants (65 DAP) in all treatments that had been harvested were removed, and their roots were cleaned from the soil. Corn plants are cut between the base of the stem and the roots. Wet weight was measured from the base of the stem to the top of the plant. Measuring

of wet and dry weight was carried out after the plants were 65 DAP. Plants that have been taken in each treatment are cleaned of dirt and soil. The next step is measuring the dry weight, which is done by first chopping it into smaller pieces and putting it in a paper wrapper. Wrapping paper containing chopped sweet corn is put in the oven, then baked for 6 h at 121°C. If the weight is constant, it can be weighed three times. Constant weight data can be retrieved and recorded. Corn cobs, cob height, and cob weight were weighed at the age of 8 WAP.

Measurement of N, P, K Level in The Soil After Planting

The test for the nutrient level content of N, P, and K of the planting soil was carried out at the Surabaya Industrial Standardization and Research Office. The soil was tested with parameters: nitrogen (N) content using the Kjeldahl method, phosphate (P) using the Spectrophotometric method, and potassium (K) using the Atomic Absorption Spectroscopy (AAS) method.

Chlorophyll Content

After harvesting, the leaves on each treatment plant were taken. Corn leaves were cut (0.1 grams). The leaf samples were then crushed in a mortar using a pestle with 80% acetone (10 mL) until all the colors were separated from the tissue. The result in the form of the extract is first filtered using filter paper and put into a centrifuge. The surface of the cuvette is cleaned, then the results of the centrifuge are transferred to the cuvette to be inserted into the spectrophotometer. Measurements with a spectrophotometer used absorbance chlorophyll solution at wavelengths of 663 nm and 645 nm (Cao et al. 2020). The concentration results are calculated by the following formula (Harborne 1987):

$$\text{Total chlorophyll (mg/L)} = (17.3 \times A645) + (7.18 \times A663)$$

Stomatal Density

Stomatal density was measured on the 6th leaf from the base of the stem using the imprint method. The leaves are first cleaned of dirt using tissue. Then, prepare transparent nail polish. Transparent nail polish was applied to the abaxial part of the 6th leaf of the corn plant, 1 cm wide, then waited for it to dry. Next, a transparent adhesive is glued to be affixed to the dry nail polish and peeled off the replica leaves, and the replica is affixed to the slide. The results on the object glass were observed using a microscope with a magnification of 400 x with a field of view of 0.025 mm^2. Stomatal density was calculated using the formula according to (Maylani et al. 2020).

Stomatal density = Number of stomata/field of view

Percentage of Mycorrhizae Infection

Mycorrhizae infection in root tissue can be done by observing the percentage of infection in root tissue. First, the roots of the corn plant were cleaned and then cut into pieces of about 1 cm, then heated in 10% KOH at 90°C for about 10 minutes. Furthermore, the soaked roots were drained and washed with distilled water. Then, the roots were put back into 0.1 N HCl drained again, and then washed with distilled water. Staining was carried out using Lactophenol Trypan Blue 0.05% for a while and added to lactoglycerol. The results on the object glass were observed using a microscope with a magnification of 400 x with a field of view of 0.025 mm^2. The percentage of mycorrhizal infection in the roots was calculated using the formula (Nurhidayati et al. 2010):

$$\text{Mycorrhizae infection (\%)} = \frac{Number\ of\ infected\ root}{Number\ of\ roots\ observed} \times 100\%$$

Data Analysis

This research is an experimental study to know the effect of the combination of compost, mycorrhizae, PGPR consortium, and low-dose NPK variation on the growth of sweet corn. This study used a completely randomized design with 5 replications. The data that has been obtained will be tested for normality using the Shapiro-Wilk test. If the treatment has a significant effect, the p-value is more than 0.05 or has a significant effect, and the data is normally distributed, a follow-up test will be carried out using Way Analysis of Variance (ANOVA), and if it is not normally distributed, a non-parametric test will be used. (Kruskal-Wallis). Data analysis visualization was performed on RStudio.

RESULTS AND DISCUSSION

In this study, we treated the maize with different supplementation combinations of mycorrhiza, PGPR consortium, and different doses of NPK. To avoid the redundancy of the treatment groups explanation, the treatment grouping is as follows:

K1: Control (no supplementation)

K2: 100% dose of NPK fertilizer (4.8 gram/polybag)

K3: Mycorrhizal (100 g of AMF per polybag)

P0: PGPR consortium + mycorrhiza

P1: PGPR consortium + mycorrhiza + 25% dose of NPK (1.2 gram/polybag)

P2: PGPR consortium + mycorrhiza + 50% dose of NPK (2.4 gram/polybag)

Note :

NPK dose (25% = 1.2 g, 50% = 2.4 g, 100% = 4.8 g)

Mycorrhizae (100% = 100 gr/polybag)

The Effect of Mycorrhiza and PGPR Supplementation on the Growth of Maize

Growth parameters (height, stem diameter, number of leaves, and total leaf area) were observed weekly for 8 weeks in maize with various combinations between mycorrhiza, a consortium of PGPR, and different doses of NPK. In week 8th, the P2 treatment group, which is maize supplemented with PGPR consortium, mycorrhiza, and 50% dose of NPK, showed the highest score overall except for the leaf number. The maize in the P2 treatment group reached 97.8 ± 8.70 cm as the mean height, 1.29 ± 0.11 cm as the mean of the stem diameter, 9.6 ± 0.89 as the mean number of the leaf, and 359.25 ±32.83 cm^2 as the mean of total leaf area. Whereas the K3 treatment group, where we supplemented the maize with the mycorrhiza only, showed the overall lowest score except for the stem diameter. The maize in the K3 treatment group reached only 78 ± 26.05 cm as the mean height, 1.11 ± 0.33 cm as the mean of the stem diameter, 8.4 ± 1.52 as the mean number of the leaf, and 285.05 ± 72.64 cm^2 as the mean of total leaf area. For the increase of the overall growth parameters, the maize from the P2 treatment group showed the highest growth from week 1 to week 8 (Fig. 1).

The Effect of Mycorrhiza and PGPR Supplementation on the Maize's Productivity

At 65 days after planting (DAP), we harvested the cob and measured the length and the weight, as well as the maize fresh and dry weight. All treatment groups showed almost similar cob lengths (20.68 – 21.58 cm) except the K3 treatment group, which showed to have the shortest cob with a mean cob length is 16.06 ± 9.38 cm (Fig. 2A). K3 treatment group exhibited the lowest cob weight as well (40.3 ± 9.38 gram), and the P2 treatment group had the highest cob weight (60.712 ± 1.85 gram) (Fig. 2B). Both fresh weight (p-value > 0.05) and dry weight (p-value > 0.05) there was no significant difference among treatments. The average fresh weight and dry weight of all treatments are presented in Fig. 2C. P2 treatment showed the highest fresh weight compared to all treatments.

The Effect of Mycorrhiza and PGPR Supplementation on the Chlorophyll Content and Stomatal Density

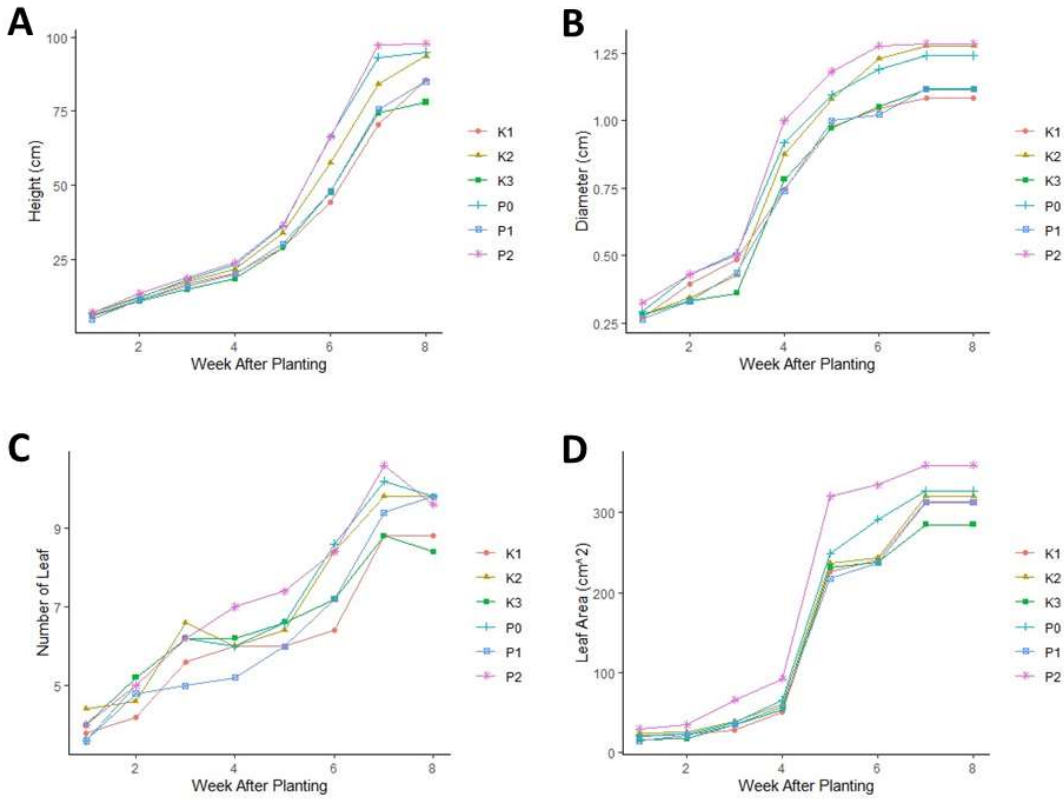

Fig. 1: The effect of mycorrhiza, PGPR consortium, and NPK fertilizer on maize's growth parameters: (A) height, (B) stem diameter, (C) leaf number, and (D) leaf area. The graphs represent the mean of the value (n=5).

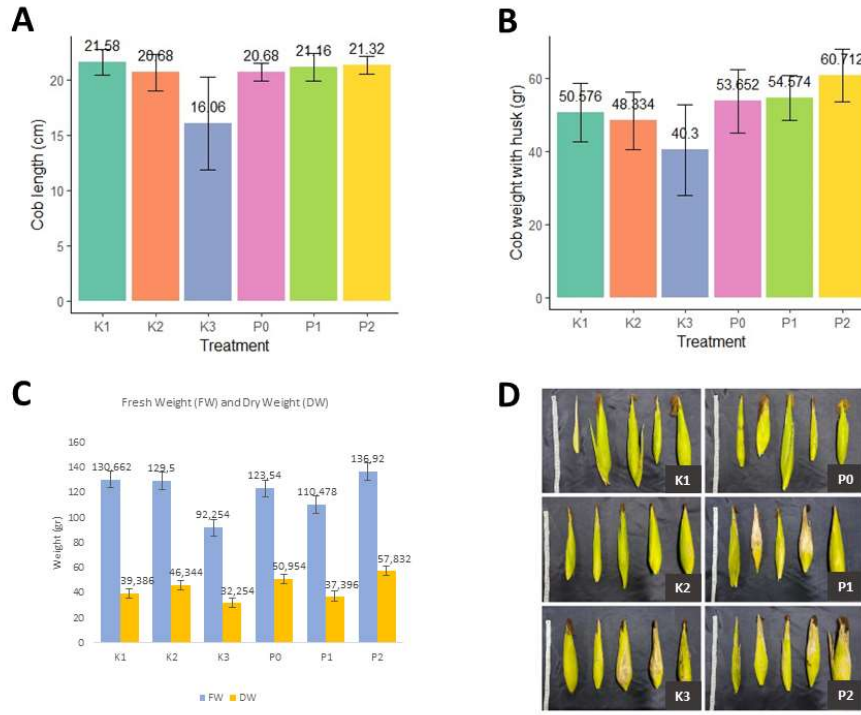

Fig. 2: The effect of mycorrhiza and PGPR supplementation on the maize's productivity (A) Cob length (B) Cob weight (C) Fresh and dry weight (D) Cob in each treatment.

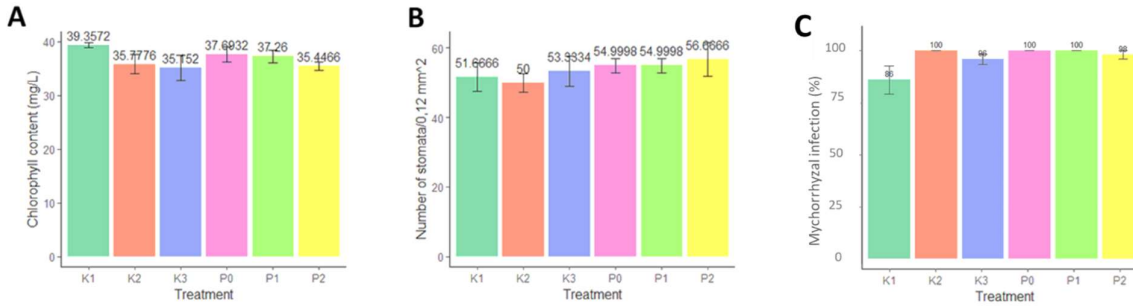

Fig. 3: The effect of mycorrhiza, PGPR consortium, and NPK fertilizer on chlorophyll content and stomata density (A) chlorophyll content (B) stomata density.

Besides measuring the productivity parameters, we also measured the chlorophyll content and stomatal density post-harvesting. We observed there was no significant difference for these parameters with different treatments. Based on the results of the ANOVA test, chlorophyll levels were not affected by the treatment given (p-value > 0.05). The average chlorophyll content in all treatments is presented in Fig.3.

Based on Fig. 3A, the highest chlorophyll content was in the K1 treatment with compost fertilizer. Stomatal density is defined as the number of stomata in one field of view. Stomatal density can be indicated as the plant transpiration rate, where the more stomata, the higher the plant transpiration rate (Maylani et al. 2020). Stomata regulate gas exchange between plants and the environment and control water loss (Man et al. 2015). The process of transpiration in plants is influenced by several factors, one of which is the number of stomata (Jiaying et al. 2022). Based on the results of statistical tests that showed that the stomatal density was not normally distributed, then Kruskal-Walli's test was performed with a p-value >0.05 or no significant effect from each treatment. The results of the average stomatal density in each treatment are shown in Fig. 3B.

Based on the research results presented in Fig. 3C, all treatments show infection percentages ranging from 75 – 100%, indicating high infection levels (Padri et al. 2015). The planting media provided with mycorrhiza are

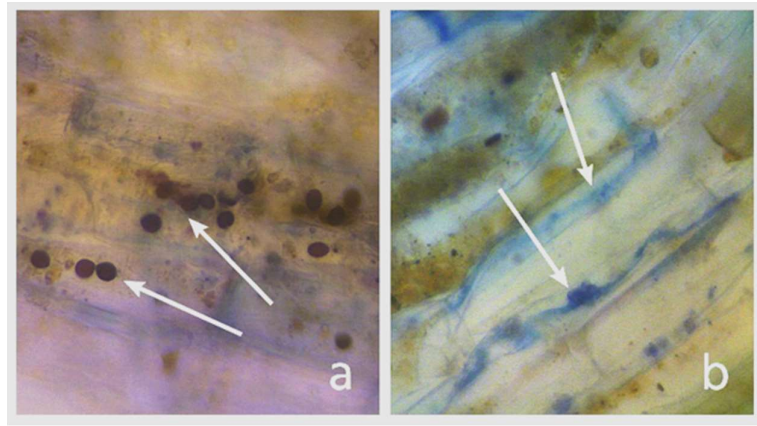

Fig. 4: Mycorrhizal infection on the root of maize (M= 400x). a) Spores of Mycorrhizae,b) Hifa of Mycorrhizae.

treatments K3, P0, P1, and P2. The occurrence of infection demonstrates the ability of both Indigenous (native spores of mycorrhyza in planting medium) and exogenous mycorrhiza (spores of mycorrhyza added to the planting medium) to form a mutualistic symbiosis with the host plant, maize (Fig. 4). PGPR positively influences this symbiosis through various mechanisms, such as enhancing spore germination and hyphal permeability in plant roots (Ramasamy et al. 2011). Similarly, treatments K1 and K2, which were not supplemented with mycorrhiza, were also capable of infecting maize plants. This suggests the involvement of indigenous mycorrhiza present in the planting media. The presence of Indigenous spores is greatly influenced by biotic factors (such as humans and animals, propagules, and mycorrhiza dispersal) and abiotic factors (wind, soil pH and temperature, crop rotation, fertilizers and organic matter content, soil moisture, pesticides, heavy metals, and salinity) (Bueno & Moora 2019, Vikas et al. 2016). Therefore, the presence of native mycorrhiza in treatments K1 and K2 is presumed to be due to favorable abiotic and biotic conditions.

The effect of mycorrhiza, PGPR consortium, and NPK fertilizer on maize growth is shown in Fig. 1. The highest height of P2 treatment has been influenced by the treatment of these fertilizers. The 50% NPK dose in the P2 treatment was suspected of helping plant height growth because there were elements of N, P, and K. Nitrogen is regarded as an essential macronutrient for the growth of plants. It involves the morphological and physical development of plants. N is a crucial component in building the structural integrity of plant proteins. Furthermore, the N function controls a variety of plant enzymatic processes (Ghorai & Ghosh 2022). Additionally, this substance (nitrogen) can promote plant height, root branching, shoot branching, flowering, and fruiting (de Bang et al. 2021).

The addition of biological fertilizers, such as AMF and the PGPR consortium, in the P2 treatment, also helps the height growth of corn plants. Compost provides organic matter that is degraded by microorganisms so that the nutrients contained in compost can be used for plant growth (de Bang et al. 2021). Thus, the presence of AMF and PGPR in P2 treatment could help plants by degrading compost and increasing plant height. The results of P2 treatment are in line with research by (de Bang et al. 2021), which showed that the highest plants were found in the PGPR application and the *Glomus mosseae* application, which was also a combination of AMF (*G. mosseae*) and the PGPR consortium. AMF functions in increasing root growth and uptake of water and nutrients by hyphae growth, which increases plant height. PGPR can also increase plant height by producing phytohormones that stimulate root growth and enrich nutrient uptake areas by fixing nitrogen from the atmosphere, dissolving P, and producing plant growth hormones (de Bang et al. 2021).

The P2 treatment, which consisted of a plant with full treatment, including compost, AMF, PGPR consortia, and 50% dose of NPK, had the largest stem diameter. The content of the applied complete fertilizer has an impact on the production of stem diameter. The NPK fertilizer application to the P2 treatment had a higher dose than P0 and P1. These findings are consistent with those of Sayara et al. (2020), who found that the more NPK fertilizer is applied to plants, the more nutrients (N, P, and K) are made available to them. These nutrients are then used by plants for metabolism, growth, and development, one of which is the increase in stem diameter. The availability of nitrogen can boost photosynthesis results to be converted into protein and create protoplasm, which impacts the expansion of stems. The N element released from NPK fertilizer affects the growth of stem diameter, which plays a role in the

enlargement of organs such as stems (Khalediyan et al. 2021, Kuila et al. 2020). It was also believed that the addition of AMF and PGPR to the P2 treatment would have supported the growth in stem diameter. By causing the release of IAA and GA hormones, which might impact cell elongation, the administration of PGPR to plants helps to promote growth (Gusta & Same 2022, Marler 2022). One consequence is the lateral lengthening of stem cells, which increases stem diameter.

Additionally, the N, P, Ca, K, and Na content of plants can be improved by combining PGPR and AMF (Cao et al. 2020). When plants are infected with AMF, the presence of PGPR raises the nitrogen capacity of leaves. In addition to the element N, PGPR bacteria can also support AMF symbiosis by increasing the available bio phosphate because P will be dissolved by organic acids produced by plants and bacteria to increase absorption by plant root hairs. In addition, AMF microorganisms applied to plants can help plants scavenge P outside the rhizosphere region and make P available to plants (Marler 2022). Therefore, P2 plants are thought to be able to increase stem diameter with the help of AMF and the PGPR consortium.

The P2 plants with the complete composition of fertilizer, which included compost, AMF, PGPR, and NPK 50%, aged 7 WAP, had the highest number of leaves, where this composition was thought to affect the growth of plant leaves. The presence of nitrogen perhaps affected the number of leaves in the P2 treatment. Nitrogen nutrients will be translocated to the vegetative part of the plant, such as the leaf (Adekiya et al. 2020). In addition, the increase in the number of leaves in the P2 treatment was thought to have a role from the AMF and the PGPR consortium. AMF and PGPR are able to help provide nutrients, including phosphorus and nitrogen, which plants use for the growth of organs such as leaves (Adekiya et al. 2020). This is supported by the opinion of Cao et al. (2020), who states that the addition of PGPR combined with AMF can increase the content of N, P, Ca, K, and Na in plants.

Furthermore, the addition of NPK in P2 treatment with a dose of 50%, which was the highest dose between P0 and P1, was thought to affect the increase in the number of plant leaves. NPK fertilizer contains elements needed for plant growth, such as elements of N, P, and K (Umami et al. 2019). Therefore, the P2 treatment got a nutrient supply from NPK fertilizer, which was used to increase the number of leaves.

The P2 treatment with a full composition of compost, AMF, PGPR consortium, and 50% dose of NPK produced the highest Leaf Area Index (LAI) from 1 to 8 WAP, as well as the highest yields in plant height, stem diameter, and number of leaves. It is believed that the type of fertilizer used to feed plants can influence how much leaf area grows. The P2 treatment had the most leaf area because it had an adequate supply of N and P. It was believed that N and P in the P2 treatment came from NPK fertilizer. The nutrients in NPK, particularly nitrogen and phosphorus, aid in cell division and elongation, which increases the size, length, and rate of development of leaves (Johnson 2010, Sokoto et al. 2012). The results of the P2 treatment are in line with the study by Kuila et al. (2020), which showed higher leaf area yields in the combination of AMF and PGPR, compared to the leaf area yields of single microorganisms. The presence of PGPR allows for the growth of leaf area by dissolving P and nitrogen fixation that plants can use to expand leaves (Johnson 2010, Sokoto et al. 2012). The results of plant growth, stem diameter, number of leaves, and leaf area had the same relative highest yield in P2 treatment. This is thought to be closely related to the final yield of N levels in plants. In the post-harvest soil of P2 plants, it is known that P2 plants have the lowest levels of N and P. This is thought to be due to the harvest. The soil will lose N and/or P after harvesting because it is taken up by plants (Liu et al. 2021, Wang & Ning 2019).

Based on Fig. 2, it is shown the effect of mycorrhiza, PGPR, and NPK supplementation on the maize's productivity. The highest cob weight results were found in the P2 treatment. NPK fertilizer is thought to be able to provide nutrients for N, P, and K elements that can be absorbed by plants, thereby enriching plant nutrients that can provide higher yields (Hu et al. 2020). NPK given in the P2 treatment is thought to also help increase the weight of the seeds. According to Xu et al. (2020), P affects seed filling because P in vegetative organs is reused to support the growth of developing grains.

Furthermore, the aging leaves (senescence) transfer at least 50% of the P content to the grain. Then, the element K which was also found in NPK fertilizer, which was applied to the P2 treatment, also increased the weight of the cobs. Elemental K can increase productivity by being involved in plant physiological processes such as assisting the activation of more than 60 enzymes that catalyze the uptake and transport of metabolite and nitrate products from the roots to the top of the plant where this process also affects plant productivity and adds weight to the ear (Senbayram et al. 2015). The P2 treatment was also given biological fertilizers, namely AMF and the PGPR consortium, which were suspected to be involved in the weight gain of the cobs. This is thought to be due to the symbiotic relationship between the two, which is able to enrich nutrients for plants, thus affecting the weight of the cobs. The combination of AMF and PGPR is known to increase the uptake of N and P elements in the soil, which can be utilized by plants for growth and productivity (Tulung et al. 2021). Thus, AMF and

PGPR help plants utilize the available N and P to increase the weight of the cobs.

The results of fresh and dry weight, which are shown in Fig. 2C, indicate that the application of 50% compost, AMF, PGPR, and NPK to P2 produces the highest fresh weight. In comparison to all plants, it was believed that the largest fresh weight, P2, would accumulate water and produce the maximum photosynthetic yields. The P2 treatment, which had the largest dose of NPK fertilizer relative to P0 and P1, was then assumed to also contribute to the increase in fresh weight. According to Friede et al. (2016), a larger dose of NPK fertilizer will enhance crop yields. Crop yields are derived from N and P components, and the higher the amount of nutrients taken by the plant, the higher the plant growth, which in turn affects the fresh weight.

Additionally, P2 treatment has inoculated PGPR, which also has an impact on the fresh weight. By delivering N fixed from the environment, PGPR had a function as diazotroph bacteria engaged in biological N2 fixation (BNF), which may have a direct impact on the plant's N budget (Okonwu & Mensah 2012). AMF is believed to have an impact on the wet weight of P2 treatments in addition to PGPR since it can supply nutrients (N, P, and K) to the soil to promote growth (Chapin 2003). Fresh weight and growth parameters are positively correlated because fresh weight is an accumulation of photosynthetic products during the growth process (Liu et al. 2021). Therefore, the growth yield of P2 treatment was positively correlated with the fresh weight yield.

The dry weight (DW) parameter was in line with the yield of plant height and LAI, where the P2 treatment plants had the highest result. Dry weight is supported by the presence of nutrients in the soil. The results of the P2 treatment are in accordance with the research of Barin et al. (2022), where the application of NPK can increase plant growth, such as height, leaf area, and dry weight. The photosynthetic process is assumed to produce the dry weight at P2, with nutrients coming from the complete composition of fertilizers (compost, AMF, PGPR consortium, and 50% NPK) being applied. Dry weight is the result of the formation (95%) of various organic compounds from the photosynthesis process (the use of light energy to reduce carbon dioxide into sugar) (Ma et al. 2021). Dry weight accumulation is influenced by the process of photosynthesis in leaves (Anwar et al. 2020). One of the factors that affect the process of photosynthesis is the content of nutrients, such as N. Application of NPK can increase the process of photosynthesis (Anwar et al. 2020). Therefore, the application of NPK will affect the photosynthetic process which has an impact on the accumulation of plant dry weight. Thus, it can be said that the presence of NPK fertilizer may influence the dry weight of the P2 treatment. The higher the dose of NPK given, the higher the N element obtained by the plant used for photosynthesis, which affects the dry weight of the plant. The highest dose of NPK fertilizer (50%), compost, and a combination of AMF and PGPR are thought to help the accumulation of dry weight in P2 treatment. The presence of microorganisms like AMF and PGPR was also believed to have contributed to the elevation in dry weight in the P2 treatment. A study showed consistent results that an increase in plant dry weight occurred when *Glomus intraradices* (included in AMF) was applied alone or in combination with *Pseudomonas fluorescens*, which is one of the phosphate solubilizing bacteria, where phosphate can increase the dry weight (Li et al. 2020, Song et al. 2019).

In line with the fresh weight yield, the lowest dry weight was found in the K3 treatment with the fertilizer composition consisting of compost and AMF. When compared to P2, the lack of K3 nutrient sources is also suspected to be the cause of the low dry weight because it affects the photosynthesis process. After all, when compared to P2, which is the treatment with the highest dry weight, it has a complete fertilizer composition. The results of the lowest mean dry weight of K3 treatment were also thought to be because the application of AMF to plants was not very effective. The cause of the ineffectiveness of AMF in the plant growth process that correlated with dry weight was the absence of symbiosis of AMF with PGPR and the interaction of parasitism between AMF and host plants (He et al. 2019, Raklami et al. 2019).

The high chlorophyll content in the K1 treatment was thought to be due to the high content of K elements. The high content of K elements in plants will affect plant metabolic activities, such as playing a role in activating protein synthesis enzymes, sugar transport, N and C metabolism, and photosynthesis (Andriani et al. 2017). The influence of N in chlorophyll synthesis will affect the chlorophyll content in leaves. Therefore, the chlorophyll content in K1 increases, assisted by the K element in the soil. Morphologically, the control K1 showed greener leaves than all treatments. In addition, the results of this high chlorophyll content were thought to influence the productivity of maize treated with K1, which also showed the highest average cob length. Chlorophyll in plants can affect growth because photosynthetic products are used by plants, one of which is to increase growth (Campbell et al. 2021). The lowest chlorophyll content was found in the K3 treatment, which was treated with compost and AMF. In addition to chlorophyll content, K3 treatment also showed the lowest growth in plant height and leaf area. Chlorophyll is a photosynthetic pigment that involves photosynthetic

capacity and affects plant growth (Li et al. 2018, Maylani et al. 2020, Wankmüller & Carminati 2022). The small leaf area in the K3 treatment was thought to affect the chlorophyll because the leaf area index (LAI) is a biophysical parameter that has a strong correlation with chlorophyll that indicates photosynthetic capacity for plant yields (Jo & Shin 2021). Campbell et al. (2021) and Li et al. (2018) said that plants use chlorophyll for photosynthesis and produce sucrose, which is used to increase growth.

The highest stomatal density was found in the P2 treatment with the composition of fertilizers, compost, AMF, PGPR consortium, and 50% NPK (highest dose), which was in line with the yield of plant height, stem diameter, number of leaves, and leaf area which also showed the highest yields. Stomatal density and soil fertility, which support the availability of nutrients, are correlated with the photosynthetic process of plants. AMF and PGPR, which were applied to the P2 treatment, were thought to affect the stomatal density of the leaves. Sakoda et al. (2020) said that one of the factors that influence stomatal density is soil fertility. Soil fertility can be increased by adding compost, AMF, PGPR consortium, and NPK to provide nutrients in the form of N, P, K, Ca, Mg, and S (Ashari et al. 2017, Khalediyan et al. 2021, Raklami et al. 2019, Xue et al. 2020). The elements N, P, and K correlated with an increase in the photosynthetic product on the dry weight. Stomatal density in P2 treatment was thought to play a role in the accumulation of plant dry weight. The dry weight of plants is one of the results of photosynthesis, which requires CO_2 through stomata from the environment (Jiaying et al. 2022, Sun et al. 2020). The process of photosynthesis is influenced by elements such as N, P, and K because they can increase photosynthetic capacity (Ashari et al. 2017). These elements and the exchange of CO_2 through the stomata will help increase the photosynthetic yield (dry weight). Therefore, the high dry weight in the P2 treatment correlated with the stomatal density and the higher the nutrients NPed by the P2 treatment plants.

The lowest stomatal density was found in K2 treatment with 100% NPK fertilizer and compost. Compost fertilizer and 100% NPK were thought to be ineffective in increasing the number of stomata. The low density of stomata is thought to be influenced by the fertilizer applied. One study said that chemical fertilizers can significantly reduce soil pH, which is closely related to a decrease in bacterial diversity and a significant change in the composition of the bacterial community (Wang et al. 2021). Therefore, the presence of microorganisms in K2 plants may be affected because the presence of NPK is at most at a dose of 100% or 4.8 grams, which causes the innate microorganisms in the soil to be disturbed and cannot help regulate hormones and water, which affects the number of stomata in leaves. In addition, this result is also in line with Sashinta's research (Ashari et al. 2017), where a mixture of organic fertilizer and NPK fertilizer does not have a significant effect on plants, presumably because stomatal density is more influenced by factors of temperature, sunlight, and plant adaptation to the environment. Low water supply will negatively affect the formation of stomata, so plants reduce the number of stomata to avoid water deficit.

CONCLUSION

In all treatment groups, nitrogen (N) and potassium (K) levels increased, whereas phosphorus (P) levels decreased compared to the control group (soil without treatment). However, there were no notable differences observed for each parameter except in the P2 treatment that comprised compost, PGPR consortium, AMF, and 50% of NPK, which displayed the most favorable growth and productivity outcomes. In addition, all treatment shows a high percentage of mycorrhizal infection. In summary, the findings suggest that the combination of PGPR and AMF effectively halved the use of chemical fertilizers.

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