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EFFECT OF MICROBIOME INOCULATION IN CORN CROP (*ZEA MAYS*) FOR BABY CORN AND FORAGE PRODUCTION ON GROWTH AND BIOMASS RATIO

Arif Ragil Saputra[1], Nyimas Popi Indriani[2], Mansyur[2]
[1]*Postgraduate Study Program Faculty of Animal Husbandry, Padjadjaran University*
[2]*Department of Animal Nutrition and Feed Technology, Faculty of Animal Husbandry, Padjadjaran University*
Jl. Raya Bandung Sumedang KM 21, Jatinangor, Sumedang, 45363, Indonesia.
[a]*email:* nyimas.popi@unpad.ac.id

Abstract

This study aims to determine the effect of microbiome inoculation on the growth and biomass ratio of th corn crop, producing baby corn and forage. This research was conducted in the Ciparanje research field and The Animal Food Plant Laboratory, Faculty of Animal Husbandry, Padjadjaran University. The method used was an experimental method with a completely randomized design (CRD) consisting of six treatments and four replicates in each treatment. The treatments consisted of P1= BP4, P2= Probiotic LAB, P3= Mycofer (a consortium of arbuscular mycorrhizal fungi: *Glomus manihotis, Glomus etunicotum, Gigaspora sp., and Acaulospora tuberculata*), P4= BP4 + Mycofer, P5= LAB + Mycofer, P6= BP4 + LAB + Mycofer. There are five parameters observed, consisting of plant height every week, number of leaves, age of plant at tassel emergence, leaf-to-stem ratio (LSR), and shoot to root ratio. The data were then analyzed using Analysis of Variance (ANOVA), and if it showed significant results, it was continued with Duncan Test. The results showed no significant effect of microbiome inoculation on, the age of the plant at tassel emergence and leaf-to-stem ratio. Significant results were obtained in the 9th-week plant height parameter (best in P5 at 158.25 cm), a number of leaves (best in P5 at 15.75), and shoot-to-root ratio (best in P6 at 1.58). Overall, it can be concluded that microbiome inoculation can increase nutrient use efficiency and reduce inorganic fertilizers by as much as 50%, supporting environmentally friendly and sustainable agricultural and livestock practices.
Keywords: Microbiome, Baby corn, Plant growth, Biomass ratio, Forage

PENGARUH INOKULASI MIKROBIOMA PADA TANAMAN JAGUNG (ZEA MAYS) PENGHASIL JAGUNG SEMI DAN HIJAUAN PAKAN TERHADAP PERTUMBUHAN DAN RASIO BIOMASSA TANAMAN

Abstrak

Penelitian ini bertujuan untuk mengetahui pengaruh inokulasi mikrobioma terhadap pertumbuhan tanaman dan rasio biomassa tanaman jagung penghasil jagung semi dan hijauan pakan. Penelitian dilaksanakan di lahan penelitian Ciparanje dan Laboratorium Tanaman Makanan Ternak (TMT) Fakultas Peternakan Universitas Padjadjaran. Metode yang digunakan adalah eksperimental dengan Rancangan Acak Lengkap (RAL) yang terdiri dari enam perlakuan dan empat ulangan. Perlakuan terdiri dari P1= BP4 (Lactobacillus dan Saccharomyces), P2= Probiotik BAL (Lactobacillus), P3= Mycofer (fungi mikoriza arbuskula Glomus manihotis., Glomus etunicotum, Gigaspora sp., dan Acaulospora tuberculata), P4= kombinasi BP4 dan Mycofer, P5= kombinasi BAL dan Mycofer, P6= kombinasi BP4, BAL dan Mycofer. Terdapat lima parameter yang diamati meliputi tinggi tanaman setiap minggu, jumlah daun per tanaman, umur muncul bunga jantan, rasio daun- batang, dan rasio tajuk- akar. Data penelitian dianalisis menggunakan Analisis of Variance (ANOVA) kemudian apabila menunjukkan hasil yang signifikan dilanjutkan dengan uji lanjut Duncan. Hasil penelitian menunjukkan bahwa inokulasi mikrobioma yang berbeda tidak berpengaruh nyata terhadap umur muncul bunga jantan dan rasio daun - batang. Hasil signifikan didapatkan pada parameter tinggi tanaman minggu ke-9 dengan hasil terbaik didapat oleh P5 (kombinasi BAL dan Mycofer) yaitu 158,25 cm. Data jumlah daun menunjukkan hasil yang signifikan dengan hasil terbaik didapat oleh P5 (15,75 helai). Pada parameter rasio tajuk- akar juga menunjukkan hasil yang signifikan dengan nilai tertinggi didapat oleh P6 (kombinasi BP4, BAL dan Mycofer) sebesar 1,58. Secara keseluruhan, dapat disimpulkan bahwa inokulasi mikrobioma dapat meningkatkan efisiensi penggunaan nutrien dan mengurangi penggunaan pupuk anorganik sebanyak 50% sehingga mendukung praktik pertanian dan peternakan yang ramah lingkungan dan berkelanjutan.
Kata kunci: Mikrobioma, Jagung Semi, Pertumbuhan Tanaman, Rasio Biomassa, Hijauan Pakan.

INTRODUCTION

Forage plays a crucial role in animal husbandry as the primary feed source for ruminants, and significantly impacting livestock productivity. One of the main obstacles farmers face in procuring forage is its limited availability, which is influenced by the season. Forage tends to be abundant during the rainy season, while during the dry season, forage will be challenging to obtain (Sihombing et al., 2021). This is due to the tendency of farmers to rely on wild grasses, making the types of forage and their availability unpredictable. Field grass combines various local grasses that grow wildly, not because of cultivation (Wahyono et al., 2019). Field grasses' productivity and nutrient quality vary and tend to be low depending on the species. One option for a green source to replace field grass is maize forage.

Maize crops have an essential role as a source of food as well as a source of forage for livestock. Maize as the main product is a source of carbohydrates, fiber, and various essential nutrients such as vitamin B, iron, and magnesium, making it an essential component in meeting human food needs (Lestari et al., 2023). In addition, corn also provides benefits as a source of forage for livestock; its leaves, stems, and corn husks can be used as a forage source for animal feed rich in fiber, protein, and energy (Zullaikah et al., 2023). One of the corn products cultivated in Indonesia is the semi-corn-producing corn plant. Baby corn is a young corn of sweet corn varieties harvested when it is still young and has not formed seeds (Saputra et al., 2024). Baby corn is derived from hybrid sweet corn, but emerging male flowers are immediately removed (emasculation). As a result, corn cobs can be formed faster and in greater numbers. The baby corn forage has a smooth texture when it is still young, making it easier and faster for livestock to digests. In addition, younger plants have higher crude protein content than forage plants (stems and leaves) and lower crude fibre content (Maidah et al., 2022).

Several things must be considered to increase baby corn production, including variety, spacing, water availability, soil fertility and fertilization. An important issue that needs to be addressed is the excessive use of inorganic fertilizers/artificial fertilizers. The continuous use of inorganic fertilizers can affect soil quality. According to Puspitasari (2023), the continuous use of inorganic fertilizers has severe negative impacts, including soil degradation. This condition makes the soil harden faster and reduces the soil's ability to store water, which can result in decreased plant productivity. In addition, excessive use of inorganic fertilizers can pollute the soil, where chemicals enter and damage the natural environment of the soil. Another disadvantage is that the acid content of chemical fertilizers (hydrochloric acid and sulfuric acid) can increase the soil's acidity level, damaging the soil's chemical, physical and biological properties (Alfarisi, 2024).

Environmentally friendly and sustainable agricultural practices are the solution to current agricultural problems. One of the principles of sustainable agriculture is to utilize natural materials as plant fertilizers, such as microbial inoculants (bioinoculants). Microbial inoculants are microorganisms applied to soil or plants to improve plant productivity and health. Microbial inoculants can include bacteria, fungi, and algae, which can help reduce the application of inorganic fertilizers. Microbial inoculants are an environmentally friendly solution that delivers nutrients to plants sustainably (Alori & Babalola, 2018). Microbial inoculants are not the same as conventional fertilizers, they are materials that contain microorganisms that actively help the decomposition process of materials in the soil. In addition, plants can use microbial inoculants to inhibit the growth of pests and plant diseases. The advantages of microbiome inoculants for plants include not leaving residues in the soil, not damaging soil biota, not being toxic, being sourced from nature, being beneficial microorganisms, not being destructive, and being made from organic materials that are environmentally friendly and safe.

This study examines the effect of mycorrhizal inoculation of maize plants producing semi-corn and forage on plant growth and biomass ratio. This research is expected to provide information on the best microbiome that can be utilized in a more efficiently and environmentally friendly way in agriculture and animal husbandry.

MATERIALS AND METHODS

This research was conducted in the Ciparanje research field and Animal Feed Plant Laboratory, Faculty of Animal Husbandry, Padjadjaran University, from August 2023 to February 2024. This study used an experimental method with a completely randomized design (CRD) of 6 treatments and four replications. There were 24 experimental units with treatment arrangement as listed: P1 = maize treated with BP4 (Lactobacillus and Saccharomyces), P2 = Lactic Acid Bacteria (LAB *Lactobacillus sp*), P3 = Mycofer (arbuscular mycorrhizal fungi *Glomus manihotis, Glomus etunicotum, Gigaspora sp., and Acaulospora tuberculata*), P4 = combination of BP4 and Mycofer, P5 = combination of LAB and Mycofer, P6 = combination of BP4, LAB and Mycofer.

The corn seeds used were Bonanza sweet corn varieties planted in sterile soil media in polybags. The equipment used included hoes, scales, ram wire (soil filter), soil sterilization equipment (iron barrel, furnace, plastic cover and thermometer), a set of plant maintenance tools, ruler, analytical scales, chopper, drying cabinet, sample packing envelope, and stationery. Planting media was prepared by sterilizing the soil using the dry heat method then, the prepared soil was put into polybags measuring 50x50 cm. Corn seeds were planted in holes 5 cm deep with two seeds per hole, then watered and treated with microbiome inoculum. Male flowers were cut immediately when they appeared. Plant samples consisted of forage that had been separated between leaves, stems and roots, which were then chopped to a length of 2-3 cm and dried in a drying cabinet at 70 ºC for 1 week (until the sample weight stabilized).

Height measurement of the spring corn crop began when the plants were 7 days after planting (dap) until male flowers appeared (45-63 dap), with a measurement time interval of one week. Plant height was measured by measuring the stem from ground level to the tip of the last leaf upright using a ruler/ruler with cm units. Furthermore, the observation of the number of leaves of sweet corn crop began when the plants were seven days until male flowers appeared (45-63 dap) with a measurement time interval of 1 week. The number of leaves counted in the study were leaves that had opened completely. The plant age at tassel emergence was calculated from the day the seeds were planted until the male flowers bloomed. In this phase, observations were made every day so that no data was missed because each plant may have a different age of plant at tassel emergence.

Leaf-to-stem ratio and shoot-to-root ratio measurements were carried out after the fourth baby corn-harvest, which was conducted 82 days after planting. The leaf-to-stem ratio were measured by weighing the dry weight of leaves and stems using analytical scales with gram units of measurement. To quickly obtain the ratio between stems and leaves, it is necessary to separate the stem and leaf samples before the enumeration process. Meanwhile, the ratio of crown and roots was measured by weighing the dry weight of the crown (stems and leaves) and the dry weight of corn roots after drying with a drying cabinet at 80ºC until the sample weight was stable/constant. The data obtained were then tested using Analysis of Variance (ANOVA) and continued with Duncan Test.

RESULTS AND DISCUSSION

Plant Height by Week

Table 1 shows that different microbiome inoculation treatments did not significantly affect plant height per week from observation at one week after planting to 9 weeks after planting. The new microbiome inoculation treatment produced a significant effect at week 9, with the P2 treatment (LAB) significantly different from the results of other treatments. Significant results only seen at the end of the vegetative phase were thought to occur because, in the early growth phase, the microbiome inoculated in the spring maize plants had not had sufficient time to colonize and create beneficial interactions. As a result, the positive impact still needs to be visible in the early stages of growth. This is in line with the opinion of Mustafa et al. (2010), which states that microbial colonization takes time to affect maize plant height significantly. Research by Mustafa et al. (2010) showed that microbial inoculation (mycorrhiza) in sweet corn crops began to have a significantly effect on plant height at weeks 4 and 6 after planting, while at week 2 after planting (early growth phase) had not shown a significant effect.

The treatment of P5 (LAB and Mycofer combination) at week 9 produced the best plant height of 158.25 cm. This result was significantly different when compared with P2 (LAB) but not significantly different when compared with P1, P3, P4, and P6. The combination of LAB and Mycofer gave the best plant height, presumably because of the positive synergy between LAB and Mycofer. LAB inoculation can improve the soil structure used in the study. At the same time, Mycofer consists of several species of arbuscular mycorrhiza that can increase the ability of plants to absorb nutrients in the soil. This is stated by Murindangabo et al. (2023), that LAB can increase plant growth by improving nutrient availability through the decomposition of organic matter and producing organic acids and phytohormones, especially auxins. While Mycofer, according to the research by Wardhika et al. (2015), the increase in plant height due to mycorrhizal inoculation occurs due to improved plant rooting conditions. Good rooting conditions will make it easier for plants to absorb nutrients available in the soil with the help of arbuscular mycorrhizal fungi. LAB will improve soil conditions, and sufficient nutrients will be absorbed optimally by plant roots with the help of mycorrhizal fungi to increase plant growth, including the height of baby corn crops.

Number of Leaves of Baby Corn

Based on Table 2. (DMRT further test results at the 0.05 level), different microbiome inoculation treatments significantly affect the number of leaves (strands) of baby corn plants. The P2 treatment (LAB) produced the lowest average number of leaves, with 13.75 strands. This was significantly different from other microbiome inoculation treatments. Meanwhile, the best results were obtained by P5 (combination of LAB and Mycofer) with an average number of leaves of 15.75, although it was not significantly different when compared to P1, P3, P4, and P6. The superiority of P5 is thought to be due to the synergy between LAB and Mycorrhiza. LAB improves soil nutrients, which are then optimally absorbed by plant roots with the help of mycorrhiza. This is in line with the opinion of Lamont et al. (2017), who stated that LAB can produce hormones and metabolites that stimulate plant growth and improve plant responses to stress. As an organic fertilizer, LAB also accelerates the decomposition of soil organic matter, producing organic acids and bacteriocins (bioactive compounds that can kill pathogenic bacteria). On the other hand, Mycofer (mycorrhiza) plays a role in increasing the absorption of nutrients by the roots of corn crops (Abrar et al., 2024).

The difference in results indicates that when used alone, lactic acid bacteria have a less optimal effect than the combination with mycorrhiza, which most likely works synergistically to increase plant nutrient uptake. Likewise, when LAB is combined with mycorrhiza and decomposing microorganisms (*Saccharomyces* and *Lactobacillus*), it does not give a better effect when compared to the combination of LAB + mycorrhiza (P5). This is likely because the combination of several microbiomes in the plant allows competition between microbes to get the same carbon, thus reducing the effectiveness of each microbe. This is stated by Purbalisa et al. (2020) in their research that microbes can reproduce well in soil with sufficient carbon content. Carbon is used as a home and energy source for microbes and can be reduced in line with the number and time of application of soil microbes. In general, the average number of leaves in all treatments gave high results compared to previous studies conducted by Indriani (2020), where the same corn variety (Bonanza) at the end of its vegetative phase produced an average number of leaves of 10.

Age of Plant at Tassel Emergence (Days)

Based on data analysis of the research results in Table 2, microbiome inoculation treatment does not significantly affect the age of male flower emergence in baby corn crops. All treatments gave relatively similar results related to the time of planting at tassel emergence, namely 66 - 69 days after planting. This is probably because genetic factors and the macro environment influence the development of the generative phase of baby corn crops. Lee et al. (2023) states that the development of the generative phase, such as flowering, tends to be more influenced by plant genetic factors and the macro environment, such as the availability of light, temperature, and humidity. This is supported by Chaudhry et al. (2024), who stated that the transition from the vegetative phase to the reproductive phase, including the age of tasseling (male flowers appear) in corn crops, is influenced by genetic and environmental factors such as temperature, photoperiod, and stress. Although the microbiome can improve overall plant health and growth, its influence on early reproductive phases, such as aging the plant at tassel emergence, is not as strong as its influence on other aspects, such as vegetative growth.

Leaf-to-Stem Ratio (LSR)

Table 3 shows that the inoculation of different microbiomes does not significantly affect the parameters of the ratio of leaves and stems, with the average ratio of leaves and stems ranging from 0.56 - 0.61. So, it can be concluded that the different types of microbiomes inoculated do not significantly affect the leaf-to-stem ratio parameters. This insignificant result is thought to be because genetic factors and the plant environment influence the ratio of leaves and stems in baby corn crops. Research from Li et al. (2018) showed that factors such as genetics and environment have a more dominant role in maize plant morphology, and parameters such as leaf-to-stem ratio tend to be less responsive to changes caused by different microbial treatments.

The analysis showed that the inoculation of different microbiomes did not significantly affect the ratio of leaves and stems. Still, when compared with several other studies, the value was higher. Research conducted by Muhammed et al.(2018) about the effect of using chemical fertilizers compared to liquid organic fertilizers revealed that the use of POC gave better leaf-to-stem ratio results of 0.51. Another study showed that the ratio of leaves and stems of fodder corn crops of various varieties harvested at the age of 86 HST ranged from 0.11 - 0.28. (Choudhary et al., 2023). The ratio of leaves and stems is one of the parameters of forage quality. The heigher the ratio of leaves and stems, the higher the plant quality also, because generally, leaves have higher palatability, digestibility, and nutritional value when compared to stems (Sari et al., 2021).

Table 1. Average Height of Baby Corn Crops (cm) by Week

Treatment	1	2	3	4	5	6	7	8	9
P1	13.60 a	25.63 a	42.50 a	56.08 a	73.30 a	90.78 a	109.05 a	125.63 a	146.28 a
P2	12.98 a	27.93 a	42.88 a	56.83 a	70.50 a	85.50 a	100.60 a	112.48 a	130.38 b
P3	14.15 a	26.23 a	46.25 a	56.75 a	70.25 a	84.50 a	106.20 a	126.35 a	151.50 a
P4	13.35 a	25.63 a	44.75 a	61.38 a	78.83 a	94.55 a	116.75 a	132.30 a	150.85 a
P5	12.23 a	24.70 a	41.63 a	57.00 a	74.58 a	96.75 a	116.58 a	131.75 a	158.25 a
P6	12.83 a	26.03 a	37.25 a	49.05 a	59.50 a	71.00 a	91.98 a	113.63 a	146.00 a

Description: Different letters (a,b) in the column indicate significantly difference, P1: BP4, P2: BAL, P3: mycofer, P4: Combination of BP4 with mycofer, P5: Combination of LAB with mycofer, P6: Combination of BP4, LAB and mycofer.

Table 2. Average number of leaves and Age of plant at tassel emergence

Treatment	Number of Leaves (Strands)	Tassel Emergence (Days)
P1	15.00 a	67.00 a
P2	13.75 b	66.50 a
P3	15.00 a	65.75 a
P4	15.25 a	66.50 a
P5	15.75 a	66.75 a
P6	15.00 a	69.00 a

Description: Different letters in the column indicate significantly difference, P1: BP4, P2: BAL, P3: mycofer, P4: Combination of BP4 with mycofer, P5: Combination of LAB with mycofer, P6: Combination of BP4, LAB and mycofer.

Table 3. Leaf-to-Stem Ratio and Shoot-to-Root Ratio of 4th Semi Harvest Maize (82 HST)

Treatment	Leaf-to-Stem Ratio	Shoot-to-Root Ratio
P1	0.61 a	1.23 b
P2	0.60 a	1.13 b
P3	0.57 a	1.47 ab
P4	0.58 a	1.15 b
P5	0.56 a	1.36 ab
P6	0.56 a	1.58 a

Description: Different letters in the column indicate significantly different, P1: BP4, P2: BAL, P3: mycofer, P4: Combination of BP4 with mycofer, P5: Combination of LAB with mycofer, P6: Combination of BP4, LAB and mycofer.

Shoot to Root Ratio

Based on Table 3, microbiome inoculation in baby corn crops significantly affected the shoot-to-root ratio parameter. Treatment P6 (combination of BP4, LAB, and mycofer) produced the highest ratio (1.58), significantly different from the other treatments, except with P3 (mycofer) and P5 (combination of LAB and mycofer). A high shoot-to-root ratio illustrates that the distribution of photosynthesis results towards the crown is faster than towards the roots, resulting in a lower proportion of roots (Rusmana, 2017). Sari et al. (2021) state that the crown's dry weight and the plant roots' dry weight influence the shoot-to-root ratio. The higher the crown dry weight value, accompanied by the lower the root dry weight value, the higher the crown-root ratio value. This is likely because the microbiome activities in the treatment can synergize well in improving nutrients and increasing their absorption to increase plant growth properly. Moelyohadi (2015) explains that corn crops will maintain root growth and suppress crown growth so that when nutrients are available and can be adequately absorbed, the shoot-to-root ratio of corn crops will be better.

CONCLUSION

This research concludes that the inoculation of the microbiome in corn crops producing baby corn and forage has varied impacts according to the measured parameters. Treatment P5 (combination of LAB and mycofer) gave the best and most significant results in the plant height parameter (week 9) and the number of leaves parameter of baby corn. The combination of LAB and mycofer showed positive synergy in improving nutrient availability and nutrient absorption by plant roots. However, in the age parameters at tasseling and leaf-to-stem ratio, the microbiome inoculation treatment did not give significant results. These findings suggest microbiome applications can reduce inorganic fertilizer use and promote sustainable agriculture.

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AUTHORS CONTRIBUTIONS

All authors contributed equally to this research, including the study's conceptualization, design, data collection, analysis, and manuscript preparation.

CONFLICT OF INTEREST

The authors confirm that there are no conflicts of interest to disclose.

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