Potential of Cyanobacteria as biological agents to improve sweet corn (*Zea mays saccharate*) germination and growth

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Abstract. Climate change can reduce crop yields. Cyanobacteria (blue-green algae), play an important role in sustainable agriculture by increasing plant resistance to drought. These microorganisms improve soil fertility by fixing nitrogen and producing bioactive compounds that enhance plant growth. The study aims to determine the role of cyanobacteria in improving germination and growth of sweet corn. It evaluated 11 strains of cyanobacteria (S1-S11) isolated from soil and corn roots in Grobogan Regency, Central Java, for their effect on corn seed growth. The germination experiment was conducted using a Completely Randomized Design (CRD) with four replications, treatment of 11 cyanobacteria strains, and added Control (S0). Surface-sterilized corn seeds (20 per treatment) were placed in sterile Petri dishes lined with sterile rice paper and cotton fibre. The experiment continued with an in-planta test using tubes containing a nutrient solution to observe the consistency of seed growth during the vegetative stage. The parameters observed were seed germination, plant height, root length, number of roots, and the fresh weight of shoots and roots. The results showed that cyanobacteria S1, S6, S7, and S8 significantly increased the germination and growth of sweet corn, providing promise for increasing corn productivity, especially in upland areas.

1 Introduction

Climate change poses a significant threat to global agriculture, with rising temperatures, changing rainfall patterns, and increasing frequency of extreme weather events leading to reduced crop yields [1][2]. As the demand for food continues to rise, innovative and sustainable solutions are crucial to ensuring food security. One promising strategy involves

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utilizing cyanobacteria, commonly known as blue-green algae, a group of photosynthetic microorganisms. These microorganisms play a vital role in nitrogen fixation, enhancing soil nutrient levels, especially in nitrogen-deficient environments [2]. By incorporating cyanobacteria into agricultural practices, it may be possible to mitigate some of the adverse impacts of climate change on crop production, paving the way for more sustainable and productive agriculture systems. In addition, cyanobacteria play a role in improving the physical properties of the soil, such as oil particle aggregation, accumulation of organic content, and increasing the water-holding capacity of the topsoil [3].

Microbial inoculation is practiced in several crops to enhance yield and soil fertility, with cyanobacterial inoculants playing a significant role. They are the primary producers involved in C–N cycling, not only in flooded paddies but also play beneficial roles in upland rice [4], chickpeas [5], [6], flower crops chrysanthemum [7]. Cyanobacteria improve soil stability, nutrient content, and groundwater availability, and enhance maize growth and yield in dryland areas during the dry season [8], which have gained attention for their potential role in sustainable agriculture. Thus, it could provide an eco-friendly alternative to reduce the use of chemical fertilizers. In addition, using biological fertilizers can reduce the need for inorganic fertilizers, increase agricultural production, reduce environmental pollution, and maintain soil quality [9]. The use of various microbial strains as biological fertilizers has been shown to reduce the use of chemical fertilizers, thus providing better yields and harvest quality [10][11].

Corn is an agricultural commodity in Indonesia that functions as an industrial raw material and a food crop, often used as animal feed [12]. The corn is generally planted in the uplands and in the second season in rainfed rice fields, fertilization is usually carried out using organic and inorganic fertilizers, while the use of biological fertilizers has not received much attention from farmers. Combining biochar, compost, phosphate-dissolving bacteria, and NPK fertilizer can improve soil quality and the sustainability of corn [13]. According to [14] corn is grown from seeds, and its growth begins through germination, the most critical stage of the plant life cycle. Key indicators of successful germination were shoot and root length. Roots absorb water and nutrients from the soil, while shoots transport these essential resources throughout the plant. Several factors, including seed quality and environmental conditions, influence seed germination and seedling development [15]. The study aims to investigate the germination and growth of corn seedlings under various cyanobacteria treatments to promote better growth and, ultimately, higher yields. The implication of this study is cyanobacteria application in corn enhances germination and growth, increases the yield and resistance of corn plants planted in upland, and can reduce chemical fertilizers.

2 Material and Method

This experiment evaluated 11 strains of cyanobacteria (S1-S11) isolated from soil and corn roots in Grobogan Regency, Central Java on corn at germination and vegetative growth. The experiment used a Completely Randomized Design (CRD), repeated four times, with treatment consisting of 11 cyanobacteria strains and added control (S0). In the germination experiment, surface-sterilized corn seeds (20 per treatment) were placed in sterile Petri dishes lined with rice paper and cotton fibre as a substrate. The experiment continued with an in-planta test using tubes consisting of a nutrient solution to observe the consistency of seed growth during the vegetative phase. The parameters observed were seed germination, plant height, root length, number of roots, fresh shoots weight, and fresh roots and shoots weight.

2.1 Seed preparation

A total of 20 corn seeds (Bimmo-Jawara variety) were placed in sterile Petri dishes, each lined with two sheets of straw paper and 0.8 g of cotton, which served as the substrate. The seeds were sterilized in chlorine oxide and soaked in a 70% alcohol solution for 30 seconds. Afterwards, the solution was discarded and the seeds were rinsed three times with sterile water until the smell of chlorine oxide and alcohol was eliminated. Finally, the seeds were germinated in prepared petri dishes according to the treatment.

2.2 Cyanobacteria preparation and application in the germination experiment

A total of 10 g of fresh cyanobacteria plus 100 ml of sterile distilled water was fragmented using a blender, then grown in an Erlenmeyer flask containing 400 ml of sterile BG11 media, aerated and with lighting at room temperature to support its growth for 14 days. For germination testing, 2 ml was taken and inoculated into a filled petri dish with corn seeds, then 20 ml or more of sterile water was poured into until the substrate was moist. The seeds were incubated in a dark place or covered with a cloth until protected from room light for three days. Then, the seeds germinated, and the cover was opened.

2.3 In planta experiment

This experiment used test tubes with a diameter of 2.5 mm and a height of 20 cm, and the content of the tube was 75 ml liquid. A total of 10 ml of fragmented cyanobacteria was added to a sterile test tube, followed by the addition of a nutrient solution containing 65 ml of macro and micronutrients from AB-Mix, with a concentration of 5 ml/l each for components was added and then covered with rock wool to place the planted seeds. The seeds were incubated in a dark place or covered with a cloth until protected from room light for three days. Then, the seeds germinated, and the cover was opened.

2.4 Statistical analysis

The data was analyzed using the SPSS statistical program (version 25). Descriptive statistics and ANOVA were performed for each treatment. Where significant differences were observed, the mean was separated using the Duncan Multiple Range Test at $p<0.05$.

3 Results and Discussion

The application of cyanobacterium increased the height of sweet corn plants grown in planta in the growth room. Some stain cyanobacteria (S1, S2, S3, S6, S7, S8, and S11) show a significant increase in plant height compared to the control (Table 1). The data suggests that cyanobacteria can significantly increase the growth of sweet corn, particularly strains S7, S8, S6, S2, and S11. These strains show consistent and strong growth-promoting effects across the different growth stages. In contrast, the control (S0) and strain S10 show slower growth, especially at the later stages of plant development. The present indicates that the selected cyanobacteria strains potentially increase crop productivity, especially in early and mid-vegetative stages.

These results indicate that cyanobacteria could improve crop growth and yields, which is promising for sustainable agriculture, especially under conditions where crop productivity might be compromised, such as in nutrient-poor or drought-prone soils. Application of

Cyanobacteria and green algae, Microcystis aeruginosa MKR 0105, Anabaena sp. PCC 7120 (Cyanobacteria), and Chlorella sp. (microalgae), on corn roots significantly increased germination and growth of corn seedlings [16].

The growth of sweet corn plants in test tubes showed noticeable variation (Figure 1). The visually better plant growth was observed in treatments S2, S6, S7, and S8. In contrast, the control plants (grown without cyanobacteria) appeared smaller. The roots displayed a range of intriguing colours, including brown, green and turquoise.

Table 1. The Effect of several types of cyanobacteria on the height of corn sweet plants at 5, 6, 7, 8, 9, 10, 11, and 12 days after planting in the growth room

Treatmens	5 DAP	6 DAP	7 DAP	8 DAP	9 DAP	10 DAP	11 DAP	12 DAP
				……………………………….. cm …………………………………				
S0	2.58a	8.20 a	12.03 abc	13.78 c	17.33 c	20.58 cd	22.20 de	24.80 c
S1	2.50a	7.53 ab	11.63 abc	17.25 ab	21.50 ab	23.80 ab	25.30 bcd	33.50 ab
S2	2.13ab	7.25 abc	11.50 a-d	17.13 ab	22.78 ab	23.95 ab	27.28 abc	37.75 a
S3	2.58a	7.68 ab	13.10 ab	18.63 a	21.68 ab	26.35 a	29.58 a	34.58 ab
S4	2.43 a	7.43 ab	11.25 bcd	16.38 ab	20.25 b	22.43 bc	25.33 bcd	32.48 ab
S5	1.53 b	6.83 bc	9.78 d	15.48 bc	21.08 ab	22.53 bc	26.10 a-d	34.70 ab
S6	1.93 ab	7.28 abc	11.17 cd	17.65 ab	22.03 ab	23.50 ab	27.25 abc	36.33 a
S7	2.45 a	7.95 ab	13.20 a	18.83 a	23.23 ab	24.90 ab	28.15 abc	36.88 a
S8	2.08 ab	6.70 bc	11.83 abc	17.18 ab	24.03 a	25.90 a	29.60 a	36.20 a
S9	2.65 a	7.85 ab	11.48 a-d	16.60 ab	20.88 ab	24.23 ab	25.13 cd	34.05 ab
S10	2.15 ab	6.08 c	8.15 e	11.05 d	16.43 c	18.68 d	20.65 e	29.20 bc
S11	2.63 a	7.50 ab	12.48 abc	18.43 a	21.88 ab	23.85 ab	29.45 ab	37.45 a

Remarks: Numbers in the same column followed by the same letter are not significantly different within 5% DMRT. DAP: Days After Planting

Fig .1. Performance of sweet corn plant with cyanobacteria treatment (from right to left S0, S1, S2 … S11, and selected cyanobacterial roots (from right to left S0, S6, S7, and S8)

The application of cyanobacteria significantly increased plant height, root count and length, and wet plant weight compared to control (Figure 2). Cyanobacteria strains S2, S6, S7, S8, and S11 significantly increased the height of sweet corn plants grown in-planta. In contrast, inoculation of cyanobacteria strain S10 did not increase plant height compared to control treatment. Corn plants inoculated with cyanobacteria were approximately 10-15%

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better than those not inoculated in terms of SPAD value, plant height, and available nitrogen (N) in the soil [17].

Some strains of cyanobacteria can increase the root count of sweet corn plants in in-plant experiments in the growth room, except for strain S8 (Figure 2). Significant cyanobacterial strains increase the number of sweet corn roots, including strains S1, S3, S6, and S7. These results are suitable for the application of cyanobacteria biofertilizer (CB), significantly improved corn growth, reduced Cd accumulation [18], increased grain yield of corn, and N efficiency use [19]. Previous study papers reported that cyanobacteria application can improve soil structure and N fixation, reduce salinity, increase crop yields, and absorb carbon [20].

Cyanobacterial inoculation noticeably increases the root length of the sweet corn plant. The root length of sweet corn increased in plants fed cyanobacteria compared to the control. Feeding cyanobacteria given strains S2, S6, S7, S8, and S11 gives a longer and more pronounced root length contrasted with the control treatment.

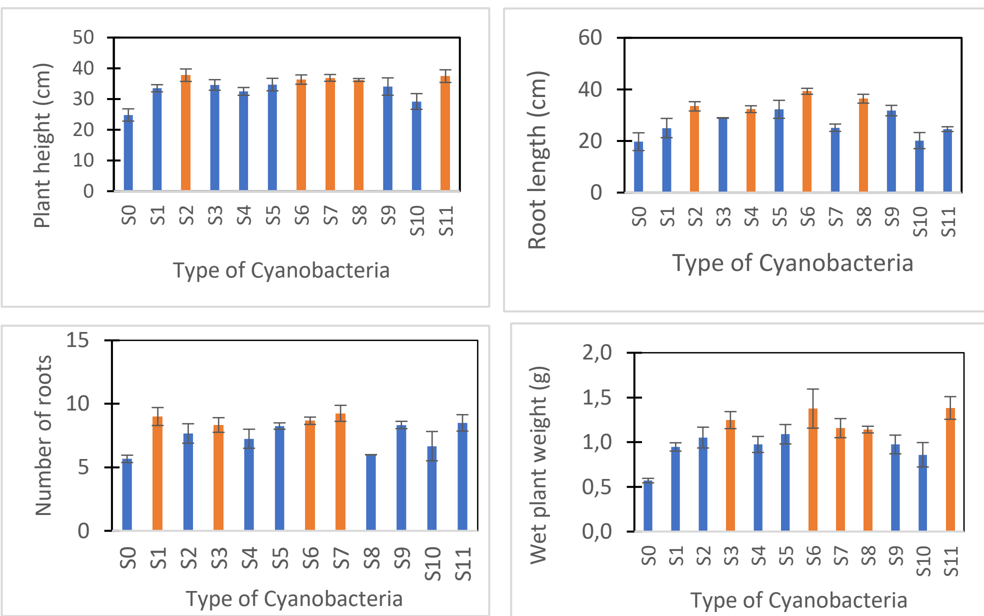

Fig. 2. Effect of cyanobacterial inoculation on plant height, number and length of roots, and wet weight of sweet corn plants

The application of cyanobacteria significantly increased the weight of fresh sweet corn plants compared to the control (S0, without cyanobacteria). The highest fresh weight of the sweet corn plant was obtained by applying S3, S6, and S11 cyanobacteria, followed by S7 and S8. The application of eleven types of cyanobacteria had varying effects on the wet weight of sweet corn plants. These findings highlight cyanobacteria's vital role in enhancing sweet corn plants' fresh weight.

Cyanobacteria application can increase nitrogen availability, improve plant physiology, and increase biomass. The results of this study are in line with [21], which shows that cyanobacteria can increase the corn germination rate, shoot and root lengths, total nitrogen content, nitrogen activity, and grain yield.

4 Conclusion

Cyanobacteria significantly promote the growth of sweet corn plants under controlled conditions in a growth room, improving plant height, root length, root number, and the fresh weight of both the plants and roots. Among the tested types S1, S6, S7, and S8 demonstrated the greatest ability to enhance the germination and growth of sweet corn in the growth room.

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