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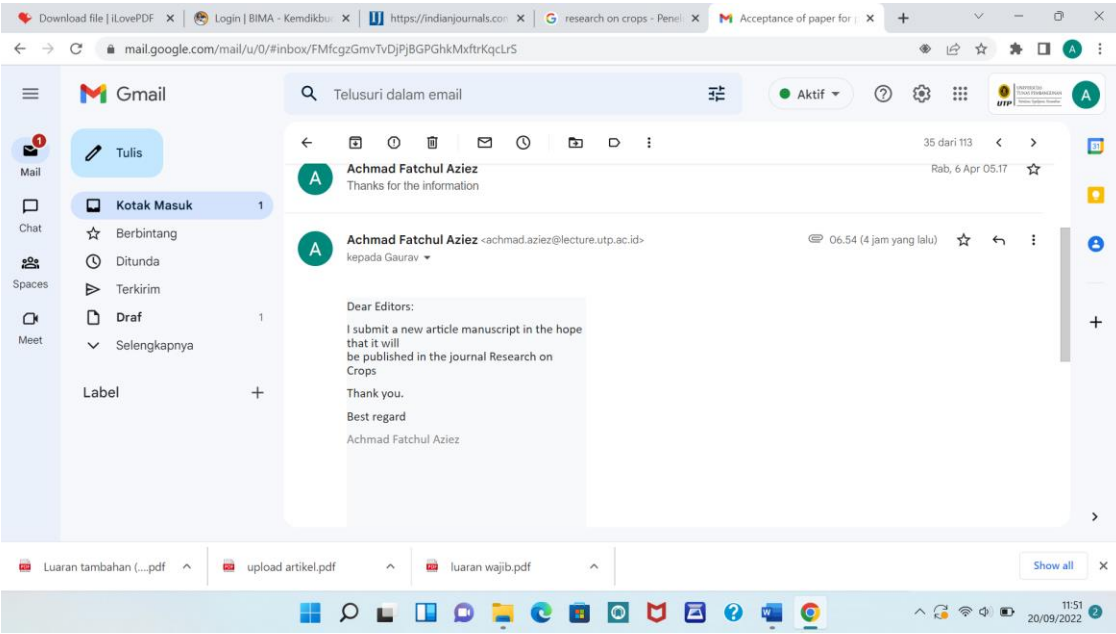


# PAPER SUBMISSION

# Contribution of Diazotrophic Endophytic Bacteria Consortium on Leaf Area Index, Leaf Area Duration, Net Assimilation Rate and Crop Growth Rate of Various Rice Varieties in Rainfed Lowland

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## ABSTRACT

**Abstract**: Rainfed rice fields in general often lack water and nutrients that are difficult for their roots to reach. Consortium of endophytic bacteria can assist in absorbing water and nutrients to increase the efficiency of nitrogen and phosphorus fertilizers. The purpose of this study was to determine the analysis of the growth of paddy varieties at various doses of the endophytic bacteria consortium. This research used a completely randomized block design with two factors and three replications. The first factor was a consortium of endophytic bacteria with a dose of 0, 20, 30, and 40 l/ha/application, while the second factor was varieties padddy ai. Situbagendit, Ciherang and Mekongga. The authors conducted this study in rainfed rice fields in Demangan, Sambi, Boyolali, Central Java, Indonesia, from June, 2022, to September, 2022, at an altitude of 113 m above sea level.The results showed that the dose of endophytic bacteria consortium 40 l/ha/application showed an increase in LAI, LAD, NAR and CGR compared to doses of 0, 20 and 30 l/ha/application.

**Keywords**: Consortium of endophytic bacteria, crop growth rate, leaf area index, paddy fields, rainfed paddy fields

## INTRODUCTION

Rainfed land uses rainwater for irrigation and differs from irrigated rice fields. Rainfed rice fields have a low available P content due to groundwater leaching (Meng *et al*., 2018). In general, improper agricultural management, long-term application of chemical fertilizers, and inefficient fertilizer use decrease the soil productivity of rice fields.

Drought stress is one of the most destructive abiotic stresses affecting plant growth and development. Drought stress affects physiological processes, biochemical changes, formation of secondary metabolites, significantly accumulates endogenous reactive oxygen species (ROS), and increases toxin levels (Hasanuzzaman *et al.*, 2017).

Drought stress greatly reduces rice grain yields and vegetative growth (Ahadiyat, Hidayat, and Susanto 2014; Maisura *et al*. 2014). Water-scarce conditions generally reduce grain size, grain weight, and seed formation rates (Kumar *et al*., 2014; Raman *et al*., 2012). Drought stress during the booting, flowering, and terminal stages can interfere with floret initiation, cause grain sterility, lower grain weight, and ultimately lower grain yield (Acuña, Lafitte, and Wade 2008). The rate of grain yield loss depends on the duration of water scarcity, plant growth stage, and stress intensity (Gana, 2011; Kumar *et al*., 2014).

One of the efforts to overcome drought stress is microbial-based technology, such as a consortium of endophytic bacteria. Endophytic bacteria are found in the host plant [Kumar, 2017)]. This type of bacteria creates a complex relationship with the host plant where it acts as a plant growth promoter. The role of plant-associated bacteria in increasing crop production and soil fertility Glick BR (2020). Microbial components in the plant endosphere and rhizosphere form beneficial associations with plants that can increase crop productivity (Ali, 2017). These bacteria increase plant resistance to various abiotic and biotic factors that limit growth and production (Kumar, 2018). These microbes can live both internally and externally in host plant tissues. For example, rhizosphere bacteria inhabit plant roots in the soil, and epiphytic bacteria inhabit the leaf surfaces of plants.

Rhizobacteria refers to the plant growth promoting bacteria present in the rhizosphere. The rhizosphere consists of a narrow zone of soil that is influenced by the plant root system where maximum microbial activity occurs (Verma, 2019). The rhizosphere zone is an ecological niche that provides a rich source of nutrients and energy for plant growth. Rhizobacteria are abundant plant partners in the rhizosphere, but they differ in their role in the promotion of plant growth. Various interactions occur between plants and rhizobacteria in the rhizosphere. These interactions are equally important, and involve signals between rhizobacteria and plant roots that regulate their biochemical activity (Bhattacharyya, 2012). Rhizobacteria are essential in the rhizosphere for nutrient cycling, carbon sequestration, and ecosystem functions that promote plant growth, yield and nutrition. Various genera of bacteria have been used as plant growth-promoting rhizobacteria (PGPR), including Burkholderia, Pseudomonas, Arthrobacter, Bacillus, Serratia, Micrococcus, Chromobacterium, Erwinia, Azospirillum, Caulobacter, Agrobacterium, and Azotobacter (Verma, 2019).

Rhizobacteria produce plant growth-regulating phytohormones such as ethylene, gibberellins, and auxins. Other important metabolites include the production of siderophores, enzymes, organic acids, antibiotics, biosurfactants, nitric oxide, and osmolytes. Metabolites are responsible for increasing nutrient absorption, tolerance to abiotic stress, nitrogen fixation, suppression of pathogenic organisms (Pii, 2015).

In addition, this trait is inherited and can be transferred through seeds, making it more suitable and effective in promoting plant growth (Verma, 2019). These heritability factors are important in selecting adaptive and effective endophytes associated with certain crops that are important for agriculture, especially in plant breeding and addressing challenges related to climate change. Their capacity to tolerate and induce resistance to biotic and abiotic stresses in plants can be harnessed to solve the associated edaphic and pathogenic challenges facing the crop production sector. According to AfzalI (2019), the various benefits associated with endophytes can be more striking when plants are subjected to adverse environmental stress. Habitat-induced stress triggers plant microbial signaling, which forms complex communications

Endophytic bacteria positively affect host plant development without significant harm while suppressing pathogens that may attack the plant (ZhangY, 2019). In return, endophytic microbes benefit and use the plant endosphere as a unique and safe haven that is not disturbed by harsh climatic conditions that can harm and affect its function (Le Cocq K, 2017). Moreover, Most of the endophytic bacteria exhibit a biphasic life cycle in which they alternate between soil and plant environment, thus surviving between seasons (Singh, 2017). Other bacteria form symbiotic structures such as nodules from beans that harbor various strains of bacteria. Only the rhizobia responsible for nitrogen fixation are well known, while other endophytic bacteria are poorly studied (AfzalI, 2019).

The purpose of this study was to determine the leaf area index, leaf area duration, net assimilation rate and crop growth rate on various varieties of lowland rice due to the administration of a consortium of diazotropic endophytic bacteria in paddy fields on rain-fed areas.

## Materials and methods

### *Study area*

The team conducted the research in Demangan, Sambi, Boyolali, Central Java, Indonesia, from June to September 2022 with alfisol soil. A geographical position was between 110° 22'-110° 50' east longitude and between 7°7'-7°36' south latitude with a height of 184 m above sea level (ASL). The average rainfall and temperature were 139 mm month$^{-1}$ and 26-32ºC, respectively.

### *Experimental design*

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This research was arranged in a randomized completely block design (RCBD) with two factors and three replications. The first factor was the dose of a consortium of endophytic bacteria consisting of four levels, i.e. doses of 0, 20, 30, and 40 l/ha/application,. The second factor was the second factor was varieties of rice fields ai. Situbagendit, Ciherang and Mekongga. In this study, there were 12 treatment combinations. Each treatment combination was three times replications, and each replication consisting of five plant samples.

This research used a completely randomized block design with two factors and three replications. The first factor was a consortium of endophytic bacteria with a dose of 0, 20, 30, and 40 l/ha/application, while the second factor was varieties of padi padi ai. Situbagendit, Ciherang and Mekongga.

### *Research procedures*

Before the research, the team conducted a chemical analysis of the soil used for the research substrate. The results showed an $H_2O$ pH of 6.52 (slightly sour), C concentration of 1.34% (low), organic matter concentration of 2,28% (low), total N concentration of 0.22% (low), available P of 9.49 ppm (very high), available K of 0.28 me/100 g (high)

The media used was alfisol soil. The length and width of the experimental plots were 500 cm and 200 cm, respectively. The water level was 5 cm deep, with the plants spaced 20 xm x 20 cm apart. The experimental field was weeded at 2 and 4 weeks after planting and controlled pests and diseases using organic pesticides. Urea, NPK Phonska and SP-36 fertilizers at a dose of 200, 100 and 75 kg $ha^{-1}$, respectively, were applied at planting time and five weeks after planting. The harvest criterion was the seed shells above the panicle being clean and firm.

### *Measurement*

The parameters observed were the leaf area index (LAI), leaf area duration (LAD), net assimilation rate (NAR), and crop growth rate (CGR). The data observation was conducted in 6 and 8 WAP. LAI was calculated from the ratio between the total leaf surface area per unit ground area. LAI was determined by the intensity of radiation intercepted divided planting spacing. LAD is the time a leaf could last on the plant. LAD was calculated from leaf area ($cm^2$) divided by time (week)

NAR is the ability of plants to produce dry materials that assimilate each unit of leaf area at each unit of time, which is stated in Eq. 1.

$$\text{NAR} = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1}, \text{ (in g.cm}^{-2}\text{.weeks}^{-1}\text{)} \qquad \text{(Eq. 1)}$$

CGR is the ability of plants to produce dry materials that assimilate each unit of land area at each unit of time, which is stated in Eq. 2.

$$\text{CGR} = \frac{1}{G} \times \frac{W_2 - W_1}{t_2 - t_1}, \text{ (in g.m}^{-2}\text{.weeks}^{-1}\text{)} \qquad \text{(Eq. 2)}$$

Description: $W_1$ = total dry weight per plant at the time of $t_1$. $W_2$= Total dry weight per plant at the time of $t_2$. $LA_1$= Total leaf area per plant at the beginning. $LA_2$ = Total leaf area per plant at the time of $t_2$. G = the area of land overgrown with plants. $t_1$ = harvest time in the beginning. $t_2$ = harvest time in the end

### *Statistical analysis*

Observational data were analyzed using analysis of variance (ANOVA) with the SAS 9.1 program. If the treatment had a significant effect, then to know the difference between treatments was done using Duncan's new multiple range tests (DMRT) at 5% significance level(Gomez and Gomez 1984).

## Results

### *Analysis of variance*

Based on the analysis of variance, the dose factor of the endophytic bacteria consortium had a significant difference in LAI, LAD, NAR and CGR, but there was no significant difference in the variety of rice varieties. There was no interaction between the dose of the endophytic bacteria consortium and the varieties tested on LAI, LAD, NAR and CGR.

Table 1: Analysis of variance of all parameters

| Parameter | Endophytic bacteria consortium (D) | Varieties of paddy (V) | D x V | CV (%) |
|---|---|---|---|---|
| Leaf area index (LAI) | 4.31** | 0.63ns | 2.20 ns | 15.76 |
| Leaf area duration (LAD) | 6.66** | 0.79ns | 2.18ns | 16,35 |
| Net assimilation rate (NAR) | 5.40** | 0.14ns | 1.12ns | 39.25 |
| Crop Growth Rate (CGR) | 3.29** | 0.21ns | 1.17ns | 36.33 |

Note: ** = Signinificance at 1% significant levels, * = Signinificance at 5% significant levels, and ns = Non significant at 5%. WAP = week after planting

***Leaf area index (LAI)***

Based on the Duncan 5% test (Table 2), the leaf area index with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Table 2. LAI of various dosage of endophytic bacteria consortium of paddy at 6-8 WAP

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 l | 20 l | 30 l | 40 l |
| 8.64 b | 8.09 b | 9.08 b | 10.90 a |

Note: The numbers followed by the same characters indicate no significant difference based on DMRT at 5% significant levels. LAI = leaf area index WAP = week after planting

Based on Duncan's test with a significance level of 5% (Table 3), the leaf area index of the three varieties, namely situbagendit, mekongga and ciherang were not different, because LAI was more influenced by the genetic characteristics of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

Table 3. LAI of various variety of paddy at 6-8 WAP

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 9.21 a | 9.48 a | 8.84 a |

Note: The numbers followed by the same characters indicate no significant difference based on DMRT at 5% significant levels. LAI = leaf area index WAP = week after planting

### *Leaf area duration*

Based on the Duncan 5% test (Table 4), the leaf area duration with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Table 4. LAD of various dosage of endophytic bacteria consortium of paddy at 6-8 WAP

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 l | 20 l | 30 l | 40 l |
| 6838.6 b | 6463.3 b | 7266.3 b | 8731.7 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels.  LAD = leaf area duration, and WAP = week after planting

Based on Duncan's test with a significance level of 5% (Table 5), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

Table 5. LAD various variety of paddy at 6-8 WAP

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 7373 a | 7594 a | 7007 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels.  LAD = leaf area duration, and WAP = week after planting

### *Net assimilation rate*

Based on the Duncan 5% test (Table 6), the net assimilation rate with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Table 6. NAR of various dosage of endophytic bacteria consortium of paddy at 6-8 WAP

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 l | 20 l | 30 l | 40 l |
| 3272 b | 2732 b | 2515 b | 4756 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels.  NAR = leaf area duration, and WAP = week after planting

Based on Duncan's test with a significance level of 5% (Table 7), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

Table 7. NAR various variety of paddy at 6-8 WAP

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 3276 a | 3205 a | 3475 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels. NAR = leaf area duration, and WAP = week after planting

***Crop growth rate***

Based on the Duncan 5% test (Table 8), the crop growth rate with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Table 8. Crop growth rate of various dosage of endophytic bacteria consortium of paddy at 6-8 WAP

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 l | 20 l | 30 l | 40 l |
| 1704 b | 1847 b | 1817 b | 2663 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels. CGR = leaf area duration, and WAP = week after planting

Based on Duncan's test with a significance level of 5% (Table 9), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

Table 9. Crop growth rate various variety of paddy at 6-8 WAP

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 1936 a | 1969 a | 2117 a |

Note: The numbers followed by the same characters in the same column indicate no significant difference based on DMRT at 5% significant levels. CGR = leaf area duration, and WAP = week after planting

**Discussion**

Based on the observation that leaf area index, leaf area duration, net assimilation rate and crop growth rate were affected by the dose of the endophytic bacteria consortium. This is because the role of the endophytic bacterial consortium, among others, acts as a plant growth regulator. Glick (2020) states that this type of bacteria creates a complex relationship with the host plant where this bacterium acts as a plant growth promoter. These bacteria are associated with plants in increasing crop production and soil fertility. Ali (2017) stated that microbial components in the plant endosphere and rhizosphere form beneficial associations with plants that can increase plant productivity.

Meanwhile, Kumar (2018), added that these bacteria increase plant resistance to various abiotic and biotic factors that limit growth and production. These microbes can live both internally and externally in host plant tissues. Rhizosphere bacteria inhabit plant roots in the soil, and epiphytic bacteria inhabit the surface of plant leaves.

Endophytic bacteria increase growth by establishing synergistic interactions with host plants or antagonistic interactions with soil pathogens (Eljounaidi, 2016). Endophytic bacteria are also known as plant growth-promoting rhizobacteria (PGPR) and are believed to be part of the group of bacteria that occupy the rhizosphere. Several studies have defined endophytic bacteria as bacteria that do not harm plants but can be isolated in surface sterilized plant material (Liu, 2017).

The three varieties tested including the varieties of situbagendit, mekongga and ciherang did not show different characters on LAI, LAD, NAR and CGR this is because these three varieties have the same character According to Gardner et al (1991) the character of a variety is more determined by genetic factors compared to the influence of external factors, namely environmental factors including the provision of a consortium of endophytic bacteria

## Conclusion

In conclusion, our study found that dosage of endophytic bacteria consortium 40 l/ha/application increase leaf area index, leaf area duration, net assimilation rate and crop growth rate.

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**BUKTI PROSES REVIEW**

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RETURN FOR REVISION

# Evaluating diazotrophic endophytic bacteria consortium on the physiology of various rice (*Oryza sativa*) varieties in rainfed lowlands

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## ABSTRACT

Rainfed rice fields in general often lack water and nutrients that are difficult for their roots to reach. Consortium of endophytic bacteria can assist in absorbing water and nutrients to increase the efficiency of nitrogen and phosphorus fertilizers. This study was conducted during June, 2022 at rainfed rice fields in Demangan, Sambi, Boyolali, Central Java, Indonesia to determine the analysis of the growth of paddy varieties at various doses of the endophytic bacteria consortium. This research used a completely randomized block design with two factors and three replications. The first factor was a consortium of endophytic bacteria with a dose of 0, 20, 30, and 40 L/ha/application, while the second factor was varieties padddy i.e., Situbagendit, Ciherang and Mekongga. The results showed that the dose of endophytic bacteria consortium 40 L/ha/application showed an increase in LAI, LAD, NAR and CGR compared to doses of 0, 20 and 30 L/ha/application.

**Key words**: Rice, crop growth rate, endophytic bacteria, crop physiology, rainfed rice

## INTRODUCTION

Rainfed land uses rainwater for irrigation and differs from irrigated rice (*Oryza sativa* L.) fields. Rainfed rice fields have a low available P content due to groundwater leaching (Meng *et al.*, 2018). In general, improper agricultural management, long-term application of chemical fertilizers, and inefficient fertilizer use decrease the soil productivity of rice fields.

Drought stress is one of the most destructive abiotic stresses affecting plant growth and development. Drought stress affects physiological processes, biochemical changes, formation of secondary metabolites, significantly accumulates endogenous reactive oxygen species (ROS), and increases toxin levels (Hasanuzzaman *et al.,* 2017).

Drought stress greatly reduces rice grain yields and vegetative growth (Ahadiyat, Hidayat, and Susanto 2014; Maisura *et al*. 2014). Water-scarce conditions generally reduce grain size, grain weight, and seed formation rates (Kumar *et al*., 2014; Raman *et al*., 2012). Drought stress during the booting, flowering, and terminal stages can interfere with floret initiation, cause grain sterility, lower grain weight, and ultimately lower grain yield (Acuña, Lafitte, and Wade 2008). The rate of grain yield loss depends on the duration of water scarcity, plant growth stage, and stress intensity (Gana, 2011; Kumar *et al*., 2014).

One of the efforts to overcome drought stress is microbial-based technology, such as a consortium of endophytic bacteria. Endophytic bacteria are found in the host plant [Kumar, 2017)]. This type of bacteria creates a complex relationship with the host plant where it acts as a plant growth promoter. The role of plant-associated bacteria in increasing crop production and soil fertility Glick BR (2020). Microbial components in the plant endosphere and rhizosphere form beneficial associations with plants that can increase crop productivity (Ali, 2017). These bacteria increase plant resistance to various abiotic and biotic factors that limit growth and production (Kumar, 2018). These microbes can live both internally and externally in host plant tissues. For example, rhizosphere bacteria inhabit plant roots in the soil, and epiphytic bacteria inhabit the leaf surfaces of plants.

Rhizobacteria refers to the plant growth promoting bacteria present in the rhizosphere. The rhizosphere consists of a narrow zone of soil that is influenced by the plant root system where maximum microbial activity occurs (Verma, 2019). The rhizosphere zone is an ecological niche that provides a rich source of nutrients and energy for plant growth. Rhizobacteria are abundant plant partners in the rhizosphere, but they differ in their role in the promotion of plant growth. Various interactions occur between plants and rhizobacteria in the rhizosphere. These interactions are equally important, and involve signals between rhizobacteria and plant roots that regulate their biochemical activity (Bhattacharyya, 2012). Rhizobacteria are essential in the rhizosphere for nutrient cycling, carbon sequestration, and ecosystem functions that promote plant growth, yield and nutrition. Various genera of bacteria have been used as plant growth-promoting rhizobacteria (PGPR), including Burkholderia, Pseudomonas, Arthrobacter, Bacillus, Serratia, Micrococcus, Chromobacterium, Erwinia, Azospirillum, Caulobacter, Agrobacterium, and Azotobacter (Verma, 2019).

Rhizobacteria produce plant growth-regulating phytohormones such as ethylene, gibberellins, and auxins. Other important metabolites include the production of siderophores, enzymes, organic acids, antibiotics, biosurfactants, nitric oxide, and osmolytes. Metabolites are responsible for increasing nutrient absorption, tolerance to abiotic stress, nitrogen fixation, suppression of pathogenic organisms (Pii, 2015).

In addition, this trait is inherited and can be transferred through seeds, making it more suitable and effective in promoting plant growth (Verma, 2019). These heritability factors are important in selecting adaptive and effective endophytes associated with certain crops that are important for agriculture, especially in plant breeding and addressing challenges related to climate change. Their capacity to tolerate and induce resistance to biotic and abiotic stresses in plants can be harnessed to solve the associated edaphic and pathogenic challenges facing the crop production sector. According to AfzalI (2019), the various benefits associated with endophytes can be more striking when plants are subjected to adverse environmental stress. Habitat-induced stress triggers plant microbial signaling, which forms complex communications

Endophytic bacteria positively affect host plant development without significant harm while suppressing pathogens that may attack the plant (ZhangY, 2019). In return, endophytic microbes benefit and use the plant endosphere as a unique and haven that is not disturbed by harsh climatic conditions that can harm and affect its function (Le Cocq K, 2017). Moreover, most of the endophytic bacteria exhibit a biphasic life cycle in which they alternate between soil and plant environment, thus surviving between seasons (Singh, 2017). Other bacteria form symbiotic structures such as nodules from beans that harbor various strains of bacteria. Only the rhizobia responsible for nitrogen fixation are well known, while other endophytic bacteria are poorly studied (AfzalI, 2019).

The purpose of this study was to determine the leaf area index, leaf area duration, net assimilation rate and crop growth rate on various varieties of lowland rice due to the administration of a consortium of diazotropic endophytic bacteria in paddy fields on rain-fed areas.

## Materials and Methods

### *Study area*

Research was conducted in Demangan, Sambi, Boyolali, Central Java, Indonesia, from June to September 2022 with alfisol soil. A geographical position was between 110° 22'-110° 50' east longitude and between 7°7'-7°36' south latitude with a height of 184 m above sea level (ASL). The average rainfall and temperature were 139 mm per month and 26-32°C, respectively.

### Experimental design

This research was arranged in a randomized completely block design (RCBD) with two factors and three replications. The first factor was the dose of a consortium of endophytic bacteria consisting of four levels, i.e. doses of 0, 20, 30, and 40 L/ha/application,. The second factor was the second factor was varieties of rice fields ai. Situbagendit, Ciherang and Mekongga. In this study, there were 12 treatment combinations. Each treatment combination was three times replications, and each replication consisting of five plant samples.

This research used a completely randomized block design with two factors and three replications. The first factor was a consortium of endophytic bacteria with a dose of 0, 20, 30, and 40 L/ha/application, while the second factor was varieties of padi padi ai. Situbagendit, Ciherang and Mekongga.

**Research procedures**

Before the research, the team conducted a chemical analysis of the soil used for the research substrate. The results showed an $H_2O$ pH of 6.52 (slightly sour), C concentration of 1.34% (low), organic matter concentration of 2,28% (low), total N concentration of 0.22% (low), available P of 9.49 ppm (very high), available K of 0.28 me/100 g (high)

The media used was alfisol soil. The length and width of the experimental plots were 500 cm and 200 cm, respectively. The water level was 5 cm deep, with the plants spaced 20 cm × 20 cm apart. The experimental field was weeded at 2 and 4 weeks after planting and controlled pests and diseases using organic pesticides. Urea, NPK Phonska and SP-36 fertilizers at a dose of 200, 100 and 75 kg/ha, respectively, were applied at planting time and five weeks after planting. The harvest criterion was the seed shells above the panicle being clean and firm.

**Measurement**

The parameters observed were the leaf area index (LAI), leaf area duration (LAD), net assimilation rate (NAR), and crop growth rate (CGR). The data observation was conducted in 6 and 8 WAP. LAI was calculated from the ratio between the total leaf surface area per unit ground area. LAI was determined by the intensity of radiation intercepted divided planting spacing. LAD is the time a leaf could last on the plant. LAD was calculated from leaf area ($cm^2$) divided by time (week)

NAR is the ability of plants to produce dry materials that assimilate each unit of leaf area at each unit of time, which is stated in Eq. 1.

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{\ln LA_2 - \ln LA_1}{LA_2 - LA_1}, \text{ (in g/cm}^2\text{/weeks)} \qquad \text{(Eq. 1)}$$

CGR is the ability of plants to produce dry materials that assimilate each unit of land area at each unit of time, which is stated in Eq. 2.

$$CGR = \frac{1}{G} \text{ x } \frac{W_2 - W_1}{t_2 - t_1}, \text{ (in g/m}^2\text{/weeks)} \qquad \text{(Eq. 2)}$$

Where, $W_1$ = total dry weight per plant at the time of $t_1$. $W_2$= Total dry weight per plant at the time of $t_2$. $LA_1$= Total leaf area per plant at the beginning. $LA_2$ = Total leaf area per plant at the time of $t_2$. G = the area of land overgrown with plants. $t_1$ = harvest time in the beginning. $t_2$ = harvest time in the end

**Statistical analysis**

Observational data were analyzed using analysis of variance (ANOVA) with the SAS 9.1 program. If the treatment had a significant effect, then to know the difference between treatments was done using Duncan's new multiple range tests (DMRT) at 5% significance level(Gomez and Gomez 1984).

## RESULTS AND DISCUSSION

**Analysis of variance**

Based on the analysis of variance, the dose factor of the endophytic bacteria consortium had a significant difference in LAI, LAD, NAR and CGR, but there was no significant difference in the variety of rice varieties. There was no interaction between the dose of the endophytic bacteria consortium and the varieties tested on LAI, LAD, NAR and CGR.

**Leaf area index (LAI)**

Based on the Duncan 5% test (Table 2), the leaf area index with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Based on Duncan's test with a significance level of 5% (Table 3), the leaf area index of the three varieties, namely situbagendit, mekongga and ciherang were not different, because LAI was more influenced by the genetic characteristics of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

**Leaf area duration**

Based on the Duncan 5% test (Table 4), the leaf area duration with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Based on Duncan's test with a significance level of 5% (Table 5), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

**Net assimilation rate**

Based on the Duncan 5% test (Table 6), the net assimilation rate with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Based on Duncan's test with a significance level of 5% (Table 7), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

**Crop growth rate**

Based on the Duncan 5% test (Table 8), the crop growth rate with the dose of the endophytic bacteria consortium 40 l was the highest and different from the dose of the other endophytic bacteria consortium and the doses of 10 liters and 20 liters were not different from the control (0 liter/ha/application).

Based on Duncan's test with a significance level of 5% (Table 9), the leaf area duration of the three varieties, namely situbagendit, mekongga and ciherang was not different, because LAD was more influenced by the genetic nature of a variety than by environmental factors (external factors), namely a consortium of endophytic bacteria.

Based on the observation that leaf area index, leaf area duration, net assimilation rate and crop growth rate were affected by the dose of the endophytic bacteria consortium. This is because the role of the endophytic bacterial consortium, among others, acts as a plant growth regulator. Glick (2020) states that this type of bacteria creates a complex relationship with the host plant where this bacterium acts as a plant growth promoter. These bacteria are associated with plants in increasing crop production and soil fertility. Ali (2017) stated that microbial components in the plant endosphere and rhizosphere form beneficial associations with plants that can increase plant productivity.

Meanwhile, Kumar (2018), added that these bacteria increase plant resistance to various abiotic and biotic factors that limit growth and production. These microbes can live both internally and externally in host plant tissues. Rhizosphere bacteria inhabit plant roots in the soil, and epiphytic bacteria inhabit the surface of plant leaves.

Endophytic bacteria increase growth by establishing synergistic interactions with host plants or antagonistic interactions with soil pathogens (Eljounaidi, 2016). Endophytic bacteria are also known as plant growth-promoting rhizobacteria (PGPR) and are believed to be part of the group of bacteria that occupy the rhizosphere. Several studies have defined endophytic bacteria as bacteria that do not harm plants but can be isolated in surface sterilized plant material (Liu, 2017).

The three varieties tested including the varieties of situbagendit, mekongga and ciherang did not show different characters on LAI, LAD, NAR and CGR this is because these three varieties have the same character According to Gardner et al (1991) the character of a variety is more determined by genetic factors compared to the influence of external factors, namely environmental factors including the provision of a consortium of endophytic bacteria

## CONCLUSION

In conclusion, our study found that dosage of endophytic bacteria consortium 40 L/ha/application increase leaf area index, leaf area duration, net assimilation rate and crop growth rate.

## ACKNOWLEDGEMENTS

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Table 1. Analysis of variance of all parameters.

| Parameter | Endophytic bacteria consortium (D) | Varieties of paddy (V) | D × V | CV (%) |
|---|---|---|---|---|
| Leaf area index (LAI) | 4.31** | 0.63ns | 2.20 ns | 15.76 |
| Leaf area duration (LAD) | 6.66** | 0.79ns | 2.18ns | 16,35 |
| Net assimilation rate (NAR) | 5.40** | 0.14ns | 1.12ns | 39.25 |
| Crop Growth Rate (CGR) | 3.29** | 0.21ns | 1.17ns | 36.33 |

*and**: Significant at P=0.05 and P=0.01, respectively; ns: Not significant at P=0.05; WAP: Week after planting.

Table 2. Leaf area index of various dosage of endophytic bacteria consortium of paddy at 6-8 weeks after planting.

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 L | 20 L | 30 L | 40 L |
| 8.64 b | 8.09 b | 9.08 b | 10.90 a |

The figures followed by the same letters indicate no significant difference based on DMRT at P=0.05 significance levels.

Table 3. Leaf area index of various varieties of paddy at 6-8 weeks after planting.

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 9.21 a | 9.48 a | 8.84 a |

The figures followed by the same letters indicate no significant difference based on DMRT at P=0.05 significance level.

Table 4. Leaf area duration of various dosage of endophytic bacteria consortium of paddy at 6-8 weeks after planting.

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 L | 20 L | 30 L | 40 L |
| 6838.6 b | 6463.3 b | 7266.3 b | 8731.7 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

Table 5. Leaf area duration of various varieties of paddy at 6-8 weeks after planting.

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 7373 a | 7594 a | 7007 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

Table 6. Net assimilation rate of various dosage of endophytic bacteria consortium of paddy at 6-8 weeks after planting.

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 L | 20 L | 30 L | 40 L |
| 3272 b | 2732 b | 2515 b | 4756 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

Table 7. Net assimilation rate of various varieties of paddy at 6-8 weeks after planting.

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 3276 a | 3205 a | 3475 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

Table 8. Crop growth rate of various dosage of endophytic bacteria consortium of paddy at 6-8 weeks after planting.

| Dosage of endophytic bacteria consortium (/ha/application) | | | |
|---|---|---|---|
| 0 L | 20 L | 30 L | 40 L |
| 1704 b | 1847 b | 1817 b | 2663 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

Table 9. Crop growth rate of various varieties of paddy at 6-8 weeks after planting.

| Situbagendit variety | Mekongga variety | Ciherang variety |
|---|---|---|
| 1936 a | 1969 a | 2117 a |

The figures followed by the same letters in the same row indicate no significant difference based on DMRT at P=0.05 significance level.

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**Dear Dr. ACHMAD FATCHUL AZIEZ,**

We are glad to inform you that your article No. **ROC-901** entitled **" Evaluating diazotrophic endophytic bacteria consortium on the physiology of various varieties of rice (Oryza sativa) in rainfed lowlands "** has been assigned DOI Number and published online. Article is attached with DOI number. You can find your article online on https://gauravpublications.com/journal/research-on-crops/ROC-901.

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