Effectiveness Of Rhizobacteria From Muting District (DMSJ 3) And Semangga District (DSK 3) In Increasing Rice Yield (*Oryza Sativa* L.) Under Drought Stress

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Abstract.

Drought is a climatic phenomenon that can significantly disrupt the growth and reduce the yield of rice plants. Inoculation of rhizobacteria can increase the yield of rice plants under drought stress conditions. The research was conducted at the Agrotechnology Laboratory of Agronomy Unit and Experimental Garden II of Faculty of Agriculture, Halu Oleo University, Kendari from October 2024 to January 2025. The treatments in this study were drought stress and rhizobacterial isolates. Drought stress treatment consisted of control (K0), 25% drought stress (K1), 50% drought stress (K2) and 75% drought stress (K3) while rhizobacterial treatment consisted of control (B0), isolate DMSJ 3 (B1) and isolate DSK 3 (B2). Each treatment was repeated 3 times, the treatment pots were arranged according to a split-plot design consisting of 5 polybags. Observational data were statistically analyzed using analysis of variance at the real level α 0.05 and will be further tested with DMRT α 0.05 if it shows a significant effect. The results showed that inoculation of rhizobacterial isolates DMSJ 3 and DSK 3 was able to increase plant yield under drought stress conditions characterized by an increase in the number of productive tillers, flag leaf area, flowering age, total grain per panicle, percentage of filled grain per panicle, 1000 grain weight, grain weight per panicle, yield and drought tolerance index. Isolates DMSJ 3 and DSK 3 have the same ability to increase yield and induce resistance of rice plants to drought stress conditions.

Keywords: *Drought stress, rhizobacteria, rice crop and yield.*

I. INTRODUCTION

Indonesia is an archipelago country where the majority of the population is engaged in agriculture. The agricultural sector has a role in the satisfaction and support of human life needs, especially food [25]. Rice is the main staple food for the people of Indonesia [2]. Climate change is one of the challenges that may lead to a decline in rice production in Indonesia. One of the consequences of climate change is drought due to long dry spells that occur in almost all regions of Indonesia, including Southeast Sulawesi. Data from the Central Bureau of Statistics (BPS) shows that rice production in Southeast Sulawesi reached 482,371.05 tons in 2023 with an average productivity of 4.15 tons per hectare [6]. This productivity is still low in comparison to the national average productivity of 5.28 tons per hectare [5]. Drought is the phenomenon of lack of water supply due to low rainfall and high evaporation. Drought disrupts plant metabolism, affecting nutrient uptake, cell division and enlargement, and reducing enzyme activity [2]. Plant adaptation mechanisms are carried out by closing stomata, accumulating compounds that can protect cells from drought damage, and adjusting cell osmotic potential.

Osmotic adjustment is a mechanism that occurs due to changes in osmotic pressure caused by drought stress around plant roots [24].The soil around plant roots is called the rhizosphere. The rhizosphere is inhabited by several types of microorganisms, including bacteria known as rhizobacteria [9]. Rhizobacteria have the ability to stimulate growth and induce plant resistance to abiotic stresses such as drought. Rhizobacteria stimulate plant growth by producing phytohormones, fixing nitrogen and solubilizing phosphate. Rhizobacteria are also able to stimulate the production of antioxidant compounds and osmolytes, and increase enzyme activity that enables plants to adapt to stress conditions, including drought [10], [21].Rhizobacteria have the potential to increase rice yield as well as an inducer of plant resistance to drought stress. This study aims to see the extent of the ability of rhizobacteria in increasing yield component variables such as number of productive tillers, flag leaf area, 1000 grain weight, yield and tolerance index under drought stress conditions.

II. METHODS

Research Location and Timeframe

This research was conducted at the Agrotechnology Laboratory, Agronomy Unit and Experimental Garden II of the Faculty of Agriculture, Halu Oleo University, Kendari from October 2024 to January 2025.

Drought Stress Treatments

The 25%, 50% and 75% drought stress treatments were based on soil moisture content using the method of [20] with some modifications. The planting medium was first determined to have wind dry moisture content (ka) and field capacity (klp). Determination of wind dry moisture content is as follows:

1. Soil is aerated for 48 hours.
2. Soil samples were taken in amounts up to 20 g and then oven-dried at 110 ^oC for 48 hours. The dried soil samples are then weighed.
3. Wind dry moisture content (g) is calculated using the formula:

$$\text{ka} = \frac{\text{Wind-dried soil weight - Soil weight after oven drying}}{\text{Soil weight after oven drying}}$$

Determination of the field capacitance moisture content is as follows:

1. The soil is watered to saturation (the capacity of the field) and left to stand for 48 hours.
2. Soil samples were taken in amounts up to 20 g and then oven-dried at 110 ^oC for 48 hours. The dried soil samples are then weighed.
3. Moisture content at field capacity (g) is calculated using the formula:

$$\text{klp} = \frac{\text{Soil weight of field capacity - Soil weight after oven drying}}{\text{Soil weight after oven drying}}$$

The amount of water that must be added to achieve field capacity conditions in each treatment is known using the formula field capacity soil weight (klp) minus wind-dried soil weight (ka) multiplied by soil weight (bt) (g), so that the amount of water (mL) that must be added for each treatment is determined as follows:

K0 = 100% × (klp - ka) × bt
K1 = 75% × (klp - ka) × bt
K2 = 50% × (klp - ka) × bt
K3 = 25% × (klp - ka) × bt

Propagation of Rizobacteria Isolates

Rhizobacterial isolates were picked from the Eppendorf tube using an ose needle and then grown by scratching on a petri dish containing TSA media. The isolates were incubated in an incubator at room temperature for 48 hours. Colonies grown on Petri dishes were suspended in sterile distilled water [12].

Seed Treatment with Rhizobacteria

Rice seeds are selected by placing them in a container of distilled water. Floating seeds are discarded, while sinking seeds are collected and dried on tissue paper for 3 minutes. Rice seeds up to 10 g were then soaked in a suspension of each rhizobacteria isolate (10 mL) at 28 °C and shaken for 12 hours. Control treatment seeds were soaked in sterile water for the same time and conditions. The seeds were then dried in a laminar air flow cabinet for 30 minutes and planted in each experimental unit.

Harvest

Harvesting takes place when the plants are physiologically ripe, characterized by at least 85% of the grain having turned yellow. Harvesting is done by cutting the rice stem just below the base of the flag leaf.

Observation Variables

1. Number of productive tillers. This observation is made by counting the number of tillers that produce panicles. Observations were made at harvest.
2. Flag leaf area (cm^2). Observations were made by measuring the length and width of the flag leaf and multiplying them by the rice leaf constant (0.75) [13], [18]. Measurements were made during the reproductive stage.
3. Weight of 1000 grains (g). This observation was made by weighing 1000 grains of grain. The observations were made after the harvest.

4. Yield (g). The calculation is made by multiplying the weight of grain per panicle by the number of productive tillers and then multiplying the result by the number of clusters. The calculation is made after the harvest.
5. Drought tolerance index. Plant resistance to drought conditions is measured by the drought tolerance index parameter. The observation of the drought tolerance index (ITK) was made at the time of harvesting [4], [27]. Drought tolerance index is measured by the formula:

$$ITK = \frac{Yd}{Yn}$$

Notes:
ITK : drought tolerance index
Yd : plant yield under drought stress
Yn : plant yield under normal conditions
ITK > 0.5 = tolerant dan ITK < 0.5 = sensitive

Research Design

This phase of the study used a split-plot design with two factors. The main plot was drought stress, which consisted of 4 treatments: K0 (control), K1 (25% drought stress), K2 (50% drought stress), and K3 (75% drought stress). The subplots were the best rhizobacterial isolates from Muting District and Semangga District, Merauke Regency consisting of 3 treatments namely: B0 (control), B1 (rhizobacterial isolate DMSJ 3) and B2 (rhizobacterial isolate DSK 3).Each treatment was repeated 3 times so that there were 36 experimental units in total. Each experimental unit consisted of 5 polybags.

Data Analysis

Observational data were analyzed using analysis of variance (ANOVA). If the calculated F-value shows a true effect at the 95% confidence level, the Duncan's Multiple Range Test (DMRT) is used at the true level of $\alpha = 0.05$.

III. RESULT AND DISCUSSION

Number of productive tillers

Rhizobacteria can significantly increase the number of productive tillers of rice plants in drought stress treatment. The analysis showed an interaction between drought stress treatment and rhizobacteria. The treatment of isolates DMSJ 3 (B1) and DSK 3 (B2) gave a better effect in increasing the number of productive tillers in 25% (K1) and 75% (K3) drought stress treatments compared to the control (B0). However, in the 50% drought stress treatment (K2), the highest number of productive tillers was shown by the treatment of isolate DSK 3 (B2) and the control (B0) (Table 1). These results indicate a variation in the ability of rhizobacteria to increase the number of productive tillers of rice plants at different levels of drought stress.Rhizobacteria have the ability to stimulate plant growth by producing phytohormones such as cytokinins. Cytokinins play an important role in stimulating apical and axillary meristem activity and facilitating cell division in shoots [22], [23]. Rhizobacteria inoculated into plants are able to increase cytokinin levels under drought stress conditions better than uninoculated plants [11]. Cytokinin also plays a role in transmitting signals from roots to shoots to respond to changing environmental conditions and to use nutrients efficiently, resulting in an increase in the number of productive tillers [19], [23].

Table 1. Interaction effect on the number of productive tillers of rice plants

Rhizobacteria	Number of productive tillers (Tillers)			
	Control (K0)	Drought stress 25 % (K1)	Drought stress 50 % (K2)	Drought stress 75 % (K3)
Control (B0)	11.67 a p	9.20 b q	12.27 a p	8.93 b q
DMSJ 3 (B1)	10.27 a q	11.00 a p	10.13 a q	10.13 a p
DSK 3 (B2)	9.93 b q	10.80 b p	12.73 a p	10.60 b p

Flag leaf area

The treatment of drought stress and rhizobacteria can affect the flag leaf area of rice plants. The results of the analysis showed a significant effect on the independent treatment of drought stress and rhizobacteria. The control treatment (K0) and 25% drought stress (K1) showed a better effect than 50% drought stress (K2) and 75% drought stress (K3) (Table 2). Drought has an effect on reducing the rate of photosynthesis so that the formation of plant organs is disrupted. Drought stress negatively affects the rate of photosynthesis due to a decrease in total chlorophyll content, changes in chlorophyll components, and damage to the photosynthetic system [1].Treatment with rhizobacterial isolates DMSJ 3 (B1) and DSK 3 (B2) had a better effect on flag leaf area than the control (B0) (Table 2). Rhizobacteria have the ability to fix nitrogen into a form that can be absorbed by plants, thus influencing the increase in flag leaf area. Nitrogen is an essential nutrient needed to support plant growth and development. Nitrogen affects the formation of plant organ structures such as leaves because it is the primary building material for nucleotides, lipid membranes, and plant amino acids [23].

Table 2. Effect of treatments on the flag leaf area of rice plants

Treatments	Flag leaf area (cm^2)
Control (K0)	28.47 a
Drought stress 25% (K1)	27.02 a
Drought stress 50% (K2)	23.27 b
Drought stress 75% (K3)	21.27 c
Control (B0)	22.74 q
DMSJ 3 (B1)	25.84 p
DSK 3 (B2)	26.44 p

Weight of 1000 grains

The analysis showed a significant effect of the independent treatment of drought stress and rhizobacteria. The control treatment (K0) and 25% drought stress (K1) showed a better effect on the weight of 1000 grains of rice plants compared to 50% drought stress (K2) and 75% drought stress (K3) (Table 3). Drought causes changes in physiological and biochemical processes that affect development and production and reduce plant productivity. Plants respond to drought conditions by partially closing their stomata to reduce transpiration. Stomatal closure restricts the diffusion of $CO2$ into the leaves, thereby reducing the rate of photosynthesis [8], [26].Treatment with rhizobacterial isolates DMSJ 3 (B1) and DSK 3 (B2) had a better effect on the weight of 1000 grains of rice plants than the control (B0) (Table 3). Rhizobacteria have the ability to produce phytohormones such as auxins, cytokinins and gibberellins that can increase the yield components of rice plants under drought conditions. The production of phytohormones such as auxin, gibberellin and cytokinin by rhizobacteria can increase the ability of plants to absorb water, nutrients and light, resulting in an increase in the rate of photosynthesis, which ultimately has an impact on the increase in plant yield components [14], [19], [23], [28].

Table 3. Effect of treatments on the weight of 1000 grains of rice plants

Treatments	Weight of 1000 grains (g)
Control (K0)	23.08 a
Drought stress 25% (K1)	21.81 a
Drought stress 50% (K2)	17.07 b
Drought stress 75% (K3)	14.57 b
Control (B0)	17.84 q
DMSJ 3 (B1)	19.87 p
DSK 3 (B2)	19.68 p

Yield

The results showed that rhizobacteria were able to increase rice yield under drought stress conditions. Analysis of variance showed an interaction between drought stress and rhizobacteria on rice yield. The treatment of rhizobacterial isolates DMSJ 3 (B1) and DSK 3 (B2) had a better ability to increase rice yield than the control (B0) in the treatment of 25% drought stress (K1) and 50% drought stress (K2) (Table 4).

Table 4. Interaction effect on the yield of rice plants

Rhizobacteria	Yield (g)			
	Control (K0)	Drought stress 25 % (K1)	Drought stress 50 % (K2)	Drought stress 75 % (K3)
Control (B0)	187.19 a p	117.31 b q	92.18 c q	48.60 d p
DMSJ 3 (B1)	171.54 a q	162.48 a p	121.25 b p	52.90 c p
DSK 3 (B2)	177.77 a pq	170.36 a p	112.80 b p	55.38 c p

Rhizobacteria have the ability to increase plant yield under drought stress conditions through the production of phytohormones such as IAA, cytokinins and gibberellins, nitrogen fixation, ability to dissolve phosphate and increase antioxidant enzyme activity. Rhizobacteria are able to increase plant metabolism by stimulating root growth, chlorophyll synthesis, and increasing stomatal conductance, thus affecting plant yield [3], [17], [23], [29].

Drought tolerance index

The analysis of variance showed a significant effect of the independent treatment of drought stress and rhizobacteria on the drought tolerance index. The control treatment (K0) showed a better index value compared to 25% drought stress (K1), 50% drought stress (K2) and 75% drought stress (K3) (Table 5). Rice is a plant with a very high susceptibility to drought stress [7], [3]. Drought can cause oxidative damage that affects the performance of plant growth and yield [30].The treatment with rhizobacterial isolates DMSJ 3 (B1) and DSK 3 (B2) has a better ability to increase the drought tolerance index value of plants than the control treatment (B0) (Table 5). Rhizobacteria are able to induce plant resistance by increasing antioxidant compounds to reduce oxidative damage due to drought stress [15]. Rhizobacteria are also able to increase the concentration of osmolyte compounds such as proline, which can maintain cell water content, reduce cell osmotic potential and regulate transpiration rate under drought stress conditions [14], [16].

Table 5. Effect of treatments on drought tolerance index of rice plants

Treatments	Drought tolerance index
Control (K0)	1.00 a
Drought stress 25% (K1)	0.86 b
Drought stress 50% (K2)	0.63 c
Drought stress 75% (K3)	0.30 d
Control (B0)	0.61 q
DMSJ 3 (B1)	0.74 p
DSK 3 (B2)	0.74 p

IV. CONCLUSION

Rhizobacteria isolates DMSJ 3 and DSK 3 have the same ability to increase the number of productive tillers, flag leaf area, 1000 grain weight, yield and drought tolerance index of rice plants. Further studies are needed to explore the ability of rhizobacteria to induce plant resistance to environmental changes in the future.

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REFERENCES

[1] A. Mukhtiar, W. Lihong, A. Mahmood, M. Amenn, M.A. Zia, T. Arshad, M. Naqve, A.H. Wahab, A. Rasheed, S. Asghar, A. Zafar, M.U. Hassan, *The Role of Endophytes and Rhizobacteria to Combat Drought Stress in Wheat*, ***Notulae Botanicae Horti Agrobotanici Cluj-Napoca***, ***51:4***, 2023, pp. 1–28.

[2] A.R. Sumadji, K. Purbasari, *Indeks Stomata, Panjang Akar dan Tinggi Tanaman Sebagai Indikator Kekurangan Air pada Tanaman Padi Varietas IR64 dan Ciherang*, ***AGRI-TEK: Jurnal Ilmu Pertanian, Kehutanan dan Agroteknologi***, ***19:2***, 2018, pp. 82–85.

[3] B. Joshi, A. Chaudhary, H. Singh, P.A. Kumar, *Prospective Evaluation of Individual and Consortia Plant Growth Promoting Rhizobacteria for Drought Stress Amelioration in Rice (Oryza sativa L.)*, ***Plant and Soil***, ***457***, 2020, pp. 225–240.

[4] B.O. Omotobora, P.O. Adebola, D.M. Modise, S.M. Laurie, A.S. Gerrano, *Greenhouse and Field Evaluation of Selected Sweetpotato (Ipomoea batatas (L.) LAM) Accessions for Drought Tolerance in South Africa*, ***American Journal of Plant Sciences***, ***5***, 2014, pp. 3328–3339.

[5] Badan Pusat Statistik [BPS], ***Luas Panen, Produksi dan Produktivitas Padi Menurut Provinsi 2021–2023***, BPS Indonesia, 2024.

[6] Badan Pusat Statistik [BPS], ***Luas Panen, Produktivitas dan Produksi Padi Menurut Kabupaten/Kota di Provinsi Sulawesi Tenggara 2022 dan 2023***, BPS Sulawesi Tenggara, 2024.

[7] C.M. Singh, B. Kumar, S. Mehandi, K. Chandra, *Effect of Drought Stress in Rice: A Review on Morphological and Physiological Characteristics*, ***Trends in Biosciences***, ***5:4***, 2012, pp. 261–265.

[8] D. Barnawal, N. Bharti, S.S. Pandey, A. Pandey, C.S. Chanotiya, A. Kalra, *Plant Growth-Promoting Rhizobacteria Enhance Wheat Salt and Drought Stress Tolerance by Altering Endogenous Phytohormone Levels And TaCTR1/TaDREB2 Expression*, ***Physiologia Plantarum***, ***161:4***, 2017, pp. 502–514.

[9] E. Yulistiana, H. Widowati, A. Sutanto, *Plant Growth Promoting Rhizobacteria (PGPR) dari Akar Bambu Apus (Gigantochola apus) Meningkatkan Pertumbuhan Tanaman*, ***Journal of Science and Biology Education***, ***1:1***, 2020, pp. 1–7.

[10] E.H. Pudjiwati, S. Zahara, D. Sartika, *Isolasi dan Karakterisasi Rhizobakteri yang Berpotensi sebagai Agen Pemacu Pertumbuhan Tanaman*, ***Jurnal Borneo Saintek***, ***2:2***, 2019, pp. 1–10.

[11] F. Liu, S. Xing, H. Ma, Z. Du, B. Ma, *Cytokinin-Producing, Plant Growth-Promoting Rhizobacteria that Confer Resistance to Drought Stress in Platycladus orientalis Container Seedlings*, ***Appl Microbiol Biotechnol***, ***97***, 2013, pp. 9155–9164.

[12] F.P. Liu, H.Q. Liu, H.L. Zhou, Z.G. Dong, X.H. Bai, P. Bai, J.J. Qiao, *Isolation and Characterization of Phosphate-Solubilizing Bacteria From Betel Nut (Areca catechu) and Their Effects on Plant Growth and Phosphorus Mobilization in Tropical Soils*, ***Biology and Fertility of Soils***, ***50:6***, 2014, pp. 927–937.

[13] G. Mahesh, M.Y. Chandra, N.D. Saida, R.S. Narender, *Study on Flag Leaf and its Penultimate Leaves for their Association with Grain Yield in Rice (Oryza sativa L.)*, ***Biological Forum***, ***14:2***, 2022, pp. 270–274.

[14] H.M. Ahmad, S. Fiaz, S. Hafeez, S. Zahra, A.N. Shah, B. Gul, O. Aziz, M.U. Rahman, A. Fakhar, M. Rafique, Y. Chen, S.H. Yang, X. Wang, *Plant Growth-Promoting Rhizobacteria Eliminate the Effect of Drought Stress in Plants: A Review*, ***Frontiers in Plant Science***, ***13:875774***, 2022, pp. 1–19.

[15] J. Yang, J.W. Kloepper, C.M. Ryu, *Rhizosphere Bacteria Help Plants Tolerate Abiotic Stress*, ***Cell Press***, ***14:1***, 2009, pp. 1–4.

[16] J.A. Curá, D.R. Franz, J.E. Filosofia, K.B. Balestrasse, L.E. Burgueño, *Inoculation with Azospirillum sp. and Herbaspirillum sp. Bacteria Increases the Tolerance of Maize to Drought Stress*, ***Microorganisms***, ***5:41***, 2017, pp. 1–16.

[17] K. Giri, G. Mishra, D.C. Suyal, N. Kumar, B. Doley, N. Das, R.C. Baruah, R. Bhattacharyya, N. Bora, *Performance Evaluation of Native Plant Growth-Promoting Rhizobacteria for Paddy Yield Enhancement in The Jhum Fields of Mokokchung, Nagaland, North East India*, ***Heliyon***, ***9:14588***, 2023, pp. 1–10.

[18] K.M. Palaniswamy, K.A. Gomez, *Length Width Method for Estimating Leaf Area of Rice*, ***Agronomy Journal***, ***66:3***, 1974, pp. 430–433.

[19] L. Taiz, E. Zeiger, ***Plant Phisiology***, Sunderland: Sinauer Associates, 2006.

[20] M. David, *Kajian Ketahanan pada Pertumbuhan Awal Beberapa Klon Kakao (Theobroma cacao L.) terhadap Cekaman Kekeringan*, **Disertasi Doktor**, Universitas Sebelas Maret, 2008.

[21] M. Kaushal, S.P. Wani, *Plant-Growth-Promoting Rhizobacteria: Drought Stress Alleviators to Ameliorate Crop Production in Drylands*, ***Annals of Microbiology***, ***66***, 2016, pp. 35–42.

[22] M. Zaib, M.M. Sandhu, M. Zar, U. Ghani, A. Rehman, M.H. Musharraf, M. Zubair, R. Abbas, I. Raza, *A Brief Review on Plant Growth Promoting Rhizobacteria (PGPR): A Key Role in Plant Growth*, ***International Research Journal of Education and Technology***, ***5:7***, 2023, pp. 104–126.

[23] M.A. Khoso, S. Wagan, I. Alam, A. Hussain, Q. Ali, S. Saha, T.R. Poudel, H. Manghwar, F. Liu, *Impact of Plant Growth-Promoting Rhizobacteria (PGPR) on Plant Nutrition and Root Characteristics: Current Perspective*, ***Plant Stress***, ***11:100341***, 2024, pp. 1–15.

[24] M.A. Mudhor, P. Dewanti, T. Handoyo, T. Ratnasari, *Pengaruh Cekaman Kekeringan Terhadap Pertumbuhan dan Produksi Tanaman Padi Hitam Varietas Jeliteng*, ***Jurnal Agrikultura***, ***33:3***, 2022, pp. 247–256.

[25] M.S. Rizal, D. Arisanty, E. Normelani, *Karakteristik Budidaya Padi Urang Bukit Desa Cabai Kecamatan Hantakan Kabupaten Hulu Sungai Tengah*, ***JPG (Jurnal Pendidikan Geografi)***, ***4:3***, 2017, pp. 37–50.

[26] N. Bouremani, H.C. Silini, A. Silini, A.C. Bouket, L. Luptakova, F.N. Alenezi, O. Baranov, L. Belbahri, *Plant Growth-Promoting Rhizobacteria (PGPR): A Rampart Against the Adverse Effects of Drought Stress*, ***Water***, ***15:418***, 2023, pp. 1–35.

[27] S.A. Meutia, A. Anwar, I. Suliansyah, *Uji Toleransi Beberapa Genotipe Padi Lokal (Oryza sativa L.) Sumatera Barat terhadap Cekaman Kekeringan*, **Skripsi Sarjana**, Universitas Andalas, 2011.

[28] S.S.K.P. Vurukonda, S. Vardharajula, M. Shrivastava, A. SkZ, *Enhancement of Drought Stress Tolerance in Crops by Plant Growth Promoting Rhizobacteria*, ***Microbiological Research***, ***184***, 2016, pp. 13–24.

[29] T.A.A. El-Mageed, S.A.A. El-Mageed, M.T. El-Saadony, S. Abdelaziz, N.M. Abdou, *Plant Growth Promoting Rhizobacteria Improve Growth, Morph Physiological Responses, Water Productivity, and Yield of Rice Plants Under Full and Deficit Drip Irrigation*, ***Rice***, ***15:16***, 2022, pp. 1–15.

[30] X. Zhao, X. Yuan, Y. Xing, J. Dao, D. Zhao, Y. Li, W. Li, Z. Wang, *A Meta-Analysis on Morphological, Physiological and Biochemical Responses Of Plants With PGPR Inoculation Under Drought Stress*, ***Plant, Cell and Environment***, ***46:1***, 2022, pp. 1–16.