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Performance Test of Vegetative Characteristics of Pigmented Local Rice at Various Levels of Soil Water Content

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Abstract. The conversion of land to dry land promotes the use of local rice varieties capable of withstanding drought conditions, thus contributing to the development of sustainable agricultural practices. The anthocyanin content of pigmented rice may confer a greater resilience to cell damage caused by drought conditions than white rice. This study aims to evaluate the vegetative characteristics of local pigmented rice at varying soil water content levels. The study was conducted from June to August 2024 at the Agricultural Laboratory of Sebelas Maret University. Eight rice varieties were utilized, including two control rice varieties, two local white rice varieties, and four local pigmented rice varieties. The experimental design was a completely randomized block design split plot with three blocks and two factorials: eight rice varieties and four levels of soil water content. Data analysis was conducted using the ANOVA, Duncan, and regression tests. The findings indicated that Hitam Cempo and Merah Wangi exhibited optimal growth at a lower soil water content of field capacity (25% FC) than white rice and IR64 control. Hitam Mutiara and Merah Wangi exhibited optimal responses at 75% and 50% FC, respectively, compared to the white rice and IR64 control varieties. Leaf rolling scores increased in black and red rice as soil water content decreased compared to white rice. The research findings indicate that, based on the vegetative characteristics of local pigmented rice, it has the potential to be more drought tolerant than white rice. Further research on testing physiological and biochemical resistance traits is needed to support the development of rice types that can be planted in dry land.

Keywords: black rice; drought tolerant; field capacity; red rice; vegetative phase

INTRODUCTION

The conversion of agricultural land to non-productive land has been a significant phenomenon in Indonesia (Saragih et al., 2024). In response to this challenge, the Indonesian Ministry of Agriculture initiated a program of land extensification in 2021. This initiative involved the opening of new lands for agricultural use and the expansion of rice fields to dry land. The utilization of dry land represents a novel and highly suitable alternative, given the vast extent of dry land in Indonesia, estimated at approximately 148 million hectares (Amsal & Ishak-ishak, 2018; Arista et al., 2023). Dry land is defined as land that has not undergone any processing or treatment. It is typically not flooded for at least one year (Noywuli et al., 2024).

The Ministry of Agriculture has also released superior varieties suitable for planting in rain-fed areas, including Inpari 38, Inpari 39, Inpari 40, and Inpari 41. However, converting agricultural land to dry land necessitates cultivating drought-tolerant rice varieties, a prerequisite for sustainable agricultural practices. In general, rice with these characteristics is classified as a local variety. Local rice is typically cultivated by farmers on rain-fed land, which relies solely on precipitation during the growing season, increasing the risk of drought during the dry season. One variety of local rice that has been identified as suitable for cultivation in rainfed land is Silugonggo (Wihardjaka et al., 2020). This research contributes to the encouragement of exploration into local rice varieties suitable for planting in rain-fed land.

The potential of local rice must be developed because local rice contains germplasm that has superior properties and has not been developed. In rice breeding, local rice is introduced to be used as a parent to assemble new varieties (Masniawati et al., 2018). Local rice that has been found to have a drought tolerant response has been carried out on local rice from Nusa Tenggara Timur (NTT) including Boawae 100 Malam, Gogo Sikka, Gogo Jak, Hare Tora, Pak Mutin and Gogo Fatuhao (Salsinha et al., 2021), and

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local rice from Center Java including Putih Mutiara, Merah Sengreng and Merah Wangi (Fauziah et al., 2024).

Water is a crucial resource, particularly during the initial stages of planting or the vegetative phase of growth (Santhiawan & Suwardike, 2019). Drought during this period can lead to a reduction in plant height, biomass, the number of tillers, and leaf rolling (Jarin et al., 2024; Mudhor et al., 2022). Plants subjected to drought exhibit an increase in free radicals, damaging cells and inhibiting photosynthesis. The formation of free radicals can be inhibited or reduced by antioxidants (Yang et al., 2021). The pigmented rice variety is notable for its high antioxidant content, which is attributed to the presence of anthocyanin. Additionally, this anthocyanin serves as a distinctive colorant in the outer layer of seeds or bran, exhibiting a range of colors including purple, blue, red, and black (Singh, 2024). This has the potential to develop local pigmented rice, although several local varieties have been shown to have drought tolerance. Research on the vegetative characteristics of pigmented rice varieties under drought conditions is still limited. Therefore, the objective of this study is twofold: first, to explore the local varieties of pigmented rice, and second, to evaluate the vegetative characteristics of these local varieties at various soil water content levels.

METHODS

The research was conducted at the Agricultural Laboratory of Sebelas Maret University, Karanganyar, Central Java, from June to August 2024. The materials utilized in this study were two control rice varieties: Ciherang, which exhibits drought tolerance, and IR64, which is drought sensitive. The study also included two local white rice varieties from Central Java: Putih Mutiara and Putih Mentikwangi. Six local pigmented rice varieties from Central Java were included in the study: Hitam Cempo, Hitam Mutiara, Merah Sengreng, and Merah Wangi. Additionally, manure, urea fertilizer, KCl, and SP were employed.

The seeds were selected through a 17-hour soaking process in warm water. Subsequently, the selected seeds were dried and sown on a tray containing a soil and manure mixture. A 30x30 polybag containing 4.5 kg of soil was prepared and mixed with urea fertilizer. When four leaves had emerged, the seeds were transplanted. The rice was irrigated twice daily, in the morning and evening. The application of fertilizer at the vegetative stage is conducted using a dosage of urea fertilizer at one-third the standard rate, or 0.75 grams per polybag, at three specific growth stages: 7-10 Day After Planting (DAP), 25-30 DAP, and 40-45 DAP. Additionally, 0.9 grams of SP-36 fertilizer was applied to each polybag at the time of transplantation, and 0.45 grams of KCl fertilizer was applied at 25-30 DAP and 40-45 DAP. The application of urea and KCl fertilizers at the reproductive stage is initiated following the formation of the panicle. Weeding is conducted by removing weeds that emerge around the polybag. Pest and disease control is achieved through routine monitoring and the use of insecticides.

The application of the drought treatment is initiated at 6 Weeks After Planting (WAP), or when the plant has developed between five and six leaves. The vegetative characters observed were plant height and the number of tillers counted at 7 WAP or this was observed one week after the treatment specifically. The leaf rolling score was calculated based on the IRRI guidelines (2013), which define the following scoring system: 0 = healthy leaves (show no folds); 1 = leaves begin to show folds; 3 = leaves fold until they resemble the letter V; 5 = leaves fold to form the letter U; 7 = leaf edges touch each other to form the letter O; 9 = leaves are fully rolled. The scoring system employed for the assessment of leaf rolling employed the following categories: 0 = healthy leaves (show no folds), 1 = leaves begin to show folds, 3 = leaves fold until they resemble the letter V, 5 = leaves fold to form the letter U, 7 = leaf edges touch each other to form the letter O, and 9 = leaves are fully rolled.

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The experimental design employed was the Split Plot Randomized Complete Block with the main plot representing field capacity and the subplot representing varieties. The experiment was designed with two factors and three blocks. The first factor was varieties, which included eight varieties. The second factor was soil water content, which had four levels: 100%, 75%, 50%, and 25% of field capacity (FC). The total number of experimental plots was 96. The statistical analysis employed the ANOVA, Duncan, and regression tests to examine the impact of soil water content based on field capacity on vegetative characteristics.

RESULTS AND DISCUSSION

This study provides a drought treatment to various varieties during the vegetative phase. The vegetative phase is particularly vulnerable to drought compared to the tillering phase, panicle emergence, flowering, and grain filling. This study employed a variety of rice varieties, including drought-sensitive control rice, drought-tolerant control, two local white rice varieties, and two local pigmented rice varieties (black and red). The Ewere analyzed using ANOVA tests, Duncan tests, and regression analysis to determine the interaction between field capacity and plant height, field capacity and number of tillers, and field capacity and leaf rolling scores.

The drought-sensitive control utilized the IR64 variety, which is known to be highly susceptible to drought, particularly when it occurs during the flowering period. This can result in a significant reduction in yield (Mackill & Khush, 2018). The drought-tolerant control utilized the Ciherang variety, a type of upland rice predominantly cultivated in Central Java. This variety exhibits drought tolerance capabilities that enhance its resilience to drought conditions (Jarin et al., 2024). The employment of controls serves as the benchmark for ascertaining the optimal response between white rice and pigmented rice at varying soil water contents.

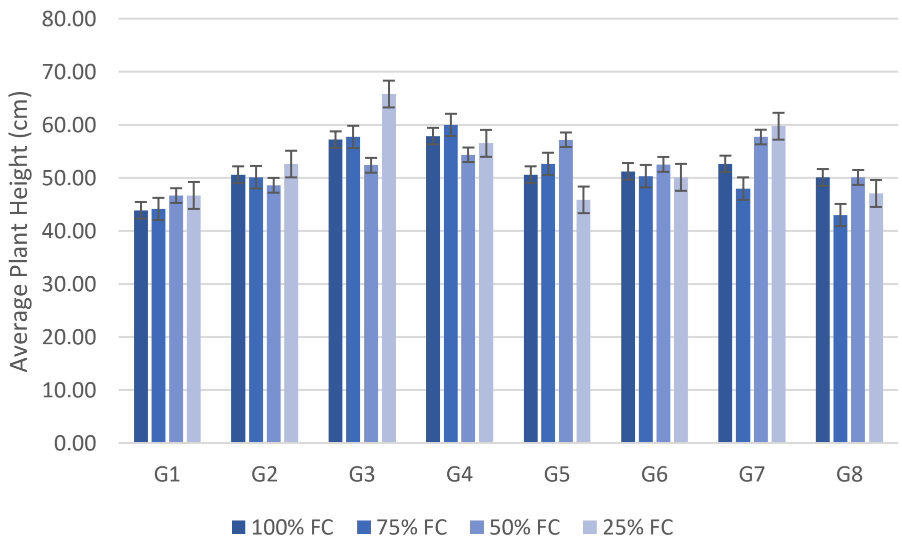

Figure 1. The Plant Height of Pigmented Rice at Various Levels of Soil Water Content. G1: IR64 control, G2: Ciherang control, G3: Hitam Cempo, G4: Hitam Mutiara, G5: Merah Sengreng, G6: Merah Wangi, G7: Putih Mutiara, and G8: Putih Mentikwangi.

As illustrated in **Figure 1**, Ciherang control exhibits the greatest plant height at 25% FC, reaching 52.60 cm. In the same field capacity, IR64 control and Putih Mutiara also had the highest height, reaching 46.67 cm and 45.79 cm, respectively. Putih Mentikwangi exhibits the highest height, reaching 50.07 cm at 50% FC. Nevertheless, the heights of IR64, Putih Mutiara dan Putih Mentikwangi at 25% and 50% FC were lower than Ciherang.

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Meanwhile, Hitam Cempo exhibits the highest height, reaching 65.80 cm at 25% FC. Merah Sengreng and Merah Wangi exhibits the highest height at 50%, reaching 57.17 cm and 52.53 cm, respectively. Hitam Mutiara exhibits the highest height at 75% FC, reaching 59.97 cm. This indicates that the height of pigmented rice varieties at 25% and 50% FC, except Hitam Mutiara, were higher than control and white rice. These results are consistent with the findings of Ula et al., (2023) who reported that Boyolali and Bantul black mutant rice exhibited elevated plant height at 50% FC, with an average of 82.56 cm and 85.51 cm, respectively. However, the drawback of tall plants is that they are not resistant to lodging.

The low proportion of plant height reduction indicates the ability to maintain growth under drought conditions. In this study, IR64, Ciherang, Hitam Cempo, and Putih Mutiara increased plant height from the control to the 25% FC drought conditions. Meanwhile, Hitam Mutiara and Merah Wangi exhibit the lowest reduction proportion, suggesting that pigmented rice may also be able to maintain growth under drought conditions.

This result also aligns with the findings of Salsinha et al. (2020), who demonstrated that Merah Noemuti can sustain its growth under drought conditions, exhibiting the least reduction in plant height when transitioning from control conditions to drought stress conditions. According to Maulani et al., (2019), the ability of the crop to withstand drought during its growth phase is attributable to the increase in anthocyanin and phenolic concentrations in pigmented rice (which results in a darker grain color) relative to the Ciherang control rice with lighter pigments.

The results of the ANOVA test indicate that there was no statistically significant difference in plant height among the various factors. Accordingly, the Duncan test was not pursued further, and a regression test was conducted to ascertain which rice variety exhibited a superior response in relation to its interaction with soil water content. In general, the application of drought conditions with severe water shortages will result in a reduction in plant height.

As illustrated in **Figure 2**, the regression test indicates that black rice exhibits a reduction in plant height as soil water content declined, compared to red rice. Merah Sengreng demonstrates a capacity to maintain growth as soil water content declines. Merah Wangi exhibits a linear increase in plant height as soil water content decreased. Meanwhile, white rice exhibits fluctuations in increases and decreases in plant height as soil water content decreased. According to Sebastian et al. (2022), red rice exhibits enhanced antioxidant activity under severe drought conditions compared to white rice. A two-fold increase in anthocyanins in red rice accompanied the observed increase in antioxidants. Anthocyanins play a crucial role in protecting the roots from damage, thereby maintaining plant growth.

As illustrated in **Figure 3**, Ciherang control exhibits no statistically significant difference in the number of tillers at 50% and 75% FC, with values of 10.33 and 16.67, respectively. At 50% FC, Hitam Cempo exhibits the highest number of tillers, reaching 3.33, while Hitam Mutiara exhibits 4.67. At 75% FC, Merah Sengreng exhibits the highest number of tillers, reaching 6.67, while Merah Wangi exhibits 20.67. Meanwhile, Putih Mutiara exhibits the highest number of tillers at 25% FC, reaching 9.33, and Putih Mentikwangi exhibits the highest number of tillers at 100% FC, reaching 28.00. IR64 also exhibits the highest number of tillers at 100% FC, reaching 17.33.

The low proportion of tiller reduction indicates the capacity to sustain growth under drought conditions. In this study, Ciherang, Hitam Cempo, Hitam Mutiara, and Putih Mutiara exhibit an increase in tiller numbers from the control to the 25% FC drought conditions. This suggests that pigmented rice may also possess the capacity to maintain growth under drought conditions. This finding aligns with the results reported by Salsinha et al. (2020), who observed that

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Hitam Maumere rice exhibited the greatest resilience to drought conditions, demonstrating the lowest reduction in the .
number of tillers compared to the control group.

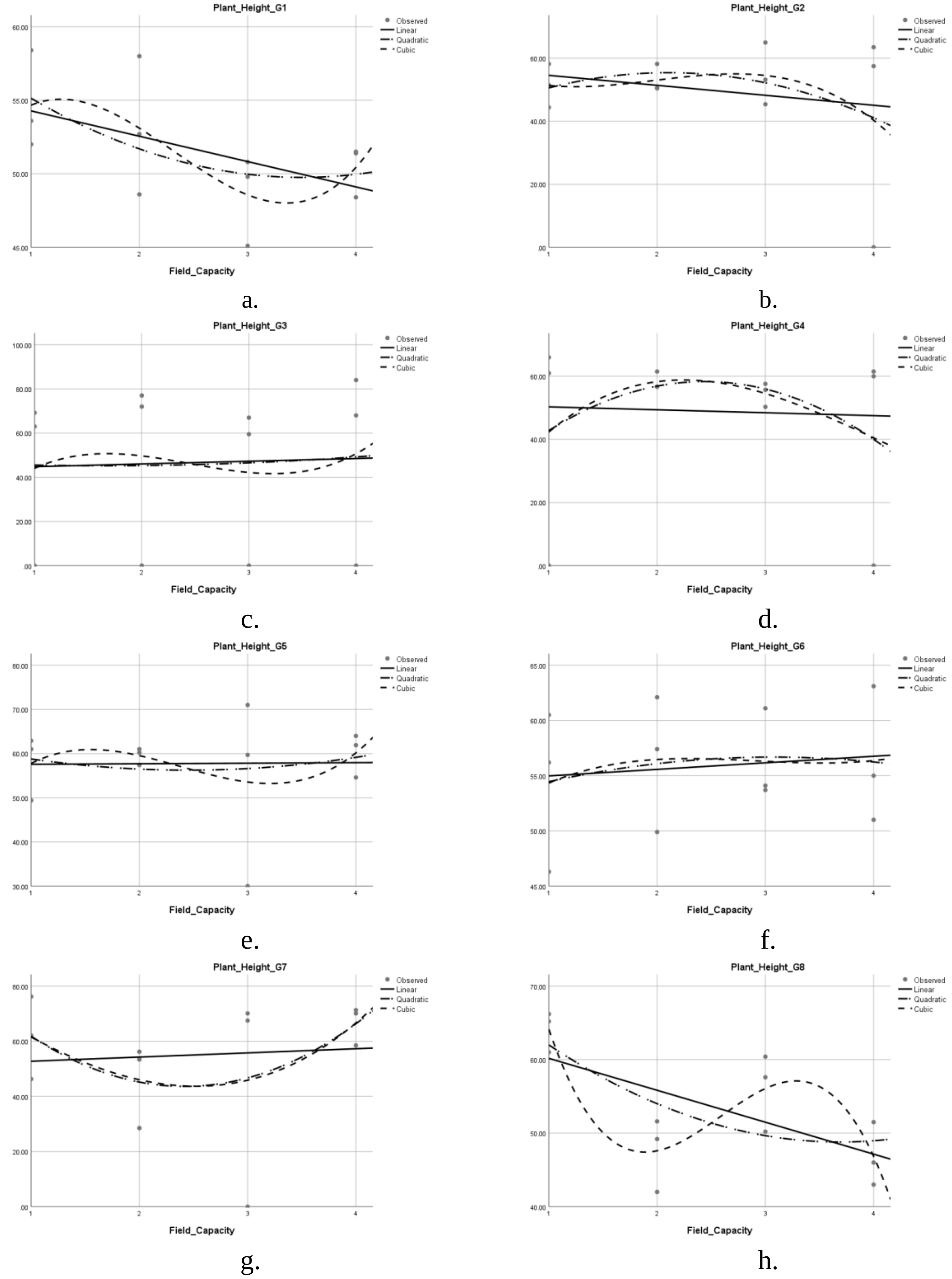

Figure 1. Regression relationship between plant height and the variation of soil water content level. The study included eight varieties of rice, a: IR64 control, b: Ciherang control, c: Hitam Cempo, d: Hitam Mutiara, e: Merah Sengreng, f: Merah Wangi, g: Putih Mutiara, and h: Putih Mentikwangi.

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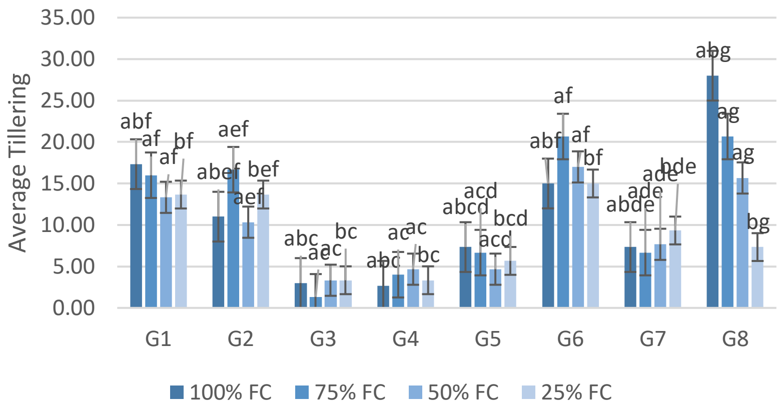

Figure 2. The Number of Tillers of Pigmented Rice at Various Levels of Soil Water Content. The Study Included Eight Varieties Of Rice, G1: IR64 control, G2: Ciherang control, G3: Hitam Cempo, G4: Hitam Mutiara, G5: Merah Sengreng, G6: Merah Wangi, G7: Putih Mutiara, and G8: Putih Mentikwangi.

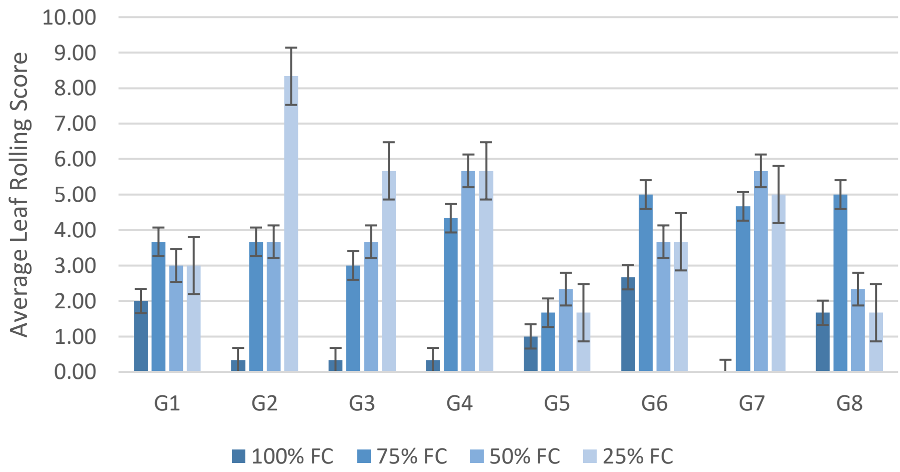

Figure 3. Rolling Score of Pigmented Rice at Various Levels of Soil Water Content. G1: IR64 control, G2: Ciherang control, G3: Hitam Cempo, G4: Hitam Mutiara, G5: Merah Sengreng, G6: Merah Wangi, G7: Putih Mutiara, and G8: Putih Mentikwangi.

As illustrated in **Figure 4**, Ciherang control exhibits the highest leaf rolling score at 25% FC among the studied rice varieties, with a value of approximately 8.33. This study also observed that Minamihatamochi, a drought-tolerant rice variety reported by Kartika et al., (2020), exhibits the highest leaf rolling score of approximately 8-9. Rice exhibiting a comparable response or displaying a leaf rolling score at an identical soil water content is classified as pigmented rice except Merah Wangi.

The highest leaf rolling score at 25% FC was observed in Hitam Cempo, with a value of approximately 5.67 cm, and in Hitam Mutiara, with a value of approximately 5.67. The highest leaf rolling score at 50% FC is observed in Merah Sengreng, with a value of approximately 2.33. Meanwhile, the highest leaf rolling score at 75% FC is observed in Merah Wangi, with a value of approximately 5.00. IR64 control exhibits a response to drought, with the highest leaf rolling score observed at 75% FC, approximately 3.67. Rice exhibiting a similar response was Putih Mentikwangi rice, which demonstrated the highest leaf rolling score at 100% FC, approximately 5.00. Putih Mutiara rice exhibited a response with the highest number of tillers at 50% FC, approximately 5.67.

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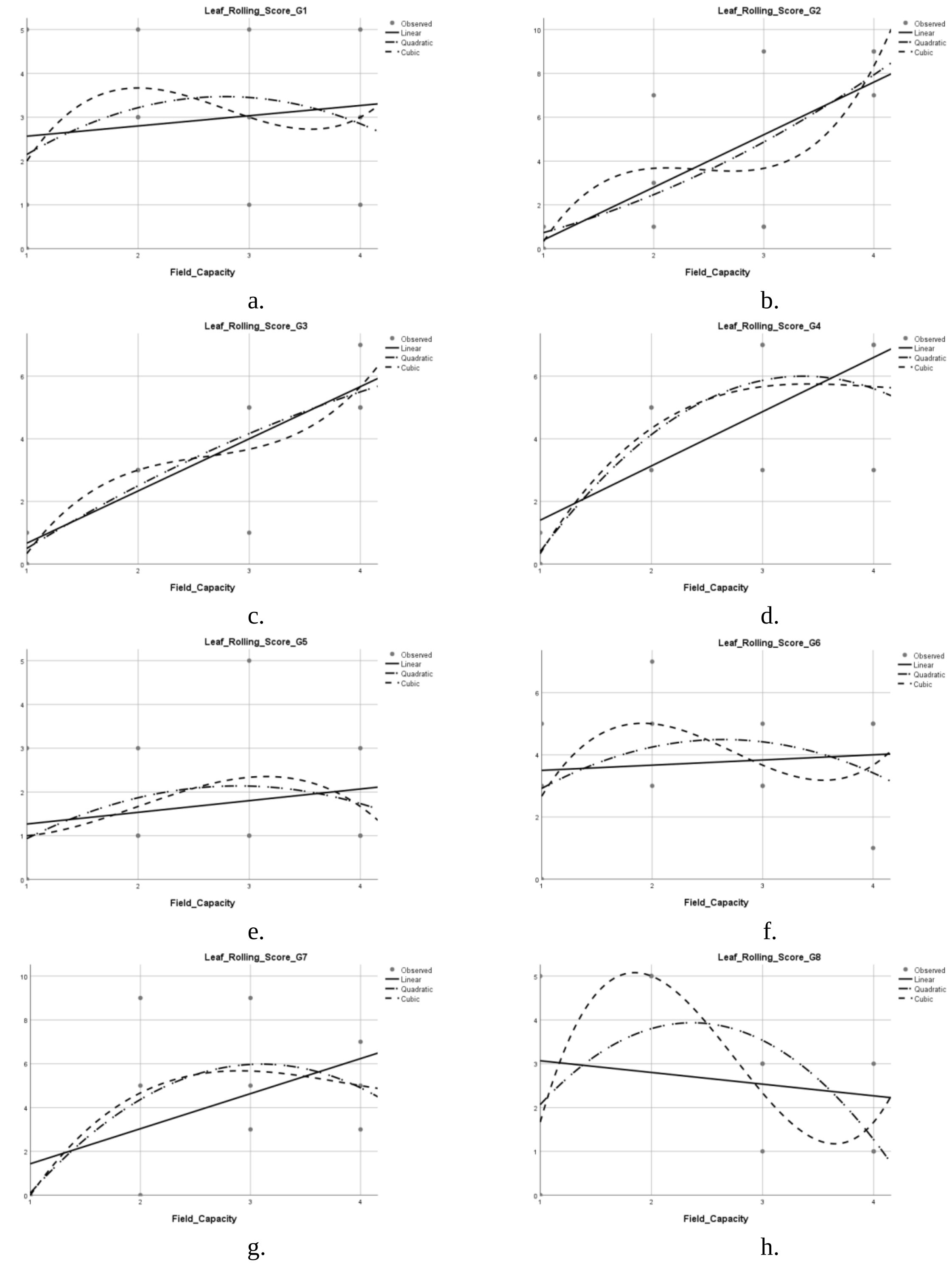

Figure 4. Regression Relationship between Leaf Rolling Score and Variations in Soil Water Content Levels. a: IR64 control, b: Ciherang control, c: Hitam Cempo, d: Hitam Mutiara, e: Merah Sengreng, f: Merah Wangi, g: Putih Mutiara, and h: Putih Mentikwangi.

Low leaf rolling scores under drought conditions with low air content in red rice were lower than in black and white rice. This finding is consistent with the results reported in a study by Sebastian et al., (2022), Merah Pari Eja, Inpari 24 and Putih Payo in severe drought produced different leaf rolling scores, with the lowest score observed in

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Merah Pari Eja (50%), while Inpari 24 and Putih Payo (100%). This finding suggests that Merah Pari Eja may be effective in preventing cell damage in leaves.

The results of the ANOVA test indicated that there was no statistically significant difference in plant height among the various factors. Accordingly, the Duncan test was not pursued further, and a regression test was conducted to ascertain which pigmented rice exhibited a superior response in relation to its interaction with soil water content. In general, drought occurring during the tillering stage affects leaf rolling at that same stage (Mukamuhirwa et al., 2019).

As illustrated in **Figure 5**, the regression test indicates that black and red rice exhibit a response, namely an increase in leaf rolling as soil water content decreases. White rice, however, exhibits a fluctuating increase in leaf rolling scores as soil water content decreases. This suggests that black and red rice exhibit a superior response to white rice, as indicated by a leaf-rolling response with a moderate or relatively higher score. Moderate leaf rolling may confer greater resilience to drought conditions than severe leaf rolling. This is because moderate leaf rolling can enhance photosynthetic efficiency by improving the leaves' upright structure and reducing the transpiration rate (Jarin et al. 2024).

CONCLUSION

The findings of this study indicate that pigmented rice (Hitam Cempo, Hitam Mutiara, Merah Sengreng and Merah Wangi) exhibits a superior response to drought conditions compared to white rice (Putih Mutiara and Putih Mentikwangi). This assessment is based on three key parameters: plant height, number of tillers, and leaf rolling score. Plant height tends to be maintained in pigmented rice varieties, such as red rice, as soil water levels decline. Conversely, black rice demonstrates an increase in the number of tillers as soil moisture decreases.

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REFERENCES

Amsal, A. & Ishak-ishak. (2018). Drought Tolerance and Evaluation of Genetic Changes in Rice Mutant Lines. *American Journal of Applied Sciences*, *15*(1), 1–9. https://doi.org/10.3844/ajassp.2018.1.9

Arista, N. I. D., Alifia, A. D., Mubarok, H., Arta, I. M. S. D., Rizva, D. N., & Wicaksono, A. I. (2023). Availability and potential for expansion of agricultural land in Indonesia. *Journal of Sustainability, Society, and Eco-Welfare*, *1*(1). https://doi.org/10.61511/jssew.v1i1.2023.242

Fauziah, Q. N., Purwanto, E., & Rahayu, M. (2024). Phylogenetic relationship of local rice from Central Java, Indonesia with Pokkali variety based on Single Nucleotide Polymorphism (SNP) markers. *Biodiversitas Journal of Biological Diversity*, *25*(10). https://doi.org/10.13057/biodiv/d251056

IRRI. (2013). *SES: Standard Evaluation System for Rice* (5th ed.). International Rice Research Institute. https://ricepedia.blogspot.com/2018/04/2013-irri-ses-standard-evaluation.html

Jarin, A. S., Islam, Md. M., Rahat, A., Ahmed, S., Ghosh, P., & Murata, Y. (2024). Drought Stress Tolerance in Rice: Physiological and Biochemical Insights. *International Journal of Plant Biology*, *15*(3), 692–718. https://doi.org/10.3390/ijpb15030051

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2092

Kartika, K., Sakagami, J.-I., Lakitan, B., Yabuta, S., Wijaya, A., Kadir, S., Widuri, L. I., Siaga, E., & Nakao, Y. (2020). Morpho-Physiological Response of Oryza glaberrima to Gradual Soil Drying. *Rice Science*, *27*(1), 67–74. https://doi.org/10.1016/j.rsci.2019.12.007

Lafitte, H., Yongsheng, G., Yan, S., & Li, Z.-K. (2006). Whole plant responses, key processes, and adaptation to drought stress: The case of rice. *Journal of Experimental Botany*, *58*(2), 169–175. https://doi.org/10.1093/jxb/erl101

Mackill, D. J., & Khush, G. S. (2018). IR64: A high-quality and high-yielding mega variety. *Rice*, *11*(1), 18. https://doi.org/10.1186/s12284-018-0208-3

Masniawati, A., Marwah Asrul, N. A., Johannes, E., & Asnady, M. (2018). Characterization of rice physicochemical properties local rice germplasm from Tana Toraja regency of South Sulawesi. *Journal of Physics: Conference Series*, *979*, 012005. https://doi.org/10.1088/1742-6596/979/1/012005

Maulani, R. R., Sumardi, D., & Pancoro, A. (2019). Total flavonoids and anthocyanins content of pigmented rice. *Drug Invention Today*, *12*(2). https://www.researchgate.net/publication/334249256_Total_flavonoids_and_anthocyanins_content_of_pigmented_rice

Mudhor, M. A., Dewanti, P., Handoyo, T., & Ratnasari, T. (2022). Pengaruh Cekaman Kekeringan Terhadap Pertumbuhan dan Produksi Tanaman Padi Hitam Varietas Jeliteng. *Agrikultura*, *33*(3), 247. https://doi.org/10.24198/agrikultura.v33i3.40361

Mukamuhirwa, A., Persson Hovmalm, H., Bolinsson, H., Ortiz, R., Nyamangyoku, O., & Johansson, E. (2019). Concurrent Drought and Temperature Stress in Rice—A Possible Result of the Predicted Climate Change: Effects on Yield Attributes, Eating Characteristics, and Health Promoting Compounds. *International Journal of Environmental Research and Public Health*, *16*(6), 1043. https://doi.org/10.3390/ijerph16061043

Noywuli, N., Limbu, U. N., Noa, M., A. Bhara, S., & Bupu, Y. (2024). Analysis of Trouble in Dry Land Management and Hills in Ngada District, East Nusa Tenggara Indonesia. *International Journal of Life Science and Agriculture Research*, *03*(07). https://doi.org/10.55677/ijlsar/V03I7Y2024-06

Salsinha, Y. C. F., Indradewa, D., Purwestri, Y. A., & Rachmawati, D. (2020). *Morphophysiological changes during vegetative stage drought stress in the local pigmented rice (Oryza sativa L.) from East Nusa Tenggara*. 030020. https://doi.org/10.1063/5.0015865

Salsinha, Y. C. F., Maryani, Indradewa, D., Purwestri, Y. A., & Rachmawati, D. (2021). Leaf physiological and anatomical characters contribute to drought tolerance of Nusa Tenggara Timur local rice cultivars. *Journal of Crop Science and Biotechnology*, *24*(3), 337–348. https://doi.org/10.1007/s12892-020-00082-1

Santhiawan, P., & Suwardike, P. (2019). Adaptasi Padi Sawah (Oryza sativa L.) Terhadap Peningkatan Kelebihan Air Sebagai Dampak Pemanasan Global. *Agricultural Journal*, *2*(2), 130–144.

Saragih, J. R., Sitepu, D. V. P. A., & Nurhayati, N. (2024). Analysis of Rice Fields Conversion to Improve Control Strategies: A SWOT Framework. *Agro Bali : Agricultural Journal*, *7*(2), 333–346. https://doi.org/10.37637/ab.v7i2.1702

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.2092

Sebastian, A., Nugroho, I. C., Putra, H. S. D., Susanto, F. A., Wijayanti, P., Yamaguchi, N., Nuringtyas, T. R., & Purwestri, Y. A. (2022). Identification and characterization of drought-tolerant local pigmented rice from Indonesia. *Physiology and Molecular Biology of Plants*, *28*(5), 1061–1075. https://doi.org/10.1007/s12298-022-01185-5

Singh, A. (2024). *Pigmented Grains: Nutritional Properties, Bioactive Potential, and Food Application* (1st ed). Elsevier Science & Technology. https://www.google.co.id/books/edition/Pigmented_Grains/bBHtEAAAQBAJ?hl=en&gbpv=1&dq=Pigmented+Grains:+Nutritional+Properties,+Bioactive+Potential,+and+Food+Application+singh+a&pg=PA388&printsec=frontcover

Ula, A. M., Purwanto, E., & Parjanto. (2023). Growth and Physiological Study of Gamma-Induced M4 Black Rice in Stress Condition. *International Journal on Advanced Science, Engineering and Information Technology*, *13*(5), 1799–1804. https://doi.org/10.18517/ijaseit.13.5.16779

Wihardjaka, A., Pramono, A., & Sutriadi, M. T. (2020). Peningkatan Produktivitas Padi Sawah Tadah Hujan Melalui Penerapan Teknologi Adaptif Dampak Perubahan Iklim. *Jurnal Sumberdaya Lahan*, *14*(1), 25. https://doi.org/10.21082/jsdl.v14n1.2020.25-36

Yang, X., Lu, M., Wang, Y., Wang, Y., Liu, Z., & Chen, S. (2021). Response Mechanism of Plants to Drought Stress. *Horticulturae*, *7*(3), 50. https://doi.org/10.3390/horticulturae7030050