Effects of Water Clover Density and Submerged NPK Fertilizer on Rice Production

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ABSTRACT

Water clover is an important weed that causes a decrease in rice yields by 15-42%. This study examined the effects of water clover density andNPK fertilizer application on rice yields. This study was arranged in a complete randomized block design with two factors. The first factor was water clover density with three levels, consisting of no water clover, one water clover, and two water clover. The second factor was the application of NPK, which was applied to the surface, submerged in 3, 6, and 9 cm—performed with three replications. Water clover density affected the number of rice panicles, the number of rice grains per panicle, the weight of 100 seeds, rice biomass, and water clover biomass. The application of submerged NPK affected rice biomass. The application of NPK on the surface reduced the highest rice biomass. Two water clovers per rice plant reduced the number of rice panicles by 39% compared to without weeds. Rice biomass decreased by 40% and 50% at weed density of one and two water clover weeds per rice plant, respectively. The higher the density of clover weeds, the higher the decline in harvest yields and the higher the biomass of clover weeds.

Keywords: Number of tillers; Rice biomass; Water clover biomass; Weight of 100 seeds

INTRODUCTION

Weeds are a significant problem in Indonesia's rice production. Rice yield losses due to weeds reach 10 to 86% (Simarmata et al., 2023). Yield losses can be reduced by controlling weeds through a cultivation system approach and weed control techniques. Increasing yield loss can cause food problems because rice is Indonesia's leading food crop commodity (Dwipa et al., 2023). The need for rice increases with population growth, in which household consumption 2022 is 20,685,619 tons. Therefore, increasing the productivity of rice plants is always attempted by suppressing weed growth (Cuaton & Delina, 2022). The most common weeds found in rice cultivation are water clover weeds. Water clover weeds are difficult to control, so they can cause suboptimal rice growth and reduce rice yields (Sulaiman et al., 2022). The decrease in rice yield due to water clover weed reached 15-42% for lowland rice and 47-87% for upland rice (Rahaman et al., 2022). Water clover weed has taproots, so the roots reach deep and spread between the rice plants, leading to the competition between weeds and rice in getting water, nutrients, and light (Az-Zahro, 2022). Weeds are competitive over cultivated

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rice since they grow taller and faster (Vu et al., 2023). Therefore, the disturbing presence of weeds is a persistent problem in rice plants (Kang-xu et al., 2022).

Weeds compete for survival with their environment above and below ground (Papapanagiotou & Vasilakoglou, 2023; Zahra et al., 2022). Weed associations may form around the primary crop if the growth requirements of weeds and the crop are similar. These associated weeds will compete for the materials they need, especially if the amount is minimal for both. Competition will be even more intense if the amount of materials competed for cannot be used together (Rodenburg et al., 2022). The highest degree of competition occurs during a critical period of growth. Cultivated plants experience a critical period when they are most sensitive to the environment, especially in competition for space, nutrients, water, and sunlight. If weeds are present and interfere with cultivated plants, cultivated plants cannot compete in utilizing the main growing environmental factors because cultivated plants are at their weakest (critical period) (Awan et al., 2022).

In addition to the weed problem, fertilizer is another important factor in improving rice yield and quality. One type of inorganic fertilizer that is effective in raising the availability of macronutrients (potassium, phosphate, and nitrogen) is compound fertilizer (Haouas et al., 2021). Compound fertilizer has a higher effectiveness in providing nutrients compared to single fertilizers. Compound fertilizers significantly stimulate plant growth and yields because nitrogen, phosphate, and potassium contribute nutrients available to plants that can support plant vegetative and generative growth (Choo et al., 2020; Singh et al., 2021). However, the depth of fertilization can be considered due to the root system of rice and weeds. Applying submerged fertilizer can be more effective than mulching because it can reduce the evaporation of organic matter (Duan et al., 2023; He et al., 2023). This study examined the effects of water clover weed density and NPK fertilizer application on rice yields.

MATERIALS AND METHODS

The research was conducted at the Field Laboratory in Bakaran Hamlet, Jumantono District, Karanganyar, Central Java, Indonesia, at coordinates 7°37°51°S 110°56°52°E. The study research was arranged in a factorial, completely randomized block design with two factors. The first factor was water clover density, namely without water clover, one water, and two water clovers with a 10-15 cm height. The second factor was the application of NPK, namely control or applied to the surface, NPK submerged in 3 cm, NPK submerged in 6 cm, and NPK submerged in 9 cm. Each treatment combination consisted of three replications, resulting in 36 experimental units. Each treatment consisted of 30 rice plant populations. The rice planting space used was 20 x 20 cm, with a plot size for each treatment of 1.2 m^2. The study used IR32 rice seeds, water clover weed 10 - 15 cm high, polybag size 50 x 50 cm, NPK fertilizer, organic fertilizer, soil, and water. The soil used in the study was alfisol soil with an acidic pH of 6, shallow organic C content of 0.387 %, external total N content of 0.08 %, moderate total P_2O_5 content of 29.21 mg/100 g, K_2O content, low total of 12.26 mg/100 g, shallow C/N content of 4.84, specific gravity including clay minerals (2.14 g/cm^3), volume weight including mineral soil (1.2 g/cm^3), and moderate porosity of 43.93. The tools used were trowels, buckets, sprayers, an oven at 60 °C, and measurement tools, including meters, rulers, and digital scales. The observed yield variables included the number of rice tillers, number of

panicles per hill, number of seeds per panicle, weight of 100 seeds, rice biomass, and clover biomass. All yield variables were observed at 42 days after planting. Data were analyzed using an analysis of variance of 5 %. If it was significant, the test of significant differences between treatments was continued with the 5 % Duncan Multiple Range Test.

RESULTS AND DISCUSSION

The density of water clover weeds and submerged NPK application did not affect the number of rice tillers (Table 1). The higher density of water clover weeds can cause a decrease in the number of rice tillers. The density of one weed led to a decline of 17.40%, while the density of two weeds caused a 22% fall compared to non-weeds. The tiller decrease was due to competition between rice and water clover weeds. Weeds can compete in absorbing water and nutrients (Li et al., 2022). The number of rice tillers correlates with the number of rice panicles, so the higher the number of tillers, the higher the number of rice panicles. Water clover weed density significantly affected the number of rice panicles (Table 2). The density of the two water clover weeds showed the lowest number of rice panicles, which was 5.17. The number of rice panicles at the density of one weed decreased by 26%. Meanwhile, the density of two weeds decreased the number of panicles by 39%. The combination of NPK fertilizer submerged in 3 cm with one weed density produced the lowest number of tillers, which was 1.77. This shows that there is competition between weeds and rice. Weed population density determines competition, leading to a decrease in crop production (Maciel et al., 2022). In addition, weeds that appear earlier or simultaneously with cultivated plants significantly impact plant growth and yields (Monteiro & Santos, 2022). Weed competition at the start of growth will

Table 1. Effects of the water clover density and application of NPK on the number of rice tillers per plant

Water clover density per rice plant	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	2.77	3.22	3.00	3.66	3.16
1	2.89	1.77	2.55	2.78	2.50
2	2.00	2.55	3.11	2.78	2.61
Average	2.55	2.51	2.89	3.07	-

Remarks: (-) there is no interaction between treatments

Table 2. Effects of the water clover density and application of NPK on the number of rice panicles per plant

Water clover density per rice plant	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	7.33	8.33	8.67	9.67	8.50b
1	4.67	7.33	7.33	5.67	6.25a
2	4.00	5.33	6.00	5.33	5.17a
Average	5.33	7.00	7.33	6.89	-

Remarks: Means followed by the same letters in the same column are not significantly different, (-) there is no interaction between treatments

Table 3. Effects of the water clover density and application of NPK on the number of spikelets per rice panicle

Water clover density	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	50.33	46.33	53.33	48.78	49.69b
1	39.00	42.33	46.44	44.89	43.17a
2	35.55	42.00	37.80	38.22	38.39a
Average	41.63	43.55	45.86	43.96	-

Remarks: Means followed by the same letters in the same column are not significantly different, (-) there is no interaction between treatments

Table 4. Effects of the water clover density and application of NPK on the weight of 100 seeds

Water clover density	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	2.27	2.34	2.58	2.36	2.39b
1	2.18	2.23	2.36	2.12	2.22ab
2	1.97	2.13	2.09	2.05	2.06a
Average	2.14	2.23	2.34	2.18	-

Remarks: Means followed by the same letters in the same column are not significantly different, (-) there is no interaction between treatments

reduce yield quantity, while competition and weed disturbance before harvest majorly affect yield quality (Grzanka et al., 2022).

The results showed that the density of weeds affected the number of shoots per rice panicle (Table 3). The highest number of nodes per panicle was in the treatment without weed. The number of rice grains decreased with the higher density of weeds. The rice grains were reduced by 22% in the treatment of two weeds per rice plant compared to without weeds. This indicates competition for water, nutrients, and light (MacLaren et al., 2020). According to Dass et al. (2017), weeds require between 330 and 1900 liters of water for every kilogram of organic matter, which is nearly twice as much as plants do. Furthermore, because weeds' roots are deeper and wider than rice's, weeds' water clovers absorb nutrients at a quicker rate than rice plants (Antralina, 2012). Weeds and rice also experience competition for light. Faster-growing weeds can shade rice plants so that the light received by rice plants is reduced. This decrease in sunlight can cause a reduction in the rate of photosynthesis so that plant growth and yield are not optimal (Rogowski et al., 2019). The lowest number of panicles was in the combination of NPK applied to the soil surface with the treatment of two weeds per rice plant, which was 35.55 panicles. These results indicate that fertilizer application to the soil surface causes leaching, and the nutrients cannot be easily absorbed by plants.

Water clover density affected the weight of 100 seeds (Table 4). However, the application of NPK did not affect the weight of 100 seeds—the highest 100-seed weight was found in the treatment without weeds. The weight of 100 seeds at the density of one weed per rice plant was not significantly different from the treatment without weeds. However, the density of two weeds per rice plant caused a higher reduction in the weight of 100 seeds. The weight of 100 seeds decreased due to competi-

Table 5. Effects of the water clover density and application of NPK on the rice biomass (g)

Water clover density	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	14.84	14.63	17.14	15.35	15.49b
1	5.32	11.80	10.70	8.85	9.17a
2	5.43	7.29	7.36	10.43	7.63a
Average	8.53a	11.24b	11.74b	11.55b	-

Remarks: Means followed by the same letters in the same column are not significantly different, (-) there is no interaction between treatments

Table 6. Effects of the water clover density and application of NPK on the water clover weed biomass

Water clover Density	NPK Fertilizer Application				Average
	In Surface	Submerged in 3 cm	Submerged in 6 cm	Submerged in 9 cm	
0	0.00	0.00	0.00	0.00	0.00a
1	20.00	18.33	6.33	19.00	15.92b
2	35.33	46.00	43.33	21.00	36.42c
Average	18.44	21.44	16.56	13.33	-

Remarks: Means followed by the same letters in the same column are not significantly different, (-) there is no interaction between treatments

tion between weeds and rice plants. The negative effect of weeds is that they reduce yield rates due to competition in taking nutrients, water, and light (Beiermann et al., 2022). Thus, to replace the competition, fertilization is carried out correctly. Fertilization aims to provide additional nutrients to the soil, which plants directly or indirectly absorb (Ma et al., 2021).

Water clover weed density and NPK application significantly affected rice biomass (Table 5). Without weed density, the highest rice biomass was 15.49 g. The density of one or two weeds per rice plant caused a decrease in rice biomass. Rice biomass decreased progressively with the increasing weed density because weed density could increase competition between weeds and plants. In addition, this water clover weed has secondary metabolites that can play a role in inhibiting the growth of rice plants (Zhu et al., 2021). Efforts to support rice yields are carried out by fertilizing with NPK fertilizer. However, this fertilizer application must be done correctly. The results showed that the application of NPK fertilizer submerged in 6 cm showed the highest rice yield because rice has fibrous roots, making the root reach not deep and wide. The soil's physical state influences rice roots' growth (Wu et al., 2020; Xiong et al., 2021). A dense soil structure will inhibit the rate of deeper root penetration. NPK fertilizer can affect plant length growth, increasing meristem activity yield at the growing point. The higher the action, the higher the plant biomass,

Water clover weed density significantly affected water clover weed biomass (Table 6). The highest water clover weed biomass was observed at the density of two weeds per rice plant, which was 36.42 g. This shows that the higher density indicates faster weed growth. The water clover biomass ratio was higher than rice biomass. This shows that water clover weed can absorb more water and nutrients than rice (Guntoro & Fitri, 2013; Kumawat et al., 2022; Vu et al., 2023). This increased

absorption is supported by the characteristics of the water clover root, namely the taproot, so the roots are not deep and broad. The wider these roots reach, the more water absorption and nutrients can be increased.

CONCLUSION

Application of NPK fertilizer submerged in the soil could increase the number of rice tillers, the number of rice panicles, and rice biomass. Two water clover weeds per rice plant reduced the number of rice panicles by 39% compared to without weeds. Rice biomass decreased by 40% at one weed density per rice plant and 50% at the weed density of two weeds per rice plant. The higher water clover weed density caused the highest yield decrease. In addition, the higher the weed density, the higher the water clover weed biomass.

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AUTHOR'S CONTRIBUTIONS

MTSB was instrumental in designing and supervising the entire study. S was involved in data analysis and preparation of the research results. MR contributed to data collection and validation processes. DS was responsible for writing the initial draft of the manuscript and editing. LIS contributed to the literature review and final revision of the manuscript. All authors have read and approved the final manuscript.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Antralina, M. (2012). Karakteristik gulma dan komponen hasil tanaman padi sawah (*Oryza sativa* L .) sistem SRI pada waktu keberadaan gulma yang berbeda. *Jurnal Agribisnis Dan Pengembangan Wilayah*, *3*(2), 9–17.

Awan, T., Ali, H., & Chauhan, B. (2022). Cyperus iria Weed Growth , Survival , and Fecundity in Response to Varying Weed Emergence Times and Densities in. *Agronomy*, *1006*(12), 1–15.

Az-Zahro, A. (2022). Keanekaragaman gulma di areal pertanaman padi sawah beririgasi di Kelurahan Mulyorejo, Kota Malang, Indonesia. *Jurnal Proteksi Tanaman*, *6*(2), 33–44.

Beiermann, C. W., Miranda, J. W. A., Creech, C. F., Knezevic, S. Z., Jhala, A. J., Harveson, R., & Lawrence, N. C. (2022). *Critical timing of weed removal in dry bean as influenced by the use of preemergence herbicides*. https://doi.org/10.1017/wet.2021.99

Choo, L. N. L. K., Ahmed, O. H., Talib, S. A. A., Ghani, M. Z. A., & Sekot, S. (2020). Clinoptilolite zeolite on tropical peat soils nutrient, growth, fruit quality, and yield of *Carica papaya* L. CV. sekaki. *Agronomy*, *10*(9). https://doi.org/10.3390/agronomy10091320

Cuaton, G., & Delina, L. L. (2022). Two decades of rice research in Indonesia and the Philippines: A systematic review and research agenda for the social sciences. *Humanities and Social Sci-*

ences Communication, *2009*. https://doi.org/10.1057/s41599-022-01394-z
Dass, A., Shekhawat, K., Choudhary, A. K., Sepat, S., Rathore, S. S., Mahajan, G., & Chauhan, B. S. (2017). Weed management in rice using crop competition-a review. *Crop Protection*, *95*, 45–52. https://doi.org/10.1016/j.cropro.2016.08.005
Duan, Q., Jiang, S., Chen, F., Li, Z., Ma, L., Song, Y., Yu, X., Chen, Y., Liu, H., & Yu, L. (2023). Fabrication evaluation methodologies and models of slow-release fertilizers : A review. *Industrial Crops & Products*, *192* (September 2022), 116075. https://doi.org/10.1016/j.indcrop.2022.116075
Dwipa, I., Rozen, N., & Kasim, M. (2023). Effect of land flooding in controlling weeds to several rice varieties in System of Rice Intensification (SRI). *IOP Conference Series: Earth and Environmental Science*, *1177*(1), 012019. https://doi.org/10.1088/1755-1315/1177/1/012019
Grzanka, M., Sobiech, Ł., & Idziak, R. (2022). Effect of the Time of Herbicide Application and the Properties of the Spray Solution on the Efficacy of Weed Control in Maize. *Agriculture (Switzerland)*, *353*(12).
Guntoro, D., & Fitri, T. Y. (2013). Aktivitas Herbisida Campuran Bahan Aktif Cyhalofop-Butyl dan Penoxsulam terhadap Beberapa Jenis Gulma Padi Sawah. *Buletin Agrohorti*, *1*(1), 140. https://doi.org/10.29244/agrob.1.1.140-148
Haouas, A., El Modafar, C., Douira, A., Ibnsouda-Koraichi, S., Filali-Maltouf, A., Moukhli, A., & Amir, S. (2021). Evaluation of the nutrients cycle, humification process, and agronomic efficiency of organic wastes composting enriched with phosphate sludge. *Journal of Cleaner Production*, *302*. https://doi.org/10.1016/j.jclepro.2021.127051
He, Y., Hou, J., Qiu, Y., Ouyang, K., Li, D., & Li, L. (2023). Microcystin-LR immersion caused sequential endocrine disruption and growth inhibition in zebrafish (*Danio rerio*) from fertilization to sexual differentiation completion. *Toxicology*, *494*(1), 1–9. https://doi.org/10.1016/j.tox.2023.153569
Kang-xu, W., Ke-rou, Z., Cou-gui, C. A. O., & Yang, J. (2022). Effect of Bt traits on growth and weed competitiveness of transgenic rice. *Journal of Integrative Agriculture, 22(8), 2346-2358*. https://doi.org/10.1016/j.jia.2023.01.001
Kumawat, K., Pankhaniya, R. M., & Parmar, S. K. (2022). *Determination of critical period of crop-weed competition in aerobic rice*. *11*(11), 2168–2171.
Li, J., Zhao, T., Chen, L., Chen, H., Luo, D., Chen, C., Miao, Y., & Liu, D. (2022). Artemisia argyi allelopathy : a generalist compromises hormone balance , element absorption , and photosynthesis of receptor plants. *BMC Plant Biology*, *368*(22), 1–17. https://doi.org/10.1186/s12870-022-03757-9
Ma, Q., Wang, M., Zheng, G., Yao, Y., Tao, R., Zhu, M., Ding, J., Li, C., Guo, W., & Zhu, X. (2021). Twice-split application of controlled-release nitrogen fertilizer met the nitrogen demand of winter wheat. *Field Crops Research*, *267*(September 2020), 108163. https://doi.org/10.1016/j.fcr.2021.108163
Maciel, J. C., Duque, T. S., Ferreira, E. A., & Zanuncio, C. (2022). Growth, Nutrient Accumulation, and Nutritional Efficiency of a Clonal Eucalyptus Hybrid in Competition with Grasses. *Forest*, *1157*(13), 1–11.
MacLaren, C., Storkey, J., Menegat, A., Metcalfe, H., & Dehnen-Schmutz, K. (2020). An ecological future for weed science to sustain crop production and the environment. A review. *Agronomy for Sustainable Development*, *40*(4). https://doi.org/10.1007/s13593-020-00631-6
Monteiro, A., & Santos, S. (2022). Sustainable Approach to Weed Management : The Role of Precision Weed Management. *Agronomy*, *118*(12), 1–14.
Papapanagiotou, A., & Vasilakoglou, I. (2023). Growth rate and competitive ability of susceptible and multiple - resistant late watergrass (*Echinochloa phyllopogon*) biotypes to rice. *Phytoparasitica*, *0123456789*. https://doi.org/10.1007/s12600-023-01084-9
Rahaman, F., Shukor Juraimi, A., Rafii, M. Y., Uddin, K., Hassan, L., Chowdhury, A. K., Karim, S. M. R., Yusuf Rini, B., Yusuff, O., Bashar, H. M. K., & Hossain, A. (2022). Allelopathic potential in rice - a biochemical tool for plant defence against weeds. *Frontiers in Plant Science*, *13*(December), 1–14. https://doi.org/10.3389/fpls.2022.1072723
Rodenburg, J., Tippe, D. E., Tour, A., & Bastiaans, L. (2022). From rice-like plants to plants lik-

ing rice : A review of research on weeds and their management in African rice systems. *Field Crops Research*, *276*(September 2021). https://doi.org/10.1016/j.fcr.2021.108397

Rogowski, P., Wasilewska-Dębowska, W., Krupnik, T., Drożak, A., Zienkiewicz, M., Krysiak, M., & Romanowska, E. (2019). Photosynthesis and organization of maize mesophyll and bundle sheath thylakoids of plants grown in various light intensities. *Environmental and Experimental Botany*, *162*(February), 72–86. https://doi.org/10.1016/j.envexpbot.2019.02.006

Simarmata, M., Apriantonedi, R., Setyowati, N., & Pujiwati, H. (2023). Possibility of glyphosate-resistant goosegrass (*Eleusine indica*) in citrus fields in Rejang Lebong Districts, Bengkulu, Indonesia. *Biodiversitas*, *24*(6), 3624–3629. https://doi.org/10.13057/biodiv/d240663

Singh, P., Benbi, D. K., & Verma, G. (2021). Nutrient Management Impacts on Nutrient Use Efficiency and Energy, Carbon, and Net Ecosystem Economic Budget of a Rice–Wheat Cropping System in Northwestern India. *Journal of Soil Science and Plant Nutrition*, *21*(1), 559–577. https://doi.org/10.1007/s42729-020-00383-y

Sulaiman, N., Norasma, N., Ya, C., Huzaifah, M., Roslim, M., Juraimi, A. S., Noor, N. M., Fazilah, W., & Ilahi, F. (2022). The Application of Hyperspectral Remote Sensing Imagery (HRSI) for Weed Detection Analysis in Rice Fields : A Review. *Applied Sciences (Switzerland)*.

Vu, D. H., Stuerz, S., & Asch, F. (2023). Rice – weed competition in response to nitrogen form under high and low transpirational demand. *Journal Agro Crop Science*, *209*(April 2021), 27–40. https://doi.org/10.1111/jac.12562

Wu, L., Jiang, Y., Zhao, F., He, X., Liu, H., & Yu, K. (2020). Increased organic fertilizer application and reduced chemical fertilizer application affect the soil properties and bacterial communities of grape rhizosphere soil. *Scientific Reports*, *10*(1), 1–10. https://doi.org/10.1038/s41598-020-66648-9

Xiong, Q., Hu, J., Wei, H., Zhang, H., & Zhu, J. (2021). Relationship between plant roots, rhizosphere microorganisms, and nitrogen and its special focus on rice. *Agriculture (Switzerland)*, *11*(3), 1–18. https://doi.org/10.3390/agriculture11030234

Zahra, N., Bilal, M., Nawaz, A., & Farooq, M. (2022). Rice production systems and grain quality. *Journal of Cereal Science*, *105*(September 2021), 103463. https://doi.org/10.1016/j.jcs.2022.103463

Zhu, X., Yi, Y., Huang, L., Zhang, C., & Shao, H. (2021). Metabolomics reveals the allelopathic potential of the invasive plant eupatorium adenophorum. *Plants*, *10*(7), 1–14. https://doi.org/10.3390/plants10071473