Optimization of lowland productivity through fertilization as a food buffer against the impact of climate change

NP. Sri Ratmini[1*], *IGM.* Subiksa[1], *Agus* Suprihatin[1], *IW.* Suastika[1] and *Damasus* Riyanto[2]

[1]Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency, Jl. Raya Bogor-Jakarta, Cibinong, Bogor 16911, West Java, Indonesia
[2]Institute of Agriculture (Intan) Yogyakarta – Magelang Street Km. 5.6 P.O Box 1059 Yogyakarta Special Region, Indonesia.

Abstract. Lowland is an agroecosystem that can be cultivated for agricultural production activities. Its wide potential and planting time are generally carried out in the dry season resulting in lowland areas being the main national food buffer during El-Nino. Its management, which is not optimal results in low production. Increased productivity of lowland land can be done by applying the optimum fertilizer. This study aims to determine the effect of NPK fertilizer on the growth and productivity of rice in lowland fields in South Sumatra. The study used a completely randomized block design with four treatments and six replications. The indicator plant uses rice variety Inpari 42. The results showed that the highest production was obtained in the combined treatment of 250 kg NPK ha^{-1} + 150 kg urea ha^{-1} + 1,000 kg dolomite ha^{-1} with a yield of 5.81 t ha^{-1}. These results indicate that NPK and urea fertilization combined with dolomite can increase the productivity of lowland rice fields as a buffer zone for rice production against the impacts of climate change.

1 Introduction

Agricultural land revitalization is one of the fundamental challenges that must be faced since it is important to meet national food needs. The Indonesian population increase quite high at a rate of 1.6% per year [1] and projected to reach 350 million people in 2050 [2]. It is due to increasing of food consumption per capita that have an impact on the increasing of national food supply. This condition could result in an increase of national food scarcity [3].

The lowland development as agricultural land is one of the efforts that can be carried out in increasing rice production to support national food security, especially on the impact of climate change. The specific advantage of lowland is as a reserve for rice production in the event of crop failure in other agricultural land, especially during El-Nino [4]. The lowland is characterized by deep puddles soil with high rainfall that varies between 50-200 cm [5] [6] at least 3 months a year. Currently, the cropping pattern management of the lowland has not been maximized resulting in low productivity namely around 3 t ha^{-1} in average [7]. This

---

[*] Corresponding author: nps_ratmini@yahoo.com

productivity is still far from the provincial rice yield average in around 5 t ha^{-1} [8] and planted with rice only once a year (CI 100) [9]. The use of technological innovations in lowland can increase rice yield, such as high-yielding varieties can increase the productivity of lowland rice in the ranges from 6-8 t ha^{-1} [10]

In addition to the use of varieties, fertilization is another effort that can be carried out to increase the productivity of lowland with low fertility status [11]. Generally, the organic-C content ranges from high to very high, the total N is classified as medium-very high, meanwhile available P, CEC and base saturation are classified as low-medium [12]. The lowland nutrients status is mainly influenced by the nutrients content of river water from the upstream area through the water runoff. The study results conducted by Syahri and Utami [13] show that the balance fertilization can increase paddy yields to 8.2 t ha^{-1} at the first planting season. Productivity in the second planting season is generally very low (< 3 t ha^{-1}), so there are few farmers planting rice in this season. Therefore, efforts are needed to increase rice production in the second planting season using balanced fertilizer and the addition of soil ameliorant in lowland rice fields. It is hoped that increasing rice productivity in the second planting season will support national food security, especially in the face of climate change.

This research aims to determine the effect of a combination of treatments between NPK and urea fertilizer and dolomite on the growth and yield of lowland rice in South Sumatra.

2 Materials and methods

The study was conducted on farmer's field at Gelebag Dalam Village, Rambutan, Banyuasin District, South Sumatra (-3,08929S; 104,85329E) (Figure 1), the annual average temperature range was 23°C-39°C. This experiment was carried out from November 2021 to February 2022. It was conducted in the second planting season (CI 200). The research location is classification as shallow non tidal swamps.

Fig. 1. Research site map at Gelebag Dalam Village, Rambutan, Banyu Asin District, South Sumatra.

Field experiments were conducted on farmers' land with a plot size of 640 m^2 and arranged using a randomized complete block design with four treatments and four replications. The treatment is shown in Table 1. The fertilization rate was determined based on the results of soil analysis using the Swamp Soil Test Kit (*PUTR*) prior to the study started. The plant indicator was paddy (*Oryza sativa*) Inpari 42 variety with a planting distance of 25 cm x 25 cm. The study used the NPK compound fertilizer (15:15:15) as basal fertilizer for all treatments. The Dolomite as ameliorant was given after the first tillage. The NPK and KCl fertilizers were applied at 7 days after planting (DAP), while the urea was applied twice at dose 50% of total for each, at the age of 7 and 30 DAP respectively.

The plant growth parameters observed were plant height and number of tillers at 30 DAP and harvest, productive tillers and yield components include panicle length, percentage of hollow grain and productivity. The statistical analysis used SPSS 22.0 including Analysis of Variance (ANOVA) and further tests with Duncan's Multiple Range Test (DMRT) at 5% level.

Table 1. List of treatments in this study.

Treatments	Remaks (kg ha^{-1})
P0 (Farmers practice)	150 Urea + 0.03 Ecofarming
P1 (Recommendation on PUTR)	250 NPK + 150 Urea + 1,000 Dolomite
P2 (75% Recommendation on PUTR)	150 NPK + 200 Urea + 1,000 Dolomite
P3 (125 % Recommendation on PUTR)	350 NPK + 100 Urea + 1,000 Dolomite

3 Results and discussion

3.1 Soil properties

Based on the initial soil sample analysis results using PUTR, it showed that the pH value of the soil is acidic, the score for N is classified as low and P and K values are moderate (Table 2). The soil sample taken after harvest showed that the average soil pH value in the treatment of P1, P2 and P3 was 5.41. This indicates an increase in pH due to the lime application. The lime application can suppress the solubility of aluminum and hydrogen to increase the soil pH. The liming process causes aluminum ions (Al^{3+}) to be replaced in the soil lattice by Ca and Mg to form Ca $(HCO_3)_2$ and Mg $(HCO_3)_2$ resulting in an increased soil pH [14]. The increasing of soil pH will affect changes in base saturation, Soil Cation Exchange Capacity, mineralization of organic matter, N transformation, nitrification, and denitrification, which further affects the production of N_2O in the soil [15] as well as the activity of microorganisms in the soil. Improvements will affect the availability of several nutrients, thereby increasing plant growth and production.

Table 2. Initial soil analysis of study site at Gelebag Dalam, Rambutan Banyuasin District, South Sumatra.

Soil chemical properties	Category
pH	Acid
N	Low
P	Moderate
K	Moderate

3.2 The effect of treatment on plant growth

The effect of fertilization on plant height, both at 30 days after planting (DAP) and prior to harvest, is presented in Fig. 2. The fertilization could increase the plant height both at the age of 30 DAP and harvest. The highest plant height at the age of 30 DAP and harvest were obtained in the P1 treatment, which was 97.60 cm and 109.56 cm respectively, while the lowest farmer's treatment was 81.20 cm. The number of productive tillers and tillers was also affected by NPK fertilization (Fig. 3). The highest number of one-month-old tillers and productive tillers were obtained in the P1 treatment, namely 24.70 stems and 20.13 stems respectively.

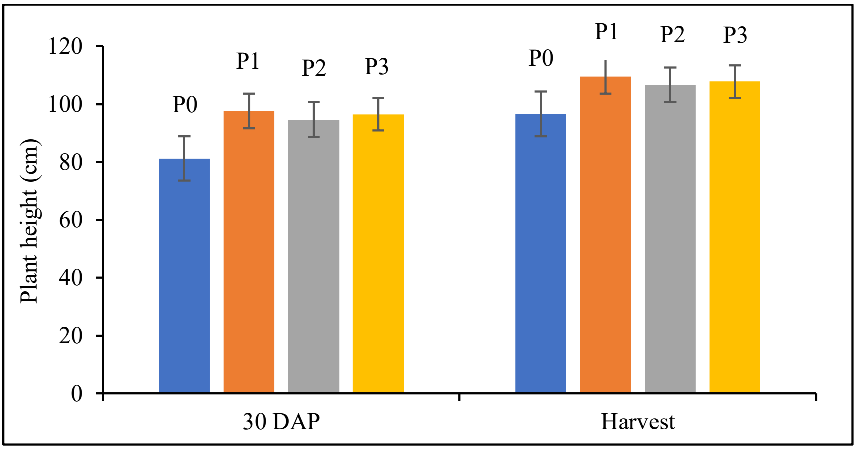

Fig. 2. The average of of plant height at 30 DAP and prior to harvest at the fertilization treatment for low land paddy plant.

Plant height parameter is one of the selection criteria in paddy plants, but the high plant height does not guarantee the level of production. Plant height has a great influence on the relationship between panicle length and yield. Well growing plants can absorb nutrients in large quantities. The availability of nutrients in the soil affects the increase in plant photosynthesis activity to increase the growth and components of plant yield [16].

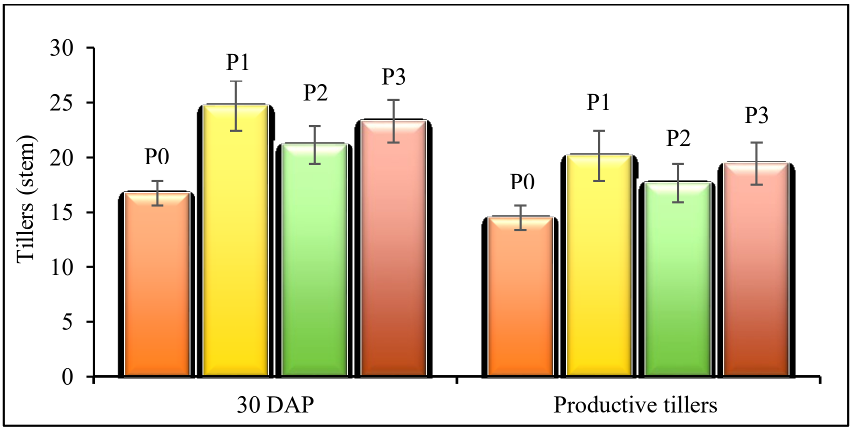

Fig. 3. The average number of tillers at 30 days after planting and the number of productive tillers at the fertilization treatment for lowland paddy plant.

3.3 The effect of treatment on yield and productivity components

The effect of fertilization on rice yield and yield components is presented in Table 3. The highest productivity obtained in the P1 treatment of 5.81 t ha^{-1} which was significantly different from the P0 (control) treatment, but not significantly different from the P2 and P3 treatments. The application of NPK fertilizer is expected to supply the availability of P and K nutrients. According to Wang et al. [17], the production can be increased by applying the balanced fertilizers. The P is very important because some of the main processes of plants include photosynthesis, root development, plant yield, and quality [18], [19], [20]. Other research results show that P fertilization can increase paddy yield, the higher the P is given, the more the production achieves [21]. The yield components of panicle length and percentage of hollow grain showed no noticeable effect on the control, but the fertilization tended to have a positive effect on the observed yield component.

Table 3. The effect of treatment on production components and paddy productivity.

Treatment	Panicle length (cm)	Hollow grain (%)	Productivity (t ha^{-1})
P0 (control)	20,22 a	16,28 a	4,82 a
P1	20,87 a	22,12 a	5,81 c
P2	20,68 a	17,97 a	5,34 b
P3	20,74 a	20,62 a	5,44 bc

Notes: P0=150 kg Urea ha^{-1} + 0.03 Ecofarming kg ha^{-1} ; P1=250 kg NPK ha^{-1} + 150 kg urea ha^{-1} + 1,000 kg dolomite ha^{-1} ; P2=150 kg NPK ha^{-1} + 200 kg urea ha^{-1} + 1,000 kg dolomite ha^{-1} ; P3=350 kg NPK ha^{-1} + 100 kg urea ha^{-1} +1,000 kg dolomite ha^{-1}. Means followed by different letters are significantly different (DMRT, $\alpha = 0.05$).

4 Conclusions

Lowland productivity can be increased by applying balanced and optimal fertilization. The application of NPK compound fertilizer combined with dolomite in accordance with the soil fertility status increased soil pH value and the plant growth, as well as rice yield up to 5.81 t ha^{-1}. These results showed that fertilizing NPK coupled with dolomite application is an opportunity to increase productivity of lowland as buffer zone in rice production against climate change impact.

References

1. G. Irianto, *Proceedings of the National Seminar on Integrated lowland Land Management* (Banjarbaru, Swamp Land Research Institute, (2006)
2. R. Saparita, J. Mathematic, Science and Technology **7**, 24 (2006)
3. S. Rusdiana and A. Maesya, Agriekonomika J **6**, 12 (2017)
4. A. A. Sulaiman, Y. Sulaeman, and B. Minasny, Resources **8**, (2019)
5. M. Noor and Y. Sulaeman *Pemanfaatan dan pengelolaan lahan Rawa* (Gadjah Mada University Press, 2021)
6. Haryono, M. Noor, Syahbuddin, M. Syarwani *Swampland research and development indonesia agency for agricultural research and development* (Jakarta: IAARD Press, 2013)
7. Suparwoto. dan Waluyo J. Pemb. Manusia **5**, 39 (2011)
8. S. S. Province and I. Figures, P*rovinsi dalam angka* (2022)
9. Sudana, J. Agricultural Policy Analysis **3**, 141 (2005)
10. NPS. Ratmini and Herwenita, in *IOP Conf Ser Earth Environ Sci* (IOP Publishing Ltd, 2021)
11. Djamhari, J. Hidrosfir Indonesia **5,** 1, (2009)
12. Waluyo, S. Djamhari, J. Sains dan Teknologi Indonesia **13,** 204 (2011)
13. Syahri, RU. Somantri, J. Assessment and Development of Agricultural Technology **17**, 211 (2014).
14. R. Paradelo, I. Virto, and C. Chenu, Agric Ecosyst Environ **202**, 98 (2015)
15. M. Shaaban, Q. an Peng, R. Hu, Y. Wu, S. Lin, and J. Zhao, Environmental Science and Pollution Research **22**, 19961 (2015)
16. S. Yoshida *Fundamental of Rice Crop Science*. (IRRI, Philippines, 269, 1981)
17. L. Wang, U. Ashraf, C. Chang, M. Abrar, and X. Cheng, J Soil Sci Plant Nutr **20**, 557 (2020)

18. D. P. Schachtman, R. J. Reid, and S. M. Ayling, *Update on Phosphorus Uptake Phosphorus Uptake by Plants: From Soil to Cell* (n.d.)
19. G. Henrique Demari, I. Ricardo Carvalho, M. Nardino, V. Jardel Simone Morgan Dellagostin, T. Corazza da Rosa, D. Nicolau Follmann, M. Andrade Monteiro, C. José Basso, T. Pedó, and T. Zanatta Aumonde, *International Journal of Current Research* **8**, 36629 (2016)
20. M. S. Imanudin, M. E. Armanto, and Bakri, Irrigation and Drainage **68**, 488 (2019)
21. P. Massawe and J. Mrema, Asian Journal of Advances in Agricultural Research **3**, 1 (2017)