Nutrient management to increase rice productivity in dry land

Nourma Al Viandari[1], *Tri Endar* Suswatiningsih[2], *Yulis* Hindarwati[1], *Sri Wahyuni* Budiarti[1], *Rajiman* Rajiman[3], and *Arif* Anshori[1*]

[1]Research Center for Food Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency, Bogor, Indonesia
[2]Department of Agribusiness, Faculty of Agriculture, Institut Pertanian Stiper, Yogyakarta, Indonesia
[3]Agricultural Development Polytechnic of Yogyakarta – Magelang, Yogyakarta, Indonesia

Abstract. Nutrient application into soil with the right dose and time will support growth and increase rice yield. This study aimed to determine the nutrient management based on differences in the frequency and timing of application in supporting plant growth and increasing rice productivity in dry land. The study was conducted in dry land Gunungkidul, D.I. Yogyakarta, Indonesia, during dry season. NPK 15-15-15 fertilizer at the dose of 300 kg ha^{-1} and N 46% at the dose of 200 kg ha^{-1} were used in this research. Nutrient management with three fertilizer applications was compared with farmer practices with two fertilizer applications, repeated 11 times. The results showed that nutrient management increased grain productivity by 1.16 times compared to farmer practices, and straw productivity by 1.02 times. Nutrient management reduced the percentage of empty grain, by 33.63% compared to farmer practice. Nutrient management also increased the tiller number at harvest, and carbon absorption in grain and straw. Adoption of nutrient management at farmer level is user-friendly and gives beneficial impact on nutrient. Nutrient management application can be suitable strategy to support dry land agriculture.

1 Introduction

Dry land stretches across Indonesia covering an area of 144.47 million hectares [1], potentially support agricultural development. Nevertheless, water availability is a major problem for dry lands. Limited water inhibits plant growth and development, further resulting in low agricultural yields. An equally important issue is soil conditions. Soil organic matter and fertility levels are low. Leaching and nutrient loss can occur rapidly, leading to a drastic decline in soil fertility [2], proper soil nutrient management (NM) is required. However, agricultural development is shifting to dry land area to reduce pressure on irrigated rice field, which without proper management can negatively impact on the agricultural sustainability.

NM rice pays attention to nutrient requirements with a supply of nitrogen, phosphorus and potassium to achieve the target harvest yield [3]. NM practices increase crop yields and incomes for farmers [4]. Additionally, NM has been proven to be able to increase rice

* Corresponding author : arifanshori@yahoo.com

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productivity on rainfed or dry land [5]. The use of NPK compound fertilizers only partially nutrient requirements. Nutrient deficiencies from NPK compound fertilizers can be met by applying single fertilizers [6]. Compound fertilizers are available locally with varying NPK ratios. Fertilizer dose are adjusted to achieve yield targets, and must be carefully considered. Yields reflect the response to each nutrient added [7]. Availability of single nitrogen fertilizers and NPK compound fertilizers can encourage farmers to improvise in fertilizer application based on frequency and timing. This study aimed to determine the NM based on differences in the frequency and timing of application in supporting plant growth and increasing rice productivity in dry land.

2 Materials and Methods

This research flowchart can be seen in Fig. 1. The research began with site observation which revealed low soil nutrient content and potentially affect on yield productivity. Based on this finding, NM treatment was designed and compared with the farmer's practice, focusing on differences in fertiliezer application time and frequency. The experimental plots were prepared following standard agronomic procedure to ensure uniform field conditions. Data were routinely collected during rice growing season and used for data analysis. Because the input management differed, plant response data are required to assess the impact of each treatment on plant perfomance. Additionally, the cost incurred by farmers was also calculated to evaluate economic feasibility, compare profitability and support scale-up and adoption of the NM strategy. This research ensure that the reccomendation practices not only agronomical effective but also practical and attractive for the farmersto adopt.

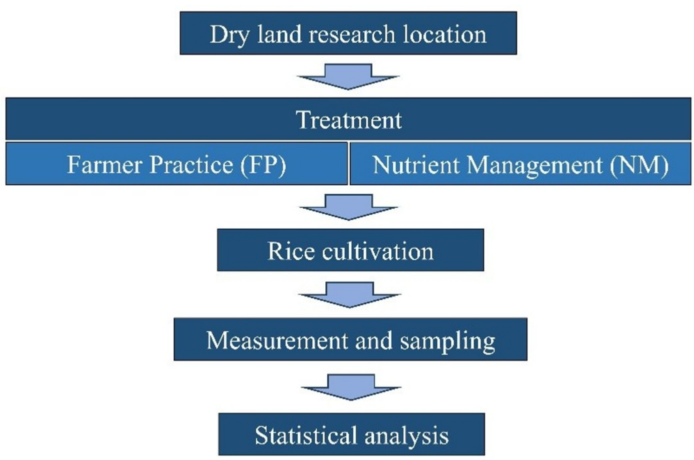

Fig. 1. Flowchart of the research as the visual representation of the entire structured research process

2.1 Location

The research was conducted from June to November 2021, during the dry season, at coordinates 7º55'60"N and 110º34'42"E, with an altitude of 206 meters above sea level, in the dry land area of Gunungkidul, D.I. Yogyakarta, Indonesia. Annual rainfall is 1,859 mm, with the highest rainfall period from October to April and the lowest from June to September. The soil is clay textured with pH ranging from 6 to 6.5. Research results of Al Viandari and Anshori [8], that soil has a low total organic matter content (1.12%), moderate total nitrogen

(0.21%), with a high cation exchange capacity (26.71 cmol(+) kg^{-1}), according to the criteria of Eviati and Sulaeman [9].

2.2 Treatment

Soil nutrient availability is often a limiting factor for rice plant growth in the dry land area, in addition to water availability. The treatments in this research involved fertilization according to farmer practice (FP) and introduction to NM, repeated 11 times. Fertilizer was applied according to the recommended dose, with FP applied at 5 and 22 days after transplanting (DAT) and NM applied at the 5, 22, and 35 DAT. Detail of treatment can be seen in the Table 1.

Table 1. Treatment of the FP and NM based on the variation in the frequancy and time

Treat ments	Types of fertilizers and nutrient content	Fertilization frequency and time			Dose of fertilizer	Total nutrients		
		5 DAT	22 DAT	35 DAT		N	P_2O_5	K_2O
		kg ha^{-1}			kg	kg		
FP	NPK 15-15-15	150	150	-	300	45	45	45
	N 46%	100	100	-	200	92	-	-
NM	NPK 15-15-15	300	-	-	300	45	45	45
	N 46%	-	100	100	200	92	-	-

2.3 Rice cultivation

The soil was plowed and mulched with a hand tractor. Inpari 42 rice seedlings, 18 days after sowing (DAS), were planted with 2-3 seedlings per hole, with a spacing of 20 x 20 cm. Weeds were controlled manually at 10, 20, 30, 40, and 50 DAT, or as needed. Rice was planted during the dry season, with mostly no rain. Irrigation was provided every 2 days, providing a flood depth of approximately 8 cm, until the plants reached 76 DAT. Harvesting took place when the rice was 96 DAT.

2.4 Measurement and sampling

Plant height and tiller number were observed three times, at 20 and 40 DAT, and at harvest. At harvest, tiling was performed to determine the weight of grain and straw. Organic carbon content in grain and straw was determined in the laboratory, which was then used to determine the weight of organic carbon in plant tissues. Harvest index was calculated based on the ratio of the weight of grain and straw from the harvest. Percentage of empty grain was calculated based on the ratio of the number of empty and filled grains.

2.5 Statistical Analysis

FP and NM data were analysed using a t-test at a 95% confidence level. Plant height, tiller number, dry grain productivity, dry straw productivity, carbon in grain, carbon in straw, and percentage of empty grain were displayed based on the cumulative frequency distributions. Regression and correlation analyses were used to determine the shape and relationship between yields of the grain and straw in FP and NM.

3 Results and Discussion

3.1 Growth of rice plant

Plant height was observed at 20, 40 DAT and at harvest, respectively for FP was 32.42 cm, 59.83 cm and 70.58 cm, for NM was 30.58 cm, 59.42 cm and 73.58 cm. Plant height was not significantly different (Fig. 2), there was no difference in plant height between FP and NM in dry land. Application of 141 kg ha^{-1} of nitrogen fertilizer was sufficient for rice plant [10]. Further, Astuti [11] reported that nitrogen fertilizer application of up to 200% of the recommended dose had no effect on plant height or growth rate of rice plants. Nitrogen is used as a reference in plant growth because it is involved in cell split and internode elongation, which play a role in increasing plant height [12].

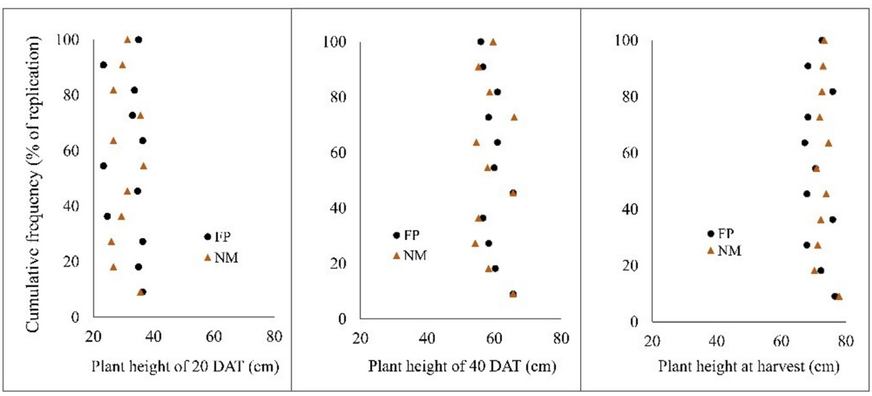

Fig. 2. Plant height at 20 DAT, 40 DAT and at harvest of the FP and NM in the dry land agriculture

The number of tillers at harvest differed significantly between FP and NM (Fig. 3), but not at 20 and 40 DAT. These results indicate that applying 46 kg ha^{-1} of nitrogen fertilizer at 35 DAT is still necessary for tiller formation in rice plants. Nitrogen stimulation at 35 DAT increases physiological processes and cellular activity, resulting in a higher number of tillers at harvest. Timing of nitrogen fertilization of rice plants is essential. In accordance with Rea et al. [13], nitrogen affects plant growth, related to physiological processes such as cell split and elongation, which then affects the number of tillers and panicle development.

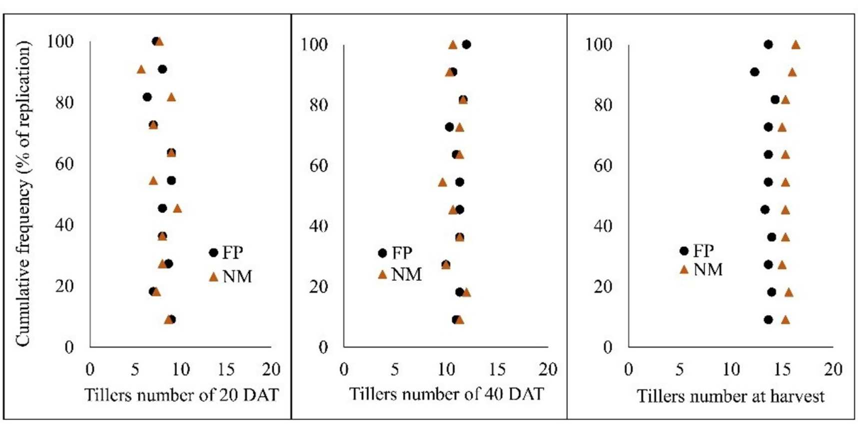

Fig. 3. Number of tillers at 20 DAT, 40 DAT and at harvest of FP and NM in the dry land agriculture

3.2 Productivity, carbon absorption and percentage of empty grain

The application of NM in dry land increased grain productivity by 1.16 times from the average yield of FP. The increase in grain productivity with NM was supported by fuller grain yields and a lower percentage of empty grains (Fig. 5). FP grain productivity ranged from 3.79 to 6.03 tons ha^{-1}, with an average value of 4.80 tons ha^{-1}. NM grain productivity was 4.09 to 6.75 tons ha^{-1}, with an average value of 5.26 tons ha^{-1} (Fig. 4). Fertilization with NPK 15-15-15 at the beginning of planting followed by two follow-up fertilizations of 46% N was able to increase rice productivity. Three fertilizations with NM reduced the initial N amount in 10 DAT, compared to two fertilizations with FP, although the total fertilizer dose remained the same. The timing of fertilization will significantly affect rice growth and yield, as has been revealed by Girsang et al. [14] in Indonesia, Buresh et al. [6] in Filipina and from India by Sharma et al. [15].

NM straw productivity was higher than FP in dry land. The application of NM in dry land increased straw productivity by 1.02 times from FP. NM straw productivity was 7.79-11.91 tons ha^{-1}, with an average of 10.11 tons ha^{-1}, higher than FP of 7.15-10.24 tons ha^{-1}, with an average of 8.91 tons ha^{-1} (Fig. 4). Application of NPK 15-15-15 fertilizer at the beginning of planting followed by two subsequent N 46% fertilizations increased straw productivity. NM contributed more straw biomass than FP.

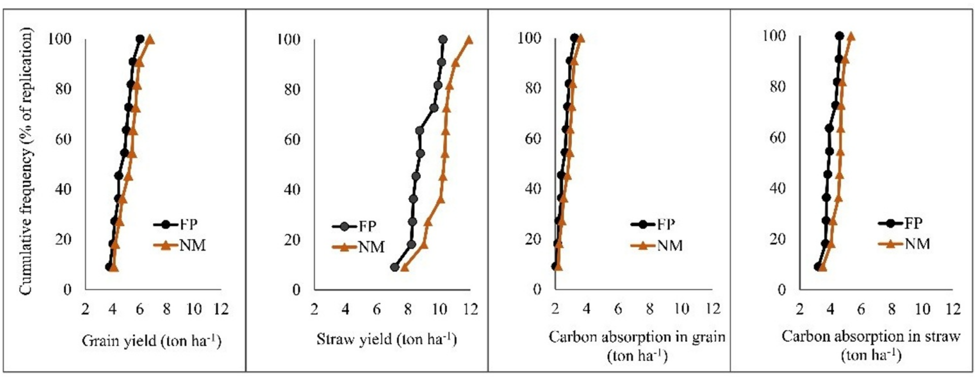

Fig. 4. Dry weight of the grain and straw and carbon absorption in the grain and straw of FP and NM

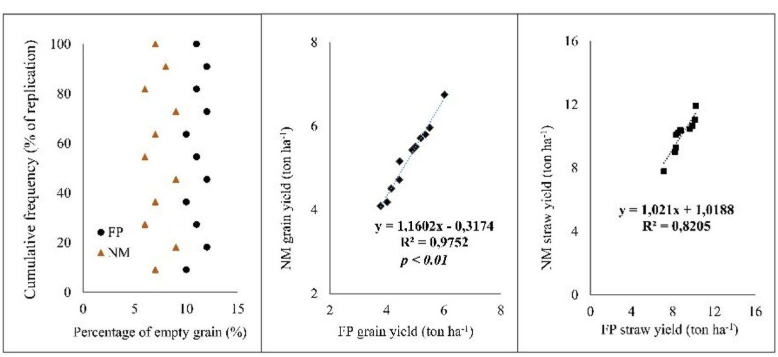

Fig. 5. Percentage of empty grain and correlation between the grain and straw yield of the FP and NM

Carbon absorption in grain of NM is higher than FP. Carbon absorption in grain of NM is 2.20-3.62 tons ha^{-1}, with an average of 2.82 tons ha^{-1}, higher than that of FP which is 2.03-3.23 tons ha^{-1}, with an average of 2.58 tons ha^{-1}. Carbon absorption in straw of NM is 3.49-

5.34 tons ha^{-1}, with an average of 4.54 tons ha^{-1}, also higher than FP which is 3.21-4.59 tons ha^{-1}, with an average of 4.00 tons ha^{-1} (Fig. 4). The application of NM has a positive impact on the absorption of organic carbon from the air, reducing greenhouse gases, mitigating climate change and improving environmental quality. According to Wihardjaka et al. [16], as a contributor to greenhouse gases, agricultural practices must take this condition.

The application of NM resulted in a lower percentage of empty grain. With NM, the percentage of empty grain was 7-9%, averaging 7.36%, lower than with FP, which was 10-12%, with an average of 11.09%. NM had a positive effect on reducing empty grain, resulting in higher quality grain. This is in line with the findings Hamdani and Haryati [17] that empty grain is closely related to soil nutrient conditions. Low soil nutrients with high levels of competition will encourage the formation of empty grain.

3.3 Cost of nutrient management

The NM practice changes farmers' habits regarding the frequency and timing of fertilizer applications. NM fertilization is carried out three-times with reduced initial nitrogen application compared to the FP two-time application, even with the same dose of nitrogen, phosphorus, and potassium. This practice increases the number of fertilizer application events, but the associated costs are relatively small and are usually met by family labor. On small-scale or limited land, NM can be considered as having minimal additional fertilizer application costs.

NM practices can increase dry land rice productivity but require additional labor for fertilizer application. Other implications may arise, including weed growth or pest and disease attacks due to shifts in fertilizer application timing. Environmental conditions influence the NM effectiveness. Therefore, implementation must align with soil and water conditions, the crop environment and farmer capacity. Generally, the adoption of NM at the farmer level is user friendly and it provides beneficial impacts for nutrient use efficiency, yield productivity, and environmental sustainability. Therefore, the application of NM can be a suitable strategy to support dry land agricultural system.

4 Conclusion

Overall, the NM treatment enhanced crop performance and nutrient use efficiency compared with the farmer’s practice. These improvements indicate that NM practice provides a more effective nutrient supply under dry land conditions and is feasible for adoption in farmer level. These findings demonstrate that NM is a promising approach to improve productivity and support environmental sustainability of dry land agricultural system.

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