Indonesian Journal of Agronomy

ISSN 2085-2916 | e-ISSN 2337-3652
Indonesian J. Agron., *51*(2), 190-201, August 2023
DOI: https://dx.doi.org/10.24831/ija.v51i2.46091

Research Article

Effect of nitrogen doses on growth and yield of several varieties of tungro-infected rice plant

Achmad Gunawan [1,3], Purwono [2,*], Iskandar Lubis [2], and I Nyoman Widiarta [3]

[1] Agronomy and Horticulture Study Program, Graduate School of IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA
[2] Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, INDONESIA
[3] Research Center for Food Crops, National Research, and Innovation Agency, Cibinong Bogor 16915, INDONESIA
* Corresponding author (✉ puripb@gmail.com)

ABSTRACT

Tungro is still a problem in efforts to increase rice production, it can disrupt the stability of rice production if conditions worsen. Plant fertilizer application is an integral part of plant cultivation, especially nitrogen fertilizer. Improper utilization of fertilizers can harm agriculture by increasing plant vulnerability to pests and diseases. Thus, the purpose of the study was to examine the effects of various doses of nitrogen on the agronomic performance of rice plants, as well as their susceptibility to tungro. The research was conducted at the Greenhouse, Sukamandi, and the Muara Experimental Field, Center for Rice Research, Bogor. The experiments, both in the greenhouse and field, used a split-plot randomized complete block design with three replications. The main plots were variety, while the subplots were nitrogen dosage. The results showed that Inpari 36 Lanrang was better than Ciherang and IR64 in terms of plant height, number of tillers, empty grain per clump, leaf greenness, and yield/pot in the greenhouse. While from the field experiment, varieties have different flowering times, plant heights, number of filled grains, number of empty grains, 1,000-grain weight, net assimilation rate, yield/plot, and tungro incidence. The use of nitrogen fertilizer affected flowering time in the greenhouse and affected productive tillers, yield per plot in the field, and the greenness of the leaves of healthy plants. The optimum dose is 167.5 kg ha^{-1} nitrogen. As a result, it is recommended that controlling tungro disease should involve the integration of fertilizer application that is balanced with the use of resistant varieties.

Keywords: *agronomic performance, nitrogen rates, plant diseases, resistant varieties, tungro infection*

Edited by:
Maya Melati

Received:
3 March 2023
Accepted:
6 July 2023
Published online:
7 August 2023

Citation:
Gunawan, A., Purwono, Lubis, I., & Widiarta, I. N. (2023). Effect of nitrogen doses on growth and yield of several varieties of tungro-infected rice plant. *Indonesian Journal of Agronomy, 51*(2), 190-201

INTRODUCTION

Rice tungro disease (RTD) is a major disease caused by viruses and causes a reduction in rice production. These viruses are transmitted through *Nephotettix virescens* or commonly known as the Green Leafhopper (GLH). If rice plants are affected by tungro disease, it can lead to a decrease in yield and may even fail the entire crop. RTD is caused by the interaction between the Rice Tungro Spherical Virus (RTSV) and the Rice Tungro Bacilliform Virus (Macovei et al., 2018; Widiarta, 2014). Widiarta (2016) reported the disease has spread widely in 23 provinces in Indonesia, covering 142 districts, especially endemic areas in Java and Bali, which are centers of rice production. Tungro disease endemic areas in Indonesia are Bali (Denpasar), South Kalimantan (Tanah Laut), South

Sulawesi (Lanrang), West Java (Subang and Bogor), Central Java (Solo), East Java (Jember), and West Nusa Tenggara (Mataram) (Suprihanto et al., 2013). According to Ditlin (2018) data, tungro disease is currently present in nearly all regions of Indonesia. It poses a major limiting factor toward sustainable agricultural production systems worldwide, especially in the tropics and subtropics. To manage plant diseases, farmers often apply agrochemicals over their recommended dose and have raised serious concerns about environmental quality and pesticide resistance (Kaur, 2013).

Fertilizer plays an important role in efforts to increase agricultural yields, its contribution is up to 24% of crop production (Zaini, 2012). The role of fertilizer application, especially nitrogen, is very important for plant growth. Sharma (2020) reports that nitrogen is considered the most important factor for the growth and development of plants, it is the building block for plant protoplasm and the chlorophyll molecule component for the photosynthesis process. According to Patti et al. (2013), nitrogen fertilizer's responsible for vegetative growth, increasing the number of tillers, increasing the number of grains/clumps, and increasing the size of rice grains. Referred to Agrios (2005), nitrogen abundance results in fresh plant growth, long vegetative periods, and delayed plant senescence These effects make plants more susceptible to pathogens.

The susceptibility of plants to pathogenic diseases can be influenced by their nutritional status. To achieve maximum crop production, it is necessary to use nutrients in a manner that not only meets the production goals for a given variety but also considers their impact on the susceptibility of plants to pest organisms. For rice production, balanced fertilization is an essential practice for both reducing the incidence of tungro disease in the field and improving efficiency. The objective of the study was to examine the effects of various doses of nitrogen fertilizer rates on the agronomic performance of rice plants, as well as their susceptibility to tungro.

MATERIALS AND METHODS

The experiments were conducted at Greenhouse, Sukamandi, Center for Rice Research, and Muara Experiment Station, Bogor for field research from January to June 2022. The green leafhopper and inoculum source for the transmission test from the West Java field was maintained in screen cages.

Field experiment

The experiment used a split-plot randomized complete block design. Variety was the main plot and N fertilizer dose was the subplot. The main plots were Ciherang, IR64, and Inpari 36 Lanrang. The subplots were nitrogen fertilizer rates derived from a combination of compound fertilizer (Phonska with ratio Nitrogen Phospor and Kalium 15:15:15) and urea consisting of 30 kg, 145 kg, 191 kg, and 260 kg nitrogen ha^{-1}. All varieties were initially sown in the greenhouse nursery for 20 days, and transplanted with a spacing of 20 cm x 20 cm with 2 plants per hole. The total experimental plots were 36 experimental units, each measuring 2.5 m x 2.5 m.

Separate sub-irrigation channels were installed around each plot and connected to the main channel for irrigation and drainage. This measure aimed to prevent nutrient leakage between adjacent fields or within plots within fields. Non-target pest control was implemented as needed, following the principles of integrated pest management.

The application of fertilizer (urea) was done twice. Initially, 50% of the nitrogen dose was applied as a base fertilizer within 0-7 days after transplanting, followed by a second application at 45 days after transplanting. Phonska compound fertilizer was applied at first stage altogether with urea. Light hand weeding was conducted at the start of each growing season. Prior to transplanting, susceptible plants were planted around the experimental plots to attract natural inoculum, promoting mass transmission of the tungro virus in the nursery by infected insects. Observations of tungro incidence were made at 2, 4, 6, and 8 weeks after planting (WAP) on all clumps following SES IRRI (2013) with the criteria. Scale 1: without symptoms; Scale 3: 1-10% reduced in height, yellow to yellow-orange leaf discoloration that is not obvious; Scale 5: 11-30% reduced in height, yellow to yellow-orange leaf discoloration that is not obvious; Scale 7: 31-50% reduced in height, with pronounced yellow to yellow-orange leaf discoloration; Scale 9: more than 50% reduced in height, with pronounced yellow to yellow-orange leaf discoloration.

The plant characteristics observed were the number of productive tillers, plant height, 50% flowering age, number of sterile grains and filled grains per hill, 1,000-grain weight, and grain weight per plot.

Greenhouse experiment

The greenhouse study used the same treatment as the field study. The study used a split-plot randomized complete block design with three replications using the pot method, with a total of 36 experimental pots. The main plots were the varieties of Ciherang, IR 64, and Inpari 36 Lanrang, while the subplots were nitrogen fertilization dose levels at 30 kg, 145 kg, 191 kg, and 260 kg per ha. The seedbed was made using soil media and moistened with water until it reached field capacity. The plants were maintained until they were 14 days old. Each plant was sown separately. The potted plant experiment in the greenhouse used the same planting media as in the field. The dose of fertilizer applied was adjusted to the plants per experimental pot i.e. 1 g, 2.25 g, 2.75 g, and 3.50 g per pot. The 14-day-old seedlings of each variety were inoculated with virulent GLH that had been fed with viruses from plants that had been reared in mesh cages. To ensure proper inoculation, at least 3-4 virulent GLH per test plant were introduced into the cages, and then a 24-hour feeding period was given to healthy plants following the method of Rosida et al. (2020). Data were collected on the seedling infection (symptom), plant height (cm), flowering age, number of productive tillers, plant height, 100-grain weight, number of filled grains and number of sterile grains per clump, and plant weight per pot.

Observation of tungro symptoms in transmission test studies was carried out at 2 and 4 WAI (weeks after inoculation) with criteria referred to SES IRRI (2013) same as field observation in tungro incidence.

Data Analysis. The analysis of variance (ANOVA) which expressed the main and interaction effects was performed by Statistical Analysis System (SAS version 9.1) for all quantitative traits. The Duncan Multiple Range Test (DMRT) was performed for mean comparison when varietal differences were found significant at $p<0.05$ level of probability. The polynomial regression tests were conducted to determine if the results of the further test indicate a quadratic response, then proceed to find the optimum point of fertilizer from the treatment.

RESULTS AND DISCUSSION

Growth and yield characters

Generally, infected rice plants show stunted and chlorotic leaves. These symptoms were observed in the greenhouse and field experiments that showed individual differences between infected plants and non-infected plants.

The observations on plant vegetative character in the greenhouse showed significant differences among varieties in terms of plant height and the number of tillers. Similarly, in the field, the varieties displayed variations in plant height and flowering age. The application of nitrogen dose influenced the flowering age of plants in the greenhouse as well as the number of tillers in the field. (Table 1). In the greenhouse, all varieties show longer flowering times, especially varieties Ciherang and IR64, although they are not significantly different. Observations in the greenhouse revealed that tungro-infected plants failed to produce grains despite flowering. Other plant observations indicated plant mortality. Bunawan et al. (2014) reported that resistant rice varieties infected with one of the tungro viruses exhibit a delayed flowering period, whereas susceptible plants do not produce flowers at all. When grown in a greenhouse, rice plants infected with tungro viruses, particularly those that are susceptible, either failed to produce any flowers or produced very few empty flowers.

The number of tillers of the Inpari 36 Lanrang variety is more than the Ciherang and IR64 in the greenhouse. Similarly, plant heights showed a very significant difference between varieties. The plant height of the Inpari 36 Lanrang variety (60.16 cm) was higher than that of the Ciherang and IR 64 varieties, which reached 38.33 cm and 34.83 cm. These results indicate that the growth of Ciherang and IR 64 varieties is stunted.

Rice plant tillers come from axial buds on the stem book and replace the leaves and grow and develop (Makarim & Suhartatik, 2009). It is estimated that the tungro's viruses suppress the growth of shoots in the process of development so that plants are unable to form new shoots as indicated by the low number of tillers in infected plants. The results showed that the Inpari 36 Lanrang variety showed a resistant reaction to the virus, which was indicated by a better number of tillers than other varieties under tungro-suppressed conditions (Table 1). The number of tillers in the greenhouse experiment had similar results to those of Ladja et al. (2011) that showed the tiller number of susceptible varieties was lower than resistant varieties. However, different results were observed in the field, this is related to random population sampling in field research so that there was no difference between varieties, while differences were shown by the effect of fertilizer dose on the number of productive tillers.

With nitrogen fertilizer, plants had higher tiller numbers compared to those without nitrogen in the field. The highest tiller number was 20.37 and obtained from the maximum fertilization treatment (Table 4). The increase in the tiller number of rice plants is strongly influenced by the provision of nitrogen, which can contribute nutrients and fulfill the nutrient demands of rice plants (Abu et al., 2017).

From the field experiment, the flowering age of the IR64 variety (75.83 days) was different from the Ciherang variety (82.58 days) and different from the Inpari 36 Lanrang variety (87.75 days). This is caused by the physiological age of the three plants being different from each other. Similarly, in the variable of plant height, Inpari 36 Lanrang was higher than Ciherang and IR 64 varieties. In the observation of plant height and flowering time in the field, the difference in plant height is more influenced by plant physiological factors. According to Alavan et al. (2015), different varieties carry different genetic, physiological, and morphological traits and will affect the diversity of plant appearance.

In the field research, the impact of the tungro virus on flowering age was not clearly observed, unlike in the greenhouse research conducted with specific plant samples inoculated with tungro. In the field research, the majority of the plant population exhibited flowering. According to Ladja et al. (2016), specific interactions between virus strains and rice varieties cause variations in disease incidence and plant height reduction rates.

The nitrogen fertilizer application has a significant effect on the flowering time of rice plants in the greenhouse. Fertilization with less addition of nitrogen/minimal (N0) resulted in a slower flowering time, while the maximum nitrogen dose resulted in early flowering. According to Agrios (2005), the abundance of nitrogen in plants causing the length of the vegetative period also causes a delay in flowering. The different results obtained are thought to be due to the influence of the viruses which cause a generally longer plant life due to the inhibition of the plant growth process. It is also because urea-minimized crops experience growth inhibition due to nitrogen deficiency. According to Vijayalakshmi et al. (2013), nitrogen plays a role in important metabolism in cells, genetically and structurally. Infected plants with the virus show disrupted plant growth due to a lack of nitrogen compared to those provided with sufficient nitrogen fertilizer.

Table 1. Effect of varieties and nitrogen doses on vegetative variables of rice plants in the greenhouse and field.

Treatment	Greenhouse			Field		
	Flowering age (days)	Plant height (cm)	Productive tillers	Flowering age (days)	Plant height (cm)	Productive tillers
Varieties						
Ciherang	100.7	38.3b**	6.7b**	82.6b**	95.9b**	16.0
IR 64	109.5	34.8b	5.8b	75.8c	73.9c	18.3
Inpari 36 Lanrang	99.4	60.2a	17.4a	87.9a	107.2a	19.1
Nitrogen doses (kg ha^{-1})						
30	81.6a*	50.1	8.7	81.3	87.5	13.0b*
145	68.3ab	40.3	10.4	81.7	95.4	18.4a
191	77.8a	47.6	9.6	82.6	93.3	19.4a
260	60.0b	39.8	11.2	82.7	93.1	20.4a
V x N	ns	ns	ns	ns	ns	ns

Note: [a] numbers in the column followed by the same letter are not significantly different according to Duncan's test at the α = 5% level.

Table 2. Effect of varieties and nitrogen doses generative variables of rice plants in the greenhouse and field.

Treatment	Greenhouse				Field			
	Number of filled grains/ panicles	Number of empty grains/ panicles	100 grains (g)	Yield/ pot (g)	Number of filled grains/ panicles	Number of empty grains/ panicles	1,000 grains (g)	Yield/ plot (g)
Varieties								
Ciherang	25.6	23.2b*	2.2	14.6b**	49.7b**	65.8a**	25.0b*	839b**
IR 64	20.8	61.4a	2.2	8.8b	38.5b	42.5b	23.8b	400c
Inpari 36 Lanrang	30.1	37.0ab	2.0	23.9a	74.0a	69.7a	27.1a	1,410a
Nitrogen doses (kg ha^{-1})								
30	26.8	39.8	2.1	13.8	46.0	54.3	25.0	509b*
145	19.5	49.6	2.2	17.3	62.1	60.9	25.6	1,064a
191	32.6	22.0	2.1	13.4	51.5	58.6	25.0	952ab
260	25.5	50.3	2.2	18.6	56.7	63.5	25.6	1,007a
Response pattern	ns	ns	ns	ns	ns	ns	ns	Q*
V x N	ns	ns	ns	ns	ns	ns	ns	ns

Note: [a] numbers in the column followed by the same letter are not significantly different according to Duncan's test at the α = 5% level. Q = Quadratic pattern

The results of the analysis of variance for generative characters in the greenhouse showed that varieties had significant differences in the number of empty grains and yield per pot but did not differ in the variables of filled grains, and 100-grain weight. From the field experiment, there were differences in the number of filled and empty grains, the weight of 1,000 grains, and yield per plot between varietal treatments. While the nitrogen doses t did not affect the generative variables of plants both in the greenhouse and field. There was no interaction between treatments on all generative observation variables in the two experimental locations (Table 2).

In the greenhouse, the IR 64 and Inpari 36 Lanrang varieties displayed the highest number of empty grains, while the Ciherang variety was different in this regard. This same trend was also observed in field crops. The presence of tungro disease in rice plants is indicated by a high number of empty grains, which means that the grains are formed but not filled. The Inpari 36 Lanrang variety had the highest yield per pot in both research locations. Widiarta et al. (2014) reported that tungro disease causes a decrease in the number of tillers on rice plants and an increase in the percentage of empty grains. According to Khatun et al. (2018), the characteristic features of tungro include sterile tillers and partially filled grains on rice plants.

The high number of sterile grains is due to the inability of plants to produce assimilate into sinks due to the disruption of leaf function as an assimilate producer. The number of filled grains of the Inpari 36 Lanrang variety is higher than the number of filled grains of the Ciherang and IR 64 varieties, as well as the observation of the number of empty grains, Inpari 36 Lanrang and Ciherang varieties show the highest value compared to IR 64 varieties. The difference in the number of filled grains/panicles of rice plants in this study may be influenced by the total yield of the three varieties, where the Inpari 36 Lanrang variety produces the highest production followed by the Ciherang and IR 64 varieties.

The greenhouse experiment showed that rice yield per plot was low because of tungro infection and the plant did not grow well. Some plants died, especially Ciherang and IR 64 varieties. This can be observed from the percentage of empty grain, which is high in Ciherang and IR 64 varieties, while the highest filled grain is obtained in the Inpari 36 Lanrang variety. The 1,000-grain weight is significantly higher in the Inpari 36 Lanrang variety compared to the Ciherang and IR 64 varieties, this shows that the grain size of Inpari 36 Lanrang is larger than the other varieties in this test.

In both greenhouse and field research, the Inpari 36 Lanrang variety had the highest yield compared to the Ciherang and IR 64 varieties. This difference can be attributed to variations in yield components among the different test varieties. As Abdullah et al. (2008) noted, rice production is determined by several key yield components, including the number of panicles per hill, the number of grains per panicle, the percentage of filled grains, and the weight of the grains.

Nitrogen doses had a significant effect on yields in the field. The highest grain yield was obtained in the recommendation treatment, which was 145 kg ha^{-1} nitrogen, while the lowest yield was obtained in the treatment with less nitrogen addition.

From this observation, the Inpari 36 Lanrang variety showed higher yields, which were attributed to its resistance to tungro viruses, as indicated by better performance in supporting variables such as the number of tillers, 1,000-grain weight, and the number of empty grains compared to other test varieties. The presence of the tungro virus in plants hinders the optimal development of rice plants, and the type of variety plays a crucial role in determining the yield of rice plants. Therefore, to control tungro disease in the field, resistant varieties, combined with recommended fertilization, are more effective (Muliadi et al., 2015).

Physiological components of plant growth

The results of the SPAD leaf chlorophyll meter reading on sample plants in the greenhouse showed that the varieties had significantly different levels of the greenness of the leaves, but they are not different among the doses of fertilization. There is no interaction between the two treatments on the variable level of leaf chlorophyll. Inpari 36 variety has the highest leaf greenness level (34.49) compared to Ciherang (27.89) and IR 64 (20.04) (Tabel 3).

Although there was no significant effect between doses, the highest leaf chlorophyll level was at the maximum dose (260 kg ha^{-1} nitrogen) at 29.19 and the lowest with less addition of nitrogen (30 kg ha^{-1} nitrogen) at 26.17.

Different results were obtained in the field on leaf green level variables. Fertilizer application gives different results on the variable level of the greenness of leaves on normal plants. The dose with less nitrogen (30 kg ha^{-1}) provided the lowest value (44.6) compared to other treatments, the highest value was obtained in the maximum dose (nitrogen 260 kg ha^{-1}) of 60.34. The availability of sufficient nitrogen in the plant will support cell formation in plant organs and can optimize the process of photosynthesis to provide sufficient dry matter production for height increase and multiplication of the number of tillers.

Table 3. Effect of varieties and nitrogen doses on physiology character of rice plants in the greenhouse and field.

Treatment	Greenhouse	Field			
	Leaf green level	Leaf green level of infected plants	Leaf green level of normal plants	Net assimilation rate (g cm^{-2} $days^{-1}$)	Plant growth rate (g m^{-2} $days^{-1}$)
Varieties					
Ciherang	27.9b**	13.7	57.25	0.3b*	0.1
IR 64	20.0c	13.9	52.3	0.7ab	0.1
Inpari 36 Lanrang	34.5a	16.2	54.2	1.4a	0.2
Nitrogen doses (kg ha^{-1})					
30	26.2	13.5	44.6b*	0.9	0.2
145	27.9	17.3	56.8a	0.6	0.1
191	26.6	13.6	56.3a	0.9	0.1
260	29.2	13.9	60.3a	0.7	0.1
V x N	ns	ns	ns	ns	ns

Note: [a] numbers in the column followed by the same letter are not significantly different according to Duncan's test at the α = 5% level.

In the field, the net assimilation rate (NAR) varied among varieties, while the plant growth rate (PGR) did not show any significant differences among the varieties. Additionally, the nitrogen doses did not have an impact on either of the observed variables. Furthermore, there was no interaction observed between varieties and fertilizer doses concerning these variables, as indicated in Table 3. According to Haque and Haque (2016), the net assimilation rate is not only influenced by nitrogen fertilization but also by cultivars. It is estimated that the presence of tungro viruses affects plant growth, particularly in susceptible plants. The Inpari 36 Lanrang variety showed better plant characteristics supported by the results of vegetative and generative observations, as evidenced by the highest NAR value obtained in this variety compared to other test varieties. The NAR value in this study may be due to virus infection on the test plants, which is also reflected in the low PGR value. The tungro virus damages the leaf, resulting in reduced assimilate production after the plant enters the generative phase, as is well known for plants infested with the tungro virus in the vegetative phase.

Photosynthesis in plants is vital for producing the carbohydrates (photosynthate) they require under optimal conditions. However, pests or diseases can impede or halt photosynthesis, resulting in a decline in rice production. Tungro's virus disrupts Photosystem II in the leaves of plants, leading to reduced photosynthesis (Khumar & Dasgupta, 2020). Additionally, tungro-infected plants exhibit a significant decrease in chlorophyll, including chlorophyll a and b, as well as carotenoids, FE, and Zn levels (Srilatha et al., 2019). Similarly, BPH infestation can decrease the rate of photosynthesis, as well as chlorophyll content and total plant dry weight, compared to the control (Nayak et al., 2019).

Yellowing symptoms are caused by viruses through interference with the photosynthetic machinery and Fe/Zn homeostasis, which is a strategy adopted by the virus to facilitate its transmission by green leafhoppers. Vector orientation through visual and olfactory cues. Yellow symptoms caused by tungro disease may be required by the virus to facilitate its transmission by attracting more vector insects. Various studies have reported that virus infection can alter the olfactory and visual cues of infected plants and subsequently bring about changes in the ecological interactions between plants and insects (Mauck et al., 2016; Shapiro et al., 2012).

Tungro disease incidence

Fertilization did not have a significant effect on the incidence of tungro virus in either the field or greenhouse, whereas the varieties had significant differences in the incidence of the disease in both locations. There was no interaction between varieties and fertilizer doses on tungro incidence in the field (Table 4). Tungro symptoms began to appear in the second observation, four weeks after planting, and peaked at six and eight weeks after planting. Mass inoculation in the seedbeds allowed tungro symptoms to appear in the early observations, but this was not observed in the field due to difficulties in detecting symptomatic plants. However, the tungro virus was thought to have spread on the plantation, as indicated by the high average number of symptoms in later observations. The Ciherang variety showed the worst symptoms, followed by the IR 64 and Inpari 36 Lanrang varieties with lower levels of infestation. Similar results were also obtained in the greenhouse observations, where the Inpari 36 Lanrang variety showed a low score two weeks after inoculation, in contrast to the Ciherang and IR64 varieties. The same trend was observed in the four weeks after inoculation, with the highest severity of tungro symptoms found in the Ciherang and IR64 varieties. According to Gunawan et al. (2022), the incidence of tungro is related to both environmental conditions and the genetic characteristics of the variety.

The experiment conducted by Suprihanto et al. (2016) using brown planthopper (BPH) insects showed that resistant rice varieties are less preferred by BPH for perching and breeding compared to susceptible varieties. Based on all observations of symptom severity both in the field and in the greenhouse, the Inpari 36 Lanrang variety showed better performance than other varieties, exhibiting fewer tungro symptoms. This variety is known to be resistant to tungro disease (Sastro et al., 2021). The IR 64 variety is known as an insect vector-resistant variety and is classified as T3 containing the glh5 resistance gene (Rosida, et al., 2020). However, observations in both field and greenhouse artificial inoculation showed that the tungro symptoms in the IR 64 variety were almost the same as those in susceptible varieties. Therefore, it can be concluded that the IR 64 variety has resistance to the green leafhopper, but not to the tungro virus.

Nutrients could affect the disease tolerance or resistance of plants to pathogens (Gupta et al., 2017). N supply can influence plant-pathogen interactions. N supply can affect plant-pathogen interactions with a variety of mechanisms including physical defense mechanism, biochemical and enzymatic defense, and molecular defense (Sharma, 2020).

There is no clear underlying model or mechanism to investigate the relationship between nitrogen uptake, metabolism, and disease infection process. Various studies have reported the impact of nitrogen fertilizer on crop disease incidence. For example, in the case of striped rust disease caused by *Puccinia striiformis* f. sp. Tritici on wheat, the severity of the infection decreased with nitrogen supply (Devadas et al., 2014). Conversely, an increase in the rate of nitrogen resulted in increased severity of sheath blight in rice caused by *Rhizoctonia solani*, as influenced by canopy structure (Wu et al., 2014). However, for foliar disease on barley caused by *Rhynchosporium secalis*, an increase in nitrogen rate did not affect disease incidence (Turkington et al., 2012). There is limited research on the effect of nitrogen supply on tungro disease incidence. In this experiment, increased nitrogen fertilization did not have a significant effect on tungro disease incidence because resistant varieties had a more dominant effect on severity both in the field and in the greenhouse. N supply can influence plant-pathogen interactions. N supply can affect plant-pathogen interactions with a variety of mechanisms including physical defense mechanism, biochemical and enzymatic defense, and molecular defense (Sharma, 2020). According to Bhadhuri (2014), there are two types of primary resistance mechanisms that mineral nutrition can affect either by the formation of mechanical barriers, primarily through the development of thicker cell walls, or the synthesis of natural defense compounds, such as phytoalexins, antioxidants, and flavonoids, that protect against pathogens.

Table 4. Effect of varieties and nitrogen doses on tungro incidence in the greenhouse and field.

Treatment	Greenhouse		Field			
	2 WAI	4 WAI	2 WAP	4 WAP	6 WAP	8 WAP
Varieties						
Ciherang	3.8a**	5.2a**	-	0.2b*	5.4b**	7.2b**
IR 64	3.5a	5.0a	-	1.3a	16.9a	17.8a
Inpari 36 Lanrang	1.0b	1.7b	-	0.4b	1.6b	0.3b
Nitrogen doses (kg ha^{-1})						
30	3.0	4.6	-	0.2	5.2	8.1
145	2.8	3.7	-	0.4	7.9	9.4
191	3.0	3.7	-	0.4	7.6	7.0
260	2.3	3.9	-	1.1	11.2	9.1
V x N	ns	ns	-	ns	ns	ns

Note: [a] numbers in the column followed by the same letter are not significantly different according to Duncan's test at the α = 5% level.

Optimum dose of nitrogen

Determination of the optimum nitrogen fertilizer treatment was carried out in this study due to analysis of variance resulting in significance in yield observations. The maximum value was made based on the yield variable in the field which resulted in a quadratic response pattern (Table 2). The response of the variable was converted into a relative yield which is the value of the variable from the treatment divided by the highest variable value obtained from each experiment and then a regression equation was made. The regression equation is used to determine the optimum point of fertilization (Arrasyid et al., 2020). The regression analysis equation is obtained according to Figure 1.

The field observations on yield variables resulted in a coefficient of determination of r^2= 0.1977, indicating that nitrogen fertilizer application contributes to 19.77% of the observed yield variation, while the remaining percentage is influenced by other factors. The recommended optimal dosage of nitrogen fertilization is 167.5 kg ha^{-1}.

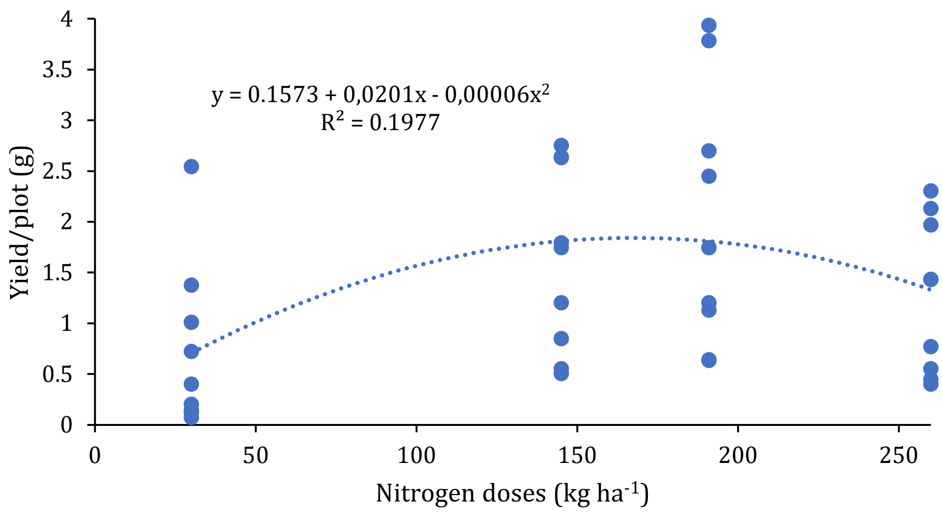

Figure 1. Relationship curve between nitrogen dose and rice yield.

CONCLUSIONS

The results showed that Inpari 36 Lanrang was better than Ciherang and IR64 based on plant growth and yield parameters including plant height, tiller numbers, empty grain per clump, leaf greenness level, and yield per pot in the greenhouse. In the field, the same treatments also had a significant impact on flowering age, plant height, number of filled grains, number of empty grains, 1,000-grain weight, assimilation rate, yield, and tungro incidence. The addition of nitrogen increases the number of productive tillers, yield per plot, and leaf greenness of normal plants. Therefore, it is recommended to control tungro disease in the field by using resistant varieties and fertilizing according to the recommended guidelines, with doses optimum in 167.5 kg ha^{-1} nitrogen. Additionally, the results suggested that the severity of tungro was mainly influenced by using varieties because they have different vulnerabilities, both in the field and in the greenhouse.

REFERENCES

Abdullah, B., & Tjokrowidjojo, S. (2008). The development and prospects for assembling a new type of rice in Indonesia. (In Indonesian.). *Jurnal Litbang Pertanian*, *27*(9), 1–9.

Abu, R. L. A., Basri, Z., & Made, U. (2017). Response of growth and yield of rice (*Oryza sativa* L.) plant on the need for nitrogen using leaf color chart. (In Indonesian.). *Jurnal Agroland*, *24*(2), 119–127.

Agrios, G. N. (2005). Plant Pathology 2.0. In *Molecular Plant Pathology* (Fifth Edition). (pp 922). Elsevier Academic Press. https://doi.org/10.1111/mpp.12135

Alavan, A., Hayati, R., & Hayati, E. (2015). Effect of fertilization on growth of upland rice varieties (*Oryza sativa* L.). (In Indonesian.). *J. Floratek*, *10*, 61–68. http://www.e-repository.unsyiah.ac.id/floratek/article/view/2331

Arrasyid, B., Lubis, I., Suwarto, & Purnamawati, H. (2020). Determination of Optimum Dosage of N, P, and K for mayas upland rice landrace in Kalimantan, (In Indonesian.). *Jurnal Agronomi Indonesia*, *48*(1), 8–14. https://doi.org/10.24831/jai.v48i1.29213

Bhaduri, D., Rakshit, R., & Chakraborty, K. (2014). Primary and secondary nutrients-a boon to defense system against plant diseases. *International Journal of Bio-Resource and Stress Management*, *5*(3), 461. https://doi.org/10.5958/0976-4038.2014.00597.1

Bunawan, H., Dusik, L., Bunawan, S. N., & Amin, N. M. (2014). Rice tungro disease: From identification to disease control. *World Applied Sciences Journal*, *31*(6), 1221–1226. https://doi.org/10.5829/idosi.wasj.2014.31.06.610

Devadas, R., Simpfendorfer, S., Backhouse, D., & Lamb, D. W. (2014). Effect of stripe rust on the yield response of wheat to nitrogen. *Crop Journal*, *2*(4), 201–206. https://doi.org/10.1016/j.cj.2014.05.002

Direktorat Perlindungan Tanaman [DITLIN]. (2018). Tungro's Infested Area on Rice Plants 2012 – 201*7. Data and Information on Food Crop Protection. (In Indonesian.).* Ministry of Agriculture.

Gunawan, A., Rosida, N., Khaerana, Muazam, A., & Mugiasih, A. (2022). Evaluation of tungro-resistant lines based on tungro disease severity and agronomic characteristics. *Journal of Tropical Plant Pests and Diseases*, *22*(2). https://doi.org/10.23960/jhptt.222134-143

Gupta, N., Debnath, S., Sharma, S., Sharma, P., & Purohit, J. (2017). Role of nutrients in controlling the plant diseases in sustainable agriculture. In *Agriculturally Important Microbes for Sustainable Agriculture* (Vol. 2, pp. 217–262). Springer Singapore. https://doi.org/10.1007/978-981-10-5343-6_8

Haque, M. A., & Haque, M. M. (2016). Growth, yield and nitrogen use efficiency of new rice variety under variable nitrogen rates. *American Journal of Plant Sciences*, *07*(03), 612–622. https://doi.org/10.4236/ajps.2016.73054

International Rice Research Institut [IRRI]. (2013). *Standard Evaluation System for Rice (SES) (*5th edition). International Rice Research Institute. Philipine.

Kaur, G. (2013). Sustainable development in agriculture and green farming in India. *OIDA International Journal of Sustainable Development*, *06*(12), 59–64.

Khatun, M., Latif, M., Rahman, M., Hossain, M., Ansari, T., Nessa, B., Khan, M., Ali, M., & Hanafi, M. (2018). Recovering ability of upland and rainfed lowland rice varieties against rice tungro disease. *Bangladesh Rice Journal*, *21*(1), 91–100. https://doi.org/10.3329/brj.v21i1.37390

Khumar, G., & Dasgupta, I. (2020). Comprehensive molecular insights into the stress responsedynamics of rice (Oryza sativa L.) during rice tungro disease by RNA-seq-based comparative whole transcriptome analysis. *Journal of Biosciences*, *45*, 27.

Ladja, F. T., Hidayat, S. H., Damayanti, T. A., & Rauf, A. (2016). Responses of Tungro resistant rice varieties and donor parents against five Tungro virus isolates from Indonesia. *Journal of the International Society for Southeast Asian Agricultural Sciences*, *22*(2), 18–27.

Ladja, F. T., Santoso, T., & Nurhayati, E. (2011). Potential of Entomopathogenic fungi (*Verticillium lecanii*) and (*Beauveria bassiana*) in controlling green leafhoppers and suppressing tungro disease intensity. (In Indonesian.). *Penelitian Pertanian Tanaman Pangan, 30*, 114-120. http://dx.doi.org/10.21082/jpptp.v30n2.2011.p114-120

Macovei, A., Sevilla, N. R., Cantos, C., Jonson, G. B., Slamet-Loedin, I., Čermák, T., Voytas, D. F., Choi, I. R., & Chadha-Mohanty, P. (2018). Novel alleles of rice eIF4G generated by CRISPR/Cas9-targeted mutagenesis confer resistance to Rice tungro spherical virus. *Plant Biotechnology Journal*, *16*(11), 1918–1927. https://doi.org/10.1111/pbi.12927

Makarim, A. K., & Suhartatik, E. (2009). *Morphology and physiology of rice plants*. (In Indonesian.). Balai Besar Penelitian Tanaman Padi. Sukamandi. Subang.

Mauck, K. ., Moraes, C. M. D., & Mescher, M. (2016). Effects of pathogens on sensory-mediated interactions between plants and insect vectors. *Plant Biology*, *32*, 53–61. https://doi.org/https://doi.org/10.1016/j.pbi.2016.06.012.

Muliadi, A., Pakki, S., & Praptana, R. H. (2015). Performance of rice tungro resistant promising line in endemic area. (In Indonesian.). *Informatika Pertanian*, *24*(2), 157–164. https://doi.org/10.21082/ip.v24n2.2015.p157-164

Nayak, A., Baig, M., Mohapatra, P., & Behera, K. (2019). Effect of insect feeding on biochemical changes in rice plant. *Journal of Entomology and Zoology Studies*, *7*(6), 138–142. http://www.entomoljournal.com

Patti, P. S., Kaya, E., & Silahooy, C. (2013). Analysis of soil nitrogen status in relation to N uptake by paddy rice plants in Waimital Village, Kairatu Subdistrict, West Seram Regency. (In Indonesian.). *Agrologia*, *2*(1). http://dx.doi.org/10.30598/a.v2i1.278

Rosida, N., Komalasari, E., & Heru, R. (2020). Green leafhopper (*Nephotettix virescens* Distant) preference for tungro-resistant rice strains. (In Indonesian.). *Agric.*, *32*(2), 105–120.

Rosida, N., Kuswinanti, T., Nasruddin, A., & Amin, N. (2020). Green leafhopper (*Nephotettix virescens* Distan) biotype and their ability to transfer tungro disease in South Sulawesi, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *486*(1). https://doi.org/10.1088/1755-1315/486/1/012147

Sastro, Y., Suprihanto, Hairmansis, A., Hasmi, I., Satoto, Apri Rumati, I., Susanti, Z., Kusbiantoro, B., Dwi Handoko, D., Rahmini, Sitaresmi, T., Suharna, Norvyani, M., & Arismiati, D. (2021). *Description of New Varieties of Rice*.- (In Indonesian.). *Agricultural Research and Development Agency*. Ministry of Agriculture.

Shapiro, L., De Moraes, C., Stephenson, A., Mescher, M., & van der Putten, W. (2012). Pathogen effects on vegetative and floral odours mediate vector attraction and host exposure in a complex pathosystem. *Ecology Letters*, *15*(12), 1430–1438. https://doi.org/https://doi.org/10.1111/ele.12001

Sharma, S. (2020). Impacts of nitrogen on plant disease severity and plant defense mechanism. *Fundamental and Applied Agriculture*, *5*(3), 303-314. https://doi.org/10.5455/faa.103334

Srilatha, P., Yousuf, F., Methre, R., Vishnukiran, T., Agarwal, S., Poli, Y., Raghurami Reddy, M., Vidyasagar, B., Shanker, C., Krishnaveni, D., Triveni, S., Brajendra, Praveen, S., Balachandran, S. M., Subrahmanyam, D., & Mangrauthia, S. K. (2019). Physical interaction of RTBV ORFI with D1 protein of *Oryza sativa* and Fe/Zn homeostasis play a key role in symptoms development during rice tungro disease to facilitate the insect mediated virus transmission. *Virology*, *526*, 117–124. https://doi.org/10.1016/j.virol.2018.10.012

Suprihanto, S., Nurhayati, E., & Harjosudarmo, J. (2013). Virulence of rice tungro virus isolates from several tungro endemic areas in Indonesia. (In Indonesian.).*Jurnal Fitopatologi Indonesia*, *9*(1), 29–37. https://doi.org/10.14692/jfi.9.1.29

Suprihanto, S., Somowiyarjo, S., Hartono, S., & Trisyono, Y. A. (2016). Brown planthopper preference for rice varieties and resistance of rice varieties to hollow dwarf virus. (In Indonesian.). *Jurnal Penelitian Pertanian Tanaman Pangan*, *35*(1), 1–8. https://doi.org/10.21082/jpptp.v35n1.2016.p1-8

Turkington, T. K., O'Donovan, J. T., Edney, M. J., Juskiw, P. E., McKenzie, R. H., Harker, K. N., Clayton, G. W., Xi, K., Lafond, G. P., Irvine, R. B., Brandt, S., Johnson, E. N., May, W. E., & Smith, E. (2012). Effect of crop residue, nitrogen rate and fungicide application on malting barley productivity, quality, and foliar disease severity. *Canadian Journal of Plant Science*, *92*(3), 577–588. https://doi.org/10.4141/cjps2011-216

Vijayalakshmi, P., Kiran, T. V., Rao, Y. V., Srikanth, B., Rao, I. S., Sailaja, B., Surekha, K., Rao, P. R., Subrahmanyam, D., Neeraja, C. N., & Voleti, S. R. (2013). Physiological approaches for increasing nitrogen use efficiency in rice. *Indian Journal of Plant Physiology*, *18*(3), 208–222. https://doi.org/10.1007/s40502-013-0042-y

Widiarta, I. N. (2014). Integrated control strategy for rice tungro disease based on vector population dynamics, pathology and virus epidemiology. (In Indonesian.). *Jurnal Litbang Pertanian*, *33*(2), 61–68.

Widiarta, I. N. (2016). *Compilation of Research Publications on Green Planthopper-Tungro Complex and Integrated Control of Tungro Disease*. (In Indonesian.). Agricultural Research and Development Agency. Ministry of Agriculture.

Widiarta, I. N., Bastian, A., & Pakki, S. (2014). Variation in rice tungro virus transmission ability by Green Leafhopper, *Nephotettix virescens* Distant. (Homoptera: Cicadellidae) on rice resistant varieties. (In Indonesian.). *Indonesian Journal of Agricultural Science*, *15*, 65–70.

Wu, W., Nie, L., Shah, F., Liao, Y., Cui, K., Jiang, D., Xie, J., Chen, Y., & Huang, J. (2014). Influence of canopy structure on sheath blight epidemics in rice. *Plant Pathology*, *63*(1), 98–108. https://doi.org/10.1111/ppa.12078

Zaini, Z. (2012). Compound fertilizer and Site-specific nutrient fertilization in lowland rice. (In Indonesian.). *Iptek Tanaman Pangan*, *7*(1), 1–7. http://webapps.irri.org/nm/id.