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RESEARCH PAPER

Incidence of dwarf disease and yield on Inpari 32 over two sequential seasons in Klaten, Central Java

Sudi Febrianto[1], Sri Sulandari[2], & Susamto Somowiyarjo[2]

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ABSTRACT

Rice dwarf disease caused by *Rice grassy stunt virus* (RGSV) and *Rice ragged stunt virus* (RRSV) is frequently found in Indonesia. This disease is transmitted by brown planthopper/BPH (*Nilaparvata lugens* Stål). The infected plants become dwarfs and lead to reduced yields. The purpose of this study is to determine the number of BPH populations due to the occurrences of dwarf disease and yield on Inpari 32 rice over two sequential planting seasons in Klaten, Central Java. The observed parameters were dwarf disease symptoms, incidence and intensity of the disease, BPH population and its natural enemy, the vegetative growth, and yields. The analysis used in this study were descriptive analysis and linear regression. The results showed that, plant growth during the dry season was better than the rainy season based on plant height and tiller number. The average population of BPH in the dry season were 0.2–4 individual/hill which is lower than in the rainy season (0.43–4.4 individual/hill). The incidence and intensity of disease in the dry season were lower than rainy season. The higher incidence and intensity of rice dwarf disease in the rainy season caused a decrease in dry harvest yields and milled dry yields were 10.95% and 10.81%, respectively.

Key words: Brown planthopper, dwarf disease, Inpari 32, sequential planting, yield

INTRODUCTION

Rice is the number one commodity in Indonesia with a consumption rate of 93.78 kg/capita/year in 2020 (Kementan, 2021). This consumption rate is larger than average consumption in Asia, which is at 77.2 kg/capita/year (OECD, 2021). Based on BPS data (2022), in 2021, rice production was 31.36 million tons, or decreased by 0.45% or 140.73 thousand tons, compared to rice production in 2020, of 31.50 million tons.

In 2021, paddy production in Indonesia was 54.42 million tons of milled dry yield compared to 2020, which was 54.65 million tons of milled dry weight and experienced a decrease of 233.91 thousand tons, or 0.43% (BPS, 2022). Decrease in productivity can caused by many factors, including brown planthoppers (BPH). BPH can directly cause damage by feeding on plant fluid using its stylet-shaped mouthparts that cause the plant to dry out and die (hopper burn) (Kalshoven, 1991). In addition, BPH can act as the vector for rice dwarf disease viruses such as *Rice grassy stunt virus* (RGSV) and *Rice ragged stunt virus* (RRSV) (Chomchan et al., 2003; Baehaki, 2012). Both viruses can cause single or dual infection on rice and be transmitted persistently by BPH (Rahmawati et al., 2015b; Kusuma et al., 2018; Helina et al., 2019). The viruses could multiply in the vector body and keep in the vector body even after the molting process, but does not inherit in the next generation through eggs (Hibino, 1986; Milne et al., 1982). Dwarf disease is a challenge in Asian countries, such as Thailand, China, Philippines, Vietnam and Indonesia (Bentur & Viraktamath, 2008; Zhou et al., 2008). It can potentially threaten self-sufficient rice programs in Asia, especially Indonesia. According to BBOPT (2021), brown planthoppers damage reached 21,016 ha and 55,526 ha during 2020-2021.

Central Java is the second largest rice-producing province in Indonesia with an average production of 9,572.45 tons of milled dry yield in 2019-2020 (BPS Jateng, 2020). Klaten is a district in Central Java Province which is one of the centers of rice production. In 2020, it experienced an increase in harvested area of 1,550 ha or 2.43% from 63,670 ha compared to 2019, which was 62,120 ha. Despite the increase in harvested areas, the attacks BPH in Central Java are also very high. According to BBOPT data (2021), Central Java is the province with the highest BPH attack area compared to

Corresponding author:
Sudi Febrianto (sudi.febrianto@mail.ugm.ac.id)

[1]Master Degree of Phytopathology, Faculty of Agriculture, Gadjah Mada University, Jl. Flora 1 Bulaksumur Yogyakarta 55281
[2]Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada, JL. Flora, Bulaksumur, Karang Malang, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta, Indonesia 55281

other provinces, which is around 18,782 ha. The high attack of BPH is compounded by the dwarf virus carried. Dwarf virus infection will cause different symptoms based on the severity of the disease, thus would affect the growth and rice yields. Field observation showed that dwarf disease was found in Inpari 32 at various locations in Klaten. Inpari 32 is a superior variety and many farmers in Klaten plant this variety. This research aimed at exploring the correlation between the amount of BPH population, incidence of dwarf disease, and the yield of Inpari 32 over two sequential seasons.

MATERIALS AND METHODS

Research Site. The research was conducted since August 2020–February 2021 in Gantiwarno, Klaten, Central Java, Indonesia. It was carried out for two sequential seasons (dry and rainy) at the same location.

Rice Dwarf Disease Symptoms. The observations were made by recording variations in the symptoms of rice dwarf disease based on the categories of mild, medium, severe and crop failure. Description of disease scores used to determine dwarf disease severity is placed in Table 1.

Observation of Disease Incidence and Intensity. The disease incidence and intensity observation were done during 4–8 WAP. The samples were taken diagonally at 3 points and at each point 100 plants were observed resulting in 300 observed plants.

According to Zadoks & Schein (1979), disease incidence and intensity were calculated using the following formula:

Disease incidence:

$$DI = \frac{n}{N} \times 100$$

DI = Disease incidence;
n = Number of infected plants;
N = Number of all plants observed.

Disease intensity:

$$DI = \sum \frac{(n_i \times v_i)}{(N \times V)} \times 100\%$$

DI = Disease intensity;
n_i = Number of plants infected at score I;
v_i = Value of score I;
N = Number of plants observed;
V = Highest score used.

BPH and Natural Enemy Population Observation. The observation of BPH was done by counting the number of individuals in each hill every week. The total number of BPH on each hill was observed from 2–10 WAP. The observation was done by sampling the plant diagonally. Meanwhile, the population of natural enemies collecting sample using a sweep net. The observations were done by sampling at 3 points in a diagonal matter. The total of natural enemies was observed from 2–10 WAP.

Rice Vegetative Growth. The observations were done from 4 to 8 WAP (week after planting). Samples were taken diagonally at 3 points. At each point, 30 infected plants were observed for the following parameters:
Plant Height. The plant height was measured from the stem base to the end of the tallest leaf of each plant.
Tiller Number. The number of tillers observed at each hill includes all tillers.
Yield Analysis of Tile. The yield observation was done using a 2.5 × 2.5 m harvest tile at each location. The

Table 1. The disease score of dwarf disease symptoms

Score	Description
(0) Healthy	No symptoms
(1) Mild	Plants show a mild symptoms, shorter height, rigged leaf edges, and fewer flowers compared to healthy plants.
(2) Medium	Plants are smaller, have many tiller, grow upright, their leaves have rigged leaf edges and darker colours, twisted leaf tips, leaf are swollen and have galls, and flowers take longer to appear.
(3) Severe	Plants are short, have very few tiller, grow upright, narrow leaves and rigged leaf edges, swollen leaf ribs, showing galls, and plants produce fewer flower with those flowers producing less yield
(4) Crop failure	Plants are dwarf, have many tiller, grow upright, short, narrow yellow leaves and show spots, and plants do not produce flowers.

Source: Helina et al. (2020)

observation was done by harvesting and weighting the crops. Yield was then calculated using the following formula (Makarim & Ikhwani, 2012; Cybext, 2019):

Tile/yield estimation=
Average yield weight x (10,000 m^2 : tile area)

Data Analysis. Disease incidence, disease intensity and yield were analyzed using descriptive analysis. Meanwhile, plant height and the number of tillers were analyzed using linear regression analysis followed methods from Teng & Gaunt (1980) that used a linear regression model Y = a + bX, where Y is the yield, a is the constant, b is the regression coefficient, and X is the week after planting.

RESULTS AND DISCUSSION

Rice Dwarf Disease Symptoms. The symptoms of the disease caused by the RGSV virus are marked by the plants becoming very dwarf, many tillers, and the leaves turning pale yellow. While the symptoms of the disease caused by the RRSV virus are characterized by plants becoming dwarf, leaves turning dark in colour with jagged edges and twisted leaf tips. A single infection is a symptom caused by one of the RGSV or RRSV viruses. Meanwhile, the double infection is a combination of symptoms caused by RGSV and RRSV viruses in one plant. The observations showed that inpari 32 rice plants were infected singly and double through persistent BPH transmission. The symptoms caused in the field are including plants becoming dwarf, leaf colour turning dark green to pale yellow, leaf edges jagged, growth upright, and leaf tips twisting (Figure 1–2). This was consistent with research conducted by Helina et al. (2020) reported that rice plants infected with the dwarf virus showed dwarf growth, dark green to yellowish green in colour, serrated leaf edges, upright growth, many tillers, and twisted leaf tips. Besides, there were variations in symptoms between the dry

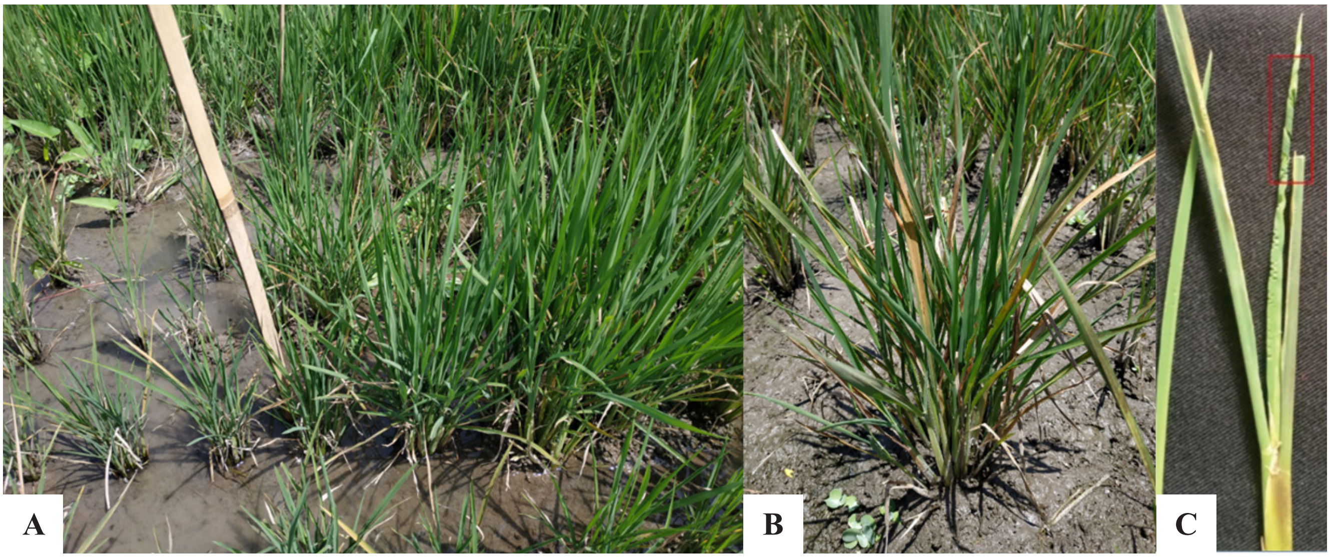

Figure 1. Dwarf disease symptoms on Inpari 32 rice in the field. A. Dwarf symptoms with upright growth; B. Brown young leaves; C. Swirling leaves with rigged edges.

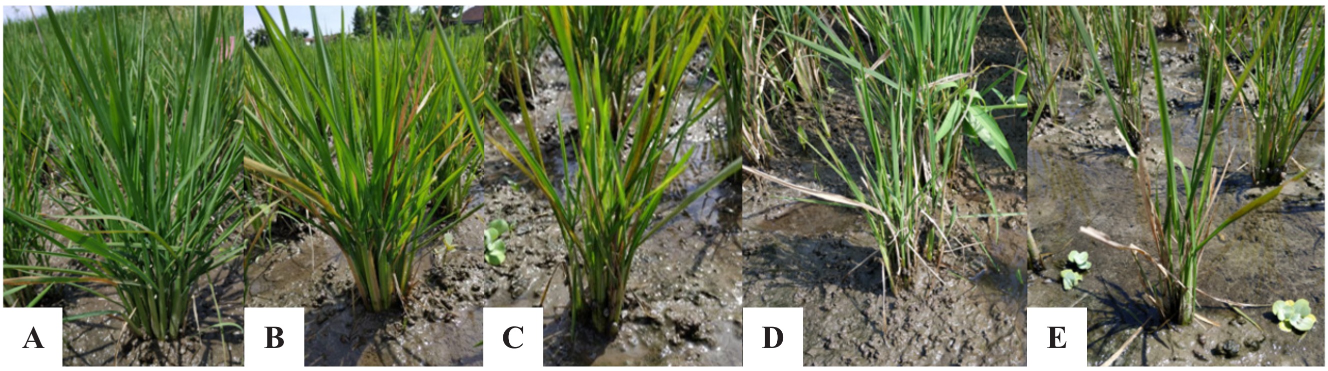

Figure 2. Variation of dwarf symptoms and severity during vegetative stage. A. Healthy plants; B. Mild symptoms; C. Medium symptoms; D. Severe symptoms; E. Crop failure.

and rainy seasons, such as mild, medium, severe, and crop failure (Figure 2). In mild symptoms, the plant is slightly dwarfed and rigged leaf edges. In the medium symptoms, the plant is a bit dwarf, the number of tillers are many, it grows upright and shortened, the edges of the leaves are jagged with a slightly dark colour, and the veins are swelling and galls. Then, in the severe symptoms, the plant becomes dwarf, the tillers are few, it is erect and shortened, the leaves are narrow and jagged with twisted ends, and the veins of the leaves are swelling and galls. In the crop failure symptoms, the plant is very dwarf, the tillers are few, erect and shortened, the leaves are narrowed, and it is slightly yellow and mottled. This variation is believed to be due to high disease incidence and intensity during the rainy season. Matthews (1992) demonstrated that many factors that affected disease symptoms include plant age, variety, climate, and plant genotype. Rahmawati et al. (2015a) stated that, weather and soil fertility also affected symptoms variety of rice dwarf disease.

Disease Incidence and Intensity. The observation results showed a different incidence between the dry and rainy seasons (Figure 3A), with a higher incidence during the rainy season compared to the dry season. The dry season had disease incidence of 76.67% and 81% during the rainy season of 10 WAP. According to Le et al. (2010), disease intensity is affected by inoculum source, vector, varieties, and suitable environment.

The disease intensity was almost similar between both seasons. Figure 3B showed that disease intensity development during the rainy season was higher compared to dry season reaching 40.83% and 39.58% at 10 WAP, respectively. The severity or intensity of the disease in both growing seasons was low. This may be caused by Inpari 32 tolerance against dwarf disease, although susceptible to BPH (Sasmita et al., 2020).

There are several factors that determine rice dwarf disease intensity. Matthews (1992) showed symptom change is affected by plant age, host, climate, and plant genotype. In addition, Rahmawati et al. (2015a) stated that other factors are such as weather and soil fertility. A different plant intensity will also result in symptom variation. A higher disease intensity resulted in more severe dwarf symptoms (Figure 4). This will change the number and quality of flowers and later yield (Figure 5).

BPH Population. The weather affects BPH population, and its population was higher in the rainy season compared to the dry season. The rainy season will cause lower temperatures and higher humidity, which will support the development of the BPH population. This is in line with research Win et al. (2011) reported that the increase in the BPH population during the rainy season was associated with high temperature or humidity. In addition, the high temperatures that occur during the dry season will affect the development of the BPH population to be less than the low temperatures during the rainy season. So BPH is more tolerant to low temperatures than high temperatures. This is to research by Piyaphongkul (2013), which states that BPH can tolerate low temperatures compared to high temperatures. Those factors support BPH population increases during the rainy season compared to the dry season.

Based on the field observations, it can be seen that the population of BPH in the rainy season is higher than in the dry season (Figure 6). This may be due the population regeneration or migration from other locations. The migration of BPH is caused by BPH behavior preferring young plants and leaving older ones. The economic threshold is usually used for making pest control decisions according to the integrated pest management (IPM) concept. The definition of an economic threshold is a pest population density that requires control measures to prevent an increase in

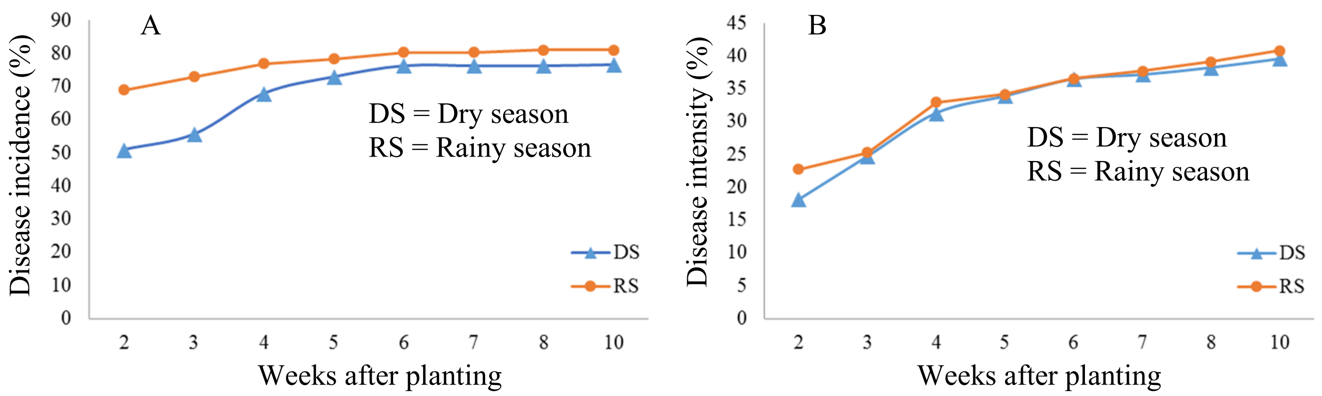

Figure 3. Dwarf disease on Inpari 32 for two seasons. A. Disease incidence; B. Disease intensity.

population from reaching a state where the population density is lowest, which can cause economic damage (Untung, 2003). According to Pujiharti et al. (2008) demonstrated that 15 BPH individuals at each hill are the economic threshold. The population of BPH in the dry season reached 0.2–4 individual/hill or lower than

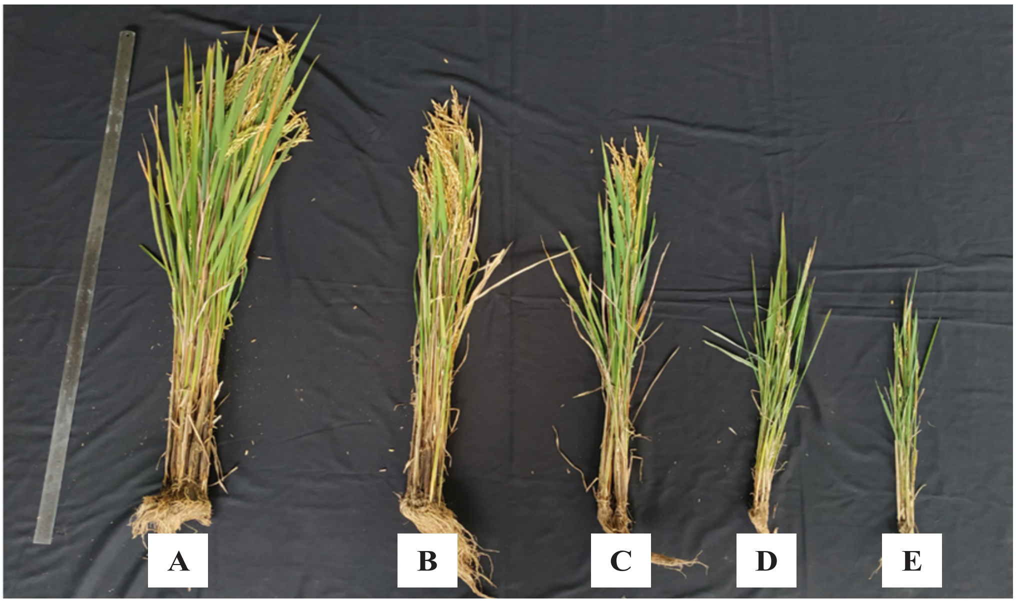

Figure 4. Variation of dwarf disease and disease intensity at generative stages. A. Healthy; B. Mild symptoms; C. Medium symptoms; D. Severe symptoms; E. Crop failure.

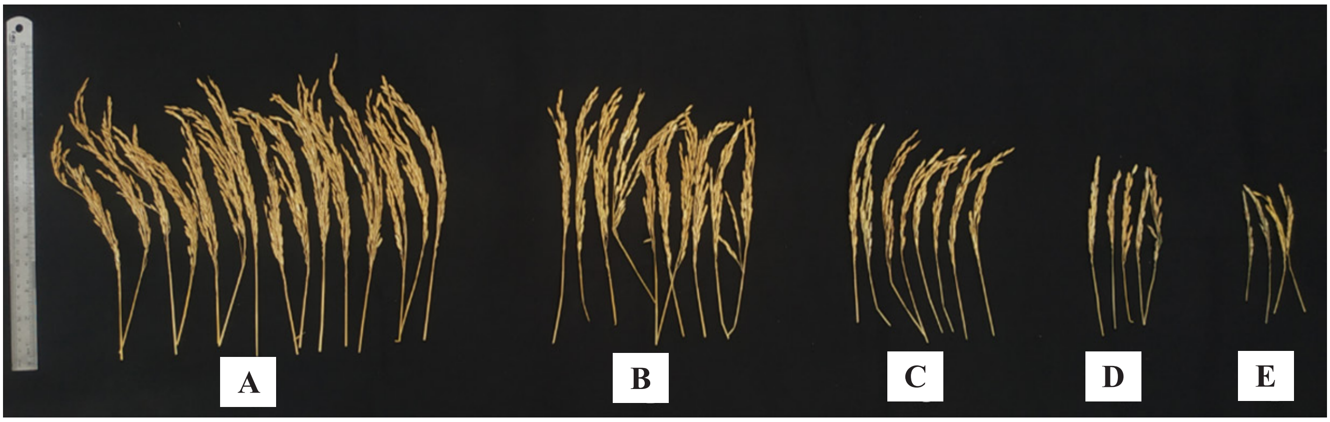

Figure 5. Comparison of average number of Inpari 32 flowers based on intensity level. A. Healthy; B. Mild symptoms; C. Medium symptoms; D. Severe symptoms; E. Crop failure.

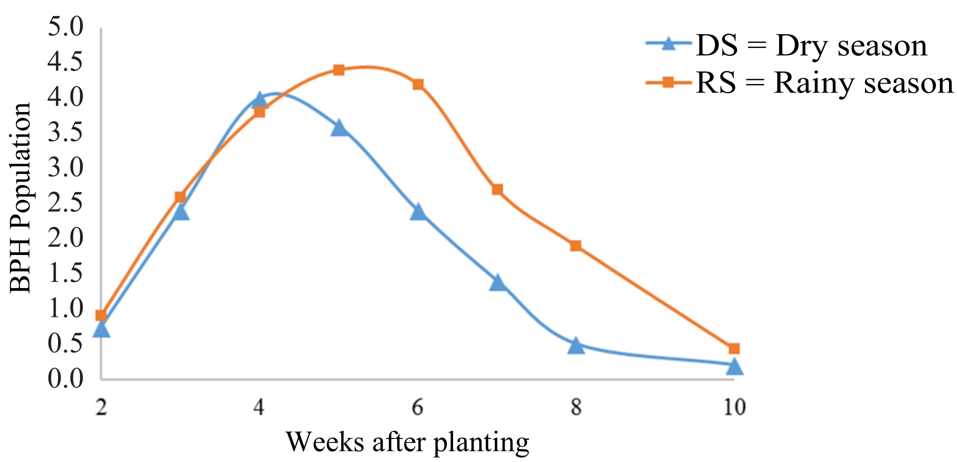

Figure 6. Population of BPH on Inpari 32 over two seasons.

in the rainy season, which reached 0.43–4.4 individual/hill (Figure 6). Although the population was under the economic threshold, they could still transmit viruses.

Population of Natural Enemies. Natural enemies are a solution to managing BPH. Kartohardjono (2011) used natural enemies to manage pests and decrease the use of synthetic pesticides, be sustainable, and compatible. Based on the field observations, the natural enemies of BPH found were predators consisting of four-jaw spiders (*Tetragnatha* spp.), coccinelid beetles (*Synharmonia octomaculata*), mirid ladybugs (*Cyrtorhinus lividipennis*), sword crickets (*Conocephalus longipennis*) and damselfly (*Agriocnemis* spp.). The five types of predators are predators that can control the BPH population in paddy fields.

During the dry season, the average number of natural enemies found were 2 four-jaw spiders (*Tetragnatha* spp.), 3 coccinellid beetles (*Synharmonia octomaculata*), 1 ladybug (*Cyrtorhinus lividipennis*), 3 sword crickets (*Conocephalus longipennis*), and 2 damselflies (*Agriocnemis* spp.). While in the rainy season, the average number of natural enemies found during weekly observations were 3 four-jaw spiders (*Tetragnatha* spp.), 4 coccinellid beetles (*Synharmonia octomaculata*), 2 mirid ladybugs (*Cyrtorhinus lividipennis*), 4 sword crickets (*Conocephalus longipennis*) and 3 damselflies (*Agriocnemis* spp.). Based on this description, it is obtained that natural enemies are found in the rainy season more often than in the dry season. This shows that the more natural enemies found, the more BPH populations in the field (Figure 6).

Vegetative Rice Growth. Based on the field observations, the vegetative growth of inpari 32 rice plants experienced growth and development disturbances caused by the dwarf virus. In addition, field observations also show various categories of symptoms with different levels of severity. The first symptom of dwarf disease in inpari 32 rice plants can be seen at 4 WAP, marked by the plants becoming dwarf, the leaves being yellowish green in colour, the leaf edges being serrated, growing upright, and the leaf tips rotating. This is in accordance with the various categories that can be seen in Table 1. Based on Figure 7, plant growth will generally increase every week. At 4 WAP, plant growth was not the same due to stunt virus infection. At 5 to 6 WAP, the symptoms of dwarf are not obvious. At 7 WAP, more dwarf symptoms were found, and spots were on the leaves. At 8 to 9 WAP, rice plants enter the generative stage, and symptoms are more ubiquitous in uneven flower occurrences.

Plant Height. The plant height data showed that during the dry season, it grew better compared to the rainy season (Figure 8). This was consistent with the higher disease incidence, disease intensity and population of BPH in the rainy season compared to the dry season (Figure 3 and Figure 6). Several factors affect plant

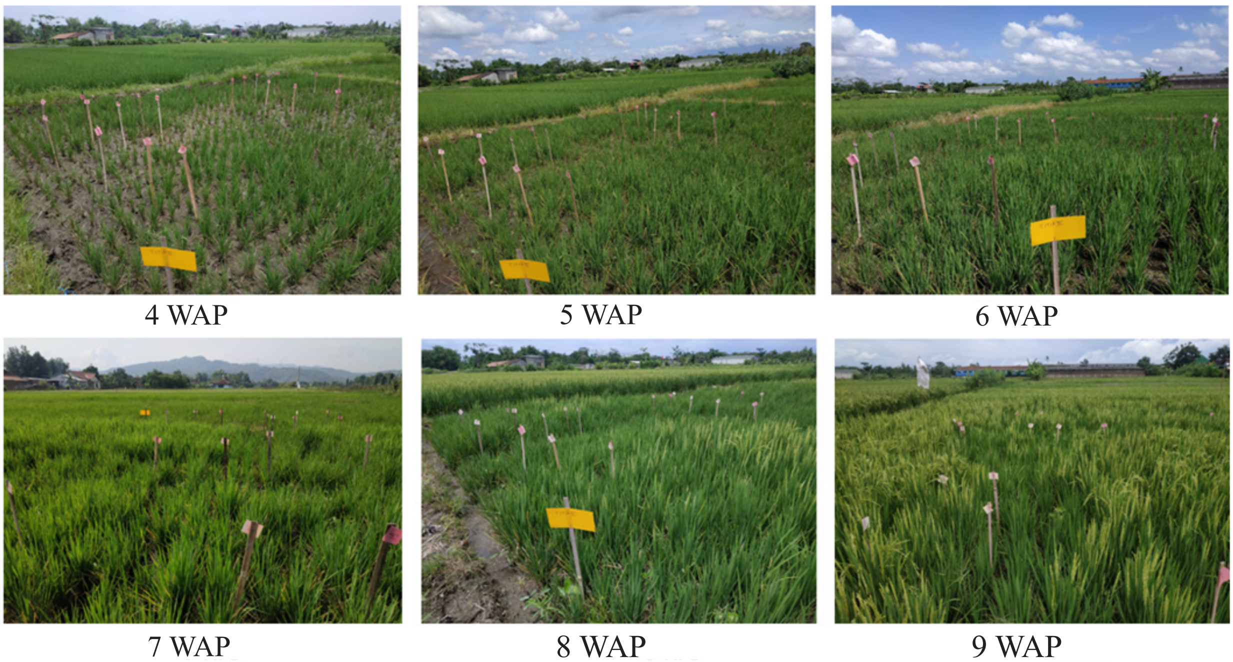

Figure 7. Inpari 32 rice growth and development of infected with rice dwarf disease from the vegetative to generative stages. WAP= Week after planting

height growth, such as physiological factors and the presence of dwarf viruses. The presence of dwarf virus in plants greatly affects the growth of rice plant height. In addition, environmental factors also affect the growth of rice plant height. These environmental factors include biological factors, vector insects, and inoculum sources. According to Dachban & Dibisono (2010), several factors affected growth and yield, including internal factors, such as genetics, plant age, plant morphology, and plant resistance, while external factors were climate and soil. Inpari 32 growth during the dry season resulted in a linear model of y= 7.8113x + 9.3413; R^2= 0.9879, while the rainy season resulted in y= 5.8733x + 13.128; R^2= 0.9786, where y is plant height (cm) and x is 4–8 WAP (Figure 8).

Tiller Number. The growth in the number of tillers, shows more tiller in the dry season than in the rainy season (Figure 9). This is in line with the higher disease incidence, disease intensity and BPH population in the rainy season compared to the dry season (Figure 3 and Figure 6). This condition will affect the yield of the number of rice tillers. In addition, RGSV and RRSV virus attacks can also affect the formation of tillers. Significant formation and increase of tiller numbers happen during the vegetative stage (Makarim & Suhartatik, 2009). On the infected plants, tillers will increase, and flower numbers will decrease depending on the disease severity. Several factors affect rice plant growth, such as nutrients, water, light, plant spacing, and culturing techniques (Suparyono & Setyono, 1993). In addition, RGSV and RRSV cause dwarfing of plants (Dini et al., 2015; Kusuma et al., 2018; Helina et al., 2020). The increase of the tiller of Inpari 32 in the dry season resulted in the linear model of y= 1.0567x + 11.842; R^2= 0.7328, while the rainy season resulted in y= 1.4511x + 4.4022; R^2 = 0.9255 with y as tiller number and x is 4–8 WAP.

Analysis of Yield. This research demonstrated that dwarf disease infection over two growing seasons caused the disturbance of plant metabolism. In the

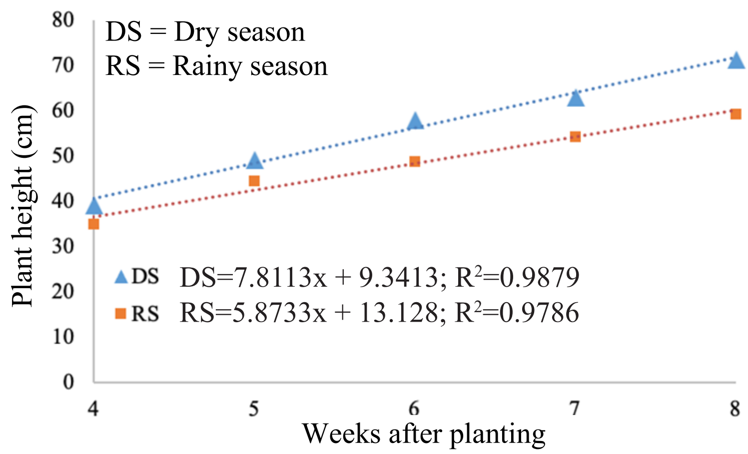

Figure 8. Weekly growth of Inpari 32 rice plant height by linear regression analysis.

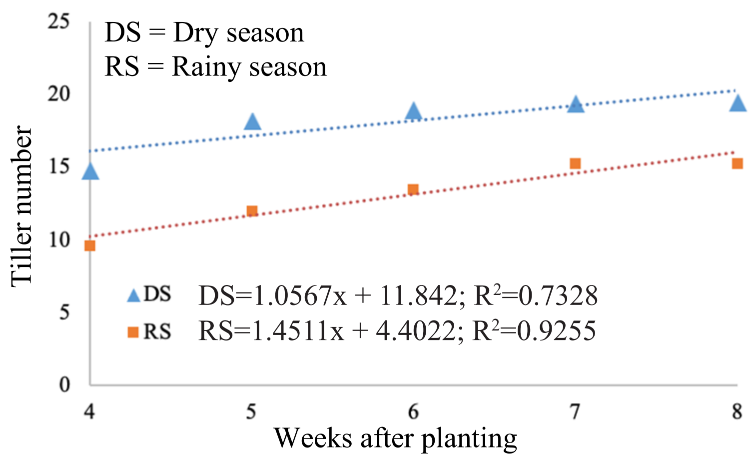

Figure 9. Increasing the number of tillers of Inpari 32 rice plants every week with linear regression analysis.

vegetative phase, the plant shows inhibit plant height growth and the number of tillers. Meanwhile, in generative phase demonstrated a decrease in yield. The yield was calculated by converting harvested dry weight (DHY) to milled dry yield (MIDY). Meanwhile, the conversion rate of DHY to MIDY drying varies from province to province. For areas in Central Java Province, the conversion value of grain drying from DHY to MIDY is 82.60% (BPS, 2018).

Table 2 shows different yields between the two seasons. The average harvested dry yield and milled dry yield were 4.93 t ha^{-1} and 4.07 t ha^{-1} for the dry season, while it was 4.39 t ha^{-1} and 3.63 t ha^{-1} for the rainy season. The results showed that yield from the rainy season was lower than the dry season. There were a decrease of 10.95% for the harvested dry yield and 10.81% for the milled dry yield for the rainy season. The decrease in crop yields in the rainy season was mainly due to the higher incidence and intensity of the dwarf disease, which was found to have an impact on the severity of the symptoms caused. The more severe the symptoms of the disease, the lower the number of panicles and the lower the quality of the grains, so it will affect the total weight of the harvest.

CONCLUSION

BPH population and dwarf disease occurrence were higher during the rainy season compared to the dry season. The average population of BPH during the dry season was 0.2-4 individual/hill, and it was 0.43–4.4 individual/hill in the rainy season. The disease incidence and intensity during the dry season were 76.67% and 39.58%, while it was 81% and 40.83% during the rainy season. The higher disease incidence, disease intensity and BPH populations in the rainy season caused a decrease in dry harvest yields and milled dry yields were 10.95% and 10.81%, respectively.

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AUTHORS' CONTRIBUTIONS

SF and SS are the main contributors. SM is member contributors. SF and SS considered the experiment, planned the experiment, performed the data analysis, and prepared the manuscript. SM determined the data analysis and discussion of the research. The author provided feedback and comments on the research flow, data analysis, and interpretation and form of the manuscript. All authors have read and approved the final manuscript.

COMPETING INTERESTS

Authors declares that there is no competing interest regarding to the publication of this manuscript.

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Table 2. Harvest tile of Inpari 32 during the rainy and dry season

Planting season	Tiles (kg)		Average of weight (kg)	DHY (t ha^{-1})	MIDY (t ha^{-1})
	1	2			
DS	2.71	3.45	3.08	4.93	4.07
RS	2.31	3.18	2.75	4.39	3.63

DS= Dry season; RS= Rainy season; DHY= Dry harvest yield; MIDY= Milled dry yield.

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