The dynamic of pests and plant diseases during three consecutive rice growing seasons

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Abstract. Pests and diseases are significant factors that affect global rice production. There is a need for pests and diseases to be continuously controlled in order to solve the pest and disease problem. The aim of this study was to observe the population dynamics of pests and diseases infestation in lowland rice fields during different cropping seasons. The data of pest and disease infestation in Pati District, Central Java Province, Indonesia during the Rainy Season (RS) 2018/2019, the Dry Season (DS) 2019, and the RS 2019/2020 were observed and analyzed. The results showed that the rice fields in Pati were susceptible to stem borer, brown plant hopper, rats, fake white pests, blast and bacterial blight during three consecutive seasons. Tungro was not found. During both the RS and DS, the areas of rice paddy in Pati approximately 470 ha season⁻¹ were affected by stem borer. The second largest damage rice area approximately 221 ha season⁻¹ was affected by blast. Grain losses due to pests and diseases infestation during the RS was higher than during the DS. Micro-climate significantly affected pests and plant diseases. The dynamic of pests and plant disease infestation provide information early warning for high-risk areas of rice production and for pests-diseases management.

1 Introduction

Indonesia is the 4th most populous country in the world and a population projected to be 305 million people by 2035 [1]. Growing population driver effort to meet basic needs. Rice is one of the most vital staple food and the production plays an important role in the economy in Indonesia. Agricultural land in Indonesia is estimated around 31.5% of national total land area [2]. An annual rice harvested area of 10.7 million ha produced 54.6 million tons of rice in 2019 [3]. Rice is affected by more than 100 species of insects, among which 20 threat pose an economic threat during rice growing season [4]. After the introduction of the green revolution in Indonesia, rice pests and diseases outbreak became more frequent. In addition, changes in climatic factors such as temperature, rainfall and humidity highly affect crop production and insect population as well as pest-disease infestation [5].

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Population and distribution of pest-disease in rice field are influenced by ecological and biological factors, crop physiology, meteorological parameters and farmer’s practices [6]. Increased temperature accelerates development in most insects because insects are poikilotherms. Shortened insects development duration may increase population size more rapidly for multivoltine species in the growing season [7]. Change in temperature and humidity influenced not only in distribution, growth development and reproduction rates but also in behaviour of the insects [8]. Study in India described that rainfall, temperature, humidity, wind speed, duration of sunshine has a remarkable influence on the fluctuations of Yellow stem borer [9]. Study in Philippines mentioned that the number of days with wind speed, mean maximum temperature, and precipitation frequency had correlated negatively with blast [10].

Knowledge of the seasonal population dynamic of insect pests plays essential role in integrated pest management strategy to ensure timely preparedness to tackle impending pest problems and prevent crop and economic losses [11]. In this regard, the study was conducted with the following objective of observe population dynamics of pests and diseases infestation in lowland rice field during different cropping seasons.

2 Materials and methods

2.1 Study Area
The research area was paddy fields in Pati Regency. Pati Regency is an area traversed by the northern coastal route in Central Java Province, Indonesia. The geographical location of Pati Regency is between 100° 50’ - 111° 15’ EL dan 6° 25’ - 7° 00’ SL.

2.2 Data collection
Pest and disease data for this study were provided by Laboratory for Forecasting Plant Pest Organisms of Pati Regency, Central Java Province, Indonesia. The data of pest and disease infestation collected during the Rainy Season (RS) 2018/2019, the Dry Season (DS) 2019, and the RS 2019/2020. Daily meteorological data were recorded from the meteorological observatory of Indonesian Agricultural Environment Research Institute (IAERI), Ministry of Agriculture.

2.3 Statistical analysis
The relationships between pest-disease and temperature, humidity, rainfall, wind speed were carried out using simple regression. Statistical considerations were based on $P < 0.05$ and $P < 0.001$ significant levels.

3 Results and discussions

3.1 Population dynamics
Rice stem borers occupied the dominant area as pest and cause considerable damage to the rice cultivation during three consecutive growing rice seasons, but the highest damage was found during the DS 2019 (Figure 1). Biotic and abiotic factors are believed to be responsible for rice stem borers population dynamics [12]. The yellow rice stem borer investigation in Semarang, Central Java found that biotic – abiotic factors and the fluctuations in the yellow rice stem borer have statistically moderate to strong correlations with correlation coefficients approximately 0.49 to 0.76 [13]. The largest area that infected by brown plant hopper (BPH) during the RS 2019/2020. The BPH cause serious damage by sucking the phloem-sap, transmitting virus to host, and leading to nutrient depletion of nutrients within the plant [14]. During the RS 2018/2019, episodic rodent outbreaks posed the largest area and this is one of threats to food security whereby the entire harvest can be lost to rodents because crop protection for mitigating rodent outbreaks are not very well-established [15]. Rice paddy area was not infected by Tungro. According to
Gour et al. 2004 [16], tungro disease causes around 38-100% yield loss in Japan, Nepal, China, Sri Lanka, Philippines, India, Vietnam, Indonesia and Pakistan. Stunting, reduction of tiller number, yellow to orange yellow colour of leaves, delay of panicle exertion and empty grains are the symptom of rice tungro disease [17]. The lowest area that infected by blast was found during the DS 2019. Rice blast is caused by the fungus *Magnaporthe oryzae* B. Couch. A strong relationship between rice blast with temperature and precipitation. Precipitation increased high disease impact and low temperatures were associated with higher disease severity [18]. The lowest infected rice area by leaf folder was found during the RS 2019/2020. Leaf folder, *Cnaphalocrocis medinalis* Guenée is a migratory pest that reduce the efficiency of photosynthesis. When rice plants were infected by bacterial blight, the yield is usually reduced by more than 10%, and severe infection can lead to no harvest [19]. During both the RS and DS, the areas of rice paddy in Pati approximately 470 ha season-1 were affected by stem borer. The second largest damage rice area approximately 221 ha season-1 was affected by blast. Tungro was not found in the rice area.

![Fig. 1 Population dynamics of pest-disease during three consecutive rice growing seasons](image)

Relationship between climatic components and pest-disease population can be found in Table 1, 2, 3 and 4. There are relationships between infected rice area of steam borer, brown plant hopper, blast and temperature (Table 1). Positive linear correlations between infected rice area of steam borer and temperature. Higher temperature resulted larger infected rice area of steam borer. Temperature is an important abiotic factor that regulates the development, phenology, and population dynamics of pest-disease. The largest rice area in Pati of 36 and 39 ha month-1 were infected at 24°C and 36°C by brown plant hopper and blast, respectively. Temperature certainly alter developmental rates and survival of pest-disease, and subsequently act upon size and density of the population [20]. This finding has a similar result with the observation that conducted in the area of rice production center in West Java, Indonesia and it was explained that the changes of temperature and humidity affected the increase of the pest and disease infestation areas. [21].

| Pest-disease | Equation | Correlation coefficient | Number of data (n) | Max area of pest-disease infestation (ha) | Optimum temperature (°C) |
|--------------|----------|-------------------------|--------------------|----------------------------------------|--------------------------|
| Steam borer  | $y = -0.036x + 38.49$ | $R^2 = 0.2879^*$ | 15 | 36 | 24.32 |
| Brown plant hopper | $y = 0.0108x^2 - 0.7676x + 37.961$ | $R^2 = 0.5591^{**}$ | 18 | 39 | 35.78 |
| Rodents      | $y = 0.021x + 37.2$ | $R^2 = 0.0462$ | 18 | 36 | 24.32 |
| Blast        | $y = 0.0016x^2 + 0.1233x + 38.155$ | $R^2 = 0.39^{**}$ | 16 | 39 | 35.78 |
| Leaf folder  | $y = 0.0925x + 37.107$ | $R^2 = 0.0519$ | 18 | 39 | 35.78 |
| Bacterial blight | $y = 0.0054x + 37.371$ | $R^2 = 0.0087$ | 18 | 39 | 35.78 |
* Indicates P < 0.05  
** Indicates P < 0.01

There are correlations between rainfall and steam borer, rodent, blast, leaf-folder, and bacterial blight (Table 2). The explanation for no correlation of rainfall and infected rice area of brown plant hopper is probably related to physical dislodging of eggs or larvae from rice or host plant by heavy rainfall. There is positive correlation between rainfall and infected rice area of rodent. Contrary, Kumar et al. (1996) [22] mentioned that weather factors had no definite role on population dynamics of pest-disease infestation due to irregular infestation level throughout the crop period and hence, it was difficult to estimate the correlation of pest-disease infestation with weather factors. On the other hand, higher population was recorded in wet season and lower population in dry season [23].

**Table 2.** Relationship between rainfall and infected rice area of pest-disease infestation

| Pest-disease         | Equation                                  | Correlation coefficient | Number of data (n) | Max area of pest-disease infestation (ha) | Optimum rainfall (mm) |
|----------------------|-------------------------------------------|-------------------------|--------------------|------------------------------------------|------------------------|
| Steam borer          | $y = -0.1604x^2 + 12.7x - 32.746$         | $R^2 = 0.2953^*$        | 16                 | 40                                       | 218.64                 |
| Brown plant hopper   | $y = -0.1193x^2 + 9.9293x + 98.149$       | $R^2 = 0.0847$          | 18                 |                                          |                        |
| Rodents              | $y = 3.2306x + 60.6$                      | $R^2 = 0.3244^*$        | 16                 |                                          |                        |
| Blast                | $y = -0.1142x^2 + 9.4677x + 32.131$       | $R^2 = 0.5671^*$        | 18                 | 41                                       | 164.10                 |
| Leaffolder           | $y = -5.7104x^2 + 63.176x + 25.765$      | $R^2 = 0.3288^*$        | 16                 | 6                                        | 200.50                 |
| Bacterial blight     | $y = -0.008x^2 + 9.2469x + 37.718$       | $R^2 = 0.6465^{**}$     | 18                 | 53                                       | 205.19                 |

* Indicates P < 0.05  
** Indicates P < 0.01

There are correlations between wind speed and pest disease (Table 3). Negative correlations between wind speed and steam borer, blast, leaf-folder, bacterial blight. A strong wind may have a detrimental effect on pest population because it may physically destruct various developmental stages of the pest [9]. The opposite study from Chapman et al. 2015 [24] described that fast-moving winds are the most influential meteorological factors in determining take-off and transport particularly for small, weak-flying species.

**Table 3.** Relationship between wind speed and infected rice area of pest-disease infestation

| Pest-disease         | Equation                                  | Correlation coefficient | Number of data (n) | Max area of pest-disease infestation (ha) | Optimum wind speed (ms$^{-1}$) |
|----------------------|-------------------------------------------|-------------------------|--------------------|------------------------------------------|-----------------------------|
| Steam borer          | $y = -0.0139x + 1.394$                    | $R^2 = 0.4007^{**}$     | 16                 |                                          | 27                         |
| Brown plant hopper   | $y = -0.0314x^2 + 0.0061x + 1.0268$      | $R^2 = 0.1964$          | 18                 |                                          | 0.53                       |
| Rodents              | $y = -0.0014x^2 + 0.0534x + 1.2441$      | $R^2 = 0.317^*$         | 18                 | 27                                       | 0.53                       |
| Blast                | $y = -0.0132x + 1.1753$                   | $R^2 = 0.4689^{**}$     | 18                 |                                          |                            |
| Leaffolder           | $y = -0.0808x + 1.2367$                  | $R^2 = 0.4998^{**}$     | 18                 |                                          |                            |
| Bacterial blight     | $y = -0.0009x + 1.1453$                  | $R^2 = 0.2911^*$        | 16                 |                                          |                            |

* Indicates P < 0.05  
** Indicates P < 0.01

This study shows that humidity has significant impact for infected rice area of rodent, and leaf-folder at 5% level (Table 4). But humidity has significant impact at for infected rice area of steam borer, blast, and bacterial blight at 1% level. Less data on infected rice area of brown plant hopper so it makes no correlation between humidity and infected rice area of brown plant hopper. Population of leaf hoper decrease in relative humidity as the highest population of leaf hopper [25]. The effect of single abiotic factor i.e. humidity or temperature cannot be estimated on the population build-up of any insect pest because abiotic factors always effect in close combination.
**Table 4. Relationship between humidity and infected rice area of pest-disease infestation**

| Pest-disease         | Equation                          | Correlation coefficient | Number of data (n) | Max area of pest-disease infestation (ha) | Optimum humidity (%) |
|----------------------|-----------------------------------|-------------------------|-------------------|------------------------------------------|----------------------|
| Steam borer          | $y = -0.0065x^2 + 0.4958x + 83.296$ | $R^2 = 0.4026^{**}$    | 16                | 38                                       | 92.75                |
| Brown plant hopper   | $y = -0.4885x^2 + 3.5349x + 86.027$ | $R^2 = 0.0966$         | 18                | 32                                       | 93.60                |
| Rodents              | $y = -0.0103x^2 + 0.667x + 82.803$  | $R^2 = 0.3473^*$       | 18                | 49                                       | 93.81                |
| Blast                | $y = -0.0045x^2 + 0.4414x + 82.99$  | $R^2 = 0.4862^{**}$    | 18                | 51                                       | 95.47                |
| Leaf folder          | $y = -0.2731x^2 + 3.1529x + 82.527$ | $R^2 = 0.3957^{**}$    | 18                | 32                                       | 93.63                |
| Bacterial blight     | $y = -0.0045x^2 + 0.4576x + 83.837$ | $R^2 = 0.4422^{**}$    | 18                | 6                                        | 95.47                |

* Indicates $P < 0.05$

** Indicates $P < 0.01$

4 Conclusions

The investigation revealed that temperature, rainfall, wind speed, and humidity have influence on the fluctuations of infected areas of pests and diseases. Understanding the relationship between climatic parameters and infected area of pest is important strategy for forecasting the seasonal occurrence of the pest-disease. The investigation of pest and disease have to be done regularly to take the consideration of appropriate management strategies against pest disease damage.

5. Acknowledgements

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