Influence of Climate Variability on Brown Planthopper Population Dynamics and Development Time

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Abstract. Brown planthopper or Nilaparvata lugens (BPH) is one of the rice major pest in Indonesia. BPH can cause extensive damage and almost always appear in each planting season, frequent explosions attack (outbreaks) resulting in very high economic losses. Outbreaks of BPH were often occurred in paddy fields in Indramayu regency and several endemic regency in Java island, where rice is cultivated twice to three times a year both in the rainy and dry cropping seasons. The output of simulation shows the BPH population starts increasing from December to February (rainy season) and from June to August (dry season). The result relatively had same pattern with light trap observation data, but overestimate to predict BPH population. Therefore, the output of simulation had adequately close pattern if it is compares to BPH attacked area observation data. The development time taken by different stages of BPH varied at different temperatures. BPH development time at eggs and adults stage from the simulation output is suitable with BPH real lifestage, but at nymphs stage the result is different with the concept of development time.

Keywords: brown planthopper, simulation, population, development time

1. Introduction

BPH is still serious pest of rice across the world, mainly in tropical climates. Outbreak frequency of BPH has been increasing in Asian rice growing countries in recent years. BPH is well known for its status as a typical outbreak-type pest, which is characterized by great fluctuations in population size from year to year and from field to field [1]. The pest feeds directly on the growing plant, reducing its yield potential. If the pest density is high, the plant will die and results a condition called hopperburn. BPH also transmit the grassy stunt and ragged stunt virus, which can further reduce yield. The alternative host for BPH are Eleusine coracana (wild millet), Leersia hexandra (southern cutgrass), Saccharum officinarum, Zea mays, and Zizania latifolia (Manchurian wildrice) [2].

BPH population always fluctuates according to the dynamic conditions of its environment. Both biotic and abiotic factors are believed to be the factor responsible for the change in population. In agricultural ecosystems, climate variability leads to changes in the biodiversity of insect pests as a result of rising temperature, changes in precipitation pattern and an increase in the frequency and intensity of some extreme climate events that cause an increase in the
frequency of occurrence of pests and diseases. Climate, mainly the temperature is known to exert a strong influence on the distribution and abundance of species, often through effects on mortality. Insects in general are poikilotherms, the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the most important environmental factor influencing insect behavior, distribution, development, survival, and reproduction [3]. Higher temperatures will cause predictions of developmental period from the mean to be too short, and lower temperatures will make them too long. The developmental response of insects to temperature is important in understanding the ecology of insect life histories. Understanding the relationship between temperature and various biological characteristics is needed for the development of reliable pest population prediction systems and management strategies.

During the dry season, when evaporation always exceeds precipitation, so that rainfall becomes a key factor determining BPH populations. However, in the wet season extra rainfall often appears, heavy rain and floods will wash nymphs and adults off the host plant, and eggs laid in the rice sheath cannot hatch after submergence. Dry weather enhances emigration but rainfall inhibits the planthoppers from taking off. BPH prefer lowland to upland rice and since thick vegetation is a better habitat for them, since various species have distinct preferences for plants at different growth stages, they proliferate when rice plants of different ages are available. The shortage of host plants results in overcrowding, which adversely affects the population buildup. It reduces the rate of nymphal development, increases the percentage of macropterous adults, lengthens the preoviposition period, and decreases the number of eggs laid [4].

BPH adults have two forms of wing, macropterous (long winged) and brachypterous (short winged). Macropterous (long winged) can fly which allows them to escape adverse habitats and track changing resources. This is the migration type. Brachypterous (short winged) are flightless but usually possess higher fecundity. This type will dominant if the host plant is abundant. Under normal conditions, the field population decreases sharply about 70 days after the rice is transplanted, because the nutritional conditions of the rice sheath on which the BPH feeds tend to deteriorate [5]. As the rice plant ages, most of the BPH population becomes macropterous and emigrates. During the first 4-5 weeks after transplantation, macropterous adults that apparently had immigrated from the outside were dominant, though some brachypterous adults probably originating from the eggs laid in the nursery bed [6].

The objective of this research is to learn the BPH characteristics including its population dynamics and development time according to climate variability using simulation model as the anticipation and adaptation efforts aimed at developing agriculture that is adaptive to climate variability and pest attacks today and in the future.

2. Materials
Area of this research is Indramayu regency which is situated in coordinate 107°51'-108°36' east longitude and 6°15' - 6°40' south latitude. Materials presented are those data which were collected from various sources. The climatological data are acquired from BMKG climatology station Dramaga from year 2007 to 2015, and data of BPH that infected in paddy fields were provided by Indramayu installation pest laboratory as input for initial BPH population and validation. The main tools utilized are CSIRO DYMEX™ Builder and Simulator version 3, and Microsoft Office 2010. The flowchart of this research is shown in figure 1.
3. Results And Discussion
During period of January 2007 to December 2015, the climate variables in Indramayu varied from years to years. Minimum temperature range is between 18°C and 27°C, maximum temperature range is between 25°C and 39°C, range of maximum RH is 55%-99%, minimum RH range from 17% to 97%, and the yearly rainfall is from 1955 mm to 3521 mm. Figure 2 shows climate parameters in Indramayu regency.

![Climate Parameters in Indramayu 2007-2015](image)

**Figure 2.** Climate parameters in Indramayu regency.
Those climate conditions are favorable for BPH to grow and multiply rapidly when the host plant is available. The climate phenomena of La Nina in late 2008 and early 2009 was followed by El Nino in late 2009 and continuous weak to moderate La Nina from April 2010 to 2012 were producing unusual climate conditions which were very conducive to the outbreaks of particular pests such as BPH [7]. Each BPH stage has their requirements to stay comfortably and active as shown on the table 1.

| Stage    | Temperature range | Optimum temperature | RH range |
|----------|-------------------|----------------------|----------|
| Eggs     | 15°-32° C         | 25°-27° C            | 70-85%   |
| Nymphs   | 15°-32° C         | 25°-30° C            | 70-85%   |
| Adults   | 10°-32° C         | 28°-30° C            | 70-85%   |

According the range on table 1, sometimes (maximum) temperature in Indramayu was higher than the range, then BPH still alive but in an aestivation mode. When an insect is progressively warmed to higher temperature, a sequence of distinct observable or measureable events occurs. Firstly, the BPH moves in an increasingly uncoordinated way and becomes immobile called ‘critical thermal temperature’ (CTmax). As the temperature is further increased, all small-scale movement of appendages (legs, antennae) ceases as the organisms enter a state of ‘heat coma’ (HCT), after which, at a higher temperature, the insect dies at its upper lethal temperature (ULT). The differences in body size and volume also affect heat tolerance; thus the CTmax, heat coma temperature and ULT of nymphs were consistently and significantly lower than that of adults, and for one of these indices (heat coma), adult males were less heat tolerant than females [8].

From the Indramayu installation pest laboratory data, we obtained the information that BPH first appearance is on the early to mid of December while the wet cropping season is about to begin and the peak population occurred on early to mid of January. In dry cropping season, BPH will appear again on mid to late of June and become highest population on about mid to late of July.

The output of simulation model for BPH population dynamics had relatively near to the pattern of the light trap observation in Indramayu installation pest laboratory from 2007-2009, but the model’s result is overestimate to predict the BPH population (figure 3). This case could explain because the BPH light trap observation data are only captured in one place and often happened the light trap tools were out of order so the monitoring of BPH population is not continuous. The model also has limitation that may hinder possible influential factors other than ones included. Meanwhile, if we compares the model’s result with the attacked area data (assumption the population has linearity with attacked area data) from 2007-2014, they shared the adequately close pattern. So, those results are sufficient to decide that the simulation model can be used for anticipation of the upcoming outbreaks of BPH and other pests.

![Figure 3. Model Output versus Observation; a) versus Light Trap; b) versus Attacked Area.](image-url)
Since insects including BPH are cold-blooded animals (poikilotherms), their rate of growth and development is proportional to ambient temperature. At very low temperatures, there is no development at all. As temperature increases, there are some points (different for various species) at which development begin to occur. This low-temperature "gate" is called the Developmental Threshold. As temperatures increase above the developmental threshold, the rate of insect development gets faster. At high temperature, development rate levels off and then drops quickly near the upper limit of survival. Similar insects reared at different temperatures will require different amounts of time to complete development. Cooler temperatures retard development, warmer temperatures stimulate development. Since the relationship between temperature and development rate is linear through a wide range of temperature, it is possible to predict how long development will take at each different temperature. The concept of Day-Degrees is a convenient way to track development at different temperatures. One day-degree is the amount of development that occurs in one day (24 hours) when the temperature is one degree above the developmental threshold. Day degrees accumulate over time, each day the temperature is above the developmental threshold, more day-degrees are added to the accumulation. Each insect species requires a certain total number of day-degrees to complete its development. This is also known as the physiological time of development [9].

**Figure 4.** Insect Developmental Threshold. (Source: [9])

Total development time of BPH from eggs to adults (one lifecycle) is about 25-55 days, depending on the environmental factors. Development time taken by different stages decreases considerably when the temperature increases. Hatching percentage was drastically reduced with increasing in temperature due to inability off eggs to hatch [10].

The model also can simulate the development time, output for development time of BPH is given in figure 5.

**Figure 5.** BPH Development Time in Indramayu.
From the figure 5, we can notice the development time at all stages in late 2009 until late 2011 is shorter than any period on the graph. We know in almost through 2010, the La Nina event occurred and made the excess precipitation in most of area in Indonesia which is favorable to BPH. Therefore, the shorter time development of BPH means the BPH grows and regenerates more quickly. Meanwhile, the occurrence of El Nino event on late 2014 was not significantly extending the BPH development time based on the graph.

The longest development time spent by first and second instars of BPH nymph stage (blue line) that took 23 days in average, while the shortest development time is fifth instar of BPH nymph stage (purple line) that only took 1-3 days because it will enter the imago (adults) stage soon.

![Figure 6. Plot of BPH Development Time versus maximum temperature; a) Eggs; b) Nymphs; c) Adults.](image)

Based on the graphs at figure 6, we obtain the relationships between development time and (maximum) temperature that are suitable to the development time concept for eggs and adults stage with high correlation. But at the nymphs stage, there are not suitable with the concept of development time. The relationships are reverse with the eggs and adults stage. This case happened because the BPH real lifestage of nymphs has five instars, but the simulation only count three instars and can occur miscounting of development time of nymphs stage. Another assumption that the nymphs stage is different with the others. BPH did the aestivation mode dominantly at this stage, so their growth rate becomes slower and automatically the development time becomes longer.

Lastly, besides using the simulation models to predict the outbreaks population of BPH in relation with climate variability as prevention to minimize risks of BPH attack, we need to do comprehensive and integrated anticipation on pest management such as using crop rotation, using pest resistant crop varieties, using the natural enemies, and using the pesticide only if necessary.

4. Conclusions
Climate variability, mainly temperatures factor plays an important role in the different biological activities on poikilothermic organisms including BPH such as population dynamics, developmental time and lifecycle. The output of simulation model for BPH population dynamics is
relatively close to the pattern of both light trap observation data and the attacked area data in Indramayu installation pest laboratory, but overestimate to predict the population. Meanwhile, the output for eggs and adults development time are match with the concept which explain the higher temperature the shorter development time but at the nymphals stage is not suitable with such concept due to the limitation of the model.

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