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RESEARCH PAPER

Biology and demographic statistics of the green leafhopper (*Nephotettix virescens* Distant) as the main vector of tungro virus in tungro-resistant rice varieties

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ABSTRACT

Tungro disease is one of the major constraints to rice production in Indonesia. Although tungro-resistant rice varieties have proven effective in reducing the spread of the virus, it is essential to consider their impact on the development of vector insect populations. This study aims to investigate the biology and demographic characteristics of *Nephotettix virescens* Distant on various tungro-resistant rice varieties. The research was conducted by maintaining and observing the development of *N. virescens* on the tungro-resistant varieties Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37, as well as the susceptible variety Taichung Native 1 (TN 1), under controlled environmental conditions with regulated temperature and humidity. Development was observed daily until the last individual died. The results indicated that the life cycle, longevity, and lifespan of *N. virescens* maintained on tungro-resistant varieties differed significantly from those on the susceptible variety TN 1. The life cycle of *N. virescens* on Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37 was 27.57, 30.50, 27.60, 30.80, and 31.64 days, respectively, whereas on the susceptible variety TN 1, it lasted only 24.94 days. Demographic statistical analysis revealed that the net reproductive rate (R_o) and intrinsic rate of increase (r) of *N. virescens* maintained on tungro-resistant varieties were lower than those on the susceptible variety TN 1. Additionally, these tungro-resistant varieties resulted in a longer generation time (T) and doubling time (DT). Consequently, the tungro-resistant varieties negatively affected the vector by prolonging its life cycle, increasing the average generation time (T) and doubling time (DT), and reducing both the net reproductive rate (R_o) and the intrinsic rate of increase (r). These five varieties can be considered as options for varietal rotation to suppress the growth of insect vector populations and limit the spread of the tungro virus, especially in tungro-endemic areas.

Key words: Intrinsic rate of increase, life table, life cycle

INTRODUCTION

Rice is a vital cultivated crop, with over 3.5 billion people worldwide consuming it as a staple food and primary source of carbohydrates. In Indonesia, rice production in 2024 is projected to reach 52.66 million tons of milled dry grain (MDG), representing a decline of 1.32 million tons MDG, or 2.45%, compared to the 2023 production of 53.98 million tons MDG (BPS, 2023).

Tungro is a major disease and a significant constraint on rice production in South and Southeast Asia (Kumam et al., 2022). The potential yield of rice cannot be fully achieved if the crop is infected with the tungro virus, particularly during the early vegetative stage (Anand et al., 2022; Buresh et al., 2021). Tungro disease is caused by the co-infection of two distinct viruses: *Rice tungro spherical virus* (RTSV) and *Rice tungro bacilliform virus* (RTBV), which interact through a helper component (HC) mechanism (Ng & Zhou, 2015). Infected plants exhibit symptoms such as leaf discoloration, stunting, reduced tillering, and delayed flowering, along with the presence of vector insects in both adult and nymph stages (Kim et al., 2019; Kumar & Dasgupta, 2021; Rahayu et al., 2024). The virulence of tungro virus varies between endemic areas in Indonesia (Widiarta & Pakki, 2015). Tungro disease symptoms generally appear 6–15 days post-infection (Srilatha et al., 2019).

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Tungro disease is transmitted in a semi-persistent manner by several leafhopper species, including *Nephotettix virescens* Distant, *Nephotettix nigropictus, Nephotettix malayanus*, *Nephotettix cincticeps*, *Nephotettix parvus*, and *Recilia dorsalis*. The development of tungro disease is significantly influenced by the resistance of the plants and the population density of vector insects (Dey, 2016; Sutrawati et al., 2021; Hutasoit et al., 2023). Among these vectors, *N. virescens* is the most efficient in transmitting tungro disease (Azgar & Hembram, 2018) and is one of the most damaging pests to rice crops in Asia (Sharma et al., 2021).

One of the most economical and effective methods for controlling tungro disease is the use of resistant varieties (Hore et al., 2022). Virus-resistant varieties are developed from parents with resistance to *Rice tungro spherical virus* (RTSV), and some, such as ARC 11554, *Oryza rufipogon, Oryza officinalis, and Oryza longistaminata*, also show resistance to *N. virescens* (Cruz et al., 1993). RTSV acts as a helper virus, facilitating the transmission of *Rice tungro bacilliform virus* (RTBV) by vector species. This interaction induces tungro disease symptoms in infected rice plants (Hibino et al., 1978). The use of tungro-resistant rice varieties has been shown to effectively reduce disease spread (Bhusal et al., 2019). However, long-term management strategies are crucial to mitigate potential impacts on vector population dynamics. The continuous cultivation of virus-resistant rice varieties may inadvertently contribute to an increase in vector insect populations, leading to severe infestations and extensive crop damage, a phenomenon known as “hopper burn” (Patel, 2022).

The early detection of *Nephotettix virescens* population dynamics on tungro-resistant rice varieties is crucial for preventing outbreaks and ensuring effective pest management, particularly in tungro-endemic regions. The development and population growth of *N. virescens* are significantly influenced by the characteristics of rice varieties (Singh et al., 2010). Demographic statistics serve as essential tools for studying insect population dynamics, providing key parameters to understand and predict population trends (Naranjo & Ellsworth, 2017).

This study aims to investigate the biology and demographic characteristics of *N. virescens* on various tungro-resistant rice varieties. The findings are expected to enhance cultivation practices and improve the management of *N. virescens* populations.

MATERIALS AND METHODS

Research Site. The study was conducted in a screen house at the Tungro Disease Research Station in Lanrang, Timoreng Panua Village, Panja Rijang Subdistrict, Sidenreng Rappang Regency, South Sulawesi (latitude -3.84922, longitude 119.82534). The research took place from June 2019 to December 2020. During this period, the average daily temperature and relative humidity inside the screen house were 29.4 ± 3.0 ºC and 72.5 ± 14.2%, respectively.

Feed Preparation for Insect Rearing and Research. The susceptible rice variety Taichung Native 1 (TN1) and the resistant varieties Inpari 7, Inpari 8, Inpari 9 Elo, Inpari 36, and Inpari 37 were sown in plastic trays filled with soil and adequately watered. The plants were maintained in wooden enclosures covered with mesh fabric (diameter= 40 cm, height= 70 cm). Rice plants at 7 days after sowing (DAS) were used as a food source for insect rearing and biological observations of *N. virescens.*

Insect Rearing. *N. virescens* used in this study was obtained from the collection of the Tungro Disease Research Station. The insects were reared on rice plants incages covered with fine mesh (40 cm in diameter, 70 cm in height). Each cage was infested with 50 pairs of adult insects (imago). After 24 h, the adults were removed and transferred to fresh plants and cages. Daily observations were conducted to monitor their development. The rearing process was maintained continuously throughout the study period to ensure a stable population for experiments.

Biological Observations and Demographic Statistics of *N. virescens*. Fifty first-instar nymphs of uniform age, obtained from the rearing process, were individually reared on different rice varieties within acrylic tube cages (6 cm in diameter, 25 cm in height). Each cage contained a single rice plant, and one first-instar nymph was introduced per cage. Host plants were replaced upon yellowing to ensure adequate nutrition. Daily observations were conducted to record survival, mortality, and molting events until the insects reached the adult stage. Instar transitions were determined based on the presence of exuviae, and the sex of newly emerged adults was recorded.

Newly emerged adults, consisting of one female and two males, were placed in acrylic tube cages (6 cm in diameter, 30 cm in height) with a rice plant approximately two weeks old. The adults were transferred daily to a fresh rice plant in a new cage until the last female died. Rice plants previously exposed to ovipositing females were maintained to determine the egg incubation period for each rice variety. The number of emerging nymphs was recorded, and unhatched or non-viable eggs were counted under a microscope. The observed biological parameters included: 1) Duration from oviposition to first-instar nymph hatching; 2) Duration from first-instar to fifth-instar development; 3) Number of emerging male and female adults; 4) Adult longevity; 5) Pre-oviposition period (time from adult emergence to the onset of oviposition); 6) Total number of eggs laid by females.

Data Analysis. The observation data of *N. virescens* during one generation were compiled into a life table. The required parameters include: (1) x–the age class of the cohort (in days); (2) l_x–the probability of survival for each individual at age x; (3) m_x–the fecundity per individual at age x; (4) l_xm_x–the number of offspring produced at age class x.

These data were analyzed using the Jackknife method (Marlena, 2014), which involves iterative resampling by excluding one observation at a time. This approach was used to estimate bias and statistical variance, commonly applied in hypothesis testing and confidence interval calculations. The analyzed population parameters included: (1) Gross Reproduction Rate (GRR)= Σm_x; (2) Net Reproduction Rate (R_0)= Σl_xm_x; (3) Intrinsic Growth Rate (r)= ln (R_0)/T; (4) Mean Generation Time (T)= $\sum xl_xm_x/\sum l_xm_x$; and (5) Doubling Time (DT)= ln (2)/r. Data on pre-oviposition, life cycle, oviposition, periodicity, and longevity of *N. virescens* were analyzed using analysis of variance (ANOVA), followed by Duncan's multiple range test (α= 0.05) using SPSS 22.

RESULTS AND DISCUSSION

Biology of *N. virescens* on Tungro-resistant and Susceptible Rice Varieties. Female *N. virescens* lay eggs in clusters on the leaf sheaths of rice plants. Initially, the eggs are translucent white, gradually turning yellowish as they near hatching. The nymphs undergo five developmental stages, molting at each stage, corresponding to five distinct instars (Figure 1).

Table 1 presents the average pre-oviposition period, life cycle duration, oviposition period, fecundity, and lifespan of *N. virescens* reared on tungro-resistant and susceptible rice varieties. The data indicate that the pre-oviposition period of female *N. virescens* was consistently longer on tungro-resistant varieties compared to the susceptible TN1 variety. This extended pre-oviposition period correlated positively with the overall life cycle duration. The life cycle, defined as the period from egg deposition to first oviposition, significantly influenced the timing and rate of reproduction.

The life cycle duration of *N. virescens* on tungro-resistant varieties was longer than that reported by Hutasoit (2020a), who documented durations of 25.68 ± 1.21 days on the Ciherang variety and 26.11 ± 2.35 days on the IR 64 variety under greenhouse conditions (29.4 ± 3.0 ºC, 72.5 ± 14.2% RH). Similar variations in developmental and life cycle durations across rice cultivars have also been observed in brown planthoppers (*Nilaparvata lugens*) (Zheng et al., 2017; Kumar et al., 2020).

Variations in life cycle duration between resistant and susceptible rice varieties are likely influenced by host-related factors such as feeding suitability, behavioral adaptations, and nutritional quality. These factors directly affect fecundity and reproductive strategies (Awmack & Leather, 2002). The compatibility between herbivorous pests and their host plants plays a crucial role in shaping insect population dynamics and development. Therefore, host plant characteristics are key determinants of insect developmental biology (Koussoroplis & Wacker, 2016; McCormick et al., 2019; Maharani et al., 2021). Furthermore, Ruimassa et al. (2023) demonstrated that several tungro-resistant rice varieties containing RTBV gene fragments not only conferred protection against tungro disease but also significantly suppressed the development and reproduction of *N. virescens*, the primary vector of the virus.

The sex ratio of *N. virescens* on tungro-resistant and susceptible TN1 rice varieties is presented in Figure 2. The number of females slightly exceeded that of males across all varieties. The female-to-male ratios for Inpari 7, Inpari 8, Inpari 9, Inpari 36, Inpari 37, and TN1 were 1.2:1, 1:1, 1.18:1, 1:1, 1.11:1, and 1.19:1, respectively. These findings closely align with those reported by Singh et al. (2010) for the PR113, PR114, PR115, PR116, and TN1 varieties. A slight female-biased sex ratio is commonly associated with adequate food quality, the high reproductive capacity of females, and the potential for parthenogenesis, all of which contribute to increased female prevalence in the population (Graham & Knight, 1967).

Survival and Daily Periodicity of *N. virescens* on

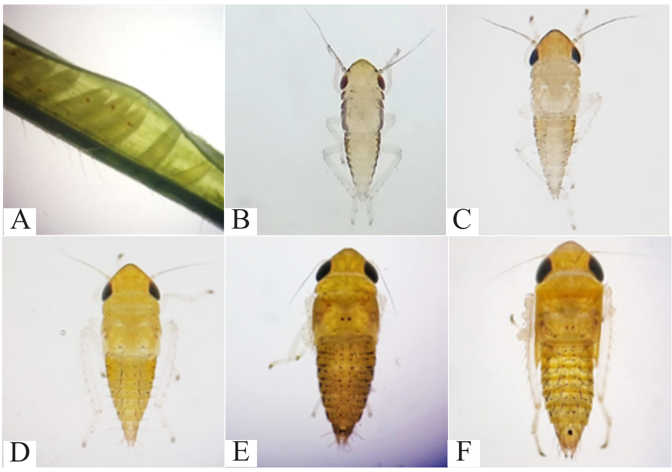

Figure 1. The pre-adult stages of *N. virescens*; A. Egg; B. First instar nymph; C. Second instar nymph; D. Third instar nymph; E. Fourth instar nymph; F. Fifth instar nymph.

Table 1. Population parameters of *N. virescens* on tungro-resistant and susceptible rice varieties

Parameters	Inpari 7	Inpari 8	Inpari 9	Inpari 36	Inpari 37	TN 1
Pre-oviposition period (days) ± SE	4.36 ± 0.16 bc	4.50 ± 0.18 c	4.50 ± 0.29 c	3.90 ± 0.15 ab	4.27 ± 0.15 bc	3.37 ± 0.11 a
Life cycle (days) ± SE	27.57 ± 0.46 b	30.50 ± 0.81 c	27.60 ± 1.13 b	30.80 ± 0.58 c	31.64 ± 0.65 c	24.94 ± 0.51 a
Oviposition period (days) ± SE	12.08 ± 1.15 c	7.42 ± 1.15 ab	9.60 ± 0.83 bc	7.70 ± 0.43 ab	5.82 ± 0.27 a	17.95 ± 1.04 d
Fecundity (eggs) ± SE	118.50 ± 14.42 b	55.67 ± 9.25 a	104.00 ± 8.20 b	54.80 ± 4.04 a	49.36 ± 3.45 a	245.68 ± 15.30 c
Longevity (days) ± SE	15.93 ± 1.93 a	12.50 ± 1.25 a	14.73 ± 1.64 a	12.60 ± 0.65 a	11.64 ± 0.47 a	25.68 ± 1.59 b

*Numbers within the same column for different varieties followed by the same letter indicate no significant difference based on the DMRT test at the 5% significance level; SE = Standard error.

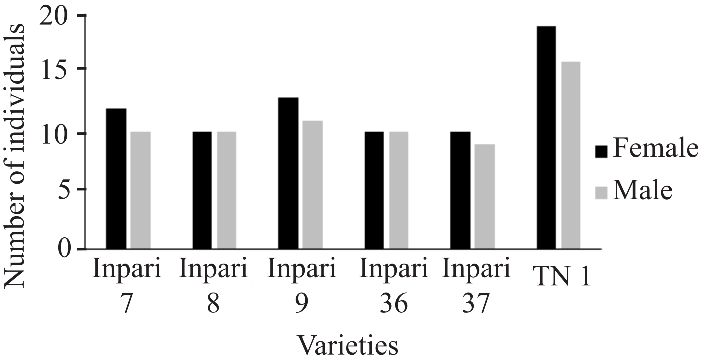

Figure 2. The proportion of females to males in tungro-resistant and susceptible rice varieties.

Tungro-resistant Rice Varieties. The survival and natality rates of *N. virescens* on the Tungro-resistant rice varieties Inpari 7, Inpari 8, Inpari 9, Inpari 36, Inpari 37, and the susceptible TN 1 variety are summarized in Table 2 and Figure 3. The highest mortality of *N. virescens* nymphs on the resistant varieties Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37 occurred during the early phase of the first instar, with mortality rates of 18%, 24%, 18%, 24%, and 30%, respectively. In contrast, the highest mortality on the susceptible variety TN 1 was observed at the third instar, with a mortality rate of 10% (Table 2). The proportion of nymphs that successfully developed into adults (imago) on the resistant varieties Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37 was 44%, 40%, 48%, 40%, and 36%, respectively. In comparison, 70% of nymphs on the susceptible TN 1 variety reached adulthood. These findings are consistent with those reported by Rosida et al. (2020), who observed lower survival rates of *N. virescens* in disease-resistant varieties compared to susceptible ones. Additionally, Singh et al. (2010) reported that survival rates of *N. virescens* nymphs on susceptible varieties can reach up to 92%.

The survival curve indicates significant differences in the survival probabilities of *N. virescens* adults between tungro-resistant rice varieties (Inpari

Table 2. Survival and fecundity of *N. virescens* on tungro-resistant and susceptible rice varieties

Stage	Inpari 7			Inpari 8			Inpari 9			Inpari 36			Inpari 37			TN 1		
	days	l_x	m_x	days	l_x	m_x	days	l_x	m_x	days	l_x	m_x	days	l_x	m_x	days	l_x	m_x
Eggs	6-8	1	-	6-8	1	-	5-8	1	-	6-9	1	-	6-9	1	-	6-9	1	-
Instar 1	1-5	0,82	-	2-5	0,76	-	2-3	0,82	-	2-4	0,76	-	2-4	0,70	-	2-4	0,94	-
Instar 2	2-5	0,70	-	2-4	0,70	-	2-6	0,76	-	2-4	0,64	-	2-5	0,58	-	2-4	0,88	-
Instar 3	2-6	0,56	-	3-6	0,54	-	2-7	0,64	-	2-6	0,50	-	2-6	0,42	-	2-5	0,78	-
Instar 4	2-6	0,50	-	2-7	0,46	-	3-12	0,56	-	2-9	0,46	-	2-9	0,38	-	2-6	0,74	-
Instar 5	3-6	0,44	-	4-9	0,40	-	3-10	0,48	-	3-10	0,40	-	2-10	0,36	-	3-7	0,70	-
Imago	4-26	0,44	10,82	7-21	0,40	8,67	3-21	0,48	10,63	10-17	0,40	8,78	9-14	0,36	8,11	14-34	0,70	18,95

7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37) and the susceptible variety TN 1. For the resistant varieties, the curve shows a steep decline shortly after adult emergence, indicating high mortality rates during the early adult stage. In contrast, the survival curve for TN 1 remains relatively stable immediately after emergence, with a sharp decline occurring only as the adults age. These patterns suggest substantially higher young adult mortality on resistant varieties, while mortality on TN 1 increases gradually with age. Specifically, for *N. virescens* reared on tungro-resistant varieties, mortality begins as early as the second day after adult emergence, while on the susceptible TN 1 variety, adult mortality starts only on the 12th day after emergence. Auclair et al. (1982) and Yesuraja & Mariappan (1993) reported that resistant and susceptible rice varieties may secrete acidic and basic compounds when consumed by *N. virescens*, potentially affecting the insect's survival. Factors such as elevated levels of sugars and amino acids, as well as the presence of aromatic compounds, attractants, or repellents in the host plant, play a crucial role in determining the lifespan of *N. virescens*. Additionally, Kobayashi et al. (1993) found that three accessions of *Oryza rufipogon* exhibited high resistance to vector insects and *Rice tungro spherical virus* (RTSV). Therefore, selecting plants solely for resistance to vector insects or specific viruses, such as RTSV and RTBV, may not guarantee the overall effectiveness of tungro disease resistance improvement programs.

N. virescens reared on both tungro-resistant and susceptible rice varieties exhibit a Type III survival curve, characterized by high mortality rates during the pre-adult stages. Survival curves are generally classified into three types: Type I, which represents low mortality during early life stages with mortality gradually increasing with age; Type II, which indicates a constant mortality rate across all life stages; and Type III, which is defined by high mortality rates in the early stages of life. The timing of increased mortality plays a critical role in shaping population dynamics (Price, 1997).

The fecundity curve (m_x) indicates that *N. virescens* begins oviposition earlier on the susceptible TN 1 variety compared to tungro-resistant varieties, with oviposition starting on day 23 after infestation. On resistant varieties such as Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37, oviposition begins consecutively on days 26, 27, 29, 30, and 30, respectively. The fecundity peak of *N. virescens* occurs earlier and is higher on the susceptible variety, reaching a maximum of 18.95 eggs on day 30 after infestation. In contrast, on the resistant varieties, the earliest and highest fecundity peak is observed on day 35 after infestation, with an average of 10.82 eggs laid on Inpari 7 (Figure 3).

The daily oviposition patterns of *N. virescens* females are irregular. On tungro-resistant varieties, females lay between 1 and 26 eggs per day, whereas on the susceptible TN 1 variety, they lay between 1 and 38 eggs per day. The total number of eggs laid by females varies significantly across resistant varieties: 118.50 on Inpari 7, 55.67 on Inpari 8, 104.00 on Inpari 9, 54.80 on Inpari 36, and 49.36 on Inpari 37. In comparison, females on the susceptible TN 1 variety lay an average of 245 eggs. These findings highlight the significant impact of host plant resistance on the reproductive performance of *N. virescens*, with susceptible varieties supporting higher fecundity and earlier oviposition peaks. Sublethal application of Sambilata extract has also been reported to reduce the fecundity of green leafhoppers (Widiarta & Kusdiaman, 2008).

The low fecundity of *N. virescens* on tungro-resistant rice varieties can be attributed to the shorter lifespan of adult females. The average lifespan of females on resistant varieties—Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37—is 15.93, 12.50, 14.73, 12.60, and 11.64 days, respectively. In contrast, females on the susceptible TN 1 variety live an average of 25.68 days. The shorter lifespan of females on resistant varieties limits their oviposition period, resulting in fewer eggs being laid. The oviposition

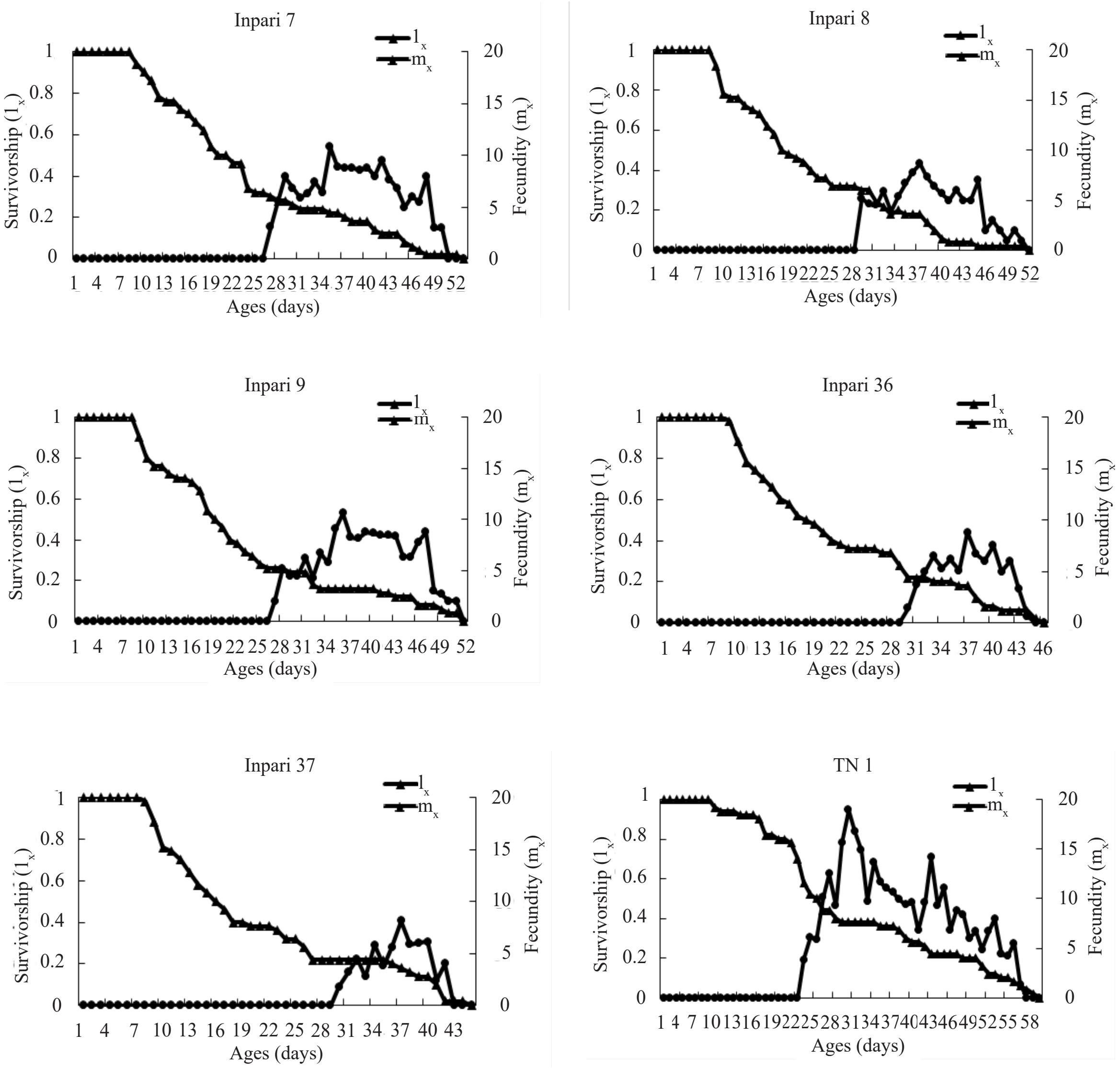

Figure 3. Survival curve (l_x) and fecundity curve (m_x) of *N. virescens* on tungro-resistant and susceptible rice varieties.

period on resistant varieties lasts 12.00, 7.42, 9.60, 7.80, and 5.82 days for Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37, respectively, compared to 17.89 days on TN 1. Differences in oviposition duration and fecundity are likely influenced by variations in the nutritional composition of host plants, which directly affect the biology of *N. virescens*. Pinto et al. (2019) reported that the nutrient content of host plants significantly affects insect lifespan and reproductive capacity. Additionally, Yesuraja & Mariappan (1993) observed that susceptible rice varieties contain higher levels of total soluble sugars, reducing sugars, and non-reducing sugars, whereas tungro-resistant varieties exhibit increased concentrations of total phenols and ortho-dihydric phenols. Furthermore, Rashid et al. (2015) demonstrated a positive correlation between the fecundity of *Nilaparvata lugens* and the total free sugar (TFS) content in plant tissues. Similarly, Vijaykumar et al. (2009) reported that phenolic compounds play a significant role in rice varieties exhibiting resistance conferred by the Gm2 gene against gall midge infestation. Our findings align with previous studies on resistance mechanisms in rice and weed cultivars. Based on honeydew analysis, insects such as *N. malayanus* preferentially feed on xylem sap, which contains lower nutrient levels, rather than on tungro virus-infected tissues (Kim et al., 1986; Favali et al., 1975). These observations collectively highlight the critical role of plant biochemical composition in influencing the survival and reproductive success of *N. virescens.*

Demographic Statistics of *N. virescens* on Tungro-Resistant Rice Varieties. The demographic parameters of *N. virescens* on tungro-resistant rice varieties and

Table 3. Demographic parameters of *N. virescens* on tungro-resistant and susceptible rice varieties

Variety	Demographic Parameters (Mean ± SE)			
	Net reproductive rate (R_0)	Intrinsic growth rate (rm)	Mean generation time (T)	Doubling time (DT)
	(individuals/female/generation)	(individuals/female/days)	(days)	(days)
Inpari 7	28.78 ± 0.08	0.10 ± 0,00	33.52 ± 0.01	6.95 ± 0.02
Inpari 8	14.47 ± 0.08	0.08 ± 0.00	34.96 ± 0.01	8.70 ± 0.02
Inpari 9	23.62 ± 0.13	0.09 ± 0.00	33.68 ± 0.03	7.67 ± 0.01
Inpari 36	11.12 ± 0.06	0.07 ± 0.00	34.68 ± 0.01	9.99 ± 0.02
Inpari 37	10.36 ± 0.06	0.07 ± 0.00	34.80 ± 0.01	10.32 ± 0.02
TN 1	100.55 ± 0.37	0.15 ± 0.00	30.97 ± 0.01	4.66 ± 0.00

the susceptible TN 1 variety are presented in Table 3. The net reproductive rate (R_o) of *N. virescens* was significantly lower on tungro-resistant varieties, with the highest value recorded at 28.78 ± 0.08 on the Inpari 7 variety. This value indicates that the next generation of *N. virescens* increases 28.78 ± 0.08 times larger than the current generation. In contrast, on the susceptible TN 1 variety, the R_o reached 100.55 ± 0.37, meaning the next generation was 100.55 ± 0.37 times larger than the current one. The lower $\mathrm{R_o}$ values observed on tungro-resistant varieties suggest their relative unsuitability as host plants for *N. virescens*. Hutasoit et al. (2020b) reported that a high R_o reflects strong compatibility between an insect pest and its host plant. Furthermore, Price (1997) explained that a population will grow if $R_o > 1$, remain stable if $R_o = 1$, and decline if $R_o < 1$.

The r value represents the intrinsic growth rate of a population in an environment with constant conditions and unlimited resources. This parameter can be used to predict the long-term population growth of insects. The intrinsic growth rate (r) of *N. virescens* on tungro-resistant varieties was found to be 0.10 per day on the Inpari 7 variety, whereas on the susceptible TN 1 variety, r reached 0.15 per day. The intrinsic growth rate of *N. virescens* on the susceptible TN 1 variety is consistent with findings reported by Valle et al. (1986), who observed a range of 0.166–0.194 individuals per female per day at temperatures between 27 ºC and 30 ºC in laboratory conditions. The lower r value observed on tungro-resistant varieties may be attributed to a longer pre-adult stage compared to the oviposition period (Fachrudin, 1980). A lower r value indicates a reduced potential for population increase in *N. virescens* on tungro-resistant rice varieties.

The average generation time (T) of *N. virescens* on the susceptible TN 1 variety is 30.97 days, while on tungro-resistant varieties, it extends to 34.80 days. The shortest population doubling time (DT) of *N. virescens* occurs on the susceptible TN 1 variety, with an average of 4.66 days, whereas the longest doubling time is observed on the Inpari 37 variety, averaging 10.32 days. The reduced fecundity of *N. virescens* on the Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37 varieties contributes to the extended population doubling time and the corresponding decline in intrinsic growth rate. A shorter generation time (T) indicates a faster population growth rate compared to populations with a longer T value. As noted by Southwood & Henderson (2000), population growth is inversely related to generation time, such that an increase in generation time results in a slower population growth rate.

CONCLUSION

The tungro-resistant rice varieties Inpari 7, Inpari 8, Inpari 9, Inpari 36, and Inpari 37 serve as suboptimal hosts for the development of *N. virescens*, as indicated by their extended life cycle, reduced fecundity, and shorter adult lifespan. The low net reproductive rate (R_0) and intrinsic growth rate (r), along with prolonged generation time (T) and slower population doubling time (DT) observed on these resistant varieties, suggest that they may effectively suppress *N. virescens* population growth and mitigate tungro virus transmission.

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AUTHORS' CONTRIBUTIONS

RTH and MJ designed and conducted the experiments. RTH and INW analyzed the data and prepared the manuscript. MJ, AS, S, and MP contributed to revising the manuscript. All authors reviewed and approved the final version.

COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have influence the work reported in this paper.

REFERENCES

Anand A, Pinninti M, Tripathi A, Mangrauthia SK, & Sanan-Mishra N. 2022. Coordinated action of RTBV and RTSV proteins suppress host RNA silencing machinery. *Microorganisms*. 10(2): 197. https://doi.org/10.3390/microorganisms10020197

Auclair JL, Baldos E, & Heinrichs EA. 1982. Biochemical evidence for the feeding sites of the leafhopper, *Nephotettix virescens* within susceptible and resistant rice plants. *Int. J. Trop. Insect Sci.* 3: 29–34. https://doi.org/10.1017/S1742758400001855

Azgar MA & Hembram TK. 2018. A Comparative studies on the population dynamic and survival of green leaf hopper and zigzag leaf hopper transmitting rice tungro virus in West Bengal. *The Bioscane.* 13(2): 607–611.

Awmack CS & Leather SR. 2002. Host plant quality and fecundity in herbivorous insects. *Annu Rev Entomol.* 47: 817–844. https://doi.org/10.1146/annurev.ento.47.091201.145300

Bhusal K, Sagar GC, & Bhattarai K. 2019. A Review of rice tungro virus in Nepal. *J. Plant Sci. Crop Prot.* 2(1): 101.

Buresh RJ, Correa Jr TQ, Pabuayon ILB, Laureles EV, & Choi IR. 2021. Yield of irrigated rice affected by asymptomatic disease in a long-term intensive monocropping experiment. *Field Crops Res.* 265: 108121. https://doi.org/10.1016/j.fcr.2021.108121

BPS. 2023. *Berita Resmi Statistik [Official Statistical Report]*. https://www.bps.go.id/id/pressrelease/2024/10/15/2376/luas-panen-padi-tahun-2024-diperkirakan-sebesar-10-05-juta-hektare-dengan-produksi-padi-sekitar-52-66-juta-ton-gabah-kering-giling--gkg--.html. Accessed 21 October 2024.

Cruz FCS, Koganezawa H, & Hibino H. 1993. Comparative cytology of rice tungro viruses in selected rice cultivars. *J. Phytopathol.* 138(4): 274–282. https://doi.org/10.1111/j.1439-0434.1993.tb01387.x

Dey SR. 2016. Green leafhopper (GLH), *Nephotettix virescens* (Distant) and rice tungro disease (RTD). *The Beats Nat. Sci.* 3(3–4): 1–7.

Fachrudin. 1980. Bionomi *Nephotettix Virescens* (Distant) (Homoptera: Cicadellidae: Euscelidae) [Bionomy of *Nephotettix virescens* (Distant) (Homoptera: Cicadellidae: Euscelidae)]. *Dissertation*. Institut Pertanian Bogor. Bogor.

Favali MA, Pellegrini S, & Bassi M. 1975. Ultrastructural alterations induced by rice tungro virus in rice leaves. *Virology.* 66(2): 502–507. https://doi.org/10.1016/0042-6822(75)90222-6

Graham SA & Knight FB. 1967. *Principles of Forest Entomology.* McGraw-Hill Book Company. New York.

Hibino H, Roechan M, & Sudarisman S. 1978. Association of two types of virus particles with penyakit habang (tungro disease) of rice in Indonesia. *Phytopathology.* 68: 1412–1416. https://doi.org/10.1094/Phyto-68-1412

Hore TK, Inabangan-asilo MA, Wulandari R, Latif MA, Nihad SAI, Hernandez JE, Gregorio GB, Dalisay TU, Diaz MGQ, Balachiranjeevi Ch, & Swamy BPM. 2022. Introgression of *tsv1* improves tungro disease resistance of a rice variety BRRI dhan71. *Sci. Rep.* 12: 18820. https://doi.org/10.1038/s41598-022-23413-4

Hutasoit RT. 2020a. Bionomi dan statistik demografi wereng hijau (*Nephotettix virescens* Distant) pada varietas Ciherang dan IR 64 [Bionomy and Demographic Statistics of the Green Planthopper

(*Nephotettix virescens* Distant) on the Ciherang and IR 64 varieties]. In: Dewi P, Widiyaningrum P, Yuniastuti A, Susanti R, Anngraito YU, Rahayuningsih M, Mubarok I, & Christijanti W (Eds.) *Prosiding Seminar Nasional Biologi VIII*. pp. 88–96. Universitas Negeri Semarang, Semarang.

Hutasoit RT, Kalqutny SH, & Widiarta IN. 2020b. Spatial distribution pattern, bionomic, and demographic parameters of a new invasive species of armyworm *Spodoptera frugiperda* (Lepidoptera; Noctuidae) in maize of South Sumatra, Indonesia. *Biodiversitas*. 21(8): 3576–3582. https://doi.org/10.13057/biodiv/d210821

Hutasoit RT, Jihad M, Listihani, & Selangga DGW. 2023. The relationship between vector insect populations, natural enemies, and disease incidence of tungro virus during wet and dry seasons. *Biodiversitas*. 24(7): 4001–4007. https://doi.org/10.13057/biodiv/d240737

Kim KH, Raymundo AD, & Aikins CM. 2019. Development of a rice tungro epidemiological model for seasonal disease risk management in the Philippines. *Eur. J. Agron.* 109: 125911. https://doi.org/10.1016/j.eja.2019.04.006

Kim HS, Heinrichs EA, & Rapusas HR. 1986. Levels of resistance of rice cultivars and the weed *Leersia hexandra* L. to *Nephotettix malayanus* Ishihara et Kawase and *N. virescens* (Distant). *Crop Prot*. 5(6): 400–405. https://doi.org/10.1016/0261-2194(86)90072-4

Kobayashi N, Ikeda R, Dominggo IT, & Vaughan DA. 1993. Resistance to infection of rice tungro viruses and vector resistance in wild species of rice (*Oryza* spp.). *Jap. J. Breed.* 43(3): 377–387. https://doi.org/10.1270/jsbbs1951.43.377

Koussoroplis AM & Wacker A. 2016. Covariance modulates the effect of joint temperature and food variance on ectotherm life-history traits. *Ecol. Lett.* 19(2): 143–152. https://doi.org/10.1111/ele.12546

Kumam Y, Rajadurai G, Kumar KK, Varanavasiappan S, Reddy MK, Krishnaveni D, Mangrauthia SK, Raveendran M, Arul L, Kokiladevi E, & Sudhakar D. 2022. Genome editing of *indica rice* ASD16 for imparting resistance against rice tungro disease. *J. Plant Biochem Biotechnol.* 31(4): 880–893. https://doi.org/10.1007/s13562-021-00765-y

Kumar G & Dasgupta I. 2021. The titers of rice tungro bacilliform virus dictate the expression levels of genes related to cell wall dynamics in rice plants affected by tungro disease. *Arch. Virol.* 166: 1325–1336. https://doi.org/10.1007/s00705-021-05006-0

Kumar V, Singh H, Kumar S, Kumar S, & Gautam MP. 2020. Age specific life table of rice brown plant hopper, *Nilaparvata lugens* Stal. on Pusa Basamati-1 and Pant Dhan-12 under natural condition. *J. Exp. Zool. India.* 23(1): 159–163.

Maharani Y, Puspitaningrum D, Istifadah N, Hidayat S, & Ismail A. 2021. Biology and life table of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) on maize and rice. *Serangga.* 26(4): 161–174.

Marlena L. 2014. Optimasi ukuran subcontoh melalui bootstrap dan jackknife untuk pendugaan statistik demografi hama Aphis glycines. [Optimization Subsample Size by Bootstrap and Jackknife to Estimate Demographic Statistic of Pest Aphis glycines]. Skripsi. Institut Pertanian Bogor. Bogor.

McCormick AC, Arrigo L, Eggenberger H, Mescher MC, & De Moraes CM. 2019. Divergent behavioural responses of gypsy moth (*Lymantria dispar*) caterpillars from three different subspecies to potential host trees. *Sci. Rep.* 9: 8953. https://doi.org/10.1038/s41598-019-45201-3

Naranjo SE & Ellsworth PC. 2017. Methodology for developing life tables for sessile insects in the field using the whitefly, *Bemisia tabaci*, in cotton as a model system. *J. Vis. Exp.* 129: e56150. https://doi.org/10.3791/56150

Ng JCK & Zhou JS. 2015. Insect vector-plant virus interactions associated with non-circulative, semi-persistent transmission: current perspectives and future challenges. *COVIRO.* 15: 48–55. https://doi.org/10.1016/j.coviro.2015.07.006

Patel LC. 2022. Efficacy of some insecticides against green leaf hopper, *Nephotettix virescens* Distant (Hemiptera: Cicadellidae) and brown plant hopper, *Nilaparvata lugens* Stal (Hemiptera: Delphacidae) in rice with safety to natural enemies. *J. Entomol. Res.* 46(4): 780–788. https://doi.org/10.5958/0974-4576.2022.00134.7

Pinto JRL, Torres AF, Truzi CC, Vieira NF, Vacari AM, & De Bortoli SA. 2019. Artificial corn-based diet for rearing *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *J. Insect Sci*. 19(4): 1–8. https://doi.org/10.1093/jisesa/iez052

Price PW. 1997. *Insect Ecology. Third Edition.* John Wiley and Sons. New York.

Rahayu S, Hannum S, Cristin L, & Tampubolon DM. 2024. Detection of *Rice tungro bacilliform virus* (RTBV) causes of tungro disease in rice plant (*Oryza sativa* L.) in Langkat, North Sumatera using PCR (Polymerase Chain Reaction) technique. *IOP Conf. Ser.: Earth Environ. Sci.* 1352: 012043. https://doi.org/10.1088/1755-1315/1352/1/012043

Rashid MM, Jahan M, & Islam KS. 2015. Response of adult brown planthopper *Nilaparvata lugens* (Stål) to rice nutrient management. *Neotrop. Entomol.* 45: 588–596. https://doi.org/10.1007/s13744-016-0401-2

Rosida N, Komalasari E, & Praptana RH. 2020. Preference test of green leaf hopper (*Nephotettix virescens* Distant) to some tungro-resistant promising lines. *Agric.* 3(2): 105–120. https://doi.org/10.24246/agric.2020.v32.i2.p105-120

Ruimassa RMR, Holle Y, & Manzila I. 2023. Endogenous like sequence *Rice tungro bacilliform virus* (RTBV) fragments in the local rice genome and its role in controlling tungro disease. *IOP Conf. Ser.: Earth Environ. Sci.* 1192: 012018. https://doi.org/10.1088/1755-1315/1192/1/012018

Sharma KR, Raju SVS, Meena RS, Babu SR, & Singla S. 2021. Weather based prediction model for green leafhopper (GLH), *Nephotettix virescens* distant of rice in middle gangetic plains. *J. Entomol. Res.* 45(4): 675–678. http://dx.doi.org/10.5958/0974-4576.2021.00106.7

Singh R, Sohi AS, & Shukla KK. 2010. Multiplication and development of *Nephotettix virescens* (Distant) (Hemiptera: Cicadellidae) on different cultivars of rice. *Indian J. Ecol.* 37(1): 86–88.

Southwood TRE & Henderson PA. 2000. *Ecological Method. Third Edition.* Blackwell Science. Oxford.

Srilatha P, Yousuf F, Methre R, Vishnukiran T, Agarwal S, Poli Y, Reddy MR, Vidyasagar B, Shanker C, Krishnaveni D, Triveni S, Brajendra, Praveen S, Balachandran SM, Subrahmanyam D, & Mangrauthia SK. 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

Sutrawati M, Ganefianti DW, Sipriyadi S, Wibowo RH, Agustin Z, Listihani, & Selangga DGW. 2021. Disease incidence and molecular diversity of Tungro virus on rice (*Oryza sativa*) in Bengkulu, Indonesia. *IJAT.* 17(5): 1973–1984.

Valle RR, Nakasuji F, & Kuno E. 1986. A comparative study of the different bionomic and demographic parameters of four green leafhoppers, *Nephotettix* spp. (Homoptera: Cicadellidae). *Appl. Entomol. Zool*. 21(2): 313–321. https://doi.org/10.1303/aez.21.313

Vijaykumar L, Chakravarthy AK, Patil SU, & Rajanna D. 2009. Resistance mechanism in rice to the midge *Orseolia oryzae* (Diptera: Cecidomyiidae). *J. Econ. Entomol.* 102(4): 1628–1638. http://dx.doi.org/10.1603/029.102.0430

Widiarta IN & Kusdiaman D. 2008. Pengaruh sublethal ekstrak sambilata (Andrographis paniculata Nees) terhadap aktivitas musuh alami dan keperidian wereng hijau. *J Trop Plant Pests Dis*. 8(2): 75–81. https://doi.org/10.23960/j.hptt.2875-81

Widiarta IN & Pakki S. 2015. Variasi virulensi virus tungro dari inokulum di daerah endemik tungro di Indonesia. *J Trop Plant Pests Dis*. 15(1): 1–9. https://doi.org/10.23960/j.hptt.1151-9

Yesuraja I & Mariappan V. 1993. Biochemical differences in the rice varieties susceptible and resistant to rice tungro virus. *Madras Agric. J.* 80(9): 486–490. https://doi.org/10.29321/MAJ.10.A01687

Zheng XM, Tao YL, Chi H, Wan FH, & Chu D. 2017. Adaptability of small brown planthopper to four rice cultivars using life table and populaion projection method. *Sci. Rep.* 7: 42399. https://doi.org/10.1038/srep42399