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An Investigation into the Biology and Lifetable characteristics of Whitebacked Plant Hopper, Sogatella furcifera (Horvath) in Paddy field

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Abstract

The white backed plant hopper, *Sogatella furcifera* (Horvath), poses a significant threat to cultivation of Pusa basmati, leading to considerable economic losses. Research conducted in Satna (M.P.) has unveiled crucial insights into its biology. Findings revealed that the average fecundity was approximately 184 ± 16.58 eggs per female. The incubation period, observed in October, lasted for about 7.4 ± 1.04 days, while the nymphal stage extended for 14.82 ± 0.62 days. Male macropterous individuals exhibited a longevity of 10.2 ± 2.44 days, while brachypterous males survived for 6.9 ± 1.78 days. Female brachypterous individuals had a lifespan of approximately 14.25 ± 1.36 days. Various reproductive parameters were also assessed, including the net fecundity rate (30.26), intrinsic rate of increase (0.124), gross reproductive rate (106.4), generation time (26.32 days), doubling time (5.86 days), finite rate of increase (1.132), and net reproductive rate (62.66). Seasonal abundance studies conducted during the rainy season on paddy fields indicated a gradual increase in incidence, with a peak observed at 31.80 and 34.40 individuals per hill at 120 DAT during the second week of November. Subsequently, the pest population declined, disappearing entirely by the third week of November, coinciding with the onset of winter, as observed in both 2022 and 2023.

Key words: *Sogatella furcifera*, growth and development, winter, macropterous, brachypterous, fecundity, longevity, paddy

Introduction:

The whitebacked plant hopper *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae) poses a significant threat to rice cultivation in eastern India. Its presence was initially documented in Japan in 1899 and in India in 1903 (Chaudhury et al., 1968; Dale, 1994).

Outbreaks have been reported in Bangladesh, Indonesia, Malaysia, Nepal, Pakistan, and Vietnam (Mochida et al., 1979). Subsequently, *S. furcifera* has progressively spread to various regions including Myanmar, China, Hong Kong, Japan, Kampuchea, Laos, the Philippines, the Ryukyu Islands, Taiwan, Thailand, the USSR, Australasia, and Pacific Islands, Australia, Fiji, Irian (Jaya), Marianas Island and Marshal Island (Dale, 1994). Khan and Misra (2003) noted its population peak in October in Uttar Pradesh, while Vijaykumar and Patil (2004) observed its presence from September to December in Karnataka. Katti et al. (2005) documented its occurrence during the rainy and summer seasons in Andhra Pradesh. In Odisha, Sarkar et al. (2018) observed the highest occurrence of *S. furcifera* during the 2nd week of November and the 3rd week of September. Kumar et al. (2015) conducted a study on the biology of *S. furcifera* on basmati rice in Haryana, revealing a fecundity of 132.8 eggs per female within a cluster of 5 to 30 eggs. Temperature's effect on its biology was investigated in Punjab (Sandhu and Suri, 2018). Lifetables analysis is commonly employed to evaluate the natality and reproduction of insect populations (Southwood, 1966; Price, 1997), as demonstrated by Chi (1988) with the brown plant hopper *Nilaparvata lugens* (Stal.).

The increasing fecundity of *S. furcifera* in Asia, particularly among Asian farmers adopting hybrid rice varieties, especially those with a cytoplasmic male sterile lineage, has become notable in recent decades. This trend may be influenced by gradual changes in global temperatures/climate (Horgan et al., 2016). Despite this, there remains a dearth of information regarding the lifetable of *S. furcifera* on rice crops in eastern India, thus prompting the present study.

Materials and Methods

A field experiment was conducted at the Agronomy field, FAST, AKS University Satna (MP) over two wet seasons from July to October (rainy season) in 2022-23. The long-duration, pest-susceptible variety Pusa basmati was transplanted in a 0.40 ha plot on 3rd July, with a spacing of 20x15cm following standard agronomic practices. Incidence of *S. furcifera* was monitored at weekly intervals, commencing 15 days after transplanting. This was achieved by trapping both nymphs and adults from 30 randomly selected plants using enamel trays measuring 30x20 cm containing a small quantity of soapy water. Additionally, data on *S. furcifera* were collected at 3-day intervals using sweeping nets and light traps; randomly selected 10 m2 areas were swept five times during the morning hours to collect *S. furcifera*. The pooled data were retransformed before undergoing statistical analysis. Simultaneously, in a separate study, *S. furcifera* were reared in the laboratory on potted rice plants of the cultivar Pusa basmati.

Initially, heavily infested plants were enclosed in a cage to establish a mass culture containing freshly emerged last instar nymphs. After one or two days, the mated females were transferred to another set of 10 potted plants covered with glass chimneys. The potted plants

were changed daily in the morning until the adults perished. This experiment was repeated five times by introducing females from each cohort into the laboratory conditions (25 to 30ºC, 80 to 85% RH). Daily observations were recorded to study the biology until the start of the subsequent generation. Parameters observed included preoviposition and oviposition periods, the period from emergence to death, and the fecundity of females. After the emergence of first instar nymphs, the plants were longitudinally cut, and the total number of hatched and unhatched eggs were counted under a microscope. The data were then used to compute the life table according to the method outlined by Southwood (1966).

Results and Discussion

Sogatella furcifera exhibited egg, nymph, and adult stages, with both male and female adults observed together immediately after emergence, remaining in close proximity for at least 3 hours. The females engaged in abdomen vibration, while the males, in an excited state, either fluttered their wings or performed a dance-like behavior before mating. Evening hours were found to be optimal for mating. While 2 to 3 males typically pursued a single female, ultimately, only one male successfully mated with a female, with the mating period lasting for an average of 159 ± 09.34 seconds. Long et al. (2012) also noted that successful mating in *N. lugens* relied on the exchange of acoustic signals between male and female. After mating, the female made vertical cuts in the mid-region of the leaf sheath and deposited approximately 21 eggs on the first day, ultimately laying a total of 184 ± 16.58 eggs in nearby 5 to 10 tillers within 8 to 10 days. The egg-laying sites manifested as brownish streaks on the leaf sheath. Macropterous males survived for an average of 10.2 ± 2.44 days, whereas brachypterous males perished after 6.9 ± 1.78 days; females survived for an average of 14.25 ± 1.36 days, remaining beside the egg slits until the emergence of the first instar nymphs. The incubation period lasted for 7.4 ± 1.04 days, with the nymphal developmental period extending to 14.82 ± 0.62 days, comprising five instars requiring 2.62 ± 0.54, 2.36 ± 0.33, 2.76 ± 0.36, 2.78 ± 0.43, and 3.44 ± 0.84 days, respectively. These findings are consistent with those reported by Kumar et al. (2015). Additionally, the net fecundity rate, mean length of generation, finite rate of increase, mean generation time, weekly population multiplication, and population doubling time were determined. The net fecundity rate (R_0) and net reproductive rate (Rt) were calculated as 30.26 and 62.66, respectively (see Table 1).

The findings of this study are consistent with those of van Lenterenand Noldus (1990), who observed that a short developmental time and high reproduction rate on a host indicate the suitability of the tested plant. Win et al. (2011) also reported a basic reproductive rate (Ro) of 10.02 for BPH, indicating a tenfold increase in population. Moreover, during the wet season, the study revealed an innate capacity (rc), intrinsic rate of increase (rm), and finite rate of increase of 0.122, 0.124, and 1.132, respectively. The intrinsic birth rate was recorded as 2.68, matching the intrinsic death rate of 2.65, resulting in a population doubling time of only 5.84 days.

Consequently, the population of *S. furcifera* could not sustain its rm value indefinitely under specific environmental conditions. These findings align with those of Win et al. (2009), who documented an innate capacity (rc) and intrinsic rate of natural increase (rm) for BPH as 0.117 and 0.122, respectively. The rm, Tc, and DT values are valuable indicators of *S. furcifera* population growth on the highly susceptible Pusa basmati variety during the wet season in West Bengal. The rm value derived from life table data offers insights into the characteristic life patterns of different species (Satpute et al., 2005), with the intrinsic birth and death rates subject to variation due to various biotic and abiotic factors.

Andrewartha and Birch (1954) noted that in populations with stable age distributions and unlimited space, both birth and death rates remain constant. Predicting the growth and decline of the WBPH population in a particular variety of rice crop could be achieved by quantifying these rates. The study revealed that the survival potential (lx) of females and the age-specific fecundity rate (mx) peaked on the second day and then gradually declined with advancing age. Early-stage mortality was high, followed by a gradual decrease in population densities throughout the lifespan. Seasonal incidence studies of *S. furcifera* indicated that it appeared with a very small average population of 0.9 macropterous adults per hill at 60 DAT during the first week of September. Nymphs appeared at 75 DAT during the second week of September, with an average population of 1.6 and 2.2 per hill during 2022 and 2023, respectively. The population increased when the second-generation nymphs emerged, averaging 3.4 and 4.3 per hill, respectively, at 105 DAT during the second week of October for the subsequent two years of study (Table 1; Fig. 1).

Sogatella furcifera incidence reached its peak at 31.80 and 34.40 individuals per hill at 120 DAT during the second week of November, followed by a sudden disappearance from the third week of November with the onset of winter. The insect exhibited a clustering habit at the base of plants or on the undersurface of leaves. Correlation analysis between incidence and weather parameters indicated a positive relationship with maximum temperature (r= 0.174 to 0.494) but a significantly negative association with minimum temperature (r= -0.166 to -0.553) during 2022. This trend remained consistent in 2023, with correlation coefficients of 0.152 to 0.164 and -0.131 to -0.173 for maximum and minimum temperatures, respectively. A positive correlation was observed with maximum relative humidity (RH) (r= 0.214 to 0.676), while a negative correlation was found with minimum RH (r= -0.169 to -0.236) during 2022. Similar positive (r= 0.161 to 0.556) and negative (-0.110 to -0.217) correlations were also observed in 2023. These findings align with those of Sarkar et al. (2018) regarding temperature and high relative humidity. Khan and Misra (2003) also noted a positive correlation with temperature and RH. The upper temperature tolerance for adult females was estimated to be between 37-41°C (Ali et al., 2019).

Conclusion

The incidence of *S. furcifera* in the Satna area is gradually reaching an alarming level. Among the life table parameters, the high net reproductive rate (Rt) and finite rate of increase, coupled with a shorter doubling time (DT), indicate that *S. furcifera* has the capacity for rapid population growth in a short span of time. The intrinsic birth rate and death rate are crucial factors in regulating its population dynamics. Therefore, based on the life table study, time-based management practices can be developed, including the conservation of natural enemies, to mitigate the negative environmental impact. The present study suggests that the optimal period for implementing control measures is the second week of October when the second-generation nymphs emerge, coinciding with favorable climatic conditions conducive to the effective buildup of pest populations in rice fields.

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Table 1. Biology and reproductive parameters of *S. furcifera* on paddy (2022 & 2023)

Stage		Life period in days at 25 to 30ºC, 80 to 85% RH	
		Days (hour/second)	References
(1) Adult stage	(i) Premating period	3.6±0.375	
	(ii) Mating period	159±9.34 second	148 second (Ahmed et al., 2016)
	(iii) Preoviposition period	4.8 days±1.88 days	3 to 8 days (Dale, 1994) 3.7± 0.3 days (Kumar et al., 2015)
	(iv) Oviposition period	5.4 days±0.96 days	10.2± 0.51 (Kumar et al., 2015)
	(vi) Adult longevity		-
	• Male (Macropterous)	10.2±2.44 days	14.4 days (Kumar et al., 2015), 12. 5 days (Ammar et al.,1980)
	• Male (Brachypterous)	6.9±1.78 days	-
	• Female (Brachypterous)	14.25±1.36 days	15.9 days (Kumar et al., 2015) 18.7 days (Ammar et al., 1980)
	(vii) Sex ratio (Female: Male)	1.2:0.68	1.0 : 0.78 (Kumar et al., 2015) 0.512:0.488. (Win et al. 2009)
(2) Egg stage	Fecundity	184±16.58 eggs/female	164 eggs (Vaidya and Kalode, 1981), 300 to 350 (Suenaga, 1963), 119 to 158 eggs (Kumar et al., 2015) (129 to 198 eggs Sandhu and Suri, 2018)
	Incubation Period	7.4±1.04 days	8.6± 0.24 (Kumar et al., 2015)
(3) Nymphal stage	First instar	2.62±0.54	2.05± 0.05 days (Kumar et al., 2015)
	Second instar	2.36±0.33	2.3± 0.12 days (Kumar et al., 2015)
	Third instar	2.76±0.36	2.6± 0.11 days (Kumar et al., 2015)
	Fourth instar	2.78±0.43	2.7± 0.10 days (Kumar et al., 2015)
	Fifth instar	3.44±0.84	2.95± 0.11 days (Kumar et al., 2015)
	Total nymphal	14.82±0.62	17. 7 days (Sandhu and Suri,

developmental period		2018)
(4) Total life cycle (from egg to adult)	22.42±1.22	23 days (Dale, 1994)
(5) Approximate generation time (T_c)	26.32 days	-
(6) Net fecundity rate ((R_0))	30.26	-
(7) Innate capacity (rc)	0.122	-
(8) Intrinsic rate of natural increase (rm)	0.124	-
(9) Finite rate of increase	1.132	-
(10) Doubling time of population (DT)	5.84 days	-
(11) Intrinsic birth rate	2.682	-
(12) Intrinsic death rate	2.646	-
(13) Gross reproductive rate	106.4	-
(14) Net reproductive rate (Rt)	62.66	-

Table 2. Correlation coefficients between *S. furcifera* incidence and weather factors

Pivotal age in days (x)	***lx***	***mx***	***lxmx***	***xlxmx***	***tx***	***lxtx***	***xlxtx***
0-24.5	-	-	-	-	-	-	-
25.5	-	-	-	-	-	-	-
26.5	0.35	7.00	2.74	78.20	17.00	6.46	176.20
27.5	0.33	31.00	10.76	309.00	69.00	23.82	678.40
28.5	0.31	40.00	13.14	388.4	79.00	25.62	750.20
29.5	0.29	8.00	2.75	81.35	19.00	6.20	181.20

Table 3. Significance of abiotic factors during both years, 2022 and 2023

Temperature				
Stages	**2022**		**2023**	
	Max	Min	Max	Min
Nymph	0.174	-0.166	0.152	-0.131
Adult	0.494	-0.553**	0.164	-0.173
Relative humidity				
Stages	**2022**		**2023**	
	Max	Min	Max	Min
Nymph	0.214	-0.169	0.161	-0.110

Adult	0.676**	-0.236	0.556**	-0.217

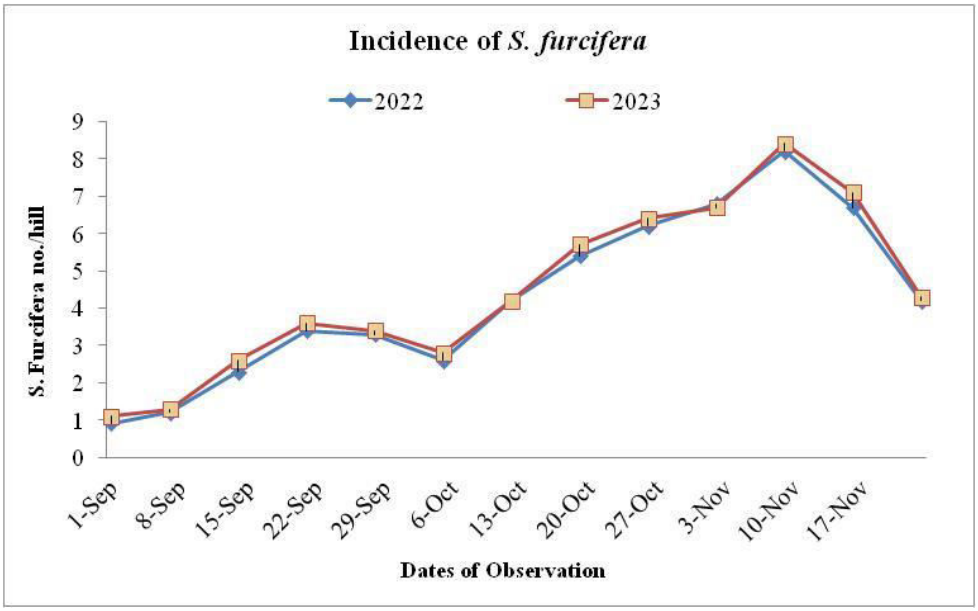

Fig. 1. Incidence of *S. furcifera* in Satna district (M.P.) during 2022 and 2023