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TEMPORAL VARIATION OF INSECT PEST POPULATIONS OF RICE AND THEIR RELATIONSHIP WITH METEOROLOGICAL VARIABLES IN BATALAGODA, SRI LANKA

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ABSTRACT

Climate and weather substantially influence on the development and distribution of insects. Forecasting of insect pest outbreaks requires data on insects and climatic information from a thoroughly maintained data base. In Sri Lanka, there are several meteorological stations recording climatic information for over many years; unfortunately, details on the insect pest population are limited. Therefore, the present study was designed to collect information on major insect pest of rice in order to study their population dynamics over the time. A light-trap survey was carried out during 2007-2014 to collect five major pests in paddy fields; Brown Planthopper, Green Leafhopper, White Backed Planthopper, Zig Zag Leafhopper and Paddy Bug to investigate the effect of climatic parameters such as maximum and minimum temperature, rainfall and relative humidity on their population level. The effect of climatic variables on the collected species was evaluated using generalized linear models with a logarithmic link function for poison distribution. Generalized additive model was used to investigate temporal trend of insect population over the time. Maximum temperature showed a significant ($P<0.005$) positive relationship on the population levels of the whole species studied, while the minimum temperature had a negative influence. Except for Brown Planthoppers and Zig Zag Leafhoppers, population levels of all other species

were negatively influenced by the rainfall. Relative humidity had significant negative impact on all insect species. Population variation between years was compared and general trends were observed and models were also developed for the prediction of future pest outbreaks.

Key words: Climatic variables, Forecasting models, Pest outbreaks, Rice pests

INTRODUCTION

Insects attack all parts of the rice plant at all stages of plant growth, causing substantial loss to the crop yield (Rosenzweigh *et al*., 2001). The pest species composition and their abundance show considerable variation with the plant growth, locations, variety and the season. Climate and weather substantially influence the development and distribution of insects (Sathischandra *et al*., 2014). Population dynamics of rice insect's pest may be mainly coincided with the major rice growing seasons in Sri Lanka, *Yala* (March - August) and *Maha* (September – February), with a significant influence of climatic variables which are different with the seasons.

Changes of climatic variables such as temperature, rainfall and humidity are negatively affected on the agricultural productivity through shifts in insect pest occurrence (Ladanyi and Horvath, 2010). Their life cycle processes are affected by climate and weather, which include lifespan duration, fecundity, diapause, dispersal, mortality, and genetic adaptation (Woiwod, 1997). For Example, temperature increases may likely accelerate the physiological process of insects thus, causing faster development, more activity and movement, reduced mortality and possibly even more generation in a season (Yamamura and Kiritani, 1998; Hansen *et al*., 2001).

Forecasting of insect pest outbreaks require data on insects and climatic information from a thoroughly maintained data base (Ladanyi and Horvath, 2010). In Sri Lanka, there are several meteorological stations have been recording weather data for over the years, unfortunately, details on the insect pest population are limited. Therefore, the present study was designed to collect information on major insect pest of rice in order to study their population dynamics over the time. This paper discussed the seasonal patterns of insect pest populations and their relationship with the climatic variables, which will be useful in developing a sound pest forecasting models in the long-run.

MATERIALS AND METHODS

A light-trap survey was carried out at Rice Research and Development Institute (RRDI) at Batalagoda (7°33’0” N 80°27’0” E) in Sri Lanka, throughout the period during 2007-2014. Five major pests in paddy fields; Brown Planthopper (BPH), Green Leafhopper (GLH), White Backed Planthopper (WBPH), Zig Zag Leafhopper (ZLH) and Paddy Bug (PB) were collected weekly. Climatic parameters such as maximum and minimum temperature, rainfall and Relative humidity (morning and evening) were also recorded by the Meteorological Observatory of RRDI to investigate the effect of climatic factors on their population variations.

The effect of climatic variables on the population levels of collected species was evaluated using generalized linear models (McCullagh and Nelder, 1989; Statacorp, 2005) with a logarithmic link function for poison distribution. Generalized additive model (GAM) was used to investigate temporal trend of insect population over the time. These models were allowed for the inclusion of a non-parametric smoothing and will fit a regression spline to data, allowing for nonlinear relationships (Wood, 2006; Zuur *et al*., 2007). Statistical software SAS 9.3 were used for the data analysis.

RESULTS AND DISCUSSION

Results of the study revealed that climatic variables such as maximum and minimum temperature, morning and evening relative humidity influenced on the population levels of insect pest of rice significantly (Table 1).

Effect of the maximum and minimum temperature

Maximum temperature had a significant ($P<0.005$) positive relationship with the population levels of all the species studied; BPH, GLH, WBPH, ZLH and Paddy bugs. This effect was much more prominent in green leaf hoppers ($E=0.5515$) than other species. Minimum temperature significantly influenced on the population of three species, namely, BPH, WBPH and ZLH. population of all other species except, BPH and ZLH, were increased when decreasing of minimum temperature. The effect of changing temperature could either be direct, through on the insects’ physiology and behavior, or may be mediated by host plants, competitors or natural enemies (Samways, 2005).

Table 1. Relationship between insect pest population and climatic parameters based on the results as per the light-trap survey conducted during 2007-2014

Species	Climatic Parameter	Estimate	SE	P
Brown plant hopper (*Nilaparvata lugens*)	Max. Temperature	0.2304	0.0681	0.0007
	Min. temperature	0.1352	0.0597	0.0236
	Rainfall	0.0000	0.0011	0.9875
	Re. humidity (Morning)	0.1095	0.0200	<.0001
	Re. humidity (Evening)	-0.0641	0.0131	<.0001
Green leaf hopper (*Nephotettix virescens*)	Max. Temperature	0.5515	0.0699	<.0001
	Min. temperature	-0.0589	0.0644	0.3603
	Rainfall	-0.0017	0.0021	0.4151
	Re. humidity (Morning)	0.1382	0.0204	<.0001
	Re. humidity (Evening)	-0.0211	0.0124	0.0893
Whitebacked plant hopper (*Sogatella furcifera*)	Max. Temperature	0.3061	0.0571	<.0001
	Min. temperature	-0.1562	0.0488	0.0014
	Rainfall	-0.0001	0.0007	0.8602
	Re. humidity (Morning)	0.1334	0.0184	<.0001
	Re. humidity (Evening)	-0.0117	0.0104	0.2619
Zig Zag leaf hopper (*Recilia dorsalis*)	Max. Temperature	0.3676	0.0833	<.0001
	Min. temperature	0.2224	0.0653	0.0007
	Rainfall	0.0009	0.0007	0.1950
	Re. humidity (Morning)	0.1171	0.0226	<.0001
	Re. humidity (Evening)	-0.0683	0.0151	<.0001
Paddy Bug (*Leptocorisa oratorius*)	Max. Temperature	0.2166	0.0641	0.0007
	Min. temperature	-0.0651	0.0569	0.2523
	Rainfall	-0.0053	0.0026	0.0438
	Re. humidity (Morning)	0.0630	0.0193	0.0011
	Re. humidity (Evening)	-0.0378	0.0127	0.0029

Effect of Rainfall

Except, BPH and ZLH, all other insect pest population levels were negatively influenced by the rainfall (Table 1), however, the impact was not significant ($P > 0.05$). This is probably due to 'wash off' effect by the rain droplets, which is a common phenomenon among sap sucking hemipteran bugs. There are few scientific evidences on the effect of rainfall on insect pest population and their growth. Some insects are sensitive to rainfall and are killed or removed from crops by heavy rains (Reiners and petzoldt, 2005). Sharma *et al*., (2004) also found that the rainfall has a negative impact on rice insect pests, particularly on hoppers.

Morning and evening Relative Humidity

Relative humidity data were collected in the morning (7.00 am) as well as in the evening (4.00 pm) for this study. The results revealed that the relative humidity in the morning has a significant influence ($P<0.005$) on BPH, GLH, WBPH, ZLH and PB population levels. The relationships were positive; hence, high relative humidity in the morning has shown a favorable effect on the insect population growth. In contrast to that, the relative humidity in the evening showed significant negative relationship in all species, except in GLH and WBPH. Sharma *et al*., (2004) also found that relative humidity could be affected negatively on insect pest of rice. The effect of relative humidity is always coinciding with the temperature. The environment with low temperature with higher relative humidity is more favourable for the population build up particularly on leaf and plant hoppers. In the evening, the temperature may increase however; the relative humidity goes down making the environment much more unfavorable to insects.

Temporal variation and annual trend of insect pest population during 2007-2014

In this analysis population variation among years were compared, so that, the general trends were observed with reference to major growing seasons *Yala* and *Maha*. Population levels of each species were analyzed using generalized additive model and it was found that population of most species were significantly different year to year. However, there was a general trend on the time of the year, which, peak population is occurring in each species. The variation of the population levels and general trends are described below.

Brown plant hopper

The general trend of BPH population during the study period is given in the table 3. According to the results, the BPH population was much lower at the beginning of the *Maha* season (September) and gradually increased and peak population level was recorded around February. During that period an increasing trend was exist in maximum and minimum temperature and morning relative humidity showing a positive relationship with the BPH population. Maximum and minimum temperature and morning and evening relative humidity is significantly influenced on the BPH populations (Table 1). While, it was also observed that the interaction between minimum temperature and evening relative humidity were significantly influenced on the BPH populations (Table 2). Their population is then beginning to decrease and become stable at average. Hence, the *Yala* season is beginning with higher BPH population in the field and compared to the *Maha* season, their population is higher in *Yala*. It is clear that the climatic variables are favorable for the BPH population build up in the *Yala* than the *Maha*, where, higher rainfall occur. According to the results, the BPH population was significantly high in year 2013 and the lowest population has been recorded in 2011. The minimum temperature in 2013 was higher than 2011 significantly while, evening relative humidity was lower in 2013 in compared to year 2011.

Table 2. Mean values and the two-way interactions of climatic parameters during the peak population of each pest species

Climatic variable (μ±SD)	BPH	GLH	WBPH	ZLH	PB
Max. Temperature	31.8 ±1.88	31.3±1.92	31.3±1.92	32.3±1.62	30.8±1.84
Min. temperature	21.6±1.52	21.1±1.21	21.1±1.21	21.2±1.17	26.3±52.05
Re. humidity (Morning)	86.2±2.73	86.2±2.73	86.3±2.72	85.8±2.81	86.5±2.81
Re. humidity (Evening)	64.9±8.61	64.2±8.95	64.2±8.95	61.4±9.08	66.8±9.42
Interactions (Pr>ChiSq)					
Max. Tem x RH (Morning)	0.2570	0.1263	0.0494*	0.7488	0.2139
Max. Tem x RH (Evening)	0.5227	0.6829	0.0364*	0.8826	0.2899
Min. Tem x RH (morning)	0.5532	0.0435*	0.0276*	0.4307	0.8424
Min. Tem x RH (Evening)	0.0292*	0.5833	0.3279	0.3578	0.4775
Max. Tem x Rainfall	0.0049*	0.5197	0.7327	0.3509	0.0426*
Min. Tem x Rainfall	0.6795	0.4505	0.5322	0.9092	0.3785

**interactions are significantly different*

This variation was much prominent around January to April, where the peak population of BPH was observed in each year (Table 3). The peak population of BPH was recorded when the maximum temperature and morning relative humidity were 31.8 ^{o}C and 86.2% respectively.

Table 3. Temporal variation of Brown plant hopper population during 2007-2014

	Mean number of BPH											
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
2007	430	470	390	230	175	146	135	129	34	51	56	39
2008	270	420	380	365	262	158	140	130	20	49	25.5	74
2009	700	1680	1352	652	480	450	390	385	28	26.5	53	68
2010	263	1354.5	239	689.5	338	67	130	120	43	73	67	73
2011	236	257	365.2	280	13	8.3	5.4	11	17	73.5	7.3	65
2012	209	1487	1148.2	348	220	196	134	141	118	100	110	123
2013	393	3948	3157	1259	526	383	329	342	431	23	76	200
2014	142	817	196	185	180	140	130	128	130	129	136	140

Green leaf hopper

GLH population was much lower compared to BPH population and remains at lower level during most of the year. Their population gradually build up around December and reached the peak between February and March (end of *Maha*). The *Yala* season begun with higher population of GLH in the field and then decreased and became stable at a low level after May. According to the table 1, maximum temperature, morning relative humidity affected significantly on the GLH populations. Although, minimum temperature alone had no significant impact on their population, there was an interaction between minimum temperature and morning relative humidity (Table 2). GLH populations were significantly high in year 2009, 2011 and 2013, while, the lowest population was recorded in 2014 (Table 4). The maximum temperature was higher in 2009, 2011 and 2013 compared to the 2014 (Table 4) showing a significant (Table 1) positive relationship with GLH. The average maximum temperature and morning relative humidity during the peak population period were 31.3 ^{o}C and 86.2%.

Table 4. Temporal variation of Grean leaf hopper population during 2007-2014

	Mean number of green leaf hoppers											
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
2007	200.5	980.5	859	156.2	45	29	19	13	6	15	6	130.5
2008	43	1781	2460	120	36	21	10	6	8	16	5	98.3
2009	36	2608	1489	416	150	18.3	3.2	5	10		13	46
2010	85	1590	1286	320	28	19	8.5	4		19	13	35
2011	63	2701	1256	438	138	18	3	5	5	14.6	19	57
2012	39	1120	2609	203.6	10.3	7.75	8.2	5	10.8	16	23	13
2013	80	2900	1212	452	34.8	20	33	21.2	68.75	12.75	49.6	112.5
2014	35	126	262.5	23.5	19	13	5	6	12	11	19	11

White backed plant hopper

Variation of population levels of WBPH was significantly different than the BPH and GLH. Maximum and minimum temperature and morning relative humidity were significantly influenced on the WBPH population levels (Table 1). It seems WBPH preferred the environmental condition in *Maha* season, because, their population level increased from September onwards and reached to the peak level in February. The population levels were high compared to the *Yala* season. This pest is considered as a minor pest in Sri Lankan conditions, although, in 2009 this pest was recorded as an epidemic level (Table 5). The average maximum temperature and morning relative humidity during the peak population of WBPH were 31.3 ^{o}C and 86.3% respectively (Table 2). In year 2009, the maximum temperature was comparatively higher, while the minimum temperature was lower than other years.

Table 5. Temporal variation of White backed plant hopper population during 2007-2014

	Mean number of white backed plant hoppers											
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
2007	86.2	105	79	39	28	25	19	16	15	16	33	68
2008	130	169	151	49	38.3	51	16	13	29	28	41	87
2009	300	358	376.2	97.4	32.5	29	13	5.2	16	40	68	150.5
2010	96	135.5	135	28	16	3	5	4	8	24.5	20	39
2011	89	40.2	40.3	19	8	5	3.2	4.2	8.75	16	19	41
2012	74.4	123	76.3	35	4.25	0.5	1.2	2.5	2.6	9	23.4	25.2
2013	112	140.6	96.5	39	5.4	2.75	8.6	3.7	12.5	14.75	28	36
2014	7.5	38.5	28	16	6.2	3	3.2	2.4	7	5.3	4	21

Zig-Zag leaf hopper

Figure 4 shows the temporal variation of ZLH population during the study. According to the results the ZLH population was very low in *Maha* season and was build up gradually from January onwards. According to the table 1, it is clear that the population levels of ZLH were significantly correlated with the maximum and minimum temperature, and evening and morning relative humidity (Table1). Usually ZLH population is higher at the beginning of the *Yala* season in the field. Similar to the BPH population, ZLH highest population level was recorded in the year 2013, and the lowest population level was recorded in 2014 (Table 6). During that period the average maximum temperature and morning relative humidity were 32.3 ^{o}C and 85.8 respectively.

Table 6. Temporal variation of Zig-zag leaf hopper population during 2007-2014

	Mean number of zig-zag leaf hopper											
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
2007	15	20.5	20	130	30	18	14	5	4	5	3	7
2008	18	26	60	125	60	18	13	8	4	5	5	5
2009	19	29	1450	210.4	158	14	15	3	4.5	1	3.7	5.5
2010	30	28	30	116.4	35	11	16	4	4.8	1	4	4
2011	28	84	1910	2567	1920	17	18	2	13	4	6	18
2012	113.7	113.2	4617	248	1110	17	12.6	13.9	31.8	3.5	6.6	20.5
2013	9.25	458.3	8100	5299	359	257	123	160.6	236.3	136	123	187.5
2014	7.5	8.5	18	14	18	6	18	16.6	12	11	1.3	8

Paddybug

Population levels of PB was significantly influenced by maximum temperature, rainfall and evening relative humidity (Table 1). Paddy bug population was high in *Maha* season compared to *Yala* season. However, their population increased at the latter part of each season (Table 7), which was different than the hopper species. This may relate with their feeding behavior, that, PB obtains ample food material in the later stage of the crop, mainly panicles. Paddy bug survive on other alternative hosts and may migrated into the paddy plants with the beginning of flowering. The highest population of PB was recorded in 2010 and it was followed in 2013. During the peak populations of the PB, the average maximum temperature and morning relative humidity were 30.8 ^{o}C and 86.5 respectively.

Table 7. Temporal variation of Paddy bug population during 2007-2014

	Mean number of paddy bugs											
	Jan	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sept**	**Oct**	**Nov**	**Dec**
2007	126	119	47.3	26.3	21	18.2	28	29	5.5	9	10	31
2008	45.5	38	29.5	21.3	15.4	12.4	13	10	15	18	15	19
2009	298	285	126	69	38.9	36.4	58	109	15	36	58	156
2010	26.4	126	11.4	9	5	7.4	3.5	5	6	8	9	9
2011	28.5	69.4	15.5	11	8	9.2	5.1	4	3.2	5	2	5
2012	30.2	38	19.2	11	5	3.2	3.2	1	5	9	5	8
2013	137	36.5	58	329	27	20	30	41	5	8	12	56
2014	3.6	58.3	8.2	2.6	3	6.3	9.3	8	7	9	5	5

Except the WBPH and PB all other species studied were preferred the conditions in *Yala* season. Most probably this is due to low rainfall associated with high temperature in *Yala* season. The results of this study provide indication of the use of these data to formulate a pest forecasting model using the climatic information, which will be much useful in predicting insect pest outbreaks in future.

Forecasting models for rice pests to predict future outbreaks

The results of this study revealed that the climatic factors such as Maximum temperature (Max_T), Minimum temperature (Min_T), Morning Relative Humidity (RhM), Evening Relative humidity (RhE) and Rainfall (RF) are affected on the populations of BPH, GLH, WBPH, ZLH and PB at various degrees. Therefore, the data collected during 2007-2014 were analyzed using poison regression to develop forecasting models for each pest that can be used in forecasting future out breaks.

Pest Species	Forecasting model
Brown Plant Hopper	log(BPH)=-9.74+ 0.235 MaxT+1.434 Min T+0.1084M-0.068E
Green Leaf Hoppers	log(GLH)= -25.51+ 0.653 MaxT+0.1252M
White Backed Plant Hoppers	l og(BPH)= -12.74+ 0.347 MaxT-0.228 Min T+0.126M
Zig zag Leaf Hoppers	log(BPH)= -20.4+ 0.435 MaxT+0.296Min T+0.105M-0.0481E
Paddy bugs	log(BPH)= -4.5954+ 0.152 MaxT+0.296Min T+0.185M-0.057E- 0.0054RF

Regular monitoring of weather data can be utilized to forecast the future outbreaks of pest species using the models given above.

CONCLUSION

Maximum and minimum temperature has a significant impact on the rice pest population. Rainfall and relative humidity have a negative effect on pest population in rice. Continuous and regular monitoring of climatic data can be used effectively to predict future insect pest outbreaks.

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