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Effect of planting dates on stem borer incidence and its natural enemies in relation to weather variables in rice ecosystem

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Abstract
The field experiment was conducted in the rice field of Regional Agricultural Research Station, Assam Agricultural University, Titabar, Assam in randomized block design sowing the seeds in three dates at an interval of twenty days between each sowing, viz., early (15th May), normal (5th June) and late (25th June) separately. Early sown was the least damaged crop (9.6% dead heart (DH) and 10.3% white ear head (WEH) as compared to normal (15.5 % DH and 16.7% WEH) and late (24.6% DH and 25.3% WEH) with a yield of 5.3t/ha in early, 4.5 t/ha in normal and 2.4t/ha in late sown crops. Spider population was significantly higher in early than that of normal and late planting, whereas the population of coccinellid beetles and the egg parasitoid, *Trichogramma japonicum* were non-significantly higher in early than that of normal sown crop, but the population of these natural enemies were significantly lower in late sown rice. The stem borer infestation was significantly higher in late sown crop with increased maximum temperature, morning humidity having a significant positive effect in all the dates of planting. There were a non- significant positive effect on population with minimum temperature (r = 0.34 for DH and r = 0.22 for WEH) and average rainfall (r = 0.20 for DH and r = 0.07 for WEH) at early sown. Maximum temperature and morning relative humidity had a significant positive effect on borer infestation as dead heart and white ear head in connection with a significant positive effect of spider population in three dates of planting. The variation in the planting times work as a means of cultural control by creating asynchrony between crop and insect pests' phenology along with crop-weather-pest interaction help in developing forewarning system to warn the farmers in advance to avoid manageable yield loss by stem borer incidences.

Keywords: Climate change, biotic factor, abiotic factor, dead heart and white ear head

Introduction
Rice feeds more than two billion people worldwide and is the number one staple food in Asia, where it provides 40-70% of the total food calories consumed [7]. Rice yield has been stagnant for the last three decades despite the improved varieties and technologies due to several factors, out of which abiotic and biotic stress are the major considerable factors. The biotic stresses which greatly constrain rice productions are insect pests and diseases [3]. The abiotic factors such as temperature, rainfall and humidity greatly influence various growth and developmental stages of a crop and indirectly the incidence of insect pests and diseases. The biotic agents like, predators and parasitoids are the natural regulators of insect pest population. Climate changes associated with alteration in sowing and planting dates have a profound effect on the insect pest incidences as well as the population of natural enemies [10] Rice is attacked by a number of pests, the stem borer being the major one, which cause losses up to 90 percent if not managed timely. Globally, stem borer alone causes yield losses of 10 million tones and accounts 50% of all insecticides used in the rice field. Due to the cryptic behavior of larvae and nocturnal habit of the moth, it is very difficult to be managed by using conventional chemical insecticides and biological methods. Ranjit is one of the most popular and extensively grown mega varieties accounting 50% of the total rice grown area in Assam. Henceforth, the effects of biotic and abiotic factors on the crop losses incurred by stem borer in relation to alteration of planting dates of the rice variety, 'Ranjit' was undertaken to combat against the adverse affects of present day's climatic aberrations.

Materials and Methods

The field experiment was conducted during *kharif*, 2017-18, 2018-19 and 2019-20 consecutively in the rice field of Regional Agricultural Research Station, Assam Agricultural University, Titabar, Assam in randomized block design. Seeds were sown in three dates at an interval of twenty days between each sowing, viz., early (15th May), normal (5th June) and late (25th June) of each year. The 30 days old seedlings were transplanted in the spacing of 20 cm x 15 cm following the recommended agronomic practices. However, no insecticide was applied till the harvest of the crop. The stem borer incidences as well as population of the major predators and the parasitoid which effect the stem borer population were recorded on the 10 hills selected randomly from each plot at weekly interval separately from the three dates of plantings. To assess stem borer, observations were recorded on total tillers (TT), dead hearts (DH) at 30 and 50 DAT, while stem borer damage at heading stage was expressed as percent white ears based on counts of panicle bearing tillers (PBT) and white ear heads (WEH). The first observations were taken 15 days after transplanting (DAT) and continued till harvesting. At the time of harvest, the grain yields from net plot leaving 2 border rows on all sides were collected and expressed as ton/ha. The meteorological data viz., maximum and minimum temperature, morning and evening relative humidity and rainfall were recorded daily in the Agro meteorology observatory of the research station during the whole crop period and stem borer incidences were correlated with the weather parameters. The percent occurrence of dead heart and white ear head were statistically correlated with the population of predators and the parasitoid as well as with meteorological data in relation to three dates of planting. All data were subjected to one way paired t-test at 5% significance level.

Results and Discussion

Out of five species of rice stem borers, white stem borer (45.67%) was found to be relatively more abundant species followed by yellow stem borer (32.45%). Therefore, the present study was undertaken on the dominant borer species, white stem borer; *Scirpophaga innotata* revealed that there were significant differences of the effect of date of planting on borer infestation in rice ecosystem. Early sown was the least damaged crop showing 9.6% DH and 10.3% WEH as compared to normal (15.5 % DH and 16.7% WEH) and late (24.6% DH and 25.3% WEH) plantings (Table 1)

Table 1: Sowing and transplanting schedules during *kharif* 2017-2019

Dates	Early	Normal	Late
Sowing	15th May	5th June	25th June
Planting	14th June	5th July	25th July

It was observed that the early sown crop gave more yield (5.3t/ha) as compared to normal (4.5 t/ha) and late sown crop (2.4t/ha) as there were less infestations in early than that of normal and late sown crops. (Table 2)

Table 2: Mean stem borer incidences and yield (t/ha) during *kharif* 2017-2019

Date of Planting	Stem borer incidences (%)		Yield (t/ ha)
	DH	WEH	
Early	9.6a (0.67)	10.3a (0.74)	5.3a (0.80)
Normal	15.5b (0.78)	16.7b (0.96)	4.5b (0.53)
Late	54.6c (1.21)	51.3c (1.04)	2.4c (0.31)

Means within column followed by different letters are significantly different (P=0.05)
(Standard errors given in brackets)

The present study was carried out in order to observe the incidences of stem borer in connection with natural enemies as well as weather parameters in all the dates of planting of the rice crop.

Incidences of stem borer in relation to date of planting and natural enemies (biotic factor): Occurrence of insect pests and their natural enemies on rice is influenced by date of planting**.** The effect of planting dates on the incidences of stem borer and population of natural enemies, viz., coccinellids, spider and *T. japonicum* were obvious. Generally, the natural enemies of a pest regulate its population dynamics. Numerous natural enemies were observed in the rice ecosystem which influences the population of stem borer, particularly coccinellids and spider were found to be common predators and *T. japonicum* was recorded as the most abundant egg parasitoid species of borer complex (Table 3)

Table 3: Effect of date plantings and populations of natural enemies on stem borer incidences in rice ecosystem during *kharif* 2017-2019

Date of Planting	Stem borer incidences (%)		Mean population of Spider (No./10 hills) hil	Mean population of Coccinellid (No/ 10 hills)	Mean population of *T. japonicum* (No/10 hills)
	DH	WEH			
Early	9.6a (0.23)	10.3a (0.28)	43.8e (0.98)	35.7d (0.56)	24.8c (0.067)
Normal	15.5b (0.08)	16.7b (0.06)	36.8d (0.67)	32.6d (0.49)	23.7c (0.21)
Late	54.6c (0.34)	51.3c (1.03)	23.6c (0.78)	27.1c (0.75)	17.9b (0.34)

Means within column followed by different letters are significantly different (P=0.05)
(Standard errors given in brackets)

Spider population was significantly higher in early planting than that of normal and late planting crop, whereas the population of coccinellid beetles and the egg parasitoid were non-significantly higher in early than those of normal planted crop, but the population of these natural enemies were significantly lower in late planting than those of other two dates of planting.

Correlation between stem borer infestation and population of natural enemies

The correlation matrices between the abundance of natural enemies and the infestation of stem borer throughout the growing season are depicted in Table 4. There was a significant positive correlation between stem borer incidences as dead heart and population of spider, coccinellid and *T. japonicum* in all the dates of planting, whereas there was a non-significant negative correlation between white ear head and the population of spider and *T. japonicum* observed during the course of study, but non-significantly positive correlation with population of coccinellids.

Table 4: Correlation between percent dead heart/white ear head and population of natural enemies in rice ecosystem during *kharif*, 2017-2019

Date of planting	Insect pest	Spider	Coccinellids	*Trichogramma japonicum*
Early	DH%	0.59*	0.90*	0.62*
	WEH%	-0.099	0.87	-0.12
Normal	DH%	0.45*	0.66*	0.61*
	WEH%	-0.067	0.59	-0.33
Late	DH%	0.64*	0.71*	0.87*
	WEH%	-0.078	0.63	-0.21

Correlation coefficient (r) at 0.05 level; *Significant

Stem borer incidences in relation to date of planting and weathers variables

The weather variables like, temperature (Max & Min), relative humidity (Morning & Evening) and rainfall were recorded during the whole crop period and are summarised according to the early, normal and late sown crop period. (Table 5)

The lower maximum temperature (30.5 °C), rainfall (4.7 mm) and relative humidity (morning) (88.3%), minimum temperature (21.3 °C) and relative humidity (evening) 62.6%) were recorded during the early sown crop than those of normal and lately sown crops. The stem borer incidences were significantly higher in late sown crop in which maximum temperature, morning relative humidity and rainfall were higher which cause more infestation of rice crop by borers, whereas lower minimum temperature, evening relative humidity causing reduction in the infestations in early sown crop.

Table 5: Effect of date plantings and abiotic factors on stem borer incidences in rice ecosystem during *kharif* 2017-2019

Date of Planting	Mean stem borer incidences (%)		Mean Maxm Temp	Mean Min temp	Mean Rainfall (mm)	Mean Morn RH%	Mean Even RH%
	DH	WEH					
Early	9.6a (0.09)	10.3a (0.07)	30.5d (0.21)	21.3c (0.06)	4.7ab (0.098)	88.3ad (0.34)	62.6ae (0.78)
Normal	15.5b (0.78)	16.7b (0.56)	31.8cd (0.20)	22.5c (0.23)	5.4bc (0.032)	90.6ce (0.45)	63.6ae (1.06)
Late	54.6 (1.08)	51.3 (1.13)	32.7cd (0.39)	24.3c (0.09)	6.9ca (0.17)	90.9ce (0.31)	65.2ae (0.23)

Means within column followed by different letters are significantly different (P=0.05) (Standard errors given in brackets)

The weather variables from sowing to harvesting during three dates of planting were correlated with stem borer infestation of the crop (Table 6)

Table 6: Correlation between dead heart/ white ear head and weather parameters in rice ecosystem during *kharif* 2017-2019

Date of planting	Insect pest	Maxm T (^{0}C)	Minm T (^{0}C)	Rainfall (mm)	Morn RH %	Even RH%
Early	DH%	0.30*	0.34	0.20	0.21*	-0.58
	WEH%	0.33*	0.22	0.07	0.78*	-0.72
Normal	DH%	0.17*	0.28	0.18	0.69*	-0.41
	WEH%	0.45*	0.68	0.34	0.65*	-0.54
Late	DH%	0.25*	0.36	0.07	0.16*	-0.35
	WEH%	0.26*	0.45	0.17	0.21*	-0.39

Correlation coefficient (r) at 0.05 level; *Significant

It is evident from the observations that the maximum temperature and morning relative humidity had a significant positive effect on dead heart and white ear head percentage in three dates of planting. There were a non- significant positive effect on borer incidences with minimum temperature (r = 0.34 and r = 0.22 at early sown) and average rainfall (r = 0.20 and r = 0.07 at early sown). Evening relative humidity had a non-significant negative effect on stem borer infestation both as dead heart and white ear head in all the dates of planting.

Correlation of interaction of stem borer incidences with abiotic and biotic factors together

It was revealed that there was a correlation between population of natural enemies and weather variables with stem borer infestation (Table 7). Maximum temperature and morning relative humidity had a significant positive effect on borer infestation as dead heart and white ear head in

connection with a significant positive effect of spider population in three dates of planting. There was a non-significant negative impact of minimum temperature and evening relative humidity as well as population of coccinellid beetles on stem borer infestations. The average rainfall had a non significant positive impact on stem borer infestation concomitant with abundance of *T. japonicum* parasitoid.

Table 7: Correlation of interaction of dead heart/ white ear head with weather variables and population of natural enemies in rice ecosystem during *kharif* 2017-2019

Date of planting	Insect pest	MaxT (^{0}C)	Min T (^{0}C)	Rainfall (mm)	Morn RH %	Even RH%	Spider	Coccinellids	*T.japonicumm*
Early	DH%	0.21*	-0.08	0.09	0.32*	-0.28	0.29*	-0.10	0.22
	WEH%	0.13*	-0.18	0.13	0.28*	-0.32	0.21	-0.17	0.12
Normal	DH%	0.27*	-0.15	0.21	0.34*	-0.21	0.34*	-0.26	0.31
	WEH%	0.31*	-0.21	0.23	0.25*	-0.34	0.37	-0.19	0.23
Late	DH%	0.35*	-0.23	0.27	0.28*	-0.15	0.30 *	-0.11	0.25
	WEH%	0.17*	-0.18	0.19	0.31*	-0.19	0.19	-0.03	0.21

Correlation coefficient (r) at 0.05 level; *Significant

The present finding was in conformity with the findings of [6] who reported that the rice planting on 1st July resulted in lower green leaf hopper, brown plant hopper and white leaf hopper incidence than on 16th July, 1st and 16th August and the abundance of natural enemies was high during early season and decline thereafter. The finding of the present study was in accordance with [11] who reported that the shifting in dates of transplanting of rice were significant indication of pest population, during first date (1st July) of transplanting were recorded lower intensity of green leaf hopper attack with respective to other plantings (40, 60 & 80 DAT).

The population of natural enemies, spider, coccinellids and *Trichogramma spp* were found to be more in early planting as compared to normal and late sown crop. Definitely, the rice crop at the early sowing was the off season planting, which was 15 days earlier from the farmers' crop growing season. At that time, most of rice fields were still fallow, so the population of natural enemies were abundantly found in the rice field [5]. As a result the stem borer damage was low indicating that pest was in larval and pupal stages, which then emerged to become adult moths in the normal and late plantings, therefore, stem borers concentrated more in the rice plants grown at the later two sowings. In early transplanted crop when the infection stage of pest and microbes are over, the inoculums would be finding a place in a late transplanting crop. In the case of late transplanting, the surrounding crop might have completed their susceptible growth stages and the entire pest inoculums would be feeding or confining to the late transplanted crop [8]. The later stages of rice plantings were more pronounced to exceedingly stem borer infestation than earlier or off season sowing [2] as the early crop escaped from the stem borer attack. The highest yield was obtained in early sown crop, and the crop sown after this date showed drastic reductions in yield was in accordance with the findings of [9], where the study implied that adjustment of planting time is the most feasible effort to reduce stem borer infestation because none of the rice cultivars tested were able to minimize damage under heavily infestation of stem borer**.**

The present finding was in conformity with the result of [1] in which high incidence of stem borer was observed in late sown crop with a 32.7 ºC maximum temperature and 90.9 percent morning relative humidity and maximum temperature had a significant and positive effect on stem borer incidences, whereas there was non-significant, positive effect on population with minimum temperature and on average rainfall. The correlation study revealed that the population build-up of different pests and their natural enemies was influenced by the weather parameters which were supported by [4].

Conclusions

The results of this research will be very useful as it is aimed at filling the gap of our knowledge on the crop weather relationship for this region of the country. This study on crop-weather-pest interaction will help in developing forewarning system to warn the farmers in advance to avoid manageable yield loss by stem borer infestation. Variation in the planting time of crops works as a means of cultural control by creating asynchrony between crop phenology and insect pest's phenology which can reduce the stem borer incidences. These findings want more research and further investigation in field level. Therefore, the present work may show a path for further and detailed research to unfold many dimensions.

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