A SEMINAR PAPER ON

Effect of Climate Change on Insects: Implications for Crop Protection and Food Security in Bangladesh

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SUBMITTED TO:

Course Instructors	Major Professor
1. Dr. Md. Mizanur Rahman Professor BSMRAU 2. Dr. A. K. M. Aminul Islam Professor BSMRAU 3. Dr. Md. Rafiqul Islam Professor BSMRAU 4. Dr. Dinesh Chandra Shaha Assistant Professor BSMRAU	Dr. Md. Ruhul Amin Professor Department of Entomology BSMRAU

SUBMITTED BY:

Md. Ariful Islam

MS Student

Reg. No.: 13-05-3011

Department of Entomology

BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY

SALNA, GAZIPUR-1706

Abstract

Nowadays climate change is a big issue worldwide. Bangladesh for its geographical location is one of the most vulnerable country for climate change. So, the effect of insects due to climate change in Bangladesh is distinguishable. Climate change effect on four major insects of Bangladesh is reviewed in this paper namely *Spodoptera litura*, *Pieris brassicae, Helicoverpa armigera and Nilaparvata lugens.* There is impact of climate change on those insects which are reviewed. Proper implication strategies such as IPM and adequate use of pesticides in the farmers fields is needed to cope with the effect of climate change on insects which ensures food security that not only means the increase in the availability but also in affordability, accessibility, and nutritional quality are important which are not considered always.

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CHAPTER I
INTRODUCTION

Response of insects to climate change are crucial for understanding how agro-ecosystems will respond to enviornmental change. Many insect species are not only pests of crops but also play crucial roles as predators and parasitoids. Changes in an insect populations physiology, biochemistry, population dynamics and biogeography, among crop types and growing season. Response of an insect population to rapidly changing climate may be a variable also when insects relates with different competitors, predators and parasitoids and impose costs at different life stages. The overall food production can be influenced by this and can be in a critical risk from the impacts of climate change. (IPCC 2014).

Due to climate change current distribution of many insects species may not be able to exten or move out of their current distribution due to a number of factors such as dispersal constrains and restriction due to parasitoids, predators/ symbionts relationships, and they are essentially stuck within the realized niche and not able to expand into their broader fundamental niche. Buffering or amplification of microclimate can occur along multiple axes. Variation of these microclimate axes can be defined as abiotic/ biotic axes, amplification versus buffering axes, and long versus short temporal and spatial scale axes. (Woods *et al.* 2015)

Nearby organisms are influced by biotic environment, such as social insect nests, insect hervivores infulenced by leaf surface temperature and humidity through stomatal opening, and leaf miners positioned under the leaf lamina. Different Stuctures such as rocks, soils, topography plant canopies are influenced the abiotic environment. Finding their most favorable microclimate the organisms can manipulate the both biotic and abiotic environments, making response to microclimate warming more difficult to assess and predict.(Andrew *et al.* 2017)

Spatial and temporal extents of microclimate are complex, especially in relation to the organism being assessed. For example wingless aphid will stay on the maternal plants within crops.(Gia and Andrew 2015) but the gregorious desert locust may swarm and travel hundreds of miles and causing a complete crop damages to over eight million people. (Latchininsky *et al*. 2011).

Different crops and areas of natural vegetation are crossed by invertebrates, or living within a complex topography, are mostly exposed themselves to a wider range of microclimates. Heterogenecity and spatial structure within an organism’s microclimate are important when assessing thermoregulation, movement and energetics of invertibrates.(Sears and Angilletta 2015).

Thermally regulation within varying microclimate is also key for changing behaviour of invertebrates. Behavioural adaptation to environment change by insects is understudied(Andrew *et al.* 2013b) but is a complex aspect of insect's response to climate change. In a cooler microclimate insect pests may be able to move to the ventral side of the leaf and deal with it or reduce their exposure to hot or extreme temperature throughout the hottest parts of the day or season, thus enabling them to search the most optimum thermal environment available within a small spatial scale.

Helicoverpa on pigeon pea is at decreasing tendency from year to year and causing less injury to crop. During last four years (2011 to 2014) there was a lot of change in prevalence of abiotic factors *viz*., rainfall, temperature and relative humidity in this region might have unpleasant the pest buildup from year to year at decreasing tendency and near future if this type of change continued with abiotic factor particularly rainfall, maximum temperature and relative humidity will play a major role to reduce to this pest status. **(**Jakhar *et al.* 2016)

Brown plant hoppers (BPH)are becoming more abundant in January and during June-July, in particular if higher temperature which are associated with more rainfall. As these months which are usually characterized by low abundances of BPH, the economic outcomes are likely to be negligible. On the other side, climate change is responsible for lower abundance of BPH during the spring and autumn seasons.(Ali *et al.* 2014)

Changing farming and integrated management strategies will be required to reduce the impact that agricultural pests have one crops (Thomson *et al*.,2010). This may include:1) Planting different plant varieties, 2) Planting at different times of the year to reduce exposure to pest outbreaks, and 3) Increasing the diversity of habitat on edges to increase natural enemy numbers. All of this strategies are used to reduce pest attack at the farm scale. Other relatively simple management strategies includes mulching, raised beds and shelters to save soil moisture, protecting crops from heavy precipitation, high tempreratures and flooding, and preventing soil loss. At the farm level and the microclimate level, changing farming management strategies are most crucial.Pesticide application are the common method of managing pests in the current world.(Ziska 2014). The usage of pestcides is correlated with temperature at sites and site minimum temperature can serve as a proxy for pesticide use.

Disclosure to sublethal concentration of pesticide could lead to cross tolerance of temperature and insecticide. As example of this is the brown planthopper(*Nilaparvata lugens*) which attacks paddy crops in Asia(Ge *et al.*,2013). When brown planthopper were disclouse to sublethal concentration of the commonly applied insecticide triazophos(40 ppm) at 40 degree centrigrade, mortality are alleviate from 94% to 50% and lethal mean time was enhanced by over 17 hours compared to control.

Food security is one of the major issues in nowadays. It not only means the increasing of food production through proper management of crops but also ensures the quality of food which is degraded through unbalanced using of pesticide.

The increase of food production per capita could be obtained by one of several ways, or from a combination of them, such as increasing the area of agricultural land, enhancing the yield of crops through the use of agrochemicals, organic fertilizers, biological controls, and improved soil and water management. Furthermore, cultivating more productive plants and plant varieties resistant to pests, and enhancing the cultivation of genetically modified organisms (GMOs) resistant to pests and diseases could work. In all of these piloted solutions some experience was obtained worldwide already. Results may be encouraging, but some are argumentative. Increasing the area of agriculture land does not seem to be facile task. Actually, nowadays there is a decrease of agriculture land (hectares per inhabitant) in all regions of the globe. Quality assurance is also a major concern nowadays in crop production.

Herbivore pests of major crops of major croping regions and key pests will be focused here. The current will be assessed of the impact that climate change is having on pest management, particularly Integrated Pest Management methods. A key focus is on ecological, physiological and behavioural responses of organisms. Proper implications for crop protection is also assessed here with food security debate which is a major issue nowadays.

The objectives of the study is-

I. To review the effect of climate change on insects
II. To investigate the measures that should be taken for crop protection due to climate change and
III. To review the food security in bangladesh.

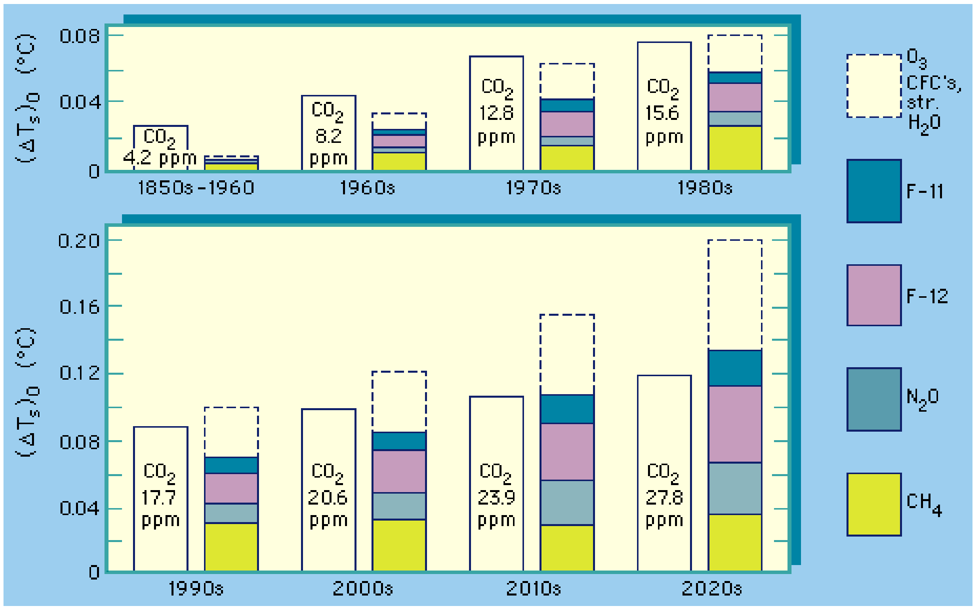
Chapter II
Methods & Materials

This paper is exclusively a review paper so that all of the information has been collected from the secondary sources. During the preparation of the review paper, I went through various relevant books, journals publications etc. The related topics have been reviewed with the help of library facilities of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Bangladesh Agricultural Research Institute (BARI) and Bangladesh Rice Research Institute (BRRI), internet browsing and CD search. After collecting all the available information, it has been presented as per the objectives of this paper.

Chapter III
Review of Findings

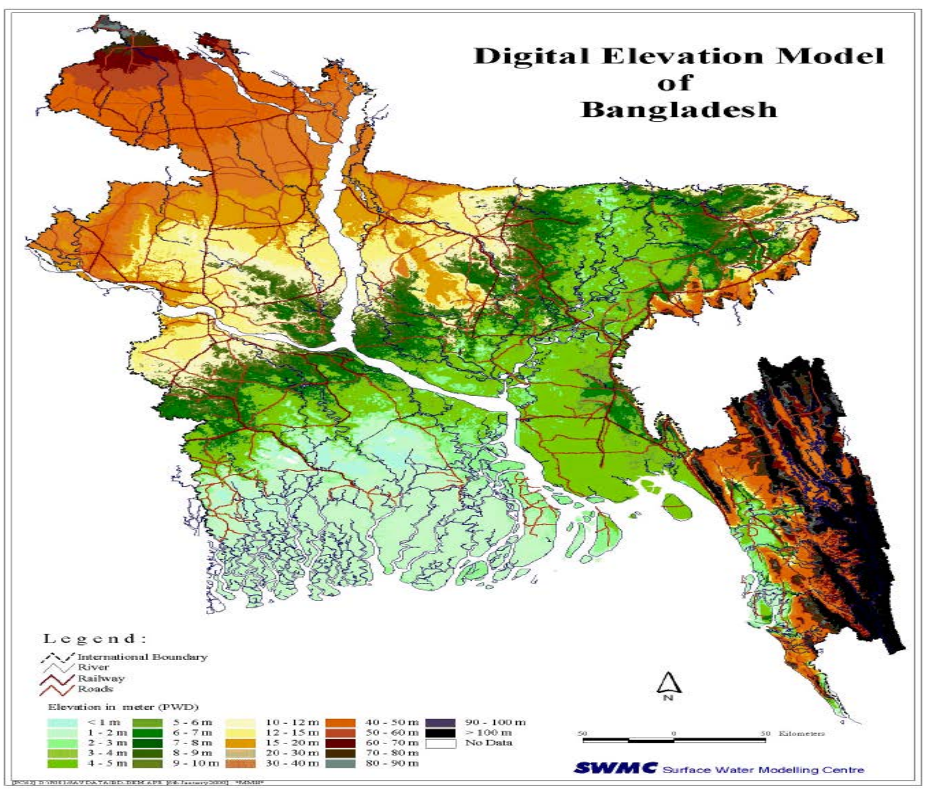
Impact of climate change on Bangladesh

Bangladesh is recognized worldwide as one of the country most vulnerable to the impacts of global warming and climate change. This is due to its unique geographic location, dominance of floodplains, and low elevation from the sea, high population density, high levels of poverty, and overwhelming dependence on nature, its resources and services. The country has a history of extreme climatic events claiming millions of lives and destroying past development gains. Variability in rainfall pattern, combined with increased snow melt from the Himalayas, and temperature extremes are resulting in crop damage and failure, preventing farmers and those dependent from meaningful earning opportunities. In a changing climate the pattern of impacts are eroding our assets, investment and future. Geologically, Bangladesh is located on an active sedimentary basin known as the Bengal Basin. The eastern Himalayan rivers (for example, the Ganges, the Brahmaputra and the Meghna) carry a large amount of sediments, part of which is deposited each year on the riverbeds and on the floodplains. It is expected that climate change induced alterations in temperature would affect the timing and rate of snow melt in the upper Himalayan reaches. As a result, the hydrological aspects of the eastern Himalayan rivers and the Ganges-Brahmaputra-Meghna (GBM) river basins could change significantly (Fig.2). GBM river systems would begin to swell early, while increased precipitation in monsoon would generate additional volumes of runoff. With only 7 percent of GBM catchment area, the country receives over 90 percent of the water discharged through the GBM river systems, and already suffers from repeated floods. Problems concerning drainage congestion will aggravate further with increasing volumes of water coming through the cross-boundary rivers during the monsoon. During the winter period, however, flows in the GBM rivers might decrease because of lower rainfall and higher surface evaporation.



Source: Website, 2007b

Fig. 1. Changes in the global mean temperature and increases in greenhouse forcing gases per decade from 1850 through the mid-1980s. (Top) and from the mid-1980s to 2020s (Predicted)(Bottom)



Source: Website, 2007c

Fig.2 Generalized Map showing elevation from sea level of different region of Bangladesh

Influence of temperature

Tendency of occurrence of *Spodoptera litura* and *Pieris brassicae* on cabbage in relation to maximum and minimum temperature on different dates of observance is presented in figure 1. Larval population of *S. litura* ranged from 0.56 to1.57 larvae/plant during 8 January to 12 February 2014 crop season. *S. litura* was first observe in the field on 8 January, 2014 (0.68 larvae/plant) with decreasing and increasing pattern which results fluctuation of population on remaining dates of observance. However, the highest observation was on 5 February 2014 (1.57 larvae/plant) at 29.5 0C temperature (Figure 3). In case of *Pieris brassicae*, larval population extend from 0.58 to1.98 larvae/plant and more or less alike tendency of population fluctuation was observed on various dates of observency. The highest observation of *P. brassicae* was also on 5 February (Figure 3). Maximum and minimum temperature had positive impact on population growth of both species. (Khan and Talukder 2017)

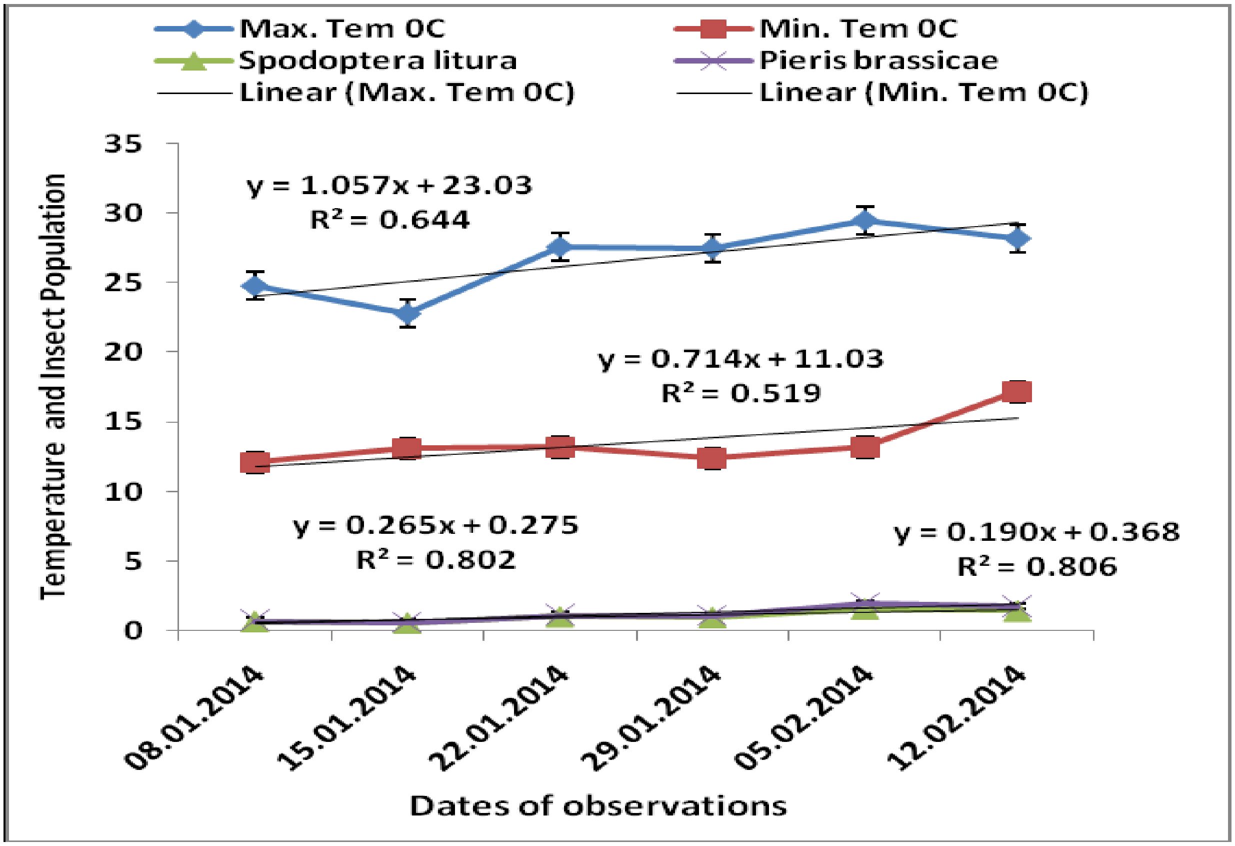


Figure 3. Trend of occurrence of *Spodoptera litura* and *Pieris brassicae* on cabbage at different dates of observations as influenced by maximum and minimum temperature.

Source: (Khan and Talukder 2017)

Influence of humidity

Tendency of occurrence of *Spodoptera litura* and *Pieris brassicae* on cabbage in relation to maximum and minimum humidity on different dates of observations is showed in figure 2. Larval population of *S. litura* ranged from 0.56 to1.57 larvae/plant during 8 January to 12 February 2014 crop season. The highest observation was on 5 February 2014 (1.57 larvae/plant) (Figure 4) at 96% and 38% relative humidity of both maximum and minimum categories. In case of *Pieris brassicae*, larval population ranged from 0.58 to 1.98 larvae/ plant and more or less alike tendency of population fluctuation was observed on various dates of observations. Likewise, the highest observation of *P. brassicae* was on 5 February (Figure 4) at alike conditions of humidity. Maximum and minimum humidity had negative impact on population growth of both species. As occurrence of pest depends on host suitability and climatic condition, therefore, occurrence and highest infestation of pest differ from variety to variety and due to variation of management practices in cabbage field. (Khan and Talukder 2017)

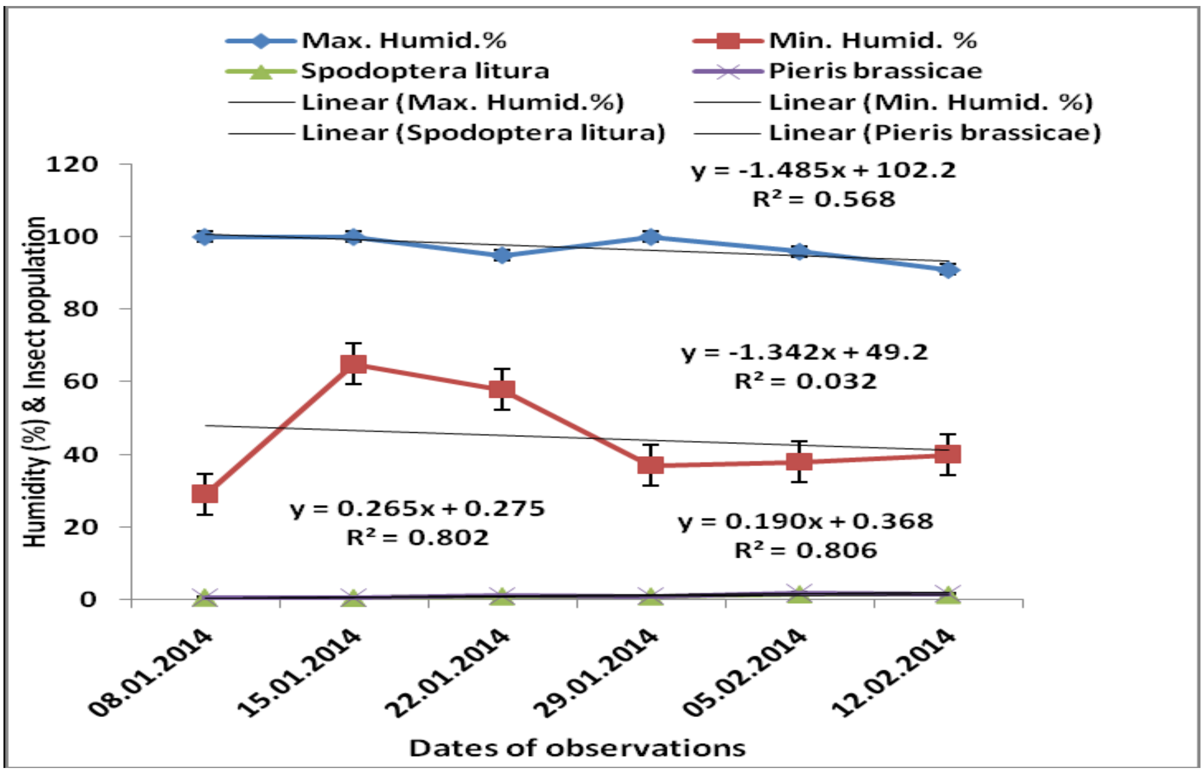


Figure4. Trend of incidence of *Spodoptera litura* and *Pieris brassicae* on cabbage at different dates of observations as influenced by maximum and minimum humidity

Source: (Khan and Talukder 2017)

Relationship of *Spodoptera litura* population with weather factors

There was a strong positive correlation (r = 0.824 and r = 0.920) between population of *Spodoptera litura* and temperature (maximum and minimum) showed in figure 5 (A&B). It shows that the population of *S. litura* increases with increasing of both maximum and minimum temperatures. The contribution of the regression (R2 = 0.679 and R2 = 0.847) was 68% and 85%, respectively. (Figure 5) (Khan and Talukder 2017)

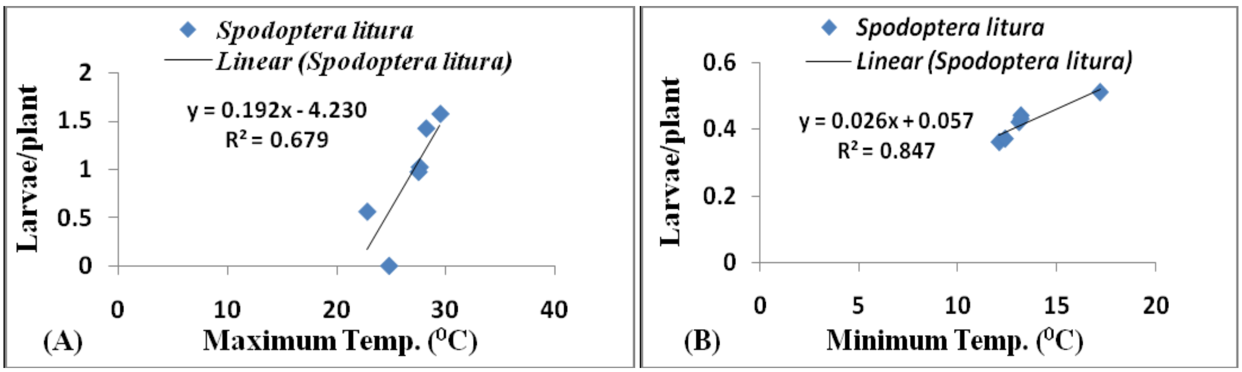


Figure 5. Relationship between *Spodoptera litura* population with (A) maximum temperature and (B) minimum temperature

Source: (Khan and Talukder 2017)

On the other hand, there was a negative correlation (r = -0.439) between population of *S. litura* and maximum relative humidity. However, a strong negative correlation (r = - 0.716) between population of *S. litura* and minimum relative humidity (Figure 6, C&D). Likely, the contribution of the regression (R2 = 0.193 and R2 = 0.513) was 19% and 51%, respectively. (Khan and Talukder 2017)

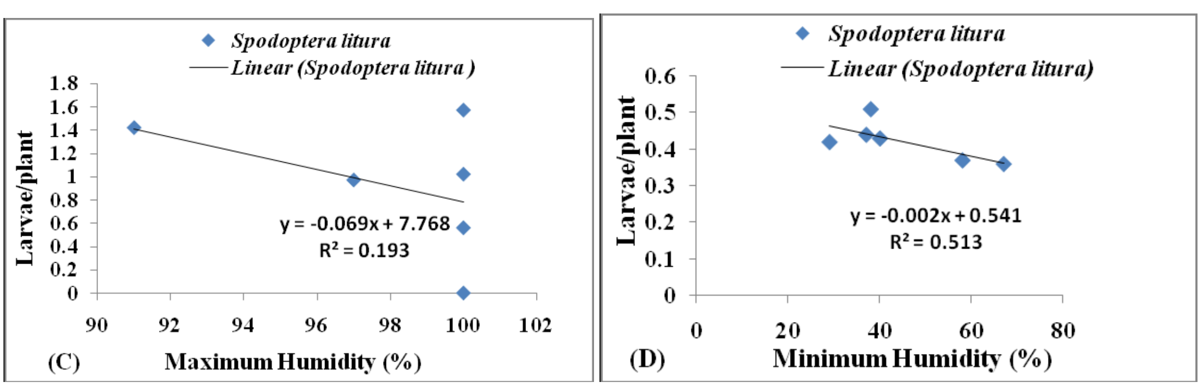


Figure 6. Relationship between *Spodoptera litura* maximum humidity (%) and minimum humidity (%) in cabbage Source: (Khan and Talukder 2017)

Relationship between *Pieris brassicae* population with weather factors

The population of *Pieris brassicae* was positively correlated (r = 0.899 and r = 0.956) with maximum and minimum temperatures (Figure 7, A&B). The relationship shows that the maximum and minimum temperatures had strong impact on the population of *P. brassicae*. The relationship can be revealed as 81% (R2 = 0.809) and 91% (R2 = 0.913), respectively by the contribution of regression. (Figure7). (Khan and Talukder 2017)

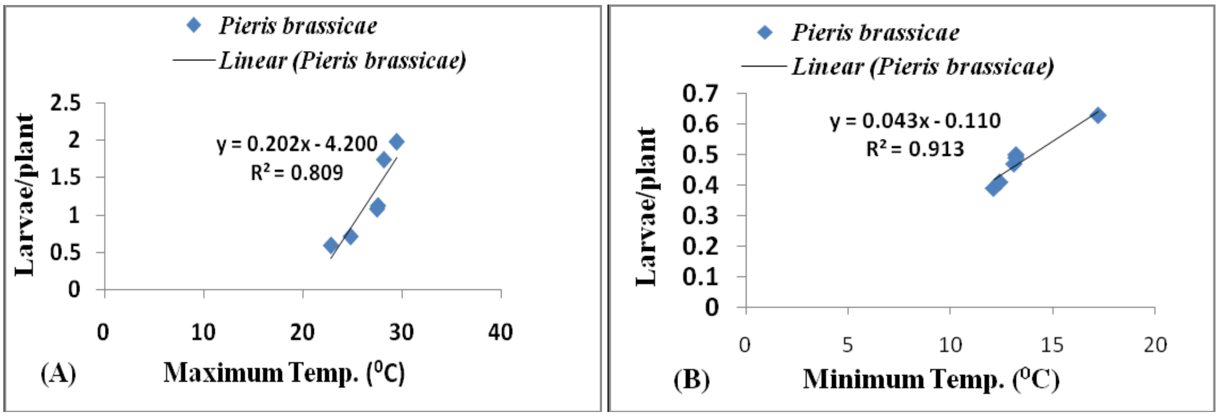


Figure 7. Relationship between *Pieris brassicae* population with (A) maximum temperature and (B) minimum temperature.

Source: (Khan and Talukder 2017)

On the other hand, there was a negative correlation (r = -0.443) between population of *P. brassicae* and maximum relative humidity and a strong negative correlation (r = - 0.645) between population of *P. brassicae* and minimum relative humidity (Figure 8, C&D). Likewise, the contribution of the regression (R2 = 0.196 and R2 = 0.421) was 20% and 42%, respectively.

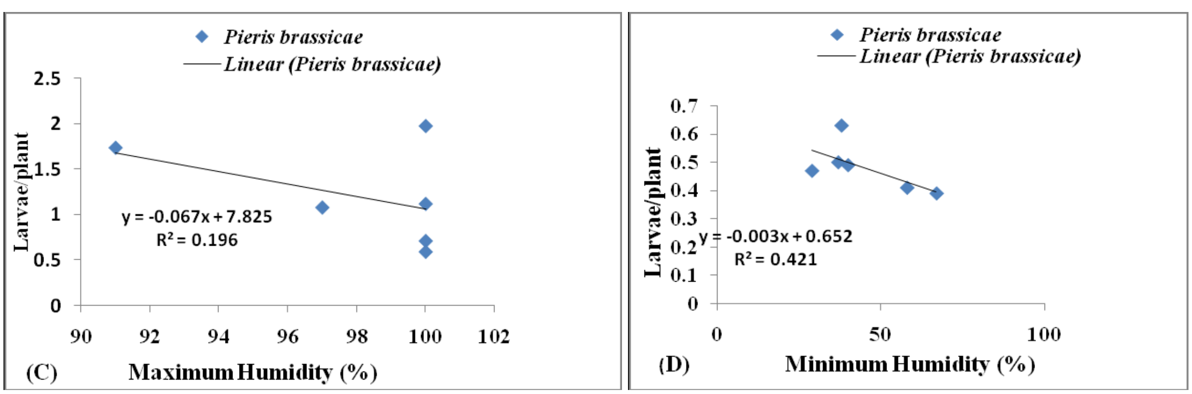


Figure 8. Relationship between *Pieris brassicae* population with maximum humidity (%) and minimum humidity (%) in cabbage

Source: (Khan and Talukder 2017)

The highest peak populations of *Spodoptera litura* and *Pieris brassicae* were found on 5 February 2014 at 29.5 0C temperature and at 96% relative humidity. Temperature had positive influence on populations of both species while humidity had negative influence on them. (Khan and Talukder 2017)

Table.1: Predicted effects of climate change on Agriculture in 2020 and 2050.

Scenario	Crop Yields	Sea Level Rise	River Flooding
Current Climate			In 1988, yields were down 45% because of flooding.
2020	Based on interpolation of published data to be consistent with climate change scenarios; rice yields have increases of up to 5%. With less optimistic assumptions about the CO_2 fertilization effect, generally have yield change -5% to +1%.	Based on interpolation, a 0.1 m SLR would inundate 0.2 MMT of production < 1% of current total.	Monsoonal floods increase yield loss.
2050	Based on interpolation of published data to be consistent with climate change scenarios; rice yields have increases of up to 10%. With less optimistic assumptions about the CO_2 fertilization effect, generally yield changes from few percent increase to 10% decrease. Pests and crop disease could reduce yields further.	0.3 SLR inundate 0.5 MMT of production ~ 2% of current total.	Monsoonal floods increase yield loss.

Source: Website, 2007a

Influence of climate change on *Helicoverpa armigera* in pigeon pea

The population dynamics of *Helicoverpa armigera* was collected from cropping season of pigeonpea during 26th standard metrological weeks (SMW) to 3rd SMW for four years from 2011, 2012, 2013 and 2014 data were collected. During 2011, the pest occurrence started in 40th SMW with0.95 larvae/plant and peak incidence of 1.75 larva/plants in 43th SMW (Table 2) there after its population started declining and was nil on 51th week. Over all that season mean occurrence of *Helicoverpa armigera* was 0.97 larvae/plants.

The pest occurrence during 2012 was initiated on 39th SMW (0.19larvae/plant) and started raising with two peaks one on 44th SMW and second on 50th SMW with 056 larvae/plant and there was drastic decrease in the pest population (Table-2). During 2013, the incidence started from 43rd SMW and continued up to 2nd SMW. Maximum occurrence of pest was noticed during 52nd SMW to 1st SMW were collected 0.45 and 0.52 larvae/plants, respectively. During 2014 also the pest occurrence was alike to that of 2013 with little more numbers. Highest and severe larval population 0.58 larvae/plants found on 50th SMW (Table 2) and onwards drastically reduced. **(**Jakhar *et al.* 2016)

Table 2. *Helicoverpa armigera* population on pigeon pea at farmer's field

MSW	2011-12	2012-13	2013-14	2014-15
30	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0
39	0.0	0.19	0.0	0.0
40	0.95	0.24	0.0	0.0
41	0.73	0.33	0.0	0.0
42	1.66	0.26	0.0	0.13
43	1.75	0.33	0.21	0.23
44	0.93	0.41	0.12	0.28
45	1.08	0.19	0.23	0.4
46	1.14	0.21	0.24	0.38
47	1.01	0.31	0.24	0.38
48	0.73	0.31	0.37	0.39
49	0.48	0.36	0.33	0.45
50	0.26	0.51	0.30	0.58
51	0.0	0.56	0.28	0.55
52	0.0	0.35	0.45	0.0
1	0.0	0.26	0.52	0.0
2	0.0	0.0	0.26	0.0
3	0.0	0.0	0.0	0.0

MSW- Meteorological Standard Week

Source: (Jakhar *et al.* 2016)

Table 3. Correlation matrix of *Helicoverpa armigera* population with environmental factors at farmer's field

Year	Rainfall	Weather factors			
		Temperature		Relative humidity	
		Maximum	Minimum	Morning	Evening
2011-12	-0.376**	-0.683**	-0.035NS	-0.467*	-0.539**
2012-13	-0.094NS	-0.640**	-0.343NS	-0.691**	-0.373*
2013-14	-0.587**	-0.847**	-0.075NS	-0.631**	-0.278NS
2014-15	-0.225NS	-0.567**	-0.328NS	-0.637**	-0.334NS
Cumulative	0.079	-0.524	-0.710	-0.827	-0.595

Source: (Jakhar *et al.* 2016)

The *Helicoverpa* population was decreasing tendency over the years. Pest population was range from 0.26-1.75 larvae/leaf and mean of 0.97 larvae/leaf during 2011 in short period of 41st to 50th SMW (Fig. 9). Average *Helicoverpa* population is 0.32 larvae/plants, which extent between 0.19-0.56 larvae/plants on 39th to 1st SMW during 2012. During 2013, it was 0.30 larvae/plants with range of 0.12 to 0.52 larvae/plants on 43rd to 2nd SMW. *Helicoverpa* population was extent between 0.13 -0.58 larvae/plant with average of 0.38 larvae/leaf during 2014. During first years, the pest population was peak and thereafter during 2012, 2013 and 2014 pest population was started declining every year. In all these year observations, peak population was observed between 50th SMW to 2nd SMW and the *Helicoverpa* population was mostly impacted by abiotic factors such as temperature and humidity. Hence, pest population was correlated with abiotic factors and showed here. **(**Jakhar *et al.* 2016)

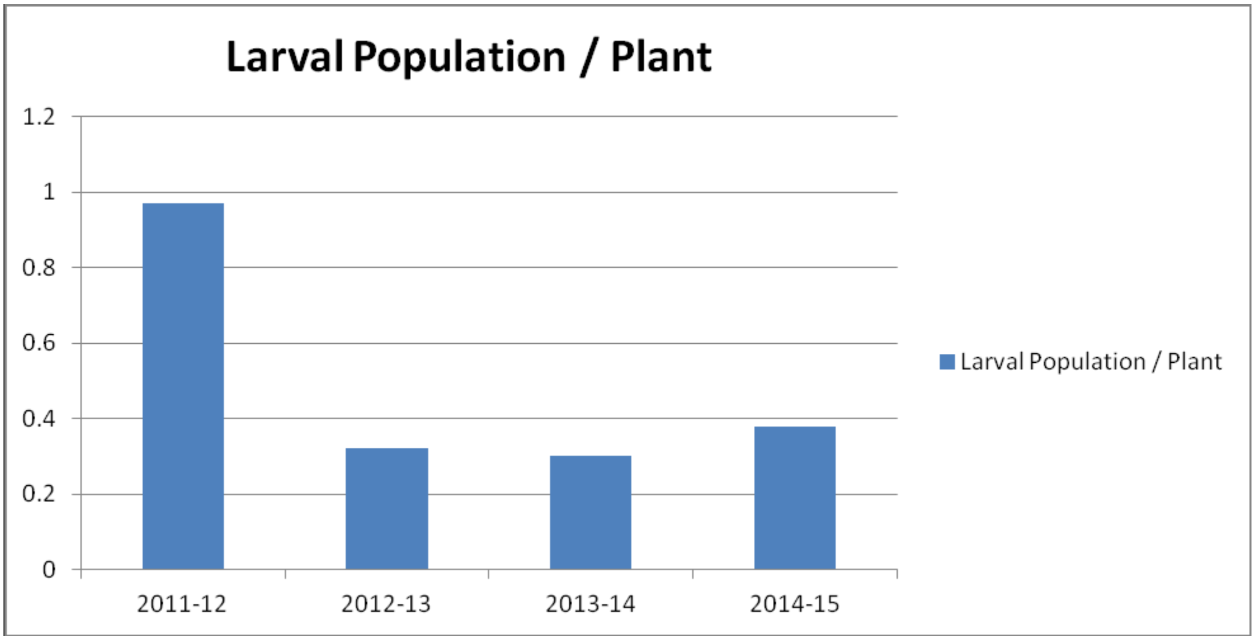


Fig. 9. Larval population of *Helicoverpa armigera* on pigeon pea

(Jakhar *et al.* 2016)

Effect of Weather Variables on the Abundance of Brown Plant hopper (*Nilaparvata lugens)***:** The time from December to February is the cold and dry season with low occurrence of plant hoppers (Fig. 10 A–C). Insectpests often respond rapidly and drastically to changes in climaticconditions affecting development (such as sudden precipitationand extreme temperatures), leading to large temporal variations ininsect pest populations.

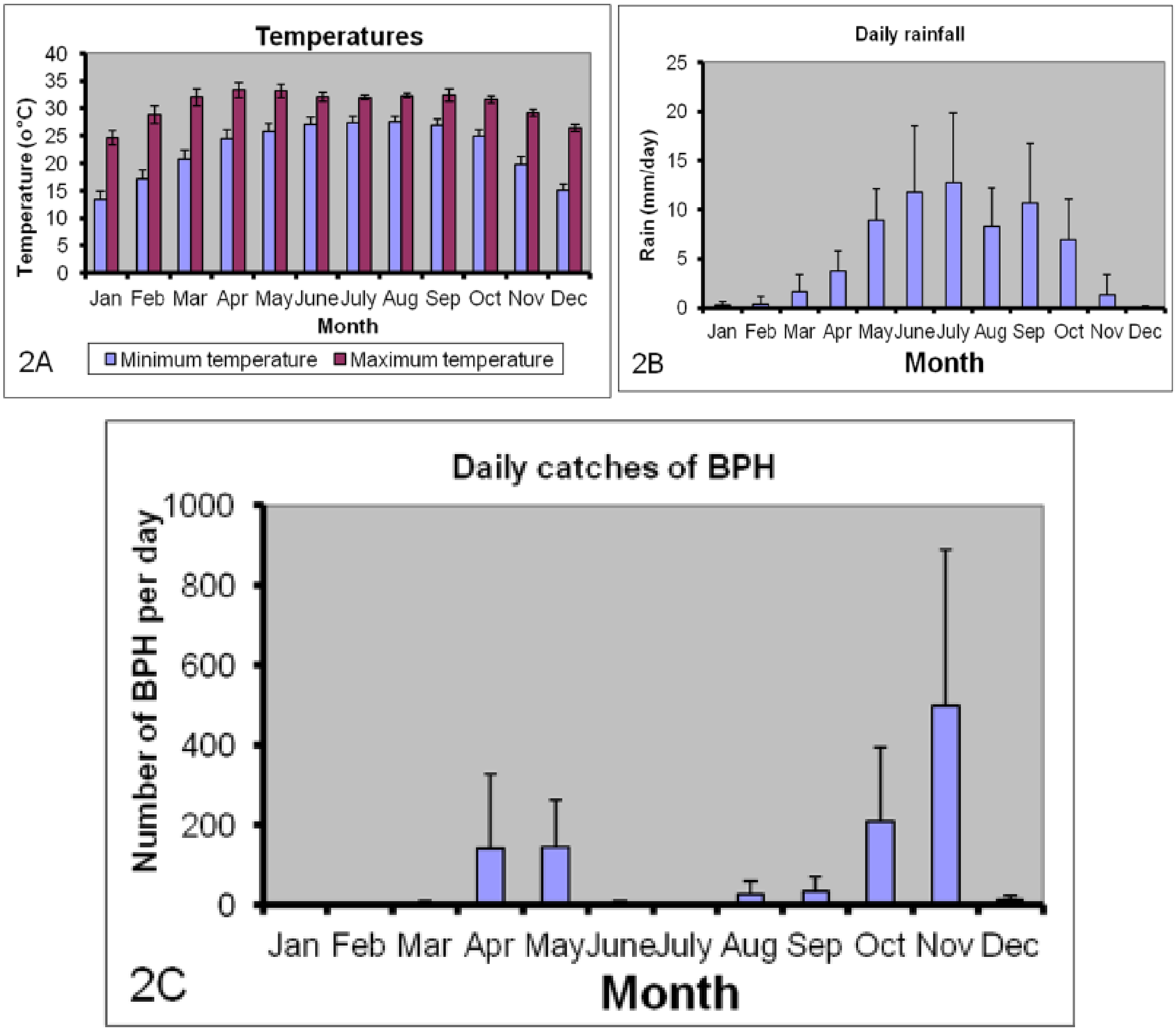


Figure 10. Monthly averages (±SD) of (A) Minimum andmaximum temperatures; (B) daily rainfall; and (C) daily catchesof Brown Planthoppers (BPH).

Source: (BRRI 2014)

Implications for crop protection:

Bangladesh has been adjusting to climate variability and change for decades. Increasingwaterlogged areas, for example, has rapid research into crop varietiestolerant of such conditions. With groundwater uptake for irrigation in some areas ofthe country's northwest beginning to show signs of desert, various policies and programshave been inspiring the agricultural development of coastal regions. Salttolerantcrop varieties and appropriate management programs are being adopted to overcomethe challenges characteristic of coastal regions. The development of higher yielding cropvarieties and other technological technologies will also help solve growing problems. (Banerjee*et al.* 2015)

Problems in using pesticides:

1. Pesticide use is recommand by short-term efficacy; the indirect and delicate effects of pesticides on their target arthropod pest species have been neglected.

2. Both direct and indirect effects of a pesticide can alter the physiology or behavior of an organism, clarifying such effects to the population whichmay translocate into community level effects that further the hierarchal system of pesticide-induced stress.

3. Individual stress response, either physiological or behavioral, may result either from the arthropod itself or from an endo-symbiont and may gleam a toxic or nontoxic (protective) reaction.

4. Quantal dose-response relationships translocate an individual stress reaction into a population stress reaction, but demographic reaction, rather than mortality, provide more strong estimates of stress that should also consider density-dependent regulation.

5. Pesticide-induced effects and behavior-mediated reactions are current topics of interest and might explain pesticide-induced incidences of arthropod pest species.

6. The co-occurrence ofmultiple species in natural systems indicates that pesticide-induced brunt may compromise the control of not only arthropod pests but also non-target yield favoring agents, such as pollinators and useful species.

7. The gross oversimplification of the potential consequences of pesticide-induced brunt on arthropod pests and associated species leads to knowledge gaps that compromise pesticide risk assessment, pesticide registration, and decision-making regarding their application. (Guedes *et al.* 2016)

Implications for reducing the effect of Pesticides:

1. The prevailing circumscribed focus of pesticide-induced brunt in arthropod pest speciesand some natural enemies, which are taking as important or are used as surrogate species in such assessments, is questionable and needs edition.

2. Demographic assessments and density-dependent regulation over time must be thinkfor in pesticide-arthropod interactions, which likely require editions to current action thresholds for decision-making regarding pest management.

3. Because single-species environments do not exist in nature, the co-occurrence of multiple species and their potentially continuous interdependent responses to pesticide applicationshould be considered, as these factors can affect pest management as well as crop yields. This reasoning is also sound for arthropod vectors of animal and human diseases.

4. New challenges in need of consider by pest management strategies include endosymbiont-mediated functions in arthropod pesticide brunt, increased application of pesticide mixtures, and landscape diversity.

5. Ecosystem-level studies and pesticide toxicology should be integrated to recommend initiatives for economic and environmentally sustainable food production and vector control. (Guedes *et al.* 2016)

IPM Strategies for crop protection:

Innovative crop protection is an important element in the science behind increasing crop yields. The Integrated Pest Management (IPM) approach has the ability to decrease the probability of catastrophic losses to pests, reduces the extent of environmental degradation and contributes to food security. The modern idea of pest management is based on ecological principles and includes the integration and synthesis of different components/control strategies into an Integrated Pest Management system. IPM, in turn, is a component of the agro-ecosystem management technology for sustainable crop production. The IPM control tactics are

(1) Biological control: protection, enhancement and use of natural enemies,

(2) Cultural practices: crop rotations, sowing time, cover cropping, intercropping, residues management, mechanically weed control,

(3) Chemical: reducing the application of synthetic pesticides in favor of bio-pesticides (fungi, bacteria and viruses) and biochemical pesticides (insect growth regulators, pheromones and hormones—naturally occurring chemicals that change pest behavior and reproduction and

(4) Resistant varieties: crop varieties bred using conventional, biotechnological and transgenic approaches.

The effective use of IPM technology and its application by farmers are important in increasing food production. Participatory IPM research, through its participation of farmers, marketing agents and the public, is designed to helping diffusion of IPM technologies. A number of tactis have been applied over time in efforts to increase diffusion of IPM globally. (Heinrichs *et al.* 2016)

Food security issue in Bangladesh:

The landless/marginal, small, and large farming households, and both urban educated and urban less educated households had a caloric shortage in the baseline. Nonagricultural rural peoples had a caloric surplus. In the absence of the Climate Change shock, by 2030 the situation was much improved as a result of sustained economic growth, with all household categories fulfill the minimum caloric requirements. When the Climate Change shock was imposed, however, urban less educated households became calorie shortage.

Considering all household categories together, in the base year there was a caloric shortage of 46 billion kcal. In 2030 in the baseline forecast, there was a surplus of over 516 billion kcal. With Climate Change, the surplus was decreased to 355 billion kcal. (Banerjee *et al.* 2015)

Table 4: Food intake in the base year, 2030 with CC and desirable food intake.

Food item	Actual kcal intake[a]	% total	2030 kcal intake with CC[a]	% total	Desired kcal intake[b]	% of desired
Rice	532	63	898	51	1,247	62
Grain	147	17	487	28	105	5
Potato	62	7	92	5	59	3
Vegetables	24	3	48	3	165	8
Pulses	23	3	42	2	136	7
Fruit	9	1	14	1	42	2
Animal-based food	30	4	92	5	237	12
Processed food	23	3	77	4	34	2
Total	850	100	1,750	100	2,025	100

[a]Model results.
[b]Follows the World Food Programme's food composition recommendations.

Source: (Banerjee*et al.* 2015)

Bangladesh has recently having self-sufficiency in rice, due mainly to increasing yields and the greatly increased area of groundwater irrigated dry season rice over the last several decades. The expected population growth will increase the demand for rice and other food for future decades. However, rice yields are well below potential and the current trends in yield, combined with the continued development of higher yielding varieties and more productive management strategies, should make Bangladesh to remain self-sufficient in rice at least to 2050. Only the lowest yield estimation coupled with the highest population estimation (which seem unlikely) show a shortage of production by 2050. Wheat production, on the other hand, is less than demand, and appears likely to continue to be shortage to 2050. Nevertheless, the demand for wheat is much less than that for rice and with increases in yield, cultivated area, and better practices, wheat can potentially fulfill demand by 2050. (Mainuddin 2015)

Ensuring continued national food security will demand solutions to main challenges. The most serious challenge for the future appears to be the reducing area of agricultural land, about 1 % of which is being converted every year into other uses. Water for irrigation will be a major problem, with concerns about unsustainable groundwater uptake. Sustainable groundwater use in some areas combined with use of more surface water and moving some production to other less intensively cultivated areas will help meet this challenge. Climate change having some challenges, particularly the potentially greater flooding and salinity in the coastal region resulting from sea level rise. Climate change is also projected to reduce yields; this impact is built into the projections and so does not appear to be a particularly serious challenge.

Food security is not in terms of total availability of food grain at the country level which does not ensure access to adequate food at household and individual levels. Apart from availability, affordability, accessibility, and nutritional quality are essential components of overall food security which are not considered always. (Mainuddin 2015)

Chapter IV

Conclusion

Bangladesh is one of the country most vulnerable to the impacts of global warming and climate change. This is due to its geographic location, dominance of floodplains, and low elevation from the sea, high population density, high levels of poverty, and over dependence on nature, its resources and services. The country has a history of extreme climatic events claiming millions of lives and destroying past development gains. Variability in rainfall pattern, combined with increased snow melt from the Himalayas, and temperature extremes are resulting in crop damage and failure, preventing farmers and those dependent from meaningful earning opportunities. Climate change have a great impact on the population dynamics of the insects. Maximum and minimum temperature had positive impact on population growth of both *Spodoptera litura* and *Pieris brassicae* species. Maximum and minimum humidity had negative impact on population growth of both *Spodoptera litura* and *Pieris brassicae* species. Brown Plant hopper pests often respond rapidly and drastically to changes in climatic conditions affecting development (such as sudden precipitation and extreme temperatures), leading to large temporal variations in insect pest populations. *Helicoverpa* population is at decreasing tendency from year to year and causing less injury to crop. The Integrated Pest Management (IPM) approach has the ability to decrease the probability of catastrophic losses to pests, reduces the extent of environmental degradation and contributes to food security. Food security is not in terms of total availability of food grain at the country level which does not ensure access to adequate food at household and individual levels. Apart from availability, affordability, accessibility, and nutritional quality are essential components of overall food security which are not considered always.

Chapter V

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