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Impact of Climate Change on Population Dynamics of Insect Pests

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Abstract: The occurrence of climate changes is evident from increase in global average temperature, changes in the rainfall pattern and extreme climatic events. These seasonal and long term changes would affect the fauna, flora and population dynamics of insect pests. The abiotic parameters are known to have direct impact on insect population dynamics through modulation of developmental rates, survival, fecundity, voltinism and dispersal. Among the climatic factors, temperature is an important factor. The studies showed that, declined survival rate of brown plant hopper *Nilaparvatha lugens* (Stal) and rice leaf folder, *Cnaphalocrocis medinalis* (Guen) at higher temperature indicates the impacts of rising temperature could do the changes in the pest population dynamics of rice ecosystem. The alteration in the voltinism also could be the results of warming and it is more profit to multivoltine species and voltinism could be reflected in changes in the geographical distribution. Beside these, elevated CO_2 also showed some impact on pest's population abundance, the crop grown under the elevated CO_2 could alter the nutritional value of plants; it may alter the insect abundance and increase the consumption rate of herbivores. Therefore climate change would result in changes in the population dynamics of insect pests. Thus temperature rise plays a pivotal role in insect population dynamics.

Key words: Climate change · Insect pests · Population dynamics

INTRODUCTION

The term global change embraces a range of natural and anthropogenic environmental changes. According to Intergovernmental Panel on Climate Change, it is defined as "Change in climate over time, either due to natural variability or as a result of human activity". The most of the warming observed over the last 50 years is attributable to human activities. The global mean surface temperature is predicted to increase by 1.4 to 5.8°C from 1990 to 2100. If temperatures rise by about 2°C over the next 100 years, negative effects of global warming would begin to extend to most regions of the world [1]. Such changes in climate and weather could profoundly affect the population dynamics and status of insect pests of crops. These may arise not only as a result of direct effects on the distribution and abundance of pest populations but also indirect effects on the pests' host plants, competitors and natural enemies[2]. Some pests which are already present but only occur in small areas, or at low densities may be able to exploit the changing conditions by spreading more widely and reaching damaging population densities [2,3]. Keeping these facts in view the topic is discussed the impact of climate change on the population dynamics of pest's populations.

Pest Population Dynamics: The population dynamics is the aspect of population ecology dealing with factors affecting changes in population densities. The seasonal effects of weather and ongoing changes in climatic conditions will directly lead to modifications in dispersal and development of insect species. The changes in surrounding temperature regimes certainly involve alterations in development rates, voltinism and survival of insects and subsequently act upon size, density and genetic composition of populations, as well as on the extent of host plant exploitation [3]. The change in the environment affects the pest population dynamics in two ways either directly or indirectly by altering the host physiology. Host availability and the probability of pest outbreaks are further determined by the incidence and character of abiotic disturbances. The developmental success of insect herbivores also indirectly depends on climate, as environmental parameters impact on plant

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physiology. Insects and plants are exposed to complex interactions among changes in temperature, precipitation and, increased levels of CO_2 and variations in nutrient availability.

Direct Effects of Climatic Parameters on Population Dynamics: Climate change is likely to involve a higher frequency of abiotic disturbance. Depending on the dimension of the disturbance, local to regional dynamics of insect populations and species composition will be strongly affected insects find optimum conditions for development within a certain range of temperature limited by species specific lower and upper developmental thresholds. These alteration and gradual changes might affect the population dynamics parameters like development and reproduction, diapauses and winter mortality and flight and dispersal[4].

Development and Reproduction: As long as species optima for development are not exceeded, there might be positive direct responses of insects to increasing temperature conditions, such as enhanced reproductive potential, are to be expected. Polyvoltine species, e.g. some economically important bark beetles like *Ips typographus*, will profit from accelerated development rates allowing for an earlier completion of life cycles and the establishment of additional generations within a season [5,6]. Temperatures above the specific optimum range lead to decreased growth rates, reduced fecundity and increased rates of mortality for a multitude of species [7]. Promoted by milder winters and decreasing frequencies of temperature extremes, enhanced reproductive capacity and changes in distribution (if host plants will be available) are to be expected for a variety of pest species. For instance, increased survival of hibernating eggs in fringe areas of occurrence is prognoses for the winter moth, *Operophthera brumata* and the autumnal moth, *Epirrita autumnata* and the gypsy moth, *Lymantria dispar* in North America [8] or the European pine sawfly, *Neodiprion sertifer* [9]. Temperature increase coupled with reduced snowfall and earlier snow melt may on the one hand lead to decreased overwinter survival of species hibernating under the protection of snow [10].

Diapauses and Winter Mortality: A phase of dormancy is essential for many species of temperate regions to complete their life cycles and to endure the low temperatures of the winter season. Increased temperature conditions may be beneficial for species with low frost resistance (like individuals of the anholocyclic development of *Elatobium abietinum*) and those, which are actively feeding during winter (like the pine processionary moth, *Thaumetopoea pityocampa*). They are not beneficial for species which do need low temperatures to manifest diapauses or to increase their frost resistance [3].

Migration and Movement: The onset of flight as well as the extent and endurance of dispersal are essential parameters in the phenology of insect herbivores, impacting the timing and intensity of mating, host finding and colonization and brood establishment. Temperature thresholds for insect flight vary both among and within species, with season and also with region. Different thresholds have also been described for different phases of flight activity. In the aphid *Aphis fabae*, 17°C is required for take-off [11], 15°C for sustained upward flight, 13°C for horizontal flight and 6.5°C for wing beating [12]. The regional spread of mountain pine beetle, *Dendroctonus ponderosae* outbreaks in British Columbia might for instance primarily be due to the dispersal of epidemic populations [13]. Besides their physiological constitution, insects are influenced in their flight activities by environmental conditions, such as the actual weather situation. Furthermore, insect emergence and first appearance after hibernation may depend on a combination of day length and temperature thresholds. E.g., the spring swarming of the European spruce bark beetle, *Ips typographus* after its termination of reproductive diapause can be predicted accurately in consideration of a specific thermal threshold for flight activity and a certain accumulated effective temperature sum above a photoperiod threshold [14]. The geographic range of many insect species of the temperate zones is determined by temperature thresholds of frost resistance. Decreasing snowfall might for instance promote the recent expansion of the pine processionary moth, *Thaumetopoea pityocampa* into high elevation stands of mountain pine. More than 50 species of butterflies showed northward range expansions and ten species of previously migrant butterflies established on Nansei Islands during 1966–1987. Global warming may be responsible for the recent decline in abundance of *Plutella xylostella* and the increase in *Helicoverpa armigera* and *Trichoplusia ni* [15].

Direct Effects of Increasing Temperature on Insect Pests: Increase in temperature might affect any stage of the life cycle and therefore limit distribution and abundance through its effects on survival, reproduction and development.

Effect Temperature on Survival Rate of Insects: Warm temperature halved the time required to reproduce (Spruce beetle, *Dentroctonus rufipennis*) [16]. The population of pine beetle is reduced drastically at -16°C (lethal) but better survival and distribution at warm winter. In case of aphids a 2°C temperatures increase causes one to five additional life cycles per season [17]. The adult survival of the brown plant hopper, *Nilapavata lugens* remained almost unchanged between 25 and 35 °C, but was drastically reduced at 40 °C. The oviposition of females at 35 and 40 °C was relatively higher than at 25 and 30 °C, but egg survival was markedly reduced at 35°C. At the higher temperatures, durations of pre-oviposition periods were also reduced. Clearly, temperatures above 35 °C are likely to limit Brown Plant Hopper [BPH] development based on these studies. The global warming is likely to increase BPH abundance in areas with temperatures below 30°C [18].

In another pest species, survival of the different stages of the rice leaffolder *Cnaphalocrocis medinalis* was greatly affected at 35 °C. Adults emerging from pupae reared at 35 °C were unable to lay eggs. The upper temperature threshold for survival of this species appears to lie between 30 and 35 °C. Shifts in climate can differentially affect the development rates of pest and predator species. In addition, temperatures can affect predator search. The egg predator (*Cyrtorhinus lividipennis*) had increased instantaneous attack rates and decreased handling times with increasing temperatures until 32 °C. At 35 °C the attack rate and handling time decreased drastically. This implies that predator activity is likely to increase with increasing temperatures up to a critical temperature of about 35 °C. In addition to affecting biological characters, global warming may cause temporal asynchrony between interacting populations [18].

Insect may also evade climate change stress through changes in life cycle. Insect populations from environments with higher temperatures may have higher fecundity and shorter growth stage durations to increase fitness. The egg duration was 10.4 days at 25 °C and 7.9 days at 27-28 °C [19]. The viability of eggs of *Helicoverpa armigera* and day degrees required for egg hatching decreased with an increase in temperature from 10 to 27° C and egg age from 0 to 3 days. The DD Degree Days requirements were highest for 0-day-old eggs at 10° C and lowest at 27° C. At 27° C with a hatchability is >75.0%. [19]. In Rice ear head bug, *Leptocorisa acuta,* the 0.5 and 2° C rise in daily average caused no affect on the generation time but 3°C rise caused 1 to 3 days increase in generation time. 0.5 to 1° C rise reduced the population of non wing-padded nymphs, wing padded nymphs and adults [20].

Effect of Temperature on Growth Rate of Insects: The rate of development of pests will enable a more rapid response to a change in temperature. The population of *Nephotettix cincticeps* will increase by a ratio of from 3 to 4. Global warming has seemingly similar influences on the abundance of *C. suppressalis* and *N. cincticeps*. An increase in winter temperature enhances the abundance of both species. However, the increment is much larger for *N. cincticeps* than for *C. suppressalis*. Such a difference may be related to the difference in the number of generations per year. *N. cincticeps* has twice the number of generations, which may cause a sensitive response to the change in temperature [21].

Winter mortality of adults of *Nezara viridula* and *Halyomorpha halys* is predicted to be reduced by 15% by each rise of 1°C and in *C. suppressalis* two generation per year after 2°C warming[15]. The infestation of mustard aphid will change with the variation in the degree days. Thermal time calculations for mustard aphid Accumulation of 250 or more degree days in January at New Delhi caused less aphid infestation. If the degree day is 200 or less it favors the higher attack. Slower accumulation of heat units promotes aphid infestation [22]. The rise in temperature beyond 3°C, affects the population growth of rice ear head bug *Leptocorisa acuta* in [20].

Effect of Temperature on Voltinism: Climate change can cause major changes to the dynamics of individual species and to those communities in which they interact. One effect of increasing temperatures is on insect voltinism, with the logical assumption that increases in surface temperatures would permit multivoltine species to increase the number of generations per year. The relationship between climate change and voltinism could be complex. Effect of increasing temperatures is on insect voltinism, with the logical assumption that increases in surface temperatures would permit multivoltine species to increase the number of generations per year. The phenology based model for grape berry moth, *Paralobesia viteana* (Clemens), predicted that the increases in mean surface temperatures > 2°C can have dramatic effects on insect voltinism by causing a shift in the ovipositional period that currently is subject to diapause-inducing photoperiods [23].

Global Warming vs Species Distributions: Distributions of spruce budworm *Choristoneura fumiferana* under climate change [24] they will shift towards the poles, distribution shifts may be good or bad, depending on the species and the regions concerned. In the forests of North America, several native and introduced insect pests have exhibited some level of response to climate change in terms of distribution and impact. The notorious example is the western spruce budworm *Choristoneura occidentalis* (Williams and Liebhold 1995) and the eastern spruce budworm *C. fumiferana* [25].

Precipitation and Drought: The regional changes in the rainfall pattern due the climate change have been predicted by various climate change studies [35]. Enhanced summer rainfall and drought conditions on soil dwelling *Agriotes lineatus (*wireworms) promote rapid increase in the population of wireworms in the upper soil [26]. In Sub-Saharan Africa, changes in rainfall patterns are driving migratory patterns of the desert locust (*Schistocerca gregaria*), [27, 28]. The deviation of rainfall during monsoon and November and its relationship with level of *Helicoverpa armigera* damage severity showed higher November rainfall favoured higher infestation [29]. Average rainfall is predicted to decrease in several regions and the occurrence of summer droughts is likely to increase. Root herbivore species responded differently to the summer rainfall manipulations. The larvae of the dominant root-chewing species, *Agriotes lineatus*, were more numerous under enhanced rainfall, in contrast, abundance of the *Coccoidea lecanopsis formicarum* was unaffected by the rainfall manipulations. The responses of root herbivores to an increased incidence of summer droughts are therefore likely to vary, depending on their feeding strategy and life history [26]. Drought conditions severely affected egg viability of *Scopelosaurus lepidus* eggs and did not hatch at all under very dry conditions [30].

Indirect Effects of Climate Change on Insect Pests via Host Plants: The nutritional quality of plant tissue for insect herbivores generally increases with nitrogen content and decreases with lower water content and rising concentrations of secondary metabolites. The atmospheric CO_2 are likely to stimulate plant defense and resistance to the colonisation of phytophagous insects. Under moderate water stress, turgor pressure and water content of plant tissue decrease, leading to tougher foliage. Under increased concentrations of tropospheric CO_2, plants react by enhanced productivity due to direct fertilisation effects [31].The larvae fed on 700 and 550 ppm CO_2foliage exhibited greater consumption.The final larval dry weights were also higher on elevated CO_2 foliage. Higher significant approximate digestibility (AD) foliage and of relative consumption rate (RCR) were observed on elevated CO_2 foliage. Lower efficiency of conversion digested food (ECD), efficiency of conversion ingested food (ECI) and relative growth rate (RGR) of larvae were noticed on elevated CO_2 foliage than chamber and open ambient foliages. Under elevated $CO_{2,}$ lower N concentration, higher C, C/N ratio and ployphenols was observed [32]. Exposure to elevated CO_2 increases significantly western corn rootworm (*Diabrotica virgifera*) adults (foliage chewer) and soybean aphids (*Aphis glycines*). Higher concentrations of CO_2 in the atmosphere may increase herbivory in the soybean agro-ecosystem [33].

Effect of Climate on Pest Population via Natural Enemies: Shifts in climate can differentially affect the development rates of pest and predator species. In addition, temperatures can affect predator search. This way it affects the insect population dynamics indirectly. Normal increases in metabolic rate with increasing temperature are accompanied with an increase in developmental rate. Hence, in biological control systems of insect pests utilising parasitoids, the temperature response of the parasitoids determines their success in controlling the pest population. The egg predator *Cyrtorhinus lividipennis* of BPH Brown Plant Hopper had increased instantaneous attack rates and decreased handling times with increasing temperatures until 32°C. At 35°C the attack rate and handling time decreased drastically. This implies that predator activity is likely to increase with increasing temperatures up to a critical temperature of about 35°C. In addition to affecting biological characters, global warming may cause temporal asynchrony between interacting populations. Although natural selection will tend to increase synchrony between hosts and parasitoids, asynchrony may occur if host and parasitoid respond differentially to changes in weather patterns. Asynchrony may introduce a partial refuge effect that can reduce parasitism. However, the lack of temporal coincidence between searching parasitoids and hosts can contribute to stability. Insect may also evade climate-change stress through changes in life cycle. Insect populations from environments with higher temperatures may have higher fecundity and shorter growth stage durations to increase fitness. For example, in BPH, egg duration was 10.4 days at 25°C and 7.9 days at 27 to 28°C [18]. The parasitoid *Campoletis chlorideae* developed successfully over the temperature range of 12-37°C. However, the developmental period was found to be inversely correlated with temperature in the range of 12–37°C. The percentage pupal mortality of *C. chlorideae* increased above and below 22°C, with the highest mortality rate occurring at 37°C. As temperature increased, longevity decreased accordingly. The highest longevity of parental females (17.2 ± 3.6 days) was recorded at 12°C and longevity decreased continuously with rising temperature, with the longevity of adult female parasitoids being less than 4 days at 37°C. The pattern of daily reproduction and the estimates of other life-table statistics of *C. chlorideae* demonstrate that its performance decreased below and above 22°C. [34].

CONCLUSION AND RECOMMENDATIONS

Effect of climate change is more in temperate insects, it permits range expansion. Among the various abiotic factors, temperature is an important force to drive the population. Temperature cause the direct effects like survival, growth and development, voltinism and dispersal. Drought and precipitation play vital role in soil insect's abundance. The CO_2 is causing indirect effect through host nutrient alteration and it has both positive and negative effects. Change in voltinism is more profit to multivoltine species than univoltine species. There may be the possibility of evolutionary adaption in insects for changing environment. Therefore climate change might change population dynamics of insect pests differently in different agro- ecosystem and ecological zones, which need greater attention to understand and address these issues through more research. From the previous studies, it can be concluded that, there is a need of investigation in systematic documentation of major as well as minor pests, through investigation of metabolic alteration in insects to changing environment, developing prediction models and studying evolutionary changes under modified environment would be useful to face the challenge in near future.

REFERENCES

1. IPCC, 2001. Climate change 2001: the scientific basis, Contribution of working group I to the third assessment report of the intergovernmental panel on climate change (IPCC). Cambridge University Press, Cambridge http://www.grida.no/climate/ipcc_tar/
2. Porter, J.H., M.L. Parry and T.R. Carter, 1991. The potential effects of climatic change on agricultural insect pests. Agrl and Forest Meteorol, 57: 221-240.
3. Bale, J., G. Masters, I. Hodkinson, C. Awmack, T.M. Jnbezemer, V.K. Brown, J. Butterfield, A. Buse, J.C. Coulson, J. Farrar, J.G. Good, R. Harrington, S. Hartley, T.H. Jones, L. Lindroth, M. Press, I. Mrnioudis, A. Watt and A. Whittaker, 2002. Herbivory in global climate change research: direct effects of rising temperature on insect herbivores. J. Global Change Biol., 8: 1-16.
4. Warren, M.S., J.K. Hill, J.A. Thomas, J. Asher, R. Fox and B. Huntley, 2001. Rapid responses of British Butterfl ies to opposing forces of climate and habitat change.Nature, 414: 65-69.
5. Lange, H., B. Okland and P. Krokene, 2006. Thresholds in the life cycle of the spruce bark beetle under climate change. Int. J. for Complex Systems, 1648: 1-10.
6. Jönsson, A.M., G. Appelberg, S. Harding and L. Bärring, 2009. Spatio-temporal impact of climate change on the activity and voltinism of the spruce bark beetle, *Ips typographus*. Glob Chang Biol., 15: 486- 499.
7. Rouault, G., J.N. Candau, F. Lieutier, L.M. Nageleisen, J.C. Martin and N. Warzee, 2006. Effects of drought and heat on forest insect populations in relation to the 2003 drought in Western Europe. Ann. of forest Sci., 63: 613-624.
8. Moore, B. and G. Allard, 2008. Climate change impacts on forest health.Forest Health and Biosecurity Working Paper FBS/34E. Rome, FAO.

9. Veteli, T.O., A. Lahtinen, T. Repo, P. Niemelä and M. Varama, 2005. Geographic variation in winter freezing susceptibility in the eggs of the European pine sawfly (*Neodiprion sertifer*). Agric. and Forest Ent., 7(2): 115-120.
10. Ayres, M.P. and M.J. Lombardero, 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Sci. total Environ., 262: 263-286.
11. Johnson, C.G. and L.R. Taylor, 1957. Periodism and energy summation with special reference to light rhythms in aphids. J. Experimental Biol., 34: 209-221.
12. Cockbain, A.J., 1961. Low temperature thresholds for flight in *Aphis fabae* Scop. Entom. Expt. et Appl., 4: 211-219.
13. Aukema, B.H., A.L. Carroll, Y. Zheng, J. Zhu, K.F. Raffa, R.D. Moore, K. Stahl and S.W. Taylor, 2008. Movement of outbreak populations of mountain pine beetle: influences of spatiotemporal patterns and climate, Ecography, 31(3): 348-358.
14. Baier, J., A. Pennerstorfer and P. Schopf, 2007. A comprehensive phenology model of*Ips typographus*(L.) (Col. Scolytidae) as a tool for hazard rating of bark beetle infestation,.Forest Ecol. and Mgt., pp: 171-186.
15. Kiritani, K., 2006. Predicting impacts of global warming on population dynamics and distribution of arthropods in Japan. Popln. Ecol., 48: 5 12.
16. Berg, E.E., J.D. Henry, C.L. Fastie, A.D. De Volder and S.M. Matsuoka, 2006. Spruce beetle outbreaks on the Kenai Peninsula, Alaska and Kluane National Park and Reserve, Yukon Territory: Relationship to summer temperatures and regional differences in disturbance regimes. Forest Ecol. and Mgt., 227(3): 219-232.
17. Yamamura, K. and K. Kiritani, 1998. A simple method to estimate the potential increase in the number of generations under global warming in temperate zones. Appld. Entomol. Zool., 33: 289-298.
18. Heong, K.L., Y.H. Song, S. Pimsamarn, R. Zhang and S.D. Bae, 1995. Global Warming and Rice Arthropod Communities In: Climate Change and Rice. (Eds. Peng, S., Ingram, K.T., Neue, H.U. and Ziska, L.H.), Springer publications, Berlin, pp: 327-335.
19. Dhillon, M.K. and H.C. Sharma, 2007. Effect of storage temperature and duration on viability of eggs of *Helicoverpa armigera* (Lepidoptera: Noctuidae). Bull. Entomol., Res., 97: 55-59.
20. Reji, G. and S. Chander, 2008. A degree-day simulation model for the population dynamics of the rice bug, *Leptocorisa acuta* (Thunb.). J. Appld. Entomol., 132: 646-653.
21. Yumamura, K., M. Yokazawa, M. Nishimori, Y. Ueda and T. Yokosuka, 2006. How to analyse long- term insect population dynamics under climate change: 50 year data of three insect pests in paddy fields. Popln. ulation Ecol., 48: 38-48.
22. Chakravarty, N.V.K. and R.D. Gautam, 2002. Forewarning mustard aphid. Division of Agricultural Physics. Indian Agricultural Research Institute, New delhi. pp: 49.
23. Tobin, P.C, S. Nagarkatti, G. Loeab and M.C. Saunders, 2008. Historical and projected interactions between climate change and insect voltinism in a multivoltine species. Global Change Biol., 14: 951-957.
24. Regniere, J., R. Amant and P. Duval, 2010. Predicting insect distributions under climate change from physiological responses: spruce budworm as an example. Biol Invasions.
25. Gray, D.R., 2008. The relationship between climate and outbreak characteristics of the spruce budworm in eastern Canada. Climate Change, 87: 361-383.
26. Staley, J.T., C.J. Hodgson, S.R. Mortimer, M.D. Morecroft, G.J. Masters, V.K. Brown and M.E. Taylor, 2007. Effects of summer rainfall manipulations on the abundance and vertical distribution of herbivorous soil macro-invertebrates. Eur. J. Soil Biol., 43: 189-198.
27. Cheke, R.A. and J.A. Tratalos, 2007. Migration, patchiness and population processes illustrated by two migrant pests. Biosci., 57: 145-154.
28. Hulme, M., R. Doherty, T. Ngara, M. New and D. Lister, 2001. African climate change: 1900–2100. Climate Res., 17: 145-168
29. Srivastava, C.P., N. Joshi and T.P. Trivedi, 2010. Forecasting of *Helicoverap armigera* population and impact of climate change. Ind. J. Agrl. Sci., 80(1): 3-10.

30. Johnson, S.N., P.J. Gregory, J.W. McNicol, Y. Oodally, X. Zhang and P.J. Murray, 2010. Effects of soil conditions and drought on egg hatching and larval survival of the clover root weevil (*Sitona lepidus*). Appld. Soil Ecol., 44: 75-79.
31. Lindroth, R.L., K.K. Kinney and C.L. Platz, 1993. Responses of deciduous trees to elevated atmospheric CO_2 productivity, phytochemistry and insect performance. Ecol.ogy, 74: 763-777.
32. Rao, M.S., K. Srinivas, M. Vanaja, G.G.S.N. Rao, B. Venkateswarlu and Y.S. Ramakrishna, 2009. Host plant (*Ricinus communis* Linn.) mediated effects of elevated CO_2 on growth performance of two insect folivores. Current Ssci.ence, 97: 7-10.
33. Dermody, O., B. F.O'Neill, A.R. Zangrel, M.R. Berenbaum and E.H. Delucia, 2008. Effects of elevated CO_2 and O_3 on leaf damage and insect abundance in soybean ecosystem. Arthropod -Plant Interaction, 2: 125-135.
34. Pandey, A.K. and C.P.M. Tripathi, 2008. Effect of temperature on the development, fecundity, progeny sex ratio and life-table of *Campoletis chlorideae*, an endo-larval parasitoid of the pod borer, *Helicoverpa armigera*. Bio Control, 53: 461-471.
35. Cumhur, A and M.S. Cresser, 2008. The effects of Global climate change on agriculture. American–Eurasian J. Agric. &Environ. Sci., 3(5): 672-676.