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Studies on flowering phenology, pollinator diversity, supplemented pollination and their impact on fruit set in apple under changing climatic scenario in Kullu valley of Himachal Pradesh

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ABSTRACT

Pollinators are considered key-stone species in many situations not only because they support humanity but also maintain diversity in ecosystem. Climate change has the potential to alter the phenological synchrony between interacting mutualists such as plants and their pollinators. The data on the impacts of climate change on crop pollination-pollinator interaction are still limited. In the present studies data on apple flowering phenology and weather parameters (average maximum and minimum temperature and rainfall) from 2004 to 2013 have been correlated to visualise the impact of climatic variations on flowering in apple. The data on first flowering date in apple showed that the apple flowering date varied from March 16 to March 29. However when this date of flowering was put to rank correlation with temperature variations showed non-significant trend. Diversity and density of different pollinators viz honey bees, bumble bees, other wild bees, syrphids, drone flies and other insects were recorded using scan sampling and sweep net method which revealed that the diversity of the groups remained same. The investigations also indicated that advancement of flowering in apple did not show any significant impact on population of insect pollinators during these years being 0.67 in 2012 and 1.31 in 2013.The role played by honey bee colonies (*Apis mellifera*) on fruit set when supplemented to apple orchards has been evaluated. Data on fruit set (on spur basis) at 60 to 200 meter from bee colonies varied between 34.13 and 49.88 per cent and 79.5 and 71.76 per cent in 2012 and 2013 respectively. The data on fruit set irrespective of the year were maximum (59.7) in apple trees near to hive bee colonies while less (31.78) were recorded 200 m away from the bee colonies.

Keywords: Climate change; apple; flower phenology; pollinator diversity; supplemented pollination

INTRODUCTION

Mean surface temperature in the Himalayas rose by 1.5°C from 1982 to 2006 compared to 0.6°C rise in the global mean from 1975 to 2005 (Gautam et al 2014). Changing environments are expected to lead changes in life cycle events (Parmesan and Yohe 2003). The climate change impacts have been clearly deciphered by changes like dry and warm climate, change in snowfall and precipitation pattern (Bhagat et al 2004).Climate produces the strongest impact upon phenological phenomena as compared to other environmental factors. Phenology is concerned with the timing of events. How flowering responses may be altered by climate change are difficult to predict but of great significance with far reaching impacts on the functioning of ecosystem (Memmot et al 2007).

Kullu (31.8763°N, 77.1541°E) district of Himachal Pradesh is a high mountain environment exhibiting most of climatic features of mountainous area. It is characterized by vertical zonation of eco-climatic zones contributing by decreasing temperatures with increasing elevation above sea level. Mountainous catchment of Himalayan region like Kullu assumes importance because of the impact of climatic variability on the extreme weather events and also economic activities like agricultural tends to be quite pronounced in such environment. Hence study of climatic variability and its effect in such areas help in maximizing knowledge on general subject of climate change itself (Aditya et al 2013).

Apple (*Malus domestica*) is one of the most important and predominant temperate fruit crops of Himachal Pradesh. In recent years it has emerged as the leading cash crop and it alone accounts for 46 per cent of total area under fruit crops and 76 per cent of the total fruits production. Kullu valley is also known for apple cultivation. Apple is very sensitive to the weather conditions prevailing during its bloom. Apple production is dependent on insect pollinators (Free 1964, Delaplane and Mayer 2000). The majority of apple cultivars is self-incompatible and depends almost entirely on insects (especially bees) for cross-pollination (McGregor 1976, Gardner and Ascher 2006).The present study is an effort to reveal the possible effect of changing climate on flower phenology, flowering period and pollinator diversity along with effect of supplemented pollination on fruit set in apple crop.

MATERIAL and METHODS

The present study was undertaken in the Kullu district of Himachal Pradesh situated at an altitude range from 500-5000 meters above the mean sea level. Experimental trials during 2012-2013 on Apple (*M domestica*) were conducted at Horticultural Research Station, Seobagh, Kullu.

Meteorological data: The data on annual mean maximum and minimum temperature and that of rainfall from 2004-2013 were procured from Horticultural Research Station, Seobagh.

Flowering period: Dates of onset of bloom, full bloom and end of bloom were recorded during 2012 and 2013. Dates of flowering period of apple flowers from 2004-2011 were collected from Horticultural Research Station, Seobagh, Kullu

Pollinator density and diversity: Diversity and density of insect pollinators on apple were recorded following Food and Agriculture Organization (FAO) protocols using scan sampling and sweep net methods.

Scan sampling: The scan sampling was done by walking slowly along a set path in between rows. Number of insect visitors was recorded on 250 flowers on 3 sunny days. The insect visitors were counted by looking at individual flower. Observations were taken at the beginning, peak and end of the blooming period.

Sweep net: The net sweeps were taken by transect walks in 25 m long plot between the apple cultivars. Sweeps were taken for 5 minutes in each plot.

Identification: The different insect pollinators collected were identified from the reference collection present in the department and in laboratory.

Supplemented pollination: Recommended honey bee colonies were introduced to experimental apple orchards at 10 per cent bloom. Activity of the hive bees was recorded on apple cultivars present at different distances ranging from as near as 60 to 300 m.

RESULTS and DISCUSSION

Trend in weather elements and flowering period

In the present study the annual data on various weather parameters (average maximum and minimum temperature and rainfall) for the last 10 years (2004-2013) were collected from Horticultural Research Station (HRS), Seobagh. The data revealed that average annual temperature did not vary significantly in last 10 years. The average temperature (maximum) ranged between 24.20 (2005) to 25.19°C (2006) with little variations during other years. The average minimum temperature varied from 8.60 (2007) to 10.11°C (2006) (Fig 1). Jangra and Sharma (2013) have reported climatic variations on maximum and minimum temperature in Kullu valley from 1962-2008 and their findings revealed that during this period the average maximum and minimum temperature of the Kullu valley rose by 0.58 and 2.75°C respectively.

Change in rainfall pattern is an indicative sign of climate change. The

precipitation amount of any place can vary widely; this trend is quite pronounced in Kullu. This valley being a hilly area sometimes witnesses sudden rainfall. During the present study the climatic data (annual rainfall) revealed that in the last 10 years maximum average rainfall was witnessed in 2013 (76.73 mm). It was observed during winters in the month of February (253.7 mm). This shifting of rainfall pattern from summers to winters confirms the effect of global warming and its impact in Kullu. Similar trend has been observed by Jangra and Sharma (2013) in precipitation pattern at Bajaura and Katrain regions of Kullu valley. Thus it was found that the weather elements did not vary significantly during one decade except for the variation in the rainfall.

Apple is very sensitive to weather condition prevailing during 3 preceding months (December, January and February) from its flowering. This duration of 3 months is the critical period with respect to apple flowering. The data on maximum and minimum temperature was computed for these 3 months in different years. The data obtained revealed more variation in the average minimum temperature for different years -0.62 (2010-2011) to 3.38ºC (2008-09) (Fig 2).

Flower phenology and climate change

The timing (onset, peak and end of bloom) of phenological events such as flowering is often related to environment variables such as temperature. The data on first flowering date in apple showed that the apple flowering date varied from March 16 to March 29; maximum shift of about 2 weeks was witnessed during ten years span. However when this date of flowering was put to rank correlation with temperature variations it showed non-significant trend (Fig 3).

Flowering duration is another phonological aspect of great significance both for plant production and pollinator food supply. The data obtained in the present study revealed that the date of first flower to open got shifted during the last 10 years. The flowering period varied with minimum (11 days) in 2010 and maximum (20 days) in 2009. These observations are in accordance with the study done by Chauhan et al (2008) on apple cultivar at Regional Horticulture Research Station, Mashobra, Shimla where the date of flowering duration was found to vary between 11 (minimum) to 16 days (maximum). Flowering duration in apple has also been reported to vary from 10-17 days by Sharma et al (2006).

Flowering and pollinator diversity

A perusal of data given in Table 1 shows that the pollinator diversity during both the years (2012, 2013) remained same viz hive bees, bumble bees, other wild bees, syrphids, drone flies and others. The observations on insect visitors by scan sampling revealed that more insect visitors

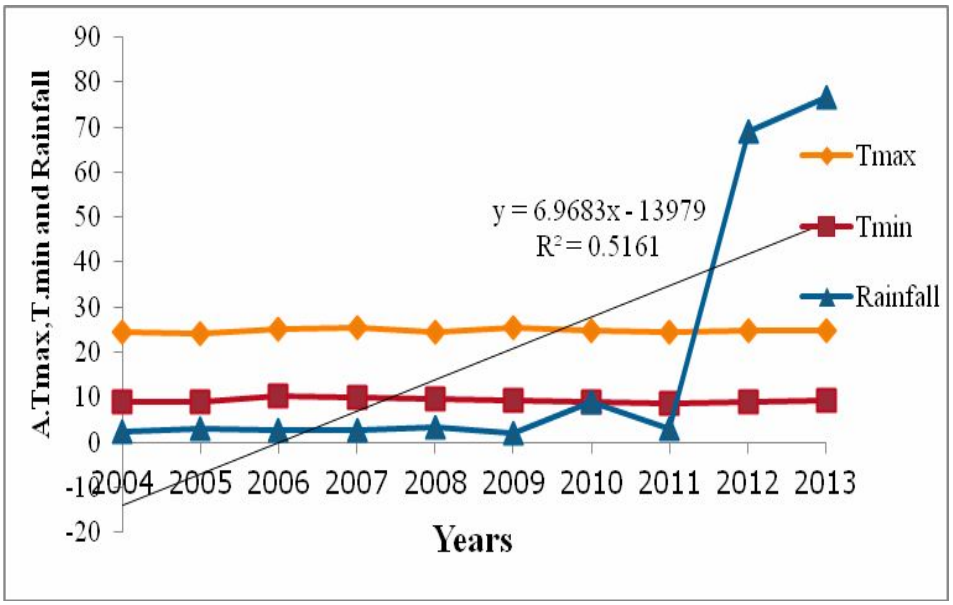

Fig 1. Temperature and rainfall data of Seobagh, Kullu from 2004 to 2013

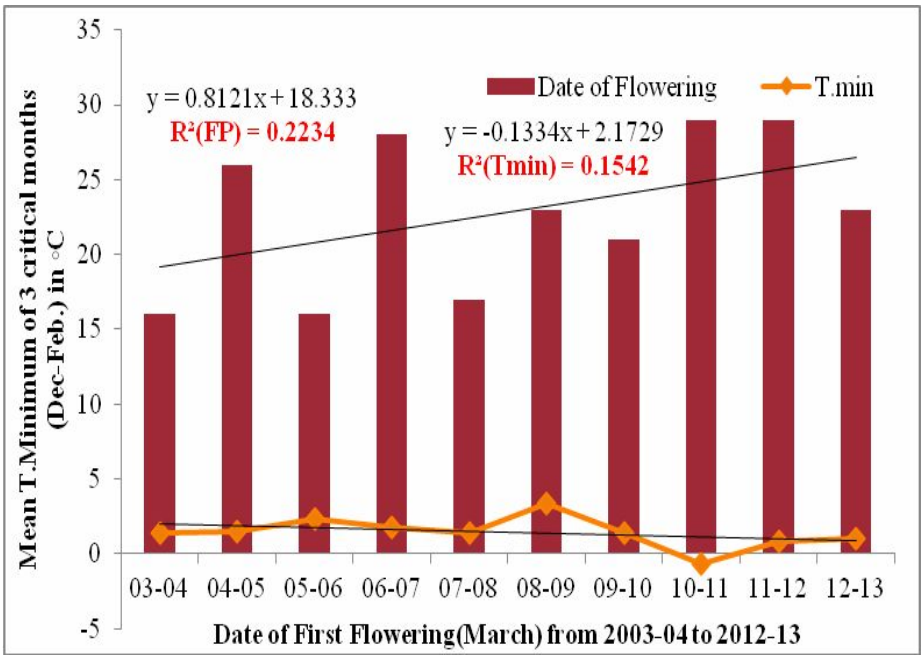

Fig 2. Variations in temperature and date of flowering from 2004 to 2013

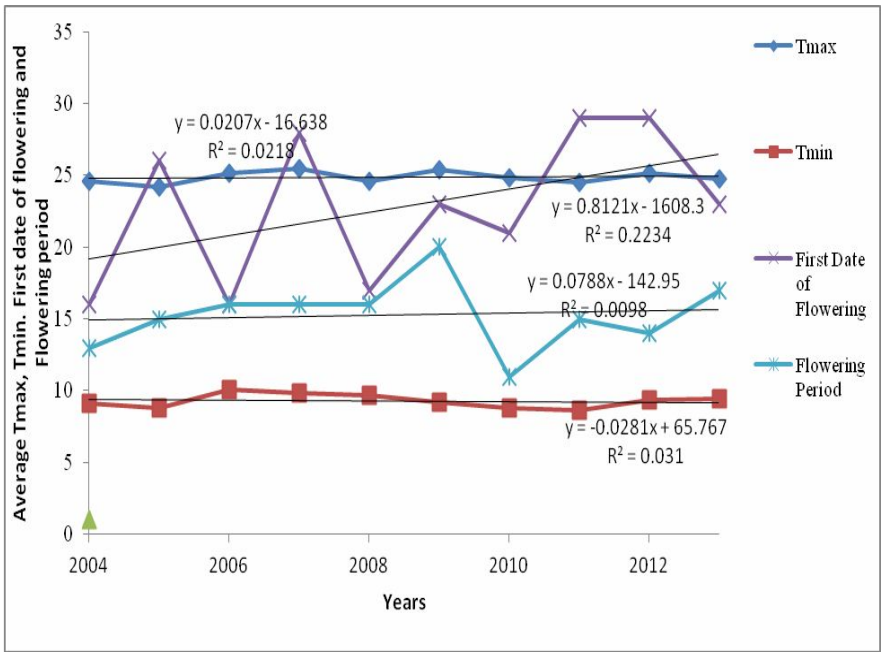

Fig 3. Shift in date of first flowering with respect to average minimum and maximum tempera ture and flowering period

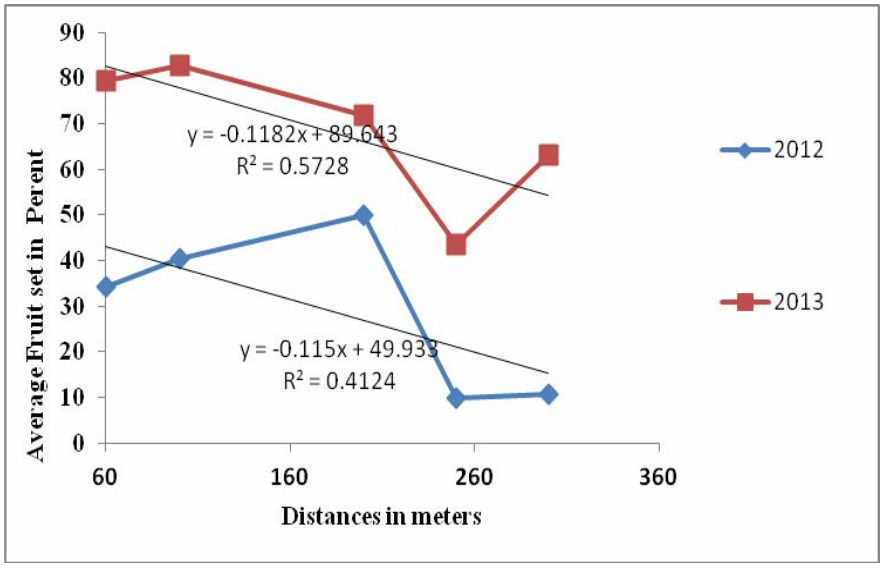

Fig 4. Diffrence in per cent fruit set at different distances durin 2012 and 2013

Table 1. Abundance of insect pollinators using scan sampling and sweep net during 2012 and 2013

Insect pollinator	Abundance of insect pollinators				Mean
	2012 Scan sampling	2013 Scan sampling	2012 Sweep net	2013 Sweep net	
Hive bees	2.23	2.13	0.56	1.27	1.55
Bumble bees	0.01	0.13	0.01	0.12	0.07
Other wild bees	0.03	0.74	0.02	0.86	0.42
Syrphids	2.13	3.37	0.97	2.47	2.24
Drone flies	1.02	1.77	0.57	1.35	1.18
Others	0.36	0.65	0.03	0.82	0.47
Mean	0.96 (1.15)	1.47 (1.35)	0.36 (0.91)	1.15 (1.25)	
CD	NS		0.24		

were recorded on apple bloom during 2013 (1.47/250 flowers) in comparison to 2012 (0.96/250 flowers) statistically being on par. The observations on insect catch by taking sweeps/5 minutes showed that more insects were caught in 2013 (1.15/5 minute sweep) in comparison to 2012 (0.36/5 minute sweep). The data further revealed that during these two years among insect pollinators syrphids were the most abundant (2.24) followed by hive bees (1.55) and drone flies (1.18). Bumble bees were the least abundant in both the years. The observations of the present study further revealed that flowering period was advanced by about one week however advancement of flowering did not have negative effect on insect pollinators visiting the apple bloom. Present investigations clearly indicate that advancement of flowering in apple did not show any negative impact on population of insect pollinators and non-significant change in average minimum and maximum temperature did not have any impact on pollinator diversity over a short span of 10 years.

Effect of supplemented pollination

Recommended colonies of *Apis mellifera* were introduced at 10 per cent bloom to see the impact of additional colonies on fruit set. Apple cultivation in Kullu valley is being practised as a monoculture which is used in different areas in apple crop and leads to increase in number of flowers in fields at particular place. This necessitates the supplemented pollination especially with hive bees in apple orchards. The data during 2012 showed decreasing trend with distance from placement of *A mellifera* colonies and it was significantly low beyond 200 meters.

Table 2. Fruit set at different distances from honey bee colonies during 2012 and 2013

Distance (m)	Per cent fruit set		Mean
	2012	2013	
60	34.13	79.5	56.81
100	40.5	82.75	61.62
200	49.88	71.75	60.81
250	9.75	43.5	26.62
300	10.75	63.13	36.94

During this year the commercial fruit was obtained up to 200 meter only. However the fruit set at 300 (63.13) in 2013 was more than that at 200 m (43.5); the possible reason for this trend could be the presence of more pollinizers at 300 m distance. Similar observations were made by Sharma et al (2002) where effect of placement of *A cerana* colonies in apple orchard showed significant increase in fruit set and fruit yield. In the present study it was observed that maximum average fruit set (59.75) was observed in apple trees near to hive bee colonies while less (31.78) fruit set was witnessed in apple trees away from the bee colonies (Table 2). Similar observations were made by Mattu and Raj (2013) in which the per cent fruit set was more in open pollinated varieties as compared to those in control. This clearly indicates the role played by pollinators in increasing fruit set. Singh (1962) and Morse (1976) reported that honey bee pollination increased quality and quantity of apple fruits. Rana et al (2010) reported similar results on fruit quality and yield in apple crop.

CONCLUSION

The study assessed the change in flowering phenology in accordance with climatic parameters to allow better understanding of the climatic effect. The non-significant change in weather elements had no effect on phenology and pollinator diversity. The pollinator diversity played important role in fruit set in apple orchards augmented with honey bee (*A mellifera*) colonies.

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REFERENCES

Aditya, Rana RS, Chauhan RC and Sen V 2013. Farmers' perception in relation to climate variability in apple growing regions of Kullu district of Himachal Pradesh. Journal of Agricultural Physics **13(1):** 48-54.

Bhagat RM, Kalia V, Sood C, Mool PK and Bajracharya S 2004. Inventory of glaciers and glacial lakes and the identification of potential glacial lake outburst floods (GLOFs) affected by global warming in the mountains of Himalayan region: Himachal Pradesh Himalaya, India. Technical report submitted to APN-START/ UNEP, Japan.

Chauhan A, Sharma G and Jindal KK 2008. Studies on flowering, pollination and fruit set in some apple cultivars. ENVIS Bulletin: Himalayan Ecology **16(1):** 33-36.

Delaplane KS and Mayer DF 2000. Crop pollination by bees. CABI Publishing, Wallingford, Oxon, UK.

Free JB 1964. Comparison of the importance of insect and wind pollination of apple trees. Nature **201:** 726-727.

Gardner KE and JS Ascher 2006. Notes on the native bee pollinators in New York apple orchards. Journal of the New York Entomological Society **114:** 86-91.

Gautam HR, Sharma IM and Kumar R 2014. Climate change is affecting apple cultivation in Himachal Pradesh. Current Science **4:** 498-499.

Jangra MS and Sharma JP 2013. Climate resilient apple production in Kullu valley of Himachal Pradesh. International Journal of Farm Sciences **3(1):** 91-98.

Mattu VK and Hem Raj 2013. Quantitative and qualitative effects of honeybee pollination on apple crop in Shimla hills of western Himalaya, India. International Journal of Advanced Biological Research **3(3):** 354-359

McGregor SE 1976. Insect pollination of cultivated crop plants. Agriculture Handbook, US Department of Agriculture, 496p.

Memmott J, Craze PG, Waser NM and Price MV 2007. Global warming and the disruption of plant-pollinator interactions. Ecology Letters **10:** 710-717.

Morse RA 1976. Efficient use of honeybees in the orchard. Proceedings, Annual Meeting of New York Horticulture Society **1021:** 61-64.

Parmesan C and Yohe G 2003. A globally coherent fingerprint of climate impacts across natural systems. Nature **421:** 37-42.

Rana RS, Sharma HK, Rana K and Rana BS 2010. Studies on *Apis mellifera* L pollination in apple and its economics. Proceedings, National Symposium on Perspectives and Challenges of Integrated Pest Management for Sustainable Agriculture, 19-21 Nov 2010, Solan, HP, India, pp 100.

Sharma G, Roshan, Anand and Sharma OC 2006. Floral biology and effect of pollination in apple (*Malus domestica*). Indian Journal of Agricultural Sciences **75:** 667-669.

Sharma HK, Gupta JK, Khajuria DR and Thakur JR 2002. Factors influencing natural crop pollination in apple and effect of placement of *Apis cerana* colonies in increasing apple productivity. In 6th AAA International Conference and World Apiexpo, Bangalore, Karnataka, India, pp 63.

Singh S 1962. Beekeeping in India (S Singh ed). Indian Council of Agriculture Research, New Delhi, India.

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