Pest Management in Horticultural Ecosystems
Vol. 29, No.1 pp 161-165 (2023)
DOI Number:10.5958/0974-4541.2023.00024.3

Thermal sensitivity of major pollinators of mango: Dipterans score high in climate resilience

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ABSTRACT: Pollination is an essential ecosystem service and climate change is a potential threat to the mutualistic interactions between plants and their pollinators. Field studies were conducted at ICAR-IIHR, Bengaluru during 2015-20 to study the effect of temperature on foraging activity of major pollinator species of a mango (Mangifera indica L.). The activity of wild honey bee, *Apis florea* (Fab.) was negatively correlated with temperature beyond 32^{o} C. while no decline was observed in case of Dipteran pollinator, *Chrysomya megacephala* (Fab.). The thermal breadth index was calculated based on density of four pollinator species foraging at different sets of prevailing temperature in the field. Species showed wide variability in their adaptability to temperature. Dipteran pollinators including *C. megacephala, Eristalinus arvorum* and *Stomorhina discolor* with higher thermal breadth index were relatively more adaptive to elevated temperature. Hence conservation of these native species is essential for climate change resilient strategies for enhancing mango production.

Keywords: Mango, pollinator, *Apis florea, Chrysomya megacephala*, thermal sensitivity, Dipterans, climate resilience, thermal breadth

INTRODUCTION

Pollination is one of the most important ecosystem services contributing to the biodiversity as well as global food security. The mutualistic interaction between plants and pollinators has evolved over centuries and been helping both natural terrestrial ecosystems as well as man-made agro-ecosystems. Animal pollinators, mainly including bees, birds and bats affect 35 per cent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide (Free, 1993). In addition to factors like habitat loss, chemical intensive agriculture, invasive species etc., climate change is emerging as one of major threats to pollination services (Hegland *et al*., 2009; Reddy *et al.,* 2012). The effect of climate change on pollinators depends upon their thermal tolerance and plasticity to temperature changes. Since bees and other insect pollinators are ectothermic, the temperature of their surroundings determines their activity. Behavioural responses of pollinator insects to avoid extreme temperatures have the potential to significantly reduce pollination services. Effective crop pollination is heavily dependent on biological timing, of both the crop and its pollinators. Crops such as mangoes in tropical regions, or almonds or apples in temperate regions, have periods of mass blooming over relatively short periods, requiring a tremendous peak in pollinators. Insects and plants react differently to changed temperature, creating temporal and spatial mismatches which could be detrimental to both plants and pollinators (Abrol, 2009; Hegland, 2009).

Mango (*Mangifera indica* L.), is the most widely cultivated and economically mportant fruit crop of India. It produces both male and hermaphrodite flowers and insects play a major role in mango pollination (Mukherjee, 1997). In India, more than 20 species of insects are reported to forage on mango inflorescence. However five species *viz. Apis florea* (Fab.) (Hymenoptera:Apidae), *Chrysomya megacephala* (Fab.) and *Stomorhina discolor* (Fab.) (Diptera:Calliphoridae), *Eristalinus arvorum* (Fab.) (Dipteral:Syrphidae) and *Tetragonula iridipennis* (Smith) are the most frequent and dominant visitors significantly contributing to mango pollination (Reddy *et al.,* 2012b). The scanty productiveness of many mango varieties has been attributed by several workers to inadequate pollination. In spite of having perfect flowers, cross pollination by insects is essential to achieve adequate fruit set and there are several studies which proved the essentiality of insects in mango pollination. About 60-100% reduction in fruit set was observed when panicles were completely excluded from insect foraging (Bhatia *et al*., 1995; Singh, 1997). In the ensuing climate change scenario, there is a possibility of shifts in pollinator diversity and their foraging behavior thus ultimately affecting their ecosystem services. Studies were conducted at ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru, India on mango to understand the impact of temperature on pollinators and their foraging behaviour.

MATERIALS AND METHODS

Field studies were conducted at ICAR-IIHR, Bengaluru during 2015-20 in a mango (cv. Totapuri) orchard of about 25 year old, maintained free from insecticide spraying. Observations were recorded on the number of insect foragers of different groups visiting the blossom at weekly interval during entire flowering period. Population counts of five major species *viz.,* little bee or dwarf bee, *Apis florea* (Fab.), stingless bee, *Tetragonula iridipennis* (Smith), calliphorid flies, *Chrysomya megacephala* (Fab.) and *Stomorhina discolor* (Fab.) and syrphid, *Eristalis arvorum* (Fab.) (Fig.1) were recorded from 10 panicles (representing all directions) on each tree. Five randomly selected trees were marked and used in the study, thus making total 50 panicles for each observation week. Each panicle was visually observed for five minutes to record the visitation by different pollinators. Mean number of foragers per 10 panicles per five minutes was taken as a unit to compare foraging activity between species and at different temperature rages. The foraging activity was correlated with maximum temperature prevailing during the study period. The data were subjected to correlation and regression analysis to understand influence of temperature on the numbers of pollinators. Analyses were carried out group wise for honey bees, (*A. florea* and *T. iridipennis*) and dipterans (*C. megacephala*, *E. arvorum* and *S. discolor*). In order to quantify the thermal sensitivity, Levin's niche breadth index was used. The physical environment and resources affect the breadth of the niche of a population. Considering temperature as an independent variable of physical environment of different pollinator species, niche breadth was calculated in terms of using the below formula (Feinsinger *et al.,* 1981).

Niche Breadth (Bn) = $1/\Sigma\, p_j^2$

Where, p_j is the proportion of individuals found in or using resource state

This index is a measurement of niche breadth (Bn) of a taxon (pollinator species in present study) and ranges from 0 to 1 whereby a value of 0 indicates least and 1 indicates highest thermal breadth at which a species forages.

RESULTS AND DISCUSSION

Data on pollinator activity in relation to the corresponding temperature indicated that temperature had significantly affected the foraging activity of pollinators and the impact differed significantly between two groups i.e. bees and flies. The activity of wild honey bee, *A. florea* was negatively correlated with temperature beyond 32° C. Their numbers were maximum (0.7-0./10 panicles/5 min) at 26-30°C, which came down drastically to less than 0.1 at temperature above 32°C. The polynomial model of regression equation was fitted with R^2 value of 0.68 indicating 68% of variability in foraging activity was influenced by the temperature (Fig. 2). In contrast, no decline was observed in case of Dipteran pollinator, *C. megacephala* and was thus less vulnerable to rise in temperature as reflected in Fig. 3 where the activity had not declined even at temperatures above 32°C. In addition, the R^2 value was low (0.46) implying that foraging activity of these two species was not significantly affected with rise in temperature prevailing during flowering period.

Environmental cues controlling the phenology of bees include maximum daily temperature, number of degree days and day length. The temperature of their surroundings determines their foraging activity. Behavioural responses of bees to avoid extreme temperatures could significantly impacts pollination services. The time taken for thermoregulation at higher temperatures comes at the cost of foraging. With increase in temperatures, the efficiency of pollen removal and deposition will change and pollinators are at risk of over heating. The honey bee's capacity to accumulate energy reserves and to manage the colony's development exerts significant adaptive pressure (Willmer and Stone, 2004; Reddy *et al.,* 2012a). In a related study, Reddy *et al*. (2015) established the adverse effect of elevated temperature on the foraging activity of Indian honey bee, *A. cerana* and present findings are in line with those observations.

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i. Apis florea

ii. Tetragonula iridipennis

iii. Chrysomya megacephala

iv. Eristalinus arvorum

v. Stomorhina discolor

Fig. 1. Major pollinator species of mango (I & ii : Hymenoptera ; iii, iv & v: Diptera)

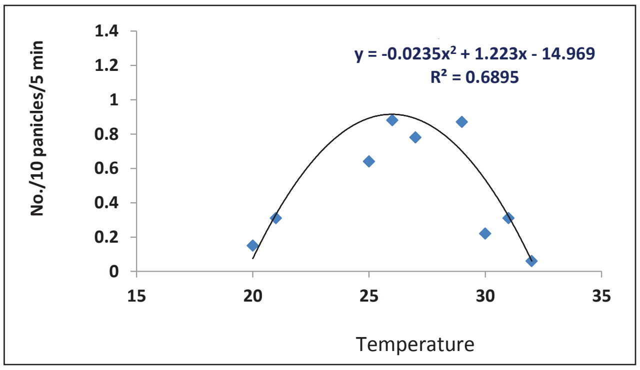

Fig. 2. Effect of temperature on foraging activity of honey bee, *A. florea*

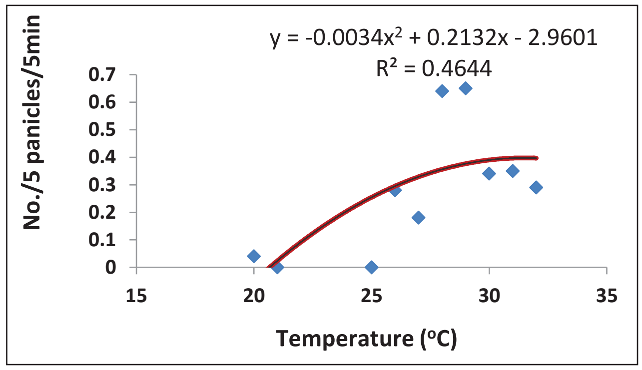

Fig. 3. Effect of temperature on foraging activity of dipteran pollinators v.z., *C. megacephala*, *E. arvorum* and *S. discolor*

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Thermal breadth index of different pollinators

The thermal breadth index was calculated based on density of four pollinator species foraging at different sets of prevailing temperature in the field. Species showed wide variability in their adaptability to temperature as evidenced through range of thermal index from lowest 0.45 in *T. iridipennis* to highest 0.64 in *C. megacephala.* The order of the thermal breadth index in descending manner was *C. megacephala* (0.64) > *S. discolor* (0.62) > *T. iridipennis* (0.54) > *A. florea* (0.45). As per Levin's index, taxon with 0 index are considered as highly specialised ones with specific niche requirement and those with 1 are generalists (Feinsinger *et al*., 1981). On these lines, pollinators with high index are capable of adjusting to wider temperature range than those with lower values. Accordingly, two dipteran pollinators with > 0.6 index are better placed than their Hymenopteran counterparts in their adaptability to enhanced temperature, an eventuality expected in the ensuing climate change scenario. Relatively lower activity of bees at higher temperature compared to flies could be due to the increased efforts needed by their colony life which demands worker bees to spend more time in regulating hive temperature. Williams *et al.* (2007) found a relationship between climatic niche and declines in British bumblebees, whereas Dormann *et al.* (2008) projected general declines in future bee species richness in Europe.

Present studies had clearly indicated that maximum temperature had significant effect on pollinator activity. Beyond 32°C, there was a decline in foraging activity of honey bees, *A. florea*. However temperature sensitivity was not uniform across species. Dipteran pollinators *viz., C. megacephala* and *S. discolor* were relatively more adaptive to temperature shifts thus making them suitable for inclusion in climate change resilient strategies for mango production. .

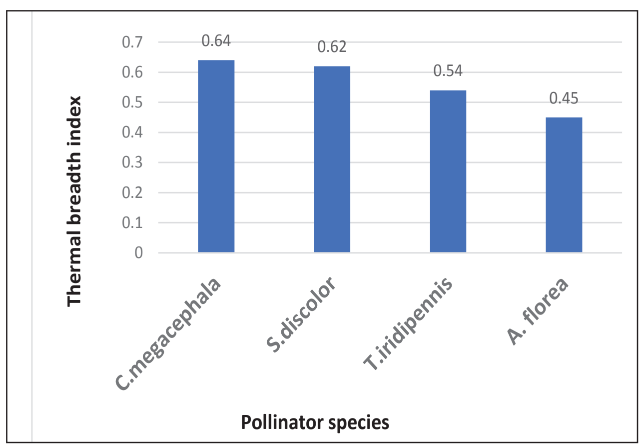

Fig. 4. Thermal breadth index of different pollinator species

ACKNOWLEDGEMENTS

The financial support from the Indian Council of Agricultural Research (ICAR) sponsored Project 'National Innovations on Climate Resilient Agriculture (NICRA)' is gratefully acknowledged. Authors also sincerely thank Director, ICAR-IIHR, Bengaluru for providing facilities and support.

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MS Received: 10 April 2023
MS Accepted: 25 May 2023