



Dynamics of climate and pollinator species influencing litchi (*Litchi chinensis*) in India

KULDEEP SRIVASTAVA¹, DEVINDER SHARMA², S D PANDEY³, A K D ANAL⁴ and VISHAL NATH⁵

ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar 842 002

Received: 8 June 2016; Accepted: 26 July 2016

ABSTRACT

The studies on pollinator complex and their impact on fruit set, yield and quality characters of litchi (*Litchi chinensis* Sonn.) cv Shahi with reference to *Apis mellifera* L. was carried at ICAR-NRC on Litchi, Muzaffarpur (Bihar) India, during 2014-15. The 20 pollinator species under 23 genera of 8 families belonging to orders Diptera, Hymenoptera and Coleoptera were recorded. Honey bee species *Apis dorsata* F; *Apis mellifera* L; *Apis cerana* F. and *Apis florea* F. were the most important and efficient pollinators of litchi flowers and constitutes more than 65% of the total pollinators. Other than *Apis* genera important pollinators were *Episyrphus balteatus*, *Melipona* sp, *Syrphus* sp, *Erisyrphus* sp, etc. The activity of *A. mellifera* visiting the flowers was highest (9.66 foragers/panicle/5 min). Correlation and regression analysis revealed that all honey bee species differed in their responses to temperature, light intensity and solar radiation, the three most important factors in foraging behavior. The yield was significantly higher in completely open pollinated plant as compared to *A. mellifera* pollinated plant. The qualitative and quantitative parameters, viz. fruit size, fruit weight, the maximum seed weight, seed size and TSS were found higher with open pollinated plants followed by *A. mellifera* pollination.

Key words: *Apis mellifera*, Litchi, Pollinators diversity

Litchi (*Litchi chinensis* Sonn.) is one of the most popular subtropical evergreen fruits grown in about 84 000 hectares in India. Litchi is highly self sterile and insect-pollination is necessary for the fruit set (Pandey and Yadava 1970, Phadke and Naim 1974). The litchi flowers are visited by a large number of insects during flowering period since they are the main source of nectar to them. It is a highly entomophilous fruit crop (Dhaliwal *et al.* 1977) and honeybees have been reported as the most outstanding beneficial insects on litchi (Groff 1943). Pollination of entomophilous crops by honey bees is considered as one of the effective and inexpensive method for improving the yield and its quality of fruit crops (King *et al.* 1989). Most of the bee keepers migrate their bee colonies to litchi orchards during this period every year for the production of litchi honey. Which has huge demand for its good colour and flavour. Honeybee pollination has become one of the important inputs for assured pollination resulting in higher yield and quality fruits. Assured pollination can only be achieved by managing optimum levels of pollinators. Therefore present investigation was undertaken to understand the effect of different weather parameters on the insect foragers, and their population dynamics in litchi and the influence of pollination by *A.*

mellifera under open and controlled condition on fruit set, yield and quality of litchi fruits.

MATERIALS AND METHODS

The studies were conducted on Research Farm, ICAR-NRC on Litchi, Muzaffarpur (Bihar), India, during 2014-15. Observations of flower-visiting insects were conducted from the start of flowering until approximate 95% of the flower faded. Samples were collected and species identification was done in the Entomology laboratory of ICAR-NRC on Litchi. The number pollinators visiting the flower were studied randomly on selected five plants during morning to afternoon (8 am to 2 pm) hour at one day interval. Observations were made in four directions of the plant. In each direction, an inflorescence (15 cm length) with bloom was observed for 5 min and statistical analysis was done using OPSTAT software.

The investigations on the effect of *A. mellifera* pollination on the litchi (cv. Shahi). The 15 plants were randomly selected in a randomized block design (RBD). There were three treatments, with five replicates, i.e. T₁- Caged tree (Excluding insect pollinators); T₂- Caged tree (with one *A. mellifera* colony); T₃- Completely open pollinated. Observation were recorded on fruit set/panicle (number of fruit set were counted on 10 randomly selected panicles on each tree) at initial development stage, and maturity stage, yield (kg/tree), fruit size (cm), fruit weight

¹Senior Scientist (e mail: kuldeep.ipm@gmail.com),
²SKUAST- J, Chatha, Jammu, Jammu and Kashmir 180 009.

(g), seed size (cm), seed weight (g) and total soluble solids (^oBrix). For evaluating impact on qualitative parameters five mature fruits were collected randomly from each tree. The length and diameter of fruits and seeds were measured with vernier calipers, fruit weight was recorded by pan balance and total soluble solid content was taken with the help of digital refractometer.

RESULTS AND DISCUSSION

Diversity of pollinators

During the observation 23 species of belonging to 4 orders and 12 families of class insecta (Table 1) was recorded during the blooming period of litchi plants. The 12 insect species belonging to the order Hymenoptera and Diptera were observed by Kumar *et al.* (2013) during the blossom period of Litchi. Hymenopterans were the most dominant visitors constituting 74.69% of the insect visitors and 25.21% others. Among these insects, honey bees *A. dorsata*, *A. mellifera*, *A. cerana* and *A. florea* were the dominant flower visitors. Their abundance was in the order: *A. mellifera* (47.52%) > *A. cerana* (20.59%) > *A. dorsata* (5.38%) > *A. florea* (0.37%). Pandey and Yadava (1970) reported *Apis* spp. and *Melipona* spp. as the major pollinators (98–99% of the total) of litchi bloom. Kitroo and Abrol (1996) and Abrol (2006) also reported that honey bee species *Apis dorsata*, *A. mellifera*, *A. cerana*. and *A. florea*. were the most and efficient pollinators of litchi flowers and constituted more than 65% of the total pollinating insects. Among other insect visitors/pollinators, syrphid flies, viz.

Eristalis spp., *Metasyrphus corollae*, *Episyrphus balteatus* were the major floral visitors (40.65%) followed by *Nomia* sp. (11.10%), *Halictus* spp. (10.31%), *Musca* sp. (7.93%), *Vespa* sp. (7.14%), *Lassioglossum* sp. (5.91%), coccinellids (5.39%), *Pieris brassicae* (2.69%), *Syrphus* sp. (3.37%) and *Canaus* (0.67%). All these insects mostly collected nectar and frequented at interrupted hours and were not considered as dependable pollinators. Similar observations has been recorded by Pandey and Yadava (1970), Phadke and Naim (1974), Dhaliwal *et al.* (1977) and Mahanata and Rahman (1997) in litchi.

Abundance of pollinators in relation to abiotic factors

Among the several factors, abiotic factors greatly influence the foraging behaviour. *A. dorsata*, *A. mellifera*, *A. cerana*, *A. florea* and other insect visitors in relation to abiotic factors revealed that activity of different pollinators varied with the variation of abiotic factors (Fig 1). However, the species differences in the population dynamics of bees were evident of all the honey bees. The order of their predominance was *A. mellifera* > *A. dorsata* > *A. cerana* > *A. florea* > others. The maximum population of *A. mellifera* (9.66) and lowest population (0.33) was recorded during March 23 and April 2, respectively. The population of *A. cerana* was maximum (7.33) on March 19 while the lowest forager's population (0.00) was on April 2. In the case of *A. dorsata*, the maximum population (5.93) was on March 23 while lowest forager's population (0.33) was recorded on April 2. Among all the pollinators, the population of *A. florea* was recorded as lowest on flowering litchi. The maximum population of *A. florea* (3.66) was recorded on March 23. The population of other pollinators remained low throughout the study period. The foraging behavior is greatly affected by the resource quantity and quality (pollen or nectar), and environmental characteristics. The correlation coefficient matrix (Table 2) shows that honey bee activity is positively correlated with maximum temperature, relative humidity (morning), sunshine and evaporation but negatively with minimum temperature, Relative humidity (evening) and rainfall. Thus bees visit increased at higher values of the former five factors and at the lower value of the last factor. The multiple linear regression analysis showed that all the weather parameters together were responsible for 97.20, 93.40, 93.60, 82.50 and 88.30% (R² value) of total variation of the foraging activity of *A. mellifera*, *A. dorsata*, *A. cerana*, *A. florea* and other pollinators, respectively. The foraging activity of all honey bee species followed the same pattern as temperature, light intensity, solar radiation, nectar sugar concentration and inversely with relative humidity (Abrol 2012). Each bee pollinator has specific ecological threshold for foraging activity which differ inter and intra specifically depending upon the level of adaptation of a given species in an environment (Burill and Dietz 1981, Abrol and Kapil 1986). The foraging behaviour of bees is a complex phenomenon which depends upon several factors. Besides the physical features of flowers such as colour, shape, and odour, the diversity of environmental factors

Table 1 Insect pollinators/visitors in litchi

Order	Family	Insect pollinators/visitors
Hymenoptera	Apidae	<i>Apis mellifera</i> , <i>Apis cerana</i> , <i>Apis dorsata</i> , <i>Apis florea</i>
	Halictidae	<i>Halictus</i> sp., <i>Lassioglossum</i> sp.
	Anthophoridae	<i>Nomia</i> sp.
	Meliponidae	<i>Melipona</i> sp.
	Formicidae	<i>Camponotus compressus</i>
	Vespidae	<i>Vespa</i> sp., <i>Polistes</i> sp.
	Apidae	<i>Xylocopa fenestrata</i>
Lepidoptera	Danaidae	<i>Danaus plexippus</i>
	Pieridae	<i>Pieris brassicae</i>
Diptera	Syrphidae	<i>Eristalis</i> sp.
	Syrphidae	<i>Syrphus</i> sp.
	Sarcophagidae	<i>Sarcophaga</i> sp.
	Syrphidae	<i>Metasyrphus corollae</i>
	Syrphidae	<i>Episyrphus balteatus</i>
	Muscidae	<i>Musca domestica</i>
Coleoptera	Coccinellidae	<i>Coccinella septempunctata</i> , <i>Menochilus sexmaculata</i> , <i>Hippodamia</i> sp.

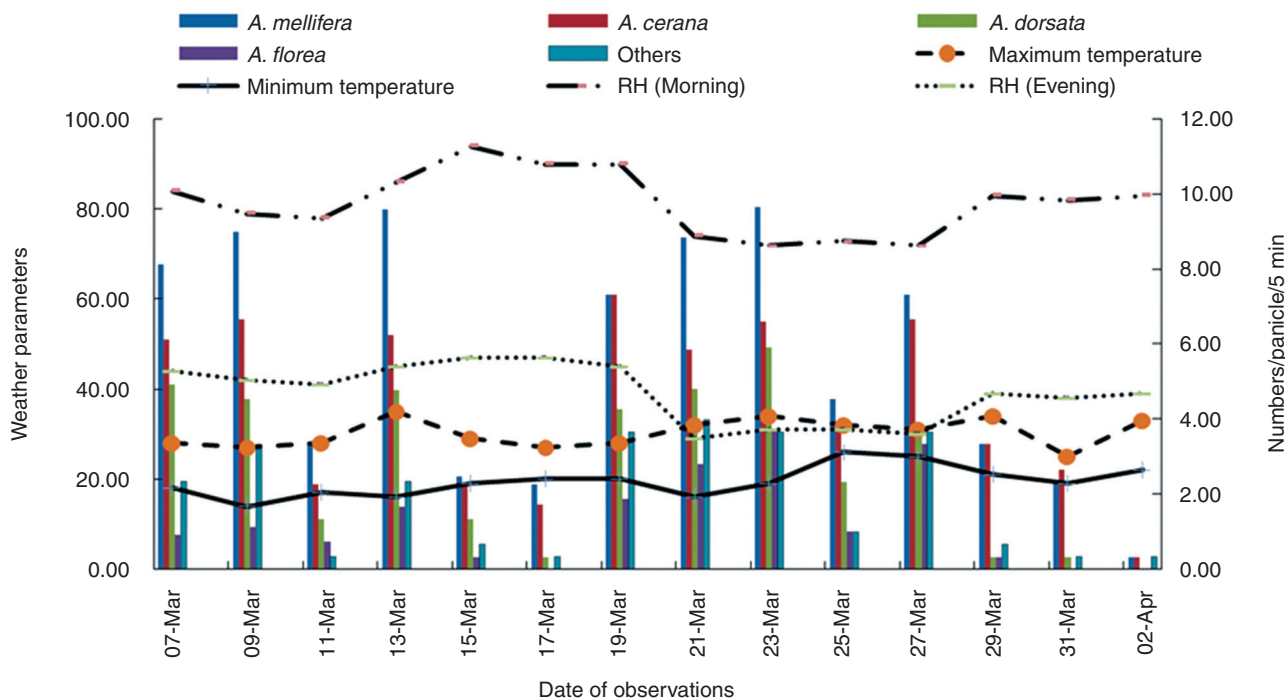


Fig 1 Foraging behaviour of pollinators on litchi

Table 2 Correlation and regression studies of pollinators in relation to abiotic parameters

Characters	‘r’ values				
	<i>A. mellifera</i>	<i>A. dorsata</i>	<i>A. cerana</i>	<i>A. florea</i>	Others
X1	0.077	0.161	0.038	0.442	0.221
X2	-0.374	-0.257	-0.385	0.044	-0.077
X3	0.075	0.064	0.043	-0.183	0.013
X4	-0.434	-0.528	-0.436	-0.538*	-0.488
X5	-0.324	-0.370	-0.318	-0.099	-0.289
X6	0.389	0.490	0.323	0.365	0.349
X7	-0.838**	-0.891**	-0.817**	-0.696**	-0.830**
X8	0.318	0.414	0.302	0.685**	0.491
Regression model	$Y_1 = -32.435 + 2.505X_1 - 1.000X_2 + 0.247X_3 - 0.144X_4 + 0.150X_5 - 0.096X_6 - 0.297X_7 - 1.155X_8$ $Y_2 = -10.838 + 0.879X_1 - 0.348X_2 + 0.128X_3 - 0.135X_4 + 0.121X_5 - 0.033X_6 - 0.723X_7 - 0.241X_8$ $Y_3 = -13.655 + 1.510X_1 - 0.627X_2 + 0.128X_3 - 0.135X_4 + 0.121X_5 - 0.033X_6 - 0.723X_7 - 0.241X_8$ $Y_4 = -9.946 + 0.885X_1 - 0.338X_2 + 0.047X_3 - 0.171X_4 + 0.117X_5 - 0.058X_6 - 0.117X_7 - 0.990X_8$ $Y_5 = -14.555 + 1.120X_1 - 0.338X_2 + 0.047X_3 - 0.171X_4 + 0.117X_5 - 0.058X_6 - 0.117X_7 - 0.990X_8$				
	$= 0.972)$ $= 0.934)$ $= 0.936)$ $- 1.453X_8 (R_2 = 0.825)$ $- 3.273X_8 (R_2 = 0.883)$				

**Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level. $Y_1 = A. mellifera$; $Y_2 = A. dorsata$; $Y_3 = A. cerana$; $Y_4 = A. florea$; $Y_5 = Others$ $X_1 = Maximum\ temperature\ (^{\circ}C)$; $X_2 = Minimum\ temperature\ (^{\circ}C)$; $X_3 = Relative\ humidity\ morning\ (\%)$; $X_4 = Relative\ humidity\ evening\ (\%)$; $X_5 = Wind\ speed\ (km/h)$; $X_6 = Sunshine$; $X_7 = Rainfall\ (mm)$; $X_8 = Evaporation$.

such as temperature, humidity, light, solar radiation, time of the day and nectar flow decisively shape the behaviour of pollinating insects (Corbet *et al.* 1993).

Impact of pollination treatments on quantitative parameters

The pollinators had a significant effect on the fruit setting which ultimately leads to higher yield of litchi crop. The studies revealed that the litchi is a cross pollinated crop which requires insect pollinators for getting maximum

yield. The maximum fruit length (3.56 cm), width (3.20 cm), weight (20.55 g) and TSS content (21.9 °Brix) were recorded in open pollinated plants followed by plants with *A. mellifera* (4.53 cm length and 3.45 cm) width, 19.75 g fruit weight, 19.10°Brix). The minimum fruit length (3.07cm), width (2.80 cm), weight (13.98 g) and TSS content (18.32 °Brix) were recorded in pollinator excluded plants (Table 3-4). According to the Stern *et al.* (1996) the pollen effect has significant on nut and kernel weight, with

Table 3 Impact of insect-pollination on the qualitative parameters of litchi

Treatment	Fruit set (%)	Size of fruit			Specific gravity	Size of seed			Specific gravity	TSS (%)	Acidity (%)	Pulp recovery (%)
		Length (cm)	Breadth (cm)	Weight (g)		Length (cm)	breadth (cm)	Weight (g)				
T1	1.02	3.07c	2.80c	13.98b	1.01c	1.55c	1.40c	3.51b	1.00	18.32	0.44a	56.99b
T2	4.53	3.45b	3.00b	19.75a	1.05b	1.80b	1.60b	3.80ab	1.06	19.10	0.48a	64.67a
T3	5.13	3.56a	3.20a	20.55a	1.14a	2.21a	1.80a	4.10a	1.16	19.33	0.35b	65.17a
CD (P=0.05)		0.05	0.09	3.55	0.02	0.20	0.17	0.30	NS	NS	0.07	5.89
SE(m) ±		0.01	0.05	0.85	0.01	0.06	0.05	0.09			0.02	1.46

Table 4 Effect of varied mode of pollination on litchi yield

Treatment	Fruit weight (g)	Fruit yield (kg/tree)	Yield increase (%) over (T1)
T1	10.98b	29.8b	
T2	19.75a	52.83a	177.28
T3	20.55a	54.67a	183.46
CD (P=0.05)	1.59	8.47	
SE(m) ±	0.49	2.60	

fruit coming from cross-pollination being heavier than that from self-pollination. Similarly, the maximum yield (54.67 kg/tree) was recorded in completely open pollinated trees followed by *A. mellifera* pollinated plants (52.83 kg/tree) and pollinator excluded plants (29.80 kg/tree). Thus, there is significant increase in yield obtained in open and bee pollinated plants as compare to pollinator excluded plants. Butcher (1957) reported that the reduced activity of insect pollinators could be major reason for low yield in litchi orchards and recommended augmenting pollination with honey bee during flowering period for increasing yield. Similarly, Badiyala and Awasthi (1991) also recorded a maximum yield (38 kg/tree) in Dehradun cultivar of litchi with bee pollination as compared to without bee pollination (9.60 kg/tree) that clearly indicates the importance of bee-pollination for enhancing litchi yield. (Pandey and Yadava 1970, King *et al.* 1989, Badiyala and Garg 1990, Stern and Gazit 1996, Mahanta and Rahman 1997, Rai and Srivastav 2012).

REFERENCES

- Abrol D P. 2012. *Pollination Biology. Biodiversity Conservation and Agricultural Production*, p 792. Springer Publication, UK.
- Abrol D P. 2006. Diversity of pollinating insects visiting litchi flowers and path analysis of environmental factors influencing behaviour of four honey bee species. *Journal of Apiculture Research* **45**(4): 180–7.
- Abrol, D P and Kapil R P. 1986. Factors affecting pollination activity of *Megachile lanata* Lepel. *Proceedings of Indian Academic Science* **95**: 757–69.
- Badiyala S D and Garg R. 1990. Studies on pollination and fruit production by *Apis mellifera* L. in seven cultivars of litchi (*Litchi chinensis* Sonn.). *Indian Bee Journal* **52**(1): 28–30.
- Badiyala S D and Awasthi R P. 1991. Physico-chemical characteristics of some litchi (*Litchi chinensis* Sonn.) cultivars grown in kangra Valley. *Indian Food Packer* **45**(1): 42–5.
- Burill R M and Dietz A. 1981. The response of honeybees to variations in solar radiation and temperature. *Apidology* **12**: 319–28.
- Butcher F G. 1957. Pollination insects on lychee blossoms. *Proceedings of the Florida State Horticultural Society* **70**: 32–8.
- Corbet S A, Fussell M, Ake R, Fraser A, Gunson C, Savage A and Smith K. 1993. Temperature and the pollinating activity of social bees. *Ecological Entomology* **18**: 17–30.
- Dhaliwal R S, Srivastava S and Adlakha R L. 1977. Insect pollination of litchi (*Litchi chinensis* Sonn.) in the valley areas of the Indian Himalayas. (In) *Proceedings of 26th International Beekeeping Congress*, Adelaide, Australia, p396.
- Groff G W. 1943. Some ecological factors involved in successful lychee culture. *Proceedings of Florida State Horticultural Society* **56**: 134–55.
- King J, Exley E M and Vithanage V. 1989. Insect pollination for yield increases in lychee. (In) *Proceedings of the Fourth Australian Conference on Trees and Nut Crops Exotic Fruit Growers Association*, Lismore, Australia, pp 142–5.
- Kitroo and Abrol D P. 1996. Studies on pollen carrying capacity and pollination efficiency of honey bee visiting litchi flowers. *Indian Bee Journal* **58**: 55–7.
- Kumar Y, Sharma R and Khan M S. 2013. Diversity and foraging behaviour of pollinator fauna on litchi (*Litchi chinensis* Sonn.). *Bioinfolet* **10**(1A): 78–81.
- Mahanta M and Rahman A. 1997. Studies on pollination of litchi (*Litchi chinensis* Sonn.) by honeybees (*Apis cerana* F.). *Indian Bee Journal* **59**(2) : 74–5.
- Pandey R S and Yadava R P S. 1970. Pollination of litchi (*Litchi chinensis*) by insects with special reference to honey bees. *Journal of Apiculture Research* **9**(2): 100–105.
- Phadke K G and Naim M. 1974. Observations on the honeybee visitation to the litchi blossoms at Pusa, Bihar, India. *Indian Bee Journal* **36**: 9–12.
- Rai V L and Srivastav P. 2012. Studies on the impact of bee pollination on yield and quality of litchi (*Litchi chinensis* Sonn.). *Progressive Horticulture* **4**(2): 262–4.
- Stern R A and Gazit S. 1996. Lychee pollination by the honey bee. *Journal of the American Society of Horticultural Science* **120**(1): 152–7.