Journal of Applied Horticulture, 24(2): 219-223, 2022
DOI: https://doi.org/10.37855/jah.2022.v24i02.40
Journal of Applied Horticulture
ISSN: 0972-1045

Yield loss assessment and control of fruit bat (*Pteropus giganteus*) in litchi orchards using artificial light method

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Abstract

Litchi (*Litchi chinensis*) is an important sub-tropical evergreen fruit crop of Punjab which is damaged by fruit bats (*Pteropus giganteus*). Since no study has been done in Punjab to assess fruit damage and control of fruit bats in litchi, the present study was conducted in litchi orchards at two different locations (six sites), Gurdaspur (Regional Research Station (PAU), villages Ranjit Bagh and Tibar) and Pathankot (villages Sujanpur, Balusa and Malikpur) each having three replications, during 2018 and 2019. Our results reported that yield loss (%) to litchi fruits by *P. giganteus* ranged from 6.85 to 8.93% and damage 5.59 kg/tree, having an average yield of 74.09 kg/tree. The average economic litchi fruit loss was calculated to be Rs. 32,232.0/acre. This damage to the litchi fruit crop was minimized by a non-lethal and non-polluting method (LED bulbs) with a one-time installation cost. It is concluded that after installation of 16 LED bulbs of 30 watts per acre at a distance of 50 feet from each other in an upward position at the height of 8 feet above tree canopy in orchard having 72 trees planted at a distance of 25×25 feet, we can reduce fruit bat damage to lower level and can give net economic return of Rs. 13448.0/acre to litchi fruit growers which will increase their farm income and help in conservation of fruit bats.

Key words: Fruit bats, LED bulb, light method, litchi crop, *Pteropus giganteus*

Introduction

Litchi (*Litchi chinensis*) is an important sub-tropical evergreen fruit crop belonging to the family Sapindaceae (Ray *et al.,* 1984; Roy *et al.,* 1984). Geographically, it is extensively grown in China, India, Thailand, Vietnam (Papademetriou and Dent, 2002), South Africa, Brazil, The Caribbean, Australia, Israel, South-Eastern United States (Crane *et al.,* 2008; Jones and Holderied, 2007). In India, litchi is grown mainly in the states of Bihar, West Bengal and Uttar Pradesh and at a limited scale in Tripura, Orissa, Punjab, Himachal Pradesh, Assam and the Nilgiri hills. Litchi crop is attacked by many pests which reduce its yield and fruit bats, *Pteropus giganteus* (Order Chiroptera: Pteropodidae), commonly known as "Indian flying fox" is an important pest among them (Mukherjee *et al.,* 2007; Srivastava *et al.,* 2018). *P. giganteus* are second most abundant group of mammals (25%) after rodents having 1200 species (Bhandarkar and Paliwal, 2014). Order Chiroptera is further divided into two sub-orders, Megachiroptera (Simmons, 2005) and Microchiroptera (smaller bats) (Vyas and Upadhyay, 2014). In India, there are about 12 species of megachiropteran bats (Wilson and Reeder, 2005), of which only three are commonly found throughout India, which include the Indian flying fox (*P. giganteus*), fulvous fruit bat (*Rousettus leschenaultia* Desmarest) and short-nosed fruit bat (*Cynopterus sphinx* Vahl) (Srinivasulu *et al.,* 2010). *P giganteus* is widely distributed throughout India and other regions of Asian countries (Jones and Holderied, 2007). Under schedule V of Indian Wildlife Protection Act 1972 and International Union for Conservation of Nature (IUCN), this species is labeled as 'vermin' on the impression that it poaches ripe fruits from orchards and defecates in public places (Venkatesan, 2007; Chakravarthy *et al.,* 2008; Hassan *et al.,* 2009) and causes heavy economic losses to guava (*Psidium guajava*) (20-28%), arecanut (*Areca catechu*) (18%), mango (*Mangifera indica*) (12-17%) and sapota (*Achrus zapota*) (12-30%) (Chakraverthy and Girish, 2003). Fruit bats cause significant loss in commercial fruit crops such as apples, bananas, carob, dates, grapefruit, litchi, mandarin, pear and pomegranate (Izhaki *et al.,* 1995). In a dietary study of *P. giganteus* on different trees, Hassan *et al.* (2015) observed that plants in the family Moraceae comprised most of the bat's diet. In contrast, fruits *Ficus golmerata* (30.9%) and *F. religiosa* (28.1%) during spring, *Diospyros peregrine* (71.9%) during autumn, *P. guajava* (19.6%), *F. bengalensis* (18.7%) and *Diospyros peregrina* (17.8%) during summer and *F. retusa* (27.5%) and *F. carica* (23.0%) during winter were the most preferred food items. The flying foxes are very conspicuous among tree roosting, and thus, many studies have been carried out on various aspects such as population ecology, reproductive behavior, roosting ecology (Caughlin, 2012; Gulraiz *et al.,* 2015), distribution and conservation issues (Kumar *et al.,* 2017). For a few decades, the population of *P. giganteus* decreased due to loss of habitat, climate change, and shift in urban areas (Parry and Augee, 2001; Jung and Threlfall, 2016).

Often difficulties exist in developing appropriate management strategies for flying foxes because there is generally very little known about their biology. Bats are nocturnal mammals and usually live in large aggregates as colonies known as roosting sites, which may vary from hundreds to thousands depending on the food availability (Williams *et al.,* 2006) and breeding season (Parry and Augee, 2001). These species provide widespread ecological and monetary services via pollination, seed dispersal

for hundreds of plant species and agricultural pest control (Goveas *et al.,* 2006; McConkey and Drake, 2006; Maas *et al.,* 2013) and they also regulate climate, rejuvenation of forests, nutrient cycling, water filtration and erosion control (Kunz *et al.,* 2011). The extent of actual damage to fruit crops is unknown and requires further investigation. Fruit bats are nocturnal and depend on eyesight for foraging activities. Light controls circadian rhythms and triggers the response, affecting bats' orientation during the night (Christian *et al.*, 2018). So, this behavior of fruit bats was exploited in the present study to prevent them from litchi orchards and reduce damage. Since no study has been done in Punjab to assess damage and control of fruit bats in litchi crop, the present study was proposed to investigate the damage and standardize traditional artificial light methods, which may help litchi fruit growers to increase their farm income.

Material and methods

Estimation of litchi fruit yield loss: To estimate litchi fruit yield loss by *P. giganteus*, the experiment was conducted in litchi orchards at two locations (six sites), each with three replications. From each replication, 20 litchi trees were selected for the study. The first location was selected from District Gurdaspur, where different litchi orchards were selected at sites, Regional Research Station, Gurdaspur (Punjab Agricultural University, Ludhiana), villages Ranjit Bagh and Tibar. The second location was selected at district Pathankot having sites in Sujanpur, Balusa and Malikpur. In both locations, orchards were 25-28 years old and trees were planted at a distance 25×25 feet, *i.e.*, 72 trees/acre (as recommended by Punjab Agricultural University, Ludhiana). These locations were selected because most of the litchi crop is cultivated here due to their sub-mountainous topography and suitable climatic conditions, also known as litchi belts of Punjab State. The litchi fruits damaged by fruit bats were recorded at weekly intervals, as suggested by Olesky *et al.* (2018) and the yield per tree of selected trees was recorded separately. Yield loss (%) caused by *P. giganteus* was calculated by using the formula: Fruit damage per tree (%)= (Weight of fruit damaged by bats/ Total fruit yield) x 100

Litchi fruit damage by *P. giganteus* can be easily identified from bird damage as bats eat fruit juice and spit out seeds, peel and pulp (Fig. 1) and bird damage was excluded during data collection. Data was further used to calculate the net economic return and loss of farmers caused by fruit bats. Generally, under Punjab conditions, the litchi crop ripens during June and harvesting is over till mid-July. So, these 30-45 days are critical for fruit bat damage to the litchi crop.

Control of *P. giganteus* in litchi orchard: To reduce litchi fruit yield loss by *P. giganteus*, the experiment for its control was conducted at two locations, one at litchi orchards of Regional Research Station, Gurdaspur (PAU, Ludhiana) and other at village Sujanpur (District Pathankot) using artificial light method. The study used light-emitting Diode bulbs (LED bulbs of Phillips Co. Ltd.) of different wattages 12, 20 and 30. In each replication, there were 9 LED bulbs placed at a distance of 50 feet from each other and 8 feet (2.5 m) above the center of the tree canopy using long bamboo sticks (one-inch diameter) to cover the full tree canopy and the adjacent trees (Fig. 2). The LED bulbs were used both in upward and downward positions. The bulbs faced an upward situation at RRS, Gurdaspur (PAU) and downward at village Sujanpur, District Pathankot. The power source for LED bulbs was electricity, and the wires used were of 1mm thickness (Havels Co. Ltd.). The observations were recorded during night hours three nights a week per location to observe any bat sitting on litchi trees causing damage. Any bulb which got fused was changed immediately. Input cost regarding the installation of LED bulbs, electric wires, bulb holders, switches and electricity consumed was calculated per acre for one month and then the economic return was calculated to analyze the effectiveness of the technique.

Result and discussion

Estimation of litchi fruit yield loss: In litchi orchards of location at district Gurdaspur (three sites), the average damage caused by *P. giganteus* ranged from 4.64 to 5.68 kg/tree with an average yield of 68.92 to 76.13 kg/tree and average yield loss (%) calculated as 6.10 to 7.45%. The moderate damage to litchi fruit/tree in District Gurdaspur was recorded to be 5.05 kg with an average yield of 73.60 kg/tree and average yield loss (%) calculated as 6.85% (Table 1). In litchi orchards of the location at district Pathankot (three sites), damaged done by fruit bats in litchi fruit ranged from 4.87 to 7.42 kg/tree with an average yield of 72.96 to 76.22 kg/tree and average yield loss (%) calculated to

Fig.1. *P. giganteus* damaged litchi fruits

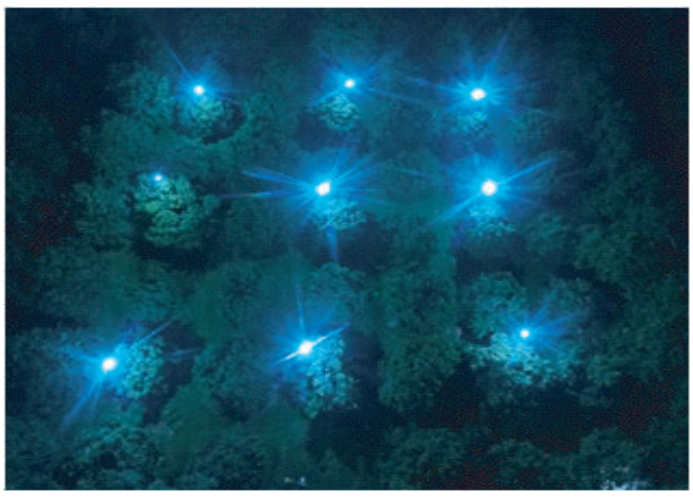

Fig.2. Installation of LED bulbs (30 watt) in litchi orchard

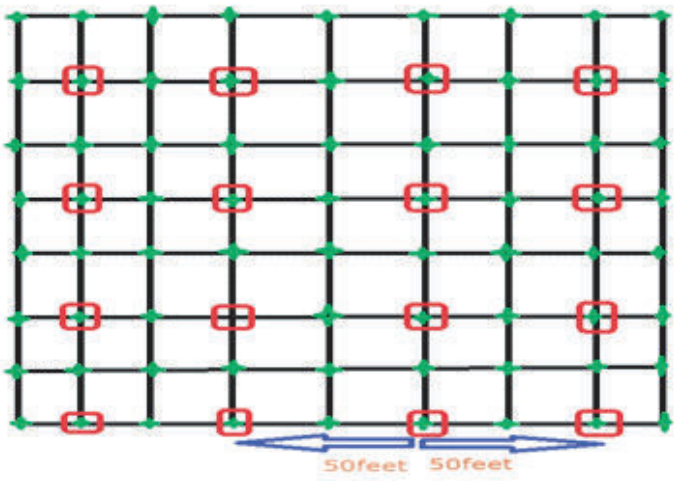

Fig. 3. Layout showing installation of LED bulbs/acre in litchi orchard. Total area 1 acre. Total number of trees (green coloured= 72. Total number of LED bulbs (red square)=16

be 6.4 to 10.70%. The average damaged litchi fruits in District Pathankot were recorded to be 6.14 kg/tree with a yield of 74.57 kg/tree and an average yield loss (%) of 8.93%. In both locations, damage done by fruit bats in litchi fruit was recorded to be 5.59 kg/tree with an average yield of 74.09 kg/tree and average yield loss (%) calculated as 7.89%. The statistical analysis shows that there is a significant difference between the damage recorded at Gurdaspur and Pathankot with *P*-value (3.4×10^{-5}) < 0.05 (Table 1). The average economic litchi fruit loss/tree and average economic litchi fruit loss/acre in both locations was reported to be Rs. 448.0 and Rs. 32232.0, respectively (Table 1). Interestingly, from the above data, it is concluded that the yield loss (%) in litchi fruits and average economic litchi fruit loss/acre for District Pathankot (8.93% and Rs. 35400.0) is more than District Gurdaspur (6.85% and Rs. 29604.0), due to more bat population near damage assessment area (Chatpat Bani village Kataru Chak) of District Pathankot as compared to District Gurdaspur. Similar studies have been done where damage to various horticultural crops like guava (*Psidium guajava*) (20-28%), arecanut (*Areca catechu*) (18%), mango (*Mangifera indica*) (12-17%) and sapota (*Achrus zapota*) (12-30%) have recorded (Chakraverthy and Girish, 2003). Extensive feeding of fruit bats on tender twigs of *Robusta coffee* leads to drying fruit-bearing branches, resulting in crop loss from 5.9-9.48% (Uma, 2014). The fruit growers estimated the fruit bats to eat 50,000kg of litchis per annum and that this damage is increasing at a rate of 10% annually (Oleksy, 2016). There are many reports from Israel where fruit bats consume commercial fruits such as apple, banana, carob, dates, grapefruit, litchi, mandarin, pear and pomegranate (Izhaki *et al.,* 1995).

Control of *P. giganteus* using artificial light method: Light as a control method for *P. giganteus* gave promising results. Initially, during year 2018, the experiment was conducted at orchards of village Sujanpur (District Pathankot) by using LED bulbs of 12 and 20 watts, but *P. giganteus* caused yield loss (%) in the range from 2.8 to 4.5% (Table 2) as compared to control (5.95%). In 2019, the experiment was conducted at two locations, orchards of village Sujanpur (District Pathankot) and Regional Research Station (PAU), District Gurdaspur, using LED bulbs of 27 and 30 watts. In both locations, by using LED bulbs of 27 watts, yield loss (%) was recorded was 1.56 to 1.88% compared to controls (4.94 to 7.01%). Interestingly, no fruit damage was recorded when LED bulbs of 30 watts were used in the orchards at both

Table 1. Yield loss assessment of fruit bat *P. giganteus* in litchi crop

Location	Site	Damaged litchi fruit /tree (kg) (n=20)	Total litchi fruit yield/ tree (kg)	Yield loss (%)	Economic fruit loss/tree (Rs.)	Economic fruit loss/acre (Rs.)
Gurdaspur	Regional Research Station (PAU)	4.83	68.92	7.01	386.0	27792.0
	Ranjit Bagh	5.68	75.76	7.45	454.0	32688.0
	Village Tibar	4.64	76.13	6.10	371.0	26712.0
	Mean	5.05	73.60	6.85	404.0	29604.0
Pathankot	Village Sujanpur	4.87	74.52	6.40	390.0	28080.0
	Village Balusa	6.14	72.96	10.70	491.0	35352.0
	Village Malikpur	7.42	76.22	9.7	594.0	42768.0
	Mean	6.14	74.57	8.93	492.0	35400.0
Total Mean		5.59	74.09	7.89	448.0	32232.0

Number of trees/acre=72; Market price of litchi=Rs. 80/kg during year 2019

Table 2. Efficacy of different wattages of LED bulbs on yield loss by *P. giganteus* bat on litchi fruits at different orchards of District Gurdaspur and Pathankot during year 2018 and 2019

Location	Site	Year	Watt (W) of LED bulb	Damaged litchi fruit/tree (kg) (n=49)	Total litchi fruit yield/ tree (kg)	Yield loss (%)	Economic fruit loss/tree (Rs.)	Economic fruit loss/acre (Rs.)
Pathankot	Village Sujanpur,	2018	(12W)	3.23	71.74	4.50	258.0	18576.0
		2018	(20W)	1.94	69.42	2.80	155.0	11160.0
		2018	Control-C1	4.53	76.12	8.95	362.0	26064.0
		2019	(27W)	1.43	75.70	1.88	114.0	8208.0
		2019	(30 W) bulb facing upwards	0	74.87	0	0	0
		2019	(30 W) bulb facing upwards	0	76.32	0	0	0
		2019	Control-C2	5.06	72.16	7.01	404.0	29088.0
Gurdaspur	Regional Research Station (PAU),	2019	(27W)	1.24	79.02	1.56	99.0	7128.0
		2019	(30W) bulb facing upwards	0	76.47	0	0	0
		2019	Control-C3	3.87	78.24	4.94	309.0	22248.0
-	Mean		Controls (C1+C2+C3)/3	4.48	75.50	6.96	358.0	25800.0

Table 3. Net economic returns for the control of fruit bat *P. giganteus* in litchi orchard using artificial light method

No. of LED bulbs installed/acre	Cost of 1 LED bulb (Rs.)	Total cost of 16 LED bulbs/acre (Rs.)	Cost of wire/acre (Rs.)	Cost of electricity/ LED bulb/8 hours/ day	Cost of electricity for 16LED bulbs/ month (Rs.)	Total expenditure for installation	Economic fruit loss/acre (Rs.)	Net economic return (Rs.)
16	600	9600	1600	2.40	1152	12352	25800	13448

Cost of electricity taken as Rs. 10/unit

locations. We also conducted one experiment at the village Sujanpur (District Pathankot) where LED bulbs of 30 watts were placed facing downwards and no fruit damage was observed (Table 2). Hence, both the techniques where LED bulbs were fitted upward or downward successfully kept the bats away from litchi orchards. It is revealed that there is a need for 16 LED bulbs of 30 watts (installed at a distance of 50 feet) for an acre orchard with 72 litchi trees planted at a distance of 25×25 feet. From the present study, a model was prepared for the installation of LED bulbs of 30 watts for an acre in a litchi orchard (Fig. 3). During the year 2019, economical fruit loss in control orchards from both locations recorded was Rs. 358.0.0/tree and Rs. 25800.0/ acre) (Table 2).

Total expenditure (input cost) for the installation of 16 LED bulbs of 30 watts was calculated to be Rs. 12352.0/acre, which includes the cost of LED bulbs, cost of electric wires and switches and cost of electricity used for one month. Economic fruit loss was calculated to be Rs. 25800.0/acre and net economic return as Rs.13448.0/acre. Thus, farmers can get a net profit of Rs. 13448.0/ acre after installation of LED bulbs of 30 watts which will help them to keep the fruit bats (*P. giganteus*) away from the litchi orchards and will increase their farm income which also helps in conservation of *P. giganteus* fruit bats.

The bulbs should be installed upwardly at 8 feet above the tree canopy. The distance between two bulbs should not be more/ less than 50 feet. In a study, Polak *et al.* (2011) revealed that illumination of foraging areas with artificial lights can prevent the foraging activity of fruit bats, reducing fruit damage. Also, an increase in insect density was recorded near illuminated areas around orchards, which may help insectivorous bats to feed upon them thus, reduce insect pest population and usage of pesticides (Eisenbeis, 2006). In Thailand, farmers set nets around fruit trees to catch fruit bats visiting their trees and prevent fruit damage (Epstein *et al.,* 2009).

In some cases, farmers developed a negative impact on bats and attempts were made to destroy the roosts which were nearby the fruit orchards (Verghese, 1998), whereas in some places, many Pteropodid bats were often shot to protect orchards from damage (Bumrungsri *et al.*, 2009). Fruits such as dates could be saved from bats by covering them with cloth bags or nets before ripening (Hadjisterkotis, 2006). In a study, the number of bat passes of *Myotis lucifugus* significantly reduced when a crossing point was artificially illuminated compared to when the lights were turned off, indicating reduced activity of bats (McGuire and Fenton, 2010). Rossiter *et al.* (2000) showed a reduction in *Rhinolophus hipposideros* activity with the presence of artificial lighting using high-pressure sodium lamps, whereas individuals of *Myotis dasycneme* modified their flight trajectories in reaction to being exposed to halogen lamps (Eklof, 2003). In a study using an integrated approach by partially covering vulnerable sections of the fruit tree canopies, illumination and scaring with noises saved 4, 6 and 11% of damaged sapota fruits, respectively (Chakraverthy and Girish, 2003).

Under normal conditions, yield loss (%) caused by *P. giganteus* in litchi fruit was calculated to be 6.85-8.93%. Installation of 16 LED bulbs/acre of 30watts at a distance of 50 feet from each other and a height of 8 feet above the top of the tree canopy for the orchard having 72 litchi trees planted at a distance of 25×25 feet helps reduce bat damage and farmers will get a net profit of Rs. 13448.0/acre.

Acknowledgements

We thank the Head, Department of Zoology, Deputy Director, KVK, Pathankot, Director, RRS Gurdaspur, Punjab Agricultural University, Ludhiana for providing the facilities to conduct this research.

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Received: October, 2021; Revised: December, 2021; Accepted: December, 2021