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Assessment of Crop Loss Due to Elephant Crop Raids and Its Eco Friendly Mitigation

Mohan I Naik [a++*], Ravikiran, K [b#] and Basavadarshan A V [a†]

[a] AINP on Vertebrate Pest Management, University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru, Karnataka, India.
[b] Department of Agricultural Entomology, University of Agricultural Sciences, Gandhi Krishi Vignan Kendra, Bengaluru, Karnataka, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The crop raiding by elephants is one of the important concern causing loss of livelihood and affects the farmer's economy. Hence a study was conducted to estimate the crop losses and to evolve an economically feasible mitigation measures. The studies were conducted in villages belonging to Kodihalli and Uyyamballi Hobli of Kanakapura Taluka, Ramanagara District, Karnataka which is surrounded by thick forest cover during 2022 to 2023. The estimation on crop loss revealed that the

[++] Professor and Scheme Head;
[#] Assistant Professor of Zoology;
[†] Senior Research Fellow;
**Corresponding author: Email: mohanishwarnaik@yahoo.com, mohanishwarnaik@yahoo.in;*

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highest crop losses were recorded in banana (5.26 to 46.54%) plantations followed by maize (2.47 to 41.87%), ragi (2.31 to 38.95%), mango (1.28 to 32.54%), pigeon pea (1.31-21.41%) and cowpea (1.46 to 12.68%). The highest economic loss was recorded in banana and mango crops. The evaluation of mitigation measures in ragi and maize crop revealed the use of bioacoustics and predator deterrent lights provided better economical feasible mitigation measures with the cost benefit ratio of 1:2.9 and 1:3.5 respectively. The use of barbed wire fence and use of solar fence (Agri solar) was also found effective in mitigating the crop raids by elephants. However, these mitigation measures are short term and has to be used in vulnerable stages of the crop only.

Keywords: Elephants; crop raiding; loss estimation; conflict mitigation.

1. INTRODUCTION

The Asian elephant (*Elephas maximus* L.) is categorized under Schedule I of the Indian Wildlife Protection Act 1972 and is endangered and a keystone species (Ramkumar et al., 2014). Increased anthropogenic activities and expanded agricultural landscape are overlapping upon natural habitat, and make the animals to compete for resources (Hedges et al., 2005), (Sukumar, 2006). The human-elephant conflict affects social and economic security of farmers and challenges conservation of elephants in their home-range. The major reason for human-elephant is expansion of agriculture fields on the forest fringe areas and various developmental activities in forest region (Gubbi et al., 2014). The loss of habitat quality, degradation of habitat, competition for water, movement pattern, palatability and nutritive value of crops have forced elephants to extend their range and raid crops to meet out their daily needs (Singh and Kumar, 2014).

One of the major components of human-elephant conflict is crop raiding and elephants can inflict severe loss to farmers with a single crop raid. During the crop raids elephants invade into human habitats and become inevitable (Webber et al., 2011), (Kiffner et al., 2021). Fragmentation of elephant habitat has led to trapping them in isolated patches which has made degradation of their habitat, competition for water, movement pattern, palatability and nutritive value of crops have made them to depredate the crops (Graham et al., 2010), (Montgomery et al., 2022). Among the elephants there was no difference in the frequency of crop raids however the males caused greater extent of economical loses. The crop raiding activity is documented throughout the country around the protected areas and elephants have inflated damage to variety of crops during the vulnerable stages of the crops (Barnes et al., 2015), (Tiller et al., 2021). The crop raids coincided with the onset of the rainy season and the intensity and frequency of crop raiding reached the peak in the months of October to December during the crop maturity stages of the crop (Osborn and Parker, 2002), (Ogunjobi et al., 2018). Elephants are intelligent animals and are capable of adapting to all kinds of attempts by man to mitigate crop losses caused by them. The elephants cannot be managed by single method and the mitigation method requires suitable plan of action keeping in mind the behaviour, ecology and habitat of the crop raiders (Graham et al., 2010), (Montgomery et al., 2010). The mitigation measures include the application of deterrents, repellents, fencing, construction of trenches, night vigils, capture and translocation methods which are cumbersome and require high monetary investments (Hedges and Gunaryadi, 2010), (Davies et al., 2015).

The forest in Kanakapura is scrub and dry deciduous, with interspersed agricultural land. The farmers in Kanakapura depend on rain fed antiquated farming practices. The increased elephant raids on crops have resulted in low agricultural productivity. In this view, a study was conducted to estimate the extent of crop damage imposed by elephants and to evolve an eco-friendly, effective and economically feasible method to mitigate the crop raids by elephant.

2. MATERIALS AND METHODS

2.1 Study Area

The experiments on the yield loss assessment and evaluation of mitigation measures against elephants were conducted in farmer's crop lands of villages belonging to Kodihalli and Uyyamballi Hobli of Kanakapura Taluka, Ramanagara District, Karnataka. These villages are surrounded by thick forest of Muneshwara forest reserve and Mugguru forest reserve.

2.2 Yield Loss Assessment

The trials for loss assessment due to elephant crop raids in different crops was conducted

during the year 2022-2023. The loss assessment was conducted by comparing the yield and plants damaged between the protected and unprotected crop fields (Prajapati et al., 2013). In the present study, crop lands protected with solar fence and trenches was considered as protected crop lands and where no control measures were taken up was regarded as unprotected crop lands. The number of attempt to raid the crops at the fortnight interval was recorded by observing the signs of dung and crop trampled marks. Besides, per cent crop loss was calculated by recoding the number of plants damaged per hectare and yield data was recorded to calculate the yield losses.

2.3 Evaluation of Mitigation Measures

The field evaluation was conducted in ragi and maize crops in the above-mentioned study area during 2022-2023 *Kharif* seasons, with the following treatments.

T1= Barbed wire fencing

T2= Bio acoustic device (Harmony Q-3) @1 per hectare

T3= Predator deterrent lights (Katidhan tech) @1 per hectare

T4= Solar fencing (Agri solar) (Portable solar fence)

T5=Bonfire (lighting fires in the ground at the edge of the crop fields)

T6= Noise: a widely used traditional method; includes purposeful shouting, crackers or drums

T7=Control

All the mitigation measures were induced during the critical crop stages (crop maturity and harvesting stages) The experiments was conducted as per the randomized block design with three replications, each block measuring about one acre and the efficacy of treatments was assessed by recording, number of attempts to raid the crop and total yield obtained after the harvesting. The recorded data was subjected to one-way analysis of variance (ANOVA) followed by Duncan multiple range tests ($P \leq 0.05$) to know the statistical differences.

3. RESULTS AND DISCUSSION

3.1 Yield Loss Assessment

Among the cereal crops, ragi and maize were more prone to crop raids., In ragi crop for instance, elephants damaged the crop by trampling and consuming the mature ear heads and vegetative structures of the crop. The average attempts to raid the crop was 8.65 ±2.41 per fortnight with the monetary loss of Rs. 2,776 to 48,311 per ha. There was a crop damage of 2.31 to 38.95 per cent. In maize, the elephants inflated damage by consuming the mature cobs with the vegetative structures and also by trampling the vegetative structures. With the monetary loss of Rs. 1,504 to 26,041 per ha there was a crop damage of 2.47 to 41.87 per cent and the average attempts to raid the crop was 7.82 ±2.41 per fortnight.

Among the fruit crops, elephants preferred banana and mango plantations while in banana plantations elephants inflated the damage by consuming mature fruits and trampling the pseudo stem. With the monetary loss of Rs. 1,28,107 to 3,69,535 per ha, there was a crop damage of 5.26 to 46.54 per cent and the average attempts to raid the crop was 9.54 ±3.74 per fortnight. In mango orchards, elephants damaged the crop by damaging the branches and consuming the fruits. The average attempts to raid the crop was 7.59 ±2.87 per fortnight with the monetary loss of Rs. 14,688 to 2,80,718 per ha and a crop damage of 1.28 to 32.54 per cent.

In pulses crops, pigeon pea and cowpea were more prone to elephant raids in cowpea crop. Elephants damaged the crop by consuming the mature pods and plats. The average attempts to raid the crop was 4.72 ±1.65 per fortnight with the monetary loss of Rs. 513 to 4,307 per ha and there was a crop damage of 1.46 to 12.68 per cent. In pigeon pea, elephants inflated the damage by consuming the mature pods and trampled the plants with the monetary loss of Rs. 1,067 to 20,532 per ha. There was a crop damage of 1.13 to 21.41 per cent and the average attempts to raid the crop was 5.47 ± 1.21 per fortnight.

The continuous habitat loss due to expansion in agricultural lands, mining, expansion of roads and other anthropological activities have made to increased crop raids by elephants (Montgomery et al., 2022). The elephants

damage the crops by trampling and consuming the crops. The intensity and frequency of damage depend on the population and size of the herd (Mackenzie and Ahabyona, 2012). In the present study, crop raiding activity by elephants was observed in all the crops and the peak crop damage and monetary losses were observed in fruit crops. In cereal crops, crop damage was found to be 2.39 to 40.41 per cent with a monetary loss of Rs. 2140 to 37,176 per ha. In pulses crops, the crop damage was 1.29 to 17.04 per cent with monetary loss of Rs. 790 to 12,419 per ha. In banana, elephant crop raids accounted for average monetary loss of Rs. 2,48,821 per ha with the damage of 5.26 to 46.54 per cent crop damage whereas, in mango the crop loss was 1.28 to 32.54 percent with an average monetary loss of Rs. 1,47,703 per ha. The results were in agreement with the studies conducted by (Ramkumar et al., 2014) who reported that banana, paddy, sorghum, areca nut, coconut were the most raided crops by elephants and accounted for crop damage of 66 to 75 per cent in groups and 25 to 34 per cent by solitary males. Sukumar, 1990 reported that raiding frequency reached peak during October to December, and crop raiding was observed every night when finger millet (*Eleusine coracana*) was cultivated in southern India. Gubbi et al.,2012 reported that elephant affected finger millet, maize, cotton, paddy and sugarcane which accounted for 86.34 per cent total crop losses around Bandipur National Park, Mudumalai and Waynaad Wildlife Sanctuaries.

3.2 Evaluation of Mitigation Measures against Crop Raiding Elephants

In ragi crop (*Kharif 2022*) there was a significant reduction in elephant crop raids with respect to different mitigation measures. Among the different mitigation measures evaluated, the least number of attempts to raid the crop (0.79 / fortnight) with the highest yield (20.31 q/ha) was recorded in T4 (Solar fencing) and it was followed by barbed wire fencing (T1) (2.32/fortnight, 19.29 q/ha), use of bioacoustics (T2) (3.61/fortnight, 18.50 q/ha), application of predator deterrent led light (T3) (4.37/fortnight, 17.97 q/ha), putting bonfire in crop border (T5) (6.79/fortnight, 13.69 q/ha) and creating frightening noise (T6) (7.51/fortnight, 13.16 q/ha). In control plots, the number of attempts to raid the crops was 8.44 per fortnight with a yield of 12.44 q per ha. The cost benefit analysis revealed that among the different mitigation measures use of predator deterrent led light was found to be the best treatment with a cost benefit ratio of 1:5.32 and it was followed by use of bioacoustics (1:3.88), solar fencing (1:2.84), barbed wire fencing (1:2.77), application of bonfire in crop border (1:2.40) and creating frightening noise (1:1.11).

Similar trends were followed in maize crop (*Kharif 2023*).The least number of attempts to raid the crop (0.91 / fortnight) with the highest yield (25.66 q/ha) was recorded in T4 (Solar fencing) and it was followed by barbed wire fencing (T1) (1.79/fortnight, 23.45 q/ha), use of bioacoustics (T2) (2.74/fortnight, 24.33 q/ha), predator deterrent led light (T3) (3.40/fortnight, 21.90 q/ha), bonfire in crop border (T5) (6.02/fortnight, 19.60 q/ha) and creating frightening noise (T6) (6.32/fortnight, 19.17 q/ha). In control plots, the number of attempts to raid the crops was 8.01 per fortnight with a yield of 18.50 q per ha. The cost benefit analysis indicated that among the different mitigation measures, use of bioacoustics device (T2) was found to be the best treatment with a cost benefit ratio of 1:2.03 and it was followed by use of predator deterrent led light (T3) (1:1.78), Solar fencing (T4) (1:1.40), bonfire in crop border (T5) (1:1.15), barbed wire fencing (T1) (1:1.09), and creating frightening noise (T6) (1:0.56). Efficacy of the mitigation methods may vary in space and time due to elephant habituation, learning, differences in elephant populations, environmental conditions, and agricultural practices (Sitati, 2006), (Davies et al.,2011) reported that spotlights, chili fences, and electric fences provide a good protection from elephant damage when used in isolation. Rao 2021 reported that bioacoustics is 92 per cent effective in dispersing wild boar and Thuppil and Coss, 2016 reported that bioacoustics can replace existing deterrent methods for vertebrates and playbacks of threatening sounds are effective in mitigating human–elephant conflict. Adams et al., 2021 reported that solar based strobe light barrier was effective in deterring elephants from entering the crop lands. Naha et al., 2020 and Wanjira et al., 2021 reported that flashing lights were effective in deterring livestock attacks by predators and human elephant conflict. In the present studies the solar fencing (Agri solar unit), use of bioacoustics and predator deterrent lights were effective in mitigating the crop raids for short term when used in vulnerable stages of the crop. The mitigation measures provided a short term relief to farmers and enhanced the crop productivity.

Table 1. Crop losses due to elephant crop raids

Crop	Average attempts to raid the crop / fortnight	Crop damage (%) (Yield loss / ha)	Monetary loss (Rs)
Ragi	8.65±2.41	2.31-38.95 (0.72-12.56 q)	2,776-48,311
Cowpea	4.72±1.65	1.46-12.68 (0.17-1.45 q)	513-4,307
Banana	9.54±3.74	5.26-46.54 (2.80-25.18 t)	1,28,107-3,69,535
Mango	7.59±2.87	1.28-32.54 (0.20-5.08 t)	14,688-2,80,718
Pigeon pea	5.47±1.21	1.13-21.41 (0.15-2.93 q)	1,067-20,532
Maize	7.82±2.41	2.47-41.87 (0.72-12.46 q)	1,504-26,041

*****Mean ± SD*

Table 2. Evaluation of mitigation measures against crop raiding elephants in ragi and maize crops

Tr. no	Treatment	Ragi			Maize		
		Average attempts to raid the crop / fortnight	Yield (q/ha)	C:B	Average attempts to raid the crop / fortnight	Yield (q/ha)	C:B
T_1	Barbed wire Fencing	2.32 $(1.67)^{c}$	19.29^{a}	1:2.77	1.79 $(1.51)^{bc}$	23.45^{abc}	1:1.09
T_2	Bioacoustics	3.61 $(2.01)^{bc}$	18.50^{ab}	1:3.88	2.74 $(1.77)^{b}$	24.33^{ab}	1:2.03
T_3	Deterrent led lights	4.37 $(2.19)^{b}$	17.97^{abc}	1:5.32	3.40 $(1.96)^{b}$	21.90^{abc}	1:1.78
T_4	Solar fencing	0.79 $(1.12)^{d}$	20.31^{a}	1:2.84	0.91 $(1.19)^{c}$	25.66^{a}	1:1.40
T_5	Bonfire	6.79 $(2.69)^{a}$	13.69^{bcd}	1:2.40	6.02 $(2.55)^{a}$	19.60^{bc}	1:1.15
T_6	Noise	7.51 $(2.83)^{a}$	13.16^{cd}	1:1.11	6.32 $(2.61)^{a}$	19.17^{bc}	1:0.56

Tr. no	Treatment	Ragi			Maize		
		Average attempts to raid the crop / fortnight	**Yield (q/ha)**	**C:B**	**Average attempts to raid the crop / fortnight**	**Yield (q/ha)**	**C:B**
T_7	Control	8.44 (2.99)[a]	9.44[d]		8.01 (2.91)[a]	15.50[c]	
	F test	**	**	-	**	**	-
	SEm±	**0.13**	**1.39**		**0.14**	**1.57**	
	CD (0.05)	**0.40**	**4.22**		**0.41**	**4.77**	
	CV%	**10.42**	**14.63**		**11.02**	**12.49**	

**Note: Figure in parenthesis is square root transformed*

4. CONCLUSION

The present studies indicate that farmers in the study area faced high crop losses due to crop raids by elephants. Among the different crops, horticultural crops such as banana and mango faced the greater extent of crop losses and monetary loss with a damage per cent of 3.27 to 39.54 per cent. The cereal crops faced the crop losses of 2.39 to 40.41 per cent and the pulses faced the crop loss of 1.29 to 17.04 per cent. Solar fencing (Agri solar unit), use of bioacoustics and predator deterrent lights provided short term effective mitigating measures when used in vulnerable stages of the crop. However, to resolve the issue of crop raiding elephants permanent long term measures are indeed needed.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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