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Estimation of crop raiding in major seasonal crops by blue bull in different areas of Muzaffarpur, Bihar.

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ABSTRACT

Crop raiding by blue bull into an agricultural field is a serious problem that can potentially undermine agricultural productivity. We employed four different approaches to estimate the extent and patterns of crop damage by Blue bull in some areas near and around Muzaffarpur, in the state of Bihar, North India. For the two major crops of the rabi and kharif seasons. The study shows an estimated damage of 12% for the unfenced fields, compared to the fenced fields. We found that the damage caused by Nilgai to the production is not as significant as we had expected.

Key Words - Crop raiding, *Boselaphus tragocamelus*, Gangetic Plain, Muzaffarpur

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INTRODUCTION

Agricultural lands often face crop raiding by wild animals, which can be a serious problem for cultivators whose earnings depend on agricultural produce. In order to avoid economic loss, cultivators apply a range of protective measures. They include manual guarding, the use of barriers, trenches, and the application of devices. The traditional barriers are made using wooden poles and thorny branches. Destructive procedures can kill or injure animals. Advanced techniques are expensive and need continuous care, and have a high risk for both cultivators and animals. However, many procedures have been developed and shown to be effective on an experimental scale; there are reasons why they achieve limited success when employed on a wider spatial scale (Watve *et al.,* 2016). Economic loss due to wildlife is a considerable threat to animal conservation due to increasing resentment among the cultivators, and may result in retaliation (Gureja & Hussain, 2002). Appropriate compensation is thought to reduce conflict, making conservation efforts more effective (Wagner, 1997). Even if we make no assumption of compensation helping conservation, from a social justice point of view, the government may accept it as its duty to compensate the cultivator's loss. Although several studies on crop raiding address the problem in different habitats, they are caused by different species of wild animals.

Few utilize attentive methods for primary estimation of damage and attempt to cross-check or validate the methods (Mathur, 2015). The legal protocols have no clear guidelines on how to estimate the extent of damage; a visual exploration and evaluation of damage is made. The design of the damage caused by different herbivores can be greatly different, and estimating them using a single method is not possible. For example, raiding by Asian elephant (*Elephas maximus*) and African elephant (*Loxodonta africana*) leads to visibly obvious damage over a measurable area whereas smaller to medium sized herbivores like, blackbuck (*Antilope cervicapra*), nilgai (*Boselaphus tragocamelus*), chital (*Axis axis*), wild pig (*Sus* *scrofa*) etc. may chew or nibble some specific parts of a plant such that the damage is not obvious at a glance (Chauhan, 1990) but yields can be affected significantly.

The crop species are also living entities that respond to inflicted damage in an adaptable manner. If the damage is not fatal to a plant, it redevelops and tries to make up for the loss at least partly. Thus, the net damage at the end of the season may be greatly different from what appears immediately after a raid. A study that addressed this question showed that the visible damage was not correlated well with the grain yield at harvest. We used four different methods of damage estimation in the study area since different methods of damage estimation have different sources of errors and biases; if they converge on a similar inference, the inference can be more reliable.

Study Area

The study area Muzaffarpur is situated at (26.60°N and 85.29° E), situated about 50 km from the capital city of Bihar and 200 km from Valmiki Tiger Reserve. The area is plain. It has an average elevation of 47m. The study area is in the North of the vast Gangetic Plain. It is situated at the foot of the great Himalaya. The city lies in a highly active seismic zone. The climate is humid subtropical. Summers in the region are very hot and dry, and the maximum temperature in the region will range from 28 to 40 °C. The winters are pleasant, cold, and dry, and the maximum temperature during this time will range around 06 to 20°C. The average rainfall is around 1346.7 mm. Muzaffarpur doesn't have forest areas or long stretches of vegetation; in fact, it is a completely forest-free area. Major vegetation is found in small patches, along roads and river sides, and naturally growing plants on barren land.

Crops are cultivated in two seasons, Kharif (monsoon crops) and Rabi (winter crops). Rice (*Oryza sativa*) is the primary kharif crop, whereas wheat (*Triticum aestivum*) is the primary rabi crop. We selected these two crop species for our observations and experiments as they are the most abundant crops in the study area.

Fig. 1: Bluebull raiding crop

Fig. 2: Raided wheat plant at different stages

Fig. 3: Agricultural land for the artificial herbivory experiment

MATERIALS & METHODS

We used four independent methods to evaluate crop damage.

(1) Periodic visual examination of crop damage along transect lines. (2) The net grain yield per unit area along the same transect lines (measured at the time of harvest). (3) Comparison of yields on fenced and exposed neighbouring farms. (4) Comparison of grain yields after controlled artificial herbivory.

Across the four methods, one or more of the three parameters were monitored:-

(i) Frequency of visits by bluebull, (ii) Visual estimate of apparent damage, and (iii) Grain yield at harvest, all three were estimated taking an individual farmer's cultivated land as a unit and then normalized by the area under cultivation in that farm. We report the results of 2 years of study from 2022 to 2024 in this paper. Due to manpower limitations, each of the four methods could not be employed across both years, but we attempted to ensure reproducibility. To compare the results of two or more of the methods, the comparison was made in the same season and the same area.

1. Visual estimates of the frequency of raids and the area encountered

Three transect lines, each 2 km long, were laid. We expected the raiding frequency to be a monotonic decreasing function of distance from the field. The geographical location of each farm that was cut by the line was recorded using a handheld GPS device (Redmi 11, Android). Baseline information about the owners and the cropping season, crop species, total area of farm, area under cultivation of each crop, irrigation facility, and other agriculture-related information were noted. A total of 14 farms along transects were then visited once every week by our team during the daytime to observe whether there were visible areas of damage. Whenever damage was noted, the approximate area with visible damage was measured in square metres. This mimics the currently employed method of visual inspection to estimate damage. The weekly observations continued until the crop was harvested. This information was treated as binary to calculate the day probability of damage, assuming that the raids were random and therefore followed a Poisson distribution.

2. Grain yield at harvest.

The farms along the transect lines mentioned above, up to 2 km, were visited at the time of harvest to note the total grain yield for each crop per unit area. The team physically verified the grain yield at the time of harvest in terms of the number of bags and actual weight in quintals. We studied the farms along transects for subsequent years and recorded yields in 14 farms for both the kharif and rabi seasons. Grain yield was normalized with individual farmers' land area under cultivation and expressed as quintals per hectare (Q/Ha).

3. Experimental plots

A plot of one hectare in proximity was used as an experimental farm. The experimental area with homogeneous soil and irrigation conditions was divided into six sub-plots, two of which were fenced with a combination of barbed wire and thorny bush, and the other three were left unprotected. Crop species, namely rice during Kharif and wheat during Rabi season, were grown in neighbouring protected and unprotected farms, keeping the parameters of cultivation, such as soil preparation, fertilizer, seed density, and irrigation, identical. All the experimental farms were protected during daytime to avoid any damage by domestic animals and were observed silently at night from traditionally prepared 10-12 ft tall wooden guarding platforms, locally known as 'machan'. The daily recorded parameters included frequency of visits by bluebull, their group size, frequency of visible damage, and area with visible damage. At the end of the season, the grain yield per unit area was recorded.

4. Artificial herbivory

To study the effect of levels of damage on individual plants, particularly their regrowth after damage and the resultant grain yield, the plants were manually cut using scissors at different heights and different ages, and compared with uncut control plants at the time of harvest. These experiments were performed in a fenced area during two consecutive seasons of 2023 and 2024. In one set of experiments, the main stems of all plants in a unit sampling area were cut at different heights from the ground in a pre-flowering stage (at 60 days for wheat). In another set of experiments, the tips comprising leaves and buds in the upper 2-3 cm were cut at different ages of the crop. The plants were allowed to regrow through the rest of the season. All the treatment plots of all crops were provided with the same amount and combination of fertilizers, pesticides, and water as the control plots. At the time of harvest, all the treatment and control plants were uprooted carefully to measure the different parameters, such as the height of the regrown plant, the number of heads, and the number of grains/seeds.

RESULTS

1. Periodic monitoring of farms along transects

The mean frequency per night, calculated using Poisson probabilities, showed a decreasing trend with distance. Although both seasons showed a declining trend with distance, the damage frequency in Kharif was nearly twice that in Rabi over the stretch. This difference is likely due to active guarding by farmers, which is difficult during the monsoon and therefore not practiced. It is important to note that the frequency of damage occurs despite manual guarding efforts.

2. Grain Yield along transect farms

The decreasing trend of visible damage by herbivores was accompanied by an increasing trend in grain yield with distance transects. Except for rice, there was a significant and consistent increasing trend with distance for wheat. The trend in the frequency of animal raids between the 1st km and the interval between the 2nd km showed a time decline in the frequency of raids. Compared to this decline the yield improved by 1.37 to 2.85 fold for wheat. The trend lines of grain yield also give us a rough estimate of average damage. A comparison of grain yields with the visual estimates of the area damaged made during weekly visits to the farms revealed a poor correlation between visually estimated damage and the reduction in net yield from the expected. For this analysis, done on two seasons (2023-2024), a cumulative of the weekly visual estimate of damage was correlated with the deficit from expected yield. The correlations were non-significant, and throughout the range, the deficit in grain yield was orders of magnitude greater than the cumulative visual estimate of damage to farms.

Rice was least damaged but still faced an 18% loss in the unfenced areas in 2023. In this season, the unprotected area yielded 6.3 Q/Ha, whereas the protected area yielded 7.68 Q/Ha.

4. Artificial herbivory

Crops are living beings; partially damaged plants can regrow. Plants can also show life history trade-offs when facing the challenge of herbivory. Artificial herbivory experiments by cutting the shoot tips at measured heights or at a certain age of plants revealed that there was substantial growth after cutting.

In wheat, we observed that plants cut at the age of 25 days from sowing regrew and gained a height comparable with the control at harvest. The grain yield was also comparable to the controls. However, when cut at later ages, it did not recover sufficiently in height or seed number. In other words, early damage appeared to allow greater time for regrowth, resulting in better grain yield. If cut after the flowering stage, there was no seed formation. Thus, in wheat, damage at later stages of crop appeared to be more serious. When groups of plants were cut at different heights in a pre-flowering stage, they recovered partially in terms of height and produced some seed, but the yield was low, the deficit in yield being proportional to the extent of cutting.

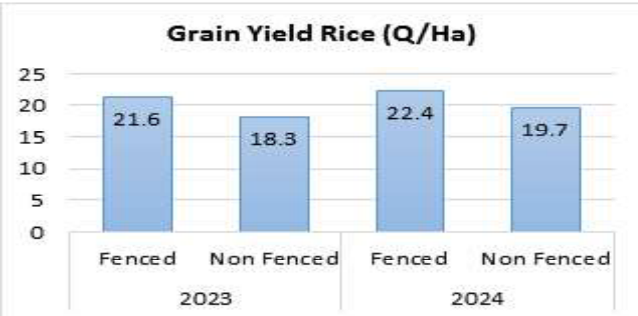
Table 1: Artificial herbivory of Rice and wheat (at different days)

Crop species	Plot area (m^2)	Height at which plants are cut (cm)	Age at which plants cut (days)	Number of plants cut (n)	Number of plants on harvest (n_1)
Rice	1	Control	Control	100	98.3
	1	5	20	100	84.2
	1	10	45	100	79.6
	1	15	60	100	64
Wheat	1	Control	Control	100	97.6
	1	5	25	100	71.6
	1	10	45	100	93
	1	15	55	100	67.6

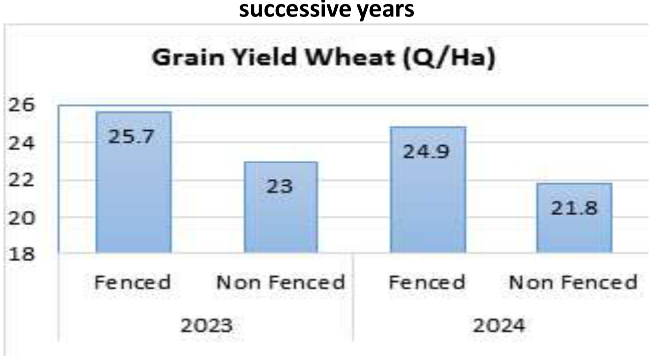
This phenomenon is known to farmers, and some of them practice controlled plucking to increase the yield. However, cutting down beyond a threshold was counterproductive and decreased regrowth as well as seed formation. A yield deficit of up to 37% was noted on cutting down a plant at a pre-flowering stage.

We did not perform artificial cutting in the case of rice, but did observe that in the unfenced and unguarded plot exposed to herbivory, the number of tillers bearing seed was about 16% less, and the number of seeds per tiller was 22% less than the protected plot.

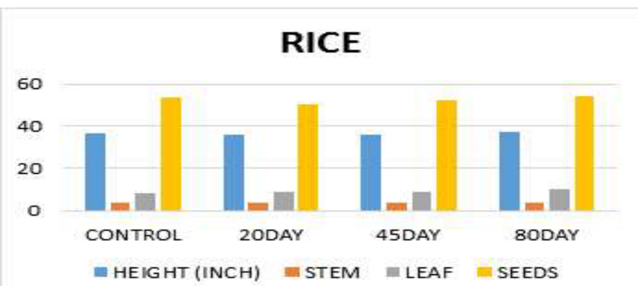
We employed four different approaches to assess and compare crop damage in the study site. Each of the methods may suffer from some flaw or shortfall. The net yield trends observed with distance from the forest are likely to be affected by other factors. It is possible to assess the two possibilities from the available data.



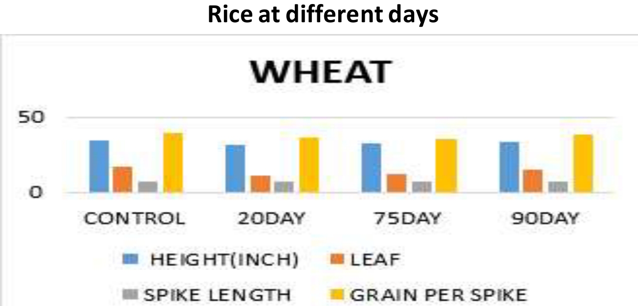
Graph 1: Grain yield (Rice) in fenced and unfenced fields in successive years



Graph 2: Grain yield (Wheat) in fenced and unfenced fields in successive years



Graph 3: Graph showing the result of artificial herbivory of Rice at different days



Graph 4: Graph showing the result of artificial herbivory of Wheat at different days

In experiments with fenced farms, for rice, the protected farm yield was 21.66 Q/Ha, and for wheat, 24.88 Q/Ha. Since giving protection alone could increase the yield to a level comparable to the highest yielding areas, the trend is due to accessibility and frequency of visits by bluebull and cultivator's discouragement from investing in intensive agriculture appear to be responsible for the trend in grain yield (Watve *et al.,* 2016).

Results of herbivory are important because a potential cause of a mismatch between a visual estimation of damage and grain yield deficit is regrowth of plants after damage (Paige, 1987). The vegetative parts of plants regrow to a considerable extent after herbivory. There are claims of herbivory being beneficial for plants owing to stimulated regrowth (Paige, 1987). Rice, on the other hand, belongs to grasses that have substantial root biomass, which is long-lived and can regrow in the following season. Therefore, on facing a greater threat of seed predation, it may strategically invest more in root biomass and less in seed production. This is important since after damage within a few days, the farm as a whole looks intact and green due to regrowth, and therefore, the damage may not be noticeable on visual inspection, but a substantial loss is incurred.

The experimental plot showed a substantial deficit in rice yield in the unprotected area as compared to the protected area. The deficit was unexpected since the observed frequency of raids was not very high. The difference can perhaps be due to post-harvest damage. The other major mismatch was that visual evaluations always gave greatly lower estimates compared to all other methods. These are possible reasons: (i) the prevalent herbivore species do more of nibbling damage, which is less noticeable than trampling or uprooting type of damage. (ii) Not all types of damage are noticeable at the same time. For example, root or stem base chewing by the Blue bull leads to slow drying of the individual, which becomes noticeable after a few days. On the other hand, nibbling the tips may be apparent after a careful look immediately after the damage, but the plants regrow soon, and the damage becomes difficult to notice after a few days. It is difficult to notice all types of damage together in a single inspection.

CONCLUSION

Previous research on crop raiding by wild animals in India is heavily biased towards damage by large herbivores, likely elephants. In this case, the damaged area is measurable, and the net loss is likely to be directly proportional to the fraction of the visibly damaged area. However, in the case of smaller to medium-sized herbivores, the case is very different. It is possible that visual evaluation of damage works for certain species of damaging animals, but fails for others. We suggest that it should be based on the grain yield or net produce at harvest rather than visually assessed vegetative loss.

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