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Grasshopper Species Composition and Severe Attack in the Semi-Arid Region of Rajasthan, India

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ABSTRACT

Adequate knowledge is needed to know when grasshopper species abundance shifts and to follow severe outbreaks during microclimatic variations. Grasshoppers regularly cause enormous harm to a wide variety of crops and grazing lands; sometimes they show a potential attack on particular crops. A study was carried out in the southern region of Jaipur, Rajasthan, where 11 sites were weekly sampled to monitor grasshopper population dynamics, grasshopper densities, species composition, and vegetation loss from July 2021 to December 2022. A serious grasshopper attack was reported in 2021, with the highest grasshopper densities ranging from 5 to 17.5 per m^2, whereas grasshopper densities dropped in 2022 from 4 to 14.5 per m^2. In the survey area, the acridid grasshopper *Hieroglyphus banian* (Acrididae:Orthoptera) was reported as the most abundant species that was accountable for the majority of the crop damage in agricultural fields, followed by *Spathosternum praciniferaum* and *Acrida turrita,* respectively. The grasshopper population density was revealed to be significantly different in 2021 and 2022 ($t = 1.568$, $df = 20$, $P = 2.086$). Severe infestation was observed in all of the pearl millet fields and also in seasonal crops and vegetables, where *H. banian* caused 91% infestation, followed by *S. praciniferaum* with 7% and *A. turrita* with 2%, respectively. The study confirmed that climatic factors were significantly related to outbreaks and assessed their effect, which revealed a rare population in the summer season and peaked in the monsoon season. The finding provides important information for grasshopper risk forecasting, which is advantageous for preparing grasshopper risk maps, predicting the intensity of outbreaks, and developing an integrated pest management plan.

Keywords Acrididae, Grasshopper, *Hieroglyphus*, Pest, Species abundance.

INTRODUCTION

Grasshoppers belong to the order Orthoptera and the family Acrididae, and they are important elements in the ecosystem (Culliney 2013). Grasshoppers are generally known as polyphagous pests, but they are also responsible for ecological functions, viz., in the food web, nutrient cycling, pollination, and plant

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growth. They are beneficial ecological markers for the health of grassland ecosystems (Tan *et al.* 2017). They feed on grasses and weeds and frequently move to agricultural fields, and the population fluctuates yearly and by location too. Grasshopper's defoliate plants, diminishing their photosynthetic capacity (Bastos *et al.* 2011). Grasshoppers are a potential pest of pearl millet in several countries around the world, including Africa (Kekeunou *et al.* 2015), Pakistan (Samejo and Sultana 2016, Soomro and Sultana 2020, Sultana *et al.* 2022), and India (Akhtar *et al.* 2012, Nayeem and Usmani 2012, Sunil and Chandra 2013, Gahukar and Reddy 2019).

At the habitat level, orthopteran species richness and abundance are influenced by land use and vegetation structure as well as abiotic variables. With plentiful rainfall and the development of annual green foliage, grasshopper populations rapidly rise and, within a month or two, begin to concentrate, leading to outbreak conditions by forming small groups of hoppers and adults. Grasshoppers should react to both biotic and abiotic variables differently due to phenology and food preference variances (Leksono *et al.* 2020). Analysis of trapping data from the past few years indicates that microclimatic changes cause a change in the phenology of the pest. Temperature is critical in the development of this insect, and global climate changes may play a role in an outbreak-like situation around the world (Pareek *et al.* 2017a,Wu *et al.* 2013). Consequently, a more thorough observation of the relationships between climatic parameters and phenology, as well as abundance and pest status, is required.

In many parts of the world, *Hieroglyphus* have evolved from minor pests to major pests, as in neighboring Pakistan (Riffat and Wagan 2007) and also described as a major pest that occasionally causes outbreaks and swarm-like scenarios (Jhala *et al.* 2004, Acharya 2010, Akhtar *et al.* 2012, Kumar and Usmani 2015). Even in India, the pest *Hieroglyphus* sp. was reported as a major pest of pearl millet, sesame cluster beans, and maize in Haryana, Gujarat, and Himachal Pradesh, as well as the desert and Aravalli region of Rajasthan and southern Rajasthan (Acharya 2010, Kumar and Usmani 2014, 2015, Pareek *et al.* 2017b). In cases of a serious infestation in pearl millet, all the leaves have been consumed by grasshoppers, leaving only the midrib (Paudel *et al*. 2020). Grasshopper population species assemblage and plant sampling are required during and following a major epidemic to comprehend the outbreak origin and population diminishment (Branson *et al.* 2006, Branson and Haferkamp 2014). Pesticides have had a negative impact on natural enemies, which subsequently contributes to the pest's development (Garratt *et al.* 2011).

After a lengthy period of time, grasshoppers were observed causing harm to pearl millet-growing areas in the southern region of Jaipur, Rajasthan. Grasshopper species composition, abundance, and vegetation have been randomly sampled during an outbreak in the agro-ecosystem of the southern region of Jaipur, which is required to learn more about what causes outbreaks and population decreases. In addition to pearl millet, the pest has also infested other crops like sesame, groundnut, cluster beans. The primary goal of this work was to discover a relationship between grasshopper population densities, composition and risk damage to agricultural crops over two years. Also providing warnings of general population levels and crop loss makes it more feasible for farmers to make decisions on pest control strategies based mostly on the last year's population.

MATERIALS AND METHODS

Study area: The study was conducted on agroecosystems in Jaipur district, which is located in the semiarid eastern plain of the north-eastern region of Rajasthan. The study was primarily undertaken in eleven different regions of Bassi Municipality within a 30-kilometer radius of the Jaipur district where the outbreak was reported (26.781436 N 76.182680 E to 26.840923 N 76.188859 E). The average maximum and minimum temperatures in the area were 40.6 degrees Celsius and 6.2 degrees Celsius, respectively. The district's annual rainfall averaged 564 mm. The predominant soil type is sandy loam. The site was comprised of mixed crops such as pearl millet, sesame cluster beans, maize, groundnut, and pulses, as well as important vegetables such as tomato, pea, chilli, brinjal, cabbage, cauliflower, and many more.

Survey and sampling: A survey was conducted to

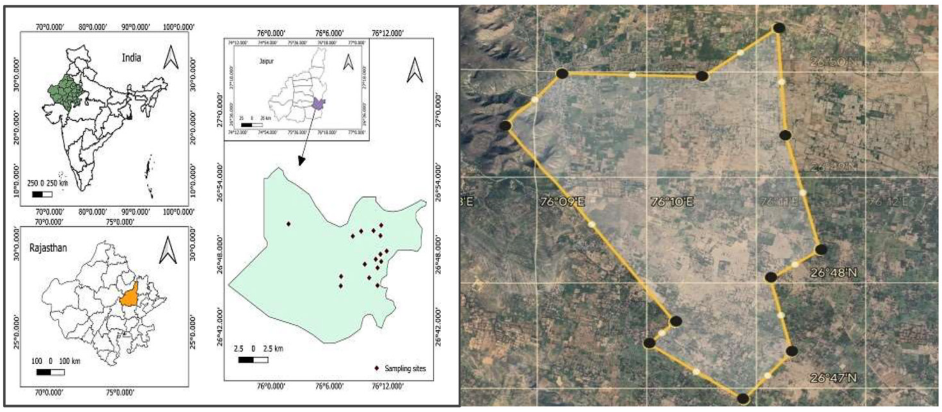

Fig 1. Study area with sampling locations for grasshopper population in the year 2021 and 2022 at Jaipur district (Rajasthan).

estimate the grasshopper population from July 2021 to December 2022. The survey was carried out in 11 different locations (n = 11), namely Baskhoh, Bhoorla, Rajwas, Rojwari, Shrinagar, Chitori, Ugawas, Rampura, Lalawala, Tilpatti and Rajpura of Bassi Municipality in the Jaipur district, where native grasshoppers invaded pearl millet crop fields (Fig 1). A few farms from each location were selected, and crops from each field were examined for plant and leaf damage as well as pest populations. Data were collected from five plots in each agricultural field at all locations. The number of grasshoppers jumping and resting in the farms was counted fortnightly between 07.00 and 12.00. Grasshoppers were sampled by sweeping and handpicking with insect nets on farms with plot sizes of 2×10 m^2. The route consisted of four 100-metre transects conducted on each farm. These data were then averaged to get the grasshopper population per square metre of area. Climate factors such as daily minimum to maximum temperature, precipitation, and humidity were all measured within the same time period. Some information was also reported and confirmed through farmer interviews.

Data collection: Acridids collected via aerial netting were managed site-wise and brought to the laboratory for further dry preservation and identification. Distributed individuals on farms were identified and recorded for visual transects without capturing them. Based on the population of the previous year, the population was again confirmed after asking farmers on regular base. The Global Positioning System (GPS) coordinates were recorded in the first year of the study and monitored in the next.

Insect identification: The grasshopper specimens collected were processed for laboratory procedures such as killing, drying, brushing, pinning, labelling, and identification. The identification was completed up to the species level using taxonomic keys (Dirsh 1965, Smith *et al.* 2004, Morris 2002) and an online database called Orthoptera Species File online version 5.0/5.0 (Cigliano *et al.* 2023) and was completed with the taxonomic expertise of Maharana Pratap University of Agriculture and Technology Udaipur. The first remarkable evidence of pest invasion was discovered in 2020, but the specimen was authentically identified in 2021 at the Locust Warning Organisation (LWO) in Jodhpur.

Data analysis: The grasshopper population (n = 11) was compared using the t-test in two consecutive years, whereas pest densities were used in both years to compare grasshopper populations. According to Riegert 1968, the regions were classified as none to very light (0–2 adults/m^2), very light (2-4 adults/m^2), light (4–8 adults/m^2), moderate (8–12 adults/m^2), and severe (>12 adults/m^2). The bray-curtis similarity index was calculated using Paleontological Statistics software (PAST4.0), and the relative abundance and other correlations between abundance and abiotic environmental parameters were calculated using MS

Excel's bar-line graph. The study area was mapped using Google Earth and qGIS software.

RESULTS

Large sporadic population of insect pests emerge during an insect attack condition, which is commonly referred to as an outbreak. It typically occurs when the pest population exceeds its general equilibrium level and threatens human interests or endeavours. A serious grasshopper pest attack in the study areas was reported in the year 2021, with highest densities ranging from 5 to 17.5 per m^2, while grasshopper densities dropped in the year 2022 from 4 to 14.5 per m^2 (Table 1, Fig 2). Grasshopper densities were recorded as 17.5, 16, 15, 14.5, and 11.5 per m^2 during surveys in the years 2021 at Shrinagar, Tilpatti Baskhoh Rajwas, and Chitori (Table 1, Fig 3), respectively. The pest had a clustered distribution, with the maximum abundance occurring during the transition period between the end of the summer season and the start of the winter season (Fig 4). However, the majority of specimens were found during the first rainy season (12.5 members per square metre), which was significantly lower during the second rainy season (10.125 members per square metre). The second-year pest population drop can be attributed to lower rainfall in 2022 compared to 2021 (Table 2). The microclimatic fluctuations (increasing rainfall and temperature) that happen steadily in the transition from the end of summer (June) to the start of the winter season (November) coincide with the production of flowers and leaves in the crops. The pest density was high during the first year of the study, and *Hieroglyphus banian* (Fab.) predominated the species composition from all the locations, while *Spathosternum praciniferaum* and

Table 1. The estimated grasshopper population and their risk category in various pearl millet growing locations of Jaipur district (2021-2023).

Sl. No.	Sampling Sites	GPS Coordinates	Estimated population per m^2 2021		Maximum risk ranking for 2022	Estimated population per m^2 2022		Maximum risk ranking for 2023
			Mean	R. A. (%)		Mean	R. A. (%)	
1.	Baskhoh	26.825196 N 76.147155 E	15	7.16%	*****	13.5	15.08%	*****
2	Bhoorla	26.790007 N 76.189135 E	11	5.25%	****	6.5	7.26%	***
3.	Rajwas	26.781436 N 76.182680 E	14.5	6.92%	*****	4.5	5.03%	***
4.	Rojwari	26.793257 N 76.171838 E	6.5	3.10%	***	4.5	5.03%	***
5.	Shrinagar	26.832955 N 76.175634 E	17.5	8.35%	*****	14.5	16.20%	*****
6.	Chitori	26.832833 N 76.154764 E	11.5	4.89%	****	10	11.17%	****
7.	Ugawas	26.840923 N 76.188859 E	6.5	3.10%	***	4	4.47%	***
8	Rampura	26.826479 N 76.187320 E	10	4.77%	****	10.5	11.73%	****
9.	Lalawala	26.800975 N 76.185999 E	5	2.38%	***	4.5	5.03%	***
10.	Tilpatti	26.804917 N 76.193494 E	16	7.64%	*****	11	12.29%	****
11.	Rajpura	26.790809 N 76.167675 E	6.5	3.10%	***	6	6.70%	***
	11	-	120	57.28%	-	89.5	42.72%	-

*****(Severe) ****(Moderate) ***(Light) ** (very light) * (None- very light) R.A.- Relative abundance.

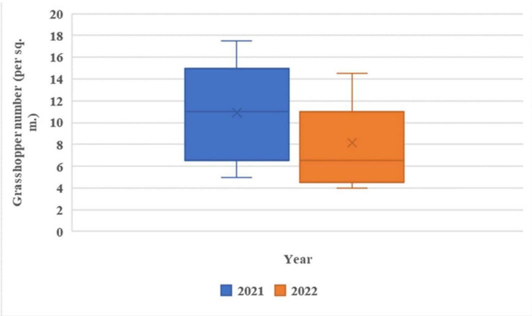

Fig. 2. Box chart plot showing the estimated average number of grasshoppers sampled from sampling locations of Jaipur district in the year 2021 and 2022.

Acrida turrita was found in a few numbers (Table 2). *H. banian* is an overwintering species that hatches in the early monsoon. The populations of the two following years were correlated to observe the relation between population densities and risk categories. The grasshopper population was found to be significantly different (t =1.568, df = 20, P = 2.086) in both 2021 and 2022. The grasshopper population was higher in the first year of the outbreak (57.28%) than in the second year (42.72%). The risk has also been high in 2021, from severe to moderate (Table 1).

Species assemblage and infestation: Acridid pests always have a species assemblage, though species densities may vary in affected areas. During sampling in two consecutive years, three acridid pest species were identified. According to rank abundance, *H. banian* had the maximum abundance, followed by S. praciniferaum and *A. turrita*. In the aerial sweep-netting collection period, *H. banian* was uniformly distributed across the sampling fields and was therefore faster to catch. Grasshopper abundance and species diversity varied among sampling sites. In the similarity index, *S. praciniferaum* and *A. turrita* are more similar than *H. banian,* which belongs to a different cluster (Fig 5). *H. banian* often lives in a solitary state. However, depending on the environment, this behaviour can shift from solitary to gregarious. In the early monsoon period in the study area, *H. banian* had the most favourable environmental conditions compared to the other acridid grasshoppers. These factors contribute to their high fecundity rate and voracious polyphagous feeding. The pest *H. banian* is vernacularly known as phadka or *kharif* grasshopper due to its food preferences for *kharif* crops (Swaminathan and Swaminathan 2019). There was a severe crop infestation in all of the pearl millet fields. The infestation by H. banian is 91%, followed by *S. praciniferaum* with 7% and *A. turrita* with 2%, which

Table 2. The estimated seasonal average grasshopper's population (per sq. m.) with infestation rate and food preference.

Species	Common name/ Vernacular name	2021-22 Summer	2021-22 Monsoon	2021-22 Winter	2022-23 Summer	2022-23 Monsoon	2022-23 Winter	Food preference	Crop infestation (%)
H. banian	Kharif Grasshopper/ Phadka	0	12.5	1.625	0	10.125	1.125	Pearl millet, Sorghum, Cluster bean, Sesame, Pulses, Bottle guard, Tomato etc.	91%
S. praciniferaum	Short horned grasshopper	0.925	3.062	0.527	0.81	2.662	0.45	Pearl millet, Vegetables and some grasses	7%
A. turrita	Chinease grasshopper	0.912	2.38	0.512	0.712	2.087	0.237	Pearl millet, Sorghum, Vegetables	2%

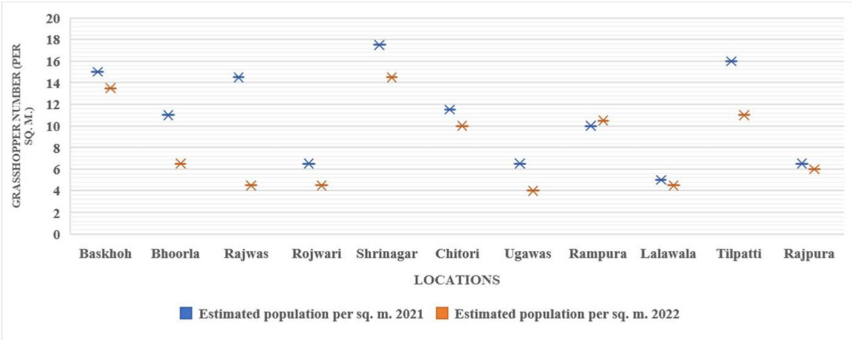

Fig 3. Box chart plot show the grasshopper population in each sampling location of Jaipur district in consecutive years 2021 and 2022.

represent pest species that feed on agri-crops (Fig 6). Grasshoppers showed high food preferences for pearl millet, sorghum, cluster beans, pulses, sesame, and vegetables belonging to the families Poaceae, Fabaceae, Pedaliaceae, Solanaceae, Brassicaceae, and Leguminosae, respectively. The most severe infestation occurred during the monsoon season, when the farms were filled with fresh crop seedlings and the hoppers emerged from the eggs at the same time. The pest abundance was highest during the monsoon season, followed by the winter and summer seasons of both years, as shown in the Table 2.

Effect of climate variables on the abundance of *kharif* grasshopper: Climate variables had a significant impact on the time required for development. Temperature and rainfall were the primary causes of the invasion, which was observed slightly different from previous years. In Rajasthan, the monsoon arrives at the end of June and departs at the beginning of October. The meteorological data in Fig 4 show that rainfall in 2020 was slightly less than normal during the monsoon months, while rainfall in 2021–22 was slightly higher during the crop growing season. In Jaipur, the second sowing period took place around July, and the small seedlings were grown on the farms by the end of August of the year. The young hoppers were migrating to crop leaves at the same time that the rainfall level was high. Temperatures and rainfall were steadily declining in September and October, and hoppers and adults were abundant on crops, causing significant damage to farm crops. In the

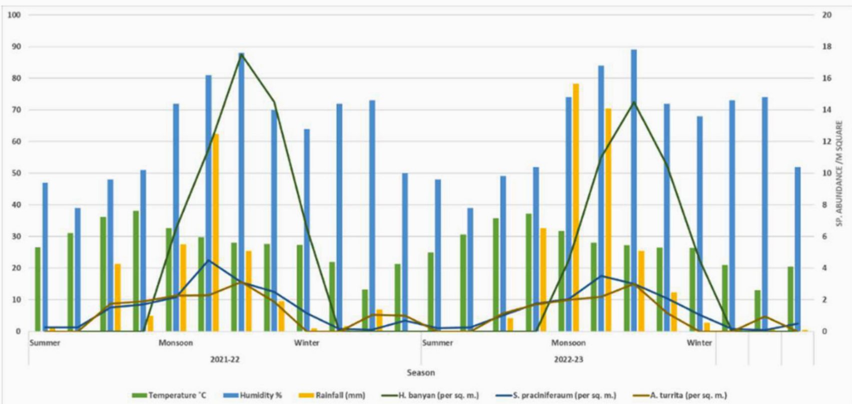

Fig. 4. Grasshopper abundance with different abiotic factors in the study area (2021-22).

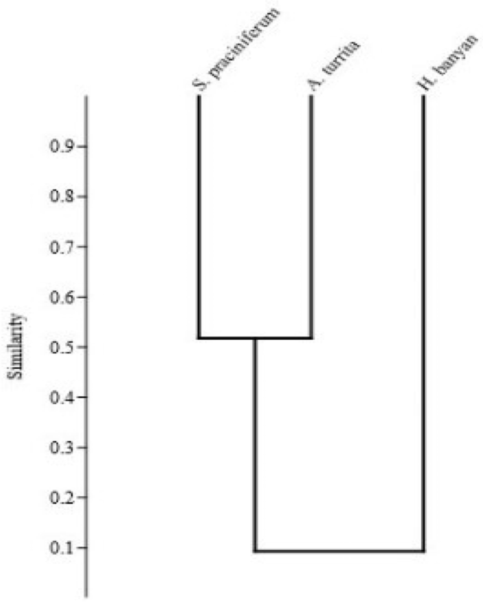

Fig. 5. The similarity index of grasshopper species abundance at different sites.

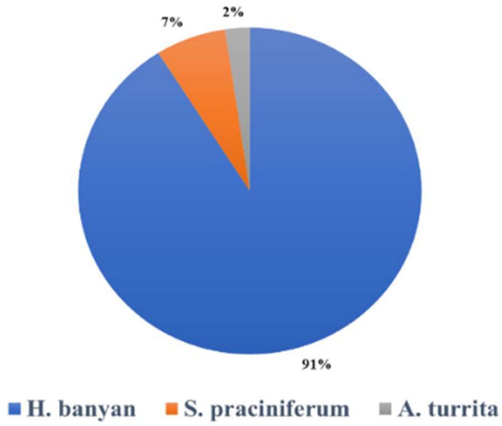

Fig. 6. Crop infestation by acridid pests.

winter, crops need to be harvested, and pest numbers start to decline. The hoppers seemed to have definite consumption periods. When the temperature dropped below 70 degrees F, the pest practically stopped feeding and was completely eradicated in December.

DISCUSSION

The typical harvest farming lands were randomly selected and a survey was carried out to find economically important acridid species and their seasonal activity patterns, as well as to determine pest status densities and compositions of major species through damage ratings, which is required to comprehend the source of the outbreak. Although there is a scarcity of data from outbreak regions where grasshopper species composition and density can be combined with vegetation, during these two-year periods, the proportional and actual abundance of H. banian changed dramatically. It has been demonstrated that pest dominance can shift quickly, even for species that were highly dominant during a severe outbreak (Paudel *et al.* 2020). The factors inducing pest population dynamics in affected areas of Jaipur are still poorly explored. There is evidence that biotic effects such as density-dependent processes caused by insufficiency of food and extreme population decreases by predator's cause population instabilities (Lankau and Strauss 2011). Generally, the environment will affect sibling species in the same way, with a few exceptions. Several studies have been conducted around the world to correlate the grasshoppers' densities as pests with climate, primarily for outbreak prediction (Barbosa *et al.* 2012; Youngblood *et al.* 2023). Previous analysis has shown that high temperatures significantly increase the growth fecundity and survivability of insect pests (Schmitz, Rosenblatt, & Smylie 2016).

The outbreak could be attributed to changes in microclimatic conditions such as relative humidity, soil temperature, and precipitation, which facilitated population growth with high reproductive capacity and population survivability. Precipitation may also be a factor favouring population growth as it encourages the development of fresh vegetation and the hatching of eggs as humidity levels go up. All of these changes in the environment and food accessibility form a complex integration that raises grasshoppers (Barbosa *et al.* 2012; Youngblood *et al.* 2023). During the course of this study, we observed that pest abundance had a seasonal trend throughout the year. As a result, farm populations, primarily herbivores, appear to be synchronised with the increased availability of food resources during this period. Newer leaves in crops are softer and have minimum toxin levels and a high nutrient value (Oliveira 2008). The accessibility of sources is important for pest seasonal patterns (Lankau and Strauss 2011). The grasshopper population was found to be decreasing from 2021 to 2022, indicating a low risk in 2023. This could be due to the control of the pest population in 2021 and also harvesting the farms with other crops. The pest infestation, according to the risk category, had a severe rating in four locations among the population of 2021. In 2023, the risk would be predicted as low because, in 2022, most of the areas were classified as moderate to light with a low pest population in farms. A similar biennial outbreak study of *H. banian* in sugarcane-growing areas of Nepal described that the pest densities were higher in some areas in the first year as compared to the second year (Paudel *et al.* 2020).

CONCLUSION

The observation in grasshopper population survey revealed that H. banian is the most abundant species in the Shrinagar, Tilpatti Baskhoh, and Chitori regions. The other species, S. praciniferaum and A. turrita, are found in smaller but significant numbers and must not be neglected because their potential for population growth is not clear but certainly possible. H. banian is a serious agricultural pest in the eastern plains of Rajasthan, and critical control is required for agricultural crop management and food security. These results deliver important information for pest managers and farmers to take the necessary actions for their pest management plans. Chemical pest control can be effective, fast-acting, and adaptable to all agricultural conditions. It was found that the pest abundance level was high in 2021 but did not encourage pest number growth in 2022 due to some chemical control application. Although, there is an urgent requirement of eco-friendly yet effective control actions to manage pest populations in natural vegetation. Grasshopper risk forecasting could be accomplished through pest sampling and valuation of future populations, which is advantageous to preparing grasshopper risk maps. Pest identification and their population dynamics are the initial steps for developing an IPM (integrated pest management) plan. Further research should be done on pest severity and risk maps using data from many years to estimate the pest population of grasshoppers in pearl millet fields for the following years.

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