Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

Prevalence of insect pests on maize crop in District Mansehra, Khyber Pakhtunkhwa, Pakistan

Prevalência de insetos-praga na cultura de milho no distrito de Mansehra, Khyber Pakhtunkhwa, Paquistão

Z. Khan[a,b,c*], S. E Sharawi[d], M. S. Khan[a,b], Suleman[a,b], L.-X. Xing,[e], Haroon[b,e], S. Ali[f,g] and N. Ahmed[g]

[a]University of Swabi, Department of Zoology, Khyber Pakhtunkhwa, Pakistan
[b]Hazara University Mansehra, Department of Zoology, Khyber Pakhtunkhwa, Pakistan
[c]Agriculture Research Station, Baffa, Mansehra, Khyber Pakhtunkhwa, Pakistan
[d]King Abdul-Aziz University, Department of Biology, Jeddah, Saudi Arabia
[e]Northwest University, College of Life Sciences, Xi'an, China
[f]University of Agriculture Dera Ismail Khan, Department of Entomology, Faculty of Agriculture Sciences, Khyber Pakhtunkhwa, Pakistan
[g]University of Swabi, Department of Agriculture, Khyber Pakhtunkhwa, Pakistan

Abstract

The maize crop is used as food for humans, livestock and poultries forms, it is also used in bread making, corn flakes, corn syrup, corn starch and corn oils. The field study consisted of one experimental trial, about the incidence of that insect pest complex on maize cultivar Azam during the Kharif season 2020 at the Agricultural, Research Station, Baffa, Mansehra. The trial was laid out in the Randomized Complete Block Design (RCBD), and then it was divided into three replications. The result obtained from the trial showed that a number of the pest species were recorded during the experimental period; however, the population was noticed at a low level. The obtained insect species were corn leaf aphid (6.90 ± 5.5) per square inch, corn leafhopper (1.32 ± 0.63), maize stem borer (0.63 ± 0.29), corn flea beetle (0.43 ± 0.28), Thrips (0.38 ± 0.22), Hairy caterpillar (0.21 ± 0.22), Grasshopper (0.17 ± 0.11) and shoot fly (0.11 ± 0.08) throughout the season

Keywords: maize variety Azam, insect pests, damages, incidence, infested plants.

Resumo

A cultura do milho é utilizada na alimentação humana, pecuária e avícola, bem como na panificação, flocos de milho, xarope de milho, amido de milho e óleos de milho. O estudo de campo consistiu em um ensaio experimental sobre a incidência desse complexo de insetos-praga na cultivar de milho Azam durante a temporada de Kharif 2020 na Estação de Pesquisa Agrícola, Baffa, Mansehra. O ensaio foi estabelecido no Randomized Complete Block Design (RCBD) e, em seguida, dividido em três repetições. O resultado obtido no ensaio mostrou que várias espécies de pragas foram registradas durante o período experimental; no entanto, foi observado um baixo nível da população. As espécies de insetos obtidas foram pulgão-da-folha-do-milho (6,90 ± 5,5) – por polegada quadrada –, cigarrinha-do-milho (1,32 ± 0,63), broca-do-caule-do-milho (0,63 ± 0,29), besouro-da-pulga-do-milho (0,43 ± 0,28), tripses (0,38 ± 0,22), lagarta-cabeluda (0,21 ± 0,22), gafanhoto (0,17 ± 0,11) e mosca (0,11 ± 0,08) ao longo da temporada

Palavras-chave: milho variedade Azam, insetos-praga, danos, incidência, plantas infestadas.

1. Introduction

The first time, maize (*Zea mays* L.) crop was cultivated in South America, then spread worldwide (Galinat, 1992; González, 2001), and came to Russia, Europe, United States of America, Canada, Mexico, Africa, China, Asia, India and Pacific Island (Blanco et al., 2014; Mallapur and Manjunath, 2015; Manjunath et al., 2016; Murthy et al., 2013; Tagne et al., 2008). The production of the maize crop would be inclined from 4554.48 to 6340.29 thousand tonnes with an increase in area 1031.07 to 1042.32 ha, from 2012 to 2017 in Pakistan (Abid et al., 2014; Tahir and Habib, 2013), probably sown twice in a year. While Muhammd et al. (2012) reported in Pakistan it was 3.34 million tons of grain was obtained from 0.939 million hectares. However, wheat and maize are the major crops of Khyber Pakhtunkhwa, growing in Charsadda, Kohat, D.I. Khan, Mardan, Banu, Malakand and Mansehra (Abid et al., 2014; Muhammd et al., 2012). They provide food for humans, livestock and poultries forms, they are also a raw material for textile industries including bread

*e-mail: khanzahid370@yahoo.com
Received: December 15, 2021 – Accepted: February 4, 2022

making, corn flakes, corn syrup, corn starch and corn oils (Gáspár et al., 2007; Khaliq et al., 2004; Morris et al., 1999; Rosegrant et al., 1999), because, they contain, starch 72%, protein 10%, oil 4.8%, fibre 5.8%, sugar 3.0%, and ash 1.7% (Hokmalipour et al., 2010). However, the crop is affected by weeds, diseases, nematodes, insect pests, birds and environmental factors (Karavina et al., 2014), because they reduce crop yield up to 75% (Kumar, 2002; Moyal, 1998; Tefera et al., 2016). The arthropod pests were found everywhere (Oliveira et al., 2014), about 40 species belong to the maize crop (Arabjafari and Jalali, 2007; Kasim et al., 2016; Moraes et al., 2005; Okweche et al., 2013; Singh and Gandhi, 2012), which cause real destruction of plants in mature and developmental stages (Mutyambai et al., 2015; Sajjad et al., 2010; Samková et al., 2017). Aphids and thrips (Khan et al., 2007; Sultana and Wagan, 2009), maize stem borer, European corn borer, pink borer, shoofly and cutworms (Khan et al., 2015, 2020) are attacking on, seed, root and lower stem feeders stalk borers, leaf feeders and ear feeders (Chouraddi and Mallapur, 2017; Rice and Davis, 2010), moreover, rootworms, white grubs, ground beetles, cutworms and termites, corn borer and corn earworm (*Helicoverpa zea*) (Bosque-Pérez, 1995; Neupane et al., 2016; Haroon et al., 2020, 2021; Khan et al., 2022), which create problems at different stages of plant growth and development. The present study aims to investigate the diversity of insect pests on maize crops in Hazara division, Khyber Pakhtunkhwa, Pakistan.

2. Materials and Methods

2.1. Study area

The district Mansehra is situated at the 34º-14´ to 35º-11´ North latitudes and 72º-49´ to 74º-08´ East of Pakistan, which consists of 4,579 km², weather is mostly cold, and the humidity reaches up to 80% (Mallick et al., 2010).

2.2. Seed choice for sowing

In the whole district, Azam maize (certified by Federal Seed Certification and Registration Department Abbottabad) was selected for sowing in different localities of the study area.

2.3. Experimental design and land preparation

The experimental trial has involved the occurrence of insect pests on maize crops and made a randomized complete block (RCB) design and it was replicated in three subplots. The area of the replicated plot is 30 m² and makes row distance as 75 cm and plant distance as 20 cm from each other respectively. Vegetation surrounded the maize crop was grown as potato, onion, garlic and white in Agriculture Research Station, Baffa, Mansehra.

2.4. Sowing and germination times

The cultivar Azam was sown in this trial on June 23, 2020, and the germination started on June 26 which was completed within a week time. The crop was kept under compliance randomly to observe the appearance of any insect pest species.

2.5. Data sampling

Mostly five maize plants were randomly selected in each replication of the selected fields. Also, the type of collected insects was identified to species level and population counts were recorded. During the data sampling of leaves and stems, faeces on the plant parts, the presence of larvae and dead hearts were also observed. All the affected plants were tagged for future observation till harvesting of the crop. Similarly, the appearance of leaf aphids was recorded in the present studies per square inch.

2.6. The formula for data sampling

The experimental field area of 30 m² was divided into three replications of equal size and for each data sampling of insect pests; five plants were randomly selected in each plot and formulated as follows (Equation 1).

$$R_1 = \left(P_1+P_2+P_3+P_4+P_5\right),\ R_2 = \left(P_1+P_2+P_3+P_4+P_5\right),\ R_3 = \left(P_1+P_2+P_3+P_4+P_5\right).$$
$$R_1=\left(P_1+P_2+P_3+P_4+P_5\right)/5,\ R_2=\left(P_1+P_2+P_3+P_4+P_5\right)/5,\ R_3=\left(P_1+P_2+P_3+P_4+P_5\right)/5, \quad (1)$$
$$Mean = \left(R_1+R_2+R_3\right)/3$$

2.7. Statistical analysis

The recorded data were averaged (mean and standard deviation) and compiled in the form of tables. The statistical analyses were performed using (ANOVA) of Graph Pad Prism 5 and EXCEL to elaborate the results.

3. Results

It has been generally observed that the heavy and extended rainy weather suppressed the reproduction and multiplication of arthropod pests in the region. However, the insect pests recorded in maize crops throughout the season are enlisted in the table and described below separately (Figures 1 to 3).

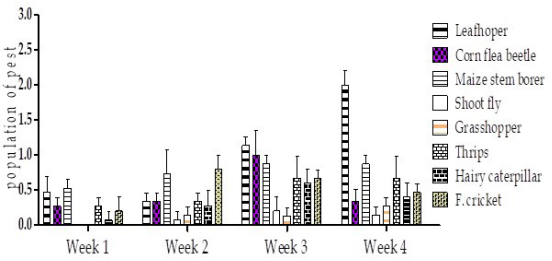

Figure 1. Incidence of insect pests on maize crop.

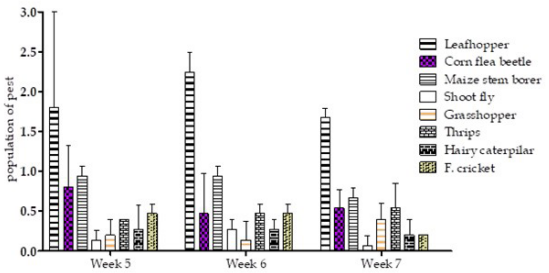

Figure 2. Incidence of insect pests on maize crop.

3.1. Corn leafhopper

Dalbiilus maidis DeLong 1923 (Cicadellidae; Hemiptera) is the vector that transmits pathogens, they were recognized as maize Rayado Fino Virus (MRFV), Maize Bushy Stunt Phytoplasma (MBP) and Corn Stunt Spiroplasma (CSS) (Ebbert and Nault, 2001). These pathogens were transmitted by *D. maidis* in a determined manner. However, among them, two pathogen species are well-known to reproduce in the *D. maidis*. Corn leafhopper was also observed as a minor pest on maize crops. The maize leafhopper feed on soft tissues of the leaves and ear rather than the stems and roots. Maize leafhopper feeding activities caused indirect damage as pale strips symptoms on the leaf with a result in plant dwarfing or death. The main damage was observed especially in plants younger than six weeks. Intense damage plants appeared yellow-green or white-yellow, stunted and with small cobs and open husks were seen from a distance. During observation, it was recorded on all the stages of maize where both the nymphs and adults were found sucking plant sap. The host plant *Zea mays* L. played a significant role to complete its life cycle and is used by adults in a wide range as a source of food, water, and shelter. In the first week's observations, the insect population was recorded as 0.47 ± 0.23/plant while in the second week it reduced to the lowest number giving an average of 0.34 ± 0.12/ plant. The population reached its peak level of 2.24 ± 0.25/plant in the sixth week of observation. During the other weeks of data observation, the population was found fluctuating between the average number of 0.93 and 2.00 hoppers/plant. The seasonal average of hopper population on maize was computed as 1.33/plant (Table 1).

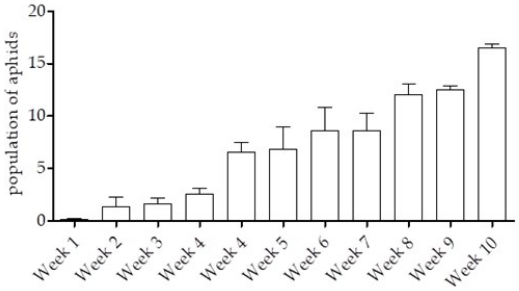

Figure 3. Incidence of aphids on maize crop.

3.2. Corn flea beetle

Corn flea beetle, *Chaetocnema pulicaria* F.E. Melsheimer 1847 (Chrysomelidae; Coleoptera) has the jumping capability. Green tissue of leaf surface becomes grey by feeding leaves. The adult is a vector of Stewart's bacteria that may cause bacterial leaf blight (Jasinski and Haley, 2014). A few species of flea beetles have been seen and recorded during the experimental period on maize plants. The numbers of the corn flea beetles found at weekly interval were 0.27 ± 0.12, 0.34 ± 0.12, 1 ± 0.35, 0.34 ± 0.31, 0.80 ± 0.53, 0.47 ± 0.50, 0.54 ± 0.23, 0.20 ± 0.20, 0.14 ± 0.23 and 0.20 ± 0.0 respectively with the seasonal average of 0.43 ± 0.28/plant. The minimum number (0.14/plant) was counted on the 9th and the maximum (1.00/plant) on the 3rd observational data (Table 1).

3.3. Maize stem borer

Maize Stem borer, *Chilo partellus* Swinhoe 1885 (Pyralidae; Lepidoptera) is a host specific and monophagous pest causing colossal destruction and loss in maize crops. It is worldwide distributed throughout the maize growing regions. It was observed during the data record that the larvae made pinholes in the row seen on opened leaves or dead hearts. The average number was recorded as 0.53 ± 0.12 in the first week, which showed a gradual increase up to the 6th week of observations. Its population counted as 0.73, 0.87, 0.87, 0.94, and 0.94 larvae per plant in the 2nd through 6th week, respectively. After the sixth week, the population was found to decline in a gradual manner until the last week of observation. The population in weeks seventh, eighth, ninth and tenth were 0.67 ± 0.12, 0.34 ± 0.12, 0.27 ± 0.12 and

Table 1. Incidence of insect pests of maize crop in Mansehra.

Weeks	LH	CFB	MSB	A/SI	Shoot Fly	GH	Thrips	HCP	FC
1st week	0.47 ± 0.23	0.27 ± 0.12	0.53 ± 0.12	0.14 ± 0.12	0.0 ± 0.0	0.0 ± 0.0	0.27 ± 0.12	0.07 ± 0.12	0.20 ± 0.20
2nd week	0.34 ± 0.12	0.34 ± 0.12	0.73 ± 0.12	1.34 ± 0.95	0.07 ± 0.12	0.14 ± 0.12	0.34 ± 0.12	0.27 ± 0.23	0.80 ± 0.20
3rd week	1.14 ± 0.12	1 ± 0.35	0.87 ± 0.12	1.6 ± 0.61	0.20 ± 0.20	0.13 ± 0.12	0.67 ± 0.31	0.60 ± 0.20	0.67 ± 0.1
4th week	2 ± 0.2	0.34 ± 0.31	0.87 ± 0.12	2.60 ± 0.53	0.14 ± 0.12	0.27 ± 0.12	0.67 ± 0.31	0.40 ± 0.20	0.47 ± 0.12
5th week	1.8 ± 1.2	0.80 ± 0.53	0.94 ± 0.12	6.5 ± 1.0	0.14 ± 0.12	0.20 ± 0.20	0.40 ± 0.0	0.27 ± 0.31	0.47 ± 0.12
6th week	2.24 ± 0.25	0.47 ± 0.50	0.94 ± 0.12	6.8 ± 2.2	0.27 ± 0.12	0.14 ± 0.23	0.47 ± 0.12	0.27 ± 0.12	0.47 ± 0.12
7th week	1.67 ± 0.12.	0.54 ± 0.23	0.67 ± 0.12	8.6 ± 1.7	0.07 ± 0.12	0.40 ± 0.20	0.54 ± 0.31	0.20 ± 0.20	0.20 ± 0.0
8th week	1.47 ± 0.12	0.20 ± 0.20	0.34 ± 0.12	12.07 ± 0.95	0.14 ± 0.12	0.14 ± 0.12	0.27 ± 0.23	0.07 ± 0.12	0.27 ± 0.12
9th week	1.2 ± 0.20	0.14 ± 0.23	0.27 ± 0.12	12.5 ± 0.42	0.07 ± 0.12	0.07 ± 0.12	0.14 ± 0.12	0.0 ± 0.0	0.2 ± 0.2
10th week	0.93 ± 0.46	0.20 ± 0.0	0.14 ± 0.12	16.47 ± 0.42	0.0 ± 0.0	0.20 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.27 ± 0.12
Average	1.33 ± 0.63	0.43 ± 0.28	0.63 ± 0.29	6.90 ± 5.5	0.11 ± 0.08	0.17 ± 0.11	0.38 ± 0.22	0.21 ± 0.22	0.40 ± 0.21

LH = leaf hopper; CFB = corn flea beetles; MSB = maize stem borer; A/SI = leaf aphid/inch^2; GH = grasshopper; HCP = hairy caterpillar; FC = field cricket.

0.14 ± 0.12 correspondingly. The seasonal average of stem borer´s population on maize during the experimental period was 0.63 ± 0.29 larvae/plant (Table 1).

3.4. Corn leaf aphid

Corn leaf aphid, *Rhospalosiphum maidis* (Fitch 1856) may be categorized as the major and abundantly prevailing pest, which belongs to the family Aphididae and order Hemiptera of class Insecta. They are phytophagous in nature and suck plant juice from leaves and corn ears by needle-like mouthparts. They rub nutrients from plants and slow down the development of the plant, pour poisons in tissue and serve as a vector of viral diseases. The nymphs and adult colonies usually aggregate at the whorls, leaves, ears and terminal stem of the plants, sucking the juices from the soft tissues. The appearance of leaf aphids was recorded in the present studies at first observation was 0.14 ± 0.12 per square inch which gradually and slightly increased during the following three weeks showing the population of 1.34, 1.60 and 2.60 aphids/square inch. The population rose abruptly in the next (5th) week showing 6.50 individuals/square inches (Table 1).

3.5. Maize shoot fly

Maize shoot fly, *Atherigona soccata* Rondani (Muscidae; Diptera) is considered a minor pest of the maize crop. The maggot of shoot fly caused the dead heart symptoms by feeding on internal growing points, tassels and ears. The infestation levels were in the range of 0.07 (2nd, 7th and 9th weeks) and 0.27 (6th week) maggot/plant while no infestation was noticed in the first and last weeks of the data record. The infestation attained in the remaining weeks was 0.20 (3rd week) and 0.14 (4th, 5th and 8th week) larvae or maggots/plant (Table 1).

3.6. Grasshopper

Grasshoppers are general feeders of vegetation and are found on rice, millets, wheat, sugarcane, and maize crops. The infestation of Grasshopper *Sphingonotus caerulans* Linnaeus 1767 (Acridoidea; Orthoptera) and *Pyrgomorpha conica* Olivier 1791 (Pyrgomorphidae; Orthoptera) were found throughout the season on maize but they were not found during the 1st week of the data record. The minimum average number was recorded in the 9th observation counted as 0.07 ± 0.0/plant while the maximum was obtained in the 7th data counted as 0.40/plant. The population was observed fluctuating throughout the cropping season. The seasonal average of the grasshopper population on maize was computed as 0.17/plant (Table 1).

3.7. Thrips

Thrips, *Thrips tabaci* Lindeman 1889 (Thripidae; Thysanoptera) feed on leaves of maize and some carrying plant viruses (Kucharczyk et al., 2011; Paweł et al., 2013). They suck juices from the soft tissues of several plants. The affected leaves become detectable of grey shine and the maize plant is stressed, so the attack is usually at its early stages. The population of thrips in the present studies recorded during the cropping season, 2020 may have been considered as a minor pest. The number remained in the range of 0.14 (in the 9th week) and 0.67/ plant in the 3rd week and 4th week with a seasonal average of 0.38/plant (Table 1).

3.8. Hairy caterpillar

Hairy caterpillar, *Diacrisia oblique* Walker 1855 (Noctuoidea; Lepidoptera) the pest was found feeding on the tender and newly grown tips of maize, like the silk of ears. The increased feeding of a hairy caterpillar on foliage was seen in the month of August. The population of hairy caterpillars recorded in the first and 8th week was the second-lowest 0.07 ± 0.12/plant after 0.00 in the last two weeks. In the third week, in contrast, the number was maximum giving the average of 0.60 ± 0.20/plant. The seasonal average of the hairy caterpillar population was calculated as 0.22/plant (Table 1).

3.9. Field cricket

The population of field cricket, *Acheta domesticus* Linnaeus 1758 (Gryllidae; Orthoptera) on maize was found in the range of 0.20 and 0.80 during the 1st, 7th, 9th and 2nd week of observation, respectively. The population was recorded at its peak level as 0.80/plant during the 2nd observation. Similarly, during the 4th, 5th and 6th week, the population remained uniform showing 0.47/plant. The seasonal average of field cricket population on maize was determined as 0.40/plant (Table 1).

4. Discussion

The present research work was done at Agricultural, Research Station, Baffa, Mansehra on maize well-adapted variety Azam. The maize is grown in different seasons of the year and many insect pests damaged the crop (Fefelova and Frolov, 2008). The insect pest species recorded during the experimentation are recognized as flea beetle, thrips, corn leaf aphid, maize stem borer, hairy caterpillar, leafhopper, field cricket, grasshopper and maize shoot fly on maize crop. The obtained results had a close relationship with the work of O'Day et al. (1998), Bowen et al. (2014) and Goergen et al. (2016) who reported corn flea beetle, seed corn maggot, wireworms, white grubs, thrips, grape colaspis, black cutworm, sod webworm, southern corn leaf beetle, seedcorn beetles, chinch bug, armyworm, stalk borer, grasshoppers, corn leaf aphid, European corn borer, Southwestern corn borer, corn rootworms, fall armyworm, and corn earworm. Because the environmental condition is the same as the respective study area.

The total seasonal average population of the reckoned insects was recorded as corn leaf aphid (6.90 ± 5.5), leafhopper (1.33 ± 0.63), maize stem borer (0.63 ± 0.29), corn flea beetle (0.43 ± 0.28), thrips (0.38 ± 0.22), hairy caterpillar (0.22 ± 0.22), grasshopper (0.167 ± 0.11) and shoot fly (0.11 ± 0.09) increased in descending order. The highest number was 6.90/plant referred to as aphids and the lowest was 0.11/plant recognized as shoot fly. The population of shoot fly was presented by Sahito et al. (2012) and showed close similarity with the present results. The authors counted the seasonal average population

of shoot fly (0.08) in maize crop, similarly, these results of present studies are also in concurrence with those of Shahzad et al. (2006) who reported infestation of shoot fly in the range of 10.67, 15.21, 11.97, and 13.35% from susceptible cultivars. Similar observations were made Apotikar et al. (2011) on *Atherigona soccata* on sorghum. Therefore, the climatic conditions and variation are the same as our research study area.

Flea beetle was considered a vector of the *Erwinia stewartii* (*Pantoea stewartii*) (Esker and Nutter Junior, 2003; Hoffmann et al., 1999) that caused Stewart bacterial wilt, an infection spread in maize. The bacterium lived in the gut of the pests and was released with feeding. Therefore, it is not only a pest itself but also spreads and transmits plant (maize) disease in the crop. Present studies revealed that the overall average population of corn flea beetle (*Chaetocnema pulicaria)* on maize was recorded as 0.43 ± 0.28/plant. The recorded results agreed with the finding of Hoffmann et al. (1999), who obtained a higher population of the corn flea beetle, in their experiment, especially during the month of May to July.

The aphid population in the present experiment was recorded as 6.90/plant. Although aphids were also reported by Jeger et al. (2018) and Macharia et al. (2016) but were not at a high number. The authors narrated that the pest was not so important. In contrast, it was found that the aphid pest occurred at financial levels of damage (Miñarro and Dapena, 2014), similarly, a lot number of the corn leaf aphid, *Rhopalosiphum maidis* reported in the range of 9.4 to 14.6 per plant during a surveillance program (Biradar et al., 2011). The authors also recorded an extended list of insect pests of maize and their natural enemies collected during the survey (Khan et al., 2019a, b, 2020, 2021; O'Gara, 2007). These results are in conformity with the present findings to a great extent indicating the incidence of the pest, however, our achievements cannot be exactly compared with those of previous researchers, which may be due to differences in environmental conditions, methodologies and pest status.

5. Conclusion

Field studies on the relative abundance of insect pests of maize were carried out at the Agricultural Research, Baffa, Mansehra. Sowing methods and crop management practices were performed uniformly for the trial. Observations were started at the appearance of the pest in respective trial and continued at weekly intervals till the maturity of the crop. The insect's population prevailed at low density, even below the economic threshold level (ETL). It remained suppressed due to unusual and heavy rain in the area. However, the insect pests obtained during the experimentation were enlisted as corn flea beetle, maize shoot fly, maize stem borer, corn leafhopper, hairy caterpillar, corn thrips, field crickets and corn aphid.

Acknowledgements

This study was supported by the Director of Agriculture, Research station, Baffa, Mansehra. Similarly, the equal respect and credits are going to Dr Sana Ullah Zoology Department of Hazara University, Mansehra helped in statistical analyses. Mr Waqar and Habib helped me in data sampling in the field.

References

ABID, S., RAZA, I., KHALIL, A., KHAN, M.N., ANWAR, S. and MASOOD, M.A., 2014. Trend analysis and forecasting of maize area and production in Khyber Pakhtunkhwa, Pakistan. *European Academic Research*, vol. 2, pp. 4653-4664.

APOTIKAR, D., VENKATESWARLU, D., GHORADE, R., WADASKAR, R., PATIL, J. and KULWAL, P., 2011. Mapping of shoot fly tolerance loci in sorghum using SSR markers. *Journal of Genetics*, vol. 90, no. 1, pp. 59-66. http://dx.doi.org/10.1007/s12041-011-0046-1. PMid:21677382.

ARABJAFARI, K. and JALALI, S., 2007. Identification and analysis of host plant resistance in leading maize genotypes against spotted stem borer, *Chilo partellus* (Swinhoe)(Lepidoptera: pyralidae). *Pakistan Journal of Biological Sciences*, vol. 10, no. 11, pp. 1885-1895. http://dx.doi.org/10.3923/pjbs.2007.1885.1895. PMid:19086556.

BIRADAR, S., KOTIKAL, Y. and BALIKAI, R., 2011. Seasonal incidence of insect pests and their natural enemies on maize. *International Journal of Plant Protection*, vol. 4, pp. 402-405.

BLANCO, C.A., PELLEGAUD, J.G., NAVA-CAMBEROS, U., LUGO-BARRERA, D., VEGA-AQUINO, P., COELLO, J., TERÁN-VARGAS, A.P. and VARGAS-CAMPLIS, J., 2014. Maize pests in Mexico and challenges for the adoption of integrated pest management programs. *Journal of Integrated Pest Management*, vol. 5, no. 4, pp. E1-E9. http://dx.doi.org/10.1603/IPM14006.

BOSQUE-PÉREZ, N.A., 1995. *Major insect pests of maize in Africa: biology and control*. Ibadan: IITA.

BOWEN, K., FLANDERS, K., HAGAN, A. and ORTIZ, B., 2014. Insect damage, aflatoxin content, and yield of Bt corn in Alabama. *Journal of Economic Entomology*, vol. 107, no. 5, pp. 1818-1827. http://dx.doi.org/10.1603/EC13442. PMid:26309272.

CHOURADDI, M. and MALLAPUR, C., 2017. Assessment of crop loss and economic injury level of maize stem borer, *Chilo partellus* (Swinhoe). *Journal of Entomology and Zoology Studies*, vol. 5, pp. 1530-1535.

EBBERT, M.A. and NAULT, L.R., 2001. Survival in *Dalbulus* leafhopper vectors improves after exposure to maize stunting pathogens. *Entomologia Experimentalis et Applicata*, vol. 100, no. 3, pp. 311-324. http://dx.doi.org/10.1046/j.1570-7458.2001.00878.x.

ESKER, P. and NUTTER JUNIOR, F., 2003. Temporal dynamics of corn flea beetle populations infested with *Pantoea stewartii*, causal agent of Stewart's disease of corn. *Phytopathology*, vol. 93, no. 2, pp. 210-218. http://dx.doi.org/10.1094/PHYTO.2003.93.2.210. PMid:18943136.

FEFELOVA, Y. and FROLOV, A., 2008. Distribution and mortality of corn earworm (*Helicoverpa armigera*, Lepidoptera, Noctuidae) on maize plants in Krasnodar Territory. *Entomological Review*, vol. 88, no. 4, pp. 480-484. http://dx.doi.org/10.1134/S0013873808040106.

GALINAT, W.C., 1992. Maize: gift from America's first peoples. In: N. FOSTER and L.S. CORDELL, eds. *Chilies to chocolate: food the Americas gave the world*. Tucson: The University of Arizona Press. http://dx.doi.org/10.2307/j.ctv1qwwjt3.8.

GÁSPÁR, M., KÁLMÁN, G. and RÉCZEY, K., 2007. Corn fiber as a raw material for hemicellulose and ethanol production. *Process*

Biochemistry, vol. 42, no. 7, pp. 1135-1139. http://dx.doi.org/10.1016/j.procbio.2007.04.003.

GOERGEN, G., KUMAR, P.L., SANKUNG, S.B., TOGOLA, A. and TAMÒ, M., 2016. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS One*, vol. 11, no. 10, e0165632. http://dx.doi.org/10.1371/journal.pone.0165632. PMid:27788251.

GONZÁLEZ, R.J., 2001. *Zapotec science: farming and food in the Northern Sierra of Oaxaca*. Austin: University of Texas Press.

HAROON, H., MENG, Y.-F., KHAN, Z., PERVEEN, F., RAFI, M.A., SHAH, S.W., SU, X.-H. and XING, L., 2020. Biodiversity of butterflies in Tangi Charsadda, Khyber Pakhtunkhwa, Pakistan. *Pakistan Journal of Zoology*, vol. 52, no. 3, pp. 835. http://dx.doi.org/10.17582/journal.pjz/20190326090338.

HAROON, M., KHAN, Z., ULLAH, I., ALI, I., MUHAMMAD, I., AHMAD, T. and XING, L., 2021. Environmental and soil gradient effects on biodiversity of butterflies in Khyber Pakhtunkhwa, Pakistan. *Arthropods*, vol. 10, no. 1, pp. 1-17.

HOFFMANN, M., HOEBEKE, R. and DILLARD, H.R., 1999. *Flea beetle pests of vegetables*. Ithaca: Cornell University.

HOKMALIPOUR, S., SHIRI-E-JANAGARD, M., DARBANDI, M.H., PEYGHAMI-E-ASHENAEE, F., HASANZADEH, M., SEIEDI, M.N., SHABANI, R., 2010. Comparison of agronomical nitrogen use efficiency in three cultivars of corn as affected by nitrogen fertilizer levels. *World Applied Sciences Journal*, vol. 8, pp. 1168-1174.

JASINSKI, J.R. and HALEY, J., 2014. An integrated pest management adoption survey of sweet corn growers in the great lakes region. *Journal of Integrated Pest Management*, vol. 5, no. 2, pp. 1-10. http://dx.doi.org/10.1603/IPM13002.

JEGER, M., BRAGARD, C., CANDRESSE, T., CHATZIVASSILIOU, E., DEHNEN-SCHMUTZ, K., GILIOLI, G., GRÉGOIRE, J.C., JAQUES MIRET, J.A., MACLEOD, A., NAVAJAS NAVARRO, M., NIERE, B., PARNELL, S., POTTING, R., RAFOSS, T., ROSSI, V., UREK, G., VAN BRUGGEN, A., VAN DER WERF, W., WEST, J., WINTER, S., MANCEAU, C., PAUTASSO, M. and CAFFIER, D., 2018. Pest categorisation of *Pantoea stewartii* subsp. stewartii. *EFSA Journal*, vol. 16, no. 7, pp. 16. PMid:32625989.

KARAVINA, C., MANDUMBU, R. and MUKARO, R., 2014. Evaluation of three-way maize (*Zea mays* L.) hybrids for yield and resistance to maize streak virus and turcicum leaf blight diseases. *Journal of Animal and Plant Science*, vol. 24, pp. 216-220.

KASIM, P.D., SUNEETHA, P., SRIDEEPTHI, R., SAHITHYA, L.U. and KRISHNA, M., 2016. Survival and development of *Chilo partellus* (Swinehoe) (Lepidoptera: Pyralidae) green gram based diet in laboratory conditions. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, vol. 7, pp. 561-567.

KHALIQ, T., MAHMOOD, T., KAMAL, J. and MASOOD, A., 2004. Effectiveness of farmyard manure, poultry manure and nitrogen for corn (*Zea mays* L.) productivity. *International Journal of Agriculture and Biology*, vol. 2, pp. 260-263.

KHAN, I., DIN, S., KHAN KHALIL, S. and ATHER RAFI, M., 2007. Survey of predatory coccinellids (Coleoptera: Coccinellidae) in the Chitral district, Pakistan. *Journal of Insect Science*, vol. 7, no. 7, pp. 7. http://dx.doi.org/10.1673/031.007.0701. PMid:20334592.

KHAN, I.U., NAWAZ, M., FAZAL, S. and KAMRAN, S., 2015. Integrated pest management of maize stem borer, *Chilo partellus* (Swinhoe) in maize crop and its impact on yield. *Journal of Entomology and Zoology Studies*, vol. 3, pp. 470-472.

KHAN, Z., KHAN, M.S., BAWAZEER, S., BAWAZEER, N., SULERMAN, IRFAN, M., RAUF, A., SU, X-H. and XING, L-X., 2022. A comprehensive review on the documented characteristics of four Reticulitermes termites (Rhinotermitidae, Blattodea) of China. *Brazilian Journal of Biology*, vol. 84, e256354. https://doi.org/10.1590/1519-6984.256354.

KHAN, Z., LI, Y.X., LIU, Q., SU, X.H. and XING, L.X., 2021. The first description of alate and supplementary description of soldier of Reticulitermes aculabialis Tsai et Hwang (Isoptera, Rhinotermitidae). *International Journal of Tropical Insect Science*, vol. 41, no. 4, pp. 2643-2648. https://doi.org/10.1007/s42690-021-00445-3.

KHAN, Z., KHAN, M.S., AIN, Q., RAQIB, A., HAROON. and XING, L., 2020. Chemical control of *Chilo partellus* on maize crop in district Mansehra. *International Journal of Tropical Insect Science*, vol. 40, no. 1, pp. 1-12. http://dx.doi.org/10.1007/s42690-019-00044-3.

KHAN, Z., AIN, Q., RAQIB, A., KHAN, M. and XING, L., 2019a. Effectiveness of granular and liquid insecticides against *Chilo partellus* on maize in Pakistan. *Polish Journal of Environmental Studies*, vol. 29, no. 1, pp. 641-651. http://dx.doi.org/10.15244/pjoes/102627.

KHAN, Z., ZHANG, M., MENG, Y., ZHAO, J., KONG, X., SU, X. and XING, L., 2019b. Alates of the termite *Reticulitermes flaviceps* feed independently during their 5-month residency in the natal colony. *Insectes Sociaux*, vol. 66, no. 3, pp. 425-433. http://dx.doi.org/10.1007/s00040-019-00698-9.

KUCHARCZYK, H., BEREŚ, P. and DĄBROWSKI, Z., 2011. The species composition and seasonal dynamics of thrips (Thysanoptera) populations on maize (*Zea mays* L.) in southeastern Poland. *Journal of Plant Protection Research*, vol. 51, no. 3, pp. 210-216. http://dx.doi.org/10.2478/v10045-011-0036-6.

KUMAR, H., 2002. Resistance in maize to the larger grain borer, *Prostephanus truncatus* (Horn)(Coleoptera: bostrichidae). *Journal of Stored Products Research*, vol. 38, no. 3, pp. 267-280. http://dx.doi.org/10.1016/S0022-474X(01)00030-3.

MACHARIA, M., TEBKEW, D., AGUM, W. and NJUGUNA, M., 2016. Incidence and distribution of insect pests in rain-fed wheat in Eastern Africa. *African Crop Science Journal*, vol. 24, no. 1, pp. 149-155. http://dx.doi.org/10.4314/acsj.v24i1.17S.

MALLAPUR, C. and MANJUNATH, C., 2015. *Stenachroia elongella* Hampson: a new threat to maize cultivation in karnataka, India. *Journal of Experimental Zoology India*, vol. 18, pp. 327-329.

MALLICK, M., AURAKZAI, J., BILE, K. and AHMED, N., 2010. Large-scale physical disabilities and their management in the aftermath of the 2005 earthquake in Pakistan. *Eastern Mediterranean Health Journal*, vol. 16, suppl., pp. 98-105. http://dx.doi.org/10.26719/2010.16.Supp.98. PMid:21495595.

MANJUNATH, C., MALLAPUR, C. and BALIKAI, R., 2016. Evaluation of biopesticides/bio-control agents against maize stem borers. *Annals of Entomology*, vol. 34, pp. 15-21.

MIÑARRO, M. and DAPENA, E., 2014. Resistance of apple cultivars to *Dysaphis plantaginea* (Hemiptera: Aphididae): Role of tree phenology in infestation avoidance. *Environmental Entomology*, vol. 36, no. 5, pp. 1206-1211. http://dx.doi.org/10.1603/0046-225X(2007)36[1206:ROACTD]2.0.CO;2. PMid:18284746.

MORAES, J.C., GOUSSAIN, M.M., CARVALHO, G.A. and COSTA, R.R., 2005. Feeding non-preference of the corn leaf aphid *Rhopalosiphum maidis* (Fitch, 1856) (Hemiptera: Aphididae) to corn plants (*Zea mays* L.) treated with silicon. *Ciência e Agrotecnologia*, vol. 29, no. 4, pp. 761-766. http://dx.doi.org/10.1590/S1413-70542005000400007.

MORRIS, M.L., RISOPOULOS, J. and BECK, D., 1999. *Genetic change in farmer-recycled maize seed: a review of the evidence*. Mexico: CIMMYT.

MOYAL, P., 1998. Infestation patterns and parasitism of the maize stalk borer, *Busseala fusea* (Fuller)(Lepidoptera: Noctuidae), in the Ivory Coast. *African Entomology*, vol. 6, pp. 289-296.

MUHAMMD, N., ASHIQ, M., GAFFAR, A., SATTAR, A. and ARSHAD, M., 2012. Comparative efficacy of new herbicides for weed control in maize (*Zea mays* L.). *Pakistan Journal of Weed Science Research*, vol. 18.

MURTHY, K.S., RAJESHWARI, R., JALALI, S. and VENKATESAN, T., 2013. Evaluation of pesticide tolerant strain of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) on maize stem borer, *Chilo partellus* (Swinhoe). *International Journal of Biodeversity and Conservation*, vol. 5, pp. 567-571.

MUTYAMBAI, D.M., BRUCE, T.J., MIDEGA, C.A., WOODCOCK, C.M., CAULFIELD, J.C., VAN DEN BERG, J., PICKETT, J.A. and KHAN, Z.R., 2015. Responses of parasitoids to volatiles induced by *Chilo partellus* oviposition on teosinte, a wild ancestor of maize. *Journal of Chemical Ecology*, vol. 41, no. 4, pp. 323-329. http://dx.doi.org/10.1007/s10886-015-0570-1. PMid:25943860.

NEUPANE, S., BHANDARI, G., SHARMA, S.D., YADAV, S. and SUBEDI, S., 2016. Management of stem borer (*Chilo partellus* Swinhoe) in maize using conventional pesticides in Chitwan, Nepal. *Journal of Maize Research and Development*, vol. 2, no. 1, pp. 13-19. http://dx.doi.org/10.3126/jmrd.v2i1.16211.

O'DAY, M.H., BECKER, A., KEASTER, A.J., KABRICK, L.R. and STEFFEY, K.L., 1998. *Corn insect pests: a diagnostic guide*. Columbia: MU Extension, University of Missouri-Columbia.

O'GARA, F.F.P., 2007. *Irrigated maize production in the top end of the Northern Territory: production guidelines and research results*. Darwin: Department of Primary Industry, Fisheries and Mines, Northern Territory Government, 85 p.

OKWECHE, S., OGUNWOLU, E. and ADEYEMO, M., 2013. Parameters, interrelationships with yield and use of carbofuran to control stem borers in maize (*Zea mays* L.) at Makurdi in the Nigerian Southern Guinea Savanna. *Greener Journal of Agricultural Sciences*, vol. 3, no. 10, pp. 702-708. http://dx.doi.org/10.15580/GJAS.2013.3.170913845.

OLIVEIRA, C., AUAD, A., MENDES, S. and FRIZZAS, M., 2014. Crop losses and the economic impact of insect pests on Brazilian agriculture. *Crop Protection*, vol. 56, pp. 50-54. http://dx.doi.org/10.1016/j.cropro.2013.10.022.

PAWEŁ, K.B., KUCHARCZYK, H. and KUCHARCZYK, M., 2013. Thrips abundance on sweet corn in southeastern Poland and the impact of weather conditions on their population dynamics. *Bulletin of Insectology*, vol. 66, pp. 143-152.

RICE, M.E. and DAVIS, P., 2010. Stalk borer (Lepidoptera: Noctuidae) ecology and integrated pest management in corn. *Journal of Integrated Pest Management*, vol. 1, no. 1, pp. C1-C6. http://dx.doi.org/10.1603/IPM10006.

ROSEGRANT, M.W., LEACH, N. and GERPACIO, R.V., 1999. Alternative futures for world cereal and meat consumption. *The Proceedings of the Nutrition Society*, vol. 58, no. 2, pp. 219-234. http://dx.doi.org/10.1017/S0029665199000312.

SAHITO, H.A., ABRO, G.H., TALPUR, M.A., MAL, B. and DHILOO, K.H., 2012. Population fluctuation of insect pests and predators in maize, *Zea mays* L. *Wudpecker Journal of Agricultural Research*, vol. 1, pp. 466-473.

SAJJAD, A., HAYAT, B., MASHWANI, M. and KHAN, M., 2010. Effect of different planting dates of maize on infestation of maize stem borer *Chilo partellus* (Swinhoe) Pyralidae: lepidoptera. *Sarhad Journal of Agriculture*, vol. 26, pp. 621-624.

SAMKOVÁ, A., JANŠTA, P. and HUBER, J.T., 2017. *Anaphes flavipes*: redescription, neotype designation, and comparison with *A. nipponicus* (Hymenoptera: Chalcidoidea: Mymaridae). *Acta Entomologica Musei Nationalis Pragae*, vol. 57, no. 2, pp. 677-712. http://dx.doi.org/10.1515/aemnp-2017-0095.

SHAHZAD, M.A., SHAHEEN, M.S., KHAN, M.T.H. and IQBAL B., 2006. Field screening of promising cultivars of maize against shootfly (*Atherigona soccata* (Rond.) and maize borer (*Chilo partellus* (Swin.) during spring season. *Pakistan Entomologist*, vol. 28, pp. 15-17.

SINGH, A. and GANDHI, S., 2012. Agricultural insect pest: occurrence and infestation level in agricultural fields of Vadodara, Gujarat. *International Journal of Scientific and Research Publications*, vol. 2, pp. 1-5.

SULTANA, R. and WAGAN, M.S., 2009. A comparative study on the morphology of egg pods, egg development and hatching of three *Hieroglyphus* species (Acrididae: orthoperta). *Pakistan Journal of Zoology*, vol. 41, no. 2, pp. 143-148.

TAGNE, A., FEUJIO, T. and SONNA, C., 2008. Essential oil and plant extracts as potential substitutes to synthetic fungicides in the control of fungi. In: *International Conference Diversifying Crop Protection*, 2008, Montpellier. New York: ISAAA, pp. 12-15.

TAHIR, A. and HABIB, N., 2013. Forecasting of maize area and production in Pakistan. *Crop Production*, vol. 2, pp. 44-48.

TEFERA, T., MUGO, S., MWIMALI, M., ANANI, B., TENDE, R., BEYENE, Y., GICHUKI, S., OIKEH, S.O., NANG'AYO, F., OKENO, J., NJERU, E., PILLAY, K., MEISEL, B. and PRASANNA, B.M., 2016. Resistance of Bt-maize (MON810) against the stem borers *Busseola fusca* (Fuller) and *Chilo partellus* (Swinhoe) and its yield performance in Kenya. *Crop Protection*, vol. 89, pp. 202-208. http://dx.doi.org/10.1016/j.cropro.2016.07.023. PMid:27812235.