proceedings

MDPI

Proceedings

Influence of Meteorological Factors on Population Dynamics of Fall Armyworm, *Spodoptera frugiperda*, Lepidoptera: Noctuidae and its Varietal Susceptiblilty to FAW †

Shahbaz Ahmad * and Muhammad Arslan Ibrahim

Deaprtment of Entomology, University of the Punjab and 54590

* Correspondence: shahbaz.iags@pu.edu.pk

† Presented at the 1st International Electronic Conference on Entomology (IECE 2021), 1–15 July 2021; Available online: https://iece.sciforum.net/.

Abstract: The invasive armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is a key pest of maize that has invaded Pakistan causing severe damage and yield losses. The current investigation was directed to visualize fall armyworm infestation on eight of the different maize varieties. Correlation analysis of FAW infestation with weather factors revealed that temperature (max., mean, and min.) had a weak positive effect on fall armyworm infestation (r = 0.139, r = 0.149 and r = 0.159, respectively) while relative humidity played a weak negative (r = -0.104) role in FAW population build-up. A seasonal mean infestation of the pest found maximum on Malka-16 which was statistically higher than any other variety. The lowest invasion was recorded on the P1543 Hybrid ($P < 0.05$). Similarly, the infestation was significantly highest in the 1st half of November ($P < 0.05$), a decline in pest population build-up was seen in December possibly by cold weather.

Keywords: Management; MaizeSpodoptera frugiperda; yield losses

Citation: Ahmad, S.; Ibrahim, M.A. Influence of Meteorological Factors on Population Dynamics of Fall Armyworm, *Spodoptera frugiperda*, Lepidoptera: Noctuidae and its Varietal Susceptiblilty to FAW, in Proceedings of the 1st International Electronic Conference on Entomology, 1–15 July 2021, MDPI: Basel, Switzerland, doi:10.3390/IECE-10609

Published: 6 July 2021

Introduction

Fall armyworm (FAW), *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) is an invasive pest of maize crop. It is native to the Americas and was first reported as an aggressive pest in Africa in the tropical zones of Nigeria, in 2016 (Akutse *et al* 2019). Subsequently, it was spread to different parts of the African continent. It was reported that fall armyworm attacks about 350 host plant species belong to 76 plant families (Montezano *et al* 2018). In Pakistan, fall armyworm was reported on maize during the fall session of 2019 in Sindh province (Naeem-Ullah *et al* 2019). Since then, it has spread to many parts of the country causing devastation to maize production.

In Pakistan, it has been seen from the recent invasions of fall armyworm that the crops planted by smallholders were more prone to damage. The reason is simple that they cannot afford expensive agricultural inputs. Most of the maize growers in the country are smallholders who always look for low-cost managemental practices to curb pest problems. The use of resistant varieties is an old method and is frequently adopted by smallholders (Abid *et al* 2019). The studies on the screening of variable varieties having different genomes against exotic pests could be an effective initiative to determine the extent of tolerance found in such varieties (Kasoma *et al* 2020).

The fluctuations in the population build-ups of insects are directly linked with biotic and abiotic factors that prevail in the micro and macro climates of insect pests (Kamata 2000). Insect populations do not remain the same throughout the year, they get vary with the change in environmental factors like temperature, humidity, or rainfall (Wallner 1987). The seasonal studies about population dynamics, depending on biotic or abiotic factors, provide necessary clues for the management of important crop pests (Aasman 2001). Population ecologists classify the factors, that determine the size of the population, into two major categories; density-independent factors (weather and climate) and density-dependent factors (diseases, competitions and natural enemies). Density independent factors are sometimes regarded as limiting factors while density-dependent factors are known as regulating factors since they keep the population in a narrow range and do not let the population expand freely (Britannica 2017).

The poikilothermic nature of the insects makes them highly sensitive to external temperatures. In general perception, temperature is regarded as the most significant environmental factor influencing the development, behaviour, distribution, reproduction, and survival of insects (Briere *et al* 1999). Temperature-dependent studies of insect pests are always very crucial in understanding the population dynamics of insects and their implementation helps in designing specific pest-control strategies (Ahmad 2016).

Another most important abiotic factor that determines insect survival is the humidity. Variation in humidity levels influences the developmental stages of insects. A high level of relative humidity (RH) could be advantageous for the survival and growth of immature stages of certain insect species (Lu & Wu 2011). A few investigations declare the higher levels of RH as a source of mortality in insects through fungal (Shipp *et al* 2003) or viral (Fuxa *et al* 1999) infections. Similarly, low RH may stop embryonic development and loss of softness in the cuticular layer (Guarneri *et al* 2002). The present study deals with fall armyworm population density on eight maize varieties grown under agroecological conditions of the Punjab, Pakistan and the relationship of weather conditions e.g., temperature and relative humidity against FAW population build up on eight maize varieties.

Materials and Methods:

Study site description:

The study was conducted at Fisheries and Crop Research Station, University of the Punjab (31.498356°N, 74.293647°E). The site was characterized by well-drained clay to loamy soil with a relatively leveled cropping area. In order to study the effects of abiotic factors on FAW infestation upon different varieties of maize, an experiment was conducted following the randomized complete block design (RCBD). Eight varieties including four conventional and four hybrids were cultivated and the sowing was done on the 18th of September 2019. All of the treatments were repeated thrice and each unit plot size was maintained at (4 x 4.5 m). Seeds were planted using seed driller with 6 inches plant to plant distance while row to row distance was maintained at 1ft. The fertilizers (N, P, K) were applied at the rate of (80, 46, 37) Kg/acre respectively. Irrigation and weed management practices were performed accordingly to the technical recommendations by Agriculture Punjab's Maize Production Technology.

Treatment variables:

Four conventional and four hybrid varieties were selected to screen out against FAW infestation. The seeds were purchased from a registered local seed distributor, Manga Mandi, Lahore. Before cultivation, seeds were treated with Topsin-M (70 WP) which is a fungicide and prevents fungal diseases. The description of varieties is given as:

Table 1. Treatment variables and description.

Varieties	Treatment No.	Developed By	Maturity (in days)
Gohar-19	V1	MMRI*	95-100
Pearl-2011	V2	MMRI	120
CIMMYT Pak	V3	MMRI	115
Malka-2016	V4	MMRI	100
Karamat Hybrid	V5	CRCI**	110
Ghouri Hybrid	V6	CRCI	115
31P41 Hybrid	V7	Pioneer	100
P1543 Hybrid	V8	DuPont	113

*MMRI= Maize and Millet Research Institute, Yousafwala, Sahiwal, Pakistan. **CRCI= Cereal Crops Research Institute, Pir Sabaq, KPK, Pakistan.

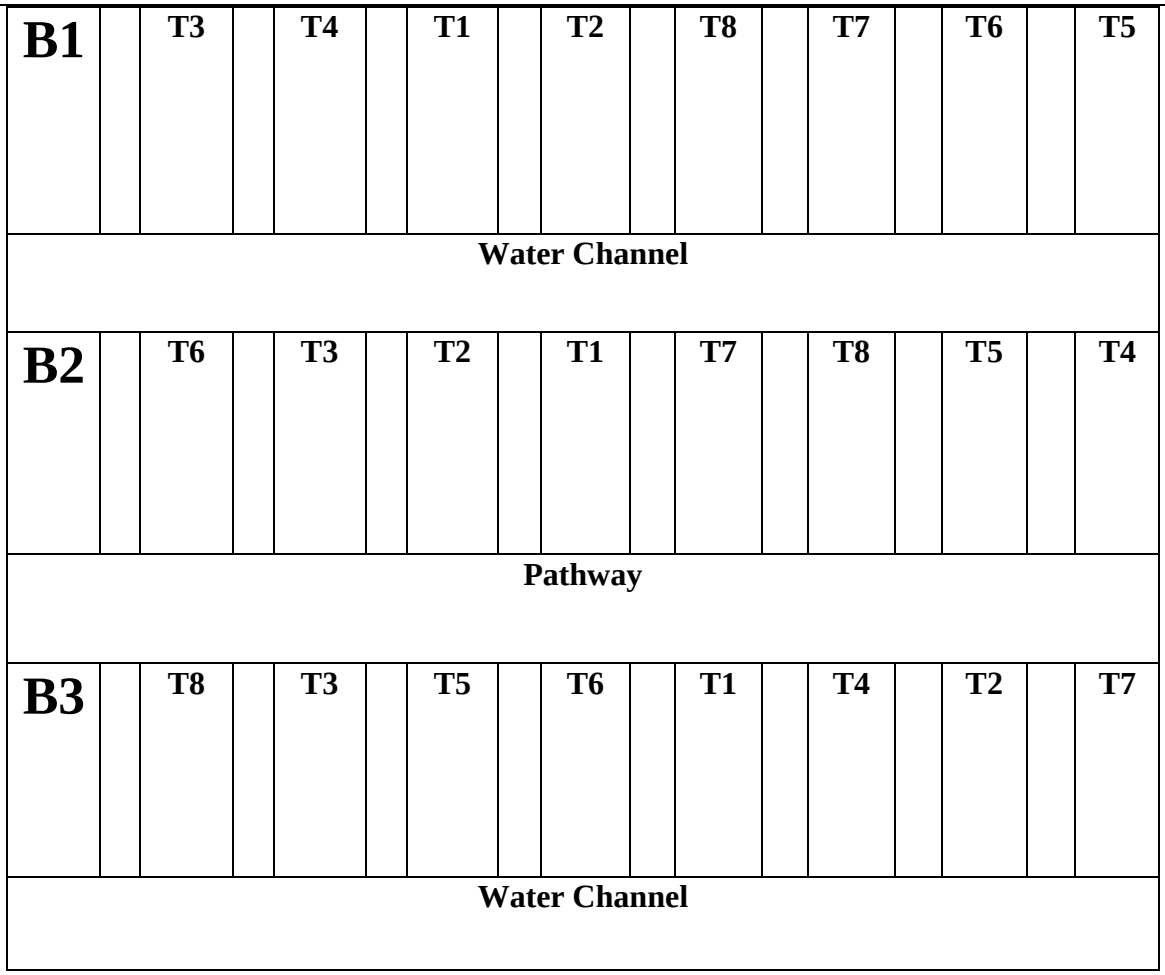


Figure 1. Field experiment design.

Data Collection:

From each of the experimental units, the data were collected from 6 different spots in a zig-zag fashion, and from each spot 10 plants were observed. Plants were inspected for the physical presence of larval form in the central whorl of the plant, egg masses, damaging signs including windowing, shot holes, lumps of frass, ragged and torn leaves. Data were taken weekly from 14-Oct-2019 to onward till the crop harvesting. To find out percentage infestation, the following formula was used as described by Mashwani *et al* (2011).

Percentage Infestation = (No. of Plants Infested / Total No. of Plants Inspected) × 100

The percentage infestation was calculated against each of the 10 plants from the single spot and the average of 6 different spots gave mean infestation present in a single experimental unit.

Meteorological Data:

Data on daily temperature and relative humidity were taken from the observatory officials of the Centres for Integrated Mountain Research (CIMR) department of University of the Punjab, Lahore, Pakistan.

Statistical Analysis:

The infestation data were subjected to ANOVA (Analysis of Variance) by using software Statistics 8.1 while means were compared through Tukey's HSD test at P = 0.05. The percentage of infestation was correlated with meteorological factors i-e., temperature (°C) and relative humidity (R.H.) (%).

Results:

The FAW infestation recorded from different maize varieties were subjected to statistical analyses. The pest infestation remained significantly different on all eight maize varieties as given by the ANOVA (Table 2).

Table 2. Analysis of variance (ANOVA) for mean infestation.

S. O. V	Df	SS	MS	F	P
W	9	17681.8	1964.65		
T	7	349.2	49.89	9.04	0.0000**
Error	63	347.8	5.52		
Total	79	18378.8			

**= Highly Significant means (P < 0.05) Grand mean 22.199 CV 10.58.

Mean comparison test (HSD) explains that the maximum cumulative mean infestation was observed on Malka-16 which was a conventional variety of maize, and statistically, it was different from Gohar-19, Karamat Hybrid, Pearl 2011, CIMMYT Pak, Ghouri Hybrid, 31P41 Hybrid, and P1543 Hybrid. The minimum infestation was recorded on the P1543 Hybrid of maize which showed some sort of resistance against FAW (Table 3).

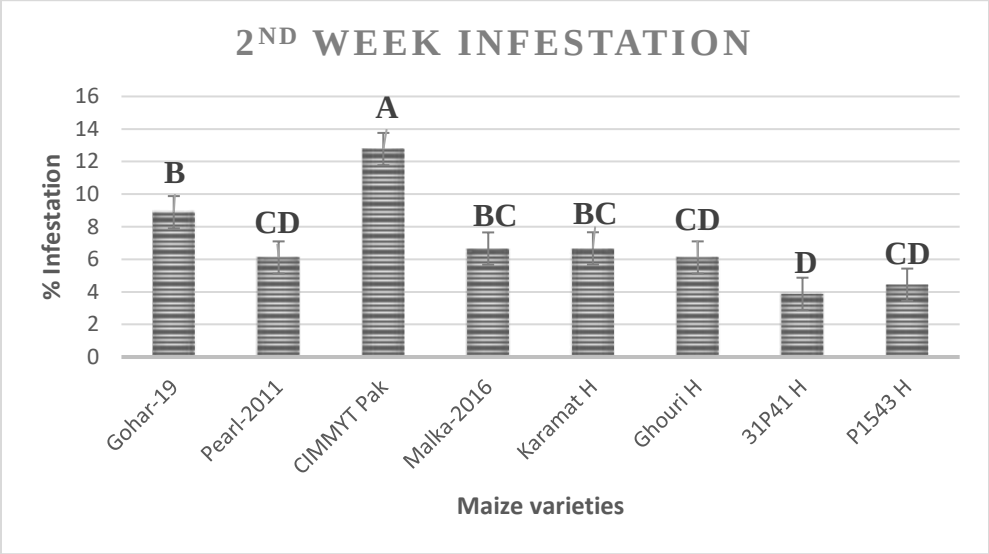
Table 3. Seasonal FAW infestation on different maize varieties.

Maize Varieties	Mean ± S.E.	Homogenous Groups
Malka-16	25.83 ± 0.77	A
Gohar-19	23.99 ± 0.86	AB
Karamat Hybrid	22.499 ± 0.731	BC
Peral-2011	22.497 ± 0.723	BC
CIMMYT Pak	22.496 ± 0.714	BC
Ghouri Hybrid	21.71 ± 0.74	BCD
31P41 Hybrid	19.94 ± 0.76	CD

P1543 Hybrid	18.60 ± 0.78	D
P < 0.05		

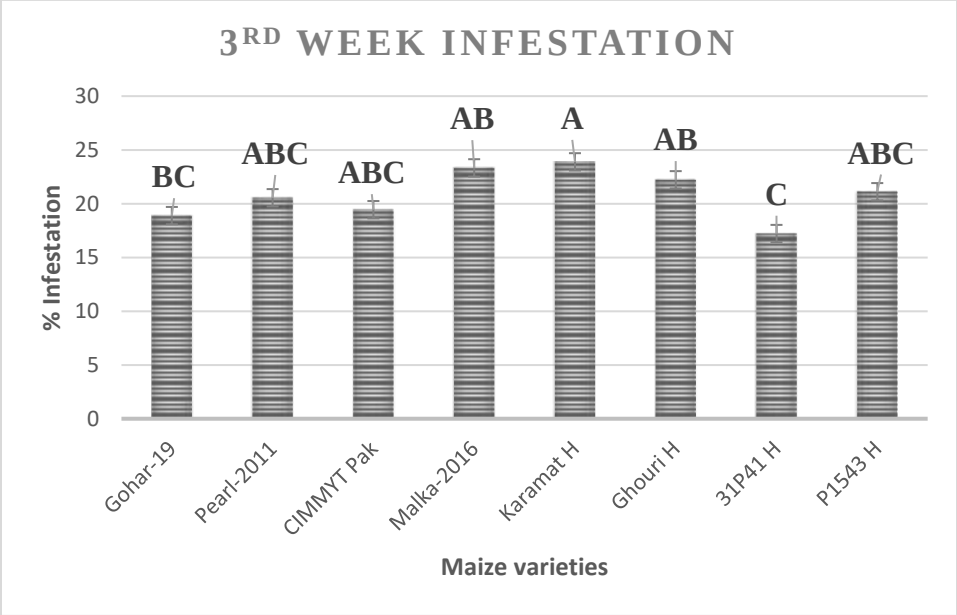
The infestation was monitored for the first time on 14-Oct-2019 and it was the minimum recorded infestation (zero in all treatments) probably because the crop was under five-leaf stage (V_5) in all treatments. But as the crop raised its level it put a positive impact on armyworm proliferation on all subsequent treatments.

The mean infestation recorded after the 2nd week is given in Graph 4.1 and it shows that mean infestation was maximum on the CIMMYT Pak while it was lowest on the 31P41 Hybrid.



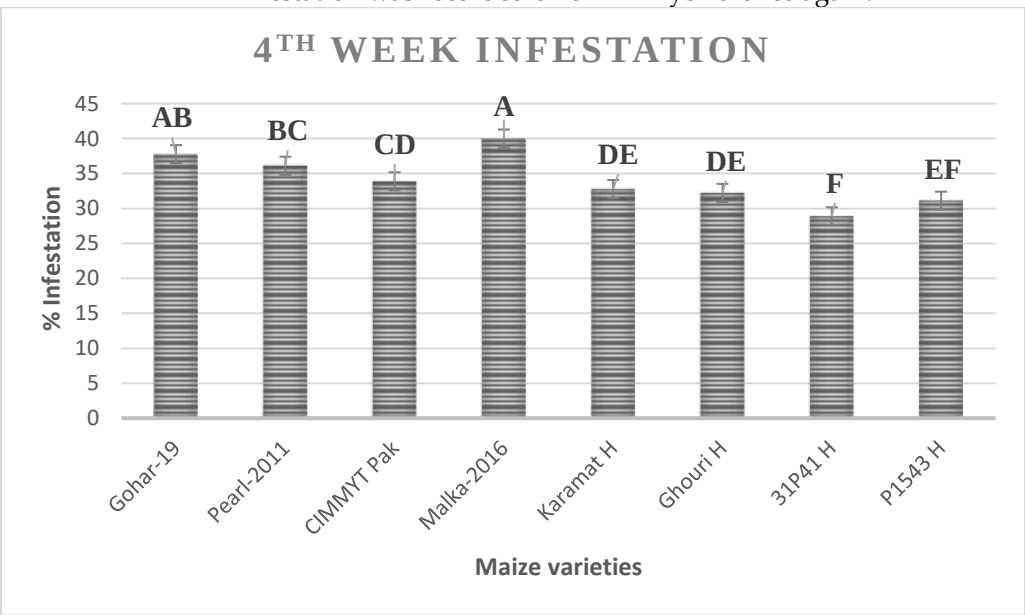
Graph 4.1: Infestation after 2nd week on different maize varieties.

Graph 4.2 is showing infestation recorded after the 3rd week. Statistically, the fall armyworm population was highest on Karamat Hybrid while 31P41 Hybrid showed some sort of tolerance once again. The rise and fall in a population could be determined by variable factors i.e., the infestation rate of FAW is not always the same on different stages of maize crop. It gets varies with the variation in each crop stage. Other than crop development, the abiotic factors like temperature and relative humidity, also determine pest infestation, abundance, and dispersal of insect pests.



Graph 4.2: Infestation after 3rd week on different maize varieties.

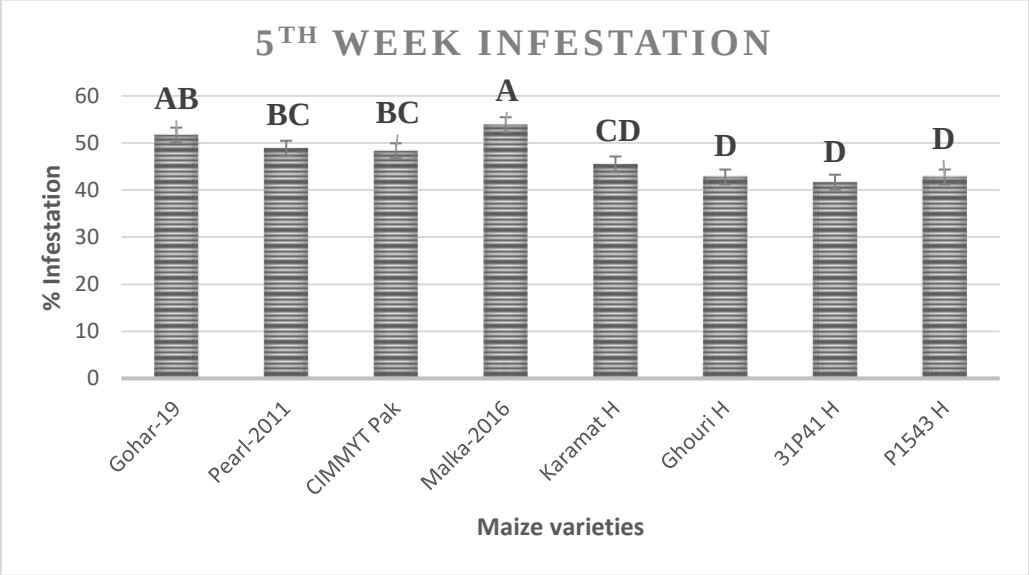
A rise in the mean infestation of the pest in individual experimental units was seen from 28-Oct-2019 to 04-Oct-2019. Malka-2016 showed statistically the highest population of fall armyworm while the least infestation was recorded on 31P41 Hybrid once again.



Graph 4.3: Infestation after 4th week on different maize varieties

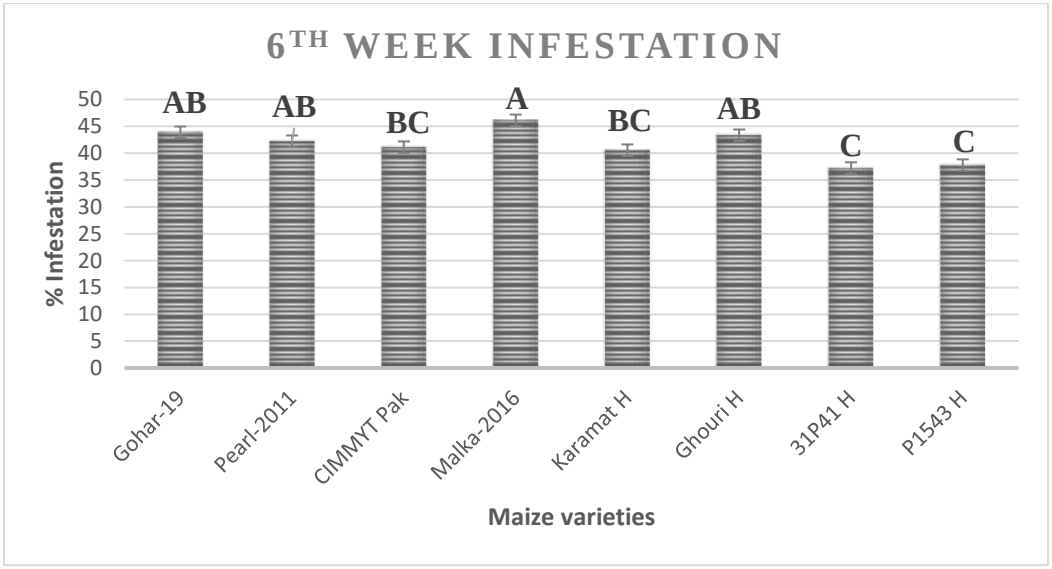
During the course of studies, the highest population build-up was seen on the 11th of November 2019. All the treatment crops observed peak pest

population possibly conditions were in favour of FAW. The highest damage of 53.88% was recorded on Malka-2016. Statistically, no difference was found among the infestation levels recorded on Ghouri Hybrid, 31P41 Hybrid and P1543 Hybrid.



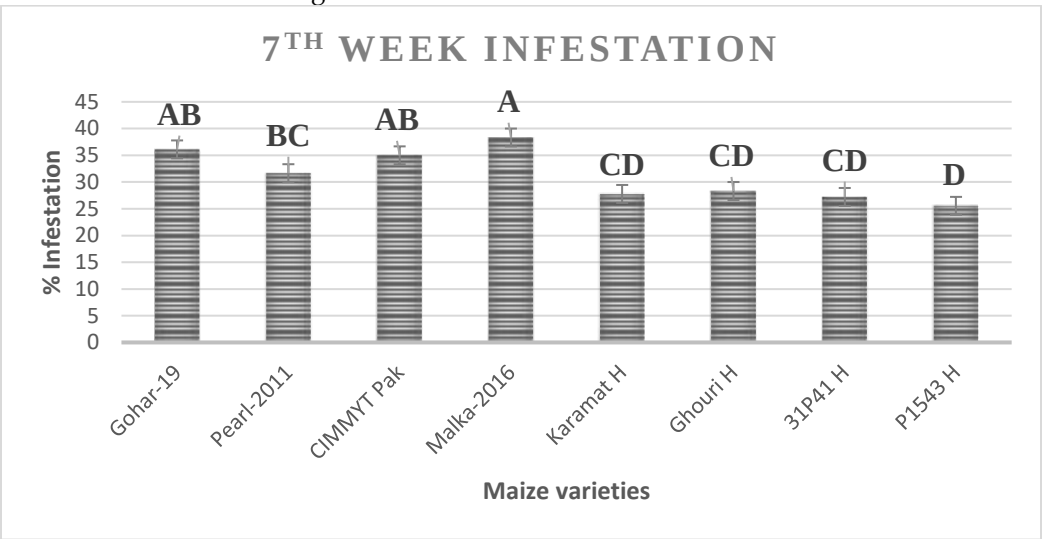
Graph 4.4: Infestation after 5th Week on different Maize Varieties

Inter-varietal infestation after the 6th week shows that Malka-2016 showed significantly highest fall armyworm damage. The levels of invasion recorded on 31P41 Hybrid and P1543 were statistically lowermost than the rest of the treatments.



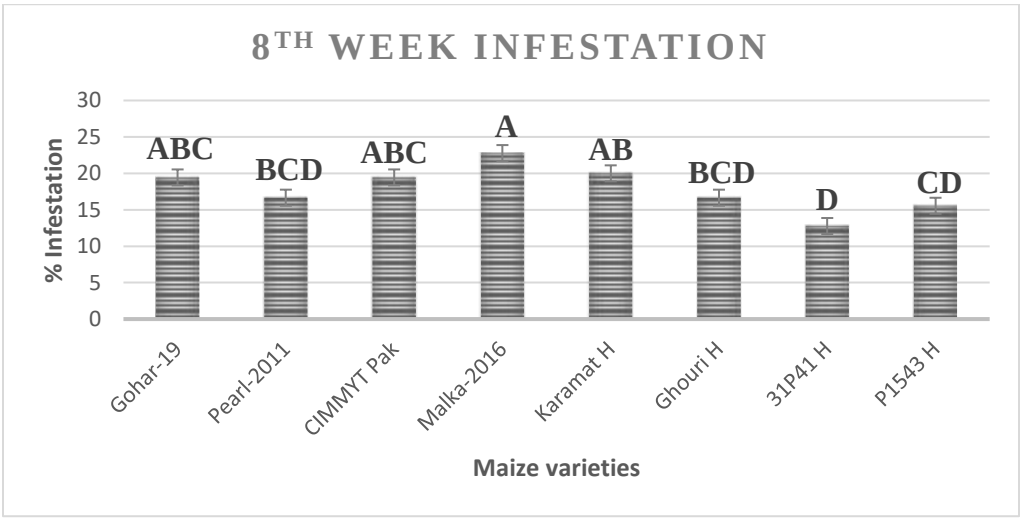
Graph 4.5: Infestation after 6th week on different maize varieties.

In the very next week, a decline in the population build-up was seen. But, the higher most infestation of fall armyworm was observed again on Malka-2016. P1543 Hybrid showed 25.55% damage which was the least damage observed in the week.



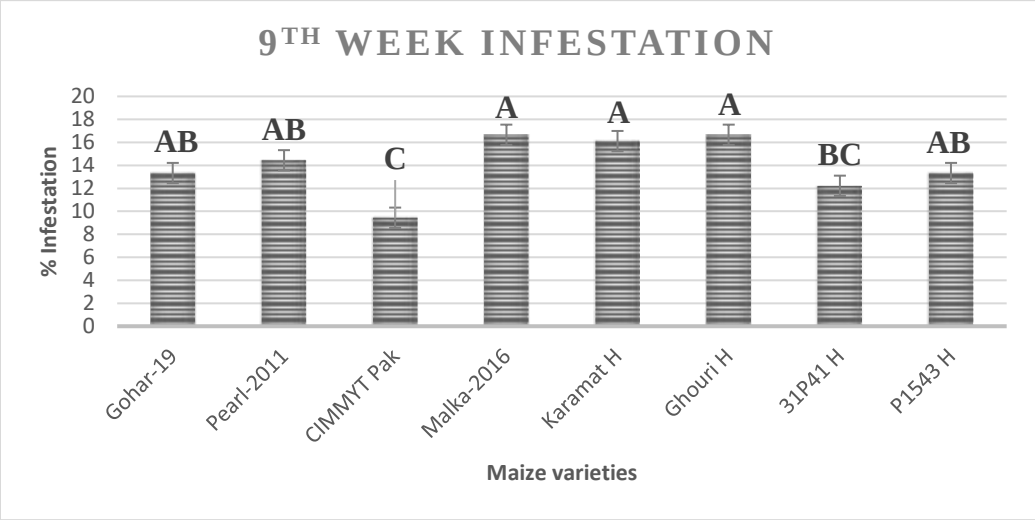
Graph 4.6: Infestation after 7th week on different maize varieties.

The subsequent reduction in the pest occurrence was seen once again after the 8th week of investigation. Graph 4.7 shows the mean infestation recorded on 03-Dec-19. Malka-2016 possessed the highest FAW infestation, 31P41 Hybrid showed some sort of tolerance against the pest and unveiled the lowest invasion.



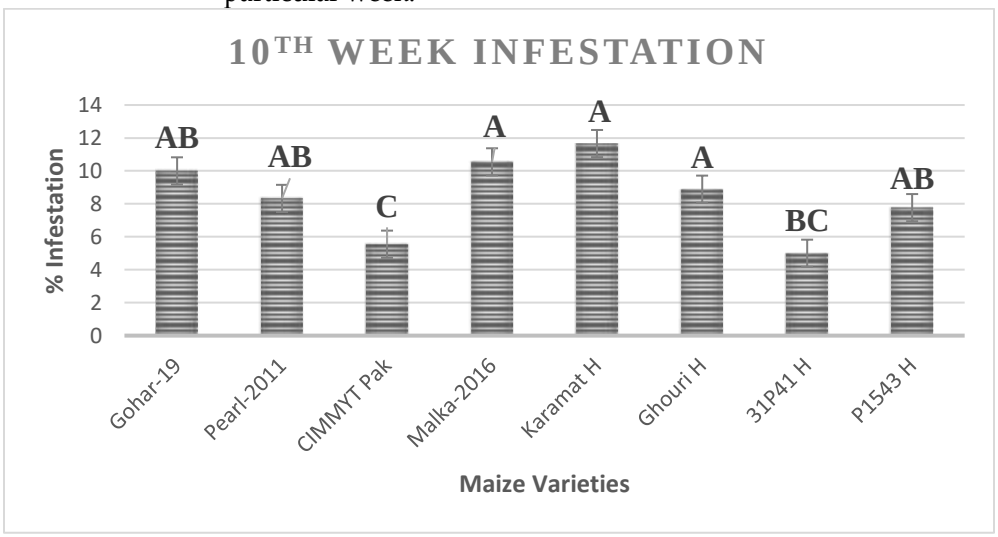
Graph 4.7: Infestation after 8th week on different maize varieties.

Temperature drop towards in the middle of December negatively influenced the population build-up of fall armyworm. Additionally, crop maturity was another factor that overlapped with temperature to reduce FAW infestation. CIMMYT Pak significantly showed lowermost invasion of the pest on 10-Dec-2019. On the other hand, Malka-2016, Karamat Hybrid and Ghouri Hybrid possessed the same levels of infestation which were highestmost.



Graph 4.8: Infestation after 9th week on different maize varieties.

Similar to the previous week, invasion recorded on 17-Dec-19 shows a subsequent drop in the pest population. Statistically, Malka-2016, Karamat Hybrid and Ghouri Hybrid showed maximum mean values of pest infestation while CIMMYT Pak showed the lowest infestation in that particular week.



Graph 4.9: Infestation after 10th week on different maize varieties.

The graphs above showing the periodic variations in the pest infestation from the early days to the maturity of the treatment crops in their respective blocks. They are also showing different susceptibility levels of the different maize varieties.

The Tukey's test on the date wise infestation showed highly significant results (Table 4), it was revealed that infestation was maximum on the 11th of November 2019 followed by 18th of November 2019. No statistical difference was found between the invasion recorded on the 17th and 21st of December 2019. The lowest population of FAW recorded on the 14th of November than 4-Nov-19, 27-Nov-19, 28-Oct-19, 03-Dec-19, and 10-Dec-19.

Table 4. FAW Infestation on Different Dates from Oct-Dec (2019).

Dates	Mean ± S.E.	Homogenous Groups
11-Nov-2019	46.95 ± 4.95	A
18-Nov-2019	41.53 ± 5.27	B
04-Nov-2019	34.1 ± 5.07	C
27-Nov-2019	31.25 ± 4.95	D
28-Oct-2019	20.83 ± 4.09	E
03-Dec-2019	17.92 ± 4.07	F
10-Dec-2019	14.03 ± 3.97	G
17-Dec-2019	8.47 ± 2.03	H
21-Oct-2019	6.94 ± 2.05	H
14-Oct-2019	0 ± 0.5	I
P	**0.0000**	**P < 0.05**

The periodic infestation on different corn varieties viz., Gohar-19, Pearl-11, CIMMYT Pak, Malka-16, Karamat Hybrid, Ghouri Hybrid, 31P41, and P1543 showed a significant and positive correlation with maximum temperature, minimum temperature, and the mean temperature. But the strength of correlation was weak possibly due to cold weather conditions. In contrast to temperature, relative humidity showed a non-significant and negative correlation with pest infestation and its strength was weak also (Table 5).

Discussion:

Spodoptera frugiperda is a polyphagous armyworm affecting various economically important cash crops worldwide (Silva *et al* 2017). The FAW infestation level in the present study varied significantly on all different maize varieties. Fall armyworm showed maximum infestation on Malka-16 while the attack on P1543 hybrid was limited. In general, conventional maize

varieties were susceptible to fall armyworm damage while hybrids showed some sort of tolerance to attack. In a similar study in Eastern Zimbabwe, Baudron *et al* (2019) visualized different agronomic practices against the invasion of fall armyworm. They inspected a total of 791 maize fields of small landowners and interviewed the farming communities. It was concluded at the end: the cropping areas that strictly followed weeding activity; less likely attacked by fall armyworm, pumpkin intercropping increased the risk of damage, even certain high-yielding maize varieties were found susceptible to the pest.

Planting a diverse range of crops on-farm support the proliferation of natural enemies and reduces the incidence of FAW. The females of *S. frugiperda* prefer to lay their eggs on maize plants, the maize monoculture provides a sea of maize plants with no diversity, hence it increases the incidence of FAW attack. When maize is intercropped with a diverse range of crops, less feeding is observed with fewer eggs laying on the maize crop (FAO 2018).

Similarly, significant variation in FAW infestation was seen during different weeks ranging from 14-Oct-2019 to 17-dec-2019 possibly due to different growth stages of crops and weather factors i.e., temperature and humidity. Considerably higher populations of the pest were observed on different dates during the 1st half of November 2019. Perhaps the cropping stage favoured its infestation because FAW develops more rapidly on the growth stages of maize crop rather than reproductive stages (Barfield & Ashley 1987). It could be due to favourable temperature and humidity. From December to onward infestation showed a decline possibly due to cold weather conditions.

The analysis of correlation with weather factors and the pest infestation showed a very weak strength of correlation probably due to a drop in temperature abruptly. The population correlation with maximum, mean and minimum temperatures were weak but positive ($r = 0.139$, $r = 0.149$ and $r = 0.159$, respectively) whereas relative humidity showed a negative but weak relation ($r = -0.104$) with infestation. Nagoshi & Meagher (2004) studied seasonal fluctuations in populations of fall armyworm and they detected the peak populations of *S. frugiperda* twice a year; during spring (March-May) and fall (October-December). Early planting and cold weather conditions could be the possible reasons for the pest decline in December 2019 in the current research work.

The results in the present investigation enlightened that in the first five weeks from 14-Oct to 11 Nov 2019 infestation on different maize varieties attained maximum values: the temperature fluctuated between 25-30 ºC while relative humidity remained inside the range of 45-55% during the phase of population build-up. But later on, an abrupt fall in temperature caused the population build-up to decline. In the studies of Valdez-Torres *et al* (2012) and Simmons (1993), it was revealed, FAW showed maximum fecundity, reproduction, growth and development in the temperature range of 22-32 ºC. In our study, the response of fall armyworm remained parallel to

the findings of Valdez-Torres *et al* (2012) and Simmons (1993), until there was a decline in temperature.

References

1. Aasman, K (2001) Effect of temperature on development and activity of maize stem borer *Chilo partellus*. Bull Environ Ent 125-127. https://doi.org/10.1017/S0007485314000601
2. Abid M, Scheffran J, Schneider UA, Elahi E (2019) Farmer perceptions of climate change observed trends and adaptation of agriculture in Pakistan. Environ manag 63(1):110-123. https://doi.org/10.1007/s00267-018-1113-7
3. Ahmad T, Hassan MW, Jamil M, Iqbal J (2016) Population Dynamics of Aphids (Hemiptera: Aphididae) on Wheat Varieties (*Triticum aestivum* L.) as Affected by Abiotic Conditions in Bahawalpur, Pakistan. Pakistan J Zool 48(4):1039-1044
4. Akutse KS, Kimemia JW, Ekesi S, Khamis FM, Ombura OL, Subramanian S (2019) Ovicidal effects of entomopathogenic fungal isolates on the invasive fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae). J Appl Entomol 143:626–663. https://onlinelibrary.wiley.com/doi/abs/10.1111/jen.12634
5. Barfield CS, Ashley TR (1987) Effects of Corn Phenology and Temperature on the Life cycle of the Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Fla Entomol 70(1):110-116. https://doi.org/10.2307/3495097
6. Baudron F, Zaman-Allah MA, Chaipa I, Chari N, Chinwada P (2019) Understanding the Factors Influencing Fall Armyworm (*Spodoptera frugiperda* JE Smith) Damage in African Smallholder Maize Fields and Quantifying its Impact on Yield. A case study in Eastern Zimbabwe. Crop Prot 120:141-150. https://doi.org/10.1016/j.cropro.2019.01.028
7. Briere JF, Pracros P, Le Roux AY, Pierre JS (1999) A Novel Rate Model of Temperature-dependent Development for Arthropods. Environ Entomol 28(1):22-29. https://doi.org/10.1093/ee/28.1.22
8. Britannica (2017) Population Ecology. https://www.britannica.com/science/population-ecology/Logistic-population-growth#ref588061. Accessed 13 July 2020
9. FAO (2018) Integrated Management of the Fall Armyworm on Maize. http://www.fao.org/3/I8665EN/i8665en.pdf. Accessed 05 May 2020
10. Fuxa JR, Richter AR, Acudelo-Silva, F (1988) Effect of Host Age and Nematode Strain on Susceptibility of *Spodoptera frugiperda* to *Steinernema feltiae*. J Nematol 20(1):91
11. Guarneri AA, Lazzari C, Diotaiuti L, Lorenzo MG (2002) The Effect of Relative Humidity on the Behaviour and Development of *Triatoma brasiliensis*. Physiol Entomol 27(2):142-147. https://onlinelibrary.wiley.com/doi/abs/10.1046/j.1365-3032.2002.00279.x
12. Kamata N (2000) Population dynamics of the beech caterpillar, *Syntypistis punctatella*, and biotic and abiotic factors. Population Ecol 42(3):267-278. https://esj-journals.onlinelibrary.wiley.com/doi/abs/10.1007/PL00012005
13. Kasoma C, Shimelis H, Laing M, Shayanowako A I, Mathew I (2020) Screening of inbred lines of tropical maize for resistance to fall armyworm, and for yield and yield-related traits. Crop Prot 105218. https://doi.org/10.1016/j.cropro.2020.105218
14. Lu Y, Wu K (2011) Effect of Relative Humidity on Population Growth of *Apolygus lucorum* (Heteroptera: Miridae). Appl Entomol Zool 46(3):421-427. https://doi.org/10.1007/s13355-011-0058-6
15. Mashwani AM, Ullah F, Sattar S, Ahmand S, Khan MA (2011) Efficacy of different Insecticides against Maize Stem Borer, *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) at Peshawar and Swat Valleys of Khyber Pakhutunkhwa, Pakistan. Sarhad J Agric 27(3):459-465
16. Montezano DG, Specht A, Sosa-Gómez DR, Roque-Specht VF, Sousa-Silva JC, Paula-Moraes SV, Peterson JA, Hunt TE (2018) Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. Afr Entomol 26:286–300. https://doi.org/10.4001/003.026.0286

17. Naeem-Ullah, U, Ansari, MA, Iqbal N, Saeed S (2019) First Authentic Report of *Spodoptera frugiperda* (J.E. Smith) (Noctuidae: Lepidoptera) an Alien Invasive Species from Pakistan. Appl Sci Bus Econ 6(1):1-3
18. Nagoshi RN, Meagher RL (2004) Seasonal Distribution of Fall Armyworm (Lepidoptera: Noctuidae) Host Strains in Agricultural and Turf Grass Habitats. Environ Entomol 33(4):881-889. https://doi.org/10.1603/0046-225X-33.4.881
19. Shipp JL, Zhang Y, Hunt DWA, Ferguson G (2003) Influence of Humidity and Greenhouse Microclimate on the Efficacy of *Beauveria bassiana* (Balsamo) for Control of Greenhouse Arthropod Pests. Environ Entomol 32(5):1154-1163. https://doi.org/10.1603/0046-225X-32.5.1154
20. Silva DMD, Bueno ADF, Andrade K, Stecca CDS, Neves PMOJ, Oliveira MCND (2017) Biology and nutrition of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) fed on different food sources. Sci Agri 74(1):18-31. https://doi.org/10.1590/1678-992x-2015-0160
21. Simmons AM (1993) Effects of Constant and Fluctuating Temperatures and Humidities on the Survival of *Spodoptera frugiperda* Pupae (Lepidoptera: Noctuidae). Fla Entomol 76(2):333-340. https://doi.org/10.2307/3495733
22. Valdez-Torres JB, Soto-Landeros F, Osuna-Enciso T, Báez-Sañudo MA (2012) Modelos de Predicción Fenológica para Maíz Blanco (*Zea mays* L.) y Gusano Cogollero (*Spodoptera frugiperda* JE Smith). Agrociencia 46(4):399-410
23. Wallner WE (1987) Factors affecting insect population dynamics: differences between outbreak and non-outbreak species. Ann rev entomol, 32(1):317-340. https://doi.org/10.1146/annurev.en.32.010187.001533

Table 5. Effect of meteorological factors (Pearson Correlation= r) on population dynamics of FAW (Noctuidae: Lepidoptera) along with different maize varieties and different times.

	Weather factors				**FAW (Mean ± S.E.) on maize varieties and correlation with weather factors**							
Date	**Max T.**	**Mean T.**	**Min T.**	**% R.H.**	**Gohar-19**	**Pearl-2011**	**CIMMYT Pak**	**Malka-2016**	**Karamat H.**	**Ghouri H.**	**31P41 H.**	**P1543 H.**
14/Oct/19	31.28	26.78	22.28	45	0 ± 0.75	0 ± 0.77	0 ± 0.70	0 ± 0.75	0 ± 0.80	0 ± 0.80	0 ± 0.85	0 ± 0.80
21/ Oct /19	31.85	27.28	22.71	48.85	8.89 ± 0.91	6.11 ± 0.94	12.77 ± 0.98	6.66 ± 0.85	6.67 ± 0.88	6.11 ± 0.94	3.88 ± 0.90	4.44 ± 0.81
28/ Oct /19	32.15	27.51	22.87	49.28	18.89 ± 1.0	20.55 ± 0.99	19.44 ± 0.86	23.33 ± 0.80	23.89 ± 0.77	22.22 ± 1.0	17.22 ± 0.89	21.11 ± 1.0
04/Nov/19	31.95	27.05	22.15	52.57	37.77 ± 1.3	36.11 ± 0.80	33.88 ± 1.02	40 ± 1.0	32.78 ± 1.12	32.22 ± 1.0	28.88 ± 1.02	31.11 ± 0.99
11/ Nov /19	28.47	25.02	21.57	54.14	51.67 ± 1.23	48.89 ± 1.51	48.33 ± 1.57	53.88 ± 1.12	45.55 ± 1.5	42.77 ± 1.1	41.67 ± 1.45	42.77 ± 1.5
18/ Nov /19	26.44	22.075	17.71	58.75	43.89 ± 1.11	42.22 ± 1.48	41.11 ± 1.39	46.11 ± 1.2	40.55 ± 1.3	43.33 ± 1.17	37.22 ± 1.22	37.77 ± 0.93
27/ Nov /19	25.12	20.485	15.85	61.14	36.11 ± 1.4	31.66 ± 1.5	35 ± 1.3	38.33 ± 1.32	27.78 ± 1.12	28.33 ± 1.22	27.22 ± 1.23	25.55 ± 1.38
03/Dec/19	23.75	19.015	14.28	63.57	19.44 ± 1.36	16.66 ± 1.11	19.44 ± 1.16	22.78 ± 1.02	20 ± 1.5	16.66 ± 1.14	12.77 ± 1.13	15.55 ± 1.05
10/Dec/19	21.43	16.925	12.42	72.15	13.33 ± 0.97	14.44 ± 0.86	9.44 ± 0.86	16.66 ± 0.84	16.11 ± 0.89	16.66 ± 0.75	12.22 ± 0.88	13.33 ± 0.89

17/Dec/19	15.57	12.925	10.28	84.28	10 ± 0.90	8.33 ± 0.82	5.55 ± 0.85	10.55 ± 0.85	11.66 ± 0.95	8.89 ± 0.86	5 ± 0.75	7.77 ± 0.89
Temperature (maximum)					r = 0.1260	r = 0.1453	r = 0.2213	r = 0.1076	r = 0.0923	r = 0.1137	r = 0.1541	r = 0.1472
Temperature (mean)					r = 0.1379	r = 0.1571	r = 0.2306	r = 0.1149	r =0.1045	r = 0.1203	r = 0.1645	r = 0.1597
Temperature (minimum)					r = 0.1496	r = 0.1684	r = 0.2379	r = 0.1216	r = 0.1170	r = 0.1262	r = 0.1742	r = 0.1718
Relative humidity					r = -0.0960	r = -0.1079	r = -0.1979	r = -0.0750	r = -0.0499	r = -0.0730	r = 0.1262	r = -0.1065
Overall correlation with different maize varieties	r = 0.1393	r = 0.1496	r = 0.1592	r = -0.1048								