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Research Paper

Evaluating maize genotypes for inherent resistance to maize stem borer, *Chilo partellus* Swinhoe

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ABSTRACT

The identification of genes responsible for inbuilt resistance against insect pests and their integration into common cultivars for inclusion in Integrated Pest Management (IPM) programme for any area against any insect pest is gaining momentum in the present day agricultural system. The incorporation of insect-resistant lines into cultivation practices lowers the incidence of infestation of insect pests. This results in better economic gains for the farmers and safer ecological conditions, by minimizing use of insecticides. The maize stem borer, *Chilo partellus* Swinhoe is one of the devastating insect pests of maize crop. The infestation can range from 40 per cent damage to crop to total crop failure in dry season. Screening of the genotypes for identification of promising lines with inbuilt resistance against maize stem borer, *C. partellus* is one of the basic steps towards the implementation of IPM. A total of 20 maize genotypes were evaluated for their reaction against maize stem borer, *C. partellus*. Under natural infestation conditions at three different altitudes of Kashmir valley. The reaction was assessed as per Leaf Injury Rating (CIMMYT, 2011) and the cultivars 'H-12' and 'H-8' manifested less leaf damage and were categorised as resistant. The reaction of cultivars was unaffected by altitude. Leaf damage was positively correlated with number of pin holes and negatively with stem diameter, plant height, number of nodes per plant and leaf trichome density. The cultivars H-12 and H-8 can further be tested for inbuilt resistance under no choice conditions and incorporated in the stem borer resistant breeding programmes for Maize.

Key words: *Chilo partellus*, Correlation, maize stem borer, maize, resistant genotypes

Maize, *Zea mays* L. is one of the world's most cultivated crop, along with rice and wheat, together form the foundation of world food security (Reeves *et al*., 2016). Maize crop has high yield potential of the order of 20 t grain ha^{-1} under favourable conditions and high radiation (Liu *et al*., 2017). However, the actual yields rarely exceed 9 tonne per hectare (Li *et al.,* 2021), with a world average of 5.6 tonne per hectare (FAO, 2019). This huge gap between actual yield potential and the realised yield potential is attributable to various biotic and abiotic stresses the crop is subjected to (Worku *et al*., 2012; Abate *et al*., 2017). As per an estimate, biotic stresses cause a 10 per cent decline in the global maize yield each year (Gong *et al*., 2014) and about 15.6 per cent of that decline is caused by insect pests alone (Dhaliwal and Arora, 2006). From among the 140 insect pests infesting maize worldwide, only 10 cause serious damage (Sarup *et al.*, 1987 and Siddiqui and Marwaha, 1993). The spotted stem borer, *Chilo partellus* (Swinhoe) (Crambidae: Lepidoptera) is the most serious one during Kharif season causing 26.7-80.4 per cent yield losses in different agro-climatic regions of India (Panwar, 2005). In Kashmir valley, the maize stem borer *C. partellus* is reported as a major insect pest in the crop (Arifie *et al.*, 2019).

In India, as per an estimate, around 25.01 per cent of total land under maize receives insecticides (Subhash *et al*., 2017). With the advent of modern agriculture, the crop protection regimes have undergone a shift from ready-use to need based use of chemical pesticides. This has resulted in integration of various techniques into a single tactic to control pests i.e. Integrated Pest Management (IPM) (Metcalf and Luckmann, 1982). Plant resistance is an important element of a pest management programme (Smith, 1989). The use of insect-resistant cultivars enables use of host plant resistance to overcome pest incidence and minimise the losses caused, and is environmentally safe, economically feasible and ethically sound (Kumar, 1997). The adoption of insect-resistant maize in crop cultivation practices resulted in 11.2 per cent less insecticide consumption, than used conventionally (Perry *et al.*, 2016). Almost 2,500 commercial maize varieties are cultivated worldwide at present (Murphy, D. 2007). The initial step in using host-plant resistance in a management programme is the evaluation (screening) of crop germplasm to identify genotypes (lines, accessions, cultivars, etc.) that express resistance to the insect or that express a phenotype putatively related to resistance (Clement and Quisen berry, 1999). Screening may be conducted in a field, greenhouse or laboratory, but field screening of genotypes gives temporal and spatial advantage over protected conditions. Natural or artificial infestations of pest insects may be used (Stout, 2014). Screening of germplasm from different parts of the world to identify the sources of resistance and utilizing them for the development of varieties have so far remained the main stay in the management of maize pests (Anuradha, 2012). Identification of genotypes with in-built resistance to maize stem borer will pave way for development of high yielding, maize stem borer resistant genotypes with no compromise in other attributes.

MATERIALS AND METHODS

The study was carried out at three locations:

i) Faculty of Agriculture, Wadura, SKUAST-K located at latitude 34˚21'00.6" N, longitude 074˚23'47.3" E and an altitude of 1590 meters above mean sea level (AMSL).
ii) Imberzal Wari located at latitude 34˚24'11.0"N, longitude 74˚25'02.4" E and an altitude of 2120 meters AMSL.
iii) Dryland Agricultural Research Station (DARS), Budgam a constituent of SKUAST-Kashmir located at latitude 33˚59'12"N, longitude 74˚47'52" E and an altitude of 1655 m AMSL.

A total of 20 maize cultivars were screened for their resistance against stem borer, *C. partellus*. The seed material was taken from DARS, Budgam SKUAST Kashmir and sown in RCBD in 3 replications for each genotype. The package of practices followed was as per recommendations of SKUAST-K (Anonymous 2016). However, no insecticidal treatment was given to experimental plots. The genotypes were screened under natural infestation conditions in the field. Three plants per replication of each treatment were tagged at random and observed for leaf damage caused by larvae of *C. partellus* S. at 40 and 60 days after sowing. The damage was ascertained on a score of 0-10 as per scale given by CIMMYT, 2011 (Table 1).

Table 1: Scale for scoring intensity of damage on leaves (CIMMYT, 2011)

S. No.	Visual rating of damage	Numerical Score	Resistance reaction
1.	No damage	0	Extremely resistant
2.	Few pin hole or fine hole of injury on 1-2 leaves.	1	Highly resistant
3.	Few small holes on few leaves	2	Resistant
4.	Few leaves with several small holes	3	Resistant
5.	Several leaves with holes	4	Moderately resistant
6.	Few leaves with elongated lesions	5	Moderately resistant
7.	Several leaves with elongated lesions	6	Susceptible
8.	Several leaves with elongated lesions	7	Susceptible
9.	Most of leaves with long lesions or severe tattering	8	Highly susceptible
10.	Most leaves with long lesions or lodged or plant dying due to severe damage	9	Extremely susceptible

(CIMMYT, 2011 scale)

On the basis of rating score, the genotypes were categorised as extremely resistant, highly resistant, resistant, moderately resistant, susceptible, highly susceptible and extremely susceptible. The interaction of altitude with genotype to possibly modify the reactions of genotypes towards the infestation of *C. partellus* was also analysed by employing appropriate statistical technique. The genotypes were also compared with each other with regard to following characters such as Leaf trichome density: Five plants per plot were taken randomly for recording the trichome density. Trichome density count was done by cutting the leaf below the first ear at the centre of blade and through a window of 1×1 centimetres, the number of trichome hairs were counted under a dissecting microscope; Stem diameter: Five plants per plot were randomly selected and the stem diameter was taken with the help of vernier calliper by measuring from the centre of third internode; Number of nodes: Total number of nodes was recorded starting from first node on randomly selected five plants per plot; Plant height: Five plants per plot after tassel emergence were taken for recording the plant height by measuring scale; Pin hole counts: Five plants were examined for number of pin holes by maize stem borer on leaves and count was made.

A simple correlation analysis using OPSTAT software was also done between the genotype characters and mean leaf damage score at 40 and 60 DAS.

RESULTS AND DISCUSSION

After assessing the leaf damage score at all the three locations and comparing it to the leaf injury rating scale as given by CIMMYT (2011), the cultivars H-17, Champion-61 and H-101 were designated as susceptible to maize stem borer; Polo, H-19, H-105, H-16, H-3, H-20, H-5, H-10 and H-7 as moderately resistant; H-11, H-18, H-14, H-6, H-1 and H-15 as resistant; H-12 and H-8 as highly resistant to maize stem borer. No cultivar was designated as extremely resistant.

Table 2: Leaf damage score by *C. partellus*

Genotypes	Imberzal Wari		DARS, Budgam		FoA, Wadura		Category
	40 DAS	60 DAS	40 DAS	60 DAS	40 DAS	60 DAS	
H-101	4.56	6. 11	4.44	6	4.78	6.11	Susceptible
Polo	4.11	5.89	4	5.78	4	5.89	Moderately Resistant
Champion 61	4.67	6.44	4.56	6.33	4.67	6.56	Susceptible
H-19	3. 33	4.33	3.22	4.22	3.33	4.44	Moderately Resistant
H-105	3.33	5.11	3.33	5	3.22	5.33	Moderately Resistant
H-11	2.11	2.44	2	2.33	1.89	2.44	Resistant
H-18	2.78	3.67	2.67	3.56	2.56	3.33	Resistant
H-17	4.67	6.78	4.56	6.67	4.78	6.44	Susceptible
H-12	0.78	1.22	0.56	1.11	0.67	0.89	Highly Resistant
H-16	4.11	4.78	4	4.67	4.22	4.44	Moderately Resistant
H-3	3.89	4.89	3.78	4.78	4	4.56	Moderately Resistant
H-14	2.78	3.11	2.67	3	2.56	2.78	Resistant
H-20	3.33	4.22	3.22	4.11	3.11	3.89	Moderately Resistant
H-8	0.78	1.11	0.67	1	0.78	0.89	Highly Resistant
H-5	3.33	4.67	3.22	4.56	3.33	4.44	Moderately resistant
H-6	2.67	3.33	2.56	3.22	2.67	3.11	Resistant
H-10	3.33	5.44	3.22	5.33	3.11	5.56	Moderately Resistant
H-1	2.44	3.11	2.22	3	2.33	3.11	Resistant
H-15	2.67	3.89	2.56	3.78	2.78	3.44	Resistant
H-7	3.22	5.11	3.11	5	3.33	4.78	Moderately Resistant
$CD_{(P\leq0.05)}$	1.04	1.03	0.97	0.93	0.99	0.99	

Each figure is mean of 3 replications.

The data generated was also analysed in a two way ANOVA to take into consideration the effect of altitude on leaf damage by *C. partellus* at 40 DAS (Table 3) and 60 DAS (Table 4). However, it was found that altitude had no significant effect on the level of leaf injury, at either 40 DAS or 60 DAS, the same genotype had no significant difference in its reaction at different altitudes, although the different genotypes differed significantly from each other at the different altitudes.

Table 3: Leaf Damage score in relation to altitude at 40 DAS

Factor	SEm ±	CD (P≤0.05)
Genotypes	0.19	0.52
Location	0.07	NS
Genotypes X Location	0.32	NS

Table 4: Leaf Damage score in relation to altitude at 60 DAS

Factor	SEm±	CD (P≤0.05)
Genotypes	0.20	0.55
Location	0.08	NS
Genotypes X Location	0.34	NS

The different morphological characters (table 5) when correlated (table 6) with leaf damage score revealed that leaf damage score was significant and positively correlated with number pin holes, whereas significant and negative correlation was found between leaf damage by stem borer and plant characters such as stem diameter, plant height, number of nodes per plant and leaf trichome density.

Table 5: Comparison of the genotypes for various characters

S. No.	Genotypes	Stem diameter (mm)	Plant height (cm)	No. of nodes per plant	Pin hole count per plant	Leaf trichome density (cm^{-2})
1.	H-101	18.80	166.6	11.40	0.80	69.60
2.	Polo	18.60	161.8	11.20	2.20	65.40
3.	Champion 61	17.80	157.1	11.00	4.80	60.80
4.	H-19	20.20	174.9	11.80	0.60	72.80
5.	H-105	18.80	162.0	11.60	2.80	67.40
6.	H-11	21.20	174.6	13.40	0.60	82.60
7.	H-18	21.20	175.2	13.20	0.80	77.00
8.	H-17	18.80	164.2	11.60	4.00	67.60
9.	H-12	19.40	167.2	11.80	2.00	71.60
10.	H-16	19.40	167.0	11.00	6.80	69.80
11.	H-3	19.60	167.0	10.60	4.40	71.00
12.	H-14	21.20	175.2	13.20	1.40	79.00
13.	H-20	20.20	175.2	11.80	3.00	75.00
14.	H-8	21.60	174.8	14.00	0.60	86.60
15.	H-5	19.40	167.9	10.80	1.60	71.60
16.	H-6	21.40	175.4	13.20	1.20	81.40
17.	H-10	21.00	174.4	11.80	0.60	75.60
18.	H-1	20.80	175.2	13.60	0.80	81.40
19.	H-15	20.40	174.4	11.80	1.00	74.80
20.	H-7	20.60	174.2	11.60	1.00	72.00
C.D (P≤0.05)		**0.78**	**2.4**	**0.66**	**0.91**	**1.73**

Maize cultivars have also been screened previously by Chatterji *et al.* (1972), Kundu (1985), Kumar & Saxena (1972), Khan *et al.* (1999), Rao & Panwar (2001), Ali *et al.* (2002), Awan & Khaliq (2003), Kakar *et al.* (2003), Chavan *et al.* (2007), Jindal & Hari (2008), Afzal *et al.* (2009), Anuradha (2012), Lella and Srivastava (2013), Alhussein *et al.* (2015), Dindor *et al.* (2016), Bhandari *et al.* (2016), Rasool *et al.* (2017), Lokesh and Mehla (2017) and Pal *et al.* (2018), by employing different methods. The leaf injury rating for categorisation of maize cultivars, as used in this study, has been previously employed by Ampofo and Saxena (1989), Kumar and Saxena (1992), Rao and Panwar (2001), Chavan *et al.* (2007), Anuradha (2012), Lella and Srivastava (2013), Alhussein *et al.* (2015), Dindor *et al* (2016), Bhandari *et al.* (2016), Lokesh and Mehla (2017), Rasool *et al.* (2017) and Vishvendra *et al.* (2017). In the present studies, the cultivars with high resistance against stem borer were 'H-12' and 'H-8' and the cultivars that were susceptible are H-101, Champion 61, H-17. The differential behaviour of genotypes for resistance against stem borer has also been reported by Chatterji *et al.* (1972), Kundu (1985), Kumar and Saxena (1992), Rao and Panwar (2001), Awan and Khaliq (2003), Kakar *et al.* (2003), Khan and Monobrullah (2003), Chavan *et al.* (2007), Arabjafari and Jalali (2007), Jindal and Hari (2008), Afzal *et al.* (2009), Anuradha (2012), Lella and Srivastava (2013), Alhussein *et al.* (2015), Dindor *et al.* (2016), Bhandari *et al.* (2016), Lokesh and Mehla (2017), Rasool *et al.*(2017), Vishvendra *et al.* (2017) and Pal *et al.* (2018).

Table 6: Correlation of Leaf Damage Score with genotype characters

Character → / LDS ↓	Stem diameter	Plant height	No. of nodes per plant	Pin hole count per plant	Leaf trichome density
40 DAS	-0.66 (0.001)	-0.57 (0.009)	-0.69 (0.001)	0.53 (0.015)	-0.73 (0.000)
60 DAS	-0.67 (0.001)	-0.60 (0.005)	-0.68 (0.001)	0.38 (0.090)	-0.77 (0.000)

Values in parenthesis are p-values

The positive correlation between leaf damage score and no. of pin holes on leaves is also in line with previous studies carried out by Rasool *et al* (2017). The more susceptible the cultivar, the incidence and infestation by the stem borer is also of higher magnitude (Anuradha, 2012). Trichomes have been reported to provide first line of defence against insect pests, inhibiting oviposition and subsequent infestation by limiting contact of herbivore with the crop (Shanower, 2008). The negative correlation between leaf damage score and leaf trichome density has also been reported by other workers in maize (Rasool *et al*., 2017; Vishvendra *et al*., 2017) and other crops as well (Bindu and Pramanik, 2017; Nasiya-Beegum and Subramanian, 2019).

The identification of genotypes with innate resistance to Maize stem borer is the first milestone in the IPM-omics inception and implementation. The genotypes screened under free-choice conditions lay the foundation for further marker assisted selection of genotypes under no-choice conditions. The screening of total 20 genotypes under different environmental conditions reveal that the genotypes H-8 and H-12 hold promising genes for resistance against maize stem borer, *Chilo partellus* and should be further analysed for their incorporation in the programme for resistant cultivar development against maize stem borer and their cultivation on commercial basis.

REFERENCES

Abate, T., Fisher, M., Abdoulaye, T., Kassie, G. T., Lunduka, R., Marenya, P. and Asnake, W. 2017. Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow? *Agriculture & Food Security*, **6**:30.

Afzal, M., Nazir, Z., Bashir, M. H. and Khan, B. S. 2009. Analysis of host plant resistance in some genotypes of maize against *Chilo partellus* (Swinhoe) (Pyralidae: Lepidoptera). *Pakistan Journal of Botany,* **41**: 421-428.

Alhussein, M. B., Idris, A. E., Sara A., Kehail, A. and Mohamed, H. A. 2015. Relative resistance of some maize (*Zea mays* L.) genotypes against stem borers (*Chilo partellus* and *Sesamia cretica*) in central Sudan. *Journal of Advances in Biology,* **7**: 1238-1243.

Ali, L., Ahmad, S., Liaquatullah, M. and Bari, F. 2002. Comparative resistance of maize cultivars to maize stem borer, *Chilo partellus* (Swinhoe). *Asian Journal of Plant Sciences*, **1**: 571-573.

Ampofo, J. K. O and Saxena, K. N. 1989. Evaluation of some maize cultivars for resistance for the stem borer, *C. partellus* (Swinhoe) in western Kenya. *Maydica*, **31**: 379-380.

Anonymous. 2016. Package of practice for cereal crops. *Division of Agronomy FoA, Wadura SKUAST Kashmir*. J&K India.

Anuradha, M. 2012. Maize inbred lines screening for resistance against *Chilo partellus*. *International Journal of Plant Protection,* **5**: 290-293.

Arabjafari, K. H. and Jalali, S. K. 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*, **10**: 1885-1895.

Arifie, U., Bano, P., Ahad, I., Singh, P. Dar, Z. A. Badri, Z., Maqbool, S., Aafreen, S. and Kumar, R. 2019. Insect pests of maize at different altitudes of north Kashmir, J&K. *Journal of Entomology and Zoology Studies,* **7**: 1123-1128.

Awan, N. H and Khaliq, A. 2003. Relative resistance of maize stem borer, *Chilo partellus* (Swinhoe) against some maize cultivars. *Pakistan Journal of Biological Sciences,* **6**: 142-145.

Bhandari, G., Achhami, B. B., Neupane, S. and Sharma, S. D. 2016. Differential resistance reaction of maize genotypes to maize stem borer (*Chilo partellus* Swinhoe) at Chitwan, Nepal. *Journal of Maize Research and Development,* **2**: 133-143.

Bindu, S. P. and Pramanik, A. 2017. Effect of Leaf Characteristics on Different Brinjal Genotypes and their Correlation on Insects Pests Infestation. *International Journal of Current Microbiology and Applied Sciences,* **6**: 3752-3757.

Chatterji, S. M., Sarup, P., Bhambrurkar, M. W., Marwaha, K. K., Panwar, V. P. S. and Siddiqui, K. H. 1972. Studies on insect-plant relationship – relative susceptibility of some promising indigenous maize germplasms to *Chilo zonellus* (Swinhoe) under artificial infestation. *Indian Journal of Entomology,* **34**: 191 – 195.

Chavan, B. P., Khot, R. B. and Harer, P. N. 2007. Reaction of maize germplasm to maize stem borer, *Chilo partellus* Swinhoe. *Journal of Entomological Research,* **31**: 187-190.

CIMMYT. 2011. Screening methods and rating in Methods of Screening Maize for Resistance to Stem Borers and Postharvest Insect Pests 9-15.

Clement, S. L. and Quisenberry, S. S. (Eds.). 1999. Global Plant Genetic Resources for Insect-Resistant Crops. *CRC Press*, Boca Raton, Florida USA (*https://doi.org/10.1201/9780429117855*).

Dhaliwal, G.S. and Arora, R. 2006. Integrated pest management: concepts and approaches. *Kalyani Publishers.* Ludhiana/New Delhi India, P-18.

Dindor, M. U., Chaudhary, R. I., Patel, R. J. and Bharpoda, T. M. 2016. Screening of maize cultivars for resistance to maize stem borer, *Chilo partellus. International Journal of Agricultural Science and Research,* **6**: 233-242.

Gong, F., Yang, L., Tai, F., Hu, X and Wang, W. 2014. ''Omics'' of Maize Stress Response for Sustainable Food Production: Opportunities and Challenges. *OMICS A Journal of Integrative Biology*, **18**: 714-732. (*DOI: 10.1089/omi.2014.0125*)

Jindal, J. and Hari. N. S. 2008. Studies on components of resistance in maize genotypes to *Chilo partellus* (Swinhoe). *Indian Journal of Entomology,* **70**: 314-318.

Kakar, A. S., Kakar, K. M., Khan, M. T., Shawani, M. I. and Tareen, A. B. 2003. Studies on varietal screening of maize against maize stem borer *Chilo partellus* (Swinhoe). *Online Journal of Biological Sciences,* **3**: 233-236.

Khan, M. S. and Monobrullah, M. 2003. Preliminary screening of maize germplasm against maize stem borer, *Chilo partellus* (Swinhoe) at intermediate zone of Rajouri (J & K). *Insect Environment,* **9**: 45-46.

Khan, N. A., Ahmad, D., Khan, M. A. and Anwar, M. 1999. Management of maize stem borer. *Sarhad Journal of Agriculture,* **15**: 467 – 471.

Kumar, H. 1997. Resistance in maize to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae): Role of stalk damage parameters and biological control. *Crop Protection,* **16**: 375-381.

Kumar, H. and Saxena, K. N. 1992. Resistance in maize cultivars to first and third-instar *Chilo partellus* larvae. *Entomologia Experimentalis et Applicata,* **65**: 75-80.

Kundu, G. G. 1985, E-304 - a high yielding sorghum derivative resistant to stem borer, *Chilo partellus* Swinhoe. *Bulletin of Entomological Research,* **26**: 25-27.

Lella, R. and Srivastava, C. P. 2013. Screening of maize genotypes against stem borer *Chilo partellus* in kharif season. *International Journal of Applied Biology and Pharmaceutical Technology,* **4**: 394-403.

Li, R., Zhang, G., Liu, G., Wang, K., Xie, R., Hou, P., Ming, B., Wang, Z. and Li, S. 2021. Improving the yield potential in maize by constructing the ideal plant type and optimizing the maize canopy structure. *Food and Energy Security,* **10**:e312.

Liu, G., Hou, P., Xie, R., Ming, B., Wang, K., Xu, W., Liu, W., Yang, Y., and Li, S. 2017. Canopy characteristics of high-yield maize with yield potential of 22.5 Mg ha^{-1}. *Field Crops Research*, **213**: 221– 230.

Lokesh and Mehla, J. C. 2017. Screening of some advanced maize (*Zea mays* L.) inbreds and inheritance of resistance against *C. partellus*. *International Journal of Pure and Applied Bioscience,* **5**: 1002-1010.

Metcalf, R. L. and Luckmann, W. H. 1982. Introduction to Integrated Pest Management. 2nd Edition. *John Wiley and Sons*, New York. USA.

Murphy, D. 2007. People, plants and genes: the story of crops and humanity. *Oxford University Press , Oxford, UK.*

Nasiya-Beegum, A. N. and Subramanian, M. 2019. Effect of trichomes in cowpea on infestation by spotted pod borer, *Maruca vitrata* (Fab.) (Lepidoptera: Crambidae). *Journal of Horticultural Science,* **14**: 69-72.

Pal, K., Singh, D. R., Sathish, B. N., Kumar, S., Kumar, S. and Singh, V.V. 2018 Studies on Resistance/Susceptibility of different maize germplasm against maize stem borer, *Chilo partellus* (Swinhoe) in rabi season. *Bulletin of Environment, Pharmacology and Life Sciences,* **7**: 84-89.

Panwar, V. P. S. 2005. Management of maize stalk borer, *Chilo partellus*. In: Stresses on maize in the tropics, *Directorate of Maize research, New Delhi* pp. 376-395.

Perry, E. D., Ciliberoto, F., Hennessy, D. A. and Moschini, G. 2016. Genetically engineered crops and pesticide use in US maize and soybeans. *Science Advances* 2: e1600850.

Rao, C. N. and Panwar, V. P. S. 2001. Biochemical plant factors affecting resistance to *Chilo partellus* (Swinhoe) in maize. *Annals of Plant Protection Sciences,* **10**: 115-119.

Rasool, I., Wani, A. R., Nisar, M., Dar, Z.A., Nehru, R.K. and Hussain, B. 2017. Antixenosis and antibiosis as a resistance mechanism to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae) in some maize genotypes. *Journal of Entomology and Zoology Studies,* **5**: 22-27.

Reeves, T. G., Thomas, G., and Ramsay, G. 2016. Cereals and us: time to renew an ancient bond. *Save and Grow in practice-maize, rice and wheat, Food and Agriculture Organization of the United Nations* pp 21.

Sarup, P., Siddique, K. H. and Marhawa, K. K.1987. Trends in maize pest management research in India together with bibliography. *Journal of Entomological Research,* **11**: 19-68.

Shanower, T. G. 2008. Trichomes and Insects. In: Capinera, J.L. (eds) *Encyclopedia of Entomology. Springer, Dordrecht.*

Siddique, K. H. and Marhawa, K. K.1993. The Vistas of Maize Entomology in India. *Kalyani publishers,* Ludhiana /New Delhi India pp 184.

Smith, C. M. 1989. Plant Resistance to Insects. John Wiley and Sons. New York USA. pp-286.

Stout, M. 2014. Host-Plant Resistance in Pest Management. *Integrated Pest Management: Current Concepts and Ecological Perspective* 1-21. (*https://doi.org/10.1016/B978-0-12-398529-3.00002-6*).

Subash, S. P., Prem, C., Pavithra, S., Balaji, S. J. and Pal, S. 2017. Pesticide Use in Indian Agriculture: Trends, Market Structure and Policy Issues. *Technical Report, 43 Policy Brief, Indian Council of Agricultural Research - National Institute of Agricultural Economics and Policy Research, New Delhi -110 012, INDIA.*

Vishvendra, D. V. S., Kumar, S., Kumar, R. and Vaibhav, V. 2017. Screening of Maize Cultivars against Maize Stem Borer “Chilo partellus” (Swinhoe), under Natural Field Condition. *International Journal of Current Microbiology and Applied Sciences,* **6**: 1414-1418. (*doi:https://doi.org/10.20546/ijcmas.2017. 610.167n*).

Warren-Wilson J. 1971. Maximum yield potential. In 'Transition from Extensive to Intensive Agriculture with Fertilizers'. Proc. 7th Colloquium Int. Potash Inst. pp. 34-56. (International Potash Institute: Berne.)

Worku, M., Legesse, W., Berhanu, T., Girma, D., Girum, A., Wende, A., Tolera, K., Gezahegn, B., Dagne, W. and Solomon, A. 2012. Status and future direction of maize research and production in Ethiopia. **In**: M. Worku, Twumasi-Afriyie, S., Wolde, L., Tadesse, B., Demisie G., Bogale, G., Wegary, D. and Prasanna, B.M. (Ed.), Meeting the Challenges of Global Climate Change and Food Security through Innovative Maize Research, Addis Ababa pp. 17.