Journal of Genetics and Cell Biology
JGCB, 4(3): 287-291
www.scitcentral.com
ISSN: 2639-3360
Review Article: Open Access

Review of Screening Methods of Maize Germplasm for Resistance Against Maize Stem Borers

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Received August 27, 2020; Revised November 18, 2020; Accepted February 21, 2021

ABSTRACT

Screening of maize germplasm for resistance against stem borers is pre-requisite for the development of resistant varieties/hybrids. Leaf injury rating, larval development period, larval weight and stem tunnel length are some of the parameters used for measuring antibiosis, while ovipositional preference, number of egg masses/eggs per plant are the parameters for antixenosis. Leaf injury rating after artificial infestation of plants by laboratory rearing the pest has been in use for screening the germplasm world over. Recently, several studies have been conducted in which a large number of germplasms are screened for resistance using their antibiotic and antixenotic traits and a robust susceptibility index is developed utilizing their results.

Keywords: Screening Methods, Resistance, Maize, Germplasm, Antibiosis, Antixenosis

INTRODUCTION

Maize (*Zea mays* L.) is widely grown throughout the world and has the highest production of all the cereals with 1.147 billion tones produced in 2018. It serves as a staple food for millions of people in different parts of the tropical world. The average yield of temperate maize (7.0 tones/ha), whereas global average is 4.2 tones/hectare. The earlier literature cites over 160 insect and mite species which attack maize crop in India [1-6] observed over 250 species of pests associated with maize in field and storage conditions. The pyralidChilo partellus and the noctuid *Sesamia inferens* and muscids, *Atherigona soccata* are important pests of maize ecosystem. A robust germplasm screening technique is pre-requisite for developing resistant hybrids against these pests. Parameters of antibiosis of germplasm were extensively used by studying leaf injury level, tunnel length caused by stem borers, larval development period, larval weight etc. Attempts are now being made to make the screening more efficient by incorporating antixenotic trait, the oviposition preference.

Germplasm screening techniques for resistance against stem borers

Screening of maize germplasm against resistance is an integral component of breeding program for developing resistant varieties/hybrids. Germplasm with broad genetic background; efficient technique to mass rear healthy insects for artificial infestation of plants; an efficient technique to infest plants uniformly and an accurate technique to evaluate insect damage in the field are some of the important aspects of maize germplasm screening for resistance. CIMMYT and its research partners around the world have worked towards developing screening techniques and breeding protocols which have enabled the development and release of resistant maize germplasm [7]. Techniques have been standardized to mass rear the stem borers on artificial diet and infest maize plants efficiently and rapidly. Recording leaf injury rating on

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Citation: Kumar P, Kaushik H, Suby SB, Sureshe S, Kaur J, et al. (2021) A Review of Screening Methods of Maize Germplasm for Resistance Against Maize Stem Borers. J Genet Cell Biol, 4(3): 287-291.

artificial infested plants was developed by Sarup [8] which is now used conventionally to screen maize germplasm.

Method used to study role of antibiosis in imparting resistance

Maize germplasms to be tested are sown in field in rows separated by non-experimental maize. Twelve days after germination, plants were infested by black-headed stage of eggs or neonate larvae from laboratory culture of stem borer. Jaswinder [9] found that 12 days after germination plants are most suitable for the establishment of stem borer larvae on them. The symptoms of feeding were displayed by number of leaves bearing holes. After 25 days of infestation, the plants were observed for leaf injury rating on 1-9 scale. In another set of infested rows, the plants were dissected after 7, 14 and 21 days of infestation to observe the tunnel length, larvae/pupae recovered. The larvae recovered were reared on baby corn till pupation in the laboratory. The larval/pupal weight and larval development period were recorded.

Method used to study the role of antixenosis in imparting resistance

Oviposition is the first interaction of stem borer females with maize plants. To study the oviposition preference, the experiment was conducted in multi-choice test and no-choice test. In multi-choice test, the germplasm to be tested were planted in pots and kept in a walk-in cage. The adult pairs were released in the ratio of one pair: four plants. The females prefer to lay more eggs on the plant of their choice germplasm. After five days of release, the plants were observed for the number of egg masses per plant, number of eggs per egg mass, the number of eggs per plant and number of plants oviposited were observed and recorded. In no-choice test, four plants of only one germplasm were kept in a versatile collapsible cage [10] and a single pair of adults were released in the cage. The gravid female had no other germplasm to choose for oviposition. After five days of release, the parameters observed in case of multi-choice test were recorded in no-choice test as well.

Review of antibiosis and antixenosis in imparting resistance

In antibiosis type of resistance, the biology of the insect is affected leading to reduced longevity and reproduction, and increased insect mortality. Antibiosis decreases larval development as well as the number of larvae per plant, thereby decreasing the stem damage levels [11]. The leaf injury rating scale to evaluate the damage caused by stem borer which could be used for screening maize germplasm was first developed by Sarup [8]. Durbey [12] showed the adverse effect of rearing C partellus on different maize germplasm. Maximum antibiosis resulted from rearing on resistant Antiqua Gr. I, Mex-17 and tolerant Ganga 5. The expression of antibiosis due to tolerant Ganga-5 revealed its intermediate behavior towards C. partellus. The average larval and pupal weights were significantly lower on resistant varieties (Antiqua Gp. I and Mex-17) as against susceptible varieties (Basi Local and Vijay composite). Chamarthi [13] opined that resistance factors which can be quantified or monitored in plant can be used as marker traits for screening germplasm against stem borers. Leaf feeding damage, which is the first larval feeding symptom, is an important marker trait which has been used by various workers in order to distinguish resistant from susceptible genotypes [14].

Singh [15] observed that the direct effect of stem tunneling on loss in maize grain yield was greater than the effect of leaf feeding. To achieve an overall improvement in the level of genotypic resistance that protects all stages of plant growth, resistance to more than one damage variable is required. Cholla [16] found a significant correlation between leaf injury rating and stem tunnel length. Based on the selection index developed using these two parameters, he identified WNZPBTL2 and PFSR 51016/1 as the resistance sources of *C. partellus*.

Morphological traits such as leaf toughness, stem penetrometer resistance, trichome density; biochemical traits such as stem sugar content and leaf injury, number of exit holes and stem tunnel length were used to develop selection index. Based on this index, 120 maize inbred were categorized into resistant, moderately resistant, moderately susceptible and susceptible germplasm [17].

Secondary metabolism, which involves specialized, often complex and species-specific biosynthetic pathways, is thought to provide compounds which are accumulated and stored, so that when attacked, the plant is already equipped with the means to deter or kill herbivores. Plants may possess constitutive defenses that can act as a physical barrier, as in lignification or resin production, or can act as a biochemical signal perceived by the herbivore, as deterrents of feeding or oviposition, or can act as a toxin. Toxic compounds e.g. alkaloids, terpenoids, phenolics, forcing specialists to invest resources in detoxification mechanisms that in turn incur growth and development costs. Plant parts that are of high fitness value or that are under a high risk of attack may be best protected by constitutive defenses, whereas others may be better defended by induced responses [18]. All the three components of resistance have been identified in stem borer resistant maize.

Gundappa [19] studied effects of two phenolic acids on *C. partellus* in maize inbred lines. Both the phenolic acids were negatively correlated with leaf injury rating and tunnel length at all the plant ages. P-coumaric acid is predominant phenolic acid in maize inbred lines compared to ferulic acid. These phenolic acids were quantified in 17 Indian maize inbred lines. p-coumaric acid and ferulic acid in leaves range from 1.3 to 3.9 mg/g and 1.5 to 4.7 mg/g respectively. Higher quantities of these acids were found in inbred lines HKI 577, HKI 323, HKI 1105. Higher quantities of these acids were recorded in plants, 10 and 25 days after germination. Bioassay of neonate larvae of *C. partellus* by diet incorporating with phenolic acids resulted in increased mortality by p-coumaric acid (41.5 %) than ferulic acid (17.70 %) over control [20].

Antixenotic mechanism of resistance, which is employed by the host plants, deters the insects from oviposition [21-23], feeding, seeking shelter [24-27]. This mechanism renders the plants undesirable or, in other words, to be bad hosts for an easy invasion of insects [28]. Oviposition of many lepidopterans is a critical step in their life cycle because of the limited mobility of first instars larvae [29,30]. Plant volatiles, especially herbivore-induced volatile components, such as green leaf volatiles, terpenes, alkenes, 14 carboxylic acids and alcohols [31], play important roles in mediating behavior such as host plant searching and acceptance in phytophagous insects; in attracting parasitoids or predators of pest insects; in directing insect oviposition as well as in influencing insect–plant interactions [32-40]. It is hypothesized that ovipositing females have evolved to lay eggs on hosts that elicit the best performance of the offspring [41,42] reported that egg-laying females choose oviposition sites that enhance their own long-term fitness at the expense of their offspring. Females when confronted with an array of potential hosts, exhibit a hierarchy in their preferences [43]. When a number of potential hosts are available, female will lay most eggs on her most preferred plant, fewer on the next preferred and so on.

Durbey [38] studied different plant parameters viz. percentage of plants oviposited, plant height, percentage of leaves oviposited and number of egg masses per plant for ovipositional responses of *C. partellus* amongst resistant (Antiqua Gr. I, Mex-17, Ganga-5) and susceptible (Basi local and Vijay composite) maize germplasm under caged conditions. They found that the moths ensured greater survival of the freshly hatched larvae to continue the progeny on susceptible germplasm than to get eliminated on resistant ones.

CONCLUSION

Oviposition preference was studied in multi-choice test and confirmed by no-choice test method in 20 germplasm by [44]. Germplasm, significantly varied on oviposition preference. The adult preference for oviposition [44] and larval performance [45] was studied on *S. inferens*. The correlation between parameters of preference and performance of Sesamia was poor (0.19). Thus, it is important to develop approaches that eventually improve the efficiency of selecting borer-resistant genotypes keeping both antibiotic and antixenotic parameters in view in a high-yielding background. The selection criteria should consider measuring the combined effect of different components of host plant resistance, an approach that requires the use of appropriate indices that result in selection for resistance as well as grain yield performance.

REFERENCES

1. Fletcher TB (1914) Some south Indian insects and other animals of importance considered especially from economic point of views. Government Printing Press Madras, pp: 565.
2. Fletcher TB (1917) Maize Pests Proceedings of 2nd Entomological Meeting. Pusa, pp: 188-193.
3. Ayyar TVR (1940) Handbook of Economic Entomology for South India, pp: 171-190.
4. Bhutani DK (1961) Insect pests of maize and their control. Indian Farming 11: 7-11.
5. Pant NC, Kalode MB (1964) Entomology in India. Entomological Society of India, New Delhi, pp: 279-292.
6. Mathur LML (1987) Bibliography of Maize Pests in India. AICMIP IARI, New Delhi, pp: 40-47.
7. Mihm JA (1984) Techniques for efficient mass rearing and infestation in screening for host plant resistance to corn earworm, *Heliothis zea*. CIMMYT, pp: 16.
8. Sarup (1983) Techniques of scoring for resistance to the major insect pests of maize. All India Co-ordinated Maize Improvement Project, Indian Agricultural Research Institute, New Delhi, pp: 64-72.
9. Kaur J, Kumar P, Singh J, Suby SB (2014) Plant-age preference for oviposition by *Sesamia inferens* (Walker) on maize Zea mays L. Indian J Ent 76: 245.
10. Pradyumn K, Suby SB, Sekhar JC, Kumar RS (2019) A collapsible insect nearing cage. Patent No 311890/29/04/2019.
11. Pimentel D (2002) Encyclopedia of pest management. New York NY: Marcel Dekker, Inc, pp: 481-487.
12. Durbey SL, Sarup P (1984) Biological parameters related to antibiosis mechanisms of resistance in maize varieties to *Chilo partellus* (Swinhoe). J Entomol Res 8: 140-147.
13. Chamarthi SK (2008) Biochemical mechanisms of resistance to shoot fly, *Atherigona soccata* (Rondani) in sorghum, Sorghum bicolor (L) Moench. PhD dissertation Jawaharlal Nehru Technological University Hyderabad, Andhra Pradesh, India.
14. Kumar H (1994) Components of resistance in maize (*Zea mays* L) to first and second generation *Chilo partellus* (Swinhoe). Maydica 39: 165-170.
15. Singh BU, Sharma HC, Rao KV (2011) Mechanisms and genetic diversity for host plant resistance to spotted stem borer, *Chilo partellus* in sorghum, Sorghum bicolor. J Appl Entomol 135: 333-392.

16. Anil C, Chander S, Kaur J, Suby SB, Kumar P, et al. (2018) Improved method of screening maize germplasm for resistance against *Chilo partellus* (Swinhoe). Indian J Genet 78: 454-459.
17. Shelmith M, Mugo SN, Otim MH, Mwolol JK, Okori P, et al. (2013) Mechanism and sources of resistance in tropical maize inbred lines to *Chilo partellus* stem borers. J Agric Sci 55: 51-60.
18. Wittstock U, Gershenzon J (2002) Constitutive plant toxins and their role in defense against herbivores and pathogens. Curr Opin Pl Bio 5: 300-307.
19. Gundappa, Kumar P, Suby SB (2013) Antibiotic effect of phenolic acids (ferulic acid and p-coumaric acid) on maize spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). Indian J Entomol 75: 247-250.
20. Gundappa (2012) Role of phenolic acids (ferulic acid and p-coumaric acid in imparting resistance against *Chilo partelus* (Swinhoe) in maize. Ph.D. thesis submitted to the faculty of PG School, Indian Agricultural Research Institute, New Delhi, pp: 73.
21. Painter RH (1951) Insect resistance in crop plants. The University Press of Kansas Lawrence KS, pp: 520.
22. Valencia L (1984) Mechanism of resistance to potato moth oviposition. Report of the 12th Planning Conference on IPM. International Potato Research Center Lima, pp: 161-187.
23. Afzal M, Nazir Z, Bashir MH, Khan BS (2009) Analysis of host plant resistance in some genotypes of maize against *Chilo partellus* (Swinhoe) (Pyralidae: Lepidoptera). Pak J Bot 41: 421-428.
24. Dabrowski ZT, Kidiavai EL (1983) Resistance of some sorghum lines to the spotted stalk borer, *Chilo partellus*, under western Kenyan conditions. Insect Sci Appl 4: 119-126.
25. Woodhead S, Taneja SL (1987) The importance of the behavior of young larvae in sorghum resistance to *Chilo partellus*. Entomol Exp Appl 45: 47-54.
26. Sharma HC, Nwanze KF (1997) Mechanisms of resistance to insects in sorghum and their usefulness in crop improvement. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India, pp: 56.
27. Dhaliwal GS, Arora R (2003) Principles of Insect Pest Management. 2nd Edn Kalyani Publishers, Ludhiana, India, pp: 90-94.
28. Schoonhoven LM, Jermy T, van Loon JJA (1998) Insect-Plant Biology: From Physiology to Evolution. Chapman & Hall, London.
29. Feeny P, Rosenberry L, Carter M (1983) S Ahmad (Eds) Herbivorous insects: host-seeking behavior and mechanisms. Academic New York, pp: 27-76.
30. Showler AT, Moran PJ (2003) Effects of drought stressed cotton, *Gossypium hirsutum* L on beet armyworm, *Spodotera exigua* (Hubner), oviposition and larval feeding preferences and growth. J Chem Ecol 29: 1997-2011.
31. Holopainen JK (2004) Multiple functions of inducible plant volatiles. Trends in Pl Sci 9: 529-533.
32. Konstantopoulou MA, Krokos FD, Mazomenos BE (2004) Chemical composition of corn leaf essential oils and their role in the oviposition behavior of *Sesamia nonagrioides* females. J Chem Ecol 30: 2243-3356.
33. Steinbauer MJ, Schiest FP, Davies NW (2004) Monoterpenes and epicuticular wax help female autumn gum moth differentiate between waxy and glossy Eucalyptus and leaf of different ages. J Chem Ecol 30: 1117-1141.
34. Rassmann S, Kollner TG, Hiltpold I, Toepfero J, Kuhlmann U (2005) Recruitment of entomopathogenic nematodes by insect-damaged maize roots. Nature 434: 732-737.
35. Ruther J, Kleier S (2005) Plant-plant signaling: Ethylene synergizes volatile emission in Zea mays induced by exposure to (Z)-3-hexen-1-ol. J Chem Ecol 31: 2217- 2222.
36. Anderson P, Alborn H (1999) Effects on oviposition behavior and larval development of *Spodoptera littoralis* by herbivore-induced changes in cotton plants. Entomol Exp Appl 92: 45-51.
37. Wink M (2003) Evolution of secondary metabolites from an ecological and molecular phylogenetic perspective. Phytochemistry 64: 3-19.
38. Durbey SL, Sarup P (1982) Preferential plant sites for oviposition of *Chilo partellus* (Swinhoe) moths in different maize germplasms. J Entomol Res 6: 116.
39. Carroll MJ, Schmelz EA, Meagher RL (2006) Attraction of *Spodoptera frugiperda* larvae to volatiles from herbivore-damaged maize seedlings. J Chem Ecol 32: 1911-1924.
40. Raguso RA (2008) The "invisible hand" of floral chemistry. Science 321: 1163-1164.
41. Thompson JN, Pellmyr O (1991) Evolution of oviposition behavior and host preference in Lepidoptera. Annu Rev Entomol 36: 65-89.
42. Scheirs J, De Bruyn L (2002) Integrating optimal foraging and optimal oviposition theory in plant-insect research. Oikos 96: 187-191.

43. Courtney SP, Chen GK, Gardner A (1989) A general model for individual host selection. Oikos 55: 55-65.

44. Kaur J, Singh J, Suby SB, Kumar P (2019) Differential preference for oviposition-A potential indicator of antixenosis in maize genotypes against *Sesamia inferens* (Walker). Indian J Exp Biol 57: 231-238.

45. Jaswinder K, Kumar P, Suby SB, Singh J, Jha GK, et al. (2016) Measurement of antibiosis in maize (*Zea mays*) genotypes against pink stem borer (*Sesamia inferens*). Indian J Agric Sci 86: 340-346.