International Journal of Plant & Soil Science
11(3): 1-8, 2016; Article no.IJPSS.26089
ISSN: 2320-7035

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Evaluation of Corn Genotypes for Resistance to *Sesamia inferens*

Mohammad Taqi Rabbani[1], Sayed Ali Yaqubi[1], Tahir Noor Mohammadi[1*], Marzia Rezaie[1] and Mostafa Ghaderian[2]

[1]Faculty of Agriculture, Balkh University, Balkh, 1701, Afghanistan.
[2]Faculty of Science, University of Malaya, Kuala Lumpur, 50603, Malaysia.

Authors' contributions

This work was carried out in collaboration between all authors. Authors MTR and MR designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors SAY and TNM managed the literature searches, analyses of the study and author MG managed the experimental process. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/26089
Editor(s):
(1) Fatemeh Nejatzadeh, Department of Horticulture, Faculty of Agriculture, Khoy Branch, Islamic Azad University, Iran.
Reviewers:
(1) Omoregbee Osazuwa, University of Benin, Nigeria.
(2) Maria Gabriela Fontanetti Rodrigues, University of São Paulo, Brazil.
(3) Vincent Ezin, University of Abomey, Benin.
Complete Peer review History: http://sciencedomain.org/review-history/14685

Original Research Article

Received 30th March 2016
Accepted 13th May 2016
Published 18th May 2016

ABSTRACT

Corn, as the second most important cereal cultivated in Afghanistan, is subjected to numerous biotic and abiotic stresses limiting its productivity. *Sesamia inferens* is a polyphagous pest attacking this crop that causes severe damage and yield losses in Afghanistan. This study was conducted to evaluate the resistance to attack by *Sesamia inferens* of different corn landraces collected from different provinces of Afghanistan along with commercial hybrids. Evaluations for agronomical performance and resistance were done in two years under natural infestation with *S. inferens*. Differences among genotypes were significant for all traits. The landraces BU_1, BU_2, BU_3 showed to be a good source of stem resistance, and the landrace BU_5 considered to be a suitable material to improve yield in further breeding programs. This is a preliminary evaluation and the resistance of these landraces should be corroborated under artificial infestation because earlier genotypes could get the silking stage before the occurrence of the peak of insect infestation.

**Corresponding author: E-mail: tahirnoormohammad@gmail.com;*

Keywords: Sesamia inferens; noctuidae; pink stem borer; early-maturing materials; stem damage.

1. INTRODUCTION

Corn (*Zea mays* L.) is the second most important cereal in Afghanistan following wheat with an annual production of 301,000 tons [1]. The occurrence of many biotic and abiotic stresses decreases its productivity in Afghanistan and no breeding programs have been implemented to overcome these issues. Among biotic stresses, Pink Stem Borer (PSB) (*Sesamia inferens* Walker; syn. *Nonagria inferens* Lepidoptera; Noctuidae), causes serious stalk and ear damage and subsequently economic losses due to yield reduction.

S. inferens is a polyphagous and widespread species from the Indian subcontinent, the southeast of Asia, and as far-east as New Guinea and the Solomon Islands and has recently known to be a key pest of rice and sugarcane. It also attacks maize, sorghum, wheat, bulrush, barley, foxtail millet, and finger millet [2,3]. This pest completes its life cycle from egg to adult varying from 46 days in summer and 71 days in winter. *S. inferens* may have two to six generations per year depending upon climatic conditions. In warm season, egg hatching takes place 5-7 days after eggs are laid, but this period may be longer in cool or dry conditions. The larval stage duration ranges 25-75 days; meanwhile Larvae make tunnels in the stalks. Larvae turn into pupa inside the stalk and the adults emerge in 12 days [4].

Corn yield losses due to borers could be primarily attributed to vascular disruption of assimilate movement and increased risk of stalk lodging, and ear dropping, and secondarily, to subsequent attack by other insects and pathogens [5]. Yield decrease associated to stalk tunneling is more critical than the borer attack to the ear [6,7]. In addition, borer damage not only can result in yield losses but also lead to harvesting problems, and poor kernel quality [8].

The common ways to control borers in corn are either the use of transgenic Bt-corn or the application of insecticides; however, in countries like Afghanistan, it is very difficult to produce and maintain genetically modified organisms and, also to apply insecticide properly. One other way that could be applied to control PSB is to cultivate PSB-resistant/tolerant varieties. The first step in developing PSB-resistant varieties is to identify sources of resistance/tolerance to *S. inferens*. Most studies investigated resistance to other corn borers like *S. calamistis, S. nonagrioides* [7,8], and European corn borer (ECB; *Ostrinia nubilalis*) [9-15]. But recently, researches have been established to study the levels of resistance and mechanisms underlying resistance to *S. inferens* in corn [16,17]. Yet, there is no published study on the evaluation of the corn resistance/tolerance to *S. inferens* in Afghanistan. Therefore, this study was conducted to examine the stem and ear resistance of available landraces and commercial hybrids of corn to *S. inferens* attack and to explore the possible relationships between yield, and other related traits to borer damage in natural conditions of Afghanistan.

2. MATERIALS AND METHODS

2.1 Plant Materials

A set of 15 genetically diverse genotypes of corn including 10 local landraces namely BU, (BU_1-BU_{10}), collected from northern provinces of Afghanistan along with five commercial hybrids (*Carolina* 17-6500, *Carolina* 17-6540, *Carolina* 17-6600, *Pioneer* 30R50, and *Pioneer* 30Y87) were evaluated for resistance to PSB (Table 2).

2.2 Field Experiments

The 15 genotypes were arranged in a 4-replication randomized complete block design with completely natural conditions of infestation. The trials were conducted in the Balkh district (66°52′ N and 36°46′ E, 380 SLA) in a silty loam soil. The genotypes were grown in five-row plots of 5 m length with 0.8 m and 0.25 m space between the rows and plant to plant, respectively. The planting date was selected in early July for two years, 2013-2014, so genotypes would be exposed to natural infestation of PSB. Plots were thinned 2 weeks after planting to obtain a final density of approximately 50000 plants ha^{-1}, and were irrigated and fertilized as needed and mechanically weeded. No insecticides were applied during the trial.

Recorded traits in each plot were: days to silking as number of days from planting to the 50% of plants showing silks, the number of borer larvae per plant, yield (expressed in t/ha), and the average length of tunnels made by borers in the stalks in 10 randomly-selected plants. Then, stem damage was calculated as:

$$\text{Stem damage} = \frac{\text{average tunnel length made by borers}}{\text{average stem length}} \times 100$$

Shank, cob, and kernel damages were independently scored on 10 or more ears per plot using a visual 9-point scale (1= fully damaged to 9= wholly healthy [8].

2.3 Data Analysis

All data were subjected to analysis of variance (ANOVA) using SAS statistical software [18]. A combined analysis of variance across years with genotype as fixed and years and replications as random factors using the PROC GLM procedure was performed. Mean comparisons were calculated using LSD when the F-value was significant (Fisher's protected LSD). To explore possible relationships between yield and traits related to damage, the correlation coefficients between each two different traits were also computed [8].

3. RESULTS

All genotypes were statistically-different for days to silking, borer per plant, shank health, ear health, kernel health, tunnel length, stem damage, and yield (Tables 1 and 2). Days to silking ranged from 47 days for BU2 and 74 days for Pioneer 30R50, respectively. The genotypes not only showed different ear health and Kernel health, but also they showed different shank health. All local landraces except BU_4, BU_5, and BU_{10} showed the lower kernel health value of 7, consequently, damage to the ear is assumed to be an important factor showing resistance to stem borer.

The pioneers hybrids seems to be the most resistant genotypes to borer because of having lower values of tunnel length and percentage of stem damage and higher value of shank and kernel health. Local landraces, BU_1, BU_2 and BU_3 had almost the same value for tunnel length and stem damage to breed varieties, but showed a lower degree of shank and kernel health. By contrast, the Carolina hybrids were among the most borer-susceptible genotypes due to having the highest value of tunnel length and stem damage, and showed relatively the same proportions of shank and kernel health to Pioneer hybrids. Generally, midseason genotypes were more susceptible to borers by producing longer tunnel length and stem damage and more damaged ears and kernel. Whereas, Carolina 17-6600 as a late genotype, had a longer tunnel length, relatively more stem damage, and less damaged ears and kernel.

Surprisingly, the average borer damage to Carolina hybrids was higher than that of Pioneer varieties and local landraces, 39.3% compared to 9.25% and 17.62%, respectively (data not shown). And also the number of borer per plant in Carolina 17-6540 (18.65) and BU_7 (13.5) were higher as compared with other genotypes.

Based on higher value of ear health, shank health, kernel health, less amount of tunnel length, and stem damage, the landraces BU_1, BU_2, BU_3, along with both pioneer hybrids were the most resistant and the least damaged genotypes, whereas other genotypes showed higher degree of susceptibility to borers. Surprisingly, Carolina 17-6500 and Carolina 17-6540 did not differ from the local landraces in response to borer and showed relatively the same reaction.

Correlation coefficients between yield and all measured-traits were calculated (Table 3). There were positively significant correlations between kernel health and shank health (r=0.73), and between percentage of stem damage and tunnel length (r=0.69). In addition, a negative correlation between yield and borer per plant, and between tunneling and shank health, ear health and kernel health were detected. No significant correlation between yield and shank health was detected.

4. DISCUSSION

The genotypes BU_1, BU_2, BU_3 and BU_5 were relatively less damaged from borers attack, and are assumed to be the most appropriate materials to obtain reduced stem damage and higher yield by *S. inferens*. Early and extra-early materials were too dry and the adult moths preferred the younger and the more tender plants for laying their eggs and could escape the attack of some borer generations. Whereas, midseason and late materials were younger and consequently, more susceptible to damage by borers. Generally, midseason and late materials stand up better until harvesting than early and extra-early materials which dry sooner and are more fragile, and subsequently they will be more damaged from borer attack.

Table 1. Mean squares of variance of 15 corn genotypes evaluated for resistance to *Sesamia inferens* in two years, 2013–2014

Source of variation	Degrees of freedom	Days to silking	Bore per plant	Shank health	Ear health	Kernel health	Tunnel length	Stem damage	Yield
Year	1	67.60	206.42	32.16*	11.10	26.46**	182.04	319.49**	4.71**
Replication/Year	6	46.39	58.57	1.90	5.85	0.71	735.86	13.89	0.09
Genotype	14	419.23**	91.80**	5.16**	4.15**	12.47**	1888.95**	852.13**	42.81**
Y× G	14	2.39	0.52	0.16	0.58	0.07	10.16	7.90**	0.13
Error	84	2.19	1.24	0.45	0.36	0.14	38.55	2.94	0.35

**, ** Significant at 0.05 and 0.01 probability level, respectively*

Table 2. Mean comaprisions of 15 corn genotypes for yield, and resistance to *S. inferens*

No .	Genotypes	Collected province	Days to silking	Ear health (1-9)	Shank health (1-9) [a]	Kernel health (1-9) [a]	Borer per plant	Tunell length (cm)	Stem damage (%)	Yield (t/ha)
1	BU1	Balkh	49gh	8.4 ab	7.3bcd	6.2f	8.6d	35.2hi	9.6hi	0.8hi
2	BU2	Balkh	47h	8.0bcd	8.3a	6.6ef	5.9f	38.5hi	10.4ghi	1.4fgh
3	BU3	Balkh	53f	8.2bc	7.6abcd	6.9de	10.5c	32.5i	8.1hi	0.9ghi
4	BU4	Samangan	63cd	7.9bcd	7.1d	7.1cd	6.9f	42.0gh	26.7c	1.6efg
5	BU5	Baghlan	53f	7.4def	7.2cd	7.5bc	2.9g	49.3ef	15.6ef	5.8c
6	BU6	Baghlan	51fg	7.6cde	7.2cd	6.6ef	6.1f	57.0d	15.8ef	1.6efg
7	BU7	Jawzejan	63cd	6.8fg	6.9d	4.9g	13.5b	77.8b	19.5de	0.4i
8	BU8	Sar-e Pol	61de	6.5g	4.7e	3.7h	8.3de	86.7a	33.1b	1.4fgh
9	BU9	Sar-e Pol	60e	7.6cde	7.0d	6.3f	7.1ef	67.5c	18.1def	3.3d
10	BU10	Konduz	60e	7.1efg	7.3bcd	7.7b	10.4c	81.2ab	23.2cd	0.6i
11	Pioneer 30R50	Market	74a	8.4ab	8.0abc	8.4a	6.3f	45.8fg	12.8fgh	7.6b
12	Pioneer 30Y87	Market	74a	9.0a	8.3a	8.5a	3.0g	47.3fg	6.5i	8.8a
13	Carolina 17-6500	Market	65bc	9.0a	8.4a	8.5a	9.0d	31.8i	37.7ab	2.2e
14	Carolina 17-6540	Market	67b	9.0a	8.3a	8.5a	18.3a	48.2fg	41.4a	0.6i
15	Carolina 17-6600	Market	66b	9.0a	8.1ab	8.5a	9.8cd	53.2de	38.6a	1.4fgh
	Mean	-	60	7.99	7.44	7.05	8.44	52.83	21.15	2.57
	LSD	-	2	0.7	0.8	0.4	1.3	7.2	5.4	0.7

a. shank health, ear health and Kernel health were scored on a 9-point scale according to Butrón et al., 2009 (1 = 90–100% damaged, 2= 80–90%, 3=70–80%, 4= 60–70%, 5= 40–60%, 6= 30–40%, 7=20–30%, 8= 1–20%, and 9 =without injury)

b. Means with the same letter are not significantly different

Table 3. Correlation coefficients among yield, yield components, and damage-related traits in 15 genotypes of corn

	Days to silking	Bore per plant	shank health	Ear health	Kernel health	Tunnel length	Stem damage	Yield
Days to silking	1.00							
Borer per plant	0.15	1.00						
shank health	0.08	-0.2	1.00					
Ear health	0.35**	-0.16	0.12	1.00				
Kernel health	0.36**	-0.11	0.73**	0.37**	1.00			
Tunnel length	0.30**	-0.13	-0.44**	-0.42**	-0.41**	1.00		
Stem damage	0.31**	0.52**	-0.17	0.19*	0.07	0.69**	1.00	
Yield	0.49**	-0.50**	0.15	0.36**	0.34**	-0.18	-0.36**	1.00

**, ** Significant at 0.05 and 0.01 probability level, respectively*

These results are in agreement with previous studies which pointed out that more attractive materials to the moths of the second generation are the midseason and late maturing corn [9,11-13,19]. There is evidence to suggest that yield losses due to second generation of corn borers injury are less significant in longer-season hybrids, especially when sewn early, as compared to shorter-season hybrids. It is suggested that the applied strategy to avoid more injury of second generation of borer is achieved by sowing long-season hybrids early, a strategy that is consistent with improving the efficiency of other agronomic factors [19].

As would be expected, higher yield losses, greater proportions of stem damage, more damages to ears, shanks and kernel, and lower degree of kernel health were also observed in the midseason and the late genotypes and Carolina hybrids. The intensity of damages resulting from assimilate disruption injury is usually dependent on corn growth stage at the time of injuries [12,20-22]. Generally, earlier infestations (relative to plant development) cause greater yield losses and more stem damages than later-occurring infestation. Maximum yield losses and higher proportions of stem damage before stem elongation have been reported [23-25]. Moreover, under abiotic stresses as drought stress, yield reductions from stalk and stem borer injuries are more pronounced [26]. However, this reaction has been shown to have a non-linear negative correlation, therefore, as the number of cavities per plant increases, yield losses per cavity (tunnel) would be expected to decrease. Noting that vascular disruption that occurs above the ear zone will have little impact on water and nutrient delivery to the seed, therefore this would lead to little yield losses [27-30].

The Carolina hybrids showed higher degree of susceptibility to stem damage and yield losses as compared to Pioneer hybrids. It is reported that material considered to be resistant in its origin country might show resistance or susceptibility in other countries [11]. It seems that these materials have been bred for resistance to borers to grow in its original country not for the harsh conditions of Afghanistan. The pionner hybrids seem to be genetically resistant/tolerant to the borers. Therefore, they would be the most suitable materials for obtaining higher yield along with reduced stem damage under high infestation pressure in areas with longer growing season.

The sowing date, as a fixed factor leading to maximum potential yields in corn and largely determines the plant growth stage at the time of borer attack, was not included in this research. This is especially true because a delayed sowing date, due to weather or other conditions, can dramatically lead to different levels of injury. Moreover, yield losses resulting from stalk lodging or ear dropping are significantly correlated with the intensity of infestation, and actual yield losses due to borer-induced breakages and droppages are largely dependent upon environmental conditions [13]. Excessive winds and temperature, which are present in summer in Balkh province, could accentuate stalk lodging, and higher temperature or moisture conditions usually encourage stalk rot diseases. In researches involving ECB, it is reported that the best strategy to avoid more damages could be obtained by sowing long-season genotypes early. Because yield reduction in shorter-season genotypes as compared with longer-season genotypes are more significant, especially when they are sown late [26]. So, it is suggested that the effect of different sowing date on the proportions of insect damage should be determined in further studies.

The general appearance of the ear seems to be one of the best signs of resistance in preliminary evaluations. Additionally, the number and length of tunnels appearing in the ear also could be a useful trait in selecting resistant ears. Except the two genotypes BU7 and BU8, the others showed relatively a higher health value of 6, the others were significantly different for ear health, shank health, and kernel health. Firstly, it may be due to different borer species occurred during growing season. Because this research has been conducted under natural infestation, and therefore, there was not any control on borer species attacking crops. Secondly, this difference may be attributed to several selection cycle by farmers leading to higher shank, ear, and kernel health. Because, most of these genotypes were cultivated for several years, and, using hand-selected seeds for further sewing year has been resulted to producing genotypes with better health conditions for shank, ear, and kernel.

S. inferens may be probably the key pest found in Balkh provine, but it seems that other borers have not been negligible in field experiments. It is true that *S. inferens* larvae usually attack stems rather than ears, as like as *S. nonagrioides* larvae [8,31-32], but *O. nubilalis* preffers the silk channel to enter the ear.

However, kernel and shank health has shown to be highly correlated and genotypes were significantly differenet for shank health. Therefore, it is clear that decreasing the value of damage on the shank could prevent, in part, kernel damage by borers. In the other hand, as shank damage reduces kernel health would increase. Consequently, genotypes BU_1, BU_2, BU_3 and BU_5 would be the most appropriate materials for further breeding programs to reduce yield losses by *S. inferens*. Additionally, it seems that kernel and ear health would have a significant correlation, and reducing ear health could lead to a higher proportion of kernel damage.

5. CONCLUSION

Under natural infestation pressure, it is recommended to select varieties with less stem and shank damage caused by *S. inferens* to reduce yield losses. In addition, it is suggested that number and length of tunnels appearing in the ear seem to be the best signs of resistance to *S. inferens* in preliminary evaluations. Hence, the landraces BU_1, BU_2, BU_3, and BU_5 are assumed to be the most resistant/tolerant materials to *S. inferens,* and could be the base materials in further breeding programs to obtain higher yield and less stem damage by *S. inferens.*

ACKNOWLEDGEMENT

We would like to thank Dr. Alireza Akhavan, Isfahan University of Technology, Iran, for critical reading of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. FAOSTAT, Database, Rome, Italy; 2013.
   Available: http://www.fao.org
2. Jepson WF. A critical review of the world literature on the lepidopterous stalk borers of tropical graminaceous crops. London, UK: Common-wealth Inst. Entomol. 1954; 127.
3. Teetes GL, Seshu Reddy KV, Leuschner K, House LR. Sorghum insect identification handbook. Information bullet. International crops res. Institute for the Semi-arid tropics. 1983;124.
4. Krishnamurti B, Usman S. The ragi stem borer *Sesamia inferens* walker. Bulletin of the Department of Agriculture, Mysore State, Entomol. Series No. 15; 1952.
5. Sobek EA, Munkvold GP. European corn borer (*Lepidoptera: Pyralidae*) larvae as vectors of *Fusarium moniliforme*, causing kernel rot and symptom less infection of maize kernels. J. Econ. Entomol. 1999;92: 503–509.
6. Avantaggiato G, Quaranta F, Desiderio E, Visconti A. Fumonisin contamination of maize hybrids visible damaged by Sesamia. J. Sci. Food Agric. 2002;83:13–18.
7. Butrón A, Sandoya G, Santiago R, Ordás A, Rial AA, Malvar RA. Searching for new sources of pink stem borer resistance in maize. Genet. Resour. Crop Evol. 2006; 53:1455–1462.
8. Butrón A, Revilla P, Sandoya P, Ordás A, Malvar RA. Resistance to reduce corn borer damage in corn for bread, in Spain. Crop Protection. 2009;28:134-138.
9. Guthrie WD, Dicke FF, Neiswander CR. Leaf and sheath feeding resistance to the European corn borer in eight inbred lines of dent corn. Ohio Agric. Exp. Stn. Res. Bull. 1960;860.
10. Sullivan SL, Gracen VE, Ortega A. Resistance of exotic maize varieties to the European corn borer, *Ostrinia nubilalis*. Environ. Entomol. 1974;3:716-720.
11. Hudon M, Chiang MS. Resistance and tolerance of maize germplasm to the European corn borer, *Ostrinia nubilalis* (Hübner) and its maturity in Quebec. Maydica. 1985;30:329-337.
12. Hudon M, Bourgeois G, Boivin G, Chez D. Yield reductions in grain maize associated with the presence of European corn borer and Gibberella stalk rot in Quebec. Phytoprotec. 1992;73:101-110.
13. Malvar RA, Cartea ME, Revilla P, Ordás A, Álvarez A, Mansilla PP. Sources of resistance to pink stem borer and European corn borer in maize. Maydica. 1993;38:313-319.
14. Malvar RA, Butrón A, Álvarez A, Ordás B, Soengas P, Revilla P, Ordás A. Evaluation of the European Union maize landrace core collection for resistance to *Sesamia nonagrioides* (*Lepidoptera*: *Noctuidae*) and *Ostrinia nubilalis* (*Lepidoptera*:

Crambidae). J. Econ. Entomol. 2004;97: 628–634.
15. Melchinger AE, Kreps R, Späth R, Klein D, Schulz B. Evaluation of earlymaturing European maize inbreds for resistance to the European corn borer. Euphytica. 1998; 99:115–125.
16. Sekhar JC, Bergvinson DJ, Venkatesh S, Sharma RK, Reddy MLK, Singh NN. Reaction of exotic maize germplasm to pink borer, *Sesamia inferens* Walker. Indian J. Ent. 2004;66:261-263.
17. Sekhar JC, Rakshit S, Kumar P, Venkatesh S, Sharma RK, Anuradha M, Sai Kumar R, Dass S. Improvement of resistance level in selected maize genotypes through cycles of selection against pink borer, *Sesamia inferens* Walker. Indian J. Genet. 2010;70(2):204-206.
18. SAS Institute Inc. SAS/STAT User's Guid. SAS Institute, Inc, Cary, NC; 1999.
19. Jarvis JL, Guthrie WD, Robbins JC. Yield losses from second-generation European corn borers (*Lepidoptera: Pyralidae*) in long-season maize hybrids planted early compared to short-season hybrids planted late. J. Econ. Entomol. 1986;79:243-246.
20. Labatte JM, Got B. Modelling damage on maize by the European corn borer, *Ostrinia nubilalis*, Ann. Appl. Biol. 1991;119:401-413.
21. Keller NP, Bergstrom GC, Carruthers RI. Potential yield reductions in maize associated with an anthracnose/European corn borer pest complex in New York, Phytopathology. 1986;76:586-589.
22. Bosque-Peréz NA, Mareck JH. Effect of the stem borer *Eldana saccharina* (Lepidoptera: Pyralidae) on the yield of maize, Bull. Entomol. Res. 1991;81:243–247.
23. van Rensburg JBJ, Walters MC, Giliomee JH. Response of maize to levels and times of infestation by *Busseola fusca* (Fuller) (*Lepidoptera: Noctuidae*), J. Entomol. Soc. South. Afr. 1988;51:283-291.
24. Moyal P. Crop losses caused by maize stem borers (*Lepidoptera: Noctuidae*, *Pyralidae*). In Cote d'Ivoire, Africa: statistical model based on damage assessment during the production cycle. J. Econ. Entomol. 1998;91:512-516.
25. Welter SC. Responses of plants to insects: eco-physiological insights, in: Buxton DR, Shibles R, Forsberg RA, Blad BL, Asay KH, Paulson GM, Wilson RF, (Eds.), International Crop Science, Crop Sci. Soc. Am., Madison, WI. 1993;773.
26. Culy MD. Yield loss of field corn from insects, in: Peterson RKD, Higley LG. (Eds.), Biotic stress and yield loss. CRC Press. 2000;53-82.
27. Berry EC, Campbell JE. European corn borer: Relationship between stalk damage and yield losses in inbred and single-cross seed corn. Iowa State J. Res. 1978;53:49.
28. Umeozor OC, Van Duyn JW, Kennedy GG, Bradley JR. European corn borer (*Lepidoptera: Pyralidae*) damage in maize in eastern North Carolina, J. Econ. Entomol. 1985;78:1488-1494.
29. Berry EC, Guthrie WD, Campbell JE. European corn borer: relationship between leaf-feeding damage and yield losses in inbred and single-cross seed corn. Iowa State J. Res. 1987;53:137-145.
30. Calvin DD, Knapp MC, Xingquan K, Poston FL, Welch SM. Influence of European corn borer (*Lepidoptera: Pyralidae*) feeding on various stages of field corn in Kansas. J. Econ. Entomol. 1988;81:1203-1028.
31. Velasco P, Revilla P, Butrón A, Ordás B, Ordás A, Malvar RA. Ear damage of sweet corn inbreds and their hybrids under multiple corn borer Infestation. Crop Sci. 2002;42:724-729.
32. Velasco P, Malvar RA, Butrón A, Revilla P, Ordás A. Ear Feeding Resistance of Sweet Corn Inbreds to Pink Stem Borer. J. Amer. Soc. Hort. Sci. 1999;124(3):268-272.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14685