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Study on correlation of the antixenosis parameters and antibiosis parameters for *Chilo partellus* (Swinhoe) infesting maize

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Abstract
Susceptibility of 10 elite maize inbred lines to maize stalk borer, *Chilo partellus* (Swinhoe) was evaluated using two screening methods *viz.*, ovipositional preference by the gravid females and artificial infestation using neonate larvae based on the principles of antixenosis and antibiosis respectively. Different parameters of each screening method were correlated to find out the extent of relationship between them. The positive correlation of average egg mass received per plant and average number of eggs per plant with LIR and Larval weight was found non-significant among germplasm tested, but found significant with other susceptibility parameters like pupal weight, pupal recovery. The correlation of percent plants oviposited and percent leaves oviposited was observed significant with the antibiosis in parameters *viz*., LIR, pupal weight and pupal recovery. Considering these results, susceptibility indices (SI) were developed for antixenosis (SI_x), antibiosis (SI_b) and also, for cumulative susceptibility (SI_s) by combining both SI for antixenosis and antibiosis to incorporate all the parameters determining susceptibility. The extent of relationship between the indices were determined using correlation and it was observed that the correlation between (SI_x) and (SI_b**)** was 0.619, correlation between (SI_b) and (SI_s) was 0.805, those between (SI_x) and (SI_s) was 0.964 indicating that the greater contribution of antixenosis in determining susceptibility of a germplasm. But, if the data on the inbred HKI-1128 is removed, the values will become 0.974 and 0.194 for correlation between (SI_b) and (SI_s) and between (SI_x) with (SI_s), respectively. This may be due to the fact that in HKI-1128 antixenosis was contributing more. The results of the analysis indicate the need to adopt the combined susceptibility index (SIs) for better germplasm screening than the current approach, which relies solely on LIR or using antixenosis and antibiosis separately.

Keywords: Antixenosis parameters, antibiosis parameters, *Chilo partellus*, maize, correlation

Introduction

Maize (*Zea mays* L) is one of the most versatile emerging crops with a greater adaptability to different agro-climatic conditions. Corn is one of the most important grains in world agriculture and is often referred to as the queen of grains. In terms of nutritional value, it is below wheat and sorghum, but well above rice. It has a very high yield potential and is considered a miracle plant. It currently covers an area of 9.23 million hectares with an average yield of 2.56 tons per hectare (IIMR, 2015-16) [5] in India. The average productivity of corn is well below its potential. The most important reason for the low productivity is the improper management of biotic and abiotic stress. Insects in particular are an acute problem for maize cultivation in tropical regions. The spotted *C. partellus* is a major pest in maize, causing significant yield losses ranging from 25-40% (Khan *et al*., 1997) [6].

In the past century to control the insect pest, chemical insecticides have been applied on blanket basis that led to development of resistance in insect pest populations, resurgence of secondary pest, pesticide residues in food and food products, adverse effects on non-target organisms, toxic effects on human beings and environmental pollution (Divekar *et al*., 2022 a, b) [1, 2]. Keeping these things in view, it is very much essential to find out an alternative and nonchemical method to manage insect pest. Host plant resistance (HPR) is one of the most important cost effective inexpensive and compatible mechanisms to manage control insect pests (Divekar *et al*., 2019 a, b) [3, 4].

Among the factors that determine the susceptibility of maize to *C. partellus*, oviposition on different genotypes and the traits involved in the initial selection of plants by the oviparous females are very important.

Most studies on the relationship between oviposition and plant susceptibility are based on recording oviposition patterns of different plant genotypes in the field or various stimuli from the plant environment are thought to influence insect orientation and subsequent oviposition on a plant, independent of plant characteristics (Saxena and Saxena, 1974) [9]. According to Kumar et al. (1985) [8] the oviposition response of C. partellus to different genotypes in the field or in the screen house is clearly caused by plant traits and is not influenced by environmental and other stimuli. The studies in Africa showed that the non-preferential oviposition by *C. partellus* in maize genotypes is due to the presence of trichomes and surface waxes (Kumar, 1997) [7].

The germplasm is examined to find sources of resistance that could be used in the breeding program to develop hybrids. Germplasm screening is performed to identify elite sources of resistance. Development of appropriate screening techniques is essential in identifying sources of resistance. The level of leaf injury caused by larvae is presently used as the determinant of susceptibility of a germplasm (Siddiqui and Marwaha, 1979) [10]. But, the choice of plant by gravid female for oviposition is made prior to plant acceptability and suitability as a source of food for larva. If the germplasm manifest discernibility at oviposition by female *C. partellus*, the elaborate process of germplasm screening by artificial infestation may not be required. The present study was conducted with a view to find the corelation of antixenosis and antibiosis parameters which are commonly used to screen the maize germplasm.

If the germplasm is recognizable at oviposition by female *C. partellus*, the laborious process of germplasm screening by artificial infestation may not be necessary. The present study was conducted with the aim of finding out the relationship between antixenosis and antibiosis parameters commonly used for screening maize germplasm.

Materials and Methods

The correlation between antixenosis in terms of ovipositional preference parameters and antibiosis in terms of germplasm susceptibility level to neonate larvae was determined to know the extent of relationship between them. The susceptibility indices (SI) were developed for antixenosis (SI_x), antibiosis (SI_b) and also, by combining the effect of both the antixenosis and antibiosis (SI_s). For calculating for antixenosis (SI_x), parameters *viz*., average egg mass/plant, number of eggs/plant, percent plants oviposited, percent leaves oviposited were considered. Similarly, (SI_b) is developed by considering the parameters *viz*., LIR, larval weight (mg) and larval recovery as these factors were found significant correlation with germplasm susceptibility study. The correlation between (SI_x) and (SI_b); (SI_x) and (SI_s), (SI_b) and (SI_s) were determined. The germplasm was categorized according to the indices. Susceptibility indices were correlated with each other and with each parameter used for deriving them. The statistical software SPSS was used for analysis.

1. Determination of correlation

The correlation coefficients were derived by using the formula:

$$r = \frac{\sum X.Y - \left(\sum X.Y\right)/N}{\sqrt{\sum X^2 - \left(\sum X\right)^2/N} * \sqrt{\sum Y^2 - \left(\sum Y\right)^2/N}}$$

Where,

X-parameter selected for oviposition preference,

Y-parameter selected for larval susceptibility level (antibiosis parameter),

N- total number of observations.

The single as well as multiple correlation was determined using the parameters listed in Table 1.

Table 1: Different parameters selected for determining correlation

Sr. No.	Oviposition preference parameter	Germplasm susceptibility parameter
1	Average Plant height	Leaf injury rating (damage)
2	Average number of egg masses per plant	Larval weight
3	Average number of eggs per plant	Larval recovery
4	Serial number of leaves received eggs	Pupal weight
5	Percentage of plants received eggs	Pupal recovery
6	Percentage of leaves received eggs	Percent pupation

2. Formulation of indices of susceptibility

(SI_x)= (Average egg mass/plant × Average no. of eggs/plant) X (Average percentage of plants received eggs ×Average percentage of leaves received eggs)/100) /25

The factor 25 was used to bring down (SI_x) into the scales of (SI_b).

(SI_b) = (LIR+ Larval weight (mg)/10+ Percent Larval recovery/10) / 3

The factor 10 was used to bring down larval weight and larval recovery into the scales of LIR. The factor 3 was used to bring down (SI_b) as an average of all the three parameters.

Another SI for cumulative susceptibility (SI_s) was developed by combining the SI for antixenosis and antibiosis.

(SI_s) = (SI_x) + (SI_b)

Results and Discussion

The results of the correlation between the antixenosis in relation to oviposition preference parameters and antibiosis in relation to germplasm susceptibility level of ten maize germplasm are presented in Table 1. It clearly shows that the number of eggs per plant has a significant correlation with the other oviposition preference parameters except for the average number of eggs per egg mass, with which there is a negative correlation. The antibiosis parameters such as LIR, larval weight (mg) and pupal weight (mg), larval recovery and pupal recovery showed a high correlation with each other and all these parameters showed a poor correlation with the percent pupation.

It was observed that the correlation between average number of eggs per plant with antibiosis parameters *viz*., LIR, larval weight, larval recovery, pupal weight, pupal recovery and percent pupation were 0.572, 0.547, 0.612, 0.866**,0.856** and 0.538 respectively. The correlation between average number of egg mass/plant and antibiosis parameters *viz*., LIR, larval weight, larval recovery, pupal weight, pupal recovery and percent pupation was 0.615, 0.613, 0.652*, 0.895**, 0.890** and 0.565, respectively. The correlation of percentage of plants received eggs with the antibiosis parameters *viz*., LIR, larval weight, larval recovery, pupal weight, pupal recovery and percent pupation was 0.648*, 0.598, 0.722*, 0.863**, 0.909**, 0.526, respectively. The correlation between percentage of leaves received eggs and antibiosis parameters *viz*., LIR, larval weight, larval recovery, pupal weight, pupal recovery and percent pupation was 0.674*, 0.684*, 0.545, 0.844**, 0.753* and 0.501, respectively**.** The correlation of average number of eggs/egg mass with the with the antibiosis parameters *viz*., LIR, larval weight, larval recovery, pupal weight, pupal recovery and percent pupation were -0.832**, -0.792**, -0.626, -0.648*, -0.698* and -0.391, respectively (Table 1, 2, 3)

The correlation between different susceptibility indices were found to know the extent at which they were contributing to the overall susceptibility. The correlation between (SI_b) and (SI_x) was 0.619, those between (SI_s) and (SI_b) was 0.805 and (SI_x) and (SI_s) was 0.964. Based on the cumulative susceptibility index (SI_s) the maize germplasm were categorized accordingly (SI_s), the inbred HKI 1128 come under highly susceptible and the rest of the germplasm come under least susceptible category. The table 4 clearly showed that (SI_b) contributes more to the cumulative susceptibility index (SI_s) than (SI_x). The trend between LIR, susceptibility index for antibiosis (SI_b) and cumulative susceptibility index (SI_s) was more or less the same.

The results of the correlation between the antixenosis and the antibiosis of ten maize germplasm showed that the plant height showed a significant correlation with the other oviposition preference parameters and not with the antibiosis parameters except pupal recovery and pupal weight. The parameters like LIR, larval weight (mg), pupal weight (mg), larval recovery and pupal recovery showed a high correlation among themselves and all these parameters showed a poor correlation with the parameter Percent Pupation, suggesting that these parameters contribute more to the germplasm Susceptibility (antibiosis) (Table 4, 5, 6).

The correlation between the average number of eggs/plant and the average egg mass/plant, the percentage of oviposited plants and the percentage of oviposited leaves with the LIR, larval weight, larval recovery, pupal weight and pupal recovery was found to be significant. Thus, we cannot say that the antixenosis in terms of ovipositional preference can be used as a substitute for screening the maize germplasm in place of antibiosis in terms of LIR but can act only as a complementary to the LIR (table 4, 5, 6).

The extent of relationship between the indices were determined using correlation and it was observed that the correlation between (SI_x) and (SI_b**)** was 0.619, correlation between (SI_s) and (SI_b) was 0.805, those between (SI_s) and (SI_x) was 0.964 indicating that the greater contribution of antixenosis in determining susceptibility of a germplasm. But, if the data on the inbred HKI-1128 is removed, the values will become 0.974 and 0.194, respectively for correlation of (SI_b) and (SI_x) with (SI_s). This may be due to the fact that in HKI-1128 antixenosis is contributing more. The results of the analysis indicate the need to adopt the combined susceptibility index (SIs) for better germplasm screening than the current approach, which relies solely on LIR or using antixenosis and antibiosis separately (Tables 4, 5, 6).

Table 1: Correlation between different oviposition preference (antixenosis) parameters

Different oviposition preference parameters	Plant height (cm)	Ave. egg mass/plant	No. of eggs/ plant	Percent plants oviposited	Percent leaves oviposited	No. of eggs/ egg mass
Plant height (cm)	1	0.747*	0.810**	0.851**	0.703*	-0.481
Ave. egg mass/plant		1	0.987**	0.959**	0.882**	-0.636*
No. of eggs/ plant			1	0.969**	0.866**	-0.560
Percent plants oviposited				1	0.791**	-0.608
Percent leaves oviposited					1	-0.756*
No. of eggs/egg mass						1
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).						

Table 2: Correlation between different antibiosis (germplasm susceptibility) parameters

Different antibiosis parameters	LIR	Larval weight at 25DAI (mg)	Larval recovery	Pupal weight (mg)	Pupal recovery	Percent pupation
LIR	1	0.937**	0.870**	0.757*	0.820**	0.314
Larval weight at 25DAI (mg)		1	0.894**	0.840**	0.835**	0.350
Larval recovery			1	0.852**	0.920**	0.391
Pupal weight (mg)				1	0.948**	0.466
Pupal recovery					1	0.531
Percent pupation						1
*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).						

Table 3: Correlation between different antixenosis and antibiosis parameters with each other

Parameters	Germplasm	LIR	Larval weight (mg)	Larval recovery	Pupal weight (mg)	Pupal recovery	Percent pupation	Plant height (cm)	Ave. egg mass/plant	No. of eggs/plant	Percent plants oviposited	Percent leaves oviposited	No. of eggs/egg mass
Germplasm	1	0.266	0.180	0.200	0.348	0.447	.830**	0.501	0.615	0.637*	0.609	0.519	-0.374
LIR		1	0.937**	0.870**	0.757*	0.820**	0.314	0.543	0.615	0.572	0.648*	0.674*	-0.832**
Larval weight(mg)			1	0.894**	0.840**	0.835**	0.350	0.399	0.613	0.547	0.598	0.684*	-.792**
Larval recovery				1	0.852**	0.920**	0.391	0.535	0.652*	0.612	0.722*	0.545	-0.626
Pupal weight(mg)					1	0.948**	0.466	0.643*	0.895**	0.866**	0.863**	0.844**	-0.648*
Pupal recovery						1	0.531	0.663*	0.890**	0.856**	0.909**	0.753*	-0.698*
Pupal period(days)							-0.373	-0.653*	-0.869**	-0.863**	-0.845**	-0.783**	0.606
Development period(days)							-0.373	-0.653*	-0.869**	-0.863**	-0.845**	-0.783**	0.606
Percent pupation							1	0.380	0.565	0.538	0.526	0.501	-0.391
Plant height(cm)								1	0.747*	0.810**	0.851**	0.703*	-0.481
Ave. egg mass/plant									1	0.987**	0.959**	0.882**	-0.636*
No. of eggs/plant										1	0.969**	0.866**	-0.560
Percent plants oviposited											1	0.791**	-0.608
Percent leaves oviposited												1	-0.756*
No. of eggs/egg mass													1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Table 4: Values showing LIR and different Susceptibility Indices with respect to different maize germplasm

Germplasm	LIR	SI (antixenosis)	SI (antibiosis)	SI (cumulative)
BML-6	7.33	0.45	6.57	7.02
BML-7	4.20	0.02	3.4	3.42
CM-139	7.47	0.13	6.25	6.38
CM-140	7.07	0.17	6.62	6.79
HKI-161	6.27	0.01	5.41	5.42
HKI-163	7.20	0.39	5.36	5.75
HKI-193-1	8.53	0.93	6.01	6.94
HKI-323	5.07	0.47	3.72	4.19
HKI-1105	6.40	0.39	5.33	5.72
HKI-1128	8.60	10.06	8.06	18.12

Table 5: Correlation coeffients between different susceptibility indices and different susceptibility parameters

Different parameters	SI (antibiosis)	SI (antixenosis)	SI (cumulative)	LIR	Larval weight (mg)	Larval recovery	Ave. egg mass/plant	No. of eggs/plant	Percent plants oviposited	Percent leaves oviposited
SI(antibiosis)	1	0.619	0.805**	0.895**	0.970**	0.838**	0.649*	0.568	0.620	0.711*
SI(antixenosis)		1	0.964**	0.493	0.562	0.574	0.945**	0.898**	0.845**	0.785**
SI(cumulative)			1	0.674*	0.751*	0.717*	0.933**	.870**	0.847**	0.833**
LIR				1	0.937**	0.870**	0.615	0.572	0.648*	0.674*
Larval weight (mg)					1	0.894**	0.613	0.547	0.598	0.684*
Larval recovery						1	0.652*	0.612	0.722*	0.545
Ave.egg mass/plant							1	0.987**	0.959**	0.882**
No. of eggs/plant								1	0.969**	0.866**
Percent plants oviposited									1	0.791**
Percent leaves oviposited										1
**. Correlation is significant at the 0.01 level (2-tailed).										
*. Correlation is significant at the 0.05 level (2-tailed).										

Table 6: Maize germplasm categorization based on cumulative SI

Cumulative Susceptibility Index (Sis)	Level of susceptibility	Germplasm
3-8	Less susceptible	BML-7, HKI-323, HKI-1105, HKI-163, HKI-193-1, CM-139, CM-140, HKI-161, BML-6
8.1-13	Moderately susceptible	-
13.1-18	Highly susceptible	HKI-1128

Conclusion

The purpose of this study was to find out the suitability of oviposition preference as a screening method instead of the widely used LIR method for screening corn germplasm. Therefore, the former is economical and requires less time, space and labor. However, the results suggest that oviposition preference may complement, not replace, the LIR along with other parameters. Thus, the combined susceptibility index (SIs) can be used for better germplasm screening than the current approach that relies on only LIR or only on antixenosis or antibiosis.

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