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Genetic analysis of resistance to charcoal rot of Maize

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The inheritance as well as combining abilities for resistance to charcoal rot disease [*Macrophomina phaseolina* (Tassi) Goid.] in maize was studied by evaluating the diallel crosses among nine inbred lines excluding the reciprocals under artificial epiphytotic condition in the Gangetic plains of West Bengal during the *rabi* (= winter) season. Genetic analysis of the data showed that additive gene effect was predominant over nonadditive gene effect. General combining ability (gca) effect showed that the parents CM-104, CM-202 and CM-300 were the best general combiners towards desirable direction of resistance to this disease, while the specific combining ability effects were recorded to be highest in the crosses CM-202xCM-120 and CM-206 x CM-115 where all the parents except CM-104 had undesirable sca effect. None of the good general combiners could produce any desirable sca effect as in the crosses CM-115 x CM-104, CM-206 x CM-300, CM-206 x CM-104 and CM-202 x RN-6. Varietal heterosis was, however, not well defined in any case and the parental resistance did not show any precise relationship with gca effect and varietal heterosis. Average disease index of the parents and their F_1 progenies further showed that resistance was dominant over susceptibility.

Key words : Genetic analysis, Inbred line, Resistance, Susceptibility, Maize, *Macrophomina phaseolina*.

INTRODUCTION

Charcoal rot [*Macrophomina phaseolina* (Tassi) Goid.—*Rhizoctonia botaticola* (Taub.) Butler] is one of the six major stalk rot diseases of maize (*Zea mays* Linn.) that occurs in both tropical and temperate environments as delineated by Renfro and Ullstrup (1976). The disease is widely prevalent over different parts of India including North Western plains, North Eastern plains and Peninsular India and it may cause crop loss upto 39.5% (Payak and Sharma, 1978) in comparatively dry and low rainfall areas. The disease generally appears after flowering. Early symptoms include drying of the lowermost leaves from tip upwards and browning discolouration of the root tips. In the advance stage of infection the outside of the lower internodes become straw coloured, and even the pith sometimes become dark brown. In the disintegrated strands of the pith small, black sclerotia appear.

The genetic analysis of resistance to some other major stalk rots of maize has been reported from time to time by different workers (Furguson 1965 ; Kappleman and Thompson, 1966 ; Khan and Paliwal, 1979 ; Singh, 1979). Although charcoal rot of maize occurs every year in various parts of India including West Bengal, the knowledge on the genetics of host resistance to this disease is not well established.

MATERIALS AND METHODS

The study was undertaken at the Maize Research Station of Bidhan Chandra Viswavidyalaya, Kalyani (22.5°N. 88.2°E) located on the Gangetic plains of West Bengal during the months from December to May (*rabi*= winter season) of 1988. The soil of the experimental field was alluvial with pH 6.5. The field for the previous seasons had grown only maize with normal agronomic practices. From ecological point of view the existing weather conditions during the *rabi* season in the Gangetic plains at Kalyani are conducive for the development of charcoal rot of maize (Kaiser and Das, 1988).

In the experimental procedure, diallel crosses in all possible combinations among nine inbred lines of maize, namely CM-104, CM-105, CM-115, CM-120, CM-202, CM-206, CM-300, CM-500 and RN-6 excluding the reciprocals were made on the basis of disease reaction at different locations of All India Coordinated Maize Improvement Project. The resultant thirty six hybrids, and their parents were then evaluated for resistance to charcoal rot pathogen, *M. phaseolina* under artificial epiphytotic condition. Seeds of F_1 hybrids and their parents were planted in a randomized block design in 2-row plots with 3 replications. Each row was 5 m long and contained 25 plants. Normal agronomic practice was followed and no plant protection measure was undertaken.

The standard stalk inoculation method (Young, 1943) was followed to inoculate the basal internodes of the test plants at flowering using a virulent isolate of *M. phaseolina* from a susceptible hybrid VL-54. Inoculum from the stock culture was multiplied on round bamboo toothpicks and was used for field inoculation. Controls were kept by inoculating with sterile toothpicks only. Symptoms appeared in about 21 days and the disease incidence was recorded after splitting open the internodes longitudinally following the 1 (25% of the inoculated internode discoloured) to 10 (plants prematurely killed) scale (Payak and Sharma, 1982 (that has been described elsewhere in details (Kaiser and Das, 1988). Finally the type of disease reaction in a test genotype was determined as follows.

Average disease index	Reaction
1.0 to 2.0	Resistant
2.1 to 4.0	Moderately resistant
4.1 to 6.0	Moderately susceptible
6.1 to 8.0	Susceptible
8.1 to 10.0	Highly susceptible

The statistical analysis II of Gardner and Eberhert (1966) for variety cross diallel was adopted to estimate the general combining ability (gca) and various components of specific combining ability (sca) i.e., average heterosis (h), variety heterosis (hi) and specific heterosis (sij). In the present case gca is equivalent to variety effect of Gardner and Eberhert (1966) and the components of heterosis combined together are equivalent to sca of Griffing's (1956) of Model I.

RESULTS AND DISCUSSION

The average disease index of F_1 hybrids and their parents on reacting with the charcoal rot pathogen *M. phaseolina* were significantly different as evidenced by the general analysis of variance, and hence the analysis of variance for general combining ability was followed as presented in Table 1. The data show that the variance for gca and sca are highly significant and significant respectively which indicates the presence of both additive and nonadditive genes in controlling resistance to this disease. It is also evident that the estimated variance for gca as exhibited by the combining ability is very much higher than that of sca thereby indicating the predominance of additive genetic effects in controlling resistance to this disease. A study by Boiling and Grogan (1965) to determine the genetics of host resistance to *Fusarium* ear rot (*F. moniliforme*) of corn revealed that the estimates of additive genetic effects proved to be important in the inheritance of host resistance. Kappleman and Thompson (1966) also observed that the additive genetic effects were significant for eight populations studied in *Diplodia* stalk rot (*D. maydis*) of corn. Kulkarni and Sinde (1985), however, reported the importance of both additive and nonadditive genetic effects in

Table 1 : Analysis of variance for combining ability and heterosis of 9 x 9 crosses diallel of maize for resistance to charcoal rot pathogen *M. phaseolina*.

Source	d. f.	M.S.
gca (gi)	8	8.4659**
sca or Heterosis (hij)	36	0.488*
Average heterosis (h)	1	0.168 NS
Variety heterosis (hi)	8	0 331 NS
Specific heterosis (sij)	27	1.121 **
Error	80	0 378 NS

$6^2g=0.725$ $6^2s=-0.001$

** =Significant at 1% level of probability

* =Significant at 5% level of probability

NS =Not significant

determining the *Striga* resistance in corn. Hence it may be concluded that the pedigree method of selection may be followed also for the improvement of resistance to charcoal rot infection in maize.

The average disease index, gca effect, sca effect and the respective standard error are presented in Table 2. From the average disease index it appeared that only three parents (CM-104, CM-202 and CM-300) were moderately resistant, while the remaining six parents (CM-105, CM-115, CM-120, CM-206, CM-500 and RN-6) were moderately susceptible to susceptible in disease reaction. Among the thirty six F_1 hybrids tested eleven hybrids were moderately resistant, while the remaining twenty five hybrids were moderately susceptible in disease reaction. It also appeared from the data that in a cross combination where both the parents were moderately resistant the resultant F_1 progenies always reacted towards moderately resistant. Similarly, in certain cross combinations where one of the parents was moderately resistant and the other was either moderately susceptible or susceptible the F_1 progenies were either moderately resistant or moderately susceptible in the respective crosses. Therefore, from the average disease index of the parents and their respective crosses it might be concluded that resistance to charcoal rot of maize in general is dominant over susceptibility. Similar phenomenon was observed by different workers in case of some other maize diseases, for example, in case of (i) *Diplodia* stalk rot (Furguson, 1965 ; Kappleman and Thompson, 1966), (ii) *Fusarium* ear rot (Boiling and Grogan, 1965) (iii) *Cephalosporium* stalk rot (Khan and Paliwal, 1980) and (iv) in *Erwinia* stalk rot (Singh, 1979). It was further interesting to note that the cross between a moderately resistant (CM-202) and a moderately susceptible (CM-115) parent and between a moderately susceptible (CM-115) and a susceptible (CM-206)

Table 2. Average disease index (upper diagonal), varietal heterosis (hi), gca effect (gi), sca effect (off diagonal), average heterosis ($\bar{h}$) and respective standard error of 9x9 cross diallel of maize for resistance to charcoal rot pathogen *M. phaseolina*

Parent	CM-104	CM-120	CM-105	CM-300	CM-115	RN-6	CM-202	CM-500	CM-206	Vertical heterosis effect	gca effect
CM-104	3.5	6.0	5.0	3.0	3.5	4.5	3.0	5.5	6.0	0.004 NS	-0.803**
CM-120	0 464NS	7.0	7.0	6.0	7.0	7.0	4.0	7.5	6.0	0.254 NS	1.106**
CM-105	-0.536NS	-0.445NS	6.5	6.0	7.0	6.5	5.5	8.0	6.5	0.647 NS	1.106**
CM-300	-0.263NS	0.828NS	0 827NS	2.5	4.0	4.0	3.5	4.0	4.0	0.218 NS	-1.167**
CM-115	-0 718NS	0 873NS	0.873NS	0.146NS	5.0	5.0	4.5	5.0	4.0	-2.246 NS	-0.212NS
RN-6	0.282NS	0.873NS	0.373NS	0.146NS	0.191NS	4.5	4.0	5.5	4.5	0.147 NS	-0.212NS
CM-202	-0.491NS	-1.400*	0 100NS	0.373NS	0.418NS	-0.082NS	3.5	5.0	5.5	-0.210 NS	-0.939**
CM-500	0.282NS	0.373NS	0.873NS	-0.854NS	-0.809NS	-0.309NS	-0.082NS	7.0	6.5	-0.246 NS	0.788**
CM-206	1.237NS	0.663NS	-0.172NS	-0.400NS	-1.354*	-0.854NS	0.873NS	0.146NS	6.5	-0.567 NS	0.333NS

Average heterosis $(\bar{h})=0.153$; $SE(gi)=\pm 0.236$; $SE(gi-gj)=\pm 0.354$; $SE(sij)=\pm 0.671$; $SE(sii-sij)=\pm 0.936$; $SE(sij-sik)=\pm 1.119$; and $SE(sij-skl)=\pm 1.062$.

**=Significant at 1% level of probability

*=Significant at 5% level of probability

NS=Not significant.

parent produced moderately susceptible and moderately resistant F_1 progenies in the respective crosses. Similarly, the cross between CM-104 (moderately resistant) and RN-6 (moderately susceptible) resulted moderately susceptible F_1 progeny. Thus, the presence of gene interaction was evidenced in the present case.

The data in Table 2 further showed that among the nine parents studied three moderately resistant parents CM-104, CM-202 and CM-300 were the best general combiners, while the three susceptible parents CM-105, CM-120 and CM-500 were the poor general combiners for resistance. The varietal heterosis effect was, however, not significant in any case although it was highest in case of CM-105. The results showed that parental resistance did not exhibit any precise relationship with gca effect and varietal heterosis. However, the parent CM-202 ranked top among all the general combiners for resistance to this disease. It was clear that some of the crosses exhibited nonsignificant negative sca effects with the involvement of a good general combiner and a poor general combiner e. g. CM-115 x CM-104, CM-206 x CM-200 and CM-202 x RN-6.

Among the thirty six different sca effect the best specific combiners were recorded in the crosses between CM-202 x CM-120 and CM-206 x CM-115 where the only parent CM 202 had desirable gca effect. None of the positive sca effects were, however, significant in the present case. The highest positive sca effect was exhibited by the cross CM-206 x CM-104 where the parent CM-206 had undesirable gca effect. Intra -and interspecific crosses of jute made by Haque *et al.* (1979) also revealed that moderately resistant to moderately susceptible progenies against the stem rot pathogen *M. phaseolina* could be developed in B_3F_6. However, in the crossing programme those workers used both cultivars and wild type disease resistant parents. As already mentioned that some of the crosses (CM-115 x CM-104, CM-206 x CM-300, CM-206 x CM-104 and CM-202 x RN-6) failed to exhibit any desirable sca effect even with the involvement of a good general combiner. Thus a good general combiner may not be a good specific combiner. However, sca effect is not so much important in plant improvement as reported by Chandra and Sengupta (1986).

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