22. BROWN STRIPE AND SUGARCANE DOWNY MILDEWS OF MAIZE: GERMPLASM EVALUATION, RESISTANCE BREEDING AND CHEMICAL CONTROL

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Maize crop suffers enormously due to brown stripe (BSDM; *Sclerophthora rayssiae* var. *zeae*) and sugarcane downy mildews (SDM; *Sclerospora sacchari*) in several parts of India. Several released hybrids and composites as well as all the local cultivated varieties were observed highly susceptible to both the downy mildews (Anonymous, 1972; Lal *et al.*, 1973). For SDM, no resistant mazie cultivar has been released in our country so far (Payak, 1973). Also effective and economic schedule to control these two nemesis have not been worked out. The informations presented here are based on the research work done at G.B. Pant University of Agriculture and Technology, Pantnagar, India on germplasm evaluation, resistance breeding and chemical control of these downy mildews.

Germplasm Evaluation

***Sclerophthora rayssiae* var. *zeae*:**

Before the first "International Workshop on Downy Mildew Diseases of Maize and Sorghum" at Pantnagar in 1969 several materials such as Antigua Gr. I, Antigua 2 D, Carribian Flint Composite, Eto Amarillo and Dorado de Tequisate were known to have considerable resistance to BSDM in India. With the result, hybrid Ganga 5 was released in 1968 to replace the highly susceptible Ganga 3. Since 1969, extensive programme of testing world germplasm has been in progress at Pantnagar to locate the additional sources of resistance. The Maize inbred lines CM 103 (Col 1×38-11), CM 104 (A Theo-21 B), CM 105 (Peru 330), CM 111 (Cuba 342), CM 113 (Eto 190 C), CM 201 (G. 715-A1), CM 202 (C 121 E), CM 300 (Eto P1-13), CM 400 (Tenn 29), Venz 1-42, Cuba 24, Adec A-257, Eto 25 A and Kmr-35 were observed to have high degree of resistance. Other germplasms like Puerto Rico Gr. 1, Mich 166×Eto Blanco and Puerto Rico 22 D×P. Rico 17 D also possess considerable resistance. These materials have been well utilized to develop BSDM resistant cultivars such as Ganga 4, Ganga 7 (EH 2365), EH 3047, D_1 Composite and TAD. Amongst the dwarf hybrids, CM 110×CM 113 br, CM 105×CM 113 br, CM 110×CM 202 br, CM 201×CM 105 br and CM 400×CM 600 br showed marked tolerance under Pantnagar conditions. The later hybrid has shown promise in National Varietal Demonstration trials conducted in several districts of western Uttar Pradesh in 1973 and 1974 crop seasons. Two opaque composites Ambar Op_2 and Protina were also fairly resistant.

A total of 937 cultivars, selected by the breeders on the basis of their performance at different maize research stations in the country, were evaluated in artificial epiphytotic conditions at Pantnagar in 1971 through 1974. Most resistant among them are as follows: EH V.L.-45, VLD 68, VLD 90, VL 54 A, EH 2420, EH 2246, EH 2468, EH 2306, EH 2576, EH 2130, EH 2250, EH 2280, EH 2320, EH 2330, EH 2380, EH 2466, EH 3136, EH 3597, EH 3136, EH 4028, EH 4245-2, EH 4297-73, EH 4244-72, EH 4260-72, EH 4208,

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EH 4207, EH 4396-73, Tuxpeno br. 2, Semi dwarf Ganga 5, D 38, D 37, Pioneer Hyb. 102, Pioneer Hyb. 222, EHP 100-74, Bihar Ear 47×(Ant. Gr. II×USArg #-1), (CM 400 ×CM 300)× J_1 (W), Composite B 5, J 22, IACP Comp. 101, (St. Croix 5 D×4 D)× (Guadalupe 14 D×16 D), (St. Croix 5 D×4_2 D)× Carotigua, Vijay×Cuba 19 F_2, Ba-Jaura 1, Bajaura 2, JML 236, (52 C) Op_2×(K 858 Kawanda Nig. 2533 nig×EB) Op F_5, B_1 Recons, Jawahar Recons., Sona Recons., Kisan MMH_2 Recons, J_1 (W), Late White Flint 71×Tainan 2, (College white×Tuxp)×Tainan 5 (W), 2 P—SC-1 (FAO 700), JML 22×(A_1×Ant. Gr. I) F_5, JML-25, Guatamalan, J_1 (Arr) F_3, EH 10 (USA), Hyb. 3374 (USA) and 3030 (USA).

Among 96 IMAN materials tested, Hibrido Houduras H-5, ICA H 207, DV 351 SM 111 Ciclo, Chontalpa, Guat H-2, Enano and Comp. L (Me) C_5 were least susceptible. Of 21 Hungarian maize hybrids tested in 1972 K, MVTC 651, 590 and 660 were at per with most tolerant hybrid Ganga 5.

Of 387 materials planted in 1973 and 1974 *Kharif* seasons, several especially from Mexico showed a good deal of resistance to BSDM. These are saint Croix 4119–4186##, 1961#, Tuxp. br 2×NICAR 14 Sianto 10, 505#, A6 br 2 Blanco, 506#, A6 br Amar, 688# Comp. Rep. dom br 2, Tux 61, CIMMYT Op_2 Comp. 1044#, Samara Comp. II (O_2O_2), 1045# Comp. I (Ne) $O_2O_2O_2$, POEYT-27, 80, 66, 72, 10512, 10520, 10549, 10553, Guetamalan 209, A235 PL##, Tainan DMR Comp. 11, MV 26-#, 887 (17 ears) ##, POEYT-2 10510-#, H632 ##, Tw×P-PR-PR Baja-#, Comp. 108##, HC 15C-##, H512##, Ant. Gr. 2 Sel Blanco, Antigua 8D## and Cuba-#-#.

***Sclerospora sacchari*:**

Performance of all the germplasms obtained from Indian sources (Hybrids, their parents, composits and local cultivated varieties) were observed against *S. sacchari* through artificial inoculations. Amongst them only Hybrid Ganga 2 was least susceptible followed by A_2 synthetic (29 lines). Other cultivars have shown more than 10 percent mildew incidence. Inbred lines DA-1-5-f-1-#-#-#-#-bulk-#-#, EH 203-#-#-#. 2039-2-2-#-#-#-#, (PTR×K61)-1, Pr-#-# and Pr-1-#-# have shown good resistance (Anonymous, 1972).

A collection of germplasm resistant to downy mildew in various countries like Philippines, Taiwan, Indonesia, Thailand and Texas were tested in 1970 through 1972. Of these 15 composites/varieties and 26 inbred lines have shown less than 2% infection. Some of the resistant populations are College Wt.×Tuxpeno, MIT×Cuba Gr. 1 MIT ×Flint Comp. Amarillo, Chain DMR. Syn, Bogor Syn 1, Bogor Syn 2, Tainan DMR Comp. 2, Philippine DMR, 1, 2, 3, 4 and 6, Tuxpantigua×MIT. Inbred lines pH 9 DMR, T×601 and also those which were derived from MIT×Flint Comp. Amarillo, MIT×Eto Amarillo, (College White×Tux.)×Aroman WF, VIOCA var. 4×Cuba WF, Columbia 2×Aroman WF, and UPCA var 2×Aroman WF have shown a zero percent disease incidence (Anoymous, 1970; Payak, 1973). Several other populations like A 206, Mimies, DMR 131, Philippine DMR 4, Thai DMR Comp. 1 and CIMMYT-Tainan DMR Comp. 13 also have been rated to be resistant (Renfro, 1973).

Resistance Breeding

Although, downy mildew diseases have always been kept in mind in the breeding programme, but concentrated efforts to breed for disease resistance started since 1969 in 19 elite composites, viz. Guatemala×Antigua Gr II, J1(Y), J1(W), C1, C2, Jawahar 24, Jawahar 44, Sona 31, Sona 72, Kisan 70, Kisan 33, C×C_2 CBC×SW, A_2 29, B_1(Y), D_1, Tainan DMR I and Tainan DMR 3. These populations were pace planted in large plots and all the plants were artificially inoculated with both downy mildews and two stalk rot pathogens, *Erwinia carotovora* var *zeae* and *Cephalosporium acremonium*. The resistant plants with good agronomic characters were selfed to develop S lines. Similar programme

was also started in 1971 with 22 populations, viz., JML 236, Vijay, Mich 166, ×Eto Blanco, TAD, Jaunpur White, CM600, Tuxp (Comp. de com.)×Sonora Gr. II, (St. Croix 5 D ×4 D)×(Guad. 14 D×16 D), Tainan 1(Y), Tainan 1(W), Tainan 2, Tainan 3(Y), Tainan 3(W), Protina (Pure), Protina (Semi), Kisan O_2 (Pure), Kisan O_2 (Semi), Vijay O_2 (Pure) and Vijay O_2 (Semi). All the S_1 lines have been grown in the following season and the resistant plants (after artificial inoculation) have been utilized to reconstitute the populations and to maintain or develop S_2 and S_3 lines. In 1973K, all the lines were evaluated in yield trials, and ultimately 94 yellow and 8 white lines were selected. These lines were utilized in two programmes: (i) The lines were reconstituted to develop one yellow or white population in 1973 R, which have been again planted in 1974 K to do second cycle of reconstittuion. (ii) Top crosses were made in 1973 R with these selected lines using the tester parent D_1 composite for yellow and J_1(W) for whites. In 1974 K these crosses have been planted in yield trials.

In 1971, Tainan DMR Comp. 2 was crossed with 45 white composites to develop composite crosses having SDM resistance. These composite crosses have been tested in a trial in 1972 *Kharif*. Eight white selections from DMR composites Tainan 1, 2, 3, Chain DMR Syn×Flint Comp. Amarillo, College wt×Tuxpeno, MIT×Cuba Gr. 1 and DMR Syn (23 populations) were crossed in all possible ways in 1971 K and yield tested in 1972 K. Also five DMR composite viz., College wt. Tuxpeno, Tainan 2, 3, MIT×Flint Comp. Amarillo and Chain DMR syn were crossed to 21 White DMR lines and the crosses were yield tested. But all these crosses were found low yielder than the standard hybrid Ganga 2.

In 1973 K, open pollinated ears were selected from downy mildew and stalk rot resistant plants from two yield trials having yellow and white elite early composites. In 1973 R, these were planted in ear to row and best lines were reconstituted to develop two early populations. In 1974 K, second cycle of reconstitution was made in both the populations after discarding the late plants. Both the populations which were harvested only recently, have shown a maturity period of only 80 days under Pantnagar conditions.

In 1973 R, 500 full sib families were made in three elite populations of different maturity groups. These are D_1 composite (100 days), Syn P200×Kisan Syn. (90 days) and Bihar Early yellow×(Antigua Gr II×US/Agr #-1) (80 days). In 1974 K, four sets having two replications of these were planted in one row plots, each for pathology, entomology, agronomy and breeding work separately in the same field. On the basis of all the observations, best lines will be selected to reconstitute the populations.

Chemical Control

Brown stripe Downy Mildew:

Work done so far on this aspect reveals that the disease could be controlled only by frequent foliar sprays of a non-systemic fungicide, Dithane M-45 (Nene and Saxena, 1970). This disease becomes a problem in rainy season crop and most of the time such non-systemic fungicides are washed away from the leaves by the frequent rains rendering the chemical ineffective. Therefore, efforts were made with additional fungicides, especially those of systemic in nature to find out a better substitute for the control of this particular disease.

An experiment was conducted in field during Kharif 1973 to see the efficacy of 13 fungicides/chemicals (Table 1). A susceptible hybrid VL-54 was planted in a randomized block design consisting of 15 treatments in four replications. The individual plot size was 5×3 m^2. Check rows of a resistant hybrid Ganga 4 were planted around each plot length wise to minimize the interplot spread of the disease and to avoid chemical drift

Table 1. Name of fungicides, their active ingredient and sources

Sl No.	Name	a. i.	Active ingredient	Source
1.	Aureofungin	—	Heptaene antibiotic from *Streptomyces cinnanomens* var. *terricola* The aromatic moiety is N-methyl-P-aminoacetophenone and mycosamine.	Hindustan Attibiotics Pimpri Poona (India.)
2.	Benlate	50%	(Methyl-1 (butylcarbamyol)-2-benzimidazolecarbamate)	E. I. Du Pont De Nemours & Co., Wilmington, Delaware, U. S. A.
3.	Brestan	60%	Triphenyltin acetate	Hoechst Pharmaceuticals Ltd., Bombay India.
4.	Brestanol	50%	50% Triphenyltin chloride	Hoechst, Pharmaceuticals Ltd., Bombay India.
5.	Cercobin M.	70%	1, 2-Bis (3-methoxy carbomyl-1-2 thioureido) benzene, 70W	Nippon Soda Co., Japan.
6.	Cuman	40%	Zinc dimethyl dithiocarbamate (Ziram)	Ciba of India Ltd., Pesticide Depart. P. B. No. 497, Bombay, India.
7.	Demosan 65 W	65%	(1, 4, dichloro-2-5-dimethoxylbenzene)	E. I. Du Pont De Nemours & Co. Wilmington, Delaware, U. S. A.
8.	Dithane M-45	80%	A coordination product of zinc ion and manganese ethylene bisdithiocarbamate	Indofil Chemicals Bombay, India.
9.	Fytolan	50%	50% Metallic copper as copper oxychloride	Imperial Chemicals Industries (ICI) 34 Chowranghee, Calcutta, India.
10.	Kitazine	48%	0,0-Diisoprophyl-s-benzyl thiophosphate	Kumiai Chemicals Industry Co., Ltd., Tokyo, Japan.
11.	Miltox	37.5%	37.5% metallic copper as copper oxychloride and 12% zinz ethylene bisdithiocarbamate (zineb).	Sandoz House, Dr. Annie Besant Road, Worli, Bombay, India.
12.	Mertect	60%	2-(4-thiazolyl) benzimidazole	Merck & Co. Inc. Rahway, New Jersey, 07065, U. S. A.

from one plot to another. All the chemicals except Demosan 65 W were sprayed four times: first spray 15 days after planting; second 10 days after the first spray; and remaining two sprays at 14 days intervals. The first, second, third and fourth sprays were made in water at the rate of 600,750,900 and 1,000 litres per hectare, respectively. The sticker-spreader Sandovit (0.1 per cent) was added in all the spray liquids except in Bordeaux mixture. Demosan 65 W was applied as seed or/and furrow treatment at the time of planting. In the check plots, water was sprayed instead of fungicides on the same dates.

Efficacy of fungicides were noted in terms of disease incidence, grain yield, number of cobs per plant and 500 grain weight. Disease reaction of twenty plants selected at random from each plot were noted 70 days after planting on the basis 0 to 5 scale and data obtained were analysed (Table 2).

Nine fungicides viz., Miltox, Bordeaux mixture, Fytolan, Brestanol, Brestan, Demosan, Mertect, Benlate and Cuman were found to reduce the disease severity significantly over the check. Of these, the first three, Miltox, Bordeaux mixture and Fytolan were observed equally effective. Brestanol, Brestan, Demosan 65 W (Seed and furrow treatment) and Mertect were next in order of effectiveness, whereas Benlate, Cuman and Demosan 65 W (seed treatment) were comparatively less effective. Rest of the fungicides were not effective as they were found insignificantly different as compared to the check. All the spray fungicides except Fytolan and Miltox were observed non-phyto-toxic.

Table 2. Influence of fungicides on the brown stripe downy mildew incidence, grain yield, number of cobs per plant and 500 grain weight

Sl. No.	Treatments	Concentration (a. i.)	Disease incidence		Grain yield		Number of cobs per plant	500 grain weight (gm).
			Rating (0-5)	Index	kg/ha	Index		
1. *	Aureofungin+copper Sulphate	0.005% +0.005%	2.84	49.3	3,988	89	1.0	109.3
2.	Benlate	0.05%	2.46	44.6	4,000	98	1.2	114.3
3.	Bordeaux mixture	4 : 4 : 50	0.81	23.7	6,669	148	1.4	117.8
4.	Brestan	0.02%	1.65	34.9	6,772	150	1.4	129.8
5.	Brestanol	0.03%	1.60	34.4	5,775	128	1.3	113.0
6.	Cercobin M	0.05%	2.98	50.9	4,297	85	1.0	112.5
7.	Cuman	0.03%	2.98	50.9	4,606	102	1.2	111.2
8.	Demosan 65W 7gm/kg	—	2.63	46.5	4,778	106	1.2	118.8
9.	Demosan sd. tr.+Fu. Tr. 7 gm/kg+25 kg/ha	—	2.15	40.9	4,916	109	1.2	113.3
10.	Dithane M-45	0.3%	2.94	50.2	5,500	122	1.2	100.0
11.	Fytolan	0.15%	0.94	25.6	5,638	125	1.3	122.5
12.	Kitazine	0.05%	2.93	50.1	3,273	73	0.9	112.5
13.	Mertect	0.05%	2.34	43.1	4,400	98	1.1	101.3
14.	Miltox	0.20%	0.65	21.0	5,019	111	1.1	109.3
15.	Check	Water sprays	3.39	55.4	4,503	100	1.1	115.5
	C. D. (5%)	—	—	8.7	1,271	27.3	0.2	Not Significant
	C. V. (%)	—	—	14.9	18.0	—	12.0	

* Concentration was prepared by considering 100% active ingredient in the chemical

Fytolan was recorded as slightly hyto-toxic.

Only three fungicides, Brestan, Bordeaux mixture and Brestanol gave sinificantly higher grain yields as compared with the check. The increased yields obtained with the use of these fungicides were at par. The average number of cobs were maximum in Brestan and Bordeaux mixture treated plots followed by Brestanol and Fytolan. There were no significant differences amongst the 500 grain weight of the treatments. However, maximum weight was obtained in Brestan sprayed plots followed by Fytolan and Bordeaux mixture.

Considering the overall performance of these chemicals, one of the three fungicides, Brestan (0.02%), Brestanol (0.03%) or Bordeaux mixture (4:4:50) could be used as foliar spray to get effective control of the disease. Persistence studies of these fungicides indicated that the concentration of Bordeaux mixture on 13th day after the foliar spray was 1595 ppm; of Brestan on 15th day was 19 ppm; and of Brestanol on 11th day was 10 ppm approximately (Sood, 1974). Based on these informations a better spray schedule for these fungicides may be worked out by further field experiments.

Sugarcane Downy Mildew:

In the recent past, seed treatment with a systemic fungicide Chloroneb (Demosan) has been proved effective in reducing Philippine downy mildew incidence upto 2½ weeks after planting (Schultz, 1971). This logically suggested the evaluation of Demson and other systemic compounds to sugarcane downy mildew of maize also. Two experiments

were conducted under field conditions to evaluate Demosan or other systemic compounds against this disease as seed and/or furrow treatment. Susceptible cultivar, indicated with the experiment, was planted in randomized block design having four replications. A plot size of $5 \times 3\ m^2$ was maintained in both the experiments. Spreader rows of a susceptible variety "Hawaiin Sugar" were planted around each plot lengthwise to ensure high disease incidence. The chemicals were applied just before planting as seed, furrow and seed+furrow treatments. Seed treatment was done by adding few drops of water

Table 3. Effect of Chemicals af seed/furrow treatment on sugarcane downy mildew of maize (Hybrid Ganga 5)

Sl. No.	Treatments	Rate Seed tr.	Rate furrow tr.	Percent plants infected 15 days after planting	21 days after planting	30 days after planting
1.	Demosan 65 W	7 g/kg	—	3.2	11.4	13.5
2.	Demosan 65 W	7 g/kg	15 kg/ha	0	0	7.1
3.	Brestanol 50 W	5 g/kg	—	7.1	13.5	15.0
4.	Brastan 60 W	5 g/kg	—	6.0	13.1	14.3
5.	Brassicol 50 W	5 g/kg	—	8.2	13.1	17.5
6.	Bavistin 50 W	5 g/kg	—	9.3	17.2	19.5
7.	Derosal 60 W	5 g/kg	—	7.5	14.2	16.2
8.	Bleaching Powder 33 W	—	25 kg/ha	5.4	15.1	15.4
9.	Vydete*	—	2 L/ha	8.9	15.5	17.1
10.	Furadan 3%	—	25 kg/ha	7.8	12.4	15.5
11.	Dithane M-45 four foliar sprays	—	0.3%	9.2	16.2	17.1
12.	Check	—		9.6	16.6	20.9
	C. D. (5%)			4.2	5.6	5.6
	C. V. (%)			11.5	18.4	19.8

* Considered as having 100 percent active ingredient

Table 4. Effect of Demosan 65 W as seed/furrow treatment on sugarcane downy mildew of maize (C_2 composite)

Sl. No.	Treatments	Rate	Percent plants infected 2 weeks after planting	4 weeks after planting	8 weeks after planting
1.	Seed treatment	7 g/kg	0	10.46	25.38
2.	Seed+furrow treatment	7 g/kg+25 kg/ha	0	2.58	8.27
3.	Seed+furrow treatment+4 sprays of Dithane M-45	7 g/kg+25 kg/ha+0.3%	0	1.93	11.85
4.	Seed+Furrow treatment+2 sprays of Dithane M-45	7 g/kg+25 kg/ha+0.3%	0	7.45	11.15
5.	Four sprays of Dithane M-45	0.3%	12.85	23.77	25.98
6.	Check		14.36	23.81	28.17
	C. D. (1%)		8.53	10.38	13.74
	C. V. (%)		13.80	17.60	18.20

prior to addition of the dry chemicals.

In first experiment, nine chemicals were used either as seed or furrow treatment or both (Table 3). Dithane M-45 was applied four times as foliar sprays: first 15 days after the planting and remaining at 10 days intervals. Among the various treatments, only Demosan (Seed+furrow treatment) effectively checked the disease upto one month after planting. In this treatment not even a single infected plant was observed upto 21 days after planting. Seed treatment with this chemical protected the plants upto 15 days after planting. However, seed treatment was observed comparatively less effective than seed+furrow treatment. There were no adverse effect of these treatments on seed germination.

Second experiment was conducted with Demosan consisting of seed and seed+furrow treatments alone or in combinations of 2 and 4 foliar sprays of Dithane M-45. Sprays of Dithane M-45 were done 15 days after the planting at 10 days intervals (Table 4). Demosan applied as seed treatment was effective at least upto two weeks after planting. Its higher dose (Seed, 7 g/kg+furrow, 25 kg/ha) alone or in combination of Dithane M-45 was found equally effective in controlling the disease upto 8 weeks after planting. Four sprays of Dithane M-45 were not found effective.

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