Grindle M. and W. Temple

Fungicide resistance of sm co mutants of N eurospo racrassa.

We are using N. crassa as a model organism to investigate the mode of action of agricultural fungicides and the genetic and biochemical bases for fungicide resistance. Certain aromatic hydrocarbon and dicarboximide fungicides ("AHD" fungicides) presumably have a similar mode of action because mutants are usuallv cross-resistant to them. For example, Vin and os mutants of N. crassa are resistant to the aromatic hydrocarbons dicloran, chloroneb and quintozene and the dicarboximides iprodione, procymidone and vinclozolin (Grindle and Temple, 1982 Neurospora Newsl. 29: 16-17). The fungicides are used on a wide range of crops, especially grapes, soft fruits and glasshouse plants, to combat pathogens such as species of Botrytis Rhizoctonia and Sclerotinia. There is increasing concern that dicarboximide-resistant mutants of Botrytis cinerea might become a practical problem in agriculture and horticulture.

The sensitivity of Vin and os mutants to media of high osmolarity suggests that there are defects in the cell wall-plasma membrane complex of AHD resistant mutants. Many morphological mutants of N .crassa are believed to have abnormal cell walls or membranes, and the biochemical lesions and enzyme defects of some mutants have been determined (Scott 1976, Ann. Rev. Microbiol. 30: 85-104; Mishra 1977, Adv. Genet. 19: 341-405). Representative morphological mutants were analysed for resistance to AHD fungicides.

Each mutant was grown on dishes of Vogel's minimal medium (MM) and on MM containing 2-10 µg/ml vinclozoin to detect isolates that were more resistant than the wild type 74-OR8-1a. Colony diameters (mean of 2 measurements per colony were noted after I8 hr and 24 hr growth, and the growth rate (mm/24 hr increase in diameter) was calculated from the growth during 6 hr. Growth rates on MM and on fungicide-supplemented MM were used to determine the amounts of fungicide that reduced colony diameters by 50% (ED_{50}) and by 95% (ED_{95}). The ED_{50}

TABLE 1

Growth rate and fungicide resistance of smco mutants of Neurospora crassa

locus.	Allele or isolation number	FGSC stock number	Rate of growth, mm/24 hr[a]				Resistance to fungicides[b]			
			MM	CM	MM + 2% NaCl	MM + 4% NaCl	iprodione	vinclozlin	dicloran	quintozene
smco-1	Y2330	1363	58	12	14	12	0	0	0	0
smco-2	R2386	1377	24	10	0	0	+	+++	+++	+++
smco-4	R2435	1367	10	12	12	12	0	0	0	0
smco-5	R2442	1361	50	60	58	58	0	0	0	0
smco-6	R2477	1353	50	14	34	22	0	0	0	0
smco-8	R2505	1404	38	8	5	0	+	+++	+	+
smco-9	R2508	1405	56	12	18	12	+	+++	+	+
wild type	74-)R8-1a		98	112	94	78	0	0	0	0

[a]Increase in colony diameter at 26°C, mean of at least 3 replicates; diameters measured 18 hr and 24 hr after inoculation, and growth rate calculated from the growth during 6 hr. CM = MM + 0.5% casamino acids + 0.5% yeast extract.

[b]0 = sensitive (ED50<3µg fungicide/ml); + = low resistance (EDso>3< 10 µg/ml); +++ = high resistance ED_{50} > 50 µg/ml; ED_{95} >100 µg/ml ED values are concentrations of fungicide that reduce growth on MM by 50% or 95%.

values for 74-OR8-la were 2.8 µg/ml dicloran and 1.3 µg/ml vinclozolin and ED_{95} values were 7.4 µg/ml dicloran and 3.3 µg/ml vinclozolin. The smco mutants were analysed for growth on MM, CM (i.e. MM + 0.5% casamino acids + 0.5% yeast extract), MM plus NaCl and MM plus 2-100 µg/ml AHD fungicides to compare them with os mutants (Note: the ED_{50} and ED_{95} values for os mutants given in Neurospora Newsl. 29 were determined from growth on sorbose medium MS, i.e. NM + (1.5% sorbose + 0.2% sucrose; ED values are lower on MS than on MM).

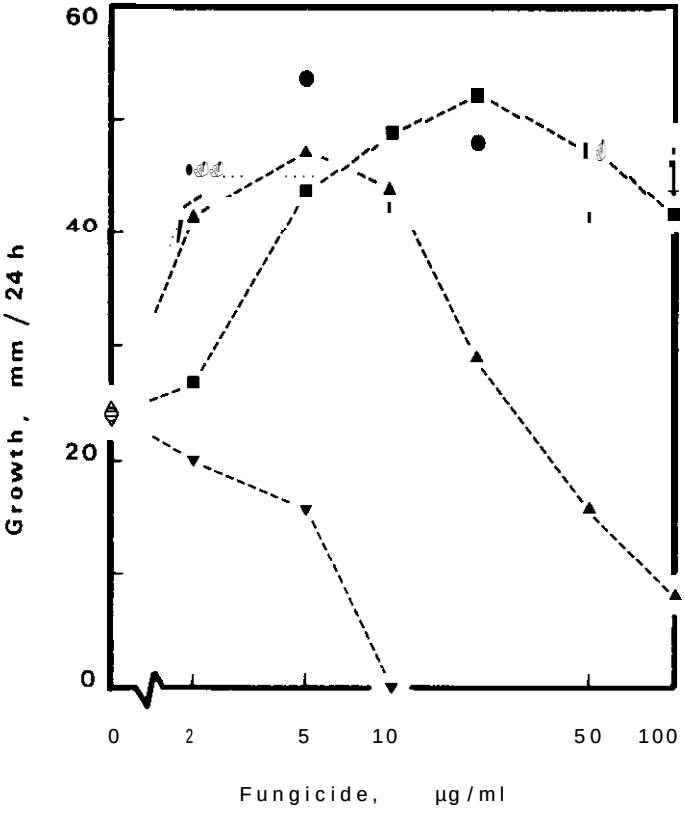

Figure 1. -- Effect of fungicides on growth of N. crassa mutant smco-2. Each point is the mean growth rate (increase in colony diameter at 26°C) of at least 3 replicates on MM containing dicloran ▲; iprodione ▼; viclozolin ■; or quintozene ●

The following mutants were sensitive as sensitive as the wild type to dicloran and vinclozolin and were not analysed further: locus cl (isolation number CL11); col-2 (Y5331); col-3 (Y5296); cot-2 (R1006t); cr-1 (B123); cr-2 (R2445); csp-1 (UCLA37); do (DS5-51): fr (B110): ain (637/3.4); gran (B42); le-i (c-M3); pat (no number); rg-1 (B53, 8187 and R2357); ro-1 (B4); ro-6 (R2431); ro-10 (AR7); sh (R2371); sn (C136); spco-5 (R2450); spco-9 (R2480); sp (1405); ti (8233).

Three smco mutants resembled some os mutants in their resistance to fungicides and sensitivity to CM and MM containing NaCl (Table I). The smco-2 mutant often grew better, and its morphology became more normal, on fungicide-supplemented MM (Figure 1). Some of our Vin mutants grow better on low levels of fungicide (i.e. about 1-3 µg/ml) than on MM but they differ from smco-2 in morphology and growth rate on MM.

We showed previously (Neurospora Newsl. 29) that resistance to AHD fungicides can result from mutations in four genes: os-1, os-4, os-5 on L.G. I and os-2 on L.G. IV. This report implicates three additional genes in AHD-resistance: smco-2 on L.G. III and smco-8 and smco-9 on L.G. IV (smco-8 and smco-9 may be closely linked to os-2 see Perkins et al. 1982. Microbial. Rev. 46: 426,470). Resistance of some mutants to the fungicides may be related to changes in cell wall composition: os-1 mutants have abnormal amounts of hexosamines and enlarged pores in their cell walls (Trevithick and Metzenberg 1966, J. Bacteriol. 92: 1016-1020); smco-8 and smco-9 have abnormal amounts of cell wall peptides (Wrathall and Tatum 1974. Biochem. Genet: 12: 59-78) and smco-9 might be defective in glucan biosynthesis (Abramsky and Tatum 1976, Biochim. Biophys. Acta 421: 106-114). However, most of the mutants with abnormal amounts of cell wall peptides (cot-2; cr-2; do; fr; gran; le-1; ro-1; spco-5; sp; ti see Wrathall and Tatum 1974) and a mutant with abnormal hexosamine content (do see Edson and Brody 1976, J. Bacteriol. 126: 799-805) are not resistant to fungicides. There is no correlation between known enzyme defects in morphological mutants (see Mishra 1977) and fungicide resistance: cr-2 (defective adenyl cyclase), csp-1 (defective cell wall autolysing enzyme), col-2 and fr (defective glucose-6.phosphate dehydrogenase), cot-3 (defective 6-phosphogluconate dehydrogenase) and rg-1 (defective phosphoglucomutase) are not resistant to AHD fungicides. The primary biochemical lesions in AHD-resistant mutants and the mode of aciton of AHD fungicides have yet to be elucidated.

We wish to acknowledge the courtesy of the Fungal Genetics Stock Center in supplying the strains.
--- Department of Genetics, The University, Sheffield S10 2TN, England.