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Effects of hydroxamic acids on the resistance of wheat to the aphid *Sitobion avenae*

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SUMMARY

Resistance to the aphid *Sitobion avenae* F. was assessed on six wheat cultivars of known concentrations of total hydroxamic acids. A range of values for intrinsic rate of increase (r_m) were obtained, 96% of the variation in which was explained by acid concentrations. Of the components of r_m, age-specific fecundity was the most significant factor contributing to resistance.

INTRODUCTION

Sitobion avenae F. is a sporadically damaging pest of wheat in temperate climates (George & Gair, 1979; Vickerman & Wratten, 1979; Carter, McLean, Watt & Dixon, 1980). Wheat extracts contain hydroxamic acids (Hx) (Willard & Penner, 1976) which have been shown to be important in resistance against insects in several Gramineae (Klun, Tipton & Brindley, 1967; Klun, Guthrie, Hallauer & Russell, 1970; Long, Dunn, Bowman & Routley, 1977; Beck, Dunn, Routley & Bowman, 1983). The most abundant of these acids in wheat is 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA). This compound has also been shown to be involved in the resistance of several wheat cultivars to the aphid species *Metopolophium dirhodum* (Wlk.), *Schizaphis graminum* (Rond.) and *Rhopalosiphum maidis* (Fitch) (Corcuera, Argandoña & Niemeyer, 1982), but *S. avenae* has not been investigated in this context.

The main objective of this investigation was to assess a range of wheat cultivars, previously assessed for hydroxamic acid levels, in order to measure and rank them for antibiotic resistance to *S. avenae*. Any correlations between aphid performance and acid levels would have implications for future screening of wheat material against this important European pest.

MATERIALS AND METHODS

Seed samples of six wheat cultivars representing a range of known Hx levels were grown under permanent light at *c.* 26 °C with a 10 °C range in a glasshouse at the University of Chile, and harvested at the two-leaf stage (G.S. 12; Zadoks, Chang & Konzak, 1974). A portion, 1·5 g, of the plant tissue (10–15 plants) was then macerated with a mortar and pestle in water (6 ml total volume), filtered through cheesecloth and left for 15 min at room temperature. The extract was adjusted to pH 3 with 1 M HCl and centrifuged at 10 000 *g* for 10 min. The supernatant was extracted three times into equal volumes of ethyl ether and the organic phases were evaporated to dryness. Hx form a blue complex (λ_{max} = 590 nm) upon the addition of ferric chloride reagent (50 g $FeFl_3.6H_2O$, 500 ml 95% ethanol and 5 ml 15 M HCl). The concentration of Hx in the tissues was determined by comparing the absorbance of extracts

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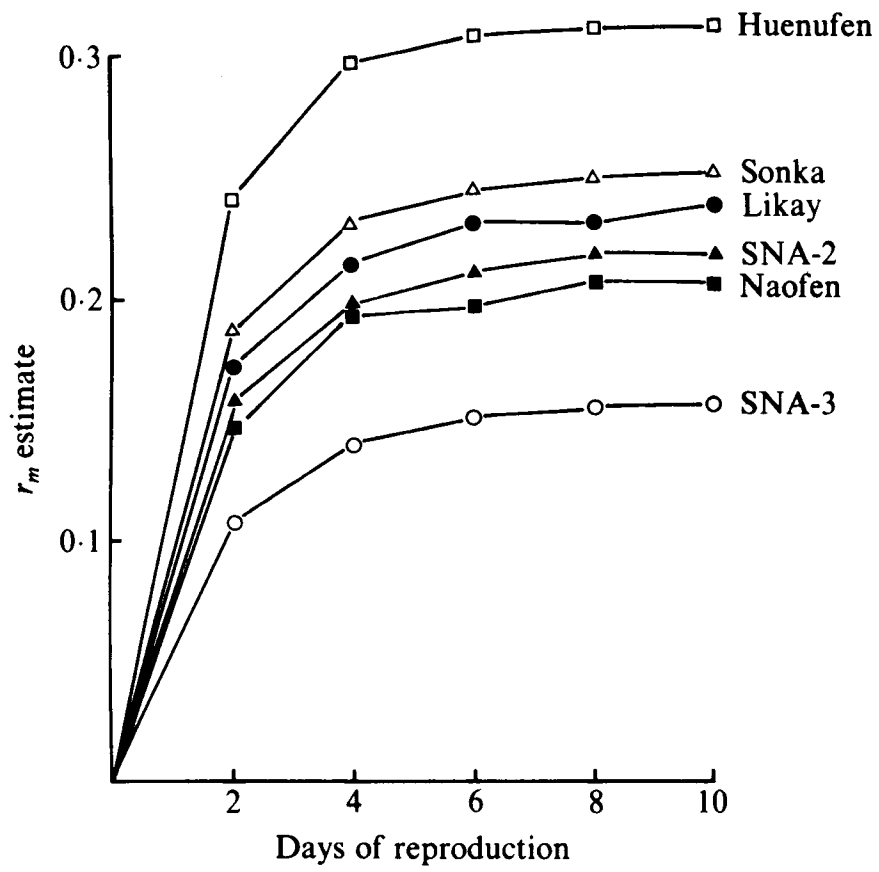


Fig. 1. Effect of assessment period on the estimate of intrinsic rate of natural increase (r_m) of *Sitobion avenae* on six wheat cultivars.

with a standard curve made with DIMBOA. The procedure was tested by adding DIMBOA to an Hx-lacking barley cultivar (cv. Fola Union – see Argandoña, Luza, Niemeyer & Corcuera, 1980). Recovery of DIMBOA was 100%. DIMBOA had previously been isolated from 7-day old seedlings of maize (cv. T 129S) by the method of Queirolo, Andreo, Niemeyer & Corcuera (1983). The names of the cultivars assessed are given in Fig. 1.

For assessment of aphid performance at Southampton, seeds of the same cultivars were planted singly in 5-cm diam. polystyrene pots containing John Innes No. 2 seed compost and were germinated in a glass-house at a temperature of 20 °C with an 8 °C range and a minimum 16 h photoperiod. They were transferred after *c.* 5 days to a culture room based on the design of Scopes, Randall & Biggerstaff (1975). They were kept at 20 °C with a 2 °C range, 60–70% r.h. and 16 h photoperiod. Light intensity was 75 μE m^{-2} s^{-1}.

Stock cultures of *S. avenae* were clonal, originating from a single parthogenetic female collected in Hampshire, UK, in 1984 and were maintained on wheat (cv. Hobbit) in the culture room under the above conditions. Adult apterous viviparae of unknown age were placed individually on the test seedlings (30 of each cultivar) which were at the two-leaf stage; these were then covered with transparent plastic cylinders 20 cm high with a Terylene mesh top. These aphids were left for 24 h to reproduce and then removed together with all but two first-instar nymphs. The latter were left undisturbed until they moulted to the adult stage, but were checked daily during this period. One was them removed and the daily fecundity of the remaining singly-caged aphids (up to 30 on each cultivar) was recorded for 10 days. Progeny of these were removed daily, using a fine paint brush, during the same 2 h period each day.

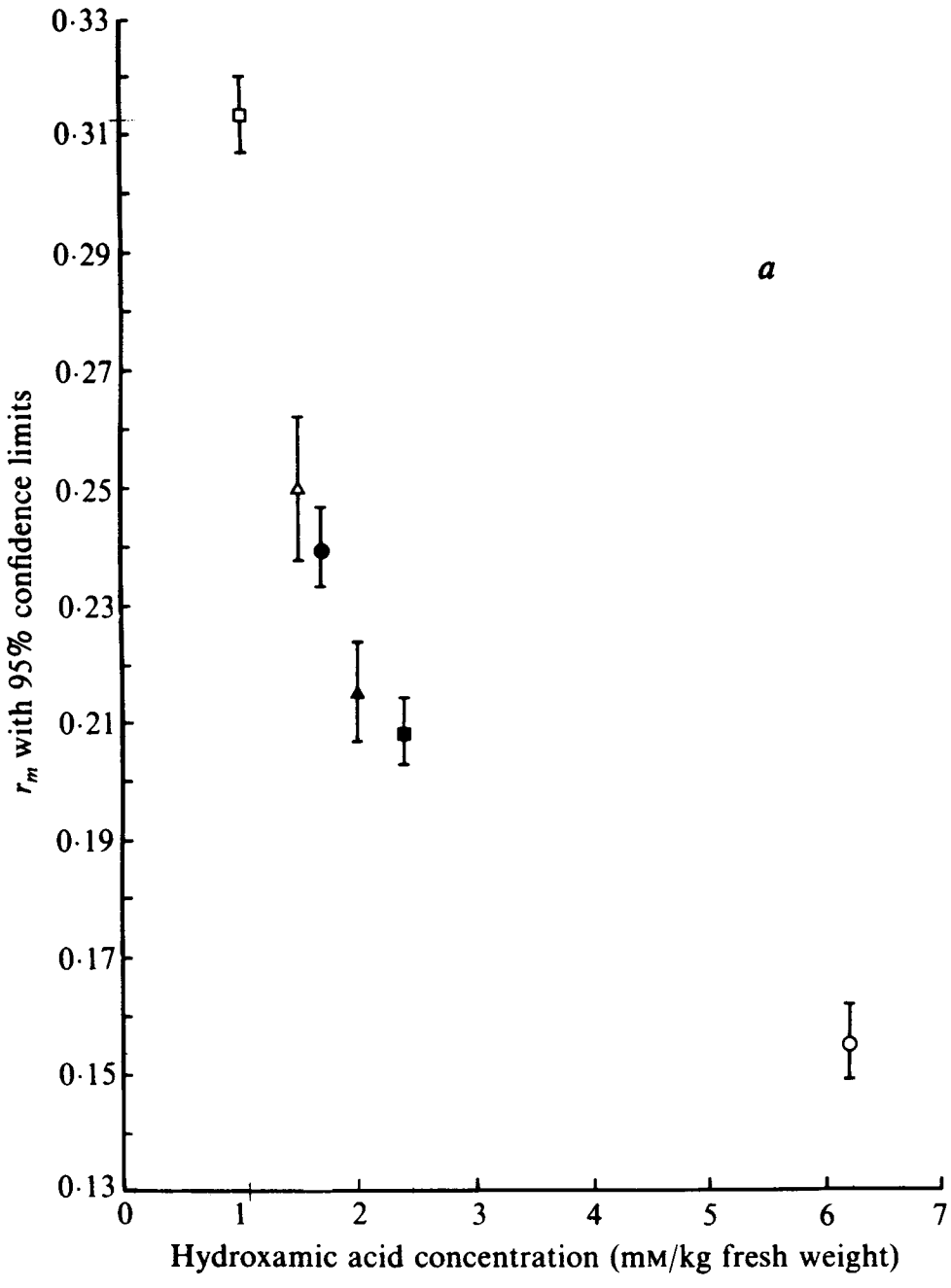
The intrinsic rate of natural increase (r_m; Birch, 1948) was calculated for the aphids on each cultivar using a program incorporating the 'Jack-knife' technique to calculate the standard error (Miller, 1974; Bissell, 1977; Birch & Wratten, 1984). Age-specific survival (l_x), and age-specific fecundity (m_x) were also computed.

RESULTS AND DISCUSSION

Estimates of r_m were calculated at daily intervals. On all cultivars, nymph production during the first few days of reproduction contributed most to the value of r_m (Fig. 1), a pattern similar to those found for other aphid species (e.g. Wyatt & White, 1977; Birch & Wratten, 1984). Values of r_m based on 10 days' recording were used in subsequent analysis.

There was a highly-significant negative relationship between the r_m value achieved on the cultivars and the concentration of hydroxamic acids in their tissues; the proportion of the variation in r_m values explained by acid levels was up to 96%, depending on whether the variables were arithmetic (Fig. 2*a*), or one, or both (Fig. 2*b*) variables, were logarithmically transformed. The confidence limits for r_m were very low; however, the parallel inter-plant chemical variation could not be calculated because of the bulking of samples needed to provide 1·5 g of plant tissue (see Methods).

Of the components of r_m, mortality did not begin on any cultivar until 16 days after birth (Fig. 3); this was well after the highest daily fecundity had been reached (8–12 days after birth). This pattern agrees with that found by Frazer (1972) for two aphid species on *Vicia faba* L. cultivars. In other work, where a wider taxonomic range of plant material has been



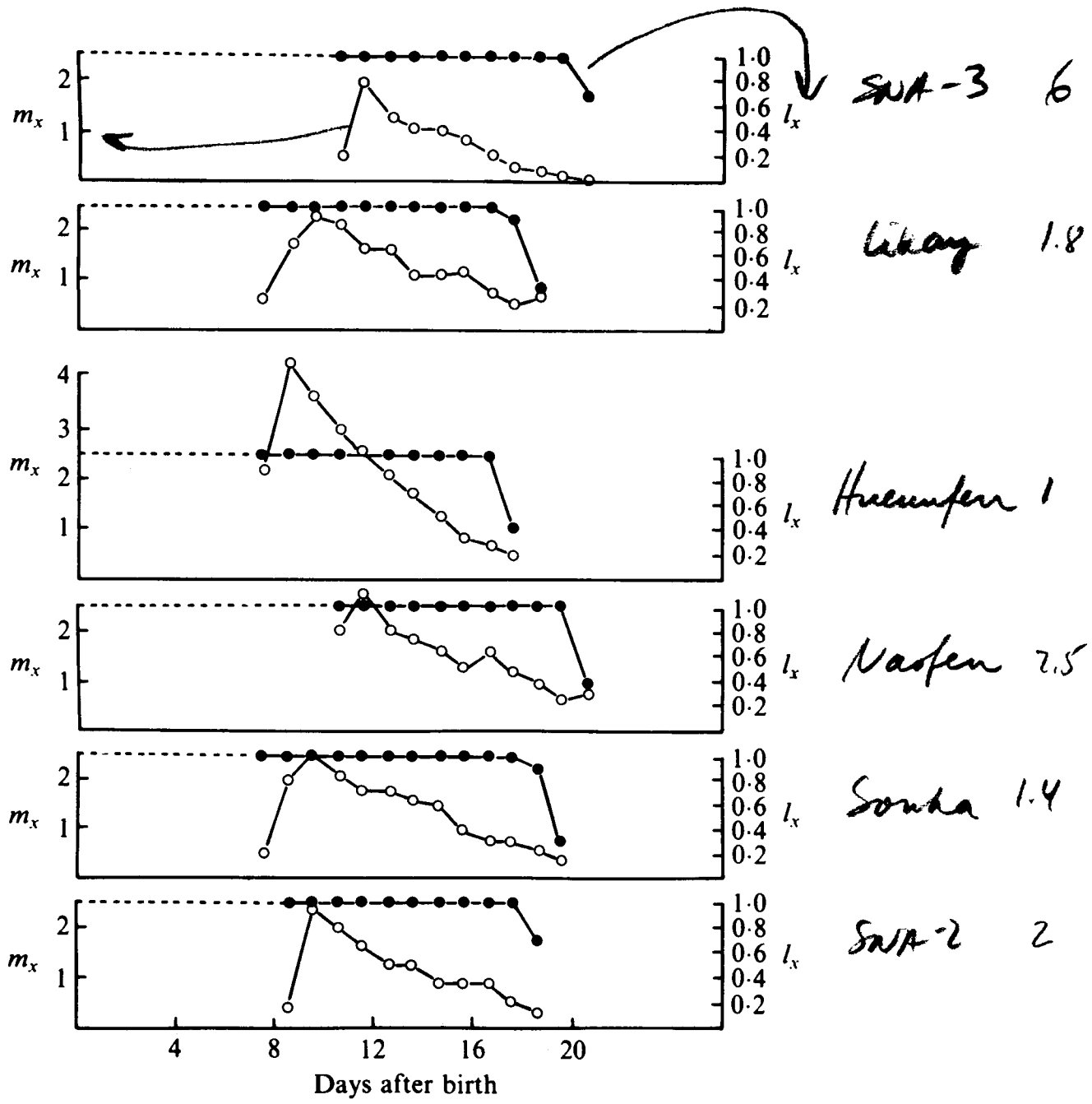


Fig. 3. Changes in age-specific fecundity (m_x, ○) and age-specific survival (l_x, ●) for the six cultivars (top to bottom): SNA-3, Likay, Huenufen, Naofen, Sonka, SNA-2.

REFERENCES

ARGANDOÑA, V. H., LUZA, J. G., NIEMEYER, H. M. & CORCUERA, L. J. (1980). Role of hydroxamic acids in the resistance of cereals to aphids. *Phytochemistry* **19**, 1665–1668.

ARGANDOÑA, V. H., NIEMEYER, H. M. & CORCUERA, L. J. (1981). Effect of content and distribution of hydroxamic acid in wheat on infestation by the aphid *Schizaphis graminum*. *Phytochemistry* **20**, 673–676.

BECK, D. L., DUNN, G. M., ROUTLEY, D. G. & BOWMAN, J. S. (1983). Biochemical basis of resistance in corn to the corn leaf aphid. *Crop Science* **23**, 995–998.

BIRCH, L. C. (1948). The intrinsic rate of natural increase of an insect population. *Journal of Animal Ecology* **17**, 15–26.

BIRCH, N. & WRATTEN, S. D. (1984). Patterns of aphid resistance in the genus *Vicia*. *Annals of Applied Biology*, **104**, 327–328.

BISSELL, A. F. (1977). The Jack-Knife. *Bias* **4**, 55–64.

CARTER, N., MCLEAN, I. F. G., WATT, A. D. & DIXON, A. F. G. (1980). Cereal aphids – a case study and review. *Applied Biology* **5**, 271–348.

CORCUERA, L. J., ARGANDOÑA, V. H. & NIEMEYER, H. M. (1982). Effect of cyclic hydroxamic acids from cereals on aphids. In *Chemistry and Biology of Hydroxamic Acids*, pp. 111–118. Ed. H. Kehl. Karger, Basel.

FRAZER, B. D. (1972). Life tables and intrinsic rates of increase of apterous black bean aphids and pea aphids on broad beans (Homoptera: Aphididae). *Canadian Entomologist* **104**, 1717–1722.

GEORGE, K. S. & GAIR, R. (1979). Crop loss assessment on winter wheat attacked by the grain aphid, *Sitobion avenae* (F.) 1974–1977. *Plant Pathology* **28**, 143–149.

KLUN, J. A., TIPTON, C. L. & BRINDLEY, T. A. (1967). 2,4-dihydroxy-7-methoxy-1,4-benzoxazin-3-one (DIMBOA), an active agent in the resistance of maize to the European corn borer. *Journal of Economic Entomology* **60**, 1529–1533.

KLUN, J. P., GUTHRIE, D. D., HALLAUER, A. R. & RUSSELL, W. A. (1970). Genetic nature of the concentration of 2,4-dihydroxy-7-methyl-1,4-benzoxazin-3(4H)-one and resistance to the European corn borer in a diallel set of eleven maize inbreds. *Crop Science* **10**, 87–90.

LONG, B. J., DUNN, G. M., BOWMAN, J. S. & ROUTLEY, D. G. (1977). Relationship of hydroxamic acid content in corn and resistance to the corn leaf aphid. *Crop Science* **17**, 55–58.

MILLER, R. G. (1974). The jack-knife, a review. *Biometrika* **61**, 1–15.

QUEIROLO, C. B., ANDREO, C. S., NIEMEYER, H. M. & CORCUERA, L. J. (1983). Inhibition of ATPase from chloroplasts by a hydroxamic acid from the Gramineae. *Phytochemistry* **22**, 2455–2458.

SCOPES, N. E. A., RANDALL, R. E. & BIGGERSTAFF, S. M. (1975). Constant temperature ventilated perspex cage for rearing phytophagous insects. *Laboratory Practice*, January 1975, 33–34.

VICKERMAN, G. P. & WRATTEN, S. D. (1979). The biology and pest status of cereal aphids in Europe: a review. *Bulletin of Entomological Research* **69**, 1–32.

WILLARD, J. I. & PENNER, R. (1976). Benzoxazinones: cyclic hydroxamic acids found in plants. *Residue Reviews* **64**, 67–76.

WYATT, I. J. & WHITE, P. F. (1977). Simple estimation of intrinsic rates of increase for aphids and tetranychid mites. *Journal of Applied Ecology* **14**, 757–766.

ZADOKS, J. C., CHANG, T. T. & KONZAK, C. F. (1974). A decimal code for the growth stages of cereals. *Weed Research* **14**, 415–421.

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