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EFFECT OF BORATE ON THE DECOMPOSITION OF 2,4-DIHYDROXY-7-METHOXY-1,4-BENZOXAZIN-3-ONE, A HYDROXAMIC ACID FROM GRAMINEAE

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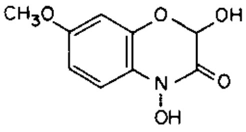
Abstract — Borate anion catalyzed the decomposition of the title compound, a resistance factor of Gramineae. The effect was attributed to the formation of a complex between borate and the open-chain hydroxamic acid intermediate in the decomposition reaction.

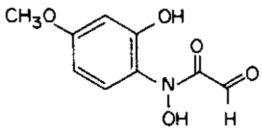
Cyclic hydroxamic acids isolated from extracts of Gramineae (Hx) play an important role in the defense of the plant against insects.[1,2] In addition, they exhibit toxic effects towards several bacteria[3] and fungi[4], and have been reported as mutagenic to bacteria.[5] While studying the aqueous decomposition of DIMBOA, 1, the main Hx in wheat and maize extracts, a catalytic effect by borate buffer was observed. In this paper this effect is described and an interpretation of its origin suggested.

The decomposition of DIMBOA was monitored spectrophotometrically at 290 nm. The main decomposition product was 6-methoxy-benzoxazolin-2-one. First order rate constants were calculated using a linear-regression computer program.[6] Analogues of DIMBOA were synthesized according to reported methods.[7,8]

The catalytic effect of borate is shown in Fig. 1. Hydroxamic acids have been shown to interact with borate.[9] However, DIMBOA decomposes with the intermediacy of the open-chain hydroxamic acid 2.[8,10,11] In order to determine which of these two hydroxamic acids interacts with borate, model compounds 3 and 4 were synthesized and their spectra recorded (Fig. 2).



DIMBOA **1**



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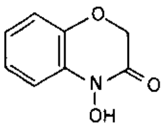

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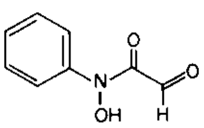

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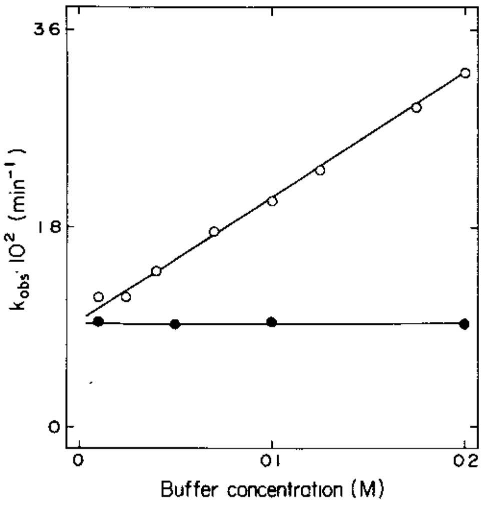


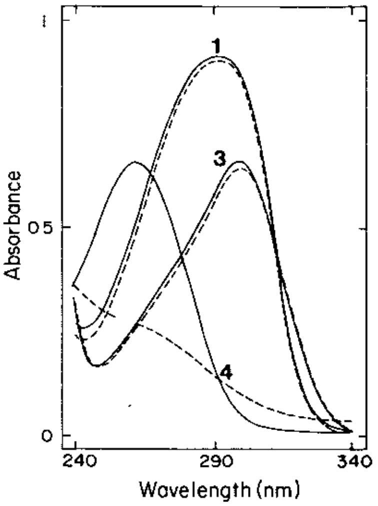
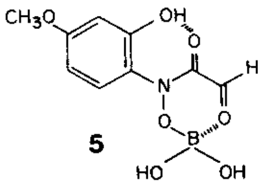


Fig. 1. Effect of borate ( ) and phosphate ( ) pH 9 on the rate of decomposition of DIMBOA ($8\ 10^{-5}$ M) at 31°.

Fig. 2. Absorption spectra of $8\ 10^{-5}$ M solutions of compounds **1**, **3** and **4** in 0.1 M phosphate (---) and borate (---) pH 9 buffers.

Fig. 2 shows that while the optical density of **4** at 260 nm substantially increased in borate as compared with phosphate buffer, the absorption peaks of **1** and **3** at 290 and 300 nm respectively, were not affected. These results indicate that only compound **4** interacts with borate, and give support to the proposal of complex formation between the open-chain form of DIMBOA, **2**, and borate. This complex was not detected in the spectrum of DIMBOA presumably due to the low equilibrium concentration of **2**.[12]

The structure of the complex can not be similar to that reported for other hydroxamic acids,[9] since no enolizable hydrogen is present in **2**. However, analogous interaction of borate with the hydroxamic hydroxyl moiety leads to structures **5** and **6**. From a thermodynamic viewpoint, complex **5** would be favored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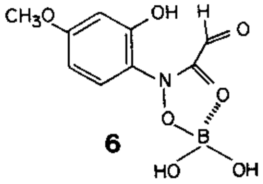
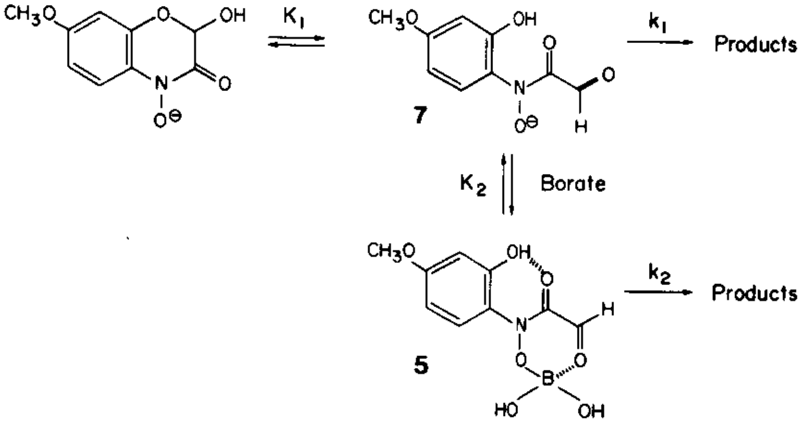

6

since it involves the formation of a 6-membered ring and is further stabilized by intramolecular hydrogen bonding.

The fact that cyclic hydroxamic acids 1 and 3 do not show interaction with borate may be rationalized on the basis of interatomic distances. The distance between the hydroxamic hydroxyl oxygen and the carbonyl oxygen has been determined crystallographically as 2.84 A in the analogue of DIMBOA lacking the 7-methoxy group.[13] This distance is 0.49 A longer than the O-O distance in boric acid. Thus, the formation of a complex of type 6 is less likely on this basis, and also because it would necessarily lead to a 5-membered ring.

The following scheme is hence postulated for the decomposition of DIMBOA in the presence of borate pH 9:



Under steady-state conditions, equation 1 is obtained.[14] This may be reduced to equation 2, in which k_{obs} and $k°_{obs}$ are the observed rate constants in the

$$v = \frac{K_1}{1 + K_1}(\mathrm{DIMBOA})\left[k_1 + k_2K_2(\mathrm{Borate})\right] \qquad (1)$$

$$\frac{v}{(\mathrm{DIMBOA})} = k_{obs} = k°_{obs} + k_{cat}(\mathrm{Borate}) \qquad (2)$$

presence and absence of borate. This model fits the experimental results shown in Fig. 1, with a catalytic constant, k_{cat}, equal to 0.103 $min^{-1}\ M^{-1}$.

The formation of products from intermediate 2 (or 5) involve the nucleophilic attack of the hydroxamic oxygen atom on the aldehydic carbonyl group.[10,11] The catalytic effect of borate may arise from both thermodynamic and kinetic factors. Since an open-chain intermediate is necessary for reaction, the displacement of equilibria towards this compound via formation of borate complex **5** favors the reaction. On the other hand, complex **5** is presumably more reactive than **7** on entropic grounds (reactive groups are held in suitable position for reaction) as well as on enthalpic grounds (strong polarization by boron of the aldehydic carbonyl group).

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14 In this equation, total concentration of DIMBOA has been used. DIMBOA is a diprotic acid with pK_a's of 6.9 and 10.9.[15] Since at pH 9 the mono-anion corresponds to 99.7% of total DIMBOA, the error involved in this equation is negligible.

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