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Foliar sprays of NPK fertilizers induce systemic protection against *Puccinia sorghi* and *Exserohilum turcicum* and growth response in maize

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Abstract

One spray of 0.1 M aqueous solutions of NPK fertilizers on the upper sides of maize leaves 1, 2, and 3, 2–4 h prior to inoculation, induced systemic resistance (ISR) against northern leaf blight (NLB) caused by *Exserohilum turcicum* and *Puccinia sorghi* which were developed on leaves 4, 5, 6, and 7. ISR was expressed as a reduction in the number and area of lesions of *E. turcicum* and in the number of sporulating or non-sporulating pustules of *P. sorghi* on leaves 4, 5, 6, and 7. The reduction in the number of NLB lesions ranged from 51% (KH_2PO_4) to 69% (K_2HPO_4) and their size reduction ranged from 73% (KNO_3) to 91% (K_2HPO_4) as compared with water prayed plants. The reduction in the number of pustules of *P. sorghi* ranged from 66 to 77%. Fertilizers consisting of various combinations of N, P and K in every case induce similar levels of protection in either host-pathogen system. The induced protection was evident regardless of the leaf position or the rate of NPK accumulation in the upper protected leaves. High fresh weight was detected in the induced plants which expressed the greatest induced protection against NLB and common rust. The possible dual use of NPK fertilizers – to supply nutrients to plants foliarly and at the same time to activate the mechanism(s) for induction of systemic protection to *P. sorghi* and *E. turcicum* in maize – is discussed.

Introduction

It is well established that resistance can be systemically induced in plants which lack the gene for resistance by inoculation with non-pathogens or restricted inoculation with pathogens or chemicals, including phosphates [Doubrava et al., 1988; Descalzo et al., 1990; Ye et al., 1995]. Induced systemic resistance (ISR) as an alternative method for disease control may provide a promising solution for the control of diseases in various agricultural crops [Tuzun et al., 1986; Biles and Martyn, 1989; Cantone and Dunkle, 1990; Conti et al., 1990].

In maize, Cantone and Dunkle [1990] reported that an inoculation with a non-pathogenic race of *Helminthosporium carbonum* induced resistance to the pathogenic race. Until recently, the relatively common occurrence of this phenomenon provided no evidence for induction of resistance in maize against other diseases, either by microorganisms or chemicals.

In support of the hypothesis that mechanism(s) for resistance are present in susceptible plants, that systemic resistance can be induced by simple inorganic or organic chemicals, and that this induced resistance is not specific [Mucharromah and Kuc', 1991], we have recently reported that phosphate spray increases growth and induces systemic protection against *S. fuliginea* in cucumbers [Reuveni, M. et al., 1993]. Similar data were reported for *P. sorghi* and *E. turcicum*, the causal organisms of common rust and northern leaf blight (NLB) in maize, respectively [Reuveni, R. et al., 1993; Reuveni, R. et al., 1994a; 1994b]. Interestingly, potassium phosphate has recently been identified as the active component in the earlier papilla formation and resistance of barley to powdery mildew [Inoue et al.,

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1994]. The objectives of the present paper are: (a) to screen the possible dual use of several NPK fertilizers as foliar spray to induce systemic protection against a facultative parasite *E. turcicum* and an obligate parasite *P. sorghi*, and to enhance growth in maize plants; (b) to investigate the relationship between total NPK elements in the upper leaves of induced plants and their resistance to both pathogens.

Materials and methods

Plants. Sweet corn inbred plants (*Zea mays* L. cv. Jubilee) were grown in a greenhouse in 10-cm-diameter plastic pots containing peat, soil and vermiculite (1:1:1, v/v).

Induction of systemic protection and growth increase. Plants at the 5–7 fully expanded leaf stage were used in all experiments, unless stated otherwise. Aqueous solutions of 100 mM of K_2HPO_4 (pH 9.4), KH_2PO_4 (pH 4.5), KH_2PO_4 (pH 9.3 adjusted with KOH), $NH_4H_2PO_4$ (pH 9.4), KCl, KNO_3 or K_2SO_4 and water as a control (all with 0.5 ml/l of Tween-20), were prepared and used for induction. This concentration was found to be the most effective in inducing systemic resistance against both diseases, while causing no damage to the treated leaves. The upper surfaces of leaves 1, 2 and 3 (unless stated otherwise) were sprayed to run-off with the fertilizers solution or water (with Tween-20). To avoid contamination, other parts of the plant and the pot were covered. The treated plants were kept for 2–4 h under greenhouse conditions (16–20 °C during the night and 22–23 °C during the day, 14 h of light per day) and were then challenged with a suspension of uredospores of *P. sorghi* or conidial suspension *E. turcicum* and transferred to separate growth chambers. Plants from some of these experiments were also used to determine the effect of fertilizers on the growth increase in maize plants.

Pathogens and inoculation. Isolates of *P. sorghi* and *E. turcicum*, obtained from plants in a field, were maintained on maize plants grown in a growth chamber. Inoculum was collected from freshly sporulating infected leaves 9–12 days after inoculation or from uredospores of *P. sorghi* which had previously been kept in a freezer. Uredospores and/or conidia were gently brushed into a small quantity of distilled water containing two drops of Tween-20 and counted with the aid of a hemocytometer to give a suspension of a known concentration of spores per milliliter. For inoculation, the upper surfaces of the upper leaves (4–7, unless stated otherwise) of each plant were uniformly sprayed to run-off with a spore suspension delivered from a glass hand sprayer. After inoculation, plants were incubated in a dew chamber at 20 °C for 24 h in darkness. Plants were then kept in a growth chamber (24 °C, 120 μmol.m^{-2}.sec^{-1}, 16 h of light per day) for disease development. The non-inoculated control plants were kept under similar conditions in a separate growth chamber, in order to avoid contamination.

Assessment of induced protection and growth increase. Induced systemic protection was determined by counting the number of pustules of common rust produced on each individual upper leaf. Six to 14 days after inoculation, the maximum pustule development was usually evident, and data obtained at this time are reported.

For NLB, the number of lesions was recorded, and the length and width of each lesion were measured and its area was calculated. Protection is expressed as the reduction of the number of lesions and their areas on each individual upper leaf and on each plant. Eight to 14 days after inoculation the number of lesions and their areas had reached the maximum, and data obtained at this time are reported for each set of experiments. The effect on growth increase was determined at the end of each experiment by measuring the fresh and dry weight of each plant after it had been cut at the base of the stem. Eight plants were used per treatment and each experiment was repeated three times. An analysis of variance (ANOVA) was performed to analyze the data, and significance was determined according to Duncan's Multiple Range Test.

Determination of total accumulation of N, P, and K on the upper leaves. Upper leaves were detached at various intervals after the spray induction from water-sprayed control, inoculated and non-inoculated, treated and non-treated plants. Leaves were oven-dried (70 °C for 3 days) and 0.2 gram of tissue was added to 4 ml of H_2SO_4. The Nessler, ammonium molybdate-sulfuric acid reagent and the flame-photometric procedures were performed to determine the accumulation of N, P and K elements, respectively, in these leaves [Chapman and Pratt, 1961]. Usually, six leaves obtained from six plants of each treatment were used for analysis at each time interval. Data were analyzed and presented as the percentage of each element in the dry weight.

Field experiment. The experiment was conducted in Newe-Yaar Research Center and consisted of 20 plants per treatment and each treatment was replicated four times in a complete block design. In this experiment, young maize (cv Jubilee) plants (8–10 leaf stage) were sprayed to run-off five times at weekly intervals with 100 mM of each of the phosphates. Disease on naturally infected plants was rated by counting the number of pustules of *P. sorghi* produced on each of eight plants per replicate and treatment 21, 28 and 35 days after the first application.

Results

Induced systemic protection against northern leaf blight (NLB). A single foliar spray of 100 mM of various NPK salts and fertilizers on the upper surfaces of the lower leaves (1, 2, 3) induced systemic protection on the upper leaves (4, 5, 6) (Figure 1A+B). At 8 days after challenge inoculation with *E. turcicum*, protection was expressed as the reduction in the total number of NLB lesions, which ranged from 51% (KH_2PO_4, pH 4.5) to 69% (K_2HPO_4) (Figure 1A) and also in reduction of lesion area which ranged from 73% (KNO_3) to 91% (K_2HPO_4) (Figure 1B) as compared with water-sprayed plants. However, the extents of the reductions in the number of lesions (30–51%) and their size (52–65%) were lower 11 days after the inoculation (Figure 1A+B). Analysis of variance for the number and the area of NLB lesions indicated that, eventually, the systemic protection was noticeable on each of leaves 4, 5 and 6; this was demonstrated for each of the NPK fertilizers and salts which were applied 2–4 h before inoculation with *E. turcicum* (Tables 1, 2). Similar results were obtained when older maize plants were used. In this case, NPK fertilizers were sprayed on leaves 3, 4 and 5 (induction) and systemic protection against NLB, expressed in reduction in lesion area, was evident on the upper leaves (6, 7 and 8) (Figure 2A+B).

Induced systemic protection to common rust. A remarkable systemic protection, expressed as a reduction in the total number of pustules of *P. sorghi* which developed on the maize upper leaves (4, 5 and 6), was induced by one spray of 100 mM of each of various NPK fertilizers on the lower leaves (1, 2 and 3) (Figure 3A). Systemic protection was expressed as a reduction of 67–77% in the total number of pustules, as compared with water-sprayed plants (Figure 3A). The systemic protection was noticeable and significant on each of leaves 4, 5 and 6 (Figure 3B). Leaf 6 was the most protected one (76–90%) under all treatments. As in the case of protection against NLB, older maize plants showed a high significant systemic protection to common rust on leaves 9 and 10 when leaves 5 and 6 were sprayed with 100 mM of each of various salts (Table 3). A total reduction in the number of pustules was observed when induction by K_2SO_4 and $NH_4H_2PO_4$ was performed 2 h before inoculation with a low concentration of conidial suspension of *P. sorghi* (Table 3).

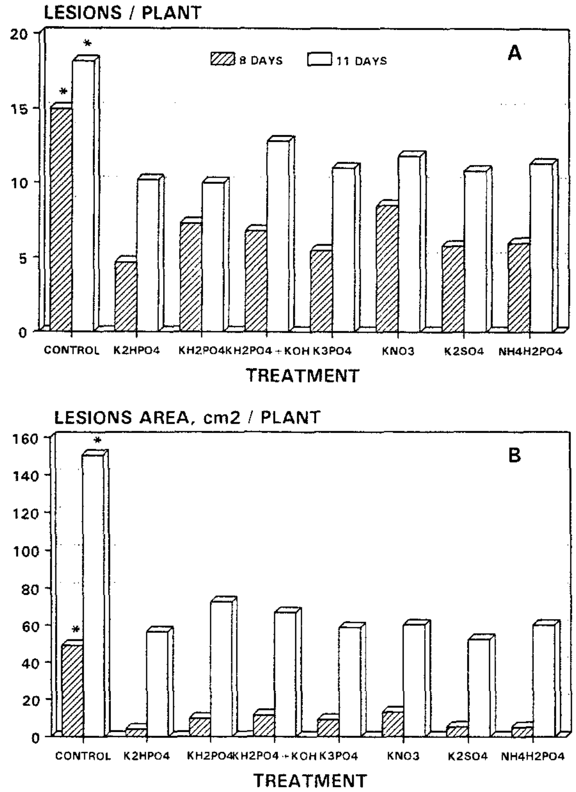

Figure 1. Induced systemic resistance to *Exserohilum turcicum* in maize plants by a foliar spray of NPK salts and fertilizers. (A) Number of NLB lesions; (B) NLB lesion areas. A solution of 100 mM of each of the salts was sprayed to run-off on the upper surfaces of the lower leaves 1, 2 and 3. As control treatment, water (with Tween-20) was sprayed on leaves 1–3. Two to 4 h after the spray, plants were challenged on leaves 4, 5 and 6 with a suspension of 2.5×10^4 conidia of *E. turcicum* per milliliter. The total number (A) and the total area (B) of lesions were recorded 8 and 11 days after inoculation and expressed per plant. Data represent the means of total lesions developed on leaves 4–6 of each of eight plants per treatment/experiment, and each experiment was repeated three times. Asterisks on the bars indicate a significant difference ($P < 0.05$) according to Duncan's Multiple Range Test.

The effect on growth. Total fresh and dry weight of the plants increased as a result of a single spray of

Table 1. Induced systemic protection against *Exserohilum turcicum* in maize plants by a foliar spray of each of various NPK salts and fertilizers

Treatment[1]	Mean number of NLB lesions on each of upper leaves					
	8 days			11 days		
	Leaf 4	Leaf 5	Leaf 6	Leaf 4	Leaf 5	Leaf 6
Control-water	3.7 a[2]	7.7 a	3.7 a	4.8 b	8.5 a	4.8 a
K_2HPO_4	1.5 ab	2.3 b	0.8 b	3.3 ab	4.0 b	2.8 ab
KH_2HPO_4	0.8 b	4.0 b	2.5 ab	1.3 c	5.5 b	3.2 b
KH_2HPO_4+KOH	1.0 b	3.7 b	2.2 ab	3.2 b	6.7 ab	3.0 ab
K_3PO_4	1.3 ab	2.5 b	1.7 ab	3.7 ab	5.0 b	3.5 ab
KNO_3	2.2 ab	4.5 b	1.8 ab	4.0 ab	4.3 b	2.3 b
K_2SO_4	1.8 ab	2.3 b	1.7 ab	3.3 ab	4.3 b	3.2 b
$NH_4H_2PO_4$	1.7 ab	2.5 b	1.8 ab	2.5 bc	5.5 b	3.3 b

[1] See footnote in Figure 1.
[2] Mean numbers within a column followed by different letters are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test).

Table 2. Induced systemic protection against *Exserohilum turcicum* in maize plants by a foliar spray of each of various NPK salts and fertilizers

Treatment[1]	Mean number of NLB lesion area (cm^2) on each of upper leaves					
	8 days			11 days		
	Leaf 4	Leaf 5	Leaf 6	Leaf 4	Leaf 5	Leaf 6
Control-water	11.0 a[2]	26.0 a	12.3 a	34.3 a	91.0 a	25.3 a
K_2HPO_4	1.7 b	2.0 b	0.7 b	16.7 b	27.7	12.2 ab
KH_2HPO_4	0.8 b	5.5 b	3.7 b	7.7 b	45.3 b	19.7 ab
KH_2HPO_4+KOH	1.7 b	6.0 b	4.0 b	12.8 b	43.0 b	11.2 b
K_3PO_4	2.2 b	5.0 b	2.2 b	13.6 b	33.0 b	12.0 ab
KNO_3	4.0 b	7.0 b	2.3 b	14.3 b	32.3 b	13.7 ab
K_2SO_4	1.2 b	2.5 b	1.8 b	17.3 b	24.3 b	11.2 b
$NH_4H_2PO_4$	1.3 b	2.3 b	1.7 b	13.8 b	31.7 b	14.5 ab

[1] See footnote in Figure 1.
[2] See footnote in Table 1.

each of the NPK fertilizers (Figure 4, fresh weight not presented). In most cases, higher dry and fresh weights were found in induced inoculated or non-inoculated plants than in non-induced plants, although the differences were not significant (Figure 4). In general, the application of the NPK fertilizers increased plant growth regardless of the rate of infection with *E. turcicum*.

Total accumulation of N, P, and K in the upper leaves. Throughout all our experiments, analysis of the content of N, P and K in the upper leaves following a foliar spray on the lower leaves indicated that no difference in accumulation of any of them was detected in the various treatments. In the first experiment, K_2HPO_4 was applied to lower leaves (2–4) on various days before inoculation of the upper leaves (5–7) with *E. turcicum*. The systemically protected leaf 6 was analyzed for the content of N, P and K at the end of the experiment (14 days after inoculation). We found that the content of each of the elements was similar following the various treatments and did not significantly differ from that in water-sprayed control plants. In another set of experiments, similar results were obtained 48 h after induction with various NPK salts and fertilizers on the lower leaves (Figure 5).

Although it seems that foliar spray of KH_2PO_4 has no effect on the total elemental concentration of Ca in the dry tissue of the upper leaf (6 or 7) of the control plants, this treatment has stabilized the Ca content in both the protected (induced) and challenged plants, as compared withthe control inoculated plants, at 72 h

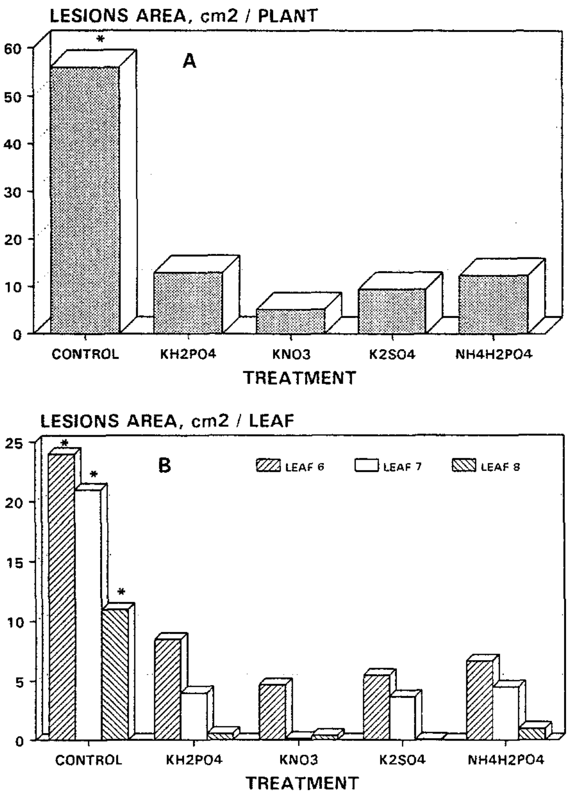

Figure 2. Systemic protection against *Exserohilum turcicum* induced in maize plants by a foliar spray of NPK salts and fertilizers. A solution of 100 mM of each of the salts was sprayed to run-off on the upper surfaces of the lower leaves 3, 4, and 5. As control treatment, water (with Tween-20) was sprayed on leaves 3–5. Two to 4 h after the spray, plants were challenged on leaves 6, 7 and 8 with a suspension of 1.5×10^4 conidia of *E. turcicum* per milliliter. The total areas of lesions were recorded 11 days after inoculation and expressed per plant (A) or per each leaf (B). Data represent the means of total area in square centimeter of lesions developed on leaves 6–8 of each of eight plants per treatment/experiment, and each experiment was repeated three times. Asterisks on the bars indicate a significant difference ($P < 0.05$) according to Duncan's Multiple Range Test.

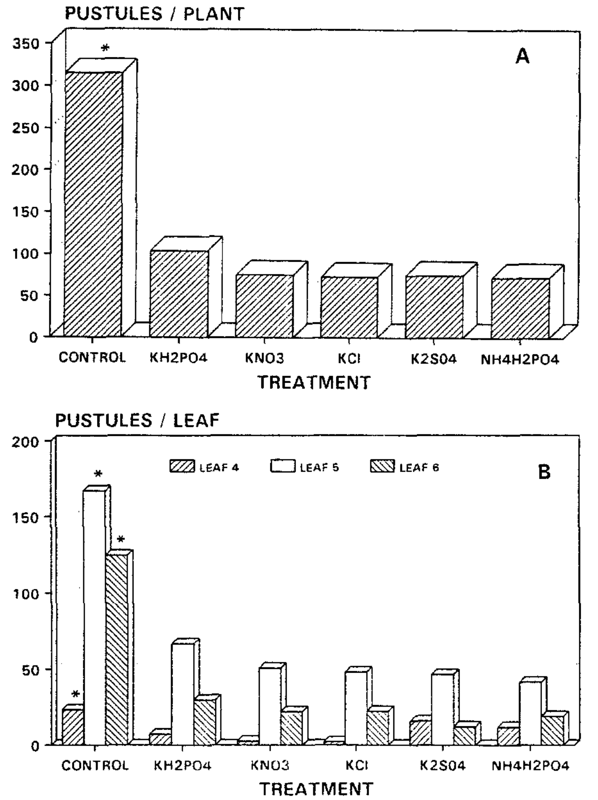

Figure 3. Systemic resistance to *Puccinia sorghi* in maize plants induced by a foliar spray of NPK salts and fertilizers. A solution of 100 mM of each of the salts was sprayed to run-off on the upper surfaces of the lower leaves 1, 2 and 3. As control treatment, water (with Tween 20) was sprayed on leaves 1–3. Two to 4 h after the spray, plants were challenged on leaves 4, 5 and 6 with a suspension of 5×10^4 spores of *P. sorghi* per milliliter. The total numbers of pustules of common rust per plant (A) and on each of leaves 4–6 (B) were recorded 10 days after inoculation. Data represent the means of total lesions developed on leaves 4–6 of each of eight plants per treatment/experiment, and each experiment was repeated three times. Asterisks on the bars indicate a significant difference ($P < 0.05$) according to Duncan's Multiple Range Test.

after inoculation (Figure 6). A similar trend was found for Mg while Na and N levels were less affected. The highest ratio between K and Ca which was detected in the protected leaves (Figure 6) within 72 h after induction, was apparent as early as 8 h after induction or challenge.

Field experiment. The efficacy of foliar sprays of phosphates in controlling common rust on field-grown maize plants was examined. The results clearly indicate that foliar sprays of phosphates significantly reduced the number of *P. sorghi* pustules on treated plants, as compared with non-treated control plants (Figure 7).

Discussion

As non-race-specific resistance does exist in plants, the induction, by various biotic or abiotic agents, of induced systemic resistance (ISR) to diseases caused by fungi, bacteria or viruses, represents another solid based confirmation to this non-specificity [Ye et al., 1995]. The present data and our previous reports [Reuveni, M. et al., 1993; Reuveni, R. et al., 1994a;

Table 3. Induced systemic resistance against *Puccinia sorghi* in maize plants by a foliar spray of NPK salts or fertilizers

Treatment[1]	Mean number of common rust pustules		
	Leaf 9	Leaf 10	Plant
Control-water	26.2 a[2]	11.8 a	38.0 a
K_2HPO_4	1.6 b	0.0 b	1.6 b
KNO_3	0.2 b	0.0 b	0.2 b
K_2SO_4	0.0 b	0.0 b	0.0 b
$NH_4H_2PO_4$	0.0 b	0.0 b	0.0 b

[1] A solution of 100 mM of each of the salts was sprayed on the upper surfaces of leaves 5 and 6 of each of six 10-leaf-old plants (owing to physiological senescence, the lower leaves (1–4) were not used). Two hours after the spray, leaves 7, 8, 9 and 10 were inoculated with a suspension of 1×10^4 spores of *P. sorghi* per milliliter. Leaves 7 and 8 were detached 50 h after inoculation and were used for determination of NPK accumulation, as described in M&M, and Figure 6. The total number of pustules produced on leaves 9 and 10 was counted 14 days after inoculation.

[2] See footnote in Table 1.

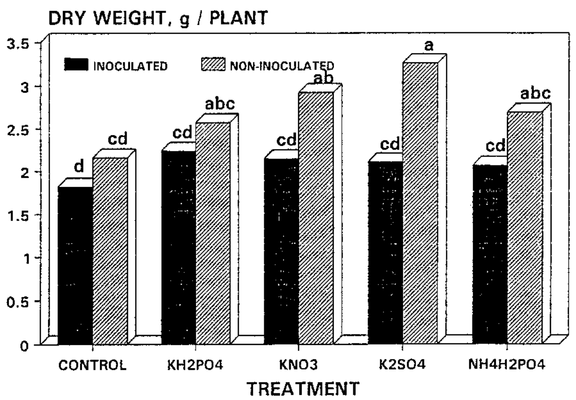

Figure 4. Effect of a foliar spray of NPK salts on growth increase in maize plants. Eleven days after inoculation (see footnote to Figure 2), plants were cut at the stem base and the means of dry weight per plant in each treatment were calculated. Different letters over the bars indicate a significant difference ($P < 0.05$) according to Duncan's Multiple Range Test.

1994b] support the hypothesis that mechanism(s) for resistance is (are) present in susceptible plants, and, more importantly, that this resistance is not specific and can be induced by the same NPK salts against facultative as well as against obligate parasites.

In addition, our results clearly show that this induced protection was evident on the upper leaves (4 to 8) as result of a rapid response of the host to foliar spray of various NPK salts on leaves 1, 2 and 3 as early as 2–4 h before the challenge with either *E. turcicum* 3). As multigenic resistance is quantitative in nature and characterized by reductions in the size and number of lesions [Jenkins and Robert, 1952], the protection against *E. turcicum* which was expressed not only by a reduction in the number of lesions (Table 1; Figure 1) but also by a restriction of further extension of the pathogen lesions (Table 2; Figures 1 and 2), indicate that the growth of the causal organism is limited.

As the protection was also observed when the NPK salts were sprayed 10 days before the challenge by *E. turcicum* or *P. sorghi* and it persisted to leaf 7 [Reuveni, R. et al., 1993], it is likely that the signal for this induction is effective for a long time and extends far from its place of activation (leaves 1, 2 and 3). This protection was not directly related to the pH of the NPK salts solution (Table 1), as reported for induced resistance in cucumbers [Mucharromah and Kuc', 1991]. Furthermore, in contrast to previous reports from ourselves and others, in which the direct or indirect influence of the phosphates on conidial germination or fungal development remained less certain, the present study clearly shows that although foliar spray of NPK salts caused no accumulation of N, P or K on the upper leaves (Figure 5), it nevertheless enhanced their resistance (Figures 1, 2 and 3; Tables 1–3). The question remains unclear whether the mechanism of this protection is associated with stress induced by the salts [Mucharromah and Kuc', 1991] or is related to an improved nutrition status or increased photosynthesis as reported by Murray and Walters in uninfected leaves of rusted broad bean [1992]. Supporting the later option, it was apparent that no visible damage, caused by a gradual appearance of metabolic perturbation and leading to stress in the host, was observed on the induced leaves (1, 2 and 3). Similarly, Mandryk [1962] found no morphological changes associated with acquired resistance to blue mold induced by stem injection of spore suspension of the causal organism *Peronospora tabacina* Adam. In addition, the previous report showed that the hypersensitive reaction of soybean to Tobacco Mosaic Virus (TMV) did not induce systemic resistance but inhibited growth [Pennazio and Roggero, 1993]. Thus growth inhibition alone, as reported in some cases, was not responsible for the resistance of protected plants [Fraser, 1979; Tuzun and Kuc', 1985]. These reports indicated that the appearance of stress signs on the induced leaves was not a prerequisite condition for the protection obtained.

As the protection against both facultative (NLB) and obligate (common rust) parasites of maize was

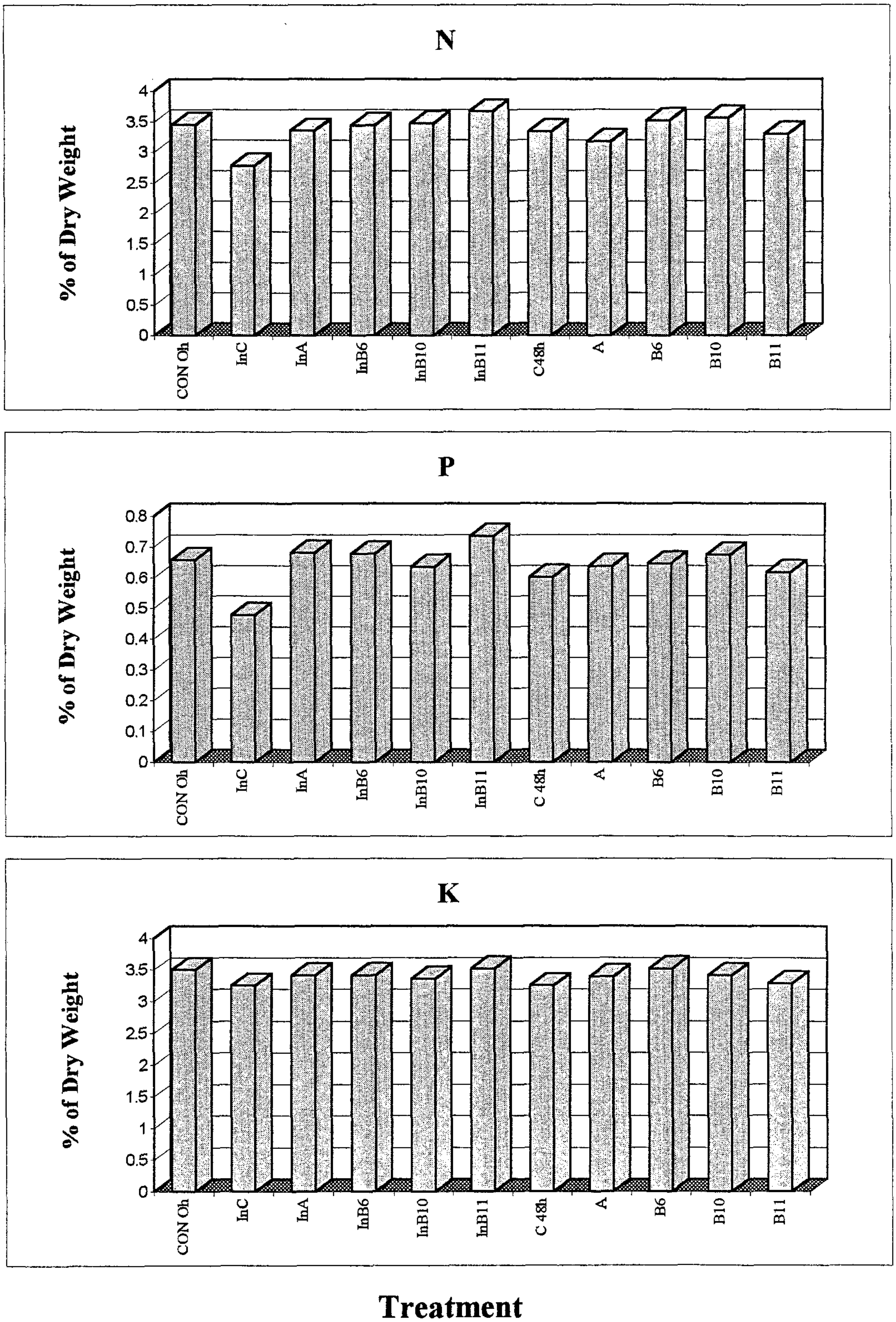

Figure 5. The effect of a foliar spray induction of various NPK salts and fertilizers on lower leaves on the accumulation of N, P, K in the upper leaves of maize plants inoculated with *Puccinia sorghi*. CON – control; A – K_2HPO_4; B6 – KNO_3; B10 – K_2SO_4; B11 – $NH_4H_2PO_4$. A solution of 100 mM of each of various NPK salts and fertilizers was sprayed on the upper surfaces of the lower leaves (5–6), 2 h before inoculation of the upper leaves (7–10) with a suspension of 1×10^4 spores of *P. songhi* per milliliter. Fifty hours after inoculation, the upper leaves (7 and 8) were analyzed for N, P and K contents, as described in M&M. (See also footnote to Table 3). Data represent means of six leaves obtained from six plants in each treatment and expressed as percentages of dry tissue weight.

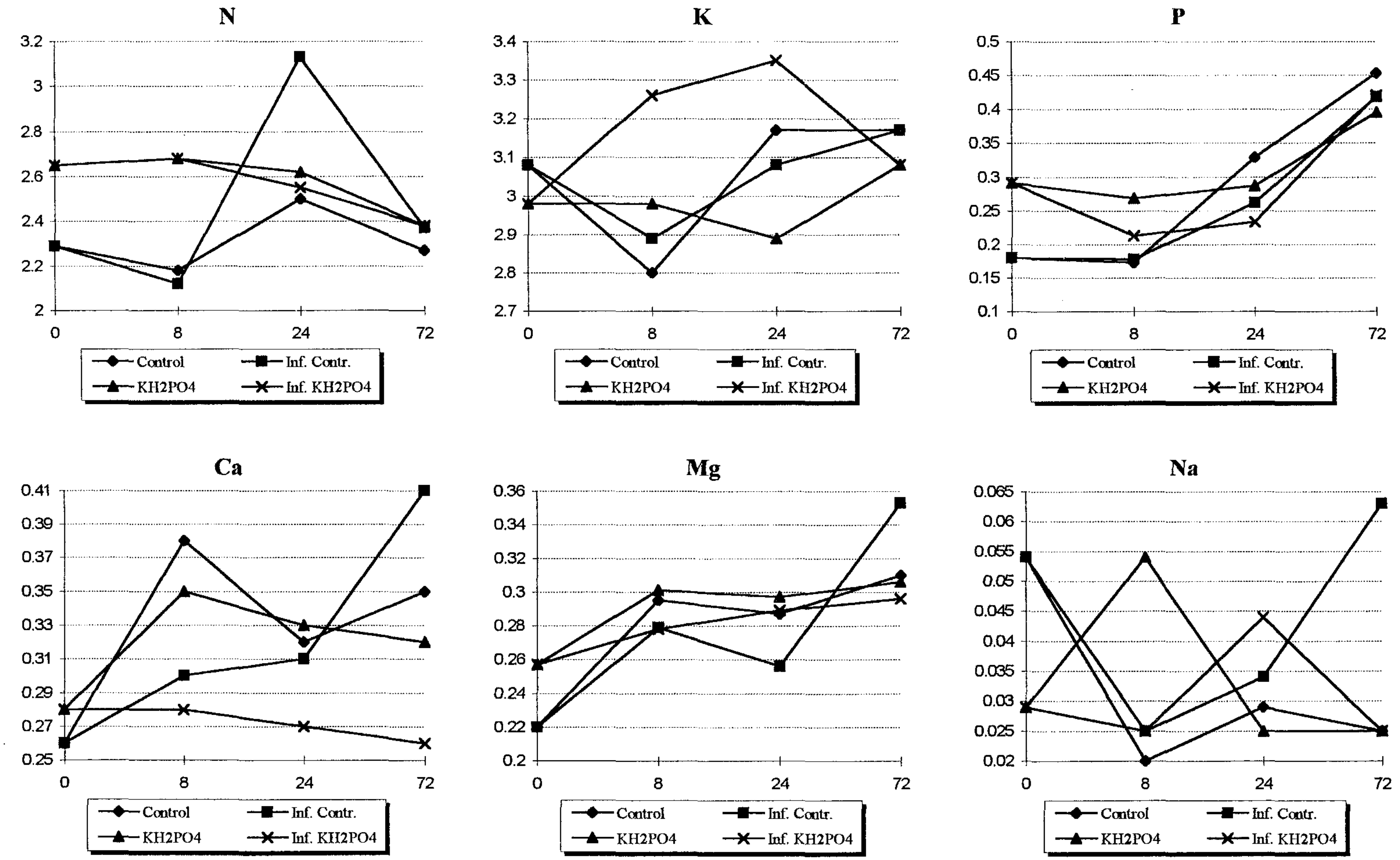

Figure 6. The effect of a foliar spray induction of KH_2PO_4 on lower leaves on the accumulation of N, P, K in the upper leaves of maize plants at various intervals after the inoculation with *Puccinia sorghi*. C: Control; C-I: Control inoculated; KH_2PO_4-I: Induced-inoculated. A solution of 100 mM of KH_2PO_4 was sprayed on the upper surfaces of the lower leaves (5–6), 2 h before inoculation of the upper leaves (7–10) with a suspension of 1×10^4 spores of *P. sorghi* per milliliter. At 8, 24 and 72 h after treatment, the upper leaves (7 and 8) were analyzed for N, P and K contents, as described in M&M. (See also footnote in Table 3). Data represent means of six leaves obtained from six plants in each treatment and expressed as percentages of dry tissue weight.

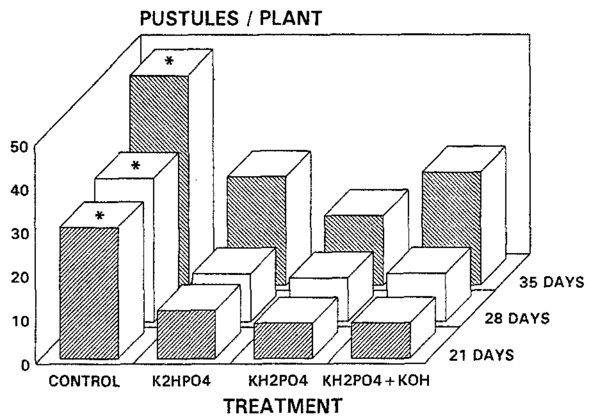

Figure 7 The efficacy of foliar sprays of phosphates in controlling *Puccinia sorghi* on field-grown maize plants. Young plants (8–10 leaf stage) were sprayed to run-off five times at weekly intervals with a fresh solution of 100 mM of each phosphate salt (all with Tween-20). The experiment was conducted in Newe-Yaar research station and consisted of 20 plants per treatment and each treatment was replicated four times in a complete block design. Disease on naturally infected plants was rated by counting the number of pustules of *P. sorghi* produced on each of eight plants per replicate and treatment 21, 28 and 35 days after the first application. Asterisks on the bars indicate a significant difference ($P < 0.05$) according to Duncan's Multiple Range Test.

sium ions acted via a non-specific mechanism in which balance between the elements might have affected either the hosts' resistance or susceptibility to NLB or common rust. Interactions between potassium and calcium in their absorption by intact barley plants showed that high potassium levels might reduce calcium absorption through the roots [Johansen et al., 1968]. However, it seems that foliar spray of KH_2PO_4 had no effect on the total elemental concentration of Ca in the dry tissue of the upper leaf (6 or 7) of the control plants but had stabilized Ca content in both the protected (induced) and challenged plants as compared with the control inoculated plants at 72 h after inoculation (Figure 7). A similar trend was found for Mg while Na and N levels were less affected. However, the highest ratio between K and Ca which was detected in the protected leaves (Figure 7) within 72 h after induction, was apparent as early as 8 h after induction or challenge. Such increase in ratio, might be involved in release of calcium which formed calcium cross-linkages between pectic polymers to make the cell wall substrate less accessible and therefore more resistant to hydrolytic enzymes produced by fungal pathogens [Tepfer and Taylor, 1981]. Such changes in the early stages of the induction by the salts containing potassium or phosphate might also be involved in the papilla formation of the induced plants as has recently been reported by Inoue et al., who identified potassium phosphate as the active component in the earlier papilla formation and resistance of barley to powdery mildew [1994].

The greatest use of resistant cultivars and induced resistance in the future would undoubtedly be within a pest management program, in which the value of even low levels of induced or non-induced resistance could be important. The potential utility of this approach was encouraged by data obtained from our field experiment, in which foliar sprays of phosphates significantly reduced the number of *P. sorghi* pustules on treated plants, as compared with non-treated control plants (Figure 8). This confirmed our previous study on their efficacy in controlling powdery mildew in field-grown winegrapes [Reuveni and Reuveni, 1995a; 1993], nectarine and mango [Reuveni, M. et al., 1995b] or greenhouse-grown roses [Reuveni, R. et al., 1994c] or cucumbers [Reuveni, M. et al., 1995]. However, no growth enhancement was detected in the field-grown crops probably due to the high availability of NPK fertilizers in the natural soil.

Our data indicate that inducible 'biofoliar-fertilizer' therapy by means of foliar NPK salt sprays may find a dual use in the future, as fertilizer and inducing agent for disease protection.

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