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Induction of Resistance in Field Pea against Rust Disease Through Various Chemicals/ Micronutrients and Their Impact on Growth and Yield

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Abstract: Field pea rust caused by *Uromyces viciae-fabae* (Pers.) de Bary is one of the most important diseases adversely affecting its yield in India. The present investigation was conducted to find out some common, inexpensive, non-toxic and simple chemical compounds as abiotic elicitors of *Pisum sativum* L. cv. 'Aparana' in relation to active defense response as possible alternative in the management of field pea rust. Forty-three chemicals alone and their combinations were tested as spray/basal treatment in Randomized Block Design with 3 replications during the year 2000-2003 to find out their role in induction of resistance. Out of 15 micronutrients tested only $CuSO_4$ and $Na_2B_4O_7$ were found most effective with 72-78% reduction in rust severity, 38-57% reduction in size of pustules and 83-92% reduction in number of pustules per leaf of pea. Among micronutrients combinations A+$KAl(SO_4)_2$+$CuSO_4$ followed by A+$CuSO_4$+$Ca(NO_3)_2$+$KAl(SO_4)_2$ were best in reducing disease severity in comparison to control. Among tested chloride form of micronutrient, organic acid and chemical the KCl, $CuCl_2$, sodium azide and sucrose were found most efficient in respect to seed yield and reduction in rust severity. The results of the present study showed a strong possibility to protect fieldpea through their natural defence system by using inducer chemicals as integration in sustainable plant disease management strategy.

Key words: Pea (*Pisum sativum* L.), *Uromyces viciae-fabae*, disease severity, micronutrient, chemicals, induce resistance, yield attributes

INTRODUCTION

Pea (*Pisum sativum* L.) is an important leguminous winter vegetable crop of India. It is grown over an area of 0.80 million hectare with a production 0.83 million tonnes and productivity 1032 kg ha^{-1} in India. The average yield in major pea growing countries viz., France (15.5 q ha^{-1}), Hungary (15.5 q ha^{-1}) and Netherland (14.3q ha^{-1}), while in India the average yield is very low i.e. 10.32 q ha^{-1} (Anonymous, 2002). There are several biotic and abiotic factors adversely affecting pea yield in Uttar Pradesh and Uttaranchal states of India. Among biotic factors, rust caused by *U. viciae-fabae* (Pers.) de Bary is one of most important disease of pea in India. The pathogen *U. viciae fabae* (Pers.) de Bary is microcyclic rust overwinters as teliospores in plant debris and completes its life cycle on peas (Pfunder and Roy, 2000). In the last few years, disease has been observed in almost epiphytotic form and could cause upto 20-100% losses in yield (Sharma, 1998; Stavely, 1991).

The disease control thus obtained by various management strategies including cultural, biological, chemical and planting resistant varieties (Xue and Warkentin, 2002; Upadhyay and Gupta, 1994; Kumar *et al*., 1994; Gupta and Shayam, 1998; Edreva, 2004). Now a day's disease control is entirely based of chemical pesticides which are exerting tremendous pressure on human health and environment. However, hazardous implications of noxious chemicals strongly necessitate the search for new harmless methods of plant disease management like induced resistance. Since the late 1950s increasing evidences of natural induced resistance has been accumulated and culminating in successful practical application in plant disease management (Kuc, 2001; Reuveni and Reuveni, 1998). Induced resistance is an alternative ecofriendly approach

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for disease management which invariably exploiting natural defense mechanism of plants against various type of pathogen. The use of chemicals as resistance inducers is the safest way to meet the requirements for secured application in greenhouses and fields condition, since such chemicals are broad spectrum in action, had no toxicity towards pathogens, plants and animals and also had no negative effects on plant growth, development and yield (Kessmann *et al*., 1994; Tally *et al*., 1999; Kuc, 2001). Thus, the appliance of chemical as inducers of resistance is an exciting new perspective to supplement the chemical means of plant disease management by providing effective and ecologically sound plant protection. So far no complete sources of resistance against *U. viciae fabae* have been reported in pea (Pal *et al*., 1980; Xue and Warkentin, 2002; Vijayalakshmi *et al*., 2005; Chand *et al*., 2006; Kushwaha *et al*., 2006) and no work has been done in India on the effect of various micronutrients, organic acid and resistance inducing chemicals in relation to development of induced resistance against rust of fieldpea and their influence on yield. In present investigation forty-three chemicals alone or their combinations were tried as spray treatment to find out their role if any, in induction of resistance against *U. viciae-fabae* the casual agent of rust of fieldpea.

MATERIALS AND METHODS

Field experiments were conducted at Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (India) which is situated at latitude of 29°N and longitude of 79.3°E at an altitude of 242.8 m from mean sea level. The experiments were laid out in Randomized Block Design with three replications. The size of each plot was 4.00×2.40 m^2. Susceptible cultivar 'Aparana' was sown on 20th November each year and recommended dose of fertilizer was applied. Forty-three chemicals alone or in their combinations were tried as spray treatment to find out their role if any, in induction of resistance against *U. vicia-fabae* the casual agent of rust of fieldpea. The fifteen chemical at different concentrations viz., T1-$CaCl_2$ (0.10%), T2-$MnSO_4$ (0.05%), T3-KNO_3 (0.10%), T4-FeEDTA (0.10%), T5-$Ca(NO_3)_2$ (0.05%), T6-$Na_2B_4O_7$ (0.10%), T7-Na_2MOO_4 (0.05%), T8-KAl $(SO_4)_2$ (0.10%), T9-$NiCl_2$ (0.05%), T10-K_2CrO_4 (0.05%), T11-$SnCl_2$ (0.05%), T12-$MgSO_4$ (0.10%), T13-$KMnO_4$ (0.05%), T14-$ZnSO_4$ (0.05%) and T15-$CuSO_4$ (0.05%), seven organic acid and chemicals *viz*., T16-Nicotinic acid (100 μg L^{-1}), T17-Aspirin (100 μg L^{-1}), T18-Ascorbic acid (200 μg L^{-1}), T19- Potassium Meta bisulphate (200 μg L^{-1}), T20-Silver nitrate (200 μg L^{-1}), T21-Sodium azide (200 μg L^{-1}) and T22-Thio urea (200 μg L^{-1}), chloride form of micronutrient viz., T23-$AlCl_3$ (0.05%), T24-KCl (0.05%), T25-$ZnCl_2$ (0.05%), T26-$CuCl_2$ (0.10%), T27-$CaCl_2$ (0.10%), T28-H_3BO_3 (0.05%) were applied in combination form in the experiment. Correspondingly, three micronutrients viz., KNO_3, $ZnSO_4$ and $Na_2B_4O_7$ were common in each combined treatment and in this study they are indicated with "A". The concentration of individual nutrient remained same in the combination treatments as when, used separately.

The above micronutrient treatment in study three micronutrient KNO_3, $ZnSO_4$ and $Na_2B_4O_7$ were common in each combined treatment as given above viz., T29-A = (KNO_3+$ZnSO_4$+$Na_2B_4O_7$), T30-A+$CuSO_4$+$Ca(NO_3)_2$+KAl$(SO_4)_2$, T31-A+$CuSO_4$+$Ca(NO_3)_2$, T 32-A+KAl$(SO_4)_2$+$Ca(NO_3)_2$, T33- A+KAl$(SO_4)_2$+$CuSO_4$, T34-A+$Ca(NO_3)_2$, T 35-A+$CuSO_4$, T36-A+KAl $(SO_4)_2$. Likewise organic acids and plant growth promoter formulations viz., T37-Tracil (0.05%), T38- Biozyme (0.1%), T39- Aminose (0.1%), T40- Malic acid (0.05%), T41-Tannic acid (0.05%), T42- Potassium oxalate (0.05%), T43-Sucrose (0.1%) were also tested in the trial. The aqueous solution of the required concentration of various treatments was prepared in water just before spraying. Two sprays of each chemical solution were given, first at 45 days after sowing and second at 60 days after sowing of the crop. The spraying was done with the help of sprayer with ensured complete coverage of plant surface and the spray drifts of different treatments were avoided by taking appropriate precautions.

Fieldpea plants were artificially inoculated by spraying urediospores/ aeciospores suspension. Pathogen inoculum was multiplied on highly susceptible variety 'Aparana' sown 30 days before planting of main experiment by inoculating aeciospores derived from single pustules. Leaves having profusely sporulating rust pustules in the field were picked up and hand rubbed in a tub containing 10 Liter water. The spore suspension thus obtained was allowed to stand for some time, to settle the dust particle and then filtered through muslin cloth to remove leaf tissues. Standard inoculation technique (Chand *et al*., 2004) was followed and spore suspension of 10^5 spore mL^{-1} was sprayed with the help of hand compressor sprayer during evening hours. Spraying of inoculum was done twice, each time before 10 days of chemical spray.

Disease observation: Fieldpea plants were carefully examined and rust disease severity was recorded at 75 days after sowing from upper, middle and lower leaves on the basis of leaf area covered by the pustules. In each plot ten plants were randomly selected and twenty leaves from each plot were randomly collected and evaluated individually by following 1-9 rating scale (Townsend and Heuberger, 1943) with slight modifications which has been described in Table 1.

The disease index for fieldpea rust was calculated by the formula as employed by Wheeler (1969):

$$\text{Disease index (\%)} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves observed} \times \text{Maximum rating}} \times 100$$

Observation of growth and yield components: The plant growth and yield attributes studies were carried out, as per procedure given below:

Plant height: The height (cm) of five randomly selected plants from each plot was recorded with the help of meter scale from the base of the plant to the top of the plants and mean values are presented.

Number of pod: The number of effective pod having seeds was collected from their respective branches of five randomly selected plants from each plot separately. They were counted and reported on per plant basis.

Average length of pod: Twenty pods were randomly selected from main shoot in each plots and their length was measured in mm with scale and reported as average length of pod in mm.

Number of grain per pod: The seeds of 10 selected pods from respective branches were threshed, counted and average number is reported on pod basis.

Thousand grain weight: One thousand seeds were counted with the help of tally counter separately from each plot and grain weight was recorded in gram with metteler monopan digital electronic balance.

Grain yield per plant: The seed obtained after threshing the pod of respective branches from five randomly selected plants were weighted and reported as yield per plant basis in gram.

Grain yield per hectare: Natural dried pea plants from the individual plot were harvested, air dried and the produce was threshed and cleaned. The clean seeds were dried up to 10% moisture by weight. The grain yield per plots was recorded in gram and after adding the weight of 5 sample plants seed previously collected from the field of respective plots to get the net plot yield. This net plot yield in gram was converted into yield quintal per hectare (q ha^{-1}).

Statistical analysis: The data were statistically analyzed using simple Randomized Block Design of statistical program MSTAT-C. Data recorded in percentage were first transformed to arisen values before analysis and the treatment were compared by means of Critical Differences (CD) at 5% level of significance:

$$CD = t\sqrt{\frac{2EMS}{r}}$$

Where:

CD = Critical difference
t = T value at error degree of freedom
EMS = Error means of square
r = No. of replication

RESULTS AND DISCUSSION

The present investigation was conducted to find out some common, inexpensive, non-toxic and simple chemical compounds as abiotic elicitors of induced resistance as possible alternative in the management of *U. viciae-fabae* the cause of rust of fieldpea.

Effect of micronutrients used for induced resistance on disease severity, number and size of pustules, growth and yield attributes under field conditions: The pooled data of three crop season (Table 2) indicated that the minimum disease severity was recorded with $CuSO_4$ (18.22%) followed by $Na_2B_4O_7$ (23.10%), $KMnO_4$ (48.00%) and $ZnSO_4$ (55.55%). The water sprayed plants exhibited comparatively large size of rust pustules (4.14 mm) on leaves, while other treatments resulted in significantly smaller size of pustules. The maximum reduction in size of pustules was observed in $CuSO_4$ (1.50 mm) followed by $Na_2B_4O_7$ (1.56 mm), $KMnO_4$ (1.67 mm) and K_2CrO_4 (1.75 mm) treatments. The control plots showed maximum number of pustules (56.71) per leaf, while all the micronutrient treatment sprayed plants showed significant reduction in number of pustules (>60%). The minimum number of pustules were observed in $CuSO_4$ (4.35) followed by $KMnO_4$(7.64 mm), KNO_3 (8.71), $Na_2B_4O_7$ (9.27) and $ZnSO_4$ (9.85) treatments. The results revealed that only $CuSO_4$ and $Na_2B_4O_7$ significantly reduced disease severity, average size and number of pustules during all the crop season. Similarly, Reuveni *et al*., (1997, 1996b) and Reuveni and Reuveni (1998) reported reduction in plant diseases severity due to various obligates parasite in various crops after a single foliar application of $CuSO_4$ and $KMnO_4$ and suggested micronutrient based induction of Systemic Acquired Resistance (SAR) in the suppression of plant diseases (Marschner, 1995).

The statistical analyses of Table 3 reveals that the treatments (KNO_3, Fe-EDTA, Na_2MOO_4, $KAl(SO_4)_2$, $NiCl_2$, K_2CrO_4, $SnCl_2$ $MgSO_4$, $ZnSO_4$) resulted significant

Table 1: Disease rating scales and their percent leaf area covered used for disease observation

Grade	Description	Leaf area covered (%)
1	No visible pustules-(highly resistant)	0.0
3	Few scattered pustules, usually seen after careful search-(resistant)	0.1-10.0
5	Pustules common on leaves and easily observed, but no apparent damage-(moderately resistant)	10.1-25.0
7	Pustules very common and damaging, but no pustules on petioles and stems-(moderately susceptible)	25-50
9	Pustules are extensive on all plants and leaves, petioles and stems, causing death of leaves and other parts-(highly susceptible)	>50

Table 2: Induction of resistance by foliar application of aqueous solution of micronutrients against *Uromyces viciae-fabae* under field conditions during 2000-2003 crop seasons

		Rust of field pea											
		2000-2001			2001-2002			2002-2003			Pooled data		
Treatments	Conc.(%)	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf
$CaCl_2$	0.10	62.66 (52.42)	1.97	18.38	66.67 (55.04)	4.20	19.06	69.33 (56.75)	3.24	18.75	62.22(55.03)	3.13	18.73
$MnSO_4$	0.05	82.66 (66.81)	2.70	13.63	74.67 (60.00)	3.24	12.00	72.00 (58.09)	4.29	12.88	76.44(61.05)	3.41	12.83
KNO_3	0.10	60.00 (50.78)	1.98	8.19	64.00 (53.29)	2.18	9.31	62.67 (52.36)	1.20	8.63	62.22(52.16)	1.78	8.71
Fe EDTA	0.10	73.23 (59.06)	2.17	12.00	69.33 (56.44)	4.09	10.13	68.00 (55.58)	3.83	11.13	70.18(57.44)	3.36	11.08
$Ca(NO_3)_2$	0.05	61.33 (51.60)	2.19	14.19	65.33 (53.94)	3.70	13.13	72.00 (58.37)	4.79	13.63	66.22(54.33)	3.56	13.67
$Na_2B_4O_7$	0.10	22.65 (28.35)	1.56	8.69	20.00 (26.57)	2.04	8.38	26.67 (30.79)	1.08	10.75	23.10(29.10)	1.56	9.27
Na_2MOO_4	0.05	64.00 (53.14)	1.92	15.19	62.67 (52.36)	1.46	14.50	68.00 (55.98)	2.12	15.00	64.89(53.74)	1.83	14.89
$KAl(SO_4)_2$	0.10	78.67 (62.51)	1.89	20.19	66.67 (55.04)	1.69	21.00	69.33 (56.64)	2.17	20.63	71.55(57.84)	1.91	20.60
$NiCl_2$	0.10	65.33 (53.98)	2.12	12.19	68.00 (55.78)	2.70	10.13	62.67 (52.36)	3.24	11.13	65.33(53.98)	2.68	11.15
K_2CrO_4	0.05	72.00 (58.08)	1.98	14.44	74.67 (59.88)	1.17	15.19	72.00 (58.08)	2.12	15.00	72.89(58.69)	1.75	14.87
$SnCl_2$	0.05	74.67 (60.00)	2.91	21.19	64.00 (53.24)	3.24	20.16	73.33 (59.05)	3.79	20.88	70.66(57.69)	3.31	20.74
$MgSO_4$	0.10	62.67 (52.34)	1.60	13.37	65.33 (53.94)	3.79	12.25	68.00 (55.97)	3.24	13.06	65.33(53.94)	2.87	12.89
$KMnO_4$	0.05	45.33 (42.31)	1.77	7.18	48.00 (43.85)	1.08	8.13	50.67 (45.45)	2.16	7.63	48.00(43.85)	1.67	7.64
$ZnSO_4$	0.10	57.33 (49.28)	2.70	9.25	53.33 (46.92)	1.69	10.44	56.00 (48.48)	3.24	10.75	55.55(47.35)	2.54	9.85
$CuSO_4$	0.05	16.00 (22.44)	1.50	4.25	18.67 (23.17)	1.46	4.38	20.00 (26.49)	1.54	15.00	18.22(22.89)	1.50	4.35
Water	–	86.67 (68.63)	3.24	55.06	81.33 (64.61)	4.70	58.32	84.00 (66.53)	4.50	56.75	84.00(66.53)	4.14	56.71
CD (p = 0.01)		16.99	0.50	2.33	19.06	0.57	0.54	18.06	0.64	2.75	19.13	0.51	2.69
CD (p = 0.05)		12.62	0.37	1.74	14.15	0.43	0.40	13.41	0.47	1.45	14.17	0.48	1.75
GM±SEM		61.58±4.37	2.13±0.13	15.64±0.61	60.17±4.90	2.69±0.15	15.40±0.14	62.17±4.64	2.91±0.16	15.64±0.24	65.64±0.54	2.51±0.26	15.14±0.64
CV (%)		12.29	12.31	7.92	14.11	11.25	1.85	12.94	11.54	6.26	13.78	12.88	6.87

Valuesgiven in parentheses are angular transformed value and average of three replications

Table 3: Effect of micronutrient on plant height, no. of pod / plant, average length of pod, no. of grain per pod and yield of fieldpea

Treatments	Conc. (%)	Plant height (cm)	Pods/plant	Average length of pod (mm)	No. of grains/ pod	1000-grain weight (g)		Grain yield/ plant (g)		Yield (q ha^{-1})
						2000-2001	2001-2002	2000-2001	2001-2002	
$CaCl_2$	0.10	66.67	27.50	61.00	3.67	120.66	123.66	6.27	8.23	11.08
$MnSO_4$	0.05	61.00	20.50	60.67	3.00	120.00	123.66	7.33	7.36	10.59
KNO_3	0.10	53.33	21.67	59.33	4.33	120.66	123.34	8.00	8.40	11.45
FeEDTA	0.10	55.00	17.67	60.00	4.00	119.35	123.66	7.37	7.27	10.29
Ca $(NO_3)_2$	0.05	51.00	16.67	59.00	4.00	122.66	123.34	7.17	7.23	10.79
$Na_2B_4O_7$	0.10	83.00	28.67	63.50	5.20	126.66	126.66	8.27	8.27	12.63
Na_2MOO_4	0.05	51.33	22.33	60.33	4.00	119.34	120.34	7.33	7.40	10.63
KAl $(SO_4)_2$	0.10	51.66	19.67	58.00	4.00	118.66	120.00	7.33	7.27	10.79
$NiCl_2$	0.05	50.33	17.67	61.33	4.33	119.34	120.66	6.40	7.43	10.74
K_2CrO_4	0.05	56.23	19.17	58.00	4.00	118.66	120.66	6.23	6.26	9.12
$SnCl_2$	0.05	52.27	23.17	54.66	4.00	120.66	123.34	7.16	8.23	11.13
$MgSO_4$	0.10	51.67	20.17	62.00	4.33	119.34	122.66	6.17	7.43	10.69
$KMnO_4$	0.05	61.66	27.67	63.00	4.33	124.50	124.66	8.23	8.27	12.29
$ZnSO_4$	0.10	55.00	26.67	62.33	3.33	118.00	124.66	8.00	8.00	10.68
$CuSO_4$	0.05	83.33	29.50	64.00	5.33	128.00	130.00	8.30	8.87	12.96
Water	–	66.33	21.00	57.33	4.00	118.66	62.33	6.16	7.16	10.50
CD(p = 0.01)		8.31	2.82	2.72	2.26	13.93	2.88	0.566	0.551	1.19
CD (p = 0.05)		6.17	2.09	2.02	1.68	10.35	2.14	0.420	0.409	0.884
GM±SEM		60.14±2.13	21.32±1.00	59.75±0.70	4.60±0.58	59.08±3.58	62.22±0.74	7.19±0.14	7.60±0.14	21.54±0.30
CV (%)		6.15	2.95	2.03	21.94	10.50	2.06	3.50	3.23	2.46

Values are average of three replications

Table 4: Induction of resistance in fieldpea plants by foliar application of some micronutrients combinations against *U. viciae fabae* under field conditions during 2000-2003 crop seasons

	Rust of field pea											
	2000-2001			2001-2002			2002-2003			Pooled data		
Treatments	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf
A=(KNO_3+$ZnSO_4$+$Na_2B_4O_7$)	5.33 (13.10)	2.33	1.33	3.67 (11.01)	3.00	1.67	4.00 (11.53)	3.67	1.67	3.83 (11.12)	3.00	2.50
A+$CuSO_4$+$Ca(NO_3)_2$+KAl $(SO_4)_2$	0.00 (0.00)	0.00	0.00	0.00 (0.00)	0.00	0.00	0.00 (0.00)	0.00	0.00	0.00	0.00	0.00
A +$CuSO_4$+Ca $(NO_3)_2$	10.33(18.46)	2.50	1.69	6.67 (14.95)	2.56	1.65	7.33 (15.70)	2.53	1.73	7.00 (15.12)	2.53	1.69
A+KAl$(SO_4)_2$+$Ca(NO_3)_2$	0.00 (0.00)	0.00	0.00	2.33 (8.44)	3.67	1.67	3.33 (10.50)	3.33	2.33	2.83 (8.75)	3.50	2.0
A +KAl$(SO_4)_2$+$CuSO_4$	0.00 (0.00)	0.00	0.00	2.12 (6.53)	2.12	1.61	2.33 (8.74)	2.08	1.73	1.83 (6.85)	2.10	1.67
A+Ca $(NO_3)_2$	15.67 (23.06)	2.66	5.33	10.00(18.42)	2.64	4.33	10.67(19.04)	2.68	5.33	10.33 (18.64)	2.66	4.16
A+$CuSO_4$	5.33 (13.10)	2.30	0.83	2.67 (9.26)	2.36	1.67	3.33 (10.49)	4.33	2.33	3.00 (9.36)	2.33	2.0
A+KAl $(SO_4)_2$	4.67 (12.45)	4.00	3.33	4.33 (11.99)	4.33	2.67	4.33 (11.99)	4.00	3.67	4.33 (11.99)	4.16	3.17
Water	84.67 (66.94)	4.33	54.00	83.33(65.90)	4.67	53.33	84.33(66.68)	4.33	54.67	83.83 (65.95)	4.50	54.00
CD (P = 0.01)	5.30	0.850	1.29	1.70	1.74	1.61	1.423	2.84	1.85	1.65	1.10	1.65
CD (P = 0.05)	3.85	0.617	0.938	1.24	1.26	1.17	1.033	2.06	1.34	1.31	1.05	1.23
GM ± SEM	14.00 ± 1.28	2.01±0.61	7.35±0.31	12.70±0.41	3.40±0.42	7.77±0.39	13.21±0.344	3.40±0.68	8.40±0.44	14.21±0.244	2.40±0.60	7.40±0.44
CV (%)	15.90	16.75	7.37	5.62	21.50	8.70	4.49	35.04	9.26	14.10	5.25	10.32

Values given in parentheses are angular transformed value and average of three replications decrease in plant height as compared to check plots. However, $CuSO_4$ and $Na_2B_4O_7$ showed significant increase in plant height 83.33 and 83.00, respectively in comparison to check (66.33 cm). There was significantly increase in number of pods per plant recorded in $CuSO_4$ (29.50) followed by $Na_2B_4O_7$ (28.67) and $KMnO_4$ (27.67) sprayed plots in comparison to check (21.0). The effect of various micronutrient sprays on the average length of pods was found at par with control. However, maximum length of pod was recorded in $CuSO_4$ (64.00 mm) which was about 9.0% more than check (57.33 mm) followed by $Na_2B_4O_7$ (63.50 mm) and $KMnO_4$ (63.00 mm) sprayed plots. Among the tested all micronutrient did not significantly increase the number of grain per pod in comparison to check, however the micronutrient $CuSO_4$ and $Na_2B_4O_7$ slightly increase number of grain per pod. One thousand grain weight of the micronutrient sprayed plots was recorded separately during 2000-2002 crop seasons, conversely none of the treatment was found significantly different in comparison to check, In the both crop season treatment $CuSO_4$, resulted maximum 1000-grain weight (128.00 g) followed by $Na_2B_4O_7$ (126.66 g) and $KMnO_4$ (124.50 g). During both crop season, higher yield per plant was recorded from $CuSO_4$ followed by $Na_2B_4O_7$, $KMnO_4$, $ZnSO_4$ and KNO_3 sprayed plots in comparison to check. Significantly higher grain yield (12.96 q ha^{-1}) was recorded in $CuSO_4$ sprayed plots followed $Na_2B_4O_7$ (12.63 q ha^{-1}), $KMnO_4$ (12.29 q ha^{-1}) however, all remaining treatments showed significantly less yield in comparison to check.

Foliar applications of essential nutrients have been found to improve the disease protection and increase in yield of various crops reported previously by different workers against different pathogens (Giskin and Nerson, 1984; Nerson *et al*., 1985; Giskin *et al*., 1984; Giskin and Efron, 1986). In the present studies, K_2CrO_4, $CuSO_4$, $KMnO_4$, $ZnSO_4$ and Fe-EDTA exhibited temporary leaf chlorosis, small punctuation, scorching, curling and some time burning symptoms, while KNO_3, $MgSO_4$, $CaCl_2$, $Na_2B_4O_7$ and K Al $(SO_4)_2$ showed no effect on leaf. In case of $CaCl_2$, spray water soluble crystals were found deposited on leaf surface whilst these visual observations showed mild stress on plant and support the results of change in physiological parameters in pea leaves. Similar responses of micronutrients appliance also have been observed in other plant species (Kessmann *et al*., 1994; Boyle and Walters, 2005, 2006; Reuveni *et al*., 1996a). Micronutrients play an important role in crop plants by affecting their degree of susceptibility to various pathogens (Marschner, 1995; Graham and Webb, 1991). Trace element Mn reduce natural resistance of asparagus bean to tobacco necrosis virus (Pennazio and Roggero, 1988), however Cu, Co and Ni increase the resistance against the disease. Single spray of 0.005 M H_3B0_3, 0.002 M $CuSO_4$+ $MnCl_2$ or $KMnO_4$ separately on the upper surface of first true leaves of cucumber plants induced systemic protection against powdery mildew disease in cucumber (Reuveni *et al*., 1997).

Effect of micronutrient combinations on induced resistance in pea plants and their impact on growth and yield attributes: Pooled data presented in Table 4 reveals that all the micronutrient combination treatments significantly reduced the rust severity in comparison to control water (83.83%). The basal nutrient combination A= (KNO_3+$ZnSO_4$+$Na_2B_4O_7$) showed rust severity index 3.83%. However, treatment A+$CuSO_4$+Ca $(NO_3)_2$+KAl $(SO_4)_2$ showed completely disease free leaf of fieldpea with a disease index (0.0), followed by A+KAl $(SO_4)_2$+$CuSO_4$ (1.83%), A+$CuSO_4$ (3.00%), A+$CuSO_4$+Ca $(NO_3)_2$ (7.00 %). The largest size of rust pustules (4.5 mm) was observed with water (control), while all other treatment resulted to significantly smaller size of pustules in comparison to check. The minimum size of pustules recorded in the treatment A+ KAl $(SO_4)_2$+$CuSO_4$ (2.10 mm) followed by A+$CuSO_4$ (2.33 mm), A+$CuSO_4$+Ca $(NO_3)_2$ (2.53 mm). The maximum number of rust pustules per leaf was recorded with water sprayed (54 pustules/leaf) while all other treatments resulted in almost complete inhibition of size of rust pustules. The minimum number of pustule recorded in treatment A+KAl $(SO_4)_2$+$CuSO_4$ (1.67pustule/leaf) followed by A+$CuSO_4$+Ca $(NO_3)_2$ (1.69 pustule/leaf) and A+$CuSO_4$ (2.0 pustule/leaf).

Data presented in Table 5 indicated that treatments A+KAl$(SO_4)_2$+$CuSO_4$ resulted significantly maximum plant height (50.0 cm) followed by A+$CuSO_4$+Ca $(NO_3)_2$ and A+$CuSO_4$ in comparison to control (30.44 cm). The treatments A+KAl $(SO_4)_2$+Ca $(NO_3)_2$, A+Ca $(NO_3)_2$ and A+KAl $(SO_4)_2$ increased 26 to 28% plant height over check. Only A+KAl $(SO_4)_2$+$CuSO_4$, A+$CuSO_4$+Ca $(NO_3)_2$ and A+$CuSO_4$ showed significantly more number of pods per plant (27.33, 23.33 and 21.45) over check (17.33). In contrast to above treatment A+ KAl $(SO_4)_2$ showed significant reduction in pods number (30.75%) in comparison to check followed by A+$CuSO_4$+Ca $(NO_3)_2$+KAl$(SO_4)_2$ (13.44%), A+Ca$(NO_3)_2$ (3.69%). The treatment A+KAl$(SO_4)_2$+$CuSO_4$ resulted significant increased in length of pods (64.67 mm) in comparison to check (50.33 mm) followed by A+$CuSO_4$+Ca$(NO_3)_2$ (61.00 mm) however, treatment A+KAl$(SO_4)_2$ showed significant decrease (8.60%) in length of pods in comparison to check. There was no significant difference in number of grains per pod due to the nutrient combination sprays in comparison to control. There was

Table 5: Effect of some micronutrient combinations on growth and yield component of fieldpea

Treatment	Plant height (cm)	Pods/plant	Average length of pod (mm)	No. of grains/ pod	Grain weight (g)	Yield (q ha^{-1})
A=(KNO_3+$ZnSO_4$+$Na_2B_4O_7$)	34.34	18.33	54.67	3.67	140.66	11.33
A+$CuSO_4$+Ca $(NO_3)_2$+KAl $(SO_4)_2$	33.67	15.00	50.33.	4.33	130.60	10.17
A+$CuSO_4$+Ca $(NO_3)_2$	48.34	23.33	61.00	4.83	150.66	12.84
A+KAl $(SO_4)_2$+Ca $(NO_3)_2$	41.00	16.30	56.00	4.00	135.54	9.83
A+KAl $(SO_4)_2$+$CuSO_4$	50.00	27.33	64.67	5.33	153.34	13.67
A+Ca $(NO_3)_2$	43.00	16.69	52.00	3.67	143.34	11.83
A+$CuSO_4$	47.34	21.45	56.33	4.50	148.50	12.50
A+KAl $(SO_4)_2$	42.67	12.00	46.00	4.33	143.34	10.83
Water	30.34	17.33	50.33	6.00	140.00	10.67
CD ($p = 0.01$)	1.62	6.01	30.48	1.42	3.70	1.07
CD ($p = 0.05$)	1.20	4.09	2.21	1.033	2.68	1.23
GM ± SEm	117.51±0.40	45.77±1.65	54.59±0.73	4.74±0.34	128±0.34	11.03±0.52
CV (%)	0.504	2.83	2.34	12.59	1.12	2.00

Value are average of three replications

no significant effect on thousand grain weight due to combination of nutrient spray treatments, but treatment A+ $KAl(SO_4)_2$+$CuSO_4$, A+ $CuSO_4$+$Ca(NO_3)_2$ and A+$CuSO_4$ showed slight increase in the grain weight in comparison to check. The treatment A+$KAl(SO_4)_2$+$CuSO_4$ gave significantly more grain yield per hectare (13.67 q ha^{-1}) in comparison to control (10.67 q ha^{-1}) followed by A+$CuSO_4$+$Ca(NO_3)_2$ (12.84 q ha^{-1}) and A+$CuSO_4$ (12.5 q ha^{-1}). The treatment A = KNO_3+$ZnSO_4$+$Na_2B_4O_7$ and A+Ca $(NO_3)_2$ also showed ten per cent increase in yield over check. A number of studies showed that application of micro and macro nutrient either single or in combination mode control the diseases and enhance the crops yield (Marschner, 1995; Huber and Graham, 1999; Graham and Webb, 1991). The result of the present studies are also partially in conformity with the results reported by Walters and Murray (1992), Reuveni *et al.* (1996a), Gottstein and Kuc (1989); Reuveni *et al.* (1994) and Irving and Kuc (1990). They envisaged that spray of micronutrient solutions singly or in combination induces local and systemic protection against plant diseases in their respective crops.

Effect of chloride form of micronutrients on pea rust severity and their impact on growth and yield component: Field experiment was conducted for induction of resistance by foliar application of aqueous solution of some selective chloride form of micronutrients against *U. viciae- fabae*. Pooled data of the trial indicated that only treatment KCl and $CuCl_2$ significantly reduced the disease severity in comparison to check (84.44%) and found effective in respect to disease control (Table 6). Significantly smaller size of rust pustules was observed in $CuCl_2$ (0.64 mm) and KCl (2.18 mm), while $CaCl_2$ (2.98 mm) and $ZnCl_2$ (4.25 mm) resulted significantly larger size of pustules in compression to check. All the micronutrients significantly reduced the number of rust pustules per plant over check (57.00 pustules/ leaf). The treatments KCl and $CuCl_2$ resulted in almost complete (>98%) reduction in number of pustules, while in $ZnCl_2$ (4.81) sprayed plants more than 90% reduction in number of pustules per leaf was recorded in comparison to control. Previously inoculated fieldpea plants with aeciospore of rust pathogen were sprayed with KCl and $CuCl_2$ solution and interestingly, KCl and $CuCl_2$, almost completely inhibited the development of rust of fieldpea with a significant decrease in disease severity, lesion size and most important the number of lesion per leaf. A similar response of foliar applications of potassium chloride has been observed in reducing rust and powdery mildew diseases in barley (Kettlewell *et al.*, 1992). In another studies foliar application of 17 mM of silicon as potassium silicate has also been shown to reduce the number of powdery mildew colonies on cucurbit species and grape leaves (Bowen *et al.*, 1992; Menzies *et al.*, 1992). These compounds may have a direct effect against the fungus, promote antagonistic phylloplane organisms, or stimulate host defence reactions.

All the treatments resulted non-significant increase in plant height, than control (Table 6). The maximum reduction in plant height was resulted in $CuCl_2$ (19.99%) followed by $ZnCl_2$ (14.87%) and KCl (10.12%) There were no significant differences in the number of pods per plant among all the treatments. However, H_3BO_3 showed slight increase in number of pods per plant over check while $CuCl_2$, $CaCl_2$ and $AlCl_3$ adversely affected the number of pods. Among the different treatments H_3BO_3 and $AlCl_3$ resulted non significant increase in the length of pods (59.67 and 58.67 mm) over check (55.00 mm), while other treatments were found at par with check. Invariably non significant difference in number of grains per pod was observed, while H_3BO_3 (5.0%) increased the number of grains per pod. However, there was slight decrease in number of grains per pod in all the spray treatment over check (5.67 grains/pod) but data was non significant. The 1000 grain weight (g) was found non-significant among all the treatments. However $CaCl_2$ $ZnCl_2$, KCl and H_3BO_3 showed slight increase in grain weight over check. Only H_3BO_3 showed significant increase in yield per plant in comparison to check while other treatments showed insignificantly response for yield per plant (Table 7). Similarly, single spray of 0.005 M H_3B0_3 separately on the upper surface of the lower leaves of cucumber plants found to induced systemic protection against powdery mildew on cucumber plants (Reuveni *et al.*, 1997, 1996b).

Induction of resistance with the help of organic acids and some chemicals and their impact on growth and yield component: Pooled results given in Table 8 indicated that sodium azide spray resulted significant minimum disease severity (21.55%), while thiourea and Aspirin also gave significant effect in comparison to control (81.100%) while, other treatments were at par with control. All the organic acids and chemicals were resulted significantly smaller size of pustules on leaves in comparison to control. The minimum size 2.53 and 2.45 mm of pustule was observed with sodium azide and Aspirin spray, while thiourea resulted largest size of pustules (3.70 mm), followed by silver nitrate (3.65 mm), Nicotinic acid (3.39 mm) and Ascorbic acid (3.33 mm). All the treatments resulted significantly less number of pustules per leaf in comparison to control (62.33 pustules/leaf). However, minimum number of pustule was recorded with sodium

Table 6: Induced resistance through chloride form of micronutrients against *U viciae-fabae* under field conditions during 1999-20002 crop seasons

		Rust of field pea											
		2000-2001			2001-2002			2002-2003			Pooled data		
Treatments	Conc.(%)	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf	Disease severity (%)	Average size of pustule (mm)	No. of pustule/ leaf
$AlCl_3$	0.05	69.33 (56.56)	2.08	22.75	72.00 (58.18)	2.33	25.18	62.66 (52.33)	2.56	19.88	67.99 (55.83)	2.32	22.60
KCl	0.05	12.00 (20.26)	2.16	2.93	11.33 (44.62)	2.00	3.06	14.00 (21.97)	2.39	2.02	12.44 (48.33)	2.18	2.67
$ZnCl_2$	0.05	53.33 (46.91)	4.15	5.25	49.33 (21.40)	4.06	3.13	60.00 (50.77)	4.56	6.06	54.22 (46.78)	4.25	4.81
$CuCl_2$	0.1	10.67 (18.99)	0.94	1.06	13.33 (19.55)	0.00	3.06	8.00 (16.14)	1.00	2.06	10.66 (19.50)	0.64	2.06
$CaCl_2$	0.1	81.33 (64.33)	3.00	20.06	49.33 (61.59)	2.43	18.87	82.66 (65.43)	3.53	21.06	71.10 (57.89)	2.98	19.99
H_3BO_3	0.05	85.33 (67.53)	2.68	12.00	13.33 (63.43)	2.81	10.06	81.33 (65.43)	2.61	13.68	59.99 (50.16)	2.70	11.91
Water	–	89.33 (71.01)	2.93	55.00	73.33 (69.73)	2.92	60.00	90.66 (72.29)	3.00	56.00	84.44 (66.23)	2.95	57.00
CD(P=0.01)		10.16	0.408	0.371	7.57	0.554	0.326	5.38	0.174	0.453	9.28	0.578	0.371
CD(P=0.05)		7.25	0.298	0.270	5.40	0.185	0.238	3.84	0.127	0.330	5.02	0.398	0.270
GM±SEM		57.33±2.35	2.56±0.10	17.00±0.911	55.90±1.75	2.36±0.625	17.62±0.80	57.04±1.25	2.80±0.429	17.25±0.11	17.85±0.67	2.65±0.10	17.00±0.611
CV (%)		7.11	7.82	1.07	5.43	5.28	0.911	3.78	3.06	1.29	6.96	8.82	2.07

Values are given in parentheses are angular transformed value and average of three replications

Table 7: Effect of micronutrient treatment on growth and yield component of field pea

Treatments	Conc. (%)	Plant height (cm)	No. of pods/ plant	Average length of pod (mm)	No. of grain/ pod	1000 grain weight (g)	Yield/plant (g)	Yield (q ha^{-1})
$AlCl_3$	0.5	54.67	25.17	58.67	5.33	105.34	7.45	10.33
KCl	0.5	50.33	26.67	54.67	4.33	122.00	7.00	10.00
$ZnCl_2$	0.5	47.67	26.00	55.67	4.00	126.00	7.50	9.67
$CuCl_2$	0.1	45.25	21.00	55.33	4.67	108.00	6.33	7.17
$CaCl_2$	0.1	53.33	23.00	55.00	5.00	127.34	6.00	8.34
H_3BO_3	0.5	53.00	30.50	59.67	6.00	122.00	8.67	11.50
Water	–	56.00	26.67	55.00	5.67	118.00	7.17	10.34
CD (P = 0.01)		1.26	2.95	2.19	2.04	9.70	1.74	1.69
CD (P = 0.05)		0.904	2.10	1.56	1.460	6.92	1.24	1.20
GM±SEM		51.14±0.293	50.85±0.68	56.33±0.509	5.0±0.4	49.19±1.12	7.15±0.444	19.23±0.39
CV (%)		0.989	2.33	1.56	16.42	4.29	9.76	3.52

Values are average of three replications azide (3.94 pustules/leaf) followed by thiourea and Aspirin with 13.61 and 15.57 pustules per leaf, respectively.

Result presented in data Table 9 revealed that sodium azide, nicotinic acid and potassium meta bi-sulphate resulted comparatively significant increase in plant height 52.0, 50.33 and 49.0 cm, respectively in comparison to check (43.5 cm) while in other treatments significantly reduction in plant height was observed. The maximum reduction in plant height was observed when ascorbic acid (19.54%) was used in comparison to check. Thiourea, sodium azide, ascorbic acid and aspirin resulted significant increase in length of pod in comparison to check. Maximum pod length was observed in Thiourea (8.53%) followed by sodium azide (8.0%), ascorbic acid (7.59%) and aspirin (7.13%) increase in pod length to check. However, other treatments showed significant reduction in the length of pod. The effect of various treatments was non significant for number of grain per pod in comparison to control. However, Silver nitrate, resulted 8.38% increase in number of grain per pod and potassium meta bi sulphate resulted 49.9% reduction in number of grain formation per pod in comparison to check. The sodium azide resulted 21.25 and 22.98% increase in grain yield per plant consequently two crop seasons over check and the effect of remaining treatment was non significant in respect to grain yield per plant, while use of thiourea exhibited 10% reduction in grain yield per hectare. Effect of some organic acids and chemicals which are also known as inhibitors to fungal growth were used under field conditions. Among these sodium azide was found most effective against rust of fieldpea, rest other chemicals were ineffective. The treatments Nicotinic acid, Aspirin and Potassium meta-bi-sulphate significantly reduced the size of pustules and other chemical treatments resulted reduction in the number of pustules per leaf. The results of the present studies are also partially in conformity with the result reported by Kessmann *et al.* (1994) and Madamanchi and Kuc (1991). They have reported that application of these chemicals reduced number of pustules and size of pustules in french bean rust caused by *U. appendiculatus* while these chemicals were found effective against rust of fieldpea, at the same time they adversely affected the growth and yield component of the crop (Table 8). Among all the chemical nicotinic acid, potassium meta bi-sulphate and sodium azide resulted significantly better plant height over control, while rest of the chemicals resulted in stunted plant height in comparison to check. However thiourea treated plants showed maximum pod length followed by sodium azide ascorbic acid, aspirin and nicotinic acid. Plants sprayed with silver nitrate resulted significant number of grain per pod than control and rest other treatments resulted non significant effect. However, the silver nitrate and sodium azide showed maximum grain yield per plant. The maximum yield was observed with sodium azide followed by ascorbic acid and silver nitrate, respectively.

Induction of resistance through organic acids and growth promoter and their impact on growth and yield component: Pooled data presented in Table 10 revealed that except biozyme all the inducer treatments, significant reduced disease severity in comparison to control. The minimum disease severity was recorded with tracil (22.67%) which resulted more than 71% reduction in disease severity over control followed by aminose (44.00%) and sucrose (59.16%) resulted in more than 45 and 26% reduction in disease severity, respectively over control (81.08%). All the treatments, except malic acid and aminose significant reduced the size of pustules in comparison to control (4.15 mm). However, minimum size of pustules were recorded with tracil (2.15 mm) and biozyme (2.60 mm) followed by sucrose (2.65 mm) and tannic acid (2.70 mm). Pooled data reveal that all the treatments significantly reduced the number of pustules per leaf. The minimum number of pustules was recorded in tracil (4.25) followed by aminose (10.66) with 92 and 81% reduction in comparison to control (54.50 pustules/leaf). Biozyme (21.0) and sucrose (22.19) resulted more than 60% reduction in the number of pustules over control.

None of the spray treatment significantly affected the plant height in comparison to control. However malic acid and tannic acid resulted 9.76 and 3.47% increase in plant height, while tracil and biozyme showed about 4.12 and 2.58% reduction in plant height in comparison to control (32.33) (Table 11). The treatment sucrose and biozyme significantly increased number of pods per plant among the various treatment tested. Only sucrose resulted significantly larger size (61.00 mm) pods, while aminose showed significantly smaller size (52.33 mm) pod in compassion to control (53.00 mm). All the spray treatments were resulted non-significant difference in number of grains per pod while aminose showed 38.83% less grains per pod in compassion to control (6.00 grains/pod). The significantly highest grain weight was recorded with malic acid (136.66 g) followed by tannic acid (131.34 g) and Sucrose (130.66 g) while during 2000-2001 crop season only malic acid (138.00 g) showed significantly more thousand grain weight over check (124.00 g). None of the treatment showed significant effect on grain yield/plant during 2000-2001 and 2001-2002 crop seasons.

Table 8: Induction of resistance by foliar application of some organic acids and chemicals against rust of field pea under field conditions during 1999-2002 crop seasons

		2000-2001			2001-2002			2002-2003			Pooled		
Treatments	Conc. ($\mu g\ L^{-1}$)	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf	Disease severity (%)	Average size of pustules (mm)	No. of pustules/ leaf
Nicotinic acid	100	71.00 (56.99)	3.00	18.67	71.66 (57.84)	4.50	19.67	71.66 (57.84)	2.67	18.16	71.44 (57.84)	3.39	18.83
Aspirin	100	66.33 (54.93)	2.66	14.66	66.60 (54.72)	2.16	16.00	66.77 (54.84)	2.53	16.05	66.53 (54.64)	2.45	15.57
Ascorbic acid	200	76.33 (61.03)	3.00	30.67	75.66 (60.56)	3.00	32.33	74.44 (61.51)	4.00	31.00	75.47 (60.10)	3.33	31.33
Potassium meta bi-sulphate	200	74.00 (59.37)	2.50	27.67	73.00 (58.71)	2.00	28.33	74.66 (59.79)	3.83	28.00	73.88 (58.75)	2.77	28.00
Silver-nitrate	200	80.67 (64.35)	3.63	26.33	78.67 (62.75)	3.33	27.33	80.00 (63.82)	4.00	26.71	79.78 (62.85)	3.65	26.79
Sodium azide	200	20.67 (26.68)	2.00	4.33	22.33 (27.76)	2.66	3.00	21.67 (27.37)	3.00	4.50	21.55 (27.01)	2.53	3.94
Thiourea	200	65.00 (53.76)	3.67	13.33	66.33 (54.55)	3.43	14.00	66.33 (54.59)	4.00	13.50	65.88 (54.50)	3.70	13.61
Water	–	80.00 (63.43)	4.66	60.00	81.66 (64.64)	4.50	65.00	81.66 (64.64)	4.00	62.00	81.10 (64.64)	4.38	62.33
CD (p = 0.01)		17.87	1.38	1.46	16.36	1.08	2.78	20.01	1.68	2.38	19.05	1.98	1.89
CD (p = 0.05)		12.87	0.99	1.05	11.79	0.78	2.00	14.42	1.21	1.71	13.12	0.96	0.87
GM±SEM		66.66±4.24	3.16±0.32	24.5±1.05	66.19±3.88	3.20±0.25	25.0±0.66	67.37±4.75	3.37±0.40	24.00±0.57	68.00±0.97	67.00±0.47	3.06±0.22
CV (%)		11.03	17.94	2.46	10.06	13.89	4.45	12.22	20.56	3.98	13.55	16.89	3.41

Values given in parentheses are angular transformed value and average of three replications

Table 9: Effect of organic acids and some chemicals on growth and yield components

Treatments	Conc. (ppm)	Plant height (cm)	Average length of pod (mm)	No. of grain/ pod	Grain yield/plant (g) 2000-2001	2002-2002	Grain yield (q ha^{-1})
Nicotinic acid	100	50.33	60.66	7.00	6.4	6.3	10.67
Aspirin	100	41.17	65.33	5.67	6.4	6.4	10.83
Ascorbic acid	200	35.00	65.66	5.67	5.6	5.9	12.10
Potassium meta bi-sulphate	200	49.00	58.33	3.67	6.0	6.6	10.67
Silver nitrate	200	41.00	61.00	8.00	6.5	6.6	11.33
Sodium azide	200	52.00	66.00	5.33	8.0	8.7	12.67
Thiourea	200	44.00	66.33	4.33	5.5	6.4	10.17
Water	–	43.50	60.67	7.33	6.3	6.7	11.63
CD (p = 0.01)		4.58	1.48	1.54	1.24	1.26	1.47
CD (p = 0.05)		3.29	1.07	1.11	1.05	1.26	1.03
GM±SEM		108.±2.17	63.00±0.35	5.91±0.36	4.45±0.20	5.25±0.20	20.61±0.37
CV (%)		3.46	0.97	10.75	8.25	7.25	1.85

Values are average of three replications

Table 10: Induction of resistance by foliar application of some organic acids and growth promoter against Uromyces viciae-fabae under field conditions

		2000-2001			2001-2002			Pooled		
Treatments	Conc. ($\mu g\ L^{-1}$)	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf	Disease severity (%)	Average size of pustules (mm)	No. of pustules/leaf
Sucrose	0.10	58.33 (49.83)	2.5	22.06	60.00 (50.78)	2.8	22.33	59.16 (50.01)	2.65	22.19
Tannic acid	0.05	76.67 (57.85)	2.5	50.00	68.33 (55.85)	2.9	49.00	72.50 (58.39)	2.70	49.50
Malic acid	0.05	72.67 (58.48)	3.5	23.33	73.00 (58.69)	3.6	23.00	72.83 (58.50)	3.55	23.16
Aminose	0.10	43.00 (40.47)	3.0	10.33	45.00 (42.12)	3.4	11.00	44.00 (42.10)	3.20	10.66
Tracil	0.5	22.67 (28.40)	2.0	4.17	26.67 (31.07)	2.3	4.33	22.67 (28.40)	2.15	4.25
Biozyme	0.10	77.00 (61.36)	2.0	21.00	74.33 (59.60)	3.2	21.00	75.66 (59.65)	2.60	21.0
Control	–	79.50 (62.77)	4.0	54.67	82.66 (65.40)	4.3	54.33	81.08 (64.89)	4.15	54.50
CD (P = 0.01)		10.35	1.58	3.68	9.50	1.28	4.85	1/.50	1.78	5.85
CD (P = 0.05)		7.39	1.13	2.63	6.78	0.91	3.460	7.78	0.95	3.060
GM±SEM		60.61 ± 2.59	2.78 ± 0.37	26.50±0.85	61.42 ± 2.20	3.21 ± 0.30	26.42±1.12	62.42 ± 2.10	3.21 ± 0.70	27.42±1.22
CV (%)		6.85	22.83	5.56	6.20	15.94	7.36	7.91	11.94	6.36

Values given in parentheses are arcsin values and Average of three replications

Table 11: Effect of some organic acids and growth promoter sprays on growth and yield component of fieldpea

						1000 grain weight (g)		Grain yield/plant	
Treatments	Conc. (%)	Plant height (cm)	Pods/plant	Average length of pod (mm)	No. of grains/ pod	2000-2001	2001-2002	2000-2001	2001-2002
Sucrose	0.10	32.50	30.00	61.00	6.33	130.66	132.00	8.00	7.67
Tannic acid	0.05	33.50	26.00	56.67	6.00	131.34	132.66	6.33	7.00
Malic acid	0.05	35.83	27.33	54.33	5.33	136.66	138.00	5.67	7.00
Aminose	0.10	32.00	24.67	52.33	3.67	120.66	122.66	5.67	6.67
Tracil	0.5	31.00	22.67	56.33	4.67	123.34	124.66	6.00	7.33
Biozyme	0.10	30.65	31.67	53.67	5.33	121.34	122.66	7.33	7.67
Control	–	32.33	25.00	53.00	6.00	121.32	124.00	6.67	7.67
CD (p = 0.01)		2.35	3.65	5.08	1.77	4.69	4.23	5.77	2.93
CD (p = 0.05)		1.67	2.60	3.62	1.26	3.63	3.00	4.12	2.09
GM±SEM		32.14±1.08	26.90±0.84	55.33±1.18	5.33±0.41	63.33±0.86	64.04±0.79	7.0±1.33	7.23±0.68
CV (%)		5.44	5.44	3.68	13.36	4.33	2.65	33.08	16.28

Value are average of three replications

Effect of some commercially available growth promoter and some organic acids used for induction of resistance in pea plants revealed that tracil and aminose were found most effective which significantly reduced disease severity, size of pustules and number of pustules per leaf during both the crop seasons followed by sucrose. Observations on various growth promoter formulations and organic acids resulted enhance the growth and yield of fieldpea. Among the various chemicals tested, sucrose was found effective in respect to pod length and grain yield per plant in both the crop seasons. While malic acid and tannic acid were effectively increase the plant height in both the years. This suggests a possibility to use of sucrose, malic acid and tannic acid as an inducer chemical for resistance in fieldpea plants against *U. viciae-fabae*.

The results of the present study show a strong possibility to protect fieldpea through their natural defense system by using inducer chemical agent as an option to choose for integration in to plant protection towards sustainability, environmental safety and the introduction of 'foreign gene' into genetically engineered resistant plants.

CONCLUSION

The results of the study have showed that micronutrients tested against *U. viciae-fabae,* only $CuSO_4$ and $Na_2B_4O_7$ were found most effective with 72-78% reduction in rust disease severity, 38 to 57% reduction in size of pustules and 83 to 92% reduction in the number of pustules per leaf of pea. Maximum grain yield was obtained with $ZnSO_4$ sprayed plots (12.68 q ha^{-1}) followed by KNO_3 and $SnCl_2$ sprayed plots. The growth components, plant height, pods per plants, was found best in $CaCl_2$ sprayed plots followed by $MnSO_4$ sprayed plots. However, minimum seed yield was obtained with K_2CrO_4 (9.12 q ha^{-1}), followed by $KMnO_4$, FeEDTA (13.14% decrease) in comparison to control (10.50 q ha^{-1}). Micronutrient combination A = KNO_3+$ZnSO_4$+$Na_2B_4O_7$ was tested as based combination and it was supplemented with combinations of $CuSO_4$, $Ca(NO_3)_2$ and $Kal(SO_4)_2$. Among the tested micronutrients combinations, the A+$CuSO_4$+$Ca(NO_3)_2$+$KAl(SO_4)_2$ combination was the best in respect to reduction in disease severity, number of pustule per leaf and average size of pustules followed by A+$KAl(SO_4)_2$+$Ca(NO_3)$ and A+$KAl(SO_4)_2$+$CuSO_4$, respectively. Five micronutrients

($AlCl_3$, KCl, $ZnCl_2$, $CuCl_2$, $CaCl_2$ and Boric acid (H_3BO_3) were found more fungitoxic against *U. viciae-fabae*. However, $ZnSO_4$, KCl, Na-azide, $Ca(NO_3)_2$, tracil and sucrose also developed resistance against rust of fieldpea. These micronutrients/chemical significantly reduce the disease severity and enhance the yield of fieldpea. There is an immense scope for the use macro/micronutrient and chemical in the plant disease management through induction of resistance. They may be incorporated as an alternative approach in integrated disease management strategies. In addition, more research is required to find out, how the micronutrient or their combinations, organic acid and growth promoter increase or decrease tolerance or resistance, what the changes are in the host metabolism and how this can be more effectively used as chemical inducer in control of plant diseases.

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