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EFFECTS OF POTASSIUM NUTRITION ON GROWTH, BIOMASS AND CHEMICAL COMPOSITION OF RICE PLANTS AND ON HOST-INSECT INTERACTION

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ABSTRACT: Effects of different levels of potassium (K) on the growth, biomass and chemical composition of rice plants and on biology and behaviour of whitebacked planthopper, *Sogatella furcifera* (Horv.) were determined through culture solution at 29°/21°C day/night temperatures and 70% RH. At low level of K, plant height, number of tillers/hill, root growth and biomass of rice plants were significantly less than the plants grown in the standard culture solution (40 ppm K). However, further increase in the amount of K from 40 ppm to 200 ppm did not significantly increase the growth and biomass of rice plants. Increase in the application of K in the culture solution increased K but decreased N, P, Mg, Si, Zn and soluble proteins in the rice plants. Deficiency of K in rice plant increased intake and assimilation of food, honey dew excretion, growth index, adult longevity and population build up of *S. furcifera*. Application of high dose of K to rice plants decreased adult life and population build up of the insect.

Key Words: Rice; Potassium; Growth; Whitebacked Planthopper; Interaction; Allelochemicals; Pakistan.

INTRODUCTION

Insects possess intimate and subtle relationships with their host plants. Therefore, even minor changes in physical or chemical attributes of plants can profoundly affect their suitability to insect pests (Salim et al., 1990).

In Pakistan more than 50 species of insect pests attack the rice crop. Of these, the whitebacked planthopper, *S. furcifera* (Horvath) (Homoptera: Delphacidae) is one of the major pests of rice and inflicts heavy damage due to 'hopperburn' (Mahar et al., 1978 and 1983; Majid et al., 1979; Salim, 1991).

Potassium is an essential element for the growth of rice plant and takes part in various physiological processes (Yoshida, 1981). The mechanism of stomatal opening and closing depend on K (Penny and Bowling, 1974; Terry and Ulrich, 1973). Potassium enhances the translocation of photosynthates and mobilizes the stored material (Mengle, 1980), and has a beneficial effect on ATP synthesis (Watanabae and Yoshida, 1970). The main function of K is activation of various enzymes (Evans and Sorger, 1966). Deficiency of K has been reported to accumulate soluble carbohydrates, amino acids and reducing sugars. It impairs the synthesis of starch as well as glycogen and blocks the respiratory substances and decreases the rate of oxidative phosphorylation and photophosphorylation (Baskaran et al., 1982).

Potassium induced changes in rice plant had profound effect on insect-host interactions. Increase in K in rice plant caused reduction in the feeding rate of brown planthopper, *Nilaparvata lugens* (Vaithilingam et al., 1976) and the rate of population build up of *N. lugens* and green leafhopper, *Nephotettix* sp. (Subramanian and Balasubramanian, 1976; Narayanasamy et al., 1976, Ittyavirah et al., 1979).

Little information was available on the effects of K on growth, biomass and chemical composition of rice plant and the effects of K-induced changes on the interaction of rice plant and *S. furcifera*, therefore, some studies were carried out on these aspects.

MATERIALS AND METHODS

Plants of TNI and IR2035-117-3 were grown through culture solution at 29°/21°C (day/night) and 70% RH. Low (3 ppm), medium (40 ppm) and high (200 ppm) levels of K were maintained in the culture solution, which was prepared following the procedure of Yoshida et al. (1976) in demineralized water.

Levels of K in the culture solution at 3,

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40 and 200 ppm were maintained by adding 0.4, 5 and 25 ml of stock solution to prepare 4l culture solution.

Seeds of TNI and IR2035-117-3 were surface sterilized with 0.1% mercuric chloride solution for two minutes and washed with demineralized water to remove mercuric chloride. Seeds were soaked for 24 hours and spread on a nylon net stretched on a styrofoam frame floating in a plastic tray having 50% culture solution. The seedlings were transplanted in plastic trays 14 days after soaking. The solution was changed at weekly intervals, the pH of the solution was adjusted daily to 5 for 20 days and 5.5 afterwards. Water level in trays was maintained daily. Plant height and root length were measured and tillers were counted. The rice plants were removed and washed with demineralized water 40 days after transplanting (DAT). Fresh weights of roots and shoots were recorded separately. To record dry weights the roots and shoots were placed in marked paper bags and the samples were dried in a Hurricane oven at 80°C for 72 hours.

Fresh leaf sheaths of 20 rice plants grown for 40 days in standard culture solution and in solution with low or high level of K were harvested, ground, steam distilled, and then extracted as described by Salim et al. (1990). The weight of steam distillate extract (allelochemicals) was recorded. Leaf sheaths of 40 day old plants grown at different levels of K of the test rice cultivars were cut and dried at 80°C for 72 hours and analyzed for N, P, K, Mg, Ca, Si, Zn, Fe, total free sugars and soluble proteins.

For analysis of total N, 50 mg of ground sample was digested in a micro kjeldahl flask with 2 ml of concentrated H_2SO_4 and 1 g catalyst mixture (Se: K_2SO_4, 20: 100 g) until clear, cooled, and brought up to volume with deionized distilled water. Nitrogen was determined colorimetrically as indo-phenol blue on an auto-analyzer (Technician Instruments, Terryton, NY).

For analysis of P, Fe and Si, 1g of sample was digested with a 10 ml mixture of $HClO_4$; NHO_3; H_2SO_4 (300: 750: 150 ml) on a hot plate at 500°C until a gelatinous white residue remained to which deionized water was added after cooling. The mixture was filtered through Wattman filter paper No. 42 to 50 ml volumetric flask. The residue on the filter paper was washed twice with 0.1M HCl and the washings were added to the filtrate. The filtrate was brought up to the volume with 0.1M HCl and shaken. Phosphorus was determined colorimetrically on the auto-analyzer using modified acid molybdate method (Zandstra, 1968). Iron was analyzed using an atomic absorption spectrometer (Perkin Elmer, Model 2380, Norwalk, CT). The residue on the filter paper was burned at 500°C for 4 to 5 hours for gravimetric determination of crude Si.

For analysis of K, Ca, Mg, and Zn, 1 g of plant sample was soaked for 24 hours in 25 ml 1M HCl and then filtered through Wattman filter paper No. 40. Potassium, Ca, Mg and Zn were analyzed in the filtrate using auto-analyzer or atomic absorption spectrometer.

For estimation of soluble proteins and free sugars, plants grown at different levels of K were analyzed on a dry weight basis following the methods of Lowry et al. (1951) and Yoshida et al. (1976).

Data for plant height, number of tillers, root length and biomass of shoot and root were subjected to analysis of variance and the means were compared using least significant differences (LSD) test at P=0.05 and 0.01 levels.

RESULTS AND DISCUSSION

Rice plants grown at low level of K had short, droopy and dark green leaves. On the lower leaves, intervenes became yellow. Yellowing was started from the tips and advanced progressively and eventually whole leaf became light brown in colour. On few leaves brown spots were also developed.

Plant Growth

Height of rice plants was recorded 10, 30 and 50 days after transplanting (DAT). Plant height was significantly less in the K-deficient rice plants than the plants grown in standard culture solution (40 ppm K) or at high level of K (200 ppm) (Table 1). However, increase in the application of K from 40 ppm to 200 ppm did not increase plant

Table 1. Plant growth at different levels of K in the culture solution

K (ppm) in Culture Solution	Plant height (cm)		Tillers/hill (No.)		Root length (cm)	
	TNI	IR2035-117-3	TNI	IR2035-117-3	TNI	IR2035 117-3
10 DAT						
3	36.3b	35.3b	5.4b	5.4b	13.5b	14.1b
40	42.4a	39.5a	6.1a	5.8a	14.3a	14.9a
200	42.4a	40.2a	6.3a	6.0a	14.1a	15.1a
30 DAT						
3	43.0c	39.9b	6.9a	7.1b	25.7c	27.2c
40	59.2b	60.7a	7.3a	8.1a	25.5b	30.1b
200	63.5a	60.7a	7.3a	8.4a	27.1a	35.7a
50 DAT						
3	63.6b	57.1c	11.2b	13.3c	37.7b	41.8b
40	71.8a	76.0b	12.4a	13.7b	38.6a	48.8a
200	71.8a	78.5a	12.6a	14.6a	38.2a	48.5a

Analysis is based on values transformed to log (X) in root length. In a column means followed by a common letter are not significantly different at P = 0.05 by LSD

height except at 30 DAT in TN1 and 50 DAT in IR2035-117-3.

At low level of K in the culture solution, number of tillers/hill were significantly less than the plants grown in standard culture solution or at high level of K except in TN1 at 30 DAT (Table 1). Excessive application of K did not increase number of tillers/hill in comparison with standard culture solution except in IR2035-117-3 at 50 DAT. However, effects of different levels of K on tillering are less evident than the effects on plant height.

Growth of roots of rice plants increased with increase in the application of K from 3 – 40 ppm. However, further increase from 40 – 200 ppm had no significant effect on root growth except at 30 DAT (Table 1).

Plant Biomass

Fresh weight of plant shoot increased with increase in the amount of K from 3 – 40 ppm in the culture solution but decreased with further increase in K (Table 2). Dry weight of rice plants grown at low level of K was significantly less than the plants grown in standard culture solution. However, further increase in K from 40 – 200 ppm had no significant effect on the dry weight of shoot of rice plants.

Both fresh weight and dry weight of roots of rice plants increased with increase in the amount of K from 3 to 40 ppm but no significant increase was found with increase in the application of K from 40 to 200 ppm (Table 2).

Chemical Composition

Increase in the application of K increased K but decreased N, Mg, Si, Zn and soluble proteins in rice plants (Table 3). Previous studies indicate that addition of K decreased N, Ca, Mg and B but increased K and had no effect on P, Cu, Zn and Mn in citrus leaves. However, in maize leaves deficiency of K in nutrient solution increased N, P, Ca, Mg, Mn, B and Zn but decreased K (Clark, 1982). Increase the quantity of allelochemicals in rice plants (Table 3).

Effect on Plant - *S. furcifera* Interactions

Deficiency of K in rice plant significantly increased food intake, assimilation of food and honey dew excretion (Table 4). Increase in the application of K from 40 to 200 ppm had no significant effect on food intake and honey dew excretion. However, higher level of K in rice plant depressed the assimilation of food by the insect and also decreased adult life and population build up (Table 4).

Increase in the application of K to plant reduced the growth index and prolonged the developmental period of *S. furcifera*. Adult

Table 2. Biomass of rice plants grown in culture solution at different levels of K

K (ppm) in Culture solution	Shoot biomass (g) TNI	Shoot biomass (g) IR-2035-117-3	Root biomass (g) TNI	Root biomass (g) IR 2035-117-3
Fresh biomass (g)				
3	43.51c	38.00c	20.68b	25.25b
40	77.49a	68.09a	38.18a	46.25a
200	67.46b	61.15b	38.17a	47.43a
Dry biomass (g)				
3	11.04b	10.57b	2.63b	3.20b
40	17.20 a	15.72a	4.68a	5.78a
200	15.56 a	14.18a	4.93a	5.57a

In a column, means followed by a common letter are not significantly different at P = 0.05 by LSD

Table 3. Chemical composition of rice plants grown in culture solution at different levels of K

Constituents	Contents in rice plants at K (ppm) in culture solution					
	TNI			IR 2035-117-3		
	3	40	200	3	40	200
N (%)	1.62	0.98	0.83	1.75	1.10	0.90
P (%)	0.31	0.26	0.22	0.40	0.34	0.30
K (%)	0.25	1.79	2.33	0.28	2.16	2.72
Mg (%)	0.28	0.19	0.10	0.27	0.25	0.17
Ca (%)	0.08	0.08	0.06	0.09	0.09	0.08
Si (%)	2.50	1.90	1.57	2.72	2.24	2.00
C (%)	40.00	39.00	39.00	39.00	39.00	38.00
Zn (ppm)	16.00	9.00	8.00	17.00	12.00	10.00
Fe (ppm)	55.00	50.00	41.00	51.00	54.00	58.00
Soluble proteins(%)	3.82	3.40	2.86	3.98	3.79	3.51
Total Free Sugars (%)	7.48	6.93	6.70	6.48	4.58	5.13
Allelo chemicals (mg)	7.15	8.55	9.35	9.40	11.75	12.80

longevity and fecundity of the insect was reduced with increase in the application of K. Deficiency of K in rice plant enhanced and application of high dose of K suppressed the population build up of *S. furcifera* (Table 4). The results of present investigations agree with others (Van Emden, 1966; Metcalfe, 1970; Sharma, 1970). Increased K level led to accumulation of more phenols which probably contributed to increased insect resistance in some rice cultivars (Vaithilingam and Baskaran, 1983).

Potassium is usually found in adequate amounts in alkaline and neutral soils. Since in Pakistan rice growing soils are primarily alkaline, therefore, in principle K-deficiency should not occur. However, K-deficiency may occur on poorly drained soils, because toxic substances produced in highly reductive soils retard K uptake and less soil K is released under poorly drained conditions (Yoshida, 1981). It may be one of the factors for low rice yields in Pakistan. Emphasis should be given on the optimum dose and appropriate time of its application. Studies carried out in Japan indicate that K application at the maximum tillering stage increased the number of panicles and spikelets. While K applied at the panicle formation stage increased number of panicles and spikelets as well as weight of grains. Application of K after panicle formation mainly increased grain weight (Su, 1976).

Low and excessive amounts of K application caused quantitative changes in the nutrients and allelochemicals in the rice plant. The quantity of N content in plant tissue increased at low level of K applica-

Table 4. Effect of K-induced changes in rice plant on the biology and behaviour of *S. furcifera*

Biological Parameters	TNI 3	TNI 40	TNI 200	IR 2035-117-3 3	IR 2035-117-3 40	IR 2035-117-3 200
Food intake (mg/female/24h)	13.1a	10.3b	9.1b	4.8a	3.9ab	2.7b
Food assimilation (mg/female/24h)	0.62a	0.53b	0.46c	0.26a	0.20a	0.11b
Honey dew (mg/female/24h)	12.4a	9.8b	8.6b	4.5a	3.7ab	2.6b
Nymphs becoming Adults (%)	97.5a	92.5a	90.0a	27.5a	20.0a	15.0a
Nymphal duration (days)	14.3b	15.0ab	15.6a	17.5c	18.5b	19.6a
Growth index (days)	6.82a	6.18ab	5.81b	1.56a	1.08ab	0.77b
Male longevity (days)	14.6a	13.2b	11.8c	8.4a	6.9b	6.0b
Female longevity (days)	20.7a	18.9b	16.6c	9.5a	7.9b	6.8b
Fecundity/female	134 a	120ab	100	5a	4b	3c
Population/pair	133 a	110ab	89b	10a	7b	4c

Analysis is based on values transformed to arcsin (SQR (x)) for percent nymphs becoming adults, log(x) for fecundity and SQR (Y) for population build up. In a row, means followed by a common letter are not significantly different at P = 0.05 by LSD.

tion in the present studies. It has been reported that high N content in plant tissues enhanced population of insects (Merino and Vazaquez, 1966; Van Emden, 1966; Metcalfe, 1970). A positive correlation was observed between the fecundity of leafhoppers and the level of soluble N in their host plants (Hinckley, 1963; Fennah, 1969). Fecundity of a planthopper, *N. lugens* also increased with N application to rice plant (Kalode, 1974; Pathak, 1975; Dyck et al., 1979). Insect digestion capacity increased at higher levels of N in the food (Scriber, 1984). Peaks of populations of insects on *Holcus mollis* corresponded very well with the peaks of N availability in the plants (Mc Neill and Southwood, 1978).

In the present studies, the K content in the plant tissue was extremely low (0.3%) at low level of K application instead of 2-3% at high level of K. It has been reported that increase in K to rice plant caused reduction in the feeding rate of *N. lugens* (Vaithilingam et al., 1976) and decrease in the population of *N. lugens* and *Nephotettix* sp. (Subramanian and Balasubramanian, 1976). Likewise, plants receiving high level of K were less preferred by *N. lugens* (Vaithilingam and Baskaran, 1982).

Sugar concentration was comparatively high in the rice plants grown at low level of K. It has been reported that high population densities of leaf sucking insect pests were associated with high concentration of reducing sugars in leaves (Fritzsche et al., 1957).

The quantity of allelochemicals was comparatively low in rice plants grown at low level of K and its quantity increased with increase in the application of K. Allelochemicals in rice plants are a large group of compounds such as essential oils, terpenoids, alcohol, aldehydes, fatty acids and waxes. They strongly influence the chemical environment of plants and hence play an important role in suppressing the population and adversely affecting the biology and behaviour of insects. Several studies have demonstrated the importance of allelochemicals affecting the host-insect interactions (Saxena and Okech, 1985; Saxena, 1986; Salim and Saxena, 1992). Various interactions between allelochemicals and nutrients may affect the suitability of insect food. Thus not only presence of nutrients but also their bioavailability may be significant (Hagen et al., 1984). They may affect the herbivore nutritional physiology (Beck and Reese, 1976; Reese, 1978).

Potassium deficiency led to accumulation of soluble carbohydrates, reducing sugars and amino acids, and impaired synthesis of starch, glycogen and protein. It also caused reduction of respiratory substrate and oxidative phosphorylation rates. Such effects predispose the plants to herbivore attack (Baskaran et al., 1982). Increased K produces better proteogenesis, and physiological phenomenon associated with diminution of amino acids and reducing sugars in the plant sap, which otherwise favour insect growth (Chaboussou, 1972).

Increase in the population of *S. furcifera* at low level of K application may be attributed to increase in N content, total free sugars, and decrease in the quantity of K and allelochemicals in the rice plant. Application of K to plants may play dual role viz. increase in the plant growth, biomass and paddy yield and increase in the expression of resistance against insect pests. Use of such resistance inducing agents as an adjunct to genetic resistance may play an important role in the management of *S. furcifera* and hopefully other insect pests and diseases.

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