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EFFECTS OF APPLIED POTASSIUM AND PHOSPHORUS ON BRONZING IN RICE GROWN IN IRON TOXIC SOILS

W.M.J. BANDARA and G.A. GUNATILAKA
Regional Agricultural Research Centre, Bombuwela.

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Abstract: Bronzing or iron toxicity is a physiological disorder of rice caused by high concentrations of soluble iron and deficiencies in P and K in wetland soils. Field experiments were conducted at Mellewa and Dodangoda to evaluate the effects of applying P and K and varietal tolerance in iron toxicity. Soil analysis showed that available P and exchangeable K were deficient while exchangeable Fe was very high in iron-toxic soils. Application of 85.8 kg K/ha reduced the bronzing symptoms and Fe content in the leaves, and increased growth and yield of rice. Very severe bronzing symptoms, corresponding to a tissue iron content > 700 mg/kg, were obtained when no fertilizers were applied. Symptoms of iron toxicity were mild after application of 57.2 kg K/ha to the tolerant variety (Bw 267-3) and after application of 85.8 kg K/ha to the susceptible variety (Bg 94-1). Growth and grain yield of rice also increased with increased application of phosphorus fertilizer. Application of 85.8 kg K/ha and 32.1 kg P/ha and varietal tolerance can significantly increase the growth and grain yield of rice grown on iron toxic mineral soil of the low country wet zone.

Key words : Iron toxicity, phosphorus, potassium, rice soils, varietal tolerance.

INTRODUCTION

Bronzing or iron toxicity is a physiological disorder of rice in Sri Lanka. It is the major soil constraint on rice cultivation in the low country wet zone. Low country wet zone(LCWZ) comprises land below 300m in elevation and receiving a rainfall > 2500 mm per annum. Of the 90000 hectares of cultivated rice lands in LCWZ, approximately 1/3 may be considered as potentially iron toxic.[1] However, this disorder is seen in localized spots rather than over continuous areas. Therefore the actual area affected by iron toxicity is about 5000 ha. Many rice varieties that are apparently tolerant to iron toxicity are affected nevertheless as shown by their low yield.

This disorder has been associated with excess soluble iron, low pH, poor drainage, low levels of phosphorus and potassium and presence of respiratory inhibitors such as hydrogen sulphide.[2-4] In LCWZ it occurs generally in the first and second order valleys due to a combination of factors mentioned above. The low silica, phosphorus and potassium concentration of sandy soils in these valleys predispose the plant to bronzing. Therefore iron toxicity is ascribed to a multiple nutritional soil stress rather than to a high level of active iron under acid condition.[5,6] This disorder is characterized by a reddish brown discoloration of the leaves,[7,8] inhibition of tillering, retardation of root growth and coarseness, discoloration and death of roots.[2,4] Tissue concentration of Fe for the occurrence of iron toxicity varies widely, depending on the variety, stage of crop and nutrient status.[9,10]

Varietal tolerance has been utilized to alleviate this disorder but is effective only at moderate levels of toxicity. Ameliorative measures such as liming, periodic surface drainage, interception of interflow and good fertilizer management are considered effective.[4,11] However most of these methods are either expensive or impractical under prevailing conditions. An integration of varietal tolerance and good fertilizer management may be the most effective and economical approach to alleviate this problem.

This paper deals with two experiments on potentially iron toxic sandy soils to determine the effectiveness of applied potassium and phosphorus in alleviating bronzing in a susceptible and tolerant rice variety.

METHODS AND MATERIALS

The experiments were carried out at Millewa and Dodangoda in Kalutara district in LCWZ of Sri Lanka. The soils at both sites were loamy sand with medium levels of organic matter, acidic in reaction and deficient in exchangeable K and available P (Table 1). The soil contained comparatively high levels of total iron with 1N ammonium acetate extract (Table 1). The rice varieties used in this study were Bg 94-1, susceptible to iron toxicity and Bw 267-3, tolerant to iron toxicity.

Effect of applied potassium on iron toxicity in rice: The first experiment was carried out to determine the effect of applied K on bronzing in rice grown in iron toxic mineral soils at Millewa. Two variable factors considered were rice variety and potassium level. Two rice varieties mentioned earlier were used. Three weeks old seedlings of both varieties were transplanted at a spacing of 20x15 cm with 3 seedlings per hill. Graded levels of potassium at 0, 28.6, 57.2, 85.8 and 114.4 kg K/ha were applied in 3 equal split doses as basal, 3 and 6 weeks after transplanting. Treatments were replicated 3 times in a randomized complete block design. Urea was applied at a rate of 72.0 kg N/ha in 3 split doses (15.4 kg N as basal, 28.3 kg N/ha each at 3 and 6 weeks after planting). Concentrated super phosphate was applied at the rate of 21.4 kg P/ha just before planting. Hand weeding was the only method of weed control adopted and was done at each fertilizer application. Insecticides were applied when required. Severity of bronzing was observed periodically and rating done according to IRRI standard evaluation system for rice.[12]

Plant growth was observed by tiller counts, plant height and yield components. Grain yield of each treatment was recorded. The experiment was repeated for two seasons, Maha 1982/83 and Maha 1983/84 in the same field.

Soil was analysed to determine the fertility level of the experimental field. Soil was extracted with 1N ammonium acetate at pH 4.8 and plant samples were digested using sulfuric/perchloric acid mixture. K and Fe in extract solution were determined by atomic absorption spectrophotometry.

Table 1: Physico-chemical properties of the soils at experimental sites

	Location	
Property	Millewa (Exp. I)	Dodangoda (Exp. II)
Clay (%)	11.8	13.8
Silt (%)	6.1	7.3
Sand (%)	82.1	79.9
Texture	loamy sand	loamy sand
Organic matter (%) (Walkley & Black method)	2.5	3.0
pH (soil:water 1:1)	4.9	4.9
Total N (%) (Kjeldahl method)	0.12	0.13
Olsen P (mg/kg)	1.6	1.8
Exchangeable cations (meq/100g) (1N Ammonium acetate extraction at pH 7.0)		
Ca	0.29	0.30
Mg	0.07	0.08
K	0.05	0.08
Na	0.03	0.03
Total Fe (%) (perchloric acid digestion and AAS determination)	2.5	2.3

Effect of applied phosphorus on iron toxicity in rice : A second field experiment was conducted to determine the effect of applied phosphorus on iron toxicity in rice. The same location as in experiment 1 was used in Yala 1984 and Maha 1984/85. In Yala 1985, the experiment was conducted in Dodangoda in the same district.

A two factor factorial experiment was laid out in a randomized complete block design with 3 replicates. The two variable parameters considered were rice varieties and phosphorus levels. The same varieties with same plant spacing were used as in experiment 1. Five graded levels of P at 0.0, 10.7, 21.4, 32.1 and 42.8 kg P/ha were applied only as basal at transplanting. Potassium was applied for all treatments at 114.4 kg K/ha to ensure K was not limiting. Nitrogen fertilizer levels, weed and pest control methods and data recorded were similar to those of experiment 1.

RESULTS AND DISCUSSION

Application of potassium reduced the bronzing symptoms, significantly improved plant growth in terms of plant height (by 24.4% in Bg 94-1 and by 28% in Bw 267-3), number of tillers per plant (by 26% in Bg 94-1 and 30% in Bw 267-3), panicle length (by 15% in Bg 94-1 and 6.6% in Bw 267-3), number of filled grains per panicle (by 56% in Bg 94-1 and 21 % in Bw 267-3) and significantly increased the grain yield (150% in Bg 94-1 and by 68% in Bw 267-3) (Tables 2 & 3). Results show that yield increase was more pronounced in the susceptible variety (Table 2).

With increased applications of potassium, potassium content in leaves increased whereas the Fe content decreased (Table 2). This effect was more pronounced in the susceptible variety (Bg 94-1) which had significantly higher Fe content at all levels of applied potassium (Table 2). A significantly negative correlation was found between Fe and K content of leaves in both varieties (Fig. 1).

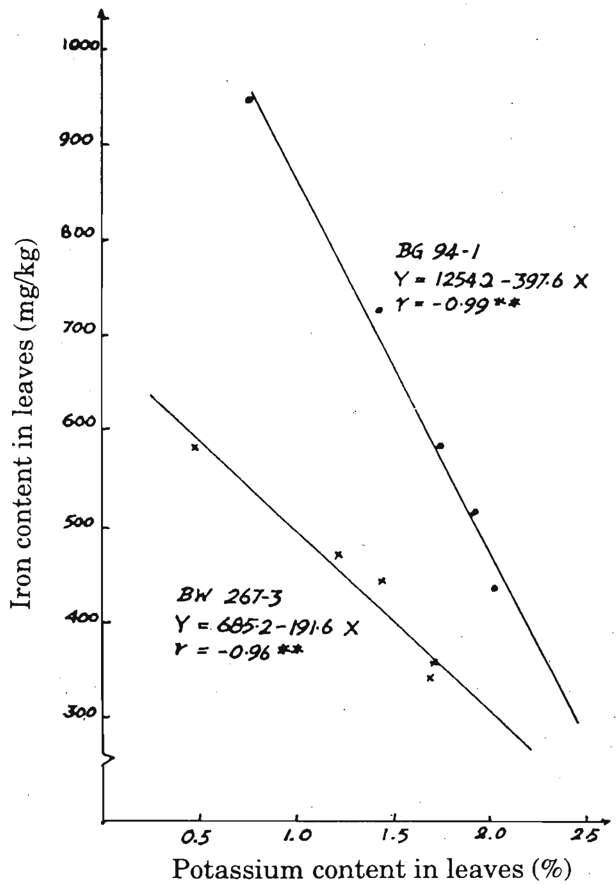

Figure 1: Relationship between leaf tissue K (%) and Fe (mg/kg) in two rice varieties grown in iron toxic mineral soil at different levels of applied K-fertilizer.

Table 2: Effect of applied potassium on bronzing, tissue concentration of Fe and K and grain yield of rice grown in mineral soil at Millewa.

Treatment		Season							
		Maha 1982/83				Maha 1983/84			
Variety	K level kg/ha	K in leaves (%)	Fe in leaves (mg/kg)	Bronzing scoring	Grain yield (t/ha)	K in leaves (%)	Fe in leaves (mg/kg)	Bronzing scoring	Grain yield (t/ha)
	0.0	0.73	950	9.0	0.75	1.04	1310	8.0	0.69
	28.6	1.38	726	7.6	1.28	1.13	1060	6.4	1.08
Bg 94-1	57.2	1.68	583	6.5	1.40	1.22	657	5.3	1.19
	85.8	1.89	523	4.0	1.60	1.26	553	3.2	1.42
	114.4	1.96	446	3.5	1.81	1.35	446	2.5	1.82
	0.0	0.44	585	5.0	1.44	0.78	1106	4.6	1.87
	28.6	1.18	480	4.3	1.81	0.89	667	3.6	2.16
Bw 267-3	57.2	1.37	454	3.0	2.10	1.08	443	2.8	2.65
	85.8	1.63	360	2.1	2.34	1.19	350	1.5	2.73
	114.4	1.63	350	1.3	2.49	1.20	250	1.2	3.05
CV%		14.5	13.4		18.0	5.4	6.2		16.9
LSD (K level) (p =0.05)		0.20	90.1		0.31	0.07	185		0.391
LSD (Variety) (p = 0.05)		0.15	57.1		0.23	0.47	135		0.247

Table 3: Effect of applied potassium on plant height and some yield components of rice grown in iron toxic mineral soil at Millewa

Treatment		Season							
		Maha 1982/83				Maha 1983/84			
Variety	K level kg/ha	No. of til. /hill	Plant height (cm)	Panicle length (cm)	No. of filled grains per panicle	No. of til. /hill	Plant height (cm)	Panicle length (cm)	No. of filled grains per panicle
	0.0	2.2	29.2	15.2	30.5	5.2	44.3	14.8	34.7
	28.6	2.5	35.2	16.2	34.5	5.2	46.5	15.3	39.8
Bg 94-1	57.2	2.8	35.5	16.8	38.5	5.5	48.2	16.0	49.5
	85.8	2.6	37.2	17.5	42.2	6.1	51.5	16.8	48.3
	114.4	2.7	37.1	17.2	48.5	6.5	53.8	17.0	52.8
	0.0	1.7	42.3	19.2	53.5	5.1	66.5	20.0	67.5
	28.6	1.8	49.0	19.3	58.5	5.5	74.4	20.3	66.0
Bw 267-3	57.2	1.9	57.3	20.3	60.5	5.8	78.8	20.7	67.8
	85.8	2.0	57.8	20.2	66.3	5.8	77.4	20.8	75.9
	114.4	2.4	57.7	20.5	68.3	6.1	79.7	21.3	76.8
CV (%)		9.3	6.8	5.4	8.5	10.2	7.5	6.5	12.5
LSD (variety) (p = 0.05)		0.4	3.15	1.04	8.5	0.3	2.8	0.95	12.5
LSD (K level) (p = 0.05)		ns	4.2	0.63	7.5	0.4	3.7	0.58	8.6

til. - tillers ns - not significant LSD - least significant difference

At low levels of K, very severe bronzing symptoms corresponding to the tissue iron content of more than 700 mg/kg were observed in the susceptible variety. The symptoms were rated to be mild at tissue iron content less than 450 mg/kg. This level was obtained in the tolerant variety at 57.2 kg K/ha and in the susceptible variety at 85.8 kg K/ha.

Effect of Phosphorus

In 1984 Yala season, phosphorus levels did not significantly increase the yield in spite of decreased iron content in leaves (Table 4). However, experiments carried out in the following two seasons showed that plant growth and grain yield increased with levels of applied P. Yield increase was 19% for Bg 94-1 whereas it was 26% for Bw 267-3. The highest yield level was obtained after application of 32.1 kg P/ha (Table 4). Visual observation also showed that bronzing symptoms slightly decreased at higher doses of P fertilizer (Table 4). Also at higher doses of P, the concentration of Fe in tissue was found to decrease while the concentration of P in tissue increased (Table 4).

Application of phosphorus improved plant growth in terms of number of tillers per square meter (by 35.6 % in Bg 94-1 and 23.3 % in Bw 267-3) number of panicles per square meter (16.6 % in Bg 94-1 and 19.7 % in Bw 267-3), number of filled grains per panicle (by 27.9 % in Bg 94-1 and 18.0 % in Bw 267-3) and panicle length (by 8.2 % in Bg 94-1 and 5.1 % in Bw 267-3) (Table 5). However, table 5 also shows that yield components were not significantly increased by P application except in 1984/85 Maha season in which P application increased the number of tillers per square meter, and number of filled grains per panicle. But it was observed in Yala 1985 season, contribution of P levels to changes in the yield components was very low (Table 5).

Application of P is not however, as effective as application of potassium in increasing the yield of rice. Under submerged conditions a large amount of P is fixed as Fe - P.[13] The need for more P in these soils is therefore, related to P- fixation. Singh & Singh[14] have reported that P content increased with K application while Fe concentration was drastically reduced indicating K-P synergism and K-Fe antagonism. Gupta *et al.*[15] showed that application of P decreased the available and reducible Fe and uptake of Fe while increasing the dry matter yield of IR-8 rice variety. It has also been proved that excessive Fe build up can be reduced if iron toxic soils are fertilized with P, K and Ca + Mg.[5]

Results obtained from both experiments showed that application of potassium and phosphorus increased yields of both varieties showing beneficial effects in potentially iron toxic soils. Such beneficial effects of potassium have been reported earlier using rice grown in solution culture.[16] However, tolerant variety Bw 267-3 recorded higher yield than Bg 94-1 at all levels of potassium indicating tolerant variety will perform better with or without K.

Applied potassium and phosphorus increased the K and P content in both varieties but Bg 94-1 had higher K content than Bw 267-3 (Tables 2 & 4). Thus

Table 4: Effect of applied phosphorus on bronzing, tissue P & Fe concentration and grain yield of rice grown in iron toxic mineral soil

Treatment		Season							
		Yala 1984 (Millewa)				Maha 1984/85 (Dodangoda)		Yala 1985 (Dodangoda)	
Variety	P level kg/ha	P in leaves (%)	Fe in leaves (mg/kg)	Bronzing scoring	Grain yield (t/ha)	Bronzing scoring	grain yield (t/ha)	Bronzing scoring	grain yield (t/ha)
	0.0	0.177	1372	7.0	3.29	5.0	2.39	4.0	2.68
	10.7	0.187	1216	5.0	3.45	4.0	2.57	4.0	2.79
Bg 94-1	21.4	0.199	1030	5.0	3.24	4.0	2.72	3.0	2.92
	32.1	0.196	703	5.0	3.53	4.0	2.76	3.0	3.18
	42.8	0.206	866	3.0	3.62	3.0	2.92	2.0	3.38
	0.0	0.151	949	5.0	3.64	4.0	2.82	3.0	2.71
	10.7	0.162	787	3.0	4.38	3.0	2.98	2.0	3.10
Bw 267-3	21.4	0.179	615	2.0	4.50	3.0	3.22	2.0	3.37
	32.1	0.181	670	2.0	4.37	2.0	3.80	1.0	3.69
	42.8	0.206	706	1.0	4.41	1.0	3.55	1.0	3.57
CV (%)		10.6	18.3		8.5		8.1		6.3
LSD (P level) (p = 0.05)		0.027	13.2		ns		0.29		0.24
LSD (variety) (p = 0.05)		ns	20.5		0.24		0.18		0.15

ns - not significant

Table 5: Effect of applied phosphorus on yield components of rice grown in iron toxic mineral soil

Treatment		Season											
		Yala 1984				Maha 1984/85				Yala 1985			
Variety	P level (kg/ha)	No.of pan. /m²	No.of til. /m²	No.of fil. gra. /pan.	Pan. length (cm)	No.of pan. /m²	No.of til. /m²	No.of fil. gra. /pan.	Pan. length (cm)	No.of pan. /m²	No.of til. /m²	No.of fil. gra. /pan.	Pan. length (cm)
	0.0	248	275	38	23.5	260	299	39	20.5	210	257	54	22.0
	10.7	268	275	40	24.2	260	342	47	20.6	193	289	58	20.9
Bg 94-1	21.4	271	322	42	22.7	270	352	48	22.7	246	309	60	22.2
	32.1	276	343	43	24.2	255	415	51	21.2	282	330	70	20.0
	42.8	264	312	42	24.4	244	370	55	22.1	267	357	67	22.0
	0.0	208	214	58	23.3	215	238	57	21.5	211	297	37	21.7
	10.7	216	250	60	24.6	231	253	60	21.5	244	295	60	21.9
Bw 267-3	21.4	242	236	61	25.5	246	281	62	21.3	237	297	64	21.7
	32.1	240	264	63	25.8	241	255	66	21.5	264	365	70	20.7
	42.8	242	268	61	26.9	254	290	66	20.9	226	303	64	21.7
CV (%)		18.3	12.5	12.5	12.5	8.9	9.8	9.1	18.5	10.7	13.1	4.3	16.3
LSD (Variety) (p = 0.05)		25.1	26.2	2.5	1.1	16.0	23	3.8	ns	21	ns	ns	ns
LSD (p level) (p = 0.05)		ns	ns	ns	ns	ns	36	6.1	ns	ns	ns	ns	ns

Pan. -panicles til. -tillers fil. -filled gra. -grains CV - coefficient of variation LSD - least significant difference ns - not significant

Bg 94-1 has a higher potassium requirement under these conditions. Adequate tissue K and P content do not impart bronzing tolerance to a variety.

Applied potassium and phosphorus depressed tissue Fe content significantly in both varieties (Tables 2 & 4). However, Bg 94-1 had significantly higher Fe content than Bw 267-3 at each level of potassium applied. The tolerant variety showed its ability to keep the tissue Fe content low in comparison to susceptible variety. However, it is not clearly known as to whether this is due to exclusion of iron in growth medium or reduced translocation.[10,17] The significantly negative correlation between K and Fe content in leaves shows that by increasing the K content through enhanced K application, the Fe content could be lowered substantially. Since the tolerant variety has low levels of Fe in leaf tissues, less potassium is required to depress it to non toxic level.

It was observed that toxicity symptoms are reduced to a mild level at about 450 mg/kg in both varieties in the K experiment. Thus for Bg 94-1, it corresponded to an application of 85.8 kg K/ha whereas for Bw 267-3 it was at 57.2 kg K/ha. But P experiment shows that 32.1 kg P/ha is sufficient for tolerant variety whereas 42.8 kg P/ha is required for susceptible variety to give moderate yield of rice when grown in iron toxic mineral soils.

The results of these two experiments demonstrate the beneficial effect of adding higher dosages of K and P fertilizer to the iron toxic soils. This is due to the amelioration of the deficiencies that increase the oxidizing capacity of roots. This is in conformity with the findings of Trolldenier,[18] that low P and K enhance iron toxicity through decreased oxidizing capacity of roots.

The overall results of this series of experiments have shown that a yield increase could be obtained by using the tolerant variety alone. Also application of 85.8 kg K and 32.1 kg P per hectare has given significant yield increase of rice irrespective of the variety. The use of the tolerant variety and the higher dosage of P and K fertilizer gave highest yield increase compared with each treatment alone.

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