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Stress manifestations in a degraded soil environment

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Abstract : An attempt was made to identify the exact influences of the unfavorable characteristics of laterite soil on the productivity process using a medicinal rice type, *Njavara.* Three distinct phases could be identified in the nutrient uptake pattern, corresponding to the development of the plant: an accumulation phase, a dilution phase and finally, a diversion phase. The diversion phase is characterized by a decrease in dry matter accumulation due Tiller decline, which can be related to stress in the plant. Very high content of micronutrients especially of iron and manganese, in the plant could lead to inhibited metabolism and was probably the reason for low realized yields. Death of late formed tillers could thus be a protective mechanism of the plant to shed the unfavourably high levels of iron and manganese which limit growth and yield. Increased nitrogen application failing to increase yield is an indication of degraded soils, where absorption of nutrients takes place, but their transformation into yield is inhibited. Amelioration of these harmful effects is the sole way of increasing productivity.

Key words : Njavara, laterite soils, tiller decline, stress influence.

Introduction

Laterite soils occupying more than 60 percent of the arable lands of Kerala state are designated as degraded soils. By definition, these soils are with SiO_2/R_2O_3 ratio of 1.33 and below. They are virtually residual masses of hydrous oxides of Fe and Al having lost all the bases and silica due to intense weathering and high rainfall. Crop yields are generally low and nutrient responsiveness is limited. The low productivity of crops is due to the influence of unfavorable characteristics of the soil. Amelioration of this is possible only when the exact influences of the productivity process is characterized and quantified. As information on these aspects is not available, preliminary studies were undertaken to study the influence of inherent soil borne characteristics on the nutrient use efficiency of *Njavara*, a medicinal rice type, and results are presented in this paper.

Materials and methods

The medicinal rice type, Njavara, used in Ayurveda for the treatment of rheumatic, muscular and nervous complaints, was the test crop in the experiment, laid out at the Regional Agricultural Research Station, Pilicode (north Kerala). The soil is lateritic clay loam of the oxisol group, with a pH of 5.3. The black glumed *Njavara* was grown in a randomized block design with four replications as an intercrop in a coconut garden. Treatments consisted of supply of nutrients in an integrated manner, through organic and inorganic sources. The seven treatments were: 100% N, P and K through fertilizers (T_1), 100% N through organic manure (T_2), 75% N though fertilizers and 25% through organic manure (T_3), 50% N through fertilizers and 50% through organic manures, (T_4), 75% N through Organic manure, (T_5), 50% N through organic manure (T_6)

Table 1. Effect of sources and source combinations on tiller number, dry matter accumulation and yield of *Njavara*

Treatment	Tiller number		Dry matter accumulation, kg ha^{-1}			Grain yield, kg ha^{-1}
	At M.T.	At P.I.	At M.T.	At P.I.	At harvest	
T_1	3.80	3.80	839	1350	1557	439
T_2	5.20	5.45	539	1383	1214	419
T_3	4.60	5.25	583	1650	1451	466
T_4	4.45	4.45	1017	1808	1453	449
T_5	4.00	4.80	511	875	1203	369
T_6	4.75	4.55	483	958	966	284
T_7	3.55	3.55	472	883	902	239
CD (0.05)	NS	NS	322	462	367	120

NS, Non significant ; M.T. - Maximum Tillering; P.I.- Panicle Initiation

Table 2. Effect of sources and source combinations on nutrient uptake (kg ha^{-1}) of *Njavara* at maximum tillering

Treatment	N	P	K	Ca	Mg	S	Fe	Mn	Zn
T_1	19.8	1.6	32.0	14.9	15.5	2.5	0.44	0.50	0.13
T_2	9.3	2.0	18.3	9.3	7.9	1.5	0.23	0.37	0.10
T_3	12.7	1.6	15.5	12.8	10.2	2.2	0.37	0.43	0.14
T_4	21.7	3.3	33.0	18.2	15.6	2.8	0.68	0.50	0.22
T_5	10.7	1.9	14.5	11.4	8.5	1.3	0.29	0.37	0.14
T_6	8.4	1.9	14.0	7.9	7.2	1.3	0.20	0.32	007
T_7	9.0	1.6	10.5	18.1	7.4	1.0	0.26	0.41	0 14
CD (0.05)	1.32	0.28	2.12	5.5	NS	0.25	0.07	0.09	0.03

NS, Non significant

and 25% N through organic manure (T_7). The last three treatments did include application of *Azospirillum* at 2 kg ha^{-1}. Observations on biometrics were recorded at fixed intervals as also plant sample collection. Chemical analysis and statical analysis were done. The procedure as described by Panse and Sukhatme (1978) was used for statistical ceralysis.

Results and Discussion

Dry matter accumulation and yield of grain had generally followed the pattern of variation in nutritional levels rather than that of the sources (Table 1). Thus the maximum yield of 466 kg grain per hectare was recorded with the highest level of nutrition of 30 kg N equivalent per hectare and the lowest yield of 239 kg grain per hectare was with 7.5 kg N equivalent ha^{-1}.

A perusal of the development process along with the uptake of nutrients (Tables 2, 3 and 4) revealed that three distinct phases could be identified. The first phase is an accumulation phase during which the crop accumulated nutrients indiscriminately. This phase extended up to the maximum tillering stage. The uptake at this period ranged from 8.4 to 21.7 kg N ha^{-1} and corresponding dry matter yields was from 483 to 1017 kg ha^{-1} with a production efficiency of 57.68 kg to 46.85 kg. The accumulation phase is followed by a dilution phase extending from maximum tillering to panicle initiation stage when the crop accumulated dry matter rapidly. It is characterized by a disproportionate increase in dry matter compared to nutrients absorbed. The dry matter production in this phase ranged from 883 to 1808 kg ha^{-1}. Finally, there occurred a diversion phase characterized by growth cessation, differentiation and discriminatory shedding and accumulation of nutrients.

The third phase, which showed a decline in dry matter accumulation (in T_2, T_3, and T_4), indicated that produced dry matter had been shed by the plant. This death of tillers was observed in all treatments, but without significant difference. Tiller decline is a symptom of stress influence in the plant, and the reason for this can be traced to the nutrient up take pattern.

Data in Tables 2 and 3 show that T_4, which produced a yield of 449 kg grain per hectare and statistically at par with T_3, 466 kg had recorded the highest content of all nutrients both at maximum tillering and panicle initiation stages. Absorption of non applied native elements, *viz.*, Ca, Mg, S, Fe and Mn, were seen to be stimulated under chemical treatments. Similar results were reported by Marykutty *et al.* (1992). Accumulation of micronutrients at levels far higher than the critical levels may be a reason for the failure of increased N application in increasing the yield. Fe and Mn are considered to be at toxic levels beyond 300 and 2500 ppm respectively. Very high contents of Fe and Mn in the plant may be main reason for non-realization of the yield potential. Interference of Fe and Mn in the productivity process had been reported by Bridgit *et al.* (1993) and Mustafa and Potty (1996). These elements acted as growth inhibitors, limiting the functional utility of the growth promoting elements, N, P and K.

De Datta (1981) plotted the rice growth from seeding to harvest and demonstrated that tiller decline did not exceed 10-15 per cent of the total tiller production in the active tillering stage. It is the late formed tillers which declined after panicle initiation stage.

The quantity of nutrients shed from panicle initiation to harvest varied with the type of nutrient. While almost 35 per cent of N was lost in this period in T_1, the loss of P was to the tune of 73 per cent and in K and Ca, the percentage losses were 34 and 21 respectively. Shedding of nutrients on such a large scale is not natural phenomenon, and cannot be conducive to growth. It is clear that major nutrients unavailability is not the problem. The plant is unable to transform nutrients absorbed to productivity. In the case of micronutrients like Fe and Zn, contents were seen to have increased in some treatments. As these elements alone would not have been absorbed selectively by the plants, it follows that all other nutrients must also have been even higher than 35 per cent, 73 per cent, and 34 per cent respectively. So, from the differentiation stage onwards, inhibited metabolism is occurring in the plant.

The degree of shedding varied with treatment also. For example, while in T_1, 33 per cent of N was shed, in T_2, it was only

Table 3. Effect of sources and source combinations on nutrient uptake (kg ha^{-1}) of Njavara at panicle initiation

Treatment	N	P	K	Ca	Mg	S	Fe	Mn	Zn
T_1	18.6	2.8	30.9	22.9	9.5	2.2	0.56	1.02	0.43
T_2	10.5	4.5	30.3	16.1	5.7	2.2	0.49	0.74	0.35
T_3	18.3	3.1	35.1	18.6	8.7	2.2	0.56	1.12	0.67
T_4	19.3	4.5	36.2	33.2	12.1	3.1	1.04	1.21	0.89
T_5	8.6	2.6	17.3	17.5	6.8	2.5	0.31	0.64	0.39
T_6	7.7	3.2	18.6	9.0	4.4	1.6	0.29	0.63	0.30
T_7	6.7	3.2	18.0	9.0	3.1	1.6	0.32	0.54	0.29
CD (0.05)	1.61	NS	1.20	2.76	0.79	NS	0.09	0.06	0.08

NS, Non significant

Table 4. Effect of sources and source combinations on nutrient uptake (kg ha^{-1}) of Njavara at harvest

Treatment	N	P	K	Ca	Mg	S	Fe	Mn	Zn
T_1	12.3	0.75	20.51	18.07	10.82	1.38	0.78	0.79	0.46
T_2	9.57	0.89	11.22	16.92	10.09	0.97	0.35	0.50	0.43
T_3	10.55	0.82	16.46	21.77	13.32	1.35	0.73	0.62	0.44
T_4	7.96	0.97	17.22	20.62	12.90	1.33	0.72	0.60	0.67
T_5	7.89	0.61	12.05	20.19	9.84	1.04	0.60	0.60	0.59
T_6	5.43	0.61	8.17	15.07	10.19	0.88	0.44	0.44	0.37
T_7	3.89	0.38	9.86	12.67	8.84	0.75	0.51	0.35	0.39
CD (0.05)	2.25	0.08	NS	NS	NS	NS	NS	NS	NS

NS, Non significant

about 9 per cent. Hence, treatments applied to the soil modified the magnitude of nutrient shedding. So it is a soil borne management effect carried to the plant, and brought about over time. Nutritional environment variations bring about these effects. Bridgit and Potty (1992) have reported loss of chlorophyll stability in laterite soils.

It follows that the decline in dry matter after the panicle initiation stage can be linked to the excess contents of Fe and Mn in the plant, and that the tiller decline which occurs in this stage is a protective mechanism of the plant to rid itself of elements at unfavorably high levels. Observation of data in Tables 3 and 4 showed that in treatment T_2, 0.49 kg Fe and 0.74 kg Mn at panicle initiation had declined to 0.35 kg Fe and 0.5 kg Mn at harvest. Thus the unusually high contents of these elements from very early stages of growth might be the cause of tiller decline and consequent shedding of nutrients.

Productivity is therefore linked not to the nutrients supplied or the inherent capacity of the plant to produce but is a plant effect modified by the soil-plant system. Productivity management should be viewed in the context of the plant effect (i.e., realized yield) suppressed by the soil nutritional environment, naturally implying that ameliorating the harmful effects in the soil is the sole way of increasing productivity. The loss of tissues is a natural consequence which the plant is adapted to cope with, and still survive and perpetuate. Thus, the high rate of tiller production in *Njavara* in upland situations is an indication of stress and is an escape mechanism of the plant to drain its system of toxic levels of growth and yield limiting elements by their natural death at later stages. Mustafa and Potty (1996) had reported similar results in rice.

These results would indicate that degradation of soil from the point of view is condition where the plant is capable of absorbing nutrients, but is unable to objectively utilize them for growth and yield.

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