RESPONSE OF WHEAT TO PHOSPHORUS FERTILIZATION ON AN OXISOL[1]

NAND KUMAR FAGERIA[2]

ABSTRACT - Phosphorus deficiency is one of the most important growth limiting factors in crop production in oxisols under cerrados of central Brazil. The objective of this study was to evaluate the effect of P fertilization on growth, yield and nutrients uptake by wheat in a dark-red latosol under greenhouse conditions. The P treatments applied were 0, 25, 50, 75, 100, 125, 150, 175 and 200 mg P/kg^{-1} of soil. Root dry weight and grain yield were significantly affected by P fertilization. Adequate P level for dry matter production was about 75 to 100 mg of P/kg^{-1}, of soil, whereas for grain yield it was about 175 mg of P/kg^{-1} of soil. Distribution of nutrients in different plant parts showed roots retaining maximum Fe; tops maximum K, Ca, Mg and Mn; grains maximum P and considerable amount of Mg and Zn. Concentrations of Ca and Mg increased with P fertilization, but Zn, Fe and Cu contents of plant tops decreased with increasing levels of P.

Index terms: dry matter production, nutrient accumulation, *Triticum aestivum*.

RESPOSTA DO TRIGO A FERTILIZANTE FOSFATADO EM OXISOLO

RESUMO - A deficiência de fósforo é um dos mais importantes fatores limitantes na produção das culturas em oxisolos sob cerrado. O objetivo deste estudo foi de avaliar o efeito do fertilizante fosfatado sobre o crescimento, produção e absorção de nutrientes pelo trigo, utilizando um Latossolo Vermelho-escuro, em casa de vegetação. Os tratamentos com fósforo foram de 0, 25, 50, 75, 100, 125, 150, 175 e 200 mg de P/kg^{-1} de solo. A aplicação do fertilizante fosfatado afetou significativamente o peso seco das raízes e da parte aérea, e a produção de grãos. O nível adequado de P para produção de matéria seca situou-se em torno de 75 a 100 mg de P/kg^{-1} e para a produção de grãos, em aproximadamente 175 mg de P/kg^{-1} de solo. A distribuição de nutrientes em diferentes partes da planta mostrou maior concentração de Fe nas raízes, de Ca e Mg na parte aérea e de P nos grãos, que também apresentaram considerável quantidade de Mg e Zn. As concentrações de Ca e Mg aumentaram com a aplicação do fertilizante fosfatado, mas as concentrações de Zn, Fe e Cu, na parte aérea, diminuiram com o aumento de P.

Termos para indexação: produção de matéria seca, acumulação de nutrientes, *Triticum aestivum*.

INTRODUCTION

Phosphorus deficiency is one of the most important yield limiting factors in Cerrado region of Brazil. When water soluble phosphate fertilizers are added to acid soils, such as Cerrado, much of the P is rendered insoluble and unavailable to plants. According to Fageria & Barbosa Filho (1987), 77 to 90% of the applied P as triple superphosphate is fixed in oxisols of Cerrado at 80-day application. The main constituents responsible for this retention in acid soils are thought to be Al and Fe, either present in the free oxide forms or supplied by dissociation of clay minerals (Mehadi & Taylor 1988).

Information about the P response of wheat, pattern of dry matter accumulation, and nu-

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[2] Eng. - Agr., Ph.D., EMBRAPA/Centro Nacional de Pesquisa de Arroz e Feijão (CNPAF), Caixa Postal 179, CEP 74000 Goiânia, GO.

trient uptake is scarce (Bauer et al. 1987). Magalhães (1979) and Magalhães et al. (1980) found response of wheat cultivars IAC 5 and Sonora 63 to P fertilization in dark-red latosol of cerrado under field conditions. Similarly, Feitosa et al. (1978) reported response of cultivar BH 1146 to P fertilization, in Red-Yellow Latosol under greenhouse conditions. Few studies have been conducted in oxisols to study dry matter accumulation and uptake and distribution of nutrients in various parts of wheat plant (Karlen & Whitney 1980). Knowledge of dry matter accumulation at different growth stages and nutrient uptake may be useful for making management decisions regarding timing of application of nutrients to avoid occurrence of nutrients deficiency. Therefore, the objective of this study was to collect information regarding influence of P on growth pattern of wheat, influence of P on uptake of other nutrients, and distribution of nutrients in different parts of wheat plant. This information can serve as a useful guide in wheat production in tropical regions where oxisols are predominant such as the Cerrado of Brazil.

MATERIALS AND METHODS

A greenhouse experiment was conducted at the National Rice and Bean Research Center of EMBRAPA, in Goiânia, GO, Brazil. The soil used in the experiment was dark-red latosol, having an initial pH of 4.8, extractable P = 0.9, Ca = 60, Mg = 12, K = 34 and Al = 36 mg/kg^{-1}. P and K were extracted by the Mehlich 1 extracting solution (0.05 mol l^{-1} HCL + 0.0125 mol l^{-1} H_2SO_4). P was determined by colorimetry and K by flame photometry. Ca, Mg and Al were extracted with 1 N KCl. Ca and Mg were determined by titration with EDTA, and Al by titration with NaOH.

The experiment was conducted in plastic pots containing 6 kg of soil. P, as triple superphosphate, was added to levels of 0, 25, 50, 75, 100, 125, 175 and 200 mg of P/kg^{-1}. Basal fertilizer applied to each pot was 400 mg of N as $(NH_4)_2SO_4$, 960 mg of K as KCl, 1000 mg of a fritted glass material as a source of micronutrients, and 15 g of dolomitic lime. Each pot received a top dressing of 400 mg of N, 49 days after sowing. The cultivar planted was Alondra, recommended for the cerrado region of Brazil.

The experimental design was a randomized complete block. The treatments were replicated fifteen times. For the growth study, three replications from each treatment were harvested at 21, 35, 56, and 73 days after sowing and the remaining three replications were harvested at maturity. All pots were watered to maintain soil moisture at approximate field capacity throughout the growing season. After harvesting the tops, the roots were removed from each pot using a water jet. Roots were washed several times with distilled water. Plant material was dried in a forced draft oven at about 70^{o}C to a constant weight and ground for nutrient analysis. Ground material was digested with a 2:1 mixture of nitric and perchloric acids. The P concentration in the digest was determined colorimetrically and remaining elements were determined by atomic absorption spectroscopy.

The P influx rate into roots, I_n (moles.g^{-1} root wt.day^{-1}), was calculated between successive harvests using the following formula (Baligar 1987):

$$I_n = [(U_2 - U_1)/(T_2 - T_1)] [(I_n W_2 - I_n W_1)/(W_2 - W_1)]$$

where U_2 and U_1, are the total quantities of P in the whole plant (roots + tops) at the start (T_1) and the completion (T_2) of the absorption period, and W_1 and W_2 are the dry weights of the roots at the successive time intervals.
time intervals.

RESULTS AND DISCUSSION

Dry matter accumulation for roots and tops at different growth periods is presented in Table 1. Weights of roots and tops were increased significantly with P fertilization. Adequate level of P was about 75 to 100 mg/kg^{-1} for the roots and tops dry matter production in most cases. At 95 days of growth, application of 25 mg of P/kg^{-1} increased root weight by 284% as compared to control treatment. At the same P level, increase in top weight was 649% as compared to control treatments. This means that P deficiency may reduce more top growth as compared to root growth. This has also been reported by Moorby & Besford (1983) that in periods when the supply of nutrients is de-

TABLE 1. Dry matter of roots and tops as influenced by P levels at different growth periods.

P level mg/kg^{-1}	Days after planting									
	21		35		56		73		95	
	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
	g/3 plants									
0	0.09	0.11	0.20	0.21	0.27	0.91	0.24	1.78	0.19	1.85
25	0.09	0.18	0.24	0.95	0.98	6.38	1.23	10.90	0.73	13.85
50	0.07	0.23	0.24	0.95	0.83	6.48	1.34	11.80	1.09	17.21
75	0.07	0.25	0.27	1.32	1.09	7.19	1.63	13.07	0.99	17.42
100	0.06	0.26	0.25	1.11	1.41	7.77	1.47	13.46	1.25	18.45
125	0.06	0.24	0.27	1.31	1.26	7.79	1.53	14.60	1.27	18.27
150	0.08	0.24	0.32	1.43	1.26	8.55	1.47	13.30	1.04	16.24
175	0.08	0.19	0.32	1.46	1.33	9.61	1.56	16.59	1.64	23.07
200	0.10	0.32	0.35	1.53	1.59	8.89	1.93	16.28	1.44	21.41
LSD (0.05)	0.04	0.08	0.07	0.30	0.32	1.20	0.84	2.48	0.44	2.47

ficient plants tend to protect the root system by reducing the proportion of the absorbed nutrients which are transported to the shoots and root growth tends to be affected less than shoot growth.

Dry matter production of roots increased with increasing age of P-treated plants up to 73 days of age. At 95 days of age, there was a small decrease in root weight. This may be related to the death of some old roots at the end of growth cycle of the crop. Reduction in root weight at maturity of various crops, including wheat, has been reported by Gerwitz & Page (1974). Weight of plant tops increased with increasing age of the plant. The maximum rate of dry matter increase for roots and shoots, was between 35 and 56 days in the growth period.

Results related to influence of P fertilization on grain yield are presented in Fig. 1. Grain yield increased with increasing levels of P in the growth medium. Maximum grain yield was obtained with application of about 175 mg of P/kg^{-1} of soil. The increase in yield was about 9-fold at the 175 mg of P/kg^{-1} treatment, as compared to control treatment. This means that soil used in the study was extremely deficient in P and needed adequate P fertilization for crop production.

Accumulation and influx of P as influenced by P levels and plant age is presented in Ta-

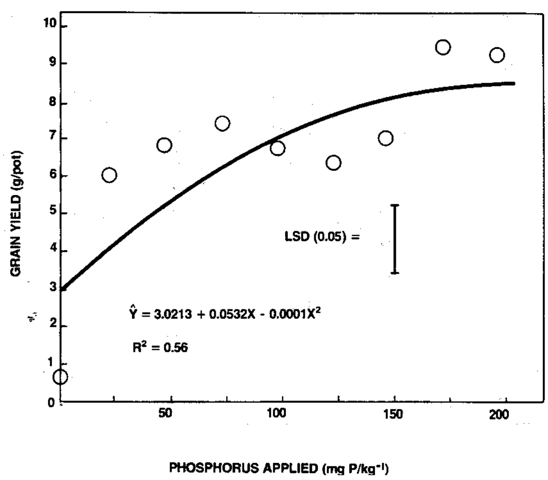

FIG. 1. Influence o. . .n grain yield of wheat in oxisol of central Brazil.

bles 2 and 3. At advanceed stage of growth, accumulation of P by roots, as well as by tops, was maximum at about 175 mg of P/kg^{-1}. Accumulation of P by roots was increased up to 56 days of age. Then there was a small decrease. Similar trend was observed in relation to P influx rate. This indicates that at later growth stages, the nutrient absorption power of roots is decreased. It has been reported by Ningping & Barber (1985) that with increasing plant age, there was a reduction in average P uptake rate by wheat roots. These authors have suggested that the reduction in P uptake rate, as the plant age, might be attributed to a reduced P influx by older or suberized roots. Accumulation of P was increased with increasing age in the tops. This may be related to dry matter accumulation.

TABLE 3. Phosphorus influx in wheat as influenced by Phosphorus levels and plant age.

P level mg/kg^{-1}	Days after planting			
	35	56	73	95
	mole/g^{-1}/day^{-1}			
0	2.68	7.12	10.54	11.78
25	49.95	45.74	35.43	50.08
50	49.29	66.05	41.81	39.13
75	65.77	60.92	42.04	47.32
100	64.55	62.77	49.53	42.66
125	106.76	64.30	47.38	44.56
150	75.46	63.00	39.22	38.07
175	80.79	69.69	51.08	45.16
200	71.57	52.18	40.99	45.67

TABLE 2. Accumulation of P by roots and tops as influenced by P levels at different growth periods.

P level mg/kg^{-1}	Days after planting									
	21*		35		56		73		95**	
	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops	Roots	Tops
	g/3 plants									
0	0.10	0.20	0.13	0.33	0.30	1.27	0.23	2.67	0.25	3.67
25	0.10	0.80	0.37	3.67	1.23	17.50	1.17	23.77	0.77	33.94
50	0.10	1.00	0.40	3.67	1.30	21.83	1.43	28.67	1.18	33.30
75	0.20	1.10	0.50	5.03	1.63	24.23	2.01	33.03	1.13	38.00
100	0.10	1.20	0.53	4.50	2.40	28.03	1.57	35.07	1.70	37.99
125	0.20	1.20	0.57	7.20	2.20	26.60	1.53	34.50	1.37	36.97
150	0.30	1.20	0.80	6.27	2.43	28.23	1.09	30.57	1.13	33.00
175	0.30	1.00	0.70	6.67	2.67	32.26	2.28	40.40	2.00	53.00
200	0.50	1.80	1.10	7.40	2.97	29.83	2.18	41.17	1.52	53.44
LSD (0.05)	-	-	0.20	1.15	0.73	3.71	1.22	6.73	0.83	3.14

* At 21 days composite samples of roots and tops were analysed for P and therefore, statistical analysis was not done.

** Accumulation of P at 95 days corresponds to total of shoot, ear chaff and grains analysed separately.

Nutrient distribution in different plant parts at the 95 days of harvest is presented in Fig. 2. On an average basis, about 4% of P retained in roots, 17% in tops, 67% translocated to grains and 12% in ear chaff. K distribution in different plant parts was: 2% in the roots, 72% in the tops, 11% in the grains, and 15% in the chaff. As regards to Ca, 5% was in the roots, 77% was in the tops, 6% was in the grains, and 12% was in ear chaff. Mg distribution was 2% in the roots, 53% in the tops, 35% in the grains and 10% in chaff.

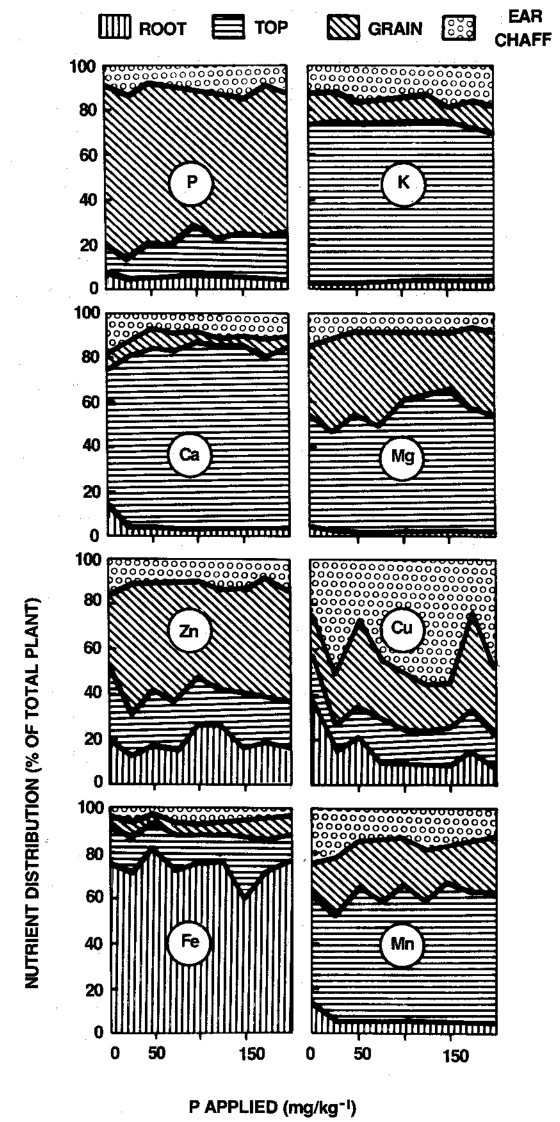

FIG. 2. Distribution of nutrients in different parts of wheat plant.

Micronutrient distribution was as follows: 18% of Zn was retained in the roots, 22% in the tops, 47% in the grains and 13% in ear chaff. Roots reatained 15% of Cu, tops, 14%, grains, 29% and chaff, 42%. Distribution of Fe was 73% in roots, 15% in tops, 5% in grains and 7% in chaff. As far as Mn is concerned, 6% was in the roots, 55% was in tops, 21% in grains and the remaining 18% was exported to ear chaff. In conclusion, roots retained maximum iron, tops maximum K, Ca, Mg and Mn, grains maximum P and a considerable amount of Mg and Zn. Large amounts of K, Ca and Mg were retained in the tops, and incorporation of plant residues in soils can improve levels of these nutrients and reduce cost of production.

Data related to concentration of macro and micronutrients in the tops of wheat plants at the 95 days of harvest are presented in Table 4. The concentration of P in the plant tis-

TABLE 4. Influence of P on the concentration of nutrients in tops of wheat plant at 95 days of growth.

P applied mg/kg-1	P	K	Ca	Mg	Zn	Fe	Mn	Cu
	%				mg/kg-1			
0	0.06	4.90	0.61	0.21	96	303	140	15
25	0.07	5.17	0.66	0.20	29	217	143	4
50	0.08	4.27	0.61	0.18	35	200	150	3
75	0.08	4.40	0.62	0.18	26	210	123	3
100	0.11	4.20	0.69	0.21	26	157	143	4
125	0.08	3.97	0.71	0.25	20	130	130	4
150	0.09	3.93	0.92	0.30	23	237	143	4
175	0.10	3.83	0.65	0.23	23	110	107	4
200	0.11	3.93	0.64	0.22	29	137	147	4
LSD (0.05)	0.04	0.75	0.15	0.06	15	112	49	2

sue increased with increasing level of P as expected. Concentrations of Ca and Mg increased with increasing level of P up to 150 mg/kg^{-1}, but at higher levels, concentrations of these elements decreased. In the case of K, concentration was increased only up to 25 mg of P/kg^{-1} treatment, then decreased. The increase in Ca may be related to increase in Ca levels due to increasing levels of triple superphosphate which has about 10 to 15% of Ca. Positive interaction between P and Mg has been reported by Sumner & Farina (1986) in several crop plants. The decrease in K, Ca and Mg concentrations at the higher levels of P may be related to nutrient imbalance (Fageria 1973). The concentration of Zn, Fe and Cu were significantly decreased with the application of higher levels of P, and Mn concentration was unchanged with P fertilization. Phosphorus induced Zn deficiency has been widely reported in the literature (Bingham 1963, Singh et al. 1986, Sumner & Farina 1986). Loneragan et al. (1982) who have shown that P induced Zn deficiency is not due to Zn metabolism in the leaves, but rather on P absorption and transport from roots. Excess phosphate in the root environment causes precipitation of Zn and also of Fe along the veins, and this may lead to iron chlorosis or to mottle leaf as an expression of Zn deficiency (Bouma 1983). Nutrient interactions involving a change in the concentration of any element in plant tissue casued by another, are quite common. A shift in the content of one element invariably is accompanied by secondary changes in tissue content of other elements, even though there is no change in the availability of the interacting nutrients (Bouma 1983). Nutrient interactions may be positive or negative (Bouma 1983). Alternative expressions for the same phenomena are synergism and antagonism (Smith 1962).

Antagonism can occur during ion uptake, during translocation and accumulation in the tissues, or in metabolism. It can involve competition between two or more elements, but also precipitation of nutrients or other phenomena (Bouma 1983). These results suggest that in acid soils with P fertilization, there exist possibilities of Zn, Fe and Cu induced deficiencies. Zn and Cu are generally at low levels in oxisols of tropical regions such as cerrado of Brazil (Lopes & Cox 1977).

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