Efficiency of fertilizer phosphorus utilization by common bean (**Phaseolus vulgaris** L.) cv 'Carioca', under different methods of applying phosphatic fertilizer*[1/]

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COMPENDIO

Un experimento fue llevado a cabo en un suelo Terra Roxa Estructurada, orden Alfisol, para estudiar 1) la eficiencia de la utilización del fósforo del fertilizante por por el frijol (Phaseolus vulgaris, *L.) cv. 'Carioca', bajo diferentes modos de aplicación de este fertilizante; 2) la influencia de una pequeña dosis de "arranque" del fertilizante nitrogenado en la utilización del fósforo del fertilizante y viceversa.*

Los datos muestran que diferentes modos de aplicación del fertilizante fosfatado no afectaron la producción. Sin embargo, el fertilizante que fue colocado en banda a 8 cm. de profundidad, 4 cm. abajo de la semilla y a distancia de 4 cm de la linea de sembradura acusó una mejor eficiencia de la utilización del fósforo aplicado.

No hubo efecto del nitrógeno de "arranque" en la utilización del fósforo del fertilizante. El peso y el número de nódulos no fueron afectados por la aplicación del nitrógeno o por el fósforo del fertilizante.

Introduction

MANY factors, such as correct localization, supply at the adequate moment, adequate quantity and source, nature of the soil, root systems of the crop, climatic conditions, chemical and physical properties of the fertilizer and interaction, which may occur between nutrients of the fertilizers, exert an influence in the fertilizer efficiency.

The fertilizer should be applied to the soil either at planting, in banding or broadcasting, incorporated or not.

Generally, the application of the fertilizer to the side and below the seed is considered to be the best method (4, 5, 6, 7, 11). However, due to the chemical properties inherent to each nutrient, contained in the fertilizers, the importance of their localization cannot be the same for all of them. For example, the nitrogen moves faster in the soil solution as nitrate ion, whereas the phosphate ion moves slowly in the soil solution and at short distances.

Procedures for the application of fertilizers have been the subject of extensive studies (3, 5, 6, 7, 11, 12, 16) but there is little information concerning the localization of fertilizer in *Phaseolus vulgaris*. Cook and Hulburt (4) suggested banding placement at 2.5 to 4.0 cm distance and 4 to 5 cm below the seed and Miranda *et al.* (15) obtained good results with banding application. Neptune *et al.* (13) observed that the broadcast application of phosphatic fertilizer was the worst placement for the bean; the best placement was the application of fertilizers at 5 cm distance from the seed row at 10 cm depth. They carried out the experiment with 'Iguaçu' cultivar in a low fertility soil (Rubrozem).

The objectives of this experiments were to study:

a) the efficiency of fertilizer phosphorus (ordinary super-phosphate-^{32}P) utilization by common bean *(Phaseolus vulgaris* L.) under different methods of applying phosphatic fertilizer.

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b) the influence of a small dose of starter nitrogen fertilizer (urea-^{15}N) on utilization of fertilizer phosphorus and on number and weight of nodules

c) the influence of fertilizer P and its method of application, on the utilization of a starter dose of fertilizer nitrogen and on number and weight of nodules

Material and methods

The crop utilized was bean *(Phaseolus vulgaris)* cultivar 'Carioca'.

This cultivar (local name: feijão Carioca) has indetermined growing habit, long peduncle and a growth cycle around 90 days. According to D'Artagnan *et al* (8), good yields have been obtained by the producers of this cultivar, which shows great resistance to diseases.

The seeds were inoculated with a mixture of strains of *Rhizobium*: 127-K-14 and 127-K-17 (from Nitragin, Co., USA) and CENA-04. The sowing was done in 02/11/74.

The experiment included 8 treatments arranged in randomized complete block (RCB) with 6 replicates.

The treatments were the following: T_1) 30 kg N/ha surface broadcast and worked into the soil to a depth of 8 cm and 80 kg P_2O_5/ha surface broadcast and worked into the soil to a depth of 8 cm. T_2) 30 kg N/ha as treatment 1 and 80 kg P_2O_5/ha surface broadcast. T_3) 30 kg N/ha as treatment 1 and 80 kg P_2O_5/ha banded on surface 4 cm away from the seed row. T_4) 30 kg N/ha as treatment 1 and 80 kg P_2O_5/ha banded at 8 cm depth (4 cm below seed and 4 cm distance from seed row, depth of seeding being 4 cm). T_5) 30 kg N/ha as treatment 1 and 80 kg P_2O_5/ha banded at 8 cm depth mid-way between rows (22.5 cm away from seed row, distance between row being 45 cm). T_6) 30 kg N/ha as treatment 1 and 258 kg/ha gypsum (rate containing an equivalent amount of sulphur to that contained in the single superphosphate supplying 80 kg P_2O_5/ha) surface broadcast and worked into soil to a depth of 8 cm. Zero P. T_7) Zero N. 80 kg P_2O_5/ha broadcast on surface and worked into the soil to a depth of 8 cm. T_8) Control - Zero, N, Zero P. 258 kg/ha gypsum (rate containing an equivalent amount of sulphur to that contained in the single superphosphate supplying 80 kg P_2O_5/ha) surface broadcast and worked into the soil to a depth of 8 cm.

Urea (45% N), ordinary superphosphate (20% P_2O_5) and potassium chloride (60% K_2O) were used as sources of N, P and K, respectively. The urea was labelled with ^{15}N at 4.0 percent atom excess, and the superphosphate was labelled with ^{32}P at 0.5 mCi/g P_2O_5.

The plots were divided into two-sub-plots, and one of which was treated with isotopically labelled fertilizer. The other received unlabelled fertilizer.

Each treatment plot consisted of 5 rows, each 10 m long with a row spacing of 45 cm. Within each row, the plants were spaced at 5 cm. Each plot was 22.5 m^2. The labelled fertilizers was applied to the sub-plot 2 m long and 90 cm wide, over an area of 1.8 m^2. Unlabelled fertilizer was applied to the rest of the plot area 20.7 m^2. Only the central one meter lenght of the middle row (row 3) of the subplot treated with labelled fertilizer was harvested for ^{15}N and/or ^{32}P analysis.

Yield measurements were made on the harvest from the 9 meters of rows 2, 3, and 4 of the whole plot, leaving out the 50 cm lengths of the rows at each end of the plot. This included the area harvested for ^{15}N and ^{32}P analysis.

The potential evapotranspiration (Et) was calculated by the method of Penman adapted to the conditions of Piracicaba (14) (Fig. 1).

Soil Analysis

The experiment was carried out in Textural B Terra Roxa Soil (TRE) order Alfisol.

Soil samples from the different horizons of the profile and composite soil samples from the experimental site, at different depths, were taken for chemical analysis. The pH value was determined by a glass electrode in soil: H_2O and soil: KCl ratio 1:2.5; organic carbon by the method of Walkley and Black, as described by Jackson (10), total nitrogen by the semi-micro-Kjeldahl, and nitrate and "exchangeable" ammonium by the magnesium oxide-Devarda alloy methods, described by Bremmer (2); soluble phosphorus was determined by photocolorimetric method after extraction with $NaHCO_3$ 0.5M (Olsen method) and H_2SO_4 0.05N; exchangeable potassium was determined by flame photometry after extraction with a solution of KCl 0.05N; exchangeable calcium and magnesium were determined by atomic absorption spectrophotometry after extraction with a solution of KCl 1N; exchangeable aluminium was titrated with a solution of NaOH 0.02N after extraction with a solution of KCl 1N; and exchangeable hidrogen was titrated with NaOH 0.02 N after extraction with calcium acetate 1N, adjusted to pH 7.0 (Table 1).

Plant Analysis

The harvested plant, separated in grain and straws (husk, stem and leaves), and the nodules were dried in a ventilated oven at 65 to 70°C and weighed. On the ground samples, passing through 40 mesh screen, total nitrogen was determined by the plant digestion procedure described by Hanway (9), and total phosphorus was determined after the plant digestion with nitric-perchloric acid, by the vanadate-molybdate-yellow method.

The radioactivity of ^{32}P was measured by Cerenkov radiation (17, 1), utilizing a liquid scintilator (Nuclear Chicago Corporation, Série 720, U.S.A.).

For the $^{14}N/^{15}N$ isotopic ratio determination, the plant samples were prepared according to the modified Dumas method (15), and the isotopic composition of N_2 liberated was determined in the mass spectrometer Varian-Mat, model CH-4, by measurement of the ion

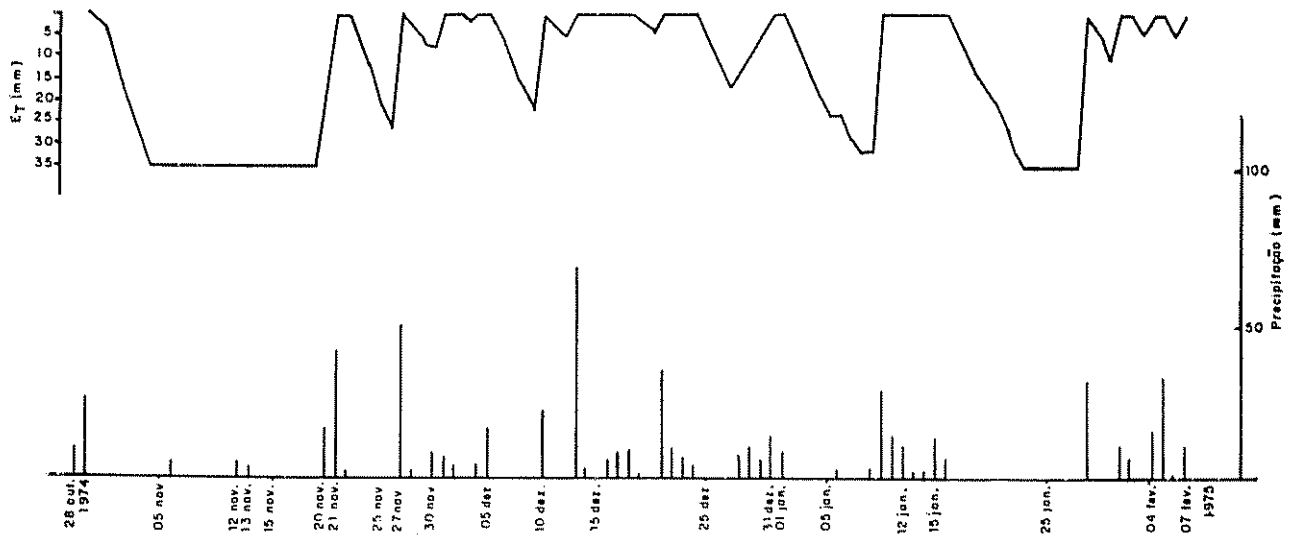

Fig. 1 —*Precipitation and Potencial Evapotranspiration (ET), calculated by the method of Penman, adapted to the conditions of Piracicaba (14)*

currents corresponding to mass 28 ($^{14}N\ ^{14}N$), mass 29 ($^{15}N\ ^{14}N$) and mass 30 ($^{15}N\ ^{15}N$).

Results and discussion

The fertility status of this sandy clay loam soil is of medium fertility with a high content of exchangeable potassium. Exchangeable aluminium content is low. The data also indicate a decrease in the contents of the exchangeable cations and soluble phosphorus in relation to the increase in the depth of soil (Table 1).

Data regarding grain and straw yield are given in Table 2. The placement of phosphorus fertilizer did not affect the yield. It can be inferred by the data that the phosphorus level of the soil was adequate for the cultivar, and, for this reason, there was no response to application of the phosporus fertilizer. The high

Table 1.—Soil analysis of the experimental site at different depths.

Depth cm	pH		m eq/100g soil						CTC
	H_2O	$CaCl_2$	K^+	Ca^{2+}	Mg^{2+}	Na^+	Al^{3+}	H^+	
0-20	5.95	5.15	0.58	5.49	1.10	0.25	0.16	3.42	11.00
20-40	6.25	5.45	0.39	4.73	1.23	0.19	0.15	3.01	10.40
40-60	6.30	5.65	0.13	4.52	1.30	0.22	0.08	3.00	9.80

Depth cm	% O.M.	N Total	P in ppm		ppm NO_3	ppm NH_4
			$NaHCO_3$ (OLSEN)	H_2SO_4 0.05 N		
0-20	1.96	0.10	2.95	8.60	6.80	1.26
20-40	1.20	0.08	0.45	3.79	2.44	1.91
40-60	1.60	0.06	0.19	2.82	1.30	1.30

Table 2.—Effect of methods of applying phosphatic fertilizer and starter nitrogen on grain and straw yield*.

Treatments	Grain	Straw
T_1**	2157	1575
T_2	2165	1588
T_3	2234	1588
T_4	2180	1563
T_5	2247	1645
T_6	2081	1486
T_7	2170	1417
T_8	2004	1388
C V %	7 87	12.22

* Means of six replicates. The values are not significantly different at the 0 05 level Tukey's test

** T_1 = surface broadcast and worked into the soil; T_2 = surface broadcast; T_3 = banded on surface 4 cm away from the seed row; T_4 = banded at 8 cm depth; T_5 = banded at 8 cm depth between rows; T_6 = gypsum; T_7 = as T_1 (without nitrogen); and T_8 = gypsum. All the treatments, except T_7 and T_8 received 30 kg N/ha.

grain yield reached can also be attributed to the favourable climatic conditions during the growing season (see Fig. 1) and to the good insect and disease control performed during the experiment.

In respect to the concentration of phosphorus and the amount of this nutrient (Table 3) in the grain and in the straw, there is no significant difference among the treatments. But the percentages of the phosphorus in the grain and in the straw, separately, derived from the fertilizer, indicate that the treatment T_4 was superior to the other treatments, followed by the treatment T_5. The similar trend was observed in respect to the percentage of the utilization of applied phosphorus in the plant (grain + straw). All those data confirm that the application of phosphorus fertilizer banded at 8 cm depth, 4 cm below the seed and 4 cm distance from seed row, was the most efficient placement. As Neptune and coworkers (13) have observed with 'Iguaçu' cultivar in a low fertility soil, in this experiment, the broadcast application of phosphatic fertilizer also resulted in a low phosphorus utilization by bean plant. The worst treatment was the surface banded application (T_3).

The data of the Table 4 indicate that the percentage and the amount of nitrogen in the grain and in the straw derived from fertilizer are approximately equal for all the treatments; this means that the placement of the phosphorus fertilizer did not affect the utilization of starter nitrogen. It is evident, therefore that

Table 3.—Effect of methods of applying phosphatic fertilizer and starter nitrogen on phosphorus utilization: % and kg/ha of total P and P derived from the fertilizer (PDFF) in the grain, straw and total; percentage of utilization of fertilizer phosphorus (% U P F.) and A value (mean of six replicates).

Treatment	% P		kg P/ha		% PDFF		kg/ha PDFF			% U P F.	A Value (kg/ha)
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Total		
T_1**	0 432	0 126	9.59	2 07	11 06c*	8 53b	1 31c	0 175c	1 49c	4 26c	228 ab
T_2	0 410	0 132	8 89	2 11	15 12b	6 40b	1 34bc	0 135c	1 48c	4 23c	206 ab
T_3	0 424	0 126	9 77	2 11	10 84c	6 53b	1 05c	0 119c	1 19c	3 39c	300 a
T_4	0 414	0 145	9 25	2 27	29 95a	13 04a	2 92a	0 308a	3 06a	8 15a	85 c
T_5	0 422	0 136	9 49	2 25	19 66b	10 82a	1 85b	0 241b	2 09b	5 98b	148 bc
T_6	0 431	0 136	9 28	2 14	—	—	—	—	—	—	—
T_7	0 431	0 134	9 35	2 00	12 28c	7 42b	1 15c	0 153c	1 30c	3 58c	253 a
T_8	0 439	0 133	9 23	1 87	—	—	—	—	—	—	—
C.V %	5 09	9.96	6 62	11 30	20 10	14 23	18 66	20 09	17 01	12 78	23.08

* Those values within a column not followed by the same letters are significantly different at the 0 05 level by Tukey s test

** T_1 = surface broadcast and worked into the soil; T_2 = surface broadcast; T_3 = banded on surface 4 cm away from the seed row; T_4 = banded at 8 cm depth; T_5 = banded at 8 cm depth between rows; T_6 = gypsum; T_7 = as T_1 (without nitrogen); and T_8 = gypsum. All the treatments, except T_7 and T_8 received 30 kg N/ha.

Table 4 —Effect of methods of applying phosphatic fertilizer and starter nitrogen on nitrogen utilization: percentage and kg/ha of nitrogen derived from the fertilizer (NDFF) in the grain, in the straw and total; percentage of utilization of nitrogen fertilizer (% U N F.); and A value (*)

Treatment	% NDFF		kg/ha NDFF			% U N F	A Value
	Grain	Straw	Grain	Straw	Total		(kg/ha)
T_1**	6 25	6 66	4 67	1 18	5 85	19 50	462
T_2	6 73	6 47	4 94	1 22	6 16	20 52	421
T_3	5 13	5 51	3 82	1 04	4 86	16 19	562
T_4	5 65	5 63	4 15	1 11	5 27	17 55	550
T_5	6 00	5 98	5 12	1 17	6 29	21 03	471
T_6	5 47	5 50	4 04	1 24	5 27	17 57	527
C.V.	17 02	18 06	16 88	15 85	14 66	14 64	17 01

* Means of six replicates. The values are not significantly different at the 0 05 level by Tukey's test

** T_1 = surface broadcast and worked into the soil; T_2 = surface broadcast; T_3 = banded on surface 4 cm away from the seed row; T_4 = banded at 8 cm depth; T_5 = banded at 8 cm depth between rows; T_6 = gypsum; T_7 = as T_1 (without nitrogen); and T_8 = gypsum All the treatments, except T_7 and T_8 received 30 kg N/ha

there was no effect of starter nitrogen. From the total of 30 kg/ha of applied nitrogen, the bean plants utilized 4 9 to 6 3 kg N/ha, corresponding to the efficiency of fertilizer nitrogen utilization of 16 2 to 21 0 per cent, respectively

The A value depends directly on the fraction of the element in the plant derived from the fertilizer. These two parameters are proportionally inverse, consequently, if the N or P fraction is low, the correspondent A value will be high. The experiment showed that the A values vary with methods of fertilizer placement (Table 3 and 4). From the soil fertility point, a relative classification of nutrient concentrations into low, medium and high A value, in different soil types, has not yet been established

Table 5 —Weight (in mg) and number of dry nodules per plant.*

Treatment	st 1st sampling		nd 2nd sampling		rd 3rd sampling	
	weight	number	weight	number	weight	number
1	35 00	21	78 00	31	22 00	10
8	68 25	19	78 00	41	39 50	16
CV%	43 15	30 38	109 53	44 88	11 49	33 67

* Means of six replicates. The values are not significantly different at the 0 05 level by Tukey's test

The data of Table 5 refers to the weight and number of nodules for the three samplings. Generally, these data show a high coefficient of variation. Apparently the starter nitrogen did not affect the weight and number of nodules.

Conclusions

The following conclusions can be drawn:

The different methods of applying phosphatic fertilizer did not affect the grain yield and starter nitrogen utilization. However, considering the fertilizer phosphorus utilization by the crop, the best treatment was that in which the phosphorus feritlizer was banded at 8 cm depth, 4 cm below the seed and 4 cm distance from the seed row, and the depth of seeding being 4 cm

There was no effect of starter nitrogen fertilizer on utilization of fertilizer phosphorus, and on the weight or number of nodules

Summary

An experiment was conducted in Textural B Terra Roxa Soil (TRE), order Alfisol, to study: 1) the efficiency of fertilizer phosphorus utilization by common beans *(Phaseolus vulgaris,* L.) cv Carioca, under different methods of applying this fertilizer; 2) the influence of a small dose of starter nitrogen fertilizer on utilization of the fertilizer phosphorus and vice-versa;

3) the influence of fertilizer P and its method of application on the utilization of starter nitrogen.

The data show that different methods of applying phosphatic fertilizer did not affect the grain yield, but considering the fertilizer phosphorus utilization by the crop, the best treatment was that in which the phosphorus fertilizer was banded at 8 cm depth, 4 cm below the seed and 4 cm distance from the seed row.

There was no effect of starter nitrogen fertilizer on the utilization of fertilizer phosphorus. The weight and number of nodules were not affected by the starter nitrogen nor by the fertilizer phosphorus.

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Notas y Comentarios

Publicaciones

Tecnología en Marcha. El Instituto Tecnológico de Costa Rica ha iniciado en 1978 la publicación de una revista trimestral, destinada a difundir los conocimientos tecnológicos. El número 3, que es el que hemos recibido, contiene trabajos sobre efectos del arrastre de implementos en un tractor, sobre burbujas magnéticas, clavado neumático de madera, deforestación y escasez de agua, sinterización de bauxitas silicosas. No figura en la revista la dirección de la Institución. En los Cuadros no hay uniformidad en la separación de decimales; en la página 25, se usan puntos, en la página 30, en el mismo artículo, se usan comas. El director de la revista es Mario Castillo Méndez; la dirección es ITCR, Apartado 159, Cartago, Costa Rica.

Seminario sobre Parques Nacionales

Se han cursado invitaciones para el Décimo Cuarto Seminario Internacional sobre Parques Nacionales y Reservas Equivalentes, a realizarse en agosto de 1979, y que está auspiciado por la Universidad de Michigan, el Servicio Nacional de Parques de los Estados Unidos, y los Parques de Canadá. Está programado para administradores, personal profesional y dirigentes responsables por el establecimiento, desarrollo y manejo de sistemas de parques y de conservación de la vida silvestre y programas asociados de turismo en todo el mundo. El énfasis principal será sobre áreas naturales con énfasis secundario en los recursos culturales. Habrá una porción apreciable del seminario que consistirá de viajes, en los que se visitarán parques nacionales de las provincias de Alberta y British Columbia en Canadá, y en los estados de Washington, Arizona y Hawaii, de los Estados Unidos. Las solicitudes para concurrir al seminario deben llegar antes del 1° de marzo de 1979 a: Tomm D. Thomas, School od Natural Resources. The University of Michigan, Ann Arbor, Michigan 48109.