INFLUENCE OF THE SOIL FERTILITY FACTORS ON THE P ABSORPTION OF RYE-GRASS GROWN IN SALINE SOILS

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INFLUENCE OF THE SOIL FERTILITY FACTORS ON THE P ABSORPTION OF RYE-GRASS GROWN IN SALINE SOILS*

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S U M M A R Y

The relation between dry matter production of rye-grass and the intensity factor in the saline soils of the province of Saragossa (Spain) was studied. The maximun yield of rey-grass was attained at different levels of phosphorus in the soil solution. These values are from 3 to 12 ppm P.

The addition of phosphorus to these soils also improves the quality of rey-grass by increasing its P content. Furthermore the salinity present in the soil affects the phosphorus concentration in the soil solution necessary to obtain 0.60 % P in rye-grass. The intensity varies from 0,86 to 8 ppm P.

In the soils studied, the phosphorus uptake by the plant is governed by the replenishment factor, as the maximum P absorption is attained at a factor of 4.

INTRODUCTION

There are many studies (Bernstein, Francois and Clarck, 1971; Cerda, Binghman and Hoffman, 1977; Eleizalde and Van Diest, 1971; Elleboudi, 1969; Fergusson and Hedlin, 1963) which show the beneficial effect of the application of P on the yield of crops grown in saline soils. An increase related to the plant dry-matter production and also an improvement in quality due to the reduction of Cl and Na contents can be seen en some crops such as: vines, carrots, green beans and certain graminae.

Nevertheless the phosphorus level in the soil solution at which this beneficial effect is produced is unknown as also whether the supply of phosphorus to rye-grass could be goberned by one or several soil fertility factors.

The inadequacy of using a single parameter to describe the P status of a range of soils has been evident for some time. According to Olsen and Khasawneh (1981) at least three factors interact with each other to determine the functional relationship between P uptake and the status of P in the soil.

An intensity factor describes the concentration of P in the soil solution (I) or it may be expressed more appropriately as the activity of the ion in solu-

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tion. A quantity (9) with the solid phase. A buffering capacity term, q/I measures the resistance of the soil system to changes in I.

Khasawneh (1971) designated as a replenishment factor the result of the interaction of three mutually dependent parameters: intensity, quantity and buffering capacity. The replenishment factor affects the supply pattern in several ways. Khasawneh (1971) postulated that P uptake would be proportional to quantity and intensity but in soils of an equal intensity factor, phosphorus uptake would be proportional to buffering capacity.

Phosphorus uptake data by rye-grass from greenhouse experiments on 24 soils confirmed the above mentioned concepts (Holford and Mattingly, 1967).

The results on the rate of P aborption by cotton also showed that a term combining the factors intensity, quantity and buffering capacity was a better measure of soil P status that either quantity or intensity alone (Khasawneh and Copeland, 1973). Similar facts were found by Gunary and Sutton (1967) when phosphorus uptake by ryegrass from a range of soils was better correlated when intensity and quantity factors were considered together.

These aspects are of great importance in the phosphate feeding of a plant, and are the objects followed in this study.

MATERIAL AND METHODS

Soils which represent important agricultural localities of the Saragossa Province (Spain) were chosen. They are: Tauste, Grañen, Belchite and Bujaraloz areas.

All these soils are calcareous and show a great variation with regard electrical conductivity (Table 1 and 2). The composition and concentration of the saturation extract were markedly affected by Na, Ca, Cl and SO_4 (Table 2) (Eleizalde and Fernández, 1982) (Eleizalde, Díaz and Altares, 1982).

Soil pH was determined in a ratio (1:2) soil-water mixture or soil-1N potassium chloride solution, by a glass electrode (Beckman Dv., pH, meter) (Eleizalde, 1983).

Calcium carbonate total and active were obtained by the Bernard and the Droineau procedures respectively, described by Droineau and Gouny (1951).

Organic carbon was obtained according to the Walkely and Black method (1934) and the organic matter by applying a factor 1.72.

Total nitrogen was obtained through the method of Kjedahl using selenium as catalyzer.

The ratio (1:5) (soil/water) was used and the electrical conductivity in the extract was read and expressed in mmhos/cm.

Soil available potassium was extracted by a 1N ammonium acetate solution buffered at pH 7. A soil/solution ratio (1/10) and an equilibrium time of 15 minutes were used. The potassium in this extract was analysed by flamephotometry.

TABLE 1

Some properties of the experimental soils

Soil type	pH water	pH 1N KCl	% $CaCO_3$ total	% $CaCO_3$ activ.	% Organic matter	% N	C/N	Exchangeable Potassium mgK/100 g soil	E.C. (mmhos/cm) in 1:5
Maral	8.3	7.9	33.9	18.9	1.3	0.09	8.2	28.5	10.9
Serosem	7.9	7.7	30.7	13.5	1.1	0.08	7.8	24.6	4.8
in Tauste	8.1	7.8	33.9	13.8	0.8	0.10	4.8	25.5	2.2
Maral	8.7	8.6	25.3	9.8	0.2	0.06	2.1	16.1	4.4
Serosem	8.8	8.6	24.5	9.0	0.1	0.06	0.8	19.4	6.8
In Tauste	8.7	8.2	24.5	8.8	0.3	0.06	2.9	9.8	1.7
Maral	7.8	7.5	37.8	8.7	1.6	0.11	8.1	49.2	11.6
Serosem	7.9	7.6	37.1	14.6	1.5	0.13	6.6	42.0	7.1
Belchite	8.0	7.6	47.0	16.4	1.4	0.09	9.5	28.6	2.4
Gypsum	8.8	8.5	33.2	20.5	0.4	0.04	5.0	11.4	10.8
Serosem	8.1	7.8	37.8	24.6	0.8	0.09	5.0	7.6	3.1
Bujaraloz	8.1	7.7	30.4	24.4	0.7	0.08	4.6	10.2	3.7

TABLE 2

Salinity in saturation extract

Soil	E.C. mmhos/cm	Cations and anions in Saturation extract (m.e/per litre)								Cation Anion ratio
		Ca	Mg	K	Na	Cl	SO_4	CO_3	HCO_3	
Maral	34.89	56.40	47.10	1.35	250.00	264.13	104.16	0.00	1.87	0.96
Serosem	15.86	40.00	45.00	0.88	77.25	123.40	41.44	0.00	1.91	0.96
In Tauste	6.96	16.00	16.00	0.64	35.76	57.47	10.76	0.00	2.16	0.97
Maral	16.76	15.30	8.30	0.76	169.00	109.33	70.70	0.00	4.77	0.99
Serosem	23.48	11.19	6.12	0.44	216.42	163.11	71.70	0.00	4.93	0.97
In Grañen	9.13	16.31	5.30	0.38	76.67	58.76	38.26	0.00	3.25	0.98
Maral	34.89	164.00	83.00	4.80	70.30	309.50	18.10	0.00	2.23	0.97
Serosem in	21.98	108.00	74.80	3.11	67.30	227.30	29.00	0.00	2.26	0.98
Belchite	4.49	35.50	16.60	1.67	4.70	21.87	34.65	0.00	1.99	0.99
Gypsum	23.68	29.10	49.00	2.42	127.50	72.53	187.78	0.00	4.47	0.96
Serosem in	7.39	37.00	23.70	0.52	16.83	8.27	68.51	0.00	2.77	0.98
Bujaraloz	7.92	32.70	31.80	0.32	18.75	15.29	65.83	0.00	2.40	1.00

The composition of the soil saturation extract was determined according to the procedures described in Handbook 60.

The greenhouse trials consisted of three repetitions for phosphorus treatment, soil with plant and two repetitions for P treatment and soil without plant (Eleizalde, Díaz and Altares, 1980).

The P amounts to be applied were based upon the «x» value obtained, following the criterion of Waugh and Fitts (1966). They ranged from 0 to 1000 P ppm and were added as monocalcium phosphate (Díaz, Eleizalde and Fernández, 1981).

The time of equilibrium between the amount of monocalcium phosphate added and soil was two weeks. After that, 10 seeds of ryegrass were sown per pot. The emergence of the seedlings took place ten days later, and until haversting the plants were fed with a complete solution following that described and recomended by Waugh and Fitts (1966).

Two months later, plant material was harvested weighed and dried at 60° C in the stove. It was again, weighed, ground and afterwards received ash digest treatment according to the procedure used by the Soil Fertility and Plant Nutrition Department the Aula Dei Experimental Station in Saragossa (Spain).

Intensity and replenishment factors are defined as P concentration in the soil solution and the replenishmen factor is taken fron the expression of Khasawneh and Copeland (1973). For this reason it is necessary to determine the phosphorus concentration in the soil saturation extracts from soil without plants.

Results and discussion

In general great differences related to dry matter production were obtained according to whether the concentration of salts was high, medium or low (Eleizalde, Díaz and Altares, 1982).

Moreover, if the EC value is higher than 30 mmhos/cm, in the case of salinity produced by chloride or sulphate, there is the possibility that the crop response to added phosphorus may be low. Due to the toxic effect of Cl on the plant or the fact that in the presence of sulphate salts phosphorus sorption by the soil increases a lower P level remains in the soil solution for use by rye-grass.

In all soils the phosphorus content of plant material is increased by the P addition to soil (Table 3).

When the relation between plant dry-matter production and P content is considered, different tendencies can be observed which are affected by the concentration and nature of the salts present in the soils, although in all soil, the maximum plant yields is attained at 0.60% P content in plant material (Eleizalde, Díaz and Altares, 1982).

TABLE 3

Phosphorus content in rye-grass expressed in %

Soil	E.C. mmhos/cm	P Treatments added to soil T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Maral	34.89	—	—	—	—	—	—	—	—
Serosem	15.86	0.08	0.13	0.25	0.40	0.45	0.60	0.68	0.83
In Tauste	6.96	0.20	0.25	0.31	0.42	0.59	0.67	0.79	0.83
Maral	23.43	0.23	0.26	0.28	0.34	0.45	0.57	0.65	0.80
Serosem	16.76	0.27	0.36	0.38	0.47	0.57	0.66	0.76	0.82
In Grañen	9.13	0.15	0.31	0.38	0.48	0.55	0.65	0.70	0.78
Maral	34.89	0.15	0.21	0.24	0.30	0.35	0.54	0.67	0.73
Serosem in	21.98	0.18	0.27	0.36	0.40	0.43	0.58	0.74	0.83
Belchite	4.49	0.15	0.28	0.34	0.42	0.48	0.66	0.78	0.87
Gypsum	23.68	0.05	0.18	0.27	0.35	0.45	0.50	0.75	0.83
Serosem in	7.39	0.08	0.18	0.22	0.32	0.48	0.55	0.72	0.84
Bujaraloz	7.92	0.10	0.28	0.36	0.41	0.54	0.61	0.75	0.88

1. *Plant yield - Intensity factor*

The response of rye-grass to the P addition in saline conditions and soils has previously been shown but at what phosphorus level in the soil solution, this beneficial effect is produced is unknown. For this reason, it would be interesting to study the relation between dry matter production and the intensity factor (P concentration in the saturation soil extract).

The relation between both variables for the soils of Tauste, Grañen, Belchite and Bujaraloz can be seen in fig. 1 (A, B, C and D) respectively.

Again, a low response of rye-grass to the P addtion is found for soils with a high content of salts such as: sodium chloride or sodium sulphate (Fig. 1 A and D). It seems that the salinity is the limiting factor under these conditions, because the plant yield was not improved by the added phosphorus fertilizer.

Soils with a low and medium degree of salinity showed different behaviours. For the former a P level about only 2 ppm in the soil solution (intensity factor) is necessary a value which increases to 4 or 6 ppm when the salinization is more pronounced.

In the case of a mixture of salts such as: sodium chloride-sodium sulphate the situation was similar to that previously described (see in fig. 1 B). The only difference was in the soil with the highest salt content, which showed a higher plant response to added P that those obtained from soils of the Tauste and Bujaraloz areas (Fig. 1 B compared to those of Fig. 1 A and 1 D).

However the maximum rye-grass productions in the soils of the Grañen area were attained at the same intensity factor, which represents about 3 ppm P in the soil solution (Fig. 1 B).

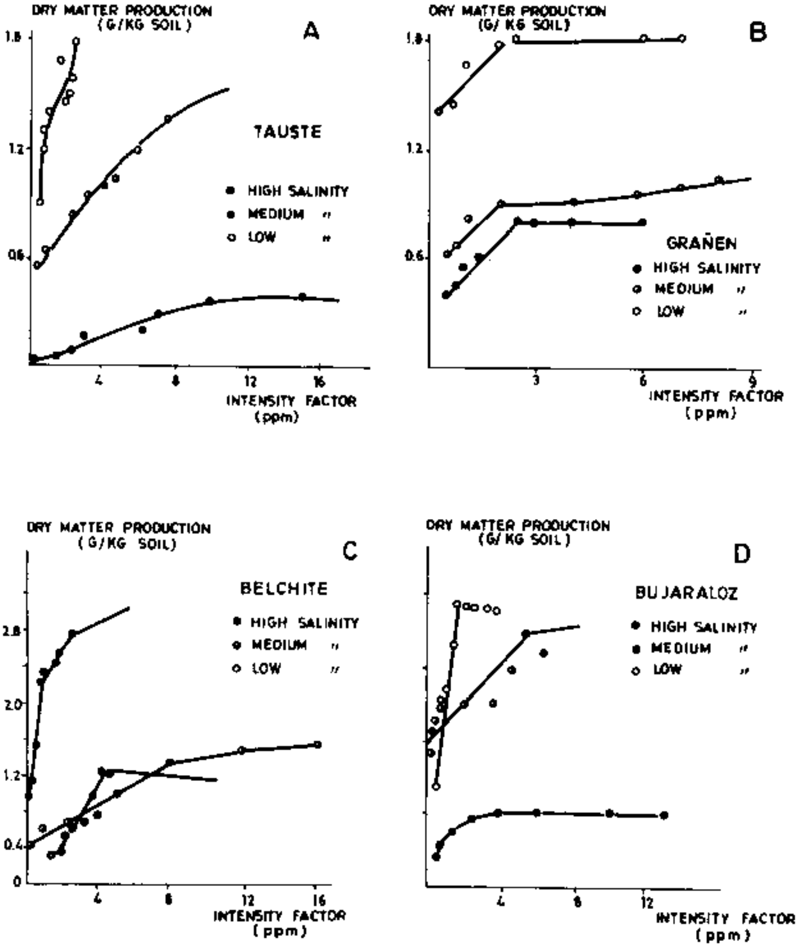

FIG. 1 Relation between dry-matter production and intensity factor in saline soils

When the salinization is produced by a combination of calcium chloride + sodium sulphate (Fig. 1 C), different plant patterns related to the phosphorus addition were observed. That is for soil with high salt content a spectacular plant yield versus intensity factor was obtained; while for soils with medium and low salt content the same plant response to P addition was obtained.

Under these conditions maximum plant yield was reached at different ranges of P level in the soil solution which streched from 2 to 12 ppm P.

It is well known that the use of fertilizers affects not only the plant production but also the quality ie the P content of a crop. In order to follow this affect the relations between P content and the intensity factor were considered. In Fig. 2 (A, B, C and D) these relations can be seen.

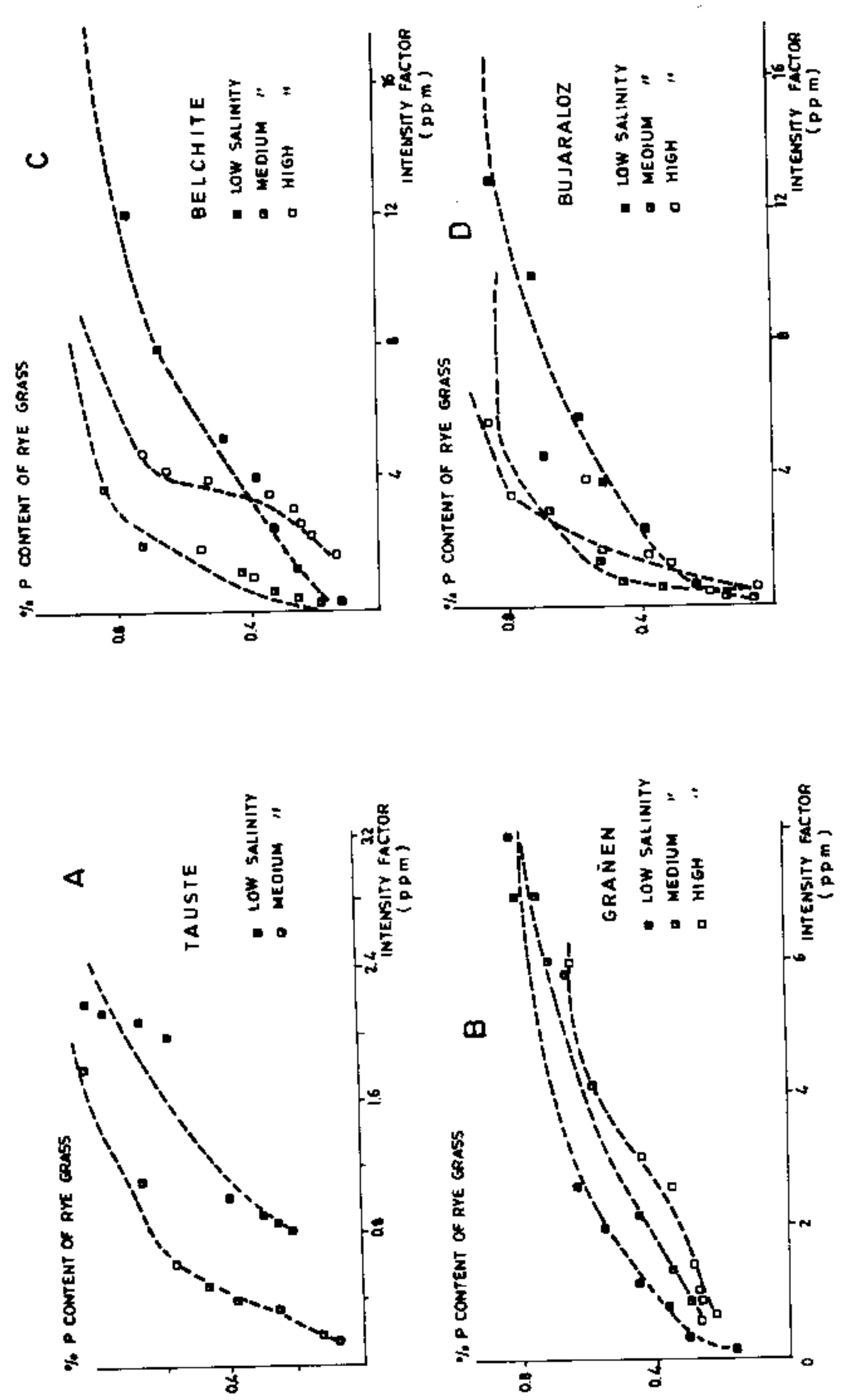

FIG. 2.—Relation between % P content of rye-grass and the intensity factor in saline soils.

The salinized areas in these Figs. 2 show that the phosphorus necessary in the soil solution for the optimum content of this nutrient, 0.60 % in rye-grass, varies with and depends greatly on the degree of salinity present in these soils.

When chlorides predominate in soils with a high salt concentration 0.82 ppm P in the soil solution is needed by rye-grass (Fig. 2 C) for a 0.60 % P in plant material and this increases to 4 ppm in the soil solution when sulphates are present (Figs. 2 B and D).

In soils with a medium degree of salinity the intensity factor reaches values of between 2 and 8 ppm in the soil solution (Figs. 2 B, C and D) decreasing to 0.6 ppm where sodium chloride salt predominates.

It can be seen that in these soils maximum plant production and phosphorus content were reached at different intensity values. It seems that the supply of this nutrient to rye-grass plants can may be controlled by more than one soil fertility factor.

2. *Phosphorus uptake by rye-grass and replenishment factor*

In this case the expression given by Khasawneh and Copeland (1973) will be useful to relate the replenishment factor to the P uptake of rye-grass, i.e, phosphorus yield of the crop.

The replenishment factor is defined by the equation (1)

$$R.F = 1 \, . \, cq^{-1/2} \, . \, K_1 K_2^{-1/4} \qquad (1)$$

where:

c = P concentration in the soil solution or intensity factor
K_1 = maximum P adsorption or quantity factor
K_2 = binding constant between soil and P
q = Any P adsorption value

The values of K_1 and K_2 for these soils were calculated in (Eleizalde and Fernández, 1982).

On the basis of the equation 1 it is easy to calculate the replenishment factor corresponding to a certain phosphorus level in the soil solution.

It the relation between phosphorus uptake and this replenishment factor is considered, it will be seen whether this new soil parameter is or is not a better measure of soil phosphorus status than the intensity factor.

In general maximum phosphorus uptake was obtained at a replenishment factor of 4 (see in Fig. 3 A, B, C and D). There was only one exception that of the soils of the Belchite area (Fig. 3 C), which reached the maximum P uptake at a level lower or higher than 4 according as the content of salt present in them was high or low.

The aproach of the replenishment factor is a good measure of the P status in the soils and confirmed the facts found by Khasawneh and Copeland (1973).

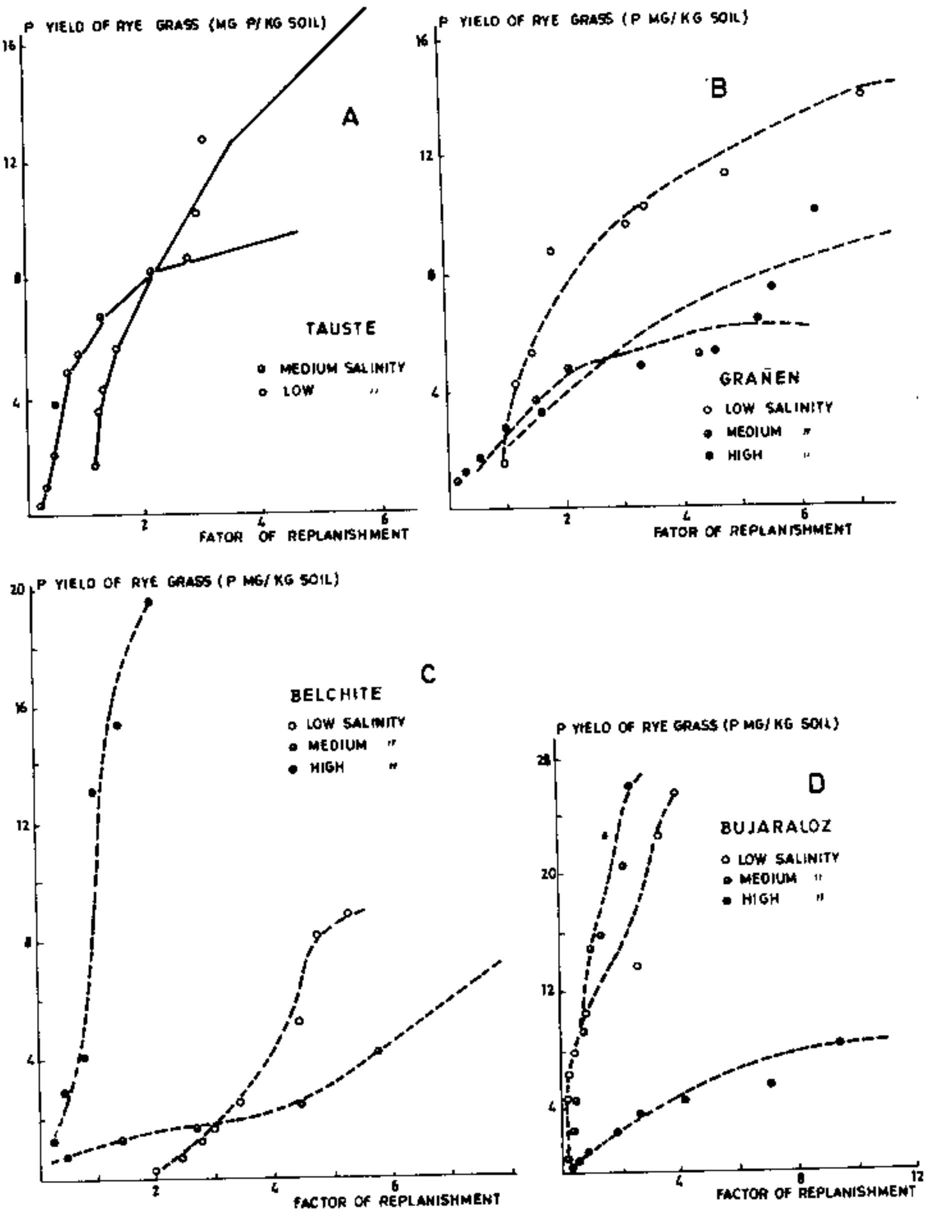

FIG. 3. Relation between P yield of rye-grass and factor of replanisment in saline soils.

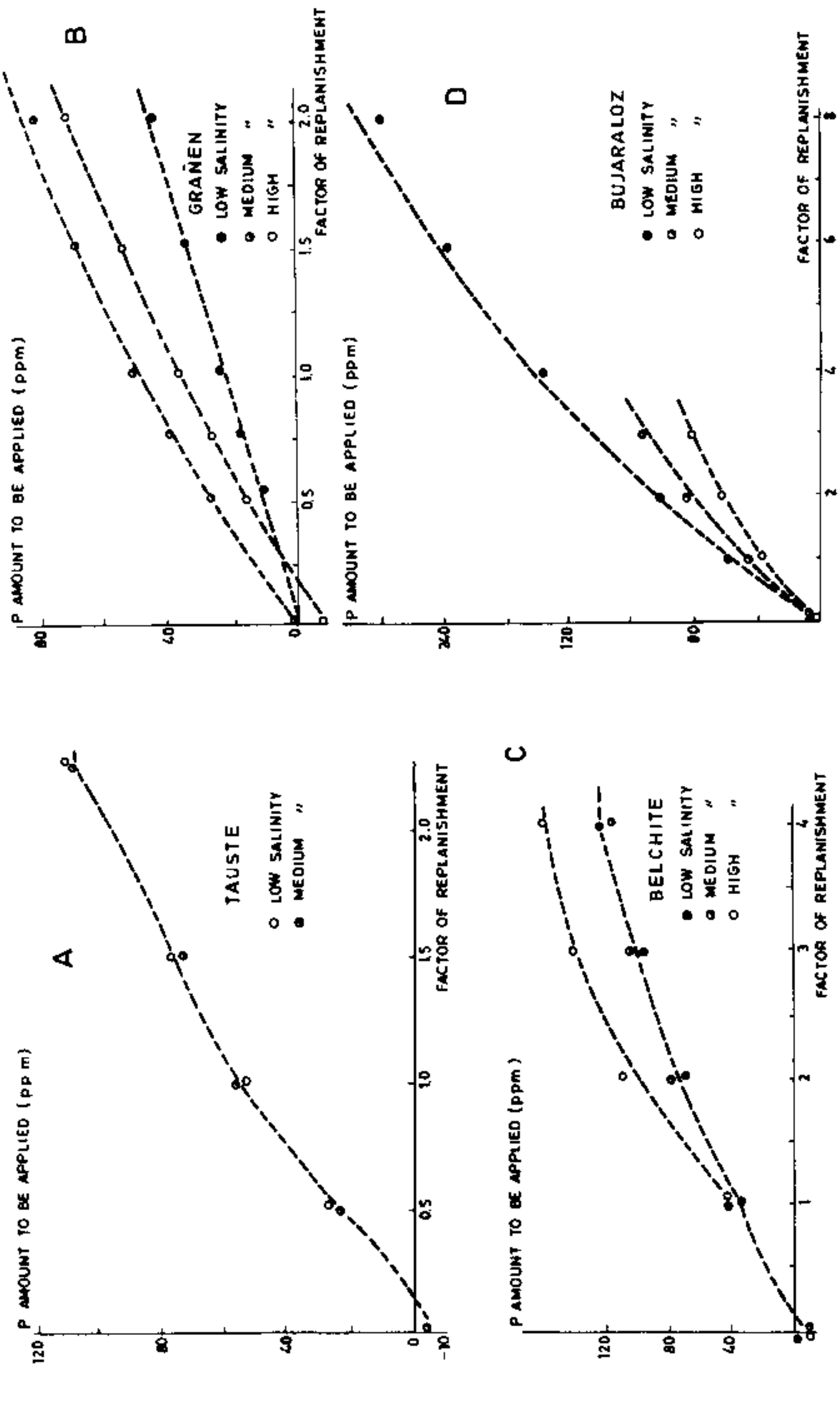

FIG. 4.- Relation between P amount to be applied to saline soils and factor of replanishment.

3. *Relation between the replenishment factor and the amount of P to be added to soil*

On the basis of these findings the quantity of P be applied to these soils can be established according to the equation (2).

$$Q = \frac{K_1 C}{K_2 + C} \qquad (2)$$

in which, Q is equivalent to the amount of fertilizer to be added, K_1 and K_2 are the maximum adsorption and binding constant previously calculated in (Eleizalde and Fernández, 1982) and C is the intensity factor.

The relation between Q and replenishment factor is plotted in Fig. 4 (A, B, C and D) and different patterns are found for these soils.

Thus in the soils of Tauste, a similar relation between both variables is noticed (Fig. 4 A), while for the soils of Grañen and Belchite (Fig. 4 B and C) different relations between Q and replenishment factor are found.

Soils rich in salts of sulphate like those of Bujaraloz, show that as salinity increases greater amounts of phosphorus are needed for a determined replenishment factor (fig. 4 D).

Conclusions

In general for the soils studied the maximum phosphorus uptake is attained at a replenishment factor of about 4. For this reason it can be believed that this factor affects the supply pattern in these soils.

For a determined replenishment factor different amounts of P are needed in these soils and saline conditions.

Resumen

INFLUENCIA DE LOS FACTORES DE FERTILIDAD DEL SUELO SOBRE LA ABSORCION DE P EN EL CRECIMIENTO DE RYE-GRASS EN SUELOS SALINOS

Se estudia la relación entre la producción de materia seca del rye-grass y el factor intensidad de suelos salinos de la provincia de Zaragoza (España). Se logra la máxima producción a concentraciones distintas de P en la solución del suelo que van de 3 a 12 ppm.

La fertilización fosfatada también mejora la calidad del rye-grass al aumentar su contenido de P. Se ve que la salinidad del suelo afecta a la concentración de P necesaria para obtener una planta con un contenido 0.60 % P; variando los valores de intensidad de 0.86 a 8 ppm en la solución del suelo.

La absorción de P por el cultivo estuvo gobernada por el factor "recuperación", debido a que en casi todos los suelos la absorción máxima de este nutriente se tiene a un factor de 4.

RESUMEE

On etudie des rapportes entre la production en materie seche du rye-grass et le facteur intensité de sols salines de Zaragoza (Espagne). On a trouvé la production la plus grand quand les concentrations de P dans la solution du sol oscillent entre 3 et 12 ppm.

Les engrais phosphatés ameliorent la qualité du rey-grass en augmentent leur contenu en P. La salinité du sol a un effet sur la concentration de P qu'on a bessoin pour obtenir un contenu de P de 0.60 % dans la plante; Les valeurs d'intensité rangent entre 0.86 et 8 ppm de P.

L'absorption de P pour les plantes est gouvernée pour le facteur "recuperation", parce que l'absorption plus grande de P est obtenu quand ce facteur est 4.

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