Effect of Seaweed on Phosphorus Availability of a Soil Derived from Volcanic Ash[1]

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ABSTRACT

A volcanic ash-derived soil was incubated up to 93 days with different amounts of seaweed. P was then extracted using an anion exchange resin method, and it was found that extractable P increased with increasing amounts of seaweed, which was added in proportions of .1, .5, 1.5, and 4.0%. Radishes grown in the same soil-seaweed mixtures absorbed more P than from the control and increased their yield with the increase of seaweed.

On adding seaweed and KH_2PO_4 simultaneously to the soil, an interaction between seaweed, soil and KH_2PO_4 occurs which results, at .1 and .5% of seaweed, in a decrease in P fixation. This could be due to the presence of alginates and alginic acids in the seaweed, since these compounds could be binding exchangeable Ca of the soil and therefore diminish P fixation by the Ca-bonding mechanism.

Additional index words: Phosphate fixation, Alginic acids, Alginates.

IN previous papers it has been shown that when seaweed is added to calcareous soils their available phosphorus increases (2, 9). This increase in available P was explained as being due either to the P contributed by the seaweed itself or to a solubilization of phosphates due to the complexing ability of some products formed during the microbiological degradation of seaweed in the soil.

The seaweed used grows abundantly on the coasts of Chile. It contains high percentages of alginic acid and alginates. The cation exchange properties of these compounds (7, 14, 15) could also contribute to the solubilization of P in the soil. Furthermore these substances may also interfere with some of the P-fixing mechanisms through their interactions with soil exchangeable Ca (7, 10, 11, 16). In the present paper the effect of different amounts of seaweed on the available P of a volcanic ash-derived soil and the interaction between seaweed and added phosphate as a function of time are studied.

The volcanic ash-derived soils (Trumaos) are important and represent around 30% of the potentially arable land of Chile. These soils are low in available P and have a rather high phosphate fixing capacity (1, 3). Due to this property the addition of phosphate fertilizer has to be high and any mechanism that could lower the amounts of P required is of interest.

MATERIALS AND METHODS

The soil used, the Arrayán series of the Trumao soils (volcanic ash derived), was collected from a nonfertilized plot situated in the Province of Bio-Bio, Chile. The top 16 cm, corresponding to A_1 horizon, were sampled; in Table 1 some of its characteristics are listed.

The seaweed is a *Macrocystis intergrifolia bory* similar to the one used in previous work (2). It was air dried, ground and

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passed through a 30-mesh sieve. The composition of this seaweed was: total P, 0.36%; P extracted with anion resin, 0.05%; sodium alginate, 32.4%; ashes (550C), 37.4%; and moisture, 10%.

Nitrogen was added in the form of KNO_3 and P as KH_2PO_4.

The soil was mixed with different amounts of seaweed to make up mixtures containing 0.1, 0.5, 1.5, and 4.0% of it. Composition of the 10 systems obtained are shown in Table 2. These mixtures were homogenized and put into 2-liter plastic containers. Distilled water was added to ⅓ of field capacity. Then they were incubated at temperatures of 18 to 23 C, water being added each 24 hours to restore that lost by evaporation.

After 13, 39, 64 and 93 days of incubation, available P was determined according to the method described by Cooke and Hislop who used an anion exchange resin as an extractant (4). Previous works have shown that a good correlation exists, for these type of soils, between the P extracted and the P content (6).

The effect of alginates on P fixation in the Arrayán soil was studied determining the maximum P-fixing capacity in the presence and absence of sodium alginate. To determine the phosphate fixation, 5-g portions of soil were shaken for 24 hours at 25 C with 100 ml of KH_2PO_4 solutions of varying concentration (between 14 and 200 ppm of P). The suspension was then filtered and residual P determined in the filtrate. P adsorption maxima were statistically calculated from the data obtained by using the Langmuir isotherm (12).

To study P-uptake from the soil-seaweed mixture (systems SNA in Table 2) a growth experiment using radishes (*Raphanous sativa*) as an indicator plant was made. Ten seeds were placed on top of the mixtures (without KH_2PO_4) contained in plastic pots and water was added daily to restore that lost by evaporation.

After 10 days the plants were reduced to 6. They were then harvested after 40 days. Yield was determined as dry-matter per pot. The aerial parts of the plants were ignited at 550 C and P determined in the ash.

All P determinations were carried out by the sulfomolybdic acid method (8). All experiments and determinations were carried out in duplicate and the mean values are reported.

RESULTS AND DISCUSSION

As can be seen in Figure 1, when the Arrayan soil is incubated with seaweed the levels of anion exchange resin-extractable P (to be called henceforth "resin P") increases. The highest values are found after incubating during 13 days. Longer periods of incubation result in a decrease of "resin-P". This decrease is more pronounced up to 39 days after which a tendency to increase can be observed and a kind of stabilization is observable after 64 days. It is, however, interesting to point out that the levels of "resin-P" show the same general pattern as the control (soil without seaweed), with only one exception.

When radishes (*Raphanous sativa*) are grown in soils incubated with seaweed for the same periods as described above, with only one exception (SNA 0.1% at 39 days), they absorb more P than those grown in the check pots. At the same time the yields increase as the amount of seaweed is increased. However, no germination of the radish seeds occurred in the systems with 4% seaweed, probably because of the physical change that took place, which resulted in a high water retention and "gelatinous" consistency of the mixture. (Table 3).

As shown in table 3, the effect of seaweed on the P level and yield of radishes is noticeable under all conditions (including the 93 days pre-incubated soil-seaweed mixture). The increase in yield over a rather extended period could be important if an agricultural use of seaweed were to be made (13).

When KH_2PO_4 is added simultaneously with seaweed to the soil, different patterns are found (Figure 2). At low levels of seaweed (0.1 and 0.5%) the "resin-P" is higher than the corresponding values of

Table 1. Some properties of the Arrayan surface soil.

pH	6.0
Available P, (with anion resin)	1.5 ppm
Total P, ppm	1,160
CEC, meq/100 g of soil	21.4
Exchangeable Ca, meq/100 g of soil	12.2
Exchangeable Mg, meq/100 g of soil	3.5
Exchangeable Na, meq/100 g of soil	0.2
Exchangeable K, meq/100 g of soil	0.4

CEC was determined using a 1 *N* pH 7 $CaCl_2$ solution (see reference 8) Exchangeable cations were determined by extracting with a NH_4 acetate solution (see reference 8).

Table 2. Composition of the ten systems studied.*

Key	Seaweed added, g	KH_2PO_4 added, 180 mg
SN	--	-
SNA 0.1%	1.2	-
SNA 0.5%	6.0	-
SNA 1.5%	18.0	-
SNA 4.0%	48.0	-
SNP	--	+
SNPA 0.1%	1.2	+
SNPA 0.5%	6.0	+
SNPA 1.5%	18.0	+
SNPA 4.0%	48.0	+

* Each system contains 1,200 g of soil and 680 mg of KNO_3.

Table 3. Yield and foliar P of radishes grown in the presence of seaweed.*

	Yield, g				P foliar, µg			
	Time of incubation before seeding, days							
Systems	13	39	64	93	13	39	64	93
SN	0.29	0.29	0.34	0.35	220	210	320	230
SNA 0.1%	0.52	0.18	0.55	0.40	420	180	620	420
SNA 0.5%	0.49	0.75	0.72	0.71	480	1,240	975	1,000
SNA 1.5%	1.28	1.04	0.84	0.83	1,590	1,950	710	995

* Per pot.

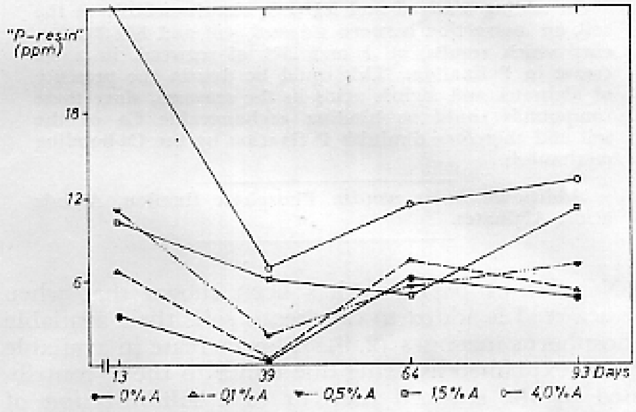

Fig. 1. Effect of varying amounts of seaweed on "P-resin" levels in systems without KH_2PO_4 (SNA).

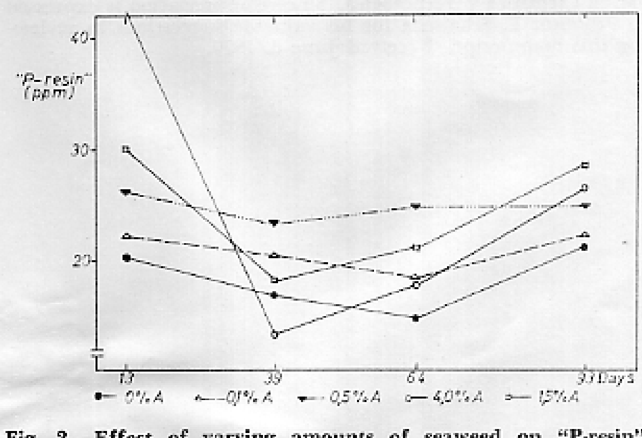

Fig. 2. Effect of varying amounts of seaweed on "P-resin" levels in systems with KH_2PO_4 (SNA).

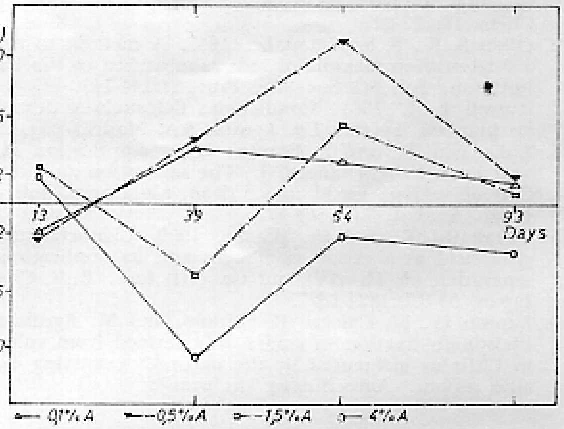

Fig. 3. Interactions of seaweed/soil/KH_2PO_4 in systems with seaweed and KH_2PO_4 (SNPA).

the control (soil with KH_2PO_4). These differences grow more pronounced up to 64 days of incubation, but then tend to decrease slightly at 93 days. The pattern of the changes occurring in these two instances is rather similar to the ones occurring in the control.

In the systems with 1.5 and 4% of seaweed, a different pattern is observed: initially and up to 13 days of incubation the maximum in "resin-P" occurs. Then a decrease is observable and the lowest values are reached after 39 days of incubation, followed by a tendency to increase again. This could be explained by an increase of the microbial population due to the more easily decomposed fraction of the organic matter provided by the seaweed. As a consequence, inorganic P would be incorporated into the cell structure of the microorganisms and only after the aging of this population would the organic bound-P be mineralized and become again available to the anion resin.

The differences between the "resin-P" of the systems containing seaweed and KH_2PO_4 (SNPA) and those containing KH_2PO_4 but not seaweed (SNP) are shown in Table 4. These values are supposed to show the increase in the amount of "resin-P" which could be attributed to the presence of seaweed in the KH_2PO_4-containing systems. To be able to express what could happen in the soil due to the addition of seaweed in the absence of added KH_2PO_4, the difference between "resin-P" of soils with seaweed (SNA) and soil alone (SN) are also shown in Table 4.

Figure 3 represents the two differences mentioned above substracted in such a manner as to obtain a value we will call "delta-P" (ΔP).

$$\Delta P = (SNPA - SNP) - (SNA - SN)$$

If it is accepted that the seaweed supplies and mobilizes from the soil the same amount of "resin-P" in the SNPA and the SNA systems, then it could be said that ΔP values equal to zero would mean that the KH_2PO_4 is able to provide the same amount of "resin-P" independently of the presence of seaweed (systems SNP and SNPA). Positive P values would mean that the presence of seaweed modified some P-fixing mechanisms in such a manner that KH_2PO_4 is able to provide a higher amount of "resin-P" to the system. On the contrary, negative ΔP values would suggest that a different mechanism comes into play

Table 4. Net P availability in systems with seaweed.*

Seaweed added, %	SNPA - SNP				SNA - SN			
	Time of incubation, days							
	13	39	64	93	13	39	64	93
0.1	1.5	3.8	4.5	2.2	3.5	0.0	1.5	0.6
0.5	5.1	6.3	10.6	3.8	7.3	2.4	-0.9	2.3
1.5	9.6	1.2	6.9	7.8	7.1	6.2	1.3	7.1
4.0	22.7	-3.4	3.6	5.2	20.8	7.2	5.6	6.5

* Expressed as ppm on a dry matter basis.

Table 5. Effect of sodium alginate on P fixation in Arrayan soil.*

Concentration P sol, added, moles/lt. 10^{-3}	P fixed, mg P/100 g soil**		P adsorption maximum, mg P/100 g soil**	
	Without alginate	With alginate	Without alginate	With alginate
0.48	39.9	37.4	443.8	359.5
1.61	97.9	86.9		
3.22	137.9	144.9		
4.83	203.7	175.6		
6.44	260.8	215.3		

* 100 mg alginate per 5 g of soil. ** Expressed on 100° C dry weight basis.

because of the presence of seaweed, yielding a lower amount of "resin-P".

As can be seen from Figure 3, in systems with 0.1 or 0.5% of seaweed, positive ΔP values are obtained, except at 13 days of incubation. When using 1.5% seaweed a negative ΔP is observed only at 39 days. At 4% seaweed all ΔP values except the 13 days value, are negative.

When negative ΔP values are obtained, principally in the systems with 1.5 and 4.0% of seaweed, the increased microbial population could be responsible for an additional P-fixation mechanism through their biological activity.

It is difficult to ascertain what kind of interaction occurs when seaweed is added together with KH_2PO_4 to the soil and a positive ΔP value is obtained. Undoubtedly some complexing substances would be formed which could interact with Fe, Al, or Ca and therefore diminish P-fixation and so contribute to positive ΔP. At the same time, the alginates and alginic acids present in the seaweed, and which are very resistant to microbial degradation (5), could also play a role through their cation exchange properties. They could compete for the Ca present in the natural exchange complexes of the soil (10, 11), decreasing its activity, and consequently inhibit some of the Ca-phosphate binding (16) which results in a higher "resin-P". This hypothesis can be based on the results shown in Table 5, where it is shown that sodium alginates decreases P fixation when it is added to the Arrayán soil.

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