# Effect of Seaweed on the Levels of Available Phosphorus and Nitrogen in a Calcareous Soil[1]

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**ABSTRACT**

**The objective of the present investigation was to study changes in levels of phosphorus and nitrogen in soils supplemented with dry, ground seaweed, $KNO_3$, and $KH_2PO_4$. After intervals of 21, 42, 76, and 105 days, phosphorus, nitrate, and ammonium were determined. The results showed that the seaweed affected the status of total inorganic N and P in the soil.**

**In all systems the levels of available inorganic phosphorus increased. However, part of the N that was added as nitrate or that was originally present in the soil was immobilized. The results further indicated that inorganic P of seaweed origin was probably in a form other than simple phosphate.**

THE study of the effect of addition of seaweeds may be of practical importance in some Chilean soils. The natives of Chiloé Island in southern Chile have been adding seaweeds to the soils since before the arrival of the Spaniards. In this island seaweed is added to the volcanic ashes soils where potatoes are grown. These soils are very low in available phosphorus.

The utility of seaweed as manure and fertilizer and its humus-forming capacity have been demonstrated (4, 6, 7, 12, 15). It is well known that organic materials in decomposition liberate complexing agents which are capable of increasing the availability of some inorganic elements in soils (9, 12, 13). To this direct complexing action the role of microorganisms must be added. In a medium that is rich in organic materials these organisms may mobilize elements like Fe and Mn, through the action of some complexing agents, enzymes, and other substances that they excrete or deliver to the medium in which they grow (2).

The purpose of this work was to study the effect of the addition of the seaweed *Macrocystis intergrifolia* Bory (MIB) to soil samples with and without fertilizers. After the seaweed addition the amounts of available P, $NO_3^-$, and $NH_4^+$ and the pH were measured at different incubation times.

## MATERIALS AND METHODS

A calcareous soil of the Maipo silt loam series uncultivated for 2 years prior to the sampling was used. It was obtained from the first 16 cm and had a pH of 7.7.

The seaweed MIB is characteristic of the coast of the central zone of Chile. Its chemical analysis appears in Table 1. This material was air dried and sieved through a 30-mesh sieve. The nitrogen utilized in the experiment was added as $KNO_3$ (Merck p.a.) and the phosphorus as $KH_2PO_4$ (Merck seg. Sörensen). Eight different mixtures were prepared. They are indicated in Table 2.

The different mixtures were homogenized (10) and put in plastic bags and the bags were placed in containers of impermeable paper painted with dark color to avoid any effect of light.

To each sample 15% of water on 110 C dry soil weight basis was added. This moisture conferred to the soil an adequate consistency for a good aeration. The samples were installed in an incubation chamber where the temperature was maintained within 18 and 23 C. The weight was controlled every 48 hours. The loss of weight was restored with distilled water.

Chemical determinations were made at the time of preparing the mixtures and after 21, 42, 76, and 105 days of incubation. At 140 days, only P was determined.

Measurements performed and techniques used were as follows:

1) Phosphorus availability determination: The Olsen method was applied (10). This method shows a good correlation between the levels of available P and the yields of field experiments[4].

2) Nitrate determination: The technique described by Chapman (8) that utilized water as extracting agent was used.

3) Exchangeable ammonium determination. The ammonium was extracted with the technique indicated by Jackson (10) and determined spectrophotometrically with the Nessler reagent. During the determination, gum arabic solution was added to the samples in order to stabilize the colored complex that is formed (8, 11). In tables we present the addition of the values of nitrate N and ammonium N as total inorganic nitrogen.

4) pH determination: The soil pH values were obtained in a 1:1 soil water suspension using a glass electrode.

5) Polyphosphate determination: The Bell technique was applied (3).

## RESULTS AND DISCUSSION

In Table 3 the values of phosphorus at various time intervals are shown. These results show clearly that the seaweed supplies available P at mixing time. At

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**Table 1. Chemical analysis of seaweed, M.I.B.**

| | | | |
|---|---|---|---|
| Total nitrogen | 1.8% | P soluble in $NaHCO_3$ (0.5N, pH 8.5) | 0.22% |
| Inorganic nitrogen | 0.17% | Sodium alginate | 31.8% |
| Total phosphorus | 0.38% | Ashes 550 C | 38.5% |

* Expressed on dry weight basis.

**Table 2. Composition of the eight different systems in study.**

| KEY | Soil (400 g) | Seaweed (4 g) | $KNO_3$ (74 mg) | $KH_2PO_4$ (29 mg) |
|---|---|---|---|---|
| SA | + | + | − | − |
| SNA | + | + | + | − |
| SN | + | − | + | − |
| SP | + | − | − | + |
| SPA | + | + | − | + |
| SPNA | + | + | + | + |
| S | + | − | − | − |

**Table 3. Levels of phosphorus and total inorganic nitrogen in the different systems through time.**

| Systems | Phosphorus (ppm P*†) | | | | | | Total inorganic nitrogen, ppm† | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days of incubation | | | | | | Days of incubation | | | | |
| | 0 | 21 | 42 | 76 | 105 | 140 | 0 | 21 | 42 | 76 | 105 |
| S | 39.2 | 42.9 | 46.3 | 50.9 | 56.2 | 60.5 | 19.5 | 33.2 | 13.8 | 17.5 | 36.4 |
| SA | 48.7 | 52.9 | 56.5 | 53.2 | 60.5 | 61.3 | 42.3 | 38.7 | 20.9 | 21.6 | 31.6 |
| SN | 39.2 | 39.0 | 47.0 | 60.7 | 57.3 | 60.9 | 23.8 | 32.3 | 19.8 | 29.5 | 54.6 |
| SNA | 48.7 | 50.8 | 51.9 | 58.7 | 62.8 | 57.7 | 46.7 | 35.8 | 23.1 | 26.5 | 38.2 |
| SP | 61.8 | 50.7 | 53.9 | 80.7 | 84.8 | 54.5 | 19.5 | 20.9 | 12.0 | 19.5 | 33.6 |
| SPA | 70.8 | 61.5 | 49.2 | 75.1 | 72.3 | 57.4 | 42.3 | 20.2 | 19.3 | 17.5 | 29.8 |
| SPN | 61.8 | 41.9 | 66.9 | 61.1 | 60.1 | 50.3 | 23.8 | 22.2 | 21.6 | 21.8 | 44.4 |
| SPNA | 70.8 | 54.1 | 55.3 | 65.8 | 78.6 | 56.7 | 46.7 | 29.7 | 15.7 | 24.3 | 37.8 |

* All the values are expressed on dry weight. Typical experiment from a series of three similar. The results represent the average of two determinations.
† From the addition of the values of N of nitrate and N of ammonium.

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21 days a slight increase of the phosphorus level is observed in the systems that contained the seaweed as the only phosphorus source. In the other systems that contained P as $KH_2PO_4$, with or without seaweed, a large decrease in the level of phosphorus is observed. These facts suggest that the available P of the seaweed is in a different chemical state from that of the added inorganic phosphorus. The data of Table 3 may indicate that the soil has not fixed this seaweed phosphorus or that microorganisms have not immobilized it preferentially. The interpretation of these results is difficult but it is possible to consider the possibility that the P of the seaweed is forming part of compounds of difficult degradation by microorganisms. These compounds would be able to form soluble complexes with the major elements of soils (Ca, Fe, Al) hindering in this way the fixation of P (V) by the soil in an insoluble form. Polyphosphates satisfy these conditions and some published data (11) indicate that some seaweed species contain up to 21% of their phosphorus in this state. Polyphosphate were determined in MIB, using 0.5 $N$ $NaHCO_3$ as extractive solution. The results obtained with the Bell technique (3) showed that the amount of polyphosphate extracted by the bicarbonate solution in the seaweed used in this work is negligible.

At 21 days the presence of nitrogen does not affect the phosphorus level in the system in which the MIB is the only source of P. However, in the systems with inorganic P the presence of nitrogen diminishes clearly the level of P. This different nitrogen effect may be attributed to a different chemical state of the P from the seaweed that makes it less susceptible to be immobilized by microorganisms.

It is observed in Fig. 1 and 2 that the addition of seaweed raises the level of phosphorus in all the treatments and that the shape of these P curves in time seems not to be affected by the presence of the seaweed.

The higher level of P observed in the systems containing the seaweed may be explained by considering two mechanisms. 1) In a medium that is rich in nutrients, the decomposition of the seaweed would be enhanced by the higher population of microorganisms, and as a consequence of this the seaweed would contribute with phosphorus of its own structure. 2) The seaweed causes the mobilization of P from the soil through a liberation of chelating substances that originate during its microbiological decomposition. Seaweed, because of its chemical constitution, might liberate during the decomposition process in the soil compounds like carbohydrates of variable complexity. Other substances of high complexing nature that could appear in the soil during this process are amino acids and some organic molecules with nitrogen in their structure and also some other compounds of indeterminate character, possibly organic acids, polyhydroxy compounds, ketonic structures, etc. The action of these compounds would be to solubilize the insoluble phosphates like those of Al, Ca and Fe, possibly through a mechanism of complexation of these metallic ions, leaving the phosphate in the soil in an available form for the plants (12).

The effect of the nitrogen in the treatments SA and SP can be estimated from Fig. 3 and 4. The P values of these figures were obtained by subtracting from the P in these treatments the value of available P in the soil alone.

When N is added to the system containing inorganic P the fluctuations of P values in time are larger than in the absence of N (Fig. 3). On the other hand, as shown in Fig. 4, with the addition of N to systems whose only source of P is the seaweed the fluctuation of P values tends to diminish.

The "net availability" of P in the systems with seaweed is shown in Fig. 5. The "net availability"

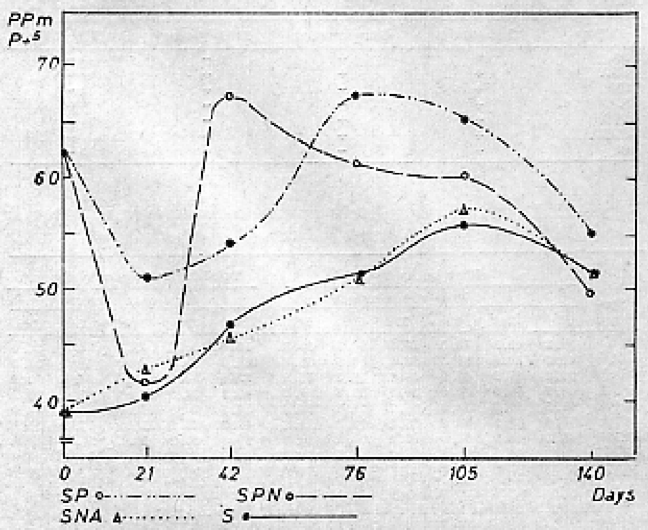


Fig. 1. Levels of available phosphorus in systems without seaweed.

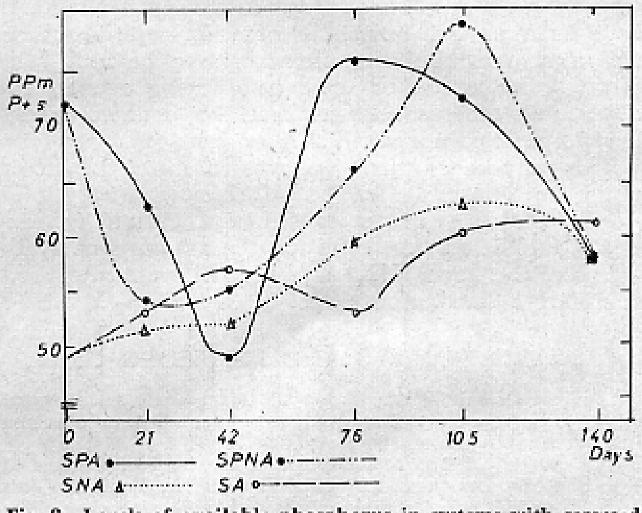


Fig. 2. Levels of available phosphorus in systems with seaweed.

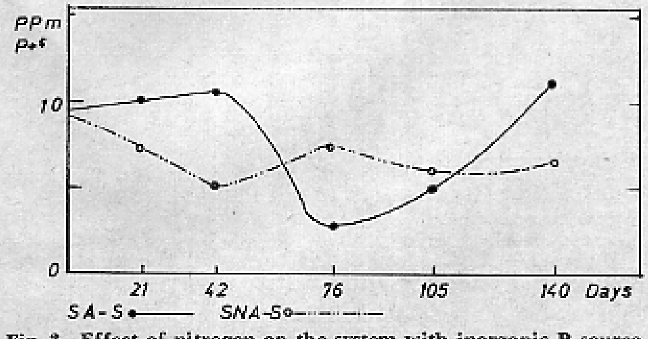


Fig. 3. Effect of nitrogen on the system with inorganic P source.

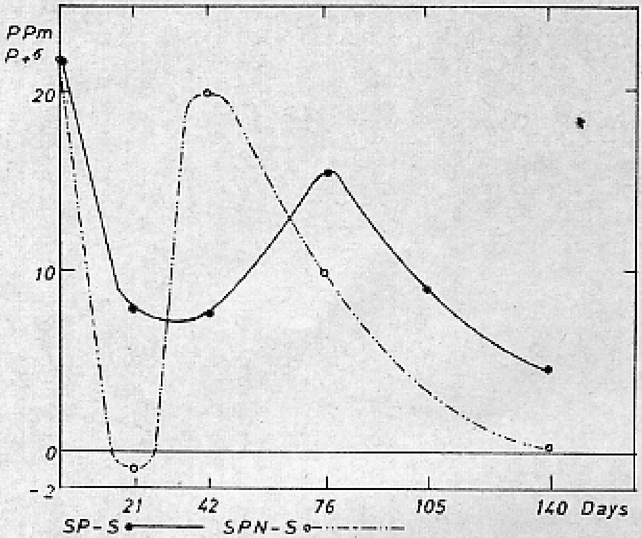


Fig. 4. Effect of nitrogen on the system with seaweed as P source.

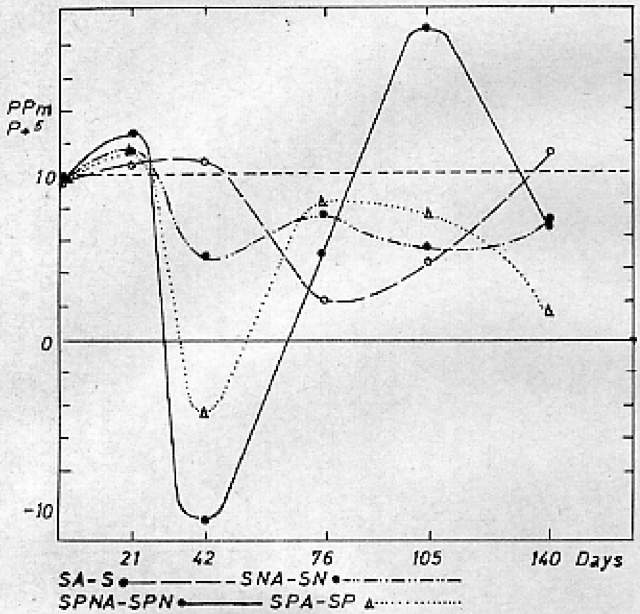


Fig. 5. Net availability of phosphorus in systems with seaweed.

of P was obtained by subtracting from the P level of the systems with seaweed the level of P of a similar system without seaweed. The level of this kind of P remained constant until the 21st day and then descended in apparent correlation with the growing number of nutrients added to each treatment. This results suggest that these systems richer in nutrients allow for a greater proliferation of microorganisms with a consequent immobilization of P. In these systems the net availability of P increased after 42 days so that they reached the original levels thereafter. In the entire experiment only the difference for the pair SPNA-SPN shows a level of phosphorus higher than that of the original. That level was reached at 105 days of incubation.

The effect of the seaweed on the nitrogen levels through time is shown in Fig. 6. In this figure the inorganic N plotted is the difference in N between two corresponding treatments: one with and the other

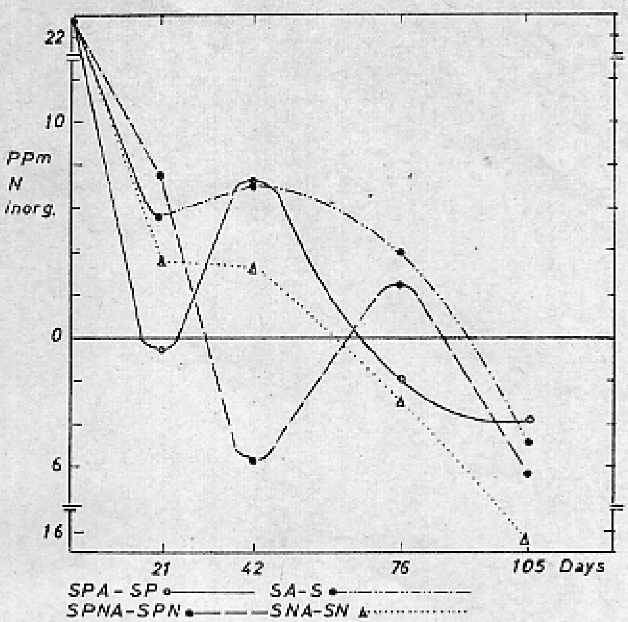


Fig. 6. Effect of seaweed on inorganic nitrogen levels.

without the seaweed. The net levels of inorganic nitrogen experienced a clear decrease that fluctuated between 14 and 20 ppm during the period of study. This decrease in inorganic nitrogen was probably due to its transformation to organic forms by the microorganisms. This phenomenon of nitrogen immobilization is stimulated by the presence in the system of an organic material with a low content of nitrogen like the seaweed. It can be observed in Fig. 6 that the most pronounced decrease occurs in the systems to which inorganic nitrogen was added (1, 5, 12).

The pH in all systems showed an initial increase and then stabilized around a value near 8 at 42 days in systems without seaweed and at 76 days in those with seaweed.

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