

Effects of Seaweed on Potato Yields and Soil Chemistry

M.E. López-Mosquera and P. Pazos

Departamento de Ingeniería Agroforestal y Producción Vegetal, Escuela Politécnica Superior, University of Santiago Compostela, 27002 Lugo, Spain

In parts of northwest Spain, seaweeds have traditionally been used as fertilizer for potatoes. In the work reported here, a potato field was divided into plots which were fertilized with seaweed (20, 40 or 80 t ha⁻¹), or fertilized by conventional means (46.5 t ha⁻¹ cattle manure plus 1 t ha⁻¹ NPK 8:24:16), or not fertilized. Soil properties were monitored before planting and at the "end of season" phase. Fertilization with seaweed reduced the acidity, which was demonstrated as a pH increase from 0.3 to 0.6 in the plots fertilized with seaweed; the concentration of exchangeable Ca doubled, when compared to the traditional fertilizer, and the percentage of Al saturation decreased to 4.5% for the dose of 80 t ha⁻¹ of seaweed, with respect to the initial values (19.2%). Assimilable K levels rose significantly, from 0.41 to 0.68 cmol kg⁻¹ with 80 t ha⁻¹ seaweed which did not cause salinization (E.C. < 0.5 dS m⁻¹). Crop yield in plots which received 80 t ha⁻¹ of seaweed was significantly higher than in all other plot types (1.6 t ha⁻¹) against 5.5 t ha⁻¹ in unfertilized plants and 8.2 t ha⁻¹ in conventional plots, significant differences which are also evident in the single-potato weight.

INTRODUCTION

In coastal regions of Galicia (northwest Spain), seaweed has traditionally been used as a fertilizer. Currently, however, the practice is rare, mainly because seaweed collection is highly labour-intensive. Nevertheless, the increasing cost of chemical fertilizers and the trend towards use of sustainable resources means that this traditional practice is once more attracting interest. This is particularly true in Galicia, which has excellent potential for seaweed production (Ferreiro *et al.*, 1993), which is presently being insufficiently exploited.

Though it is well known that certain crops, including the potato, benefit from seaweed application (Booth, 1966; Chapman & Chapman, 1980; Blunden, 1991; Verkleij, 1992), there have been relatively few controlled studies aimed at quantification of the effects of this practice on crop yield and

soil properties (Andrade *et al.*, 1983; Mateos & Andrade, 1985). In the present study, the effects of seaweed application on soil chemistry and potato yield were investigated with the aim of justifying seaweed application and confirming the benefits which are usually attributed to its use in the region in an empirical way.

MATERIALS AND METHODS

The trials were carried out in Muxía (Galicia, northwest Spain) in a field which had been fertilized exclusively with seaweed for the last 8 years (average dose $40 \text{ t ha}^{-1} \text{ year}^{-1}$). The soil is a humic Cambisol (FAO, 1990). Climate in the study area is Maritime Mediterranean (classification of Papadakis, 1966).

The field was divided into fifteen 20 m^2 plots, all of which were planted with potato (the semi-early variety Kennebec). Sowing was carried out on 23 March 1994 and harvesting was done on 18 August of the same year. Plots were randomly assigned to one of five treatment groups: no fertilization, fertilization with seaweed, 20 t ha^{-1} , fertilization with seaweed, 40 t ha^{-1} , fertilization with seaweed, 80 t ha^{-1} or conventional fertilization. In all cases fertilizer was applied 30 days after planting. Conventional fertilization was with 46.5 t ha^{-1} of cattle manure (dry matter = 20%, N = 0.55%, P = 0.065%, K = 0.5%) and 1 t ha^{-1} of NPK (8:24:16), as normally used for potato cultivation in the study region. A mixture of seaweeds was collected from the beach (in accordance with traditional practice) and left to stand for 8 days before adding it to the soil (dry matter = 13.3%). The mix contained *Halidrys siliquosa* (L.) Lungbye, *Laminaria hyperborea* (Gunner) Foslie, *Fucus vesiculosus* L., *Fucus spiralis* L., *Fucus serratus* L., *Gelidium sesquipedale* (Turn.) Thuret, *Ulva rigida* C. Agardh., *Enteromorpha intestinalis* L., *Enteromorpha compressa* L. and *Cystoseira baccata* (Gmelin) Silva.

The nutrients provided by the different treatments in kg ha^{-1} were: 20 t ha^{-1} seaweed: 268 N, 12 P, 70K; 40 t ha^{-1} seaweed 536 N, 24 P, 140 K; 80 t ha^{-1} seaweed 1072 N, 48 P, 280K; conventional fertilizer: 335.7 N, 134.8 P, 365.3 K

To determine the chemical composition of the seaweed mix, samples were first dried and ground. C, N and S were determined with a Leco CMN-1000 automatic analyser. P was determined after wet ashing, by the colorimetric method of Chapman & Pratt (1984). Other elements (K, Ca, Mg, Na, Fe, Mn, Cu, Cr, Ni, Zn, Cd, Pb and Al) were determined by atomic emission or absorption spectrophotometry following acid digestion (HCl 2M). The mean chemical composition of the seaweed mix was: In % (1.34 N, 0.06 P, 0.35 K, 21.1 C, 2.12 Ca, 0.58 Mg, 1.9 Na, 0.27 S), in mg kg^{-1} (3575 Fe, 50 Mn, <25 Cr, <25 Ni, 45 Zn, 4 Cd, <25 Pb and 3250 Al).

Soil samples were taken from each plot **before** planting and 70 days after planting, given that at **this** time, under experimental conditions, the plant was in its phenological phase at the "end **of** the season", the phase after which **the** crop begins, essentially, to retranslocate and the extractions which it makes from the soil **are** minimal (McCollum, 1978a, 1978b). The depth of the sampling was 30 cm. Chemical-analyses were carried out on the < 2 mm fraction after drying at 20°C. C and N were determined **as** for the analysis **of** seaweed. pH was determined in saturated paste and electrical conductivity in a saturation extract (Richards, 1973). Exchangeable **Ca**, **Mg** and **Al** were extracted with 1 M NH_4Cl (Peech *et al.*, 1947) and determined by atomic absorption spectrophotometry. Exchangeable Na and K were likewise extracted with 1 M NH_4Cl and determined by atomic emission spectrophotometry. Available P was determined following extraction with 0.5 M NaHCO_3 , by a modification of the method of Olsen & Dean (1965).

Effects of the different treatments on crop yield and crop **quality** were assessed by determination of total weight and total number of potatoes **per** plot, and mean minimum diameter and mean weight of individual potatoes **in** each plot.

Data was analysed by analysis of variance the statistics package Statgraphics version 3.0 (STSC, 1986). Statistical significance was calculated using **LSD** for $p = 0.05$.

RESULTS

Effects of seaweed application on total C and total N

Total C did not vary significantly among plots (Table 1). This result differs from that obtained by previous authors (Rodríguez *et al.*, 1983; Mateos & Andrade, 1985), who found that organic matter content increased after application of seaweeds, and suggests that seaweeds decompose very rapidly. Nevertheless, the total N was higher in the fertilized plots than in **the** non-fertilized ones (Table 1).

Effects of seaweed application on soil pH and exchangeable cations

The present results confirm those of previous studies (Rodríguez *et al.*, 1983; Mateos & Andrade, 1985; Crouch *et al.*, 1990) which have indicated that application of seaweed has a 'liming' effect, as revealed by effects on pH, **Ca** and **Al** levels. Plots which received seaweed had significantly higher pH **than** the conventionally fertilized plots (Table 1). The difference was **most** pronounced in the case of plots which received 80 t ha^{-1} of seaweed.

TABLE 1

Soil chemistry at planting and 70 days after planting potatoes with application of seaweed or conventional fertilizer.

	At planting		70 days after planting			Conventional fertilizer	LSD (p=0.05)
	Unfertilized		Seaweed (t ha ⁻¹)				
			20	40	80		
Total C (%)	4.58	4.50	4.39	5.09	4.46	4.82	n.s.
Total N (%)	0.28	0.18	0.28	0.34	0.27	0.33	0.17
pH	5.3	5.6	5.5	5.6	5.8	5.3	0.2
Ca (cmol kg ⁻¹)	2.80	2.70	3.03	3.38	4.41	2.16	2.35
Mg (cmol kg ⁻¹)	0.57	0.52	0.54	0.52	0.65	0.51	n.s.
Na (cmol kg ⁻¹)	0.08	0.11	0.12	0.12	0.14	0.11	0.06
K (cmol kg ⁻¹)	0.41	0.42	0.48	0.55	0.68	0.47	0.31
Al (cmol kg ⁻¹)	0.92	0.58	0.84	0.46	0.28	1.03	0.89
P (mg kg ⁻¹)	70.5	71.1	72.7	70.6	83.4	80.0	17.1
E.C. (dS m ⁻¹)	0.28	0.40	0.48	0.44	0.32	0.35	n.s.

Application of seaweed also led to a marked increase in exchangeable Ca content. The increase was particularly marked, and statistically significant with respect to unfertilized and conventional plots, in the case of 20 and 40 t ha⁻¹ seaweed. Exchangeable Mg content also showed a tendency to increase with increasing seaweed dose (Table 1), though the observed differences with respect to the control plot were not statistically significant.

In accordance with the results for pH and Ca exchangeable, Al levels were likewise reduced in seaweed-treated plots (Table 1). This is most apparent in plots which received the highest seaweed dose (80 t ha⁻¹), in which exchangeable Al content was significantly lower than in control plots and conventionally-fertilized plots, throughout the growth period. The observed effect on soil Al levels may be attributable to the displacement effect which the Ca has on the Al, and to the pH levels reached which maintain this element as a precipitate. On the other hand, the seaweed contains alginic acid which could act as a cation exchanger, thus reducing Al levels in the soil (Caiozzi *et al.*, 1986). This effect is of particular interest in Galicia, where Al levels in most soils exceed the optima for plant growth.

Effects on P and K levels

Analysis of variance showed an overall significant (p < 0.05) effect of treatment on the soil P level although individual treatments did not differ significantly in paired comparison (Table 1). The highest value for P was in

plots fertilized with 80 t ha^{-1} . The fact that the availability of P increases may be explained by the pH increase, and the decrease in Al which normally precipitates with P forming insoluble phosphates. On the other hand, as in the case of A1, this (apparent) effect may also be attributable to the high alginic acid content of seaweeds. Specifically, this acid may act to reduce levels of Al^{3+} and Fe^{3+} . Since both ions precipitate phosphates, their sequestration by alginic acid will tend to lead to an increase in plant-available P.

Soil P levels as measured in the various plots ranged from 71.1 to 83.4 mg kg^{-1} . These values are high for potato plots, and by comparison with Galician soils in general. In view of the present results, this can probably be attributed to the use of seaweed for fertilization of the study plot over the 8 years prior to this study.

K levels were markedly and significantly higher in seaweed-treated plots than in the control and conventionally fertilized plots, and the increase in K levels was roughly proportional to the seaweed dose (Table 1). Despite these increases, however, K-to-Mg ratio remained in all cases acceptable (e 1.5).

Na and conductivity

In general, Na levels were higher in seaweed-treated plots (particularly with 80 t ha^{-1}) than in the control and conventionally fertilized plots (Table 1). Despite the high Na and Cl contents of the seaweed mix, salinity (as reflected by electrical conductivity of saturation extracts) remained low in all plots, in no case exceeding 0.5 dS m^{-1} (Table 1). This can probably be attributed to the sandy texture of the soils studied, and to the high rates of leaching (annual precipitation = 1650 mm).

Yield

Regardless of treatment, yields were in all cases low by comparison with the typical yield for potato in this region (about $28\text{--}30 \text{ t ha}^{-1}$). Low yields were likewise obtained in the year of study by the region's commercial potato farmers, because of unfavourable weather and losses due to Colorado beetle and mildew.

In relative terms, however, yield from plots with seaweed at 80 t ha^{-1} was markedly and significantly higher than from the remaining plots, for which mean yields were similar (Table 2). These plots performed better than other plots not only in terms of weight of crop, but also number of potatoes. However, neither mean number of potatoes nor mean single potato size differed significantly between these plots and the rest.

TABLE 2

Effect of seaweed and conventional fertilization on potato yield characteristics.

	Unfertilized		Seaweed (t ha ⁻¹)			Conventional fertilizer	LSD (p= 0.05)
			20	40	80		
Yield (t ha ⁻¹)	5.5	7.4	7.4	11.6	8.2	6.8	
No. of potatoes ha ⁻¹	78000	92000	97000	134700	99500	n.s.	
Mean minimum tuber diameter (mm)	44.7	49.1	49.2	48.5	49.3	n.s.	
Mean tuber weight (g)	70.0	79.9	76.4	86.0	83.1	19.1	

DISCUSSION

In the present study, fertilization of potato plots with seaweed had a number of beneficial effects on soil properties. First, seaweed application had effects similar to those of liming, i.e. increased pH, increased exchangeable Ca, and reduced exchangeable Al. Secondly, seaweed-treated plots showed *increased* P levels, probably attributable at least in part to the reduction *m exchangeable* Al. **Thirdly**, seaweed-treated plots showed **a pronounced increase in K levels**. This increase was dose-dependent and much higher than that produced by conventional fertilization, despite the fact that the K content of the seaweed mix used was considerably lower than that of the conventional fertilizer; this suggests that the K present in seaweed is a readily available **form**.

Furthermore, fertilization with seaweed did not lead to unacceptably high Na levels or soil salinity, despite the high Na and Cl contents of the seaweed mix used. This suggests that seaweed may be used for fertilization without **risk** of salinization; clearly, however, care should be taken with crops grown under cover (and thus not subject to leaching by rainwater). Finally, the highest seaweed dose tested (80 t ha⁻¹) led to a marked improvement in both yield ha⁻¹ **and** mean single potato weight. However, seaweed application had no significant effects on number of potatoes ha⁻¹ or mean single-potato size.

ACKNOWLEDGEMENTS

We thank M^a J. Lema Gesto, Laboratorio de Suelos- Estación Fitopatológica do Areeiro-Pontevedra and the laboratory of Departamento de Edafología y Química Agrícola, Facultad Biología-Universidad Santiago Compostela, for providing the laboratory facilities for the chemical analyses.

References

- Andrade Couce, M.L., Rodríguez Seoane, P., Guitián Rivera, F., López, M.I. & Guitián Oja, F. (1983). Uso de algas marinas como fertilizante de suelos gallegos. II. Efecto de las algas marinas en la disponibilidad y contenido total de diversos oligoelementos en suelos de cultivo de la provincia de Pontevedra. *Anales de Edafología y Agrobiología*, **XLII**, 11-12, 1851-1865.
- Blunden, G. (1991). Agricultural uses of seaweeds and seaweed products. In *European Seaweed Resources: Uses and Potential* (M.D. Guiry & G. Blunden, eds.) pp. 65-81. J. Wiley and Sons; Chichester.
- Booth, E. (1966). Some properties of seaweed manures. *Proceedings of the 5th International Seaweed Symposium*, pp. 349-357. Pergamon Press; Oxford.
- Caiozzi, M., Bone, G., Baherle, P., Matus, M. & Zambrano, K. (1986). Uso de algas marinas como matriz de fertilizantes de entrega lenta y acción sostenida. I. Estudio del comportamiento del sistema *Macrocystis-Fósforo*. *Anales de Edafología y Agrobiología*, **XLIV**, 11-12, 1717-1726.
- Chapman, H.D. & Pratt, P.F. (1984). *Métodos de Análisis para Suelos. Plantas y Aguas*. Trillas; México.
- Chapman, V.J. & Chapman, D.J. (1980). *Seaweeds and their Uses*. Chapman & Hall; London, New York.
- Crouch, I.J., Beckett, R.P. & van Staden, J. (1990). Effect of seaweed concentrate on the growth and mineral nutrition of nutrient-stressed lettuce. *Journal of Applied Phycology*, **2**, 269-272.
- F.A.O. (1990). *The Soil Map of the World*. FAO-UNESCO, Rome.
- Ferreiro, I.A., Acuña, R. & Durán, C. (1993). *As Algas en Galicia. Alimentación e Outros Usos. Consellería de Pesca, Marisqueo e Acuicultura*. Xunta de Galicia.
- Guitián, F., Carballas, T. (1976). *Técnicas de Análisis de Suelos*. Pico Sacro. Santiago de Compostela.
- Mateos Beato, A. & Andrade Couce, M.L. (1985). Contribución de diversas especies de algas marinas a la fertilidad del suelo. *Congreso Científico Europeo de Agricultura Biológica*, pp. 119-126. IFOAM; Madrid.
- McCollum, R.E. (1978a). Analysis of potato growth under differing P regimes. I. Tuber yields and allocation of dry matter and P. *Agronomy Journal*, **70**, 51-57.
- McCollum, R.E. (1978b). Potato growth under differing P regimes. II. Time by P-status interactions for growth and leaf efficiency. *Agronomy Journal*, **70**, 58-66.
- Olsen, S.R. & Dean, L.A. (1965). Phosphorous. In *Methods of Soil Science* (C.A. Black, ed.), pp. 1035-1049. American Society of Agronomy; Madison, Wisconsin, U.S.A.
- Papadakis, J. 1966. *Climates of the World and their Agricultural Potentialities*. Autor; Buenos Aires.
- Peech, M., Alexander, L.T., Dean, L. & Reed, J.F. (1947). Methods of soil analysis for soil fertility investigations. *United States Department Agriculture. Circular*, 757.
- Richards, L.A. (1973). Diagnóstico y rehabilitación de suelos salinos y sódicos. *USDA Manual N. 60*. Limusa; México.
- Rodríguez, P., Andrade, M.L., López, M.I. & Guitián, F. (1983). Uso de algas marinas como fertilizante de suelos gallegos. *Anales de Edafología y Agrobiología*. Vol. **XLII**, 11-12, 1837-1850.
- Verkleij, F.B. (1992). Seaweed extracts in agriculture and horticulture: a review. *Biological Agriculture and Horticulture*, **8**, 309-324.

(Received 16 January 1996; accepted 12 August 1996)