Compost Science & Utilization, (2008), Vol. 16, No. 2, 119-124

# Seaweed Compost as an Amendment for Horticultural Soils in Patagonia, Argentina

**M. C. Eyras[1], G. E. Defossé[2] and F. Dellatorre[1]**
*1. Centro Nacional Patagónico (CENPAT-CONICET) and Universidad Nacional de la Patagonia, Puerto Madryn, Chubut, Argentina*
*2. Centro de Investigación y Extensión Forestal Andino Patagónico (CIEFAP-CONICET) and Universidad Nacional de la Patagonia, Esquel, Chubut, Argentina*

Seaweed (fresh, dry) or its products (extracts, composts, soil conditioners) have been long used in agriculture to enhance plant growth and productivity. In this study, we evaluated the effects that seaweed composts at different doses and degree of maturation had on the yield of tomatoes (*Licopersicon esculentum* Mill. cv. platense) grown on a horticultural soil in northeastern Patagonia. We used 10 tomato plants per treatment plot set in a randomized block design. Treatments were: 1) soil without amendment, control (S); 2) 5 kg $m^{-2}$ of compost aged 9 months (C9-5); 3) 10 kg $m^{-2}$ of compost aged 9 months (C9-10); 4) 5 kg $m^{-2}$ of compost aged 20 months (C20-5); and 5) 10 kg $m^{-2}$ of compost aged 20 months (C20-10). Total weight and number of tomatoes, and aerial plant biomass (excluding fruits) were significantly higher for the compost treatments than those of the control. Also, compost treated plants bore mature fruits, in average, 9 days earlier and presented higher resistance to diseases than controls. The weight of tomatoes per plant grown in C20 was significantly higher than that of C9, differences that could be attributed to the lower salinity of compost C20 (C20 and C9 electrical conductivities were 1.5 and 15 dS $m^{-1}$, respectively). The increased yield and resistance to diseases on tomato plants by addition of seaweed compost appear to be related to a complex number of factors not yet fully understood. It seems, however, that a combination of higher nutrient availability (mainly P) due to slight increases in pH of the soil amended, together with increases in readily available K and an improvement in soil physical conditions (increase in pore size and probably amelioration of hydric conditions), may have been responsible for the higher production of seaweed amended plots as compared to the control.

## *Introduction*

Seaweed or its products are commonly used in agriculture to stimulate plant growth and increase crop productivity. Their beneficial effects include enhanced seed germination, plant yield, root growth, tolerance to different plant stresses and increase in plant resistance to infections or insect attack (Abetz 1980; Blunden 1991). These products contain all major plant nutrients, trace elements, organic compounds (carbohydrates, amino acids, and vitamins) as well as substances of stimulatory and antibiotic nature (Crouch and van Staden 1993). These compounds could vary according to the seaweed species used, the method of preparation, the concentration used, the kind of substrate and soil amended, and the crop being tested (Blunden 1991). Nevertheless, researchers have reported mixed results on the effectiveness of these products (Tourte *et al.* 2000; Edmeades 2002). Apart from seaweed extracts or the application of seaweed directly to a soil, either fresh or dried and chopped (Haslam and Hopkins 1996; López-Mosquera and Pazos 1997; Montero Vilariño *et al.* 1999), seaweed also have been used for preparation of composts (Mazé *et al.* 1993; Vallini *et al.* 1993; Cuomo *et al.* 1995; Eyras *et al.* 1998; Klock-Moore 2000; Orquín *et al.* 2001; Eyras 2002,Vendrame and Klock-Moore 2005).

The interest in the use of seaweed in composts increased in the last decades due to an unusual increase in algal biomass, particularly that from green seaweeds, resulting from the progressive eutrophication of some coastal ecosystems. There are several ways of removing and treating seaweed biomass that have been developed (Morand and Briand 1996). Composting has been proposed as one of the best methods for removing seaweed biomass in an environmentally sound way, that at the same time is economical and technologically feasible (Mazé *et al.* 1993).

On the coast of Puerto Madryn in northeastern Patagonia, Argentina, seaweed biomass is periodically cast ashore and constitutes a serious problem during the summer months. The local municipality collects tons of this biomass (Piriz *et al.* 2003) and throws it inland without any treatment. We developed a program to prepare compost as an environmentally sound disposal method of this seaweed, using it then as a soil amendment in different laboratory and field experiments (Eyras *et al.* 1998; Eyras 2002). One of these experiments was carried out in the horticultural area of the nearby Lower Chubut Valley, where there is a general consensus among farmers that soil fertility has progressively declined, and the use of chemical fertilizers and pesticides is increasing. The objective of this study was to determine the effect of two differently aged seaweed composts, applied at two different doses, on the yield and resistance/tolerance to common infections of tomato plants (*Licopersicon esculentum* Mill. cv. platense) grown on an horticultural soil of northeastern Patagonia.

## Materials and Methods

### Composting

Material used for composting was beach-cast seaweed and ligno-cellulosic refuses. Seaweed used were collected on the beaches of Puerto Madryn (42° 45′ S; 64°55′ W). *Ulva* spp. was the most important component of the seaweed wrack (35% in dry weight), while *Codium vermilara* (Olivi) Delle Chiaje, *Dictyota dichotoma* (Hudson) Lamouroux and *Ceramium rubrum* (Hudson) C. Agardh were the co-dominant taxa. Several species of green, red, and brown algae completed the floristic wrack composition (Piriz *et al.* 2003). In samples taken after collection, organic matter represented 40% of the total dry weight, while the rest was sand. The compost was prepared by mixing the seaweed with ligno-cellulosic material (wood chips, yard trimmings and sawdust) in 3:1 ratio (in fresh weight). This material was composted in static piles, and was mechanically turned at weekly intervals during the first 60 days of composting. Two composts (C20 and C9, respectively) were then prepared. For C20, we mixed 6 $m^3$ of materials, and the pile was periodically irrigated for a year with waste water coming from the local Cooperative of Public Services of Puerto Madryn, and with clean running water thereafter until the experiment was set 8 months later. The compost C20 had a total of 20 months of maturation. The other compost (C9) was prepared in a similar way as the other by using 14 $m^3$ of the same material, and irrigated only with running water until it was used for the experiment 9 months later. Samples of each compost, and of the soil in which this experiment was conducted, were analyzed for total C (Nelson and Sommers 1982), total N (Kjeldahl method, Bremner and Mulvaney 1982), available P, extracted with $NaCO_3H$ and determined by colorimetry (Olsen and Sommers 1982), and interchangeable K (Bremner and Mulvaney 1982). Before setting the experiment, we determined particle size for both composts, and pH and electrical conductivity (in saturation extracts) of each compost and of the soil used as a control.

### Field Experiment

The field experiment was conducted on a horticultural farm located near the town of Gaiman (43° 17′ S; 65°29′ W), on the Lower Chubut River Valley, in northeastern Patagonia, Argentina. Soils are Torrifluvents and Haplargids (Laya 1981). On a small allotment of this farm, whose general soil characteristics could be considered representative of the horticultural soils of the area, we set five treatments, as follows: 1) control (S); 2) 5 kg $m^{-2}$ of compost C9 (C9-5); 3) 10 kg $m^{-2}$ of compost C9 (C9-10); 4) 5 kg $m^{-2}$ of compost C20 (C20-5); and 5) 10 kg $m^{-2}$ of compost C20 (C20-10). The composts were applied by plowing the soil to a depth of 30 cm and mixing them in the furrows in which the tomato seedlings were going to be planted, while the same plowing treatment was performed in control plots. Each treatment was replicated 5 times, in a randomized block design. Samples were taken from each amended plot (C9-5, C9-10, C20-5 and C20-10) to determine their pH and electrical conductivity (in saturation extracts). In each plot (1.6 x 3 m) we planted 10 tomato seedlings of similar age, size, and number of leaves, in two furrows 60 cm apart. All plants were irrigated by inundating each furrow with water taken from a nearby canal. This was done at about 15 days intervals during the whole experiment. The yield of tomato fruits was evaluated by the weight and number of tomatoes per plant. These tomatoes were harvested (as they matured, pink-red) at weekly intervals (14 times from January 17 up to May 2). After harvest, each tomato was visually inspected and those showing signs of infection by pathogens (virus/bacteria/fungi) recorded for each treatment. Dry biomass of each plant (excluding fruits) was determined at the end of the experiment for each treatment. Data were analyzed by ANOVA techniques and means were separated by Duncan´s multiple range test ($\alpha$=0.05) using the SPSS 6.1 statistical package (Norusis 1993).

## Results

### Substratum Chemical and Physical Properties

Both composts (C20 and C9) had low concentrations of the main nutrients except phosphorous,

TABLE 1.
Initial physical and chemical analyses of composts (C20 and C9) and of the soil (S) used as a control

| Treatment | Total C (%) | TKN (%) | C/N | P (ppm) | K (cmol kg$^{-1}$) | EC (dSm$^{-1}$) | pH | Particle size mm (% in weight) >4 | <4 >2 | <2 >1 | <1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| C20 | 2.18 | 0.195 | 11.2 | 86.7 | 4.9 | 1.5 | 7.5 | 6.8 | 6.6 | 6.7 | 79.8 |
| C9 | 3.31 | 0.300 | 11.0 | 76.6 | 0.4 | 15.0 | 8.0 | 23.7 | 10.2 | 7.2 | 58.9 |
| S Control | 2.09 | 0.206 | 10.1 | 17.1 | 3.6 | 0.7 | 6.0 | nd. | nd. | nd. | nd. |

n.d. not determined

while their pH was higher than the control (S) (Table 1). The electrical conductivity (EC) was 0.7 dSm$^{-1}$ in the control (S), 1.5 dSm$^{-1}$ in the C20 compost and 15 dSm$^{-1}$ for the C9 compost. Both the control and C20 were within the EC range of acceptance for mature composts, which has been set at 2 dSm$^{-1}$ (Costa *et al.* 1995). The other compost (C9) had EC values that exceeded this range. The degree of decomposition of the lignocellulosic material of the composts (expressed as the percentage of particles <4 mm) was higher in C20 as compared to the C9 (Table 1). The addition of compost to the soil on each amended treatment plot increased EC as compared to the soil control (Table 2). Treatment C9-5 had an EC of 1.8 dSm$^{-1}$, C9-10 of 2.7 dSm$^{-1}$, while both C20-5 and C20-10 presented identical EC values (0.9 dSm$^{-1}$). The addition of compost slightly increased pH values on amended plots as compared to the control (Table 2.).

TABLE 2.
Electrical conductivity and pH of the soil amended with composts (C20 and C9) and that of the soil (S) used as a control.

| Treatment | EC (dSm$^{-1}$) | pH |
|---|---|---|
| C20-5 | 0.9 | 6.5 |
| C20-10 | 0.9 | 6.9 |
| C9-5 | 1.8 | 6.7 |
| C9-10 | 2.7 | 7.0 |
| S | 0.7 | 6.0 |

### *Plant Yield*

Plants grown in plots amended with either composts (C20 and C9) produced the first harvest of mature tomatoes, on average, 9 days before those produced in the controls (S). This represents 5% of the total weight or number at the end of the harvest period. At the end of this experiment, the total weight of tomatoes per plant was significantly higher (representing 35 and 65% more) for C9 and C20 than for that of the control. However, the doses applied did not show any significant differences within composts (Figure 1). The total weight of tomatoes per plant grown in compost C20 was also significantly higher than those grown in the compost C9 (Figure 1). With slight differences, the average number of tomatoes per plant and treatment showed a similar trend (Figure 2, left axis). The proportion of infected fruits was lower in compost amended plots although not significantly different than those of control plants (Figure 2, right axis). The average dry weight of aerial biomass per plant (excluding fruits) was significantly higher for those grown in compost plots as compared to controls, while no differences were found between composts (Figure 3).

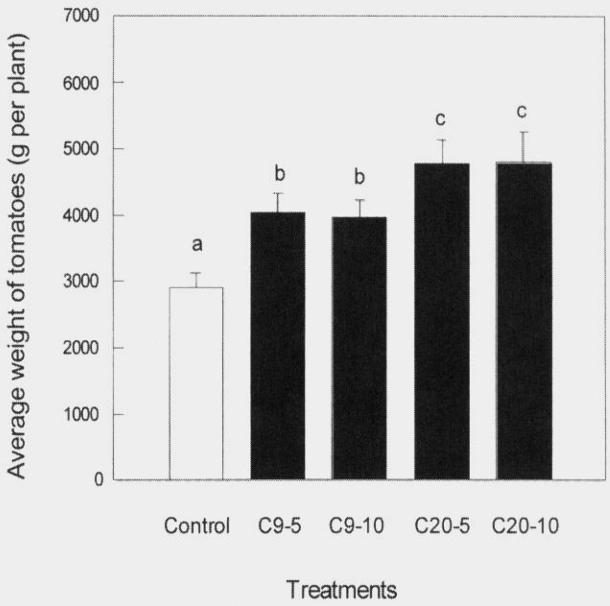


FIGURE 1: Average weight of tomatoes per plant at the end of the growing cycle for treatments and doses: 1) Control (S); 2) 5 kg m$^{-2}$ of compost C9 (C9-5); 3) 10 kg m$^{-2}$ of compost C9 (C9-10); 4) 5 kg m$^{-2}$ of compost C20 (C20-5); and 5) 10 kg m$^{-2}$ of compost C20 (C20-10). Vertical lines indicate the standard error; n=40. Different letters indicate significant differences at $P \leq 0.05$.

## *Discussion*

Seaweed compost enhanced the yield of tomato plants as evidenced by an increase in the weight of

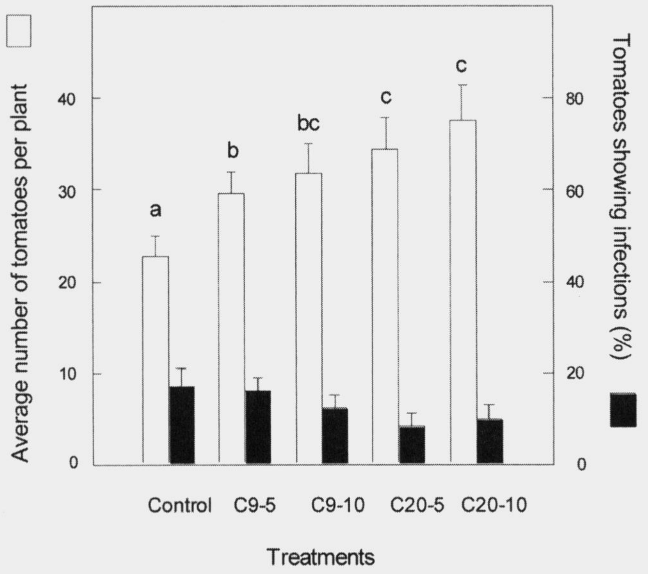


FIGURE 2: Average number of tomatoes per plant (left axis) and percent of tomatoes showing infections (right axis) for the different treatments and doses: 1) Control (S); 2) 5 kg $m^{-2}$ of compost C9 (C9-5); 3) 10 kg $m^{-2}$ of compost C9 (C9-10); 4) 5 kg $m^{-2}$ of compost C20 (C20-5); and 5) 10 kg $m^{-2}$ of compost C20 (C20-10). Vertical lines indicate the standard error; n=40. Different letters indicate significant differences at P $\leq$0.05.

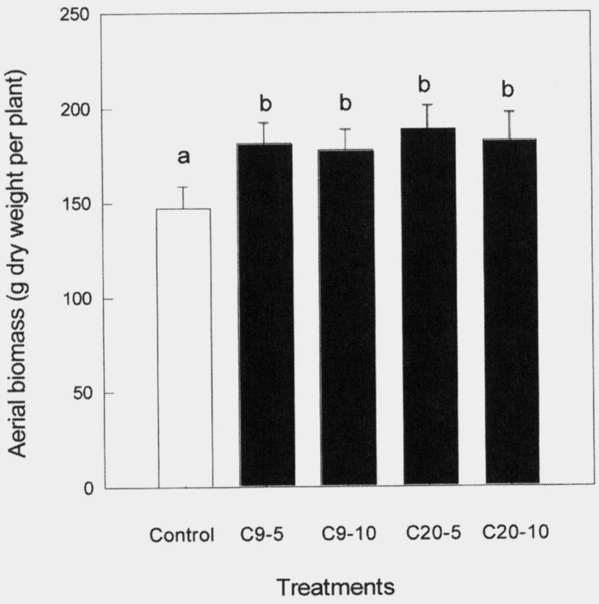


FIGURE 3: Average dry weight of tomato plants (excluding fruits) per treatment and doses: 1) Control (S); 2) 5 kg $m^{-2}$ of compost C9 (C9-5); 3) 10 kg $m^{-2}$ of compost C9 (C9-10); 4) 5 kg $m^{-2}$ of compost C20 (C20-5); and 5) 10 kg $m^{-2}$ of compost C20 (C20-10). Vertical lines indicate the standard error; n=40. Different letters indicate significant differences at P$\leq$0.05.

fruits per plant, in the number of fruits, and in aerial plant biomass (excluding fruits) as compared to the control. Also tomato fruits produced in plants grown in compost plots, showed lower pathogens infections than those produced by plants grown in the control soil.

The compounds or properties of seaweed composts that underlie their growth-promoting effects remain to be determined. Seaweed contains mineral elements and organics compounds that could improve the physical, chemical and biological soil properties, exert synergistic or allelopatic effects, and/or act as signals for the activation of stress-response and defense pathways in terrestrial plants. Although this level of complexity was not addressed in our study, some considerations could explain, in part, the results obtained.

Because we only measured particle size of the composts, these measurements were insufficient to draw conclusive remarks about its importance in the results obtained. Nevertheless, it should be considered that the soil used as a control had a considerable amount of clay in its composition (Laya 1981) and the addition of seaweed compost may have increased pore volume and aggregate stability, as shown in a related study in the area (Eyras 2002). The addition of seaweed compost can also increase soil microbial biomass and biological activity (Haslam and Hopkins 1996).

The pH values of our seaweed composts coincide with those presented by Vendrame and Klock-Moore (2005) and Orquín *et al.* (2001) and were above soil value. López- Mosquera and Pazos (1997) have indicated that seaweed application to a soil had effects similar to those of liming, i.e. increased pH, increased exchangeable Ca, and reduced exchangeable Al. Another study emphasized that in a soil amended with seaweed, an increase in the content of exchangeable cations and an effective cationic exchange capacity were the responsible for the higher yields of *Hordeum vulgare* L. (Montero Vilariño *et al.* 1999). In our experiment, the addition of compost slightly increased pH values on amended plots as compared to the control (see Table 2), so it is probable that this could have increased nutrient availability (mainly P) and this, in turn, enhanced the yield observed in compost treated plants as compared to controls.

This could be corroborated by the analyses that revealed that phosphorous showed higher content values in both composts as compared to the soil used as a control (Table 1). Our results coincide with the ranges in P content presented by Orquín *et al.* (2001). In another study, when seaweed was added to soil, the availability of P increased and this effect was attributed to the alginic acid content of the seaweed used. This acid may sequester cations (i.e. Al and Fe) that precipitate phosphates, increasing the availability of P (López-Mosquera and Pazos 1997). In relation to nitrogen, compost values were similar to that of the control treatment. It is interesting to note that when the composting method used static piles turned mechanically (such as in our case), large quantities of this element are lost by different processes (de Bertoldi *et al.* 1982). When the composting method uses forced ventilation, instead, more nitrogen is kept in the resulting compost (Vallini *et al.* 1993; Cuomo *et al.* 1995; Eyras 2002). In the case of the interchangeable K, the soil used as a control and the C20 compost treatment had relatively higher values than the compost C9. This suggests that neither of the composts provided an additional source of K to the soil amended. However, López-Mosquera and Pazos (1997) suggest that the K present in seaweed is in a readily available form, and this could explain the higher yields of plants grown in compost C20 as compared to those grown in compost C9.

Some studies have suggested that the increase in yield of some crops could be due to the organic compounds found in seaweed rather than to mineral elements (Crouch and van Staden 1993). It has been proposed that seaweeds and seaweed products have growth regulatory substances and other organic compounds with phyto-active properties which may enhance productivity, conferring the plants treated some resistance to several environmental stresses (Zhang and Schmidt 2000; Zhang *et al.* 2003) and also to infections and insect attack (Abetz 1980; Blunden 1991). Related to this, our results suggest that plants grown in compost plots appear to have higher tolerance to infection of tomato fruits than the controls. In this sense, these results could then be considered as another contribution to the numerous reports published about disease suppression by composts produced from other organic materials (Hoitink *et al.* 1996). However, our results should be carefully analyzed, and more specific experiments would be necessary to determine the compounds and mechanisms that operate to produce this perceptible beneficial effect. This warning is presented given the fact that there are other studies, however, that contradict the results presented above (Tourte *et al.* 2000; Edmeades 2002).

Salt content of C9 (15 dS $m^{-1}$), was above the accepted standard for mature composts (2 dS $m^{-1}$, Costa *et al.* 1995). Although the mixture of 5 and 10 kg $m^{-2}$ of this compost with the soil reduced the total salinity of these plots to 1.8 dS $m^{-1}$ and 2.7 dS $m^{-1}$, respectively, these values are close to the threshold in salinity tolerance established for tomato plants (2.5 dS $m^{-1}$, Hoffman 1981). This salinity could have been responsible for its lower yield as compared to C20. Nevertheless, C9 produced significantly higher tomato yield than the control. It is suggested that EC of seaweed composts should be carefully controlled and monitored if this amendment is going to be applied often. To lower salinity content, more irrigation would then be required during composting. It is interesting to note that in another study, tomato plants have been shown to increase their resistance to osmotic stress when they were cultivated in pots containing a similarly prepared, but pure, seaweed compost (Eyras 2002).

Finally, the evaluation of differences between composts doses suggest that a compost aged 20 months (C20) at doses of about 50 ton $ha^{-1}$ added to a soil similar to the one studied, would be enough to increase productivity of tomato by about 66% above the control. This value is well above the maximum (38%) reported by Maynard (1993) for tomato plants cultivated in soils amended with 123 ton $ha^{-1}$ of compost prepared from municipal organic waste residues.

The addition of seaweed compost as an organic amendment to a horticultural soil of the Lower Chubut Valley, in Gaiman, Patagonia, Argentina, has shown an increase in yield and resistance to diseases on tomato plants. The recycling of seaweed in composts has been proven to be an environmentally sound alternative to reduce pollution in the beaches of Puerto Madryn. The utilization of this renewable resource for horticultural purposes could also be beneficial for the whole community, since it could help reduce the use of chemical fertilizers and pesticides that may be hazardous for human health.

## Acknowledgments

This study was financed, in part, by a grant given by the Ministries of Education of Argentina and of the Province of Buenos Aires (Grant SUR-AF-6009). Authors would like to acknowledge Mario Rostagno, Jorge Eyras, María del Carmen Dentoni, José Saravia and Soledad Megias for their help in field and laboratory work.

## References

Abetz, P. 1980. Seaweed extracts: Have they a place in Australian Agriculture or Horticulture?. *Journal of Australian Institute of Agricultural Science*, 46:23-29.

Blunden, G. 1991. Agricultural uses of seaweed and seaweed extracts. Pp 65-81. In: M.D. Guiry and G. Blunden (eds.) *Seaweed Resources in Europe: Uses and Potential.* John Wiley & Sons Ltd. Chichester, UK.

Bremner J.M. and C. S. Mulvaney. 1982. Nitrogen-total. Pp 595-624. In: A. Page, R. H. Miller, and D. Keeney (eds.). *Methods of Soil Analyses.* Series Agronomy 9 ASA-SSSA Madison, Wisconsin, USA.

Costa, F., C. García, T. Hernández and A. Polo. 1995. *Residuos Orgánicos Urbanos. Manejo y Utilización.* Consejo Superior de Investigaciones Científicas. Centro de Edafología y Biología Aplicada del Segura, Murcia, España.

Crouch, I.J. and J. van Staden. 1993. Evidence for the presence of plant growth regulators in commercial seaweed products. *Plant Growth Regul.*, 13:21-29.

Cuomo, V., A. Perretti, I. Palomba, A. Verde and A. Cuomo. 1995. Utilisation of *Ulva rigida* biomass in the Venice Lagoon (Italy): biotransformation in compost. *J. Appl. Phycol.*, 7:479-485.

de Bertoldi, M., G. Vallini, A. Pera, and F. Zucconi. 1982. Comparison of three windrow compost systems. *BioCycle*, 23:45-49.

Edmeades, D.C. 2002. The effects of liquid fertilizers derived from natural products on crop, pasture and animal production: A Review. *Austr. J. Agric. Res.*, 53:965-976.

Eyras, M.C., C.M. Rostagno, and G.E. Defossé. 1998. Biological evaluation of seaweed composting. *Compost Sci. Util.*, 6: 74-81.

Eyras, M.C. 2002. *Tratamiento agroecológico de las algas marinas de arribazón en Puerto Madryn, Chubut*. Tesis Doctoral. Facultad de Ciencias Naturales. Universidad Nacional de La Plata, La Plata, Argentina.

Haslam, S.F.I. and D.W. Hopkins. 1996. Physical and biological effects of kelp (seaweed) added to soil. *Appl. Soil Ecol.*, 3:257-261

Hoffman, G.J. 1981. Alleviating salinity stress. Pp 305-341. In: Arkin G.F. and Taylor H.M. (eds.). *Modifying the Root Environment to Reduce Crop Stress*. American Society of Agricultural Engineers, Michigan.

Hoitink, H.A.J., A.G. Stone, and M.E. Grebus 1996. Suppression of plant diseases by composts. Pp 373-381. In: de Bertoldi M., M. Sequi, B. Lemmes and T. Papi (eds.) *The science of composting*. Chapman & Hall, England.

Klock-Moore, K.A. 2000. Comparison of *Salvia* growth in seaweed compost and biosolids compost. *Compost Sci. Util.*, 8:24-28

Laya, H. 1981. Levantamiento semi-detallado de suelos del Valle Inferior del Río Chubut. Convenio CFI-Provincia del Chubut, Argentina.

López-Mosquera, M.E. and P. Pazos. 1997. Effects of seaweed on potato yield and soil chemistry. *Biol. Agric. Hortic.* 14:199-206

Maynard, A.A. 1993. Evaluating the suitability of MSW compost as a soil amendment in field-grown tomatoes. *Compost Sci. Util.*, 1:34-36

Mazé, J., P. Morand, and P. Potoky 1993. Stabilisation of "green tides" *Ulva* by a method of composting with a view to pollution limitation. *J. Appl. Phycol.*, 5:183-190

Montero Vilariño, M.J., P. Marcet Miramontes, M.L. Andrade Couce, and J. Estevez Sio. 1999. Influencia de la adición de diversas especies de algas sobre algunas propiedades químicas de un suelo ácido y el crecimiento de *Hordeum vulgare* L. *Ciencia del Suelo*, 17:28-38

Morand, P. and X. Briand. 1996. Excessive growth of macroalgae: a symptom of environmental disturbance. *Bot. Mar.*, 39:491-516

Nelson, D.W., and L.E. Sommers. 1982. Total carbon, organic carbon, and organic matter. Pp 539-579. In: Page A., R.H. Miller and D. Keeney (eds.). *Methods of Soil Analysis*. Series Agronomy 9. ASA-SSSA, Madison, Wisconsin, USA.

Norusis, M. 1993. *SPSS for Windows: Base System's User Guide*. SPSS Inc. Chicago, USA.

Olsen, S.R., and L.E. Sommers 1982. Phosphorus. Pp 403-430. In: Page A., R.H. Miller and D. Keeney (eds.). *Methods of Soil Analysis*. Series Agronomy 9 ASA-SSSA Madison, Wisconsin, USA.

Orquín, R., M. Abad, P. Noguera, R. Puchades, and A. Maquieira. 2001. Composting of Mediterranean seagrass and seaweed residues with yard waste for horticultural purposes. *Acta Hort.*, 549:29-36.

Piriz, M.L., M.C. Eyras, and C.M. Rostagno 2003. Changes in biomass and botanical composition of beach-cast seaweeds in a disturbed coastal area from Argentine Patagonia. *J. Appl. Phycol.*, 15:67-74.

Tourte, L., R.L. Bugg, and C. Shennan. 2000. Foliar-applied seaweed and fish powder do not improve yield and fruit quality of organically grown processing tomatoes. *Biol. Agric. Hortic.*, 18:15-27

Vallini, G., A. Pera, F. Cecchi, M.M. Valdrighi, and M.A. Sicurani. 1993. Compost stabilization of algal biomass drawn in eutrophic lagoon ecosystems. *Compost Sci. Util.*, 1:49-53.

Vendrame, W. and K. Klock-Moore. 2005. Comparison of herbaceous perennial plant growth in seaweed compost and biosolids compost. *Compost Sci. Util.*, 13:122-126.

Zhang, X. and R.E. Schmidt. 2000. Hormone-containing products impact on antioxidant status of tall fescue and creeping bentgrass subjected to drought. *Crop. Sci.*, 40:1344-1349.

Zhang, X., E.H. Ervin, and R.E. Schmidt. 2003. Plant growth regulators can enhance the recovery of Kentucky bluegrass sod from heat injury. *Crop Sci.*, 43:952-956.