

The effects of drench and foliar application of a commercial seaweed extract on the leaf nutrient content of potato, *Solanum tuberosum* 'BP1'

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Abstract

A field experiment was conducted to quantify the effects of a commercial seaweed extract (Afrikelp® LG-1) on the leaf nutrient content of the potato plant, *Solanum tuberosum* 'BP1' under soil drench and foliar application over two growing seasons, namely 2010 and 2011. Field experiments were conducted at the Agricultural Research Council (ARC) Nietvoorbij site (33°54'S; 18°14'E) in Stellenbosch, South Africa during the late autumn for both years. The experimental design followed a randomized complete block design in a factorial arrangement of one control, seven treatments (0, 2, 3, 4, 5, 6, 7 L ha⁻¹) and two application methods (drench and foliar), replicated four times. At 60 days after planting (DAP), *S. tuberosum* 'BP1', leaves were sampled for nutrient analysis. The results for the 2010 and 2011 seasons showed that there was no difference in the leaf nutrient content due to the method of application. N, P, K, Ca, Mg, Na, Mn, Cu, Zn and B increased with treatment concentrations, with minor exceptions (Cu in 2010 and Fe in 2011).

Keywords: commercial seaweed extracts, leaf nutrient content, potatoes, *Solanum tuberosum* 'BP1', drench and foliar application

INTRODUCTION

The primary focus of this study was to quantify the effects of various concentrations of the seaweed extract Afrikelp® LG-1 on the leaf nutrient content of the potato plant, *Solanum tuberosum* 'BP1'. It is envisaged that enhanced nutrient content in the potato leaves, would induce improved tuber yield. This study compared the effects of the method of seaweed extract application (drench and foliar), on the leaf nutrient content. Seaweed concentrates are known to cause many beneficial effects on plants as they contain growth promoting hormones (IAA and IBA, cytokinins), trace elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni), vitamins and amino acids (Challen and Hemingway, 1965). A previously conducted study highlighted the influence of higher leaf nutrient contents and how this is ultimately represented in the quality of the potato tuber (Torres et al., 2004). It mentions the high level of nitrogen in the tuber, and this being one of the most important macronutrients, required by the plant that influences the productivity of the plant and tuber quality. The uptake of mineral elements by plant roots, and their distribution in the leaves, has a direct impact on growth, quality and yield (Marschner, 1995; Watanabe et al., 2007; Karley and White, 2009; Miller et al., 2009; Miwa et al., 2009; Puig and Peñarrubia, 2009; Baxter, 2009; Chen et al., 2009; White and Broadley, 2009; Broadley et al., 2010).

MATERIALS AND METHODS

The seaweed extract used in the trials was a commercial seaweed product, marketed as Afrikelp® LG-1, and produced in South Africa. This product was produced from marine algae, *Ecklonia maxima* (Osbeck) Papenfuss, and prepared via cool fragmentation technology. *S. tuberosum*, certified 'BP1' tubers were selected for planting. The field experiment was

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conducted at the Agricultural Research Council (ARC) Nietvoorbij site (33°54'S; 18°14'E) in Stellenbosch, South Africa during 2010 and 2011, in late autumn of both years. The soil type of the site was sandy loam. The soil was ploughed to a depth of 40 cm prior to planting. The experimental design followed a randomized complete block in a factorial arrangement of seven treatments (0, 2, 3, 4, 5, 6, 7 L ha⁻¹) and two application methods (drench and foliar) of liquid seaweed were applied and replicated four times. Water was applied as a control treatment.

At 60 days after planting (DAP), *S. tuberosum* 'BP1', leaves were sampled for nutrient analysis. The leaves were oven-dried at 60°C for 48 h, weighed and ground into a fine powder (0.85 mm sieve) for the analysis of leaf nutrient content. Concentration of nutrients (N, P, K, Ca, Mg, Na, Mn, Fe, Cu, Zn and B) were determined by dry ashing 1 g ground sample in a porcelain crucible at 500°C overnight. This was followed by dissolving the ash in 5 mL of 6 M HCl and placing it in an oven at 50°C for 30 min; 35 mL of deionised water was added and extract was filtered through Whatman no. 1 filter paper. Nutrient concentrations in plant extracts were determined using an inductively-coupled plasma (ICP) emission spectrophotometer (IRIS/AP HR DUO Thermo Electron Corporation, Franklin, Massachusetts, USA), and results were given in mg kg⁻¹ (Giron, 1973). The experimental data were analyzed using the STATISTICA Software (StatSoft Inc., 2013) and Two-Factor analysis of variance (ANOVA) was performed. The Fisher's least significant difference (LSD) was used to compare treatment means at $P \leq 0.05$ level of significance (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The leaf nutrient concentrations (mg kg⁻¹) of the various elements in the potato leaves are given in Tables 1 and 2 for the years 2010 and 2011, respectively. The results illustrated for each leaf nutrient content are comparative with the controls. For both years the method of application (drench and foliar) had no significant effect on the concentration of elements in the leaves.

Nitrogen for the 2010 and 2011 seasons, the application rates of 5 L ha⁻¹ and above resulted in a significant increase. The higher concentration of 7 L ha⁻¹ represented a total mean increase of 84 and 85% for leaf nitrogen content. Phosphorus for 2010 and 2011 application rates of 7 L ha⁻¹ resulted in a significant increase of leaf phosphorus, which was 67% for 2010 and 50% for 2011, respectively. Potassium for the 2010 and 2011 seasons, at seaweed concentration of 7 L ha⁻¹, the results show that the seaweed had a significant effect on the leaf potassium content, which represented a total mean increase of leaf potassium of 72 and 76%. Calcium for the years 2010 and 2011, at seaweed concentration of 7 L ha⁻¹, the calcium content significantly increased, which represented a total mean increase of leaf calcium content of 64 and 65%, respectively. Magnesium for 2010 and 2011, at seaweed concentrations of 6 and 7 L ha⁻¹, respectively, leaf magnesium content was significantly increased, which represented a total mean increase of 64 and 65% for both years. Sodium for 2010 and 2011, the highest seaweed extract concentration levels of 7 L ha⁻¹ had significantly increased leaf sodium content by 63 and 70%, respectively. Manganese for 2010 and 2011, the highest seaweed concentrations of 7 L ha⁻¹ had significantly increased leaf manganese content respectively, which was a total mean increase of 55 and 62%. Iron for 2010 and 2011, the highest concentration of 7 L ha⁻¹ significantly increased leaf iron content, which was a total mean increase of leaf iron content of 61 and 62%, respectively. Copper for 2010, the results showed that no seaweed concentration had significantly affected the leaf copper content when compared with the experimental control. For 2011 this was not the situation. The concentration of 4 L ha⁻¹ and above significantly increased the leaf copper content by 61% over the control. For 2011, methods of application and the concentration levels of seaweed had significant interactions on leaf copper content in the potato leaves. Zinc for 2010 and 2011, the highest concentration 7 L ha⁻¹ had significant effects respectively on leaf zinc content, which was a total mean increase of 72 and 80%. Boron for 2010 and 2011, the highest concentration of 7 L ha⁻¹ had significant effects on leaf boron content, which had a total mean increase of leaf boron content of 64 and 69%.

Table 1. The effects of drench and foliar application of a commercial seaweed extract on the leaf nutrient content of *S. tuberosum* 'BP1' for 2010 and 2011 growth seasons.

	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Zinc (Zn)	Boron (B)	Sodium (Na)
2010 season											
Drench*	0.62±0.03a	0.03±0.002a	0.99±0.06a	0.74±0.04a	0.18±0.01a	17.90±1.14a	70.53±4.40a	4.86±0.30a	4.59±0.28a	1.44±0.07a	53.36±3.38a
Foliar*	0.56±0.04a	0.03±0.002a	0.94±0.06a	0.71±0.05a	0.17±0.01a	17.96±1.38a	76.51±7.39a	6.03±0.52a	4.72±0.34a	1.40±0.09a	52.79±4.04a
0	0.44±0.04d	0.03±0.03cd	0.75±0.08c	0.56±0.06c	0.13±0.01c	15.18±2.35bc	58.84±8.50b	4.72±1.15ab	3.64±0.42cd	1.09±0.11c	40.79±4.78bc
2	0.47±0.04cd	0.03±0.002d	0.74±0.08c	0.56±0.06c	0.13±0.02bc	11.93±1.53c	68.51±6.99ab	3.65±0.48b	3.05±0.39d	1.07±0.12c	37.44±4.53c
3	0.51±0.04cd	0.03±0.002bcd	0.89±0.10c	0.67±0.07bc	0.16±0.02bc	18.01±2.13abc	75.85±12.98ab	5.66±0.80ab	4.49±0.47bc	1.27±0.10bc	48.37±6.50abc
4	0.55±0.05cd	0.03±0.002bcd	0.93±0.08bc	0.77±0.07ab	0.18±0.02ab	20.68±2.45ab	66.02±10.22ab	5.68±0.74ab	5.39±0.54ab	1.52±0.12ab	56.88±5.21ab
5	0.62±0.06bc	0.04±0.004abc	0.99±0.09bc	0.74±0.05abc	0.19±0.02ab	18.60±2.14ab	67.26±8.07ab	5.98±0.56a	4.88±0.49abc	1.57±0.09ab	56.25±3.99ab
6	0.73±0.04ab	0.04±0.003ab	1.17±0.08ab	0.88±0.07a	0.22±0.02a	17.53±1.19abc	83.47±11.91ab	5.82±0.61ab	4.86±0.31bc	1.66±0.12a	65.37±5.26a
7	0.81±0.10a	0.05±0.005a	1.29±0.13a	0.92±0.10a	0.21±0.02a	23.59±2.63a	94.67±16.74a	6.61±0.97a	6.26±0.64a	1.79±0.18a	66.41±10.40a
2011 season											
Drench*	0.83±0.06a	0.05±0.003a	1.41±0.09a	0.93±0.06a	0.21±0.02a	20.7±1.41a	147.7±11.35a	6.9±0.55a	7.0±0.47a	2.16±0.14a	95.5±7.07a
Foliar*	0.75±0.06a	0.04±0.003a	1.29±0.10a	0.88±0.07a	0.21±0.02a	20.0±1.66a	162.4±17.01a	7.4±0.54a	6.8±0.56a	2.10±0.13a	94.4±7.63a
0	0.59±0.05c	0.04±0.004c	1.01±0.10c	0.69±0.08c	0.16±0.02cd	15.9±1.61c	119.5±15.60a	4.9±0.58c	5.1±0.55d	1.6±0.20b	71.8±12.50c
2	0.63±0.08c	0.04±0.005c	1.05±0.14bc	0.73±0.09bc	0.15±0.02d	14.4±1.91c	181.9±35.85a	5.6±0.74bc	4.8±0.71d	1.7±0.16b	74.3±6.57bc
3	0.65±0.05c	0.004±0.002c	1.11±0.08bc	0.74±0.07bc	0.18±0.02bcd	18.8±1.56abc	150.7±26.19a	6.9±0.98abc	6.0±0.47cd	1.8±0.13b	72.2±7.62c
4	0.82±0.05bc	0.05±0.004abc	1.47±0.12ab	1.10±0.09a	0.26±0.02ab	25.5±1.93a	145.3±12.72a	7.9±0.57ab	8.6±0.54ab	2.5±0.18a	122.3±14.40a
5	0.94±0.11ab	0.06±0.006ab	1.58±0.15a	1.03±0.12ab	0.24±0.03abc	24.5±3.03ab	155.9±30.14a	9.0±1.10a	8.1±0.86abc	2.5±0.20a	108.8±9.85ab
6	0.82±0.11abc	0.04±0.005bc	1.42±0.21abc	0.92±0.14abc	0.20±0.03abcd	17.9±2.67bc	138.1±15.47a	7.0±1.20abc	6.5±0.91bcd	2.1±0.26ab	97.5±15.20abc
7	1.09±0.16a	0.06±0.008a	1.78±0.24a	1.14±0.15a	0.27±0.04a	25.7±4.00a	193.8±40.21a	8.7±1.17a	9.2±1.34a	2.7±0.33a	117.5±15.75a

*Afrikelp® concentration (L ha⁻¹), Drench and foliar applications combined. Values presented are means±SE. SE=Standard Error. Means followed by similar letter(s) in a column are not significant different.

Table 2. Two-way ANOVA (F- statistics) for the effects of application methods of a commercial seaweed extract on the leaf nutrient content of *S. tuberosum* 'BP1' for 2010 and 2011 growth seasons.

Variables ^a	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Zinc (Zn)	Boron (B)
2010 season											
MA	1.69NS	0.25NS	0.64NS	0.36NS	0.01NS	0.01NS	0.001NS	0.45NS	3.73NS	0.11NS	0.18NS
C	5.95***	3.96**	4.66**	4.01**	3.99**	3.15*	2.98*	1.08*	1.46NS	4.74***	5.25***
MA×C	1.09NS	0.59NS	0.62NS	0.74NS	1.03NS	0.57NS	0.77NS	0.39NS	0.28NS	0.76NS	0.98NS
2011 season											
MA	1.7NS	1.8NS	1NS	0.3NS	0.04NS	0.01NS	0.11NS	0.5NS	0.62NS	0.13NS	0.1NS
C	4.3***	4.3***	3.4***	3**	2.8**	3.2**	3.3***	0.9NS	3.01**	4.06***	4.1***
MA×C	0.6NS	1.2NS	1.1NS	1.4NS	0.8NS	1NS	0.6NS	0.9NS	2.4**	0.53NS	1.54NS

^aMA=Method of application, C=Concentration, MA×C=Method of application×Concentration interactions, *, **, ***=significant at P≤0.05, P≤0.01, P≤0.001 respectively, NS=not significant.

The results of the current study (Tables 1 and 2) are comparable with the results of previous studies, where various marine algae in the form of commercial seaweed extracts, all resulted in increased leaf nutrient content in the plant. The positive effects were described to seaweeds containing various mineral elements and growth hormones. In the current study, for both 2010 and 2011 seasons, the seaweed extracts promoted improved leaf nutrient content of N, P, K, Ca, Mg, Na, Mn, Fe, Cu, Zn and B over the control. Macronutrients in the potato leaf such as nitrogen (N) content increased by 84% for both 2010 and 2011 growing seasons. Leaf phosphorus (P) content increased by 67 and 50%, respectively, and likewise, leaf potassium (K) content increased by 72 and 76%. Seaweed extracts contain various micro elements (Cu, Zn, Mo, B, Co) and when sprayed on plants lead to increase root growth ability, leaf nutrient concentration, stem thickness and larger yields (Jensen, 2004). A study conducted explained the relationship between leaf nutrient content and seaweed, and it outlined the usefulness of seaweed and its effects on plant nutrient uptake, leaf nutrient concentrations and the positive impacts on total yield of crops (Crouch et al., 1990). The usefulness of liquid seaweed Kelpak 66 was evaluated and applied to lettuce crops. Hormones from seaweeds had a stimulatory effect on the plant, and resulted in increased leaf nutrient content and proliferated growth of plant organs. The prime physiological responses of cytokinins are nutrient mobilization in various plant organs (Miller, 1963; Pozsár et al., 1967). The application of seaweed concentrate has shown to increase leaf chlorophyll content, root and leaf surface area of treated plants (Featonby-Smith and Van Staden, 1983). Few soils can sustain satisfactory crop production without the addition of nitrogen (N), phosphorus (P) and potassium (K) (Brady and Weil, 1996). The results of the present study showed that leaf nutrient contents were significantly increased by the highest seaweed concentration for both growth seasons. N, P and K are known to have a role in several vital functions in the plant, such as chlorophyll production, root and shoot growth, and increase leaf uptake and facilitate for higher yields (Okada et al., 2004). A low presence of important nutrients in the soil will have a retarding effect on the plant, and thereby reduce leaf nutrient content and reduce plant productivity, eventually limiting the yield (Brady and Weil, 1996). Reduction in these nutrients will slow root development, which will negatively impact on uptake and mobility of other essential plant nutrients in the plant, and consequently restrict the overall movement of nutrients in the entire plant, reducing total yield (Zafar et al., 2011). Nitrogen (N) has a profound effect on crop development and a major influence on chlorophyll content (Brady and Weil, 1996). In the current study the application of liquid seaweed Afrikelp® LG-1 has increased leaf N by 84% for both 2010 and 2011 over the control.

A field trial was conducted to investigate the effect of foliar application of seaweed extract "Primo" as an organic bio-stimulant on potato *S. tuberosum* 'Sante'. The results illustrated an improvement in growth, yield and tuber quality of potato plants (Haider et al., 2012). Potassium (K) is an essential nutrient for plant growth and forms part of many crop production systems. Large amounts of K are required to maintain plant health and vigour (Brady and Weil, 1996). Potassium plays a vital role in photosynthetic translocation, especially in grains, tubers, and fruit (Mikkelsen, 2007). In the current study, liquid seaweed Afrikelp® LG-1 promoted leaf potassium content by 72 and 76% for 2010 and 2011, respectively. In the plant, protein synthesis and nutrient mobility to the leaves are facilitated by an adequate supply of potassium (Mikkelsen, 2007; Miwa and Fujiwara, 2010). The consequences of inadequate K for crop growth will result in the inefficient utilization of other nutrients such as N and P (Mikkelsen, 2007). In the current investigation the results indicated that leaf content of K levels were significantly influenced by the higher concentrations of seaweed extracts for both growing seasons. In this study a high concentration of leaf K therefore positively affected the plants utilization and subsequently the leaf concentration of essential nutrients.

In a study conducted, the connection between higher nutrient contents and potato tuber quality with reference to potassium, nitrogen and phosphorous was illustrated. It found that potassium had a positive correlation with storage life of potato tubers. Potassium contents were found to increase in the tubers where seaweed extracts were applied. Potassium had a stimulatory effect on flower formation and ultimately tuber formation in the soil. An increase

in nitrogen contents was observed in potato tubers treated with seaweed extract. Phosphorus contents in the tuber had a stimulatory effect on root mass in the potato plant, thereby increasing nutrient uptake, and developed consistent tuber formation and improved tuber yield (Whangchai et al., 2001). The accumulation of K, P, Ca, and Na in various plant tissue, and the presence of these minerals, assists with the mobilization of nutrients to various plant tissues and organs (Martin et al., 2001; Conn and Gilliam, 2010). In the current study leaf calcium (Ca) content increased by 64 and 65% over the control. Similarly, leaf sodium (Na) content increased by 63 and 70% over the control. In our study this may have assisted in mobilization of nutrients (N, P, K, Mn, Fe, Cu, Zn and B) in the leaves and resulted in an accumulative presence in the potato plant tissues, such as the leaves and possibly the tubers.

CONCLUSIONS

The findings of this study indicated that liquid seaweed extract Afrikelp® LG-1, improved leaf nutrient concentration (N, P, K, Ca, Mg, Na, Mn, Fe, Cu, Zn, and B) of *S. tuberosum* 'BP1'. The results showed that treatments applied by means of drench and foliar both had high results and are therefore considered to be equally effective methods of application. It can be noted that significant increase of leaf nutrient concentrations had no evidence of leaf damage or nutrient concentrations toxicity due to substantial increase in macro- and micro-nutrients in the leaves. The organic make-up of this product will help maintain the required nutrient balance needed for the plant, and in so doing avoid any harmful effects on the plant and the environment, as may be the case with synthetic, inorganic, industrial fertilizers. Further investigations will reveal whether the increase in various leaf nutrient contents due to Afrikelp® LG-1 were linked to an increase in leaf chlorophyll content, growth and total tuber yield.

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