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Seaweed extract provides development and production of wheat

Extrato de alga promove desenvolvimento e produção de trigo

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Abstract. Agricultural crop performance can be improved with use of seaweed extracts. The aim of this study was to evaluate the effects of *Ascophyllum nodosum* extract on biometric, biochemical and yield parameters of the wheat. The experimental design was completely randomized with 3 treatments [control (water), seed treatment (0.1 mL of the *A. nodosum* extract on the 100 g of seeds) and soil irrigation (5 mL L^{-1} of seaweed extract, which was applied at 14th, 28th and 42nd days after sowing)] and 10 replications. Plants irrigated with *A. nodosum* extract showed increments in the height, dry mass of shoots and number of spikes (10.72%, 22.22% and 13.19%, respectively), however these plants had the lowest harvest index (reduction of 17.12%), when compared to the control. Seed treatment also increased plant height, but it did not change biochemical and productivity parameters. It is concluded that soil irrigation with 5 mL L^{-1} of *A. nodosum* extract provides development and positively affects production of 'IAC 364' wheat.

Keywords. *Ascophyllum nodosum*, Biostimulants, *Triticum aestivum*, Yield components

Resumo. O desempenho das culturas agrícolas pode ser melhorado com a utilização de extratos de algas. O objetivo deste estudo foi avaliar os efeitos do extrato de *Ascophyllum nodosum* sobre parâmetros biométricos, bioquímicos e de produção do trigo. O delineamento experimental foi inteiramente casualizado com três tratamentos [controle (água), tratamento de sementes (0,1 mL do extrato de *A. nodosum* em 100 g de sementes) e irrigação (5 mL L^{-1} do extrato de alga, que foi aplicado no 14º, 28º e 42º dias após a semeadura)] e 10 repetições. Plantas irrigadas com o extrato de *A. nodosum* apresentaram incrementos na altura, massa seca da parte aérea e número de espigas (10,72%, 22,22% e 13,19%, respectivamente); entretanto, este mesmo tratamento apresentou o menor índice de colheita (redução de 17,12%) quando comparado ao controle. O tratamento de sementes também aumentou a altura das plantas, mas não alterou os parâmetros bioquímicos e de produção. Conclui-se que a irrigação com 5 mL L^{-1} do extrato de *A. nodosum* promove o desenvolvimento e afeta positivamente a produção do trigo 'IAC 364'.

Palavras-chave. *Ascophyllum nodosum*, Bioestimulantes, *Triticum aestivum*, Componentes de produção

Wheat (*Triticum aestivum* L.) is a worldwide widespread crop by its innumerous industrialized derivatives. In order to improve the performance of agricultural crops, the use of seaweed extracts has grown, mainly because it is an environmentally friendly alternative to the use of fertilizers and plant bioregulators (Craigie, 2011; Khan et al., 2009; Khan et al., 2012; Kumar & Sahoo, 2011). *Ascophyllum nodosum* (L.) Le Jol. extract contains several compounds which are capable of stimulating plant growth, such as cytokinins, auxins, gibberellins, and alginates (Khan et al., 2009; Rayorath et al., 2008a). The improvement of seed germination and plant establishment, as well as an increase in crop productivity have been reported in some studies (Carvalho et al., 2013; Craigie, 2011; Igna & Marchioro, 2010; Kumar & Sahoo, 2011). However, plant response to *A. nodosum* extract is highly varied (Craigie, 2011). The aim of this research was to evaluate the effects of *A. nodosum* extract on biometric, biochemical and yield parameters of *Triticum aestivum* cv. IAC 364.

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The experiment was carried out in a greenhouse without a humidity and temperature control, in Piracicaba, southeastern of Brazil (22º 42' S, longitude 47º 38' W), from June to November 2011. Wheat (*Triticum aestivum* cv. IAC 364) seeds were sowed in 20 dm^3 plastic pots, filled with clay, sand and manure in ratio of 2:2:1 (v:v:v), respectively. Three plants remained in each pot.

The treatments were i) control (water), ii) 0.1 mL of the commercial *A. nodosum* extract (Acadian® Marine Plant Extract) on 100 g of seeds, and iii) soil irrigation with 5 mL L^{-1} of same extract, which was applied at 14th, 28th and 42nd days after sowing (DAS).

Plant height (cm) was assessed weekly from 30th to 51st DAS; it was obtained using arithmetic mean of values found in 3 plants that made up each pot. Assessments of chlorophyll *a* and *b*, and carotenoid contents were based on methodology modified from Lee, Brammeier and Smith (1987) and Moran (1982), 64 DAS. Determination of nitrate reductase activity was performed according to *in vivo* assay modified by Radin (1974).

At end of biological cycle, spikes were harvested to determine the number and dry mass of spikes and grains. Dry mass of 100 grains and shoots (only leaves and stems) were also determined; furthermore, the harvest index [dry mass of grains/ (dry mass of shoots + dry mass of spikes)] was calculated.

Data were subjected to analysis of variance (ANOVA) at 10% significance level, through SAS® statistical software (SAS Institute, 2011). Data regarding harvest index and dry mass of grains and spikes were transformed to x^2, and number of spikes to log10 (x), in order to be according to statistical assumptions for ANOVA performance. After analysis, data were converted back to original scale, to facilitate comparison of results among treatments. The t test ($\alpha \leq 5\%$) was used to compare means among treatments.

A. nodosum extract had significant effects on biometric, biochemical and productivity parameters of wheat. Plants irrigated with *A. nodosum* extract were higher than the control, regardless of the evaluation period (up to 10.72%), as shown in Figure 1A-D.

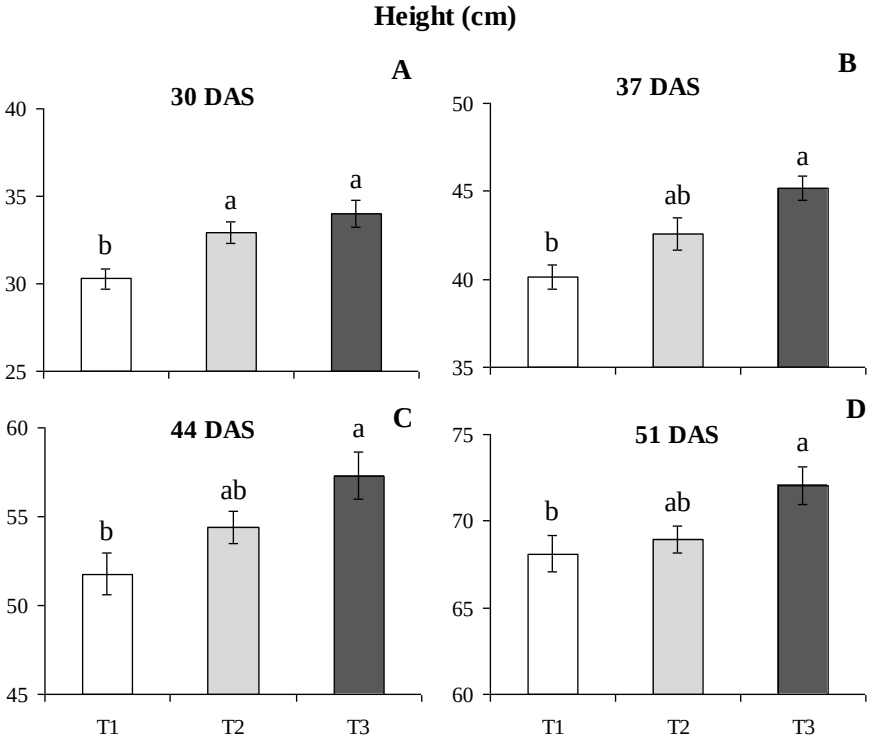

Figure 1. Effects of *A. nodosum* extract, when applied on seeds or soil irrigation, on height of wheat (*Triticum aestivum* cv. IAC 364). DAS: days after sowing. T1 - Control (water), T2 - 0.1 mL of seaweed extract on seeds and T3 - soil irrigation with 5 mL L^{-1} of seaweed extract. Means followed by distinct letters differ by t test ($\alpha \leq 5\%$). Bars express standard errors.

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Shoot height of 'Pusa Gold' wheat plants also increased (6.7% when compared to the control) after application of *Sargassum wightii* extract (Kumar & Sahoo, 2011). These effects are probably due to hormones found in seaweed liquid extracts, which are able to provide plant growth (Craigie, 2011; Khan et al., 2009). Furthermore, currently it is known that *A. nodosum* extract is able to increase gene expression of hormones such as auxin and cytokinin, which are two endogenous modulators of plant development (Rayorath et al., 2008b; Khan et al., 2011).

The number of spikes (p=0.0459) and harvest index (p=0.0427) were also significantly affected after soil irrigation with seaweed extract (Figure 2A-B).

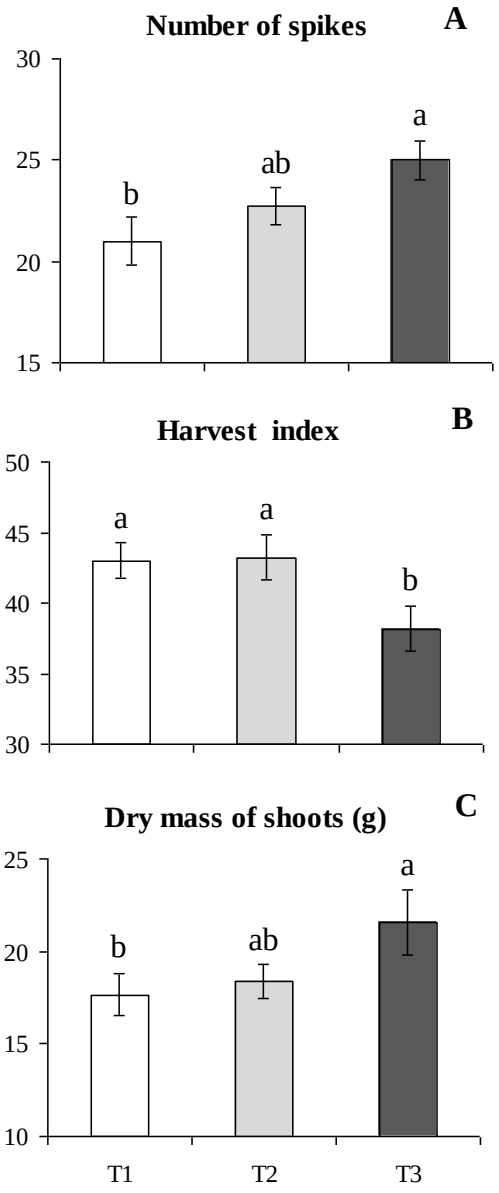

Figure 2. Effects of *A. nodosum* extract, when applied on seeds or soil irrigation, on number of spikes (A), the haverst index (B) and shoot dry mass (C) of wheat (*Triticum aestivum* cv. IAC 364). T1 - Control (water), T2 - 0.1 mL of seaweed extract on seeds and T3 - soil irrigation with 5 mL L^{-1} of seaweed extract. Means followed by distinct letters differ by t test ($\alpha \leq 5\%$). Bars express standard errors.

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The number of spikes of plants irrigated with seaweed extract was higher than the control (13.19%), as shown by Igna & Marchioro (2010) who also found an increase from 13.80 to 20.71% in wheat cv. BRS Guamirin. However, this same treatment had the lowest harvest index, when compared to control (17.12%), due to influence of higher biomass allocated in shoots (22.22%, p=0.099, Figure 2C), not related to decrease of productivity since dry mass of grains did not differ among treatments (Table1).

Table 1. Effects of *A. nodosum* extract, when applied on seeds or soil irrigation, on dry mass (g) of shoots, spikes, grains and 100 grains, foliar pigment content [clorophyll and carotenoids (mg g^{-1} fresh mass)] and nitrate reductase activity (NO^{-2} h^{-1} g^{-1} fresh mass) of wheat (*Triticum aestivum* cv. IAC 364).

Parameters	**Treatments**			***p*-value**
	T1	T2	T3	
Dry mass of spikes	27.7 ± 1.69	29.4 ± 2.91	29.6 ± 1.77	ns
Dry mass of grains	19.5 ± 1.27	20.4 ± 2.20	17.4 ± 1.99	ns
Dry mass of 100 grains	3.6 ± 0.08	3.9 ± 0.06	3.6 ± 0.20	ns
Chlorophyll *a*[1]	605.3 ± 59.27	511.4 ± 49.68	671.3 ± 61.28	ns
Chlorophyll *b*[1]	216.5 ± 27.41	181.6 ± 24.15	233.6 ± 25.25	ns
Carotenoids[1]	261.1 ± 22.93 ab	218.2 ± 21.30 b	295.8 ± 23.80 a	0.07
Nitrate reductase[1]	207.4 ± 23.39	164.5 ± 24.18	223.9 ± 32.17	ns

T1 - Control (water), T2 - 0.1 mL of seaweed extract on seeds (100 g) and T3 –soil irrigation with 5 mL L^{-1} of seaweed extract. Means ± standard error. ns: there were no significant differences among treatments (p≥0.10). Means followed by distinct letters differ by t test (α≤5%). [1]Parameters evaluated at 64 days after sowing.

The 100-grain dry mass of wheat cv. BRS Guamirin also not changed, even when applied a dose twice higher than the one used in this study (Igna & Marchioro, 2010). However, after application of *Sargassum wightii* extract on 'Pusa Gold' wheat seeds, dry mass of grains increased 22.86% (Kumar & Sahoo, 2011), which indicates, once again, that the seaweed extract effects on wheat depends on selected cultivar. Regarding biochemical analysis, foliar pigment content and nitrate reductase activity did not alter after application of seaweed extract when compared to the control (Table 1).

It is conclude that soil irrigation with 5 mL L^{-1} of *A. nodosum* extract provides development and positively affects production of wheat cv. IAC 364, but does not change evaluated biochemical parameters. Furthermore, application of seaweed extract on seeds does not influence biochemical and yield parameters of wheat cv. IAC 364, under conditions of this study. Additionally, the effects of *A. nodosum* extract on wheat, not only depends on dose, method and time of application but also changes with cultivar.

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