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EFFECT OF SEAWEED SAPS ON GROWTH, NUTRIENT UPTAKE AND YIELD OF POTATO (*Solanum tuberosum* L.)

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ABSTRACT

A field experiment was conducted during *rabi* 2012-13 at Research-cum-Instructional Farm, IGKV, Raipur, Chhattisgarh (India) to study the effects of seaweed saps on growth, yield, nutrient uptake and economic of potato in *Inceptisol* soil. Foliar spray of the extracts of two seaweeds (*Kappaphycus* and *Gracilaria*) was done on potato crop separately twice at different concentrations (0, 2.5, 5.0, 6. 25, 7.5 and 10.0% v/v). Foliar application of seaweed extract significantly enhanced growth, yield, nutrient uptake and benefit: cost ratio (B:C) in potato crop. The highest tuber yield was observed with the applications of 10% *Gracilaria* sap + recommended dose of fertilizer (RDF), followed by 10% *Kappaphycus* sap + RDF treatment showing 11.31 and 9.37% tuber yield increase, respectively, over control (water spray + RDF). The highest uptake of N, P and K by tuber and haulm was observed in 10% *Gracilaria* sap + RDF treatment. The highest net return ha^{-1} (Rs. 1,14,871) and B:C ratio (1.21) were observed with the application of 10% *Gracilaria* sap + RDF.

Key words: *Gracilaria*, *Kappaphycus*, nutrient uptake, potato yield, seaweed saps

INTRODUCTION

Seaweed extracts have been dubbed as “bio stimulants” or “metabolic enhancers” as these contain the chemicals which have growth-enhancing properties but of little nutrient value. Growth enhancement has been attributed to the presence of plant growth regulators (plant hormones), and several of these growth regulators such as cytokinins, auxins and gibberellins have been isolated from seaweed extracts (Zhang and Schmidt, 1997). The seaweeds are part of plant kingdom and like other plants manufacture their own growth regulators. Beneficial effects of the use of seaweed extracts as natural regulators include increase in crop yield, delay in fruit senescence, improvement in plant vigour and quality, and tolerance to withstand adverse conditions (Smith and Staden, 1983). The use of seaweed extracts as organic bio-stimulant is fast becoming an accepted practice in horticulture due to its beneficial effects (Verkleij, 1992). Organic fertilizers contribute raising residue deposits in soil thereby improve its physic-chemical properties; important for biological diversity and function (Galbiattia *et al*., 2007).

Marine algal seaweed species are often regarded as under-utilized bioresource, many of which have been used as a source of food, industrial raw material and therapeutic chemicals for centuries (Benjama and Masniyom, 2012). Moreover, seaweed and seaweed-derived products have widely been used as amendments in crop production systems due to the presence of a number of plant growth-stimulating compounds. However, the bio-stimulatory potential of many seaweeds has not fully been exploited due to the lack of information on growth factors present in them and their mode of action during affect on plant growth (Khan *et al.,* 2009; Yokoya *et al.,* 2010). Unlike chemical fertilizers, the extracts derived from seaweed are biodegradable, non-toxic, non-polluting and non-hazardous to humans and other animal (Dhargalkar and Pereira, 2005).

Potato (*Solanum tuberosum*) is a major staple food crop fulfilling human nutritional requirements. Worldwide, potato comes 4^{th} in terms of production after wheat, maize and rice. In ecofriendly crop production the increasing organic fertilizer demand one needs to many viable options and one such option is the use of seaweed extracts as fertilizer (Zodape, 2001). The objective of present study was aimed to assess the impact of *Kappaphycus* and *Gracilaria* sap extracts as a source of biofertilizer when applied as foliar spray in enhancing the growth, yield, nutrient uptake and economic of potato.

MATERIALS AND METHODS

The field experiments were carried out in *rabi* season, 2012-13 at Research-cum-Instructional Farm, IGKV, Raipur, Chhattisgarh (India). The experimental site falls in the 7^{th} agro-climatic region of India *i.e.* Eastern Plateau and hills which is termed as sub-humid with hot summer and cold winter. A total rainfall of 14 mm was received during cropping season and the maximum and minimum temperature ranged from 25.6 to 30.7°C and 8.3 to 18.1°C, respectively. The sun shine hours ranged from 3.3 to 9.9 h day^{-1}. The other weather parameters were normal during the season. The treatments comprized of *Kappaphycus* sp. and *Gracilaria* sp. saps, evaluated at 2.5, 5.0, 7.5, 10.0% concentration separately along with recommended dose of fertilizers {RDF} (150:100:100 kg ha^{-1}::N: P_2O_5:K_2O), water spray + RDF and 6.25% *Kappaphycus* sap + 50% RDF. Three sprays of *Kappaphycus* and *Gracilaria* were given 25, 45 and 65 days after crop planting. The soil of the site was '*Inceptisols*' (sandy loam) with pH 7.2, electrical conductivity (EC) 0.35 dSm^{-1}, organic carbon 0.55%, available N 263 kg ha^{-1}, P 12.5 kg ha^{-1} and K 338 kg ha^{-1}.

Preparation and chemical composition of liquid seaweed extracts

The algae *Kappaphycus* sp. and *Gracilaria* sp. were handpicked from the coastal area of Rameswaram, Tamilnadu (India) in September, 2011. The seaweed were washed with water to remove unwanted impurities and transported to the laboratory at Mandapum, Rameswaram. The seaweed samples were thoroughly washed using tap water and homogenized in a grinder with stainless steel blades at ambient temperature, filtered and stored (Eswaran *et al*., 2005). The liquid filtrate was taken as 100% concentration of seaweed extract and diluted as per the treatments. The nitrogen (N) content of seaweed extract was determined by taking 20 mL filtrate and oxidized by concentrate sulphuric acid (10 mL) with digestion mixture (K_2SO_4:$CuSO_4$ = 5:1) heated at 400°C for 2½ h as per semi-micro Kjeldahl's method [AOAC, 1995). The other nutrient elements were analyzed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) after wet digestion of filtrate (20 mL) with HNO_3-$HClO_4$ (10:4) diacid mixture (20 mL) and heated at 100°C for 1 h and then temperature raised to 150°C (Richards, 1954).

The experimental field was well prepared and divided into 30 plots of 4 x 4 m size. The ridges were prepared 60 cm apart in each plot. The height of ridges was kept 20 cm. The potato cv. 'Kufari Puskar' tubers were planted on the ridges at 20 cm spacing on 17 November, 2012. The experiment was laid in a randomized block design with each treatment replicated three times. Full dose of phosphorus and potassium in the form of single super phosphate and muriate of potash, respectively, and half dose of nitrogen in the form of urea were applied as basal dose at planting time. The remaining nitrogen was applied 30 days after tuber planting. Three sprays of seaweed sap were done as per the treatment. These sprays were done 25, 45 and 65 days after planting (DAP) by using knapsack sprayer. The quantity of water used was 500-600 L ha^{-1} with adjuvant.

The observations on plant height, number of shoots plant^{-1} and number of leaves plant^{-1} were recorded manually on three randomly selected plants from each plot. Also, the yield and yield attributing character were recorded as per the standard method. Plant samples were drawn from the randomly tagged plants of different rows of treated plots and analyzed. Nitrogen content in potato tuber and plant at harvest was estimated as per micro-Kjeldahl's method (AOAC, 1995). Phosphorus and potassium contents in extracts were determined after digesting the plant material with tri-acid mixture of HNO_3:H_2SO_4:$HClO_4$ (9:4:1) as per vanado-molybdo-phosphoric yellow colour and flame photometric methods, respectively (Jackson, 1973). The uptake of N, P and K by potato crop was computed on the basis of dry matter accumulation in plants. The data for various characters were analyzed by analysis of variance (Gomez and Gomez, 1984). Critical differences were assessed at 5% level of significance. The economic parameters were worked out based on the prevailing prices of output and cost of various inputs used during the period of experimentation and these included the cost of cultivation, gross return, net return and benefit: cost ratio. The cost of cultivation was worked out by taking in to consideration all the expenses incurred. Gross return was worked out by multiplying per ha tuber yield obtained in various treatments with the prevailing market selling rate. Net return was calculated by deducting the cost of cultivation from the gross return of individual treatment. Benefit: cost ratio was calculated by dividing net income by the cost of cultivation of individual treatment. The rate of sea weed sap was taken @ Rs. 30/- L^{-1} for economic computation.

RESULTS AND DISCUSSION

Growth and yield of potato

The application of different doses of sea weed sap in field significantly affected all the growth and yield parameters of potato crop (Table 1). The plant height at harvest was highest in 10% *Gracilaria* sap spray + RDF treatment which was at par with 5% *Kappaphycus* sap spray + RDF, 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF and 7.5% *Gracilaria* sap spray + RDF treatments. Maximum number of shoots plant^{-1} was observed in 10% *Gracilaria* sap spray + RDF treatment which was followed by 10% spray of *Kappaphycus* sap spray + RDF.

Table 1: Growth and yield attributing characters of potato as influenced by seaweed saps

Seaweed sap treatments	Plant height (cm)	Shoots plant^{-1} (No.)	Leaves plant^{-1} (No.)	Fresh shoot weight (g plant^{-1})	Fresh tuber weight (g plant^{-1})
2.5% *Kappaphycus* sap + RDF*	38.67	3.87	271.80	166.37	306.37
5.0% *Kappaphycus* sap + RDF	39.31	4.07	289.23	171.43	319.10
7.5% *Kappaphycus* sap + RDF	40.50	4.13	304.50	180.63	329.46
10% *Kappaphycus* sap + RDF	40.73	4.67	313.83	194.77	400.43
2.5% *Gracilaria* sap + RDF	38.40	3.87	272.80	163.53	306.81
5.0% *Gracilaria* sap + RDF	38.91	4.20	281.97	171.47	324.81
7.5% *Gracilaria* sap + RDF	39.45	4.33	295.43	179.80	336.25
10% *Gracilaria* sap + RDF	40.75	4.73	316.53	197.63	412.07
Water spray + RDF	39.00	3.67	264.67	163.87	294.38
6.25% *Kappaphycus* sap + 50% RDF	36.68	3.33	235.40	144.77	259.82
SEm±	0.53	0.10	8.24	8.16	24.40
$CD_{0.05}$	1.59	0.32	24.48	24.26	72.52

*RDF = recommended dose of fertilizers

Similarly the highest fresh weight of shoot was observed in 10% *Gracilaria* sap spray + RDF which was at par with 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF and 7.5% *Gracilaria* sap spray + RDF treatments. In case of fresh tuber weight only 10% *Kappaphycus* sap spray + RDF was at par with treatment 10% *Gracilaria* sap spray + RDF. The lowest value of these characters was observed in treatment 6.25% spray of *Kappaphycus* sap spray + 50% RDF which proved inferior to water spray control + RDF. Growth hormones like cytokinin and gibberellins have been detected in the extract of *Kappaphycus* and *Gracilaria* species which might be responsible for beneficial effects observed in the present study. Foliar application of aqueous extract improved the growth and yield of pea and black gram (Ramamoorty *et al.*, 2006a,b).

Yield of potato

The tuber yield was significantly affected by different seaweed sap sprays (Table 2). The highest marketable and total yield of potato (233.04 and 269.84 q ha^{-1}) was observed in treatment 10% *Gracilaria* sap spray + RDF. However, treatments 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF and 7.5% *Gracilaria* sap spray + RDF were at par with 10% *Gracilaria* sap spray + RDF for marketable yield whereas the treatments 5% *Kappaphycus* sap spray + RDF, 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF and 7.5% *Gracilaria* sap spray + RDF were at par with 10% spray of *Gracilaria* sap spray + RDF for total yield. The highest unmarketable yield (44.37 q ha^{-1}) was produced in treatment 6.25% *Kappaphycus* sap spray + 50% RDF which was at par with treatments 2.5% *Kappaphycus* sap spray + RDF, 5% *Kappaphycus* sap spray + RDF, 2.5% *Gracilaria* sap spray + RDF and water spray + RDF. Similarly, the lowest marketable yield and total yield was observed in 6.25% *Kappaphycus* sap spray + 50% RDF. Presence of micro-elements and plant growth regulators, especially cytokines (Zang *et al.*, 2008; Zodape *et al.*, 2009) in *Kappaphycus* and *Gracilaria* extracts appears to be responsible for the increased yield and improved nutrition of green gram receiving foliar application of the aforesaid two saps. Similar observations have been reported with respect to the foliar sprays of seaweed extract in case of canola plant, *Capsicum annuum* and *Phaseolus aureus* (Ferreira and Lourens, 2002; Arthur *et al.*, 2003; Bai *et al.*, 2008).

N, P and K uptake by potato crop

The seaweed sap sprays significantly affected the NPK uptake in potato tubers and haulm (Fig. 1 and 2). The nutrient uptake increased with increase in doses of seaweed sap. The highest N uptake by tuber and haulm was observed in 10% *Gracilaria* sap spray + RDF which was at par with 10% *Kappaphycus* sap spray + RDF in case of tuber and treatments 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF, and 5% *Gracilaria* sap spray + RDF for potato haulm.

Table 4: Yield of potato (q ha^{-1}) as influenced by seaweed saps

Seaweed sap	Marketable yield > 25 g	Un marketable yield < 25 g	Total yield (g)
2.5% *Kappaphycus* sap + RDF	205.63	42.21	247.84
5.0% *Kappaphycus* sap + RDF	219.34	41.13	260.46
7.5% *Kappaphycus* sap + RDF	224.03	37.88	261.90
10% *Kappaphycus* sap + RDF	228.72	36.44	265.15
2.5% *Gracilaria* sap + RDF	206.71	41.13	247.84
5.0% *Gracilaria* sap + RDF	217.17	38.60	255.77
7.5% *Gracilaria* sap + RDF	222.58	38.60	261.18
10% *Gracilaria* sap + RDF	233.04	36.80	269.84
Water spray + RDF	198.41	44.01	242.42
6.25% *Kappaphycus* sap + 50% RDF	196.61	44.37	240.98
SEm±	3.85	1.16	3.82
$CD_{0.05}$	11.45	3.45	11.36

*RDF = recommended dose of fertilizers

The highest P uptake was noticed in 10% *Gracilaria* sap spray + RDF by tuber and haulm which was at par with 10% *Kappaphycus* sap spray + RDF in case of tuber and water spray + RDF (control) in case of haulm. The maximum K uptake by tuber and haulm was observed in treatment 10% *Gracilaria* sap spray + RDF which was at par with treatments 7.5% *Kappaphycus* sap spray + RDF, 10% *Kappaphycus* sap spray + RDF and 7.5% *Gracilaria* sap spray + RDF in case of tuber. The lowest NP uptake by tuber and haulm was noticed in treatment 6.25% *Kappaphycus* sap spray + 50% RDF while lowest K uptake by tuber and haulm was in water spray + RDF and 2.5% *Kappaphycus* sap spray + RDF, respectively. The total nutrient uptake by potato crop (Table 5), The maximum total NPK uptake was observed in 10% *Gracilaria* sap spray + RDF which was at par with treatment 10% *Kappaphycus* sap spray + RDF for total N and K uptake. The results are in agreement with Pramanick *et al*. (2013) who noted that the foliar application of seaweed sap improved nutrient uptake capacity of crop. Presence of marine bioactive substance in seaweed sap improves stomata uptake efficiency in treated plants as compared to non-treated ones (Mancuso *et al*., 2006). Rathore *et al*. (2009) have confirmed that foliar spray of 15% (v/v) aqueous extracts of fresh *Kappaphycus alvarezii* resulted in 57% increase in *Glycine max* yield as compared to the control and intensified nutrient uptake in soybean.

Economics of cultivation

The cost of cultivation of potato varied from Rs. 86,346 to Rs. 94,865 ha^{-1} owing to the use of different doses of seaweed sap supplemented with the recommended dose of fertilizers (Table 6). Maximum marketable potato yield (233.0 q ha^{-1}) was noticed in treatment 10% *Gracilaria* sap spray + RDF which also gave maximum gross return (Rs. 2,09,736 ha^{-1}), net return (Rs. 1,14,871 ha^{-1}) and B:C ratio (1.21). This was followed by 10% *Kappaphycus* sap spray + RDF with net return of Rs 1,10,983 ha^{-1} and B:C ratio of 1.17. However, 10% *Gracilaria* sap spray G sap + RDF gave Rs. 26,067 ha^{-1} more than water spray + RDF (control). Application of seaweed extract enhanced the early growth, improved yield attribute in legume plants and gave 12-25% more yield return than control (Sethi and Adhikary, 2008).

Table 5: Nitrogen (N), phosphorus (P) and potassium (K) uptake (kg ha^{-1}) in potato as influenced by seaweed sap

Treatments	Fresh tuber yield (q ha^{-1})	Dry yield (q ha^{-1})	Fresh haulm yield (q ha^{-1})	Dry haulm yield (q ha^{-1})	Total nutrient uptake (q ha^{-1})		
					N	P	K
2.5% *Kappaphycus* sap + RDF	247.84	39.12	58.66	13.46	131.12	10.91	93.99
5.0% *Kappaphycus* sap + RDF	260.46	40.00	59.74	13.24	133.42	11.31	107.86
7.5% *Kappaphycus* sap + RDF	261.9	42.06	63.53	13.71	150.05	12.29	120.67
10% *Kappaphycus* sap + RDF	265.15	43.17	64.43	13.89	160.91	13.75	125.85
2.5% *Gracilaria* sap + RDF	247.84	40.92	60.5	13.1	135.45	11.91	107.48
5.0% *Gracilaria* sap + RDF	255.77	41.07	62.95	13.49	144.69	12.21	115.37
7.5% *Gracilaria* sap + RDF	261.18	42.28	63.49	13.82	145.19	11.76	120.24
10% *Gracilaria* sap + RDF	269.84	44.56	66.34	14.32	166.79	15.12	133.79
Water spray + RDF	242.42	36.92	62.41	13.46	132.08	12.03	93.34
6.25% *Kappaphycus* sap + 50% RDF	240.98	36.47	44.73	11.15	122.94	9.98	99.42
SEm±	3.82	1.39	0.35	0.06	3.82	0.4	3.72
$CD_{0.05}$	11.86	4.13	1.05	0.18	11.35	1.21	11.05

*RDF = recommended dose of fertilizers

Conclusion: Based on the experiment findings itmay be concluded that seaweed extracts can effectively increase the growth parameters and yield attributes in potato and its application gave maximum return. The saps also enhance nutrient uptake by potato tubers and haulm.

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