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USE OF SEAWEED SAP FOR SUSTAINABLE PRODUCTIVITY OF MAIZE

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ABSTRACT

A field experiment was conducted at Birsa Agricultural University, Ranchi , during rainy season of 2012-13 and 2013-14 with maize variety HQPM-1 in randomized block design and replicated thrice, with two sources of seaweed sap *Kappaphycus alvarezii* (K sap) and *Gracilaria edulis* (G sap) at 6 concentrations (0.0, 2.5,5.0, 7.5,10.0 and 15.0%) with RDF (150:60:40 kg $N:P_2O_5:K_2O$ ha^{-1}) and 4 concentrations (0.0, 7.5, 10.0 and 15%) with 50 % RDF, to study the effect of sea weed extracts on productivity of maize grown under *rainfed* conditions. Application of either 7.5% K sap (56.17 q ha^{-1}) or 5% G sap (54.29 q ha^{-1}) along with 100% RDF enhanced the grain yield by 34 and 30% respectively than application of 100% RDF alone (41.92 q ha^{-1}). Application of 7.5% either K sap or G sap along with 50% RDF produce similar grain yield (38.42 and 38.83 q ha^{-1} respectively) as that with 100% RDF alone and thereby saving 50% fertilizer need of the crop.Application of either 7.5% K sap or 5% G sap with 100% RDF not only increased the grain yield but also increased the nutrient uptake as well as improved soil fertility after crop harvest for sustainable crop production.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important crops and ranks third position (El-Gizawy,2009) among cereals. In India Maize is grown over an area of about 8.78 million hectare and producing 21.76 million tons with an average productivity of2.48 t ha^{-1} (Anonymous 2012). Similarly in Jharkhand maize is grown in about 1.86 lakh hectare producing 2.7 million tones with an average productivity of 1.45 tha^{-1},which is about 41.28% less than national average. Agro climatic condition of Jharkhand is favorable for successful cultivation of maize crop with high productivity.In recent years the growth rate of maize yield has been much slower as compared to 1960s and 1970s (FAO 2014), which compels the farmers to shift from biological to chemical based nutrient management, which improved the crop yield markedly but simultaneously it degrade the soil fertility by making it acidic, polluting environment, contaminating water basins, destroying beneficial soil micro flora and fauna and thereby making the crop more prone to diseases (Mishra *et al.,* 2013), rendering it unsuitable for raising healthy crops. It becomes challenging to meet out the increasing demand of maize in sustainable manner without impairing the soil fertility,as it is a very heavy feeder of nutrients due to C_4 type plant, hence the nutrient requirement is very high.But in Indian situation,farmers socio economic condition is so poor that they are unable to full fill the nutrient demand of crop for getting maximum yield. Under these situations farmers have no option left but to depend on the internal sources *i.e.* organic manures and natural fertilizers. Availability of organic resources are not enough to full fill the nutritional requirement of crop. In this situation seaweed extractsa natural source of organic liquid fertilizer are capable for supplyingmacro and micro nutrients directly to the plant,as well as seaweed manure is also a better option than conventional organic manure (farm yard manure) due to its easy decomposability of carbonaceous matter and presence of micro-nutrient (Dhargalkar and Pereia, 2005).Kaliperumal, 2000 also reported that the conjunction of seaweed manure with inorganic fertilizer has been found to be better than the other organic input for growth and development of the plant.Seaweed Liquid Fertilizer (SLF) is a blend of both plant growth regulators and organic nutrient input is ecofriendly, promoting sustainable productivity and maintaining soil health (Mohanty *et al.,* 2013). Recent researches proved that seaweed fertilizers are preferred not only due to their nitrogen, phosphorus and potash content but also because of the presence of high amount of water soluble potash (Mondal 2013). It also contain many growth substances like cytokinins, auxins and abscisic acid which affect the cellular metabolism of plant leading to enhanced growth and crop yield (Crouch *et al.,* 1992 ; Crouch and Van Staden 1993;Reitz and Trumble, 1996).Several other mineral and trace elements are also reported to be present in seaweed, which are readily absorbed by plant and they control nutrient deficiency in the plants. Many researchers proved that the foliar application of *Kappaphycus alvarezii* (Rathore *et al.,* 2009 ; Prasad *et al.*, 2010 ; Zodape *et al.*, 2010 ; Shah *et al.*, 2013 ; Mondal *et al.*, 2015) and *Gracilaria edulis* (Pramanick *et al.,* 2013 ; Pramanick *et al.,* 2014; Dwivedi *et al.,* 2014; Layek *et al.,* 2015) improved productivity and quality of crop without impairing the soil fertility. Considering the above facts, the present investigation was undertaken to find out the efficacy of of *Kappaphycus alvarezii* and *Gracilaria edulis* sap as foliar spray on maize yield, nutrient uptake, soil health and nutrient balance in soil after crop harvest.

MATERIALS AND METHODS

Experimental sites and soil information

A field experiment was conducted at Birsa Agriculture University farm Ranchi (Jharkhand) located at 25.27° N′ latitude, 93.95ºE′ longitude and at an altitude of 250 m above mean sea level, during rainy (*kharif*) seasons of2012-13 and 2013-14 on sandy loam soil, having moderate acidity (pH 5.5), organic carbon (4.5 g kg^{-1}),available nitrogen (235 $kgha^{-1}$), phosphorus (11.7 $kgha^{-1}$) and potassium (179.2 $kgha^{-1}$). The climate of the region is humid subtropical.

The experiment was laid out in a randomized block design (RBD)replicated thrice with maize variety HQPM-1 with18 treatments consisting of two seaweed sap of *Kappaphycus alvarezii* and *Gracilaria edulis* at five concentrations (2.5,5.0,7.5,10.0 and 15.0%) with 100% recommended dose of fertilizer (RDF, 150:60:40kg N:P:K ha^{-1}) *and* three concentrations (7.5,10.0 and 15.0%)with 50% RDF, besides two control (water spray) plot at 100 and 50%RDF, to find out the efficacy of of *Kappaphycus alvarezii* and *Gracilaria edulis* sap as foliar spray on maize yield, nutrient uptake, soil health and nutrient balance in soil after crop harvest. Seaweed sap as per treatmentswere sprayed on the foliage of maize thrice, at knee high stage (30 days after sowing, DAS), tasselling stage (50 DAS) and grain formation stage (70 DAS). The total volume of each spray was 650 l ha^{-1}.

Crop management

Maize cv. HQPM-1 was sown in the second fortnight of June during both the years. The seeds were manually sown in rows, 60cm apart at a depth of 4–5 cm and keeping 25 cm plant intervals. The fertilizers were applied as per treatment through urea, diammonium phosphate and muriate of potash. Half of the dose of nitrogen and full dose of phosphorus and potash were applied as basal at the time of sowing. Remaining half of the nitrogen was applied in two equal splits at knee high and tasseling stage in all the treatments. Thinning was done 10 days after sowing to remove the extra plants in order to maintain desired plant population. Weedcontrol was done by pre-emergence application of atrazine @1.5 $kgha^{-1}$ next day after sowing and manually at 20 DAS as well. Irrigation was not applied as the crop was raised under rainfed condition. Carbofuran granules (O,O-diethyl S-ethyl thio methyl phosphoro dithioate) @ 1.5 $kgha^{-1}$ was applied at four leaf stage in the leaf whorl to control shoot borer (*Chilo partellus*). During crop period 856 and 916 mm rainfall was received in both the year respectively.The crop was harvested at physiological maturity in second fortnight of October during both the years. Grain yield and stover yield was recorded in q ha^{-1}

Plant analysis

For plant chemical analysis, samples were collected from each plot, oven dried at 70°C. Available phosphorus was extracted by Bray P-1 reagent (Bray and Kurts, 1945) and estimated by spectrophotometer, whereas available potassium was extracted by neutral normal ammonium acetate method (Hanway and Hiedel, 1952) and estimated by flame photometer as described by Tandon (1999)and available N was determined by modified Kjeldahl method of digestion and distillation as outlined by Jackson (1973) and described by Tandon (1999).

Soil analysis

Soil samples were collected from 0-15cm depth from each plot before sowing and after harvest of the crop.The available nitrogen was determined by alkaline permanganate method (Subbiah, 1956),whereas available potassium and phosphorus was extracted by neutral normal ammonium acetate method (Hanway and Hiedal, 1952) and Bray P-1 reagent, respectively and estimated by flame photometer and spectrophotometer, respectively.

Statistical analysis

Data was analysed by using analysis of variance (ANOVA) following RBD (Gomez and Gomez, 1984). Differences were considered significantly at 5% level of probability.

RESULTS AND DISCUSSION

Effect of seaweed sap, its concentration and fertilizer level on yield.

Maize grown with 100% RDF and sprayed with 7.5% K sap recorded maximum pooled mean grain and stover yield i.e. 56.17 q ha^{-1} and 114.63 q ha^{-1} respectively, pooled data revealed that the grain and stover yield of maize increased with increasing level of sap concentration upto 7.5% K sap and 5% G sap with 100% RDF, thereafter it decreased significantly. Shah *et al.,* 2013 while working with wheat, also observed that yield increased with increasing concentration of K sap (up to 7.5%) and G sap (up to 5%) and in higher concentration (above 7.5% K sap and 5% G sap) it decreased the yield and yield attributes which might be due to the spraying of seaweed extract on critical growth stages which was effectively utilized by the crop and expressed higher growth and yield (Sivshankari *et al.,* 2006). Zodape *et al.*, 2011 also reported that the foliar application of liquid extract of *Kappaphycus alvarezii* trigger the yield potency of *Lycopersicon esculentum*. Increase in yield may be due to the presence of plant growth regulator in sap as well as the minerals element present in the seaweed extract, which increased the rate of photosynthate accumulation or delay the senescence of the leaves, this would have enhanced the supply of photosynthate available for grain filling, thus resulting in bolder grain and consequently higher grain yield (Beckett and Van Staden, 1990). Similarly, the decrease in maize grain yield with higher concentration of seaweed sap application (beyond 5% G sap or 7.5% K sap) was associated with less number of grains per cob and 100 seed weight, owing to very high salt index at higher concentration of sea weed sap that may be adversely affecting growth, yield and yield component (Zodape *et al.,* 2008; Aitken and Senn, 1965 and Abetz, 1980). It was also observed that application of 7.5% either K sap or G sap along with 50% RDF produce similar grain yield (38.42 and

Table 1: Effect of seaweed sap,its concentration and fertilizer level on yieldand N, P, K uptake of maize.

Treatment	Yield (q ha-1)		Nutrient Uptake (Kg ha^{-1})_		
	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Nitrogen	Phosphorus	Potassium
T1(100%RDF+ water)	41.92	90.19	76.91	15.05	46.34
T2(100%RDF+2.5% K)	45.77	96.11	83.86	16.68	51.55
T3(100% RDF+5% K)	47.58	99.56	89.57	17.80	54.35
T4(100%+7.5%K)	56.17	114.63	107.22	20.96	62.91
T5(100%RDF+10%K)	43.83	94.97	81.42	16.27	50.85
T6(100%RDF+15%K)	42.80	92.98	78.72	15.65	48.93
T7(50% RDF+7.5%K)	38.42	86.59	71.52	14.14	43.41
T8(50% RDF+10%K)	35.34	84.10	66.52	13.01	40.86
T9(50%RDF+15% K)	33.70	81.85	63.68	12.32	39.50
T10(100%RDF+2.5G)	42.40	93.36	78.65	15.59	47.52
T11(100% RDF+5% G)	54.29	104.16	104.35	20.14	58.77
T12(100% RDF+7.5G)	43.11	96.59	82.93	16.54	52.37
T13(100%RDF+10G)	43.84	97.65	84.40	16.88	52.92
T14(100RDF+15%G)	38.63	89.43	72.21	14.02	44.81
T15(50%RDF+7.5G)	38.83	88.75	72.65	14.53	45.55
T16(50%RDF+10% G)	35.06	86.22	67.91	13.33	42.13
T17(50% RDF+15% G)	34.12	83.64	65.49	12.83	40.48
T18(50%RDF+water)	30.95	77.38	59.87	11.58	37.03
CD (5%)	5.78	13.47	8.91	1.99	6.16

Table 2: Effect of seaweed sap,its concentration and fertilizer level on Nutrient Uptake and Soil Fertility Status of maize.

Treatment	Available Soil nutrient status after crop harvest			
	Organic carbon (%)	Nitrogen(Kg ha^{-1})	Phosphorus(Kg ha-1)	Potassium(Kg ha-1)
T1(100%RDF+ water)	0.42	244.96	19.98	130.29
T2(100%RDF+2.5% K)	0.43	253.02	21.03	132.82
T3(100% RDF+5% K)	0.45	254.52	22.89	136.29
T4(100%+7.5%K)	0.44	258.83	24.55	139.36
T5(100%RDF+10%K)	0.42	252.70	21.80	132.98
T6(100%RDF+15%K)	0.45	249.15	20.54	131.73
T7(50% RDF+7.5%K)	0.43	237.68	17.38	122.79
T8(50% RDF+10%K)	0.45	235.56	16.21	120.48
T9(50%RDF+15% K)	0.45	234.33	15.52	118.31
T10(100%RDF+2.5G)	0.45	250.24	18.77	130.53
T11(100% RDF+5% G)	0.44	259.15	24.68	139.74
T12(100% RDF+7.5G)	0.46	252.20	21.54	134.88
T13(100%RDF+10G)	0.43	251.47	21.86	134.64
T14(100RDF+15%G)	0.43	244.73	18.76	129.29
T15(50%RDF+7.5G)	0.43	236.88	16.29	124.33
T16(50%RDF+10% G)	0.45	234.74	15.17	120.81
T17(50% RDF+15% G)	0.42	232.99	14.03	118.52
T18(50%RDF+water)	0.43	231.83	13.52	117.53
CD (5%)	NS	22.24	1.96	11.24
Initial status	0.45	235	11.7	179.2

38.83 q ha^{-1} respectively) as that with 100% RDF alone and thereby are capable of compensating 50% fertilizer need of the crop. Sridhar and Rengasamy (2010) also observed similar results with use of liquid extract of *Sargassum wightii* and *Ulva lactuca* in field in combination with 50% dose of chemical fertilizer.

Effect of seaweed sap,its concentration and fertilizer levelon nutrient uptake by plant

Maize Crop fertilized with 100% RDF and sprayed with 7.5% K sap removed maximum total N,Pand K from soil in the pooled mean (107.22, 20.96 and 62.91 kgha^{-1} respectively) which was significantly superior over rest of the sap concentration and fertilizer level applied to maize crop except 5% G sap with 100%RDF (104.35, 20.14 and 58.77 kg ha^{-1} respectively. Similar to grain yield, N, P and K removal also increased with increasing concentration of sap upto 7.5% K sap and 5%G sap with 100%RDF and thereafter it decreased with higher concentration (Table 3). Total N,P and K uptake with 100% RDF and sprayed with 7.5% K sap increased by 39.40, 39.26 and 35.75% over control (100%RDF with water spray).Shah *et al.*, 2013 also observed that the foliar application of *Kappaphycus alvarezii* and *Gracilaria edulis* sap increased the nutrient uptake in wheat by increasing concentration of both sap and maximum uptake of N, K, Ca, Mg and S was obtained at 5% G sap whereas maximum uptake of N and P was obtained at 7.5% K sap. Zodape *et al.*, 2011 also reported that the foliar spray of 5% concentration of *Kappaphycus alvarezii* sap in tomato increased the N, P and K uptake(219, 28 and 283 kg ha^{-1} respectively)) over control and beyond

Table 3: Nitrogen balance sheet (kg ha^{-1}) after maize harvest affected by seaweed sap

Treatment	Soil Initial N(kg ha^{-1})A	N added through fertilizers (kg ha^{-1})B	Total soil N (kg ha^{-1}) A+B=C	Crop Removal (kg ha^{-1})D	Expected balance (kg ha^{-1}) C-D=E	Final available N (kg ha^{-1}) F	Gain/Loss of N(kg ha^{-1}) F-E
T1(100%RDF+ water)	235.00	300.00	535.00	153.83	381.17	251.06	-130.11
T2(100%RDF+2.5% K)	235.00	300.00	535.00	167.72	367.28	255.88	-111.40
T3(100% RDF+5% K)	235.00	300.00	535.00	179.14	355.86	257.43	-98.43
T4(100%+7.5%K)	235.00	300.00	535.00	214.44	320.56	258.39	-62.17
T5(100%RDF+10%K)	235.00	300.00	535.00	162.84	372.16	255.61	-116.56
T6(100%RDF+15%K)	235.00	300.00	535.00	157.43	377.57	252.06	-125.51
T7(50% RDF+7.5%K)	235.00	150.00	385.00	143.05	241.95	234.55	-7.40
T8(50% RDF+10%K)	235.00	150.00	385.00	133.04	251.96	229.46	-22.51
T9(50%RDF+15% K)	235.00	150.00	385.00	127.36	257.64	221.39	-36.25
T10(100%RDF+2.5G)	235.00	300.00	535.00	157.31	377.69	253.52	-124.17
T11(100% RDF+5% G)	235.00	300.00	535.00	208.70	326.30	257.79	-68.52
T12(100% RDF+7.5G)	235.00	300.00	535.00	165.86	369.14	253.42	-115.71
T13(100%RDF+10G)	235.00	300.00	535.00	168.81	366.19	251.52	-114.67
T14(100RDF+15%G)	235.00	300.00	535.00	144.43	390.57	234.88	-155.69
T15(50%RDF+7.5G)	235.00	150.00	385.00	145.31	239.69	234.33	-5.36
T16(50%RDF+10% G)	235.00	150.00	385.00	135.82	249.18	232.82	-16.36
T17(50% RDF+15% G)	235.00	150.00	385.00	130.99	254.01	233.15	-20.86
T18(50%RDF+water)	235.00	150.00	385.00	119.74	265.26	230.42	-34.84

Table 4: Phosphorus balance sheet (kg ha-1) after maize harvest affected by seaweed sap concentration

Treatment	Soil Initial P(kg ha^{-1})A	P Added through fertilizers (kg ha^{-1}) B	Total Soil P (kg ha^{-1}) A+B=C	Crop removal (kg ha^{-1})D	Expected balance (kgha^{-1}) C-D=E	Finalavailable P(kg ha^{-1})F	Gain /loss of P(kg ha^{-1}) F-E
T1(100%RDF+ water)	11.7	51.60	63.3	30.1	33.2	19.88	-13.33
T2(100%RDF+2.5% K)	11.7	51.60	63.3	33.4	29.9	20.56	-9.38
T3(100% RDF+5% K)	11.7	51.60	63.3	35.6	27.7	21.46	-6.24
T4(100%+7.5%K)	11.7	51.60	63.3	41.9	21.4	22.93	1.54
T5(100%RDF+10%K)	11.7	51.60	63.3	32.5	30.8	21.09	-9.67
T6(100%RDF+15%K)	11.7	51.60	63.3	31.3	32.0	19.93	-12.07
T7(50% RDF+7.5%K)	11.7	25.80	37.5	28.3	9.2	17.56	8.33
T8(50% RDF+10%K)	11.7	25.80	37.5	26.0	11.5	17.30	5.82
T9(50%RDF+15% K)	11.7	25.80	37.5	24.6	12.9	16.56	3.70
T10(100%RDF+2.5G)	11.7	51.60	63.3	31.2	32.1	18.50	-13.61
T11(100% RDF+5% G)	11.7	51.60	63.3	40.3	23.0	21.47	-1.54
T12(100% RDF+7.5G)	11.7	51.60	63.3	33.1	30.2	20.72	-9.51
T13(100%RDF+10G)	11.7	51.60	63.3	33.8	29.5	19.94	-9.59
T14(100RDF+15%G)	11.7	51.60	63.3	28.0	35.3	18.63	-16.64
T15(50%RDF+7.5G)	11.7	25.80	37.5	29.1	8.4	17.46	9.03
T16(50%RDF+10% G)	11.7	25.80	37.5	26.7	10.8	16.80	5.95
T17(50% RDF+15% G)	11.7	25.80	37.5	25.7	11.8	15.62	3.79
T18(50%RDF+water)	11.7	25.80	37.5	23.2	14.3	14.71	0.36

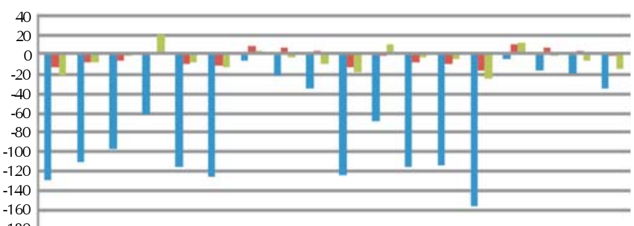
this concentration it declined. Similarly the application of seaweed sap enhanced nutrient uptake and growth on cereals and millets (Immanuel and Subramanian (1999) and yield of *Dolichos biflorus* (Ananthraj and Venkatesalu, 2002).It may be due to the presence of many organic compounds in seaweed liquid fertilizer which acts as a bio-stimulants that can increase the availability of nutrients in the plant system. Beside, the presence of natural chelating compound (i.e.manitol) in sap, might have increased nutrient availability by a better absorption of the chelated compound at leaf levels (Salat, 2004), as it increased root proliferation and establishment, thereby plants were able to mine more nutrients even from distant places and deeper soil horizon, in a balanced proportion. Prasad *et al.,* 2010 and Mancuso *et al.*, 2006 also reported that the sea weed sap contain several hormones which might be responsible for increasing nutrient uptake by increasing stomatal uptake efficiency from liquid fertilizer. Turan and Kose, (2004) reported that the seaweed extract increased the Cu uptake due to increasing membrane permeability of roots, leaves, stomata cells and hormones like activity of seaweed extract through their involvement in cell respiration, photosynthesis and enzymatic reaction. Lingakumar *et al.,* 2004 also reported that the foliar application of 1% *Gracilaria edulis* increased the germination , growth, yield and uptake of the nutrient in *Zea mays*.

Effect of seaweed sap, its concentration and fertilizer level on Post-harvest Soil fertility

Soil fertility status measured after harvest of maize revealed

Table 5: Potassium balance sheet (kg ha^{-1}) after maize harvest affected by seaweed sap concentration

Treatment	Soil Initial K(kg ha^{-1})A	K added through fertilizers (kg ha^{-1}) B	Total soil K(kg ha^{-1}) A+B=C	Crop removal (kg ha^{-1})D	Expected balance (kg ha^{-1}) C-D=E	Final available K(kg ha^{-1}) F	Gain /loss of K(kg ha^{-1}) F-E
T1(100%RDF+ water)	179.2	66.4	245.6	92.7	152.9	131.4	-21.6
T2(100%RDF+2.5% K)	179.2	66.4	245.6	103.1	142.5	133.4	-9.1
T3(100% RDF+5% K)	179.2	66.4	245.6	108.7	136.9	136.6	-0.3
T4(100%+7.5%K)	179.2	66.4	245.6	125.8	119.8	139.1	19.3
T5(100%RDF+10%K)	179.2	66.4	245.6	101.7	143.9	135.2	-8.7
T6(100%RDF+15%K)	179.2	66.4	245.6	97.9	147.7	133.3	-14.4
T7(50% RDF+7.5%K)	179.2	33.2	212.4	86.8	125.6	128.7	3.1
T8(50% RDF+10%K)	179.2	33.2	212.4	81.7	130.7	126.8	-3.9
T9(50%RDF+15% K)	179.2	33.2	212.4	79.0	133.4	123.5	-9.9
T10(100%RDF+2.5G)	179.2	66.4	245.6	95.0	150.6	132.3	-18.3
T11(100% RDF+5% G)	179.2	66.4	245.6	117.5	128.1	137.9	9.8
T12(100% RDF+7.5G)	179.2	66.4	245.6	104.7	140.9	137.5	-3.3
T13(100%RDF+10G)	179.2	66.4	245.6	105.8	139.8	134.7	-5.0
T14(100RDF+15%G)	179.2	66.4	245.6	89.6	156.0	130.5	-25.5
T15(50%RDF+7.5G)	179.2	33.2	212.4	91.1	121.3	133.4	12.1
T16(50%RDF+10% G)	179.2	33.2	212.4	84.3	128.1	126.4	-1.7
T17(50% RDF+15% G)	179.2	33.2	212.4	81.0	131.4	124.3	-7.2
T18(50%RDF+water)	179.2	33.2	212.4	74.1	138.3	122.5	-15.9



	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	T17	T18
N	-13	-11	-98	-62	-11	-12	-7.	-23	-36	-12	-69	-11	-11	-15	-5.	-16	-21	-35
P	-13	-9.	-6.	1.5	-9.	-12	8.3	5.8	3.7	-14	-1.	-9.	-9.	-17	9.0	5.9	3.7	0.3
K	-22	-9.	-0.	19.	-8.	-14	3.1	-3.	-9.	-18	9.8	-3.	-5	-26	12.	-1.	-7.	-16

Figure 1: N, P K balance in the soil after harvest of maize crop

that the available N,P and K was influenced by seaweed sap concentration and fertilizer level. Soil organic carbon remained unchanged (Table 3). It may be due to the decomposition and accumulation of soil organic matter is at equilibrium state. The seaweed extracts might have played a role in the reduction of CO_2 emission, thus reducing the carbon foot printing environmentally. This actually indicate that the crop acts as a global organic carbon sink (Sebastiaan, 2008) as the sequestered carbon dioxide is stored.This eco-friendly trait is beneficial for the atmosphere. Thus seaweeds prove to be excellent bio-fertilizers in raising better crops, not only in the farm areas but also in the arena of global warming as they have good bio sustainability.Crop fertilized with either 100% or 50% RDF and sprayed with seaweed sap maintained its initial soil nitrogen status, except the treatment where only 50% RDF applied alone. However significantly higher nitrogen (258.83 kg ha^{-1}) status than its initial value under the treatment where crop fertilized with 100%RDF and 7.5 % K sap might be due to mineralization of some of the native nitrogen under the influence of sea weed sap. Available P status of soil after crop harvest also significantly improved over its initial status irrespective of fertilizer level and sap concentration except where only 50%RDF was applied alone. Maximum available P status (24.68 kg ha^{-1}) was recorded under the treatment where crop was fertilized with 100% RDF and sprayedwith 5% G sap which was similar to 5 or 7.5% K sap with 100%RDF.Available soil K status after crop harvest decreased significantly in all the treatments than its initial status. However the rate of depletion did not vary due to application of seaweed sap at the same fertilizer level.

Seaweed extract has been shown to enhance the moisture holding capacity of soil due to presence of alginic acid. Alginic acid combine with ion in soil and form high molecular weight complex that absorb moisture,swell, retain soil moisture and improve crump formation resulting in better aeration and capillary activity of soil pores, which in turns stimulate the growth of plant root system and microbial activity (Gandhiyappan and Perumal, 2001). Further application of seaweed extract enhance the soil fertility by conversion of unavailable form of nutrient to available form by increasing the moisture holding capacity as well as improvement of soil structure (Sethi and Adhikari 2009 ; Mohanty *et al.*, 2013).

Soil nutrient balance after harvest of maize

An assessment of nutrient additions, removals, and balances in the agricultural production system generates useful, practical information on whether the nutrient status of a soil (or area) is being maintained, built up, or depleted.

Nitrogen balance in soil was negative irrespective of seaweed sap concentration and fertilizer level (Table 4 and Fig. 1). Negative balance of nitrogen decreased with increasing grain yield. Minimum negative balance was recorded in the maize plot grown with 7.5% K sap and 5%G sap with 100%RDF (-62.17 and -68.52 kg ha^{-1}respectively), where, maximum grain yield was also recorded. Similarly in the maize plot grown with 50%RDF, lowest negative nitrogen balance was observed with 7.5% G sap (- 5.36 kg ha^{-1}) followed by 7.5%K sap (-7.40 kg ha^{-1}). Negative balance decreases with increasing concentration of sap up to 7.5%K sap and 5%G sap thereafter negative valueincreased with increasing concentration of sap.

Phosphorus balance in soil was also negative in all the combination of both the sap concentration with 100%RDF except 7.5%K sap (Table 5 and Fig. 1). Whereas, incase of 50%RDF all the treatment showed the positive balance.Negative balance of P declined with the increasing concentration of sap upto 7.5%K sap and 5%G sap with 100% RDF, thereafter it increased with increasing concentration of sap. Similarly in the plot fertilized with 50%RDF, highest addition of phosphorus was observed with 7.5% of either Ksap or G sap, thereafter addition of P decreased with the increasing concentration of both the sap and minimum positive balance was at control plot with 50%RDF. Minimum negative balance of nitrogen and phosphorus with the application of 7.5% K sap and 5%G sap with 100%RDF might be due to presence of chelating compound (*i*.e. manitol)presentin seaweed extract that can increase nutrient availabilityin the soil, a better absorption of the chelated compound at leaf level has recently been suggested (Salat, 2004). In addition,sea weed extract can increase root size, thus increasing the volume of soil sampled by a plants (Nelson and Van Staden 1984),which indeed help in uptake of nutrients by plants and mobilize the nutrient from unavailable to available form through enzymatic activity on soil.

Potassium balance was also negative in all the sap concentration with 100%RDF except 7.5%K sap (19.3 kg ha^{-1}) and 5%G sap (9.8 kg ha^{-1}) which added potassium in soil, besides giving higher yield also. Similary when crop sprayed with 7.5%ofeither K sap or G sap along with 50%RDF had maximum positive K balance and maximum negative balance was observed in the control plot either at 100or 50%RDF. This might be due to the fact that the fixed potassium might havebeen made available to the crop and enriched the soil due to presence of chelating compound i.e. manitol on seaweed sap that can increase the nutrient availability. Similar finding was also reported by the Ramesh *et al.,* 2011 in sorghum.

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