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CSIR-CENTRAL SALT AND MARINE CHEMICALS RESEARCH INSTITUTE, BHAVNAGAR [CSMCRI]

Summary of Project on Multi-Institutional Demonstration Trials Showing Efficacy of Liquid Seaweed Sap From *Kappaphycus alvarezii* on Different Crops

Part of a CSIR-supported National Laboratory Project Coordinated by CSIR-CSMCRI, Bhavnagar

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Executive Summary

Liquid Seaweed Fertilizer (LSF) derived from seaweed sap (*Kappaphycus alvarezii*) is patented technology and has been granted International Patents (US Patent No 6,893,479; European Patent No. EP1534757; Indian Patent No 224938). It is already under commercialization. 2 million litres was sold during 2012-13. This project aims at validating the efficacy of *Kappaphycus* sap through multi-locational, multi crop trials carried out in collaboration with 43 Agricultural Institutions across 20 states of India. The project has an outlay of Rs 11.61 Crores and has been funded by Council of Scientific and Industrial Research (CSIR) as a Major Laboratory Project (MLP), being implemented by CSIR-CSMCRI, Bhavnagar. The key findings from 100 completed trials so far under this project are described below.

In rice, which is the staple food in India, application of *Kappahycus* sap was found to be increase the grain yield of rice significantly in most of the cases. In the Eastern and North-eastern region where rice is cultivated the most, viz., West Bengal, Odisha, Jharkhand, Bihar Assam, Meghalaya, the improvement in grain yield of rice by application of *Kappaphycus* sap (K-sap) + Recommended Dose of Fertilizer (RDF) ranged from 8.4% to 61.3%, with average improvement for the region recorded in excess of 26% over control (water spray+RDF). In the Western and North Western part of India, viz. in Rajasthan, Punjab and Gujarat, K-sap resulted in an average grain yield of 12.3%. In southern parts of the country (Karnataka, Andhra Pradesh and Tamil nadu), a modest improvement in grain yield of rice in the range of 9-11% was observed by application of higher (10 or 15%) concentration of K sap+RDF. However, there were few cases where, the improvement in yield over control was very marginal and non significant (Haryana and Hazaribagh CRRI center of Jharkhand. However, the same center (CRRI-Hazaribagh) reported that there was marked improvement by the use of *Kappaphycus* sap when another variety was used for the trials, thereby revealing that different varieties may respond differently.

Among the C4 crops, response of maize to the seaweed sap was tested in Eastern and North-eastern (West Bengal, Bihar, Jharkhand, Meghalaya), North Western (Haryana), Western (Rajasthan) and Southern (Karnataka, Andhra Pradesh and Tamilnadu) regions of the country, while response of sugarcane was reported from Assam. *Kappaphycus* sap increased the grain yield of maize. Significant average maize grain yield improvement of 27% over control was observed in the Eastern and North-Eastern region by application of RDF in conjugation with 7.5-15% concentrations of K-sap, while 12 and 16% improvement was observed at Haryana and Udaipur, Rajasthan, respectively by application of 15% K-sap. In southern region, significant improvement of 14% was recorded only at Tamilnadu. In most places, increased carbohydrate content in maize grains were observed.

At Assam, 27 and 35% improvement in sugarcane yield was observed by application of 5% K-sap in conjugation with RDF, respectively; while sucrose content in the juice also improved significantly. Potato responded significantly and the tuber yield improvement ranged from 12.3 to 37.4%, the highest being recorded at Nadia (WB). Whereas, the yield improvement ranged from 12-16% at MP, Bihar, Punjab and TN by using 10 or 15% K-sap, yield improvement over 25% was observed in both the centres of West Bengal and Dantiwada (Gujarat).

Among the two of the pulse crops, *viz.*, blackgram (Urd) and greengram (mung) tested, both responded well at higher (10 or 15%) concentrations of *Kappaphycus* in conjunction with RDF. In no cases, in the present report, the yield maximization of the pulse crops could be restricted at concentrations less than 10% in case of K-sap. Significant improvement in seed yield of blackgram averaging to ca. 47% over control was observed from both the centres of Eastern region (West Bengal) by application of RDF + 15% K-sap, whereas, the highest improvement of 67.3% was reported in Western region (Maharashtra) by the same treatment. At all the three places i.e., in Rajasthan, Uttaranchal, and Andhra Pradesh significant yield improvement in excess of 25% was observed. A modest improvement of 8-12.5% was recorded at Gujarat (Navsari cenre) and Tamilnadu (Coimbatore centre) using K-sap @ 15%. Similarly, in case of greengram, the seed yield improvement over control ranged from 39.0 to 9.3% for K-sap application. Maximum yield increase of greengram ranging from 25%-47% over control (RDF+water spray) was observed in most regions by application of K- sap+RDF (West Bengal, Rajasthan, Maharashtra, Uttaranchal and Odisha), while, like in blackgram, modest improvement (9-11%) in seed yield of greengram was observed in southern region (Tamilnadu and Andhra Pradesh).

Among the oilseeds, soybean and sesame were tested for their response to seaweed saps. In soybean, exceptionally high yield improvement of 75.5%, 45%and 39.1% was observed at Nadia (WB), Akola (MH) and Ranchi (Jharkhand), respectively by using K-sap. The effect of K saps at Indore (DSR centre) was not found significant enough, while at Dharwad, a numerical improvement of ca 20% was observed. In Andhra Pradesh centre K sap at 10% concentration recorded 38% improvement. Yield improvement in range of 20-30% was recorded from Nadia (WB), Udaipur (Rajasthan) and Ranchi (Jharkhand) by application of K-sap, while at Birbhum (WB), Dantiwada (Gujarat) and Coimbatore (TN), the response was found to be very less (ca 5% or less improvement).The effect of seaweed saps on fodder production was also found significantly improved and stover yield of berseem fodder was increased by 30-35% using 10% K sap in conjunction with RDF at Jabalpur (MP). The quality of fodder in terms of crude protein and fibre yield was also improved. Similarly, the green forage yield of fodder oat was improved by 10% K sap.

During the course of research, a new formulation derived from *Kappaphycus was* prepared by selectively removing GA_3 from pristine *Kappaphycus* sap and this was found to be useful in raising the biomass and grain yield of maize over and above the pristine *Kappaphycus* sap. This new formulation would be prepared in larger quantities and would be evaluated on a larger scale in the next year.
It may be highlighted that the scope of cultivation of seaweed in sea for deriving such plant production stimulant is virtually unlimited as it can be cultivated in the off-shore condition as well, without the need of any land, fresh water, fertilizers, and pesticides.Thus no constraint is seen in production of sap in large volumes and maximize the benefit of this low cost liquid fertilizer to Indian Agriculture, besides also boosting its exports, which has already begun.

Multi-institutional demonstration trials showing efficacy of liquid seaweed sap from *Kappaphycus alvarezii* on different crops.

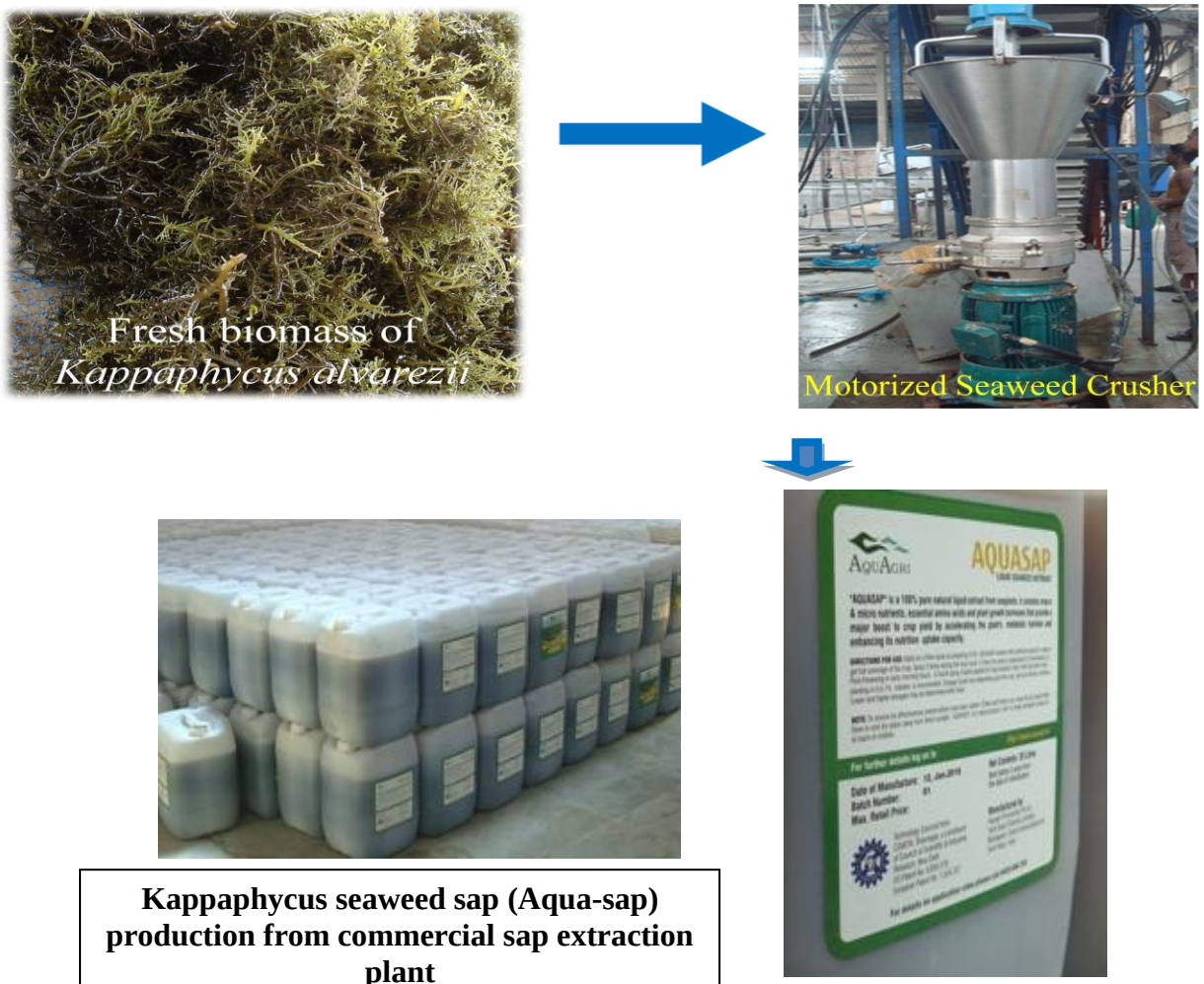
Implementing laboratory: CSIR-CSMCRI, Bhavnagar

1. Project Background/pre-feasibility work done:

CSMCRI introduced the commercially important seaweed, *Kappaphycus alvarezii*, in India and went on to develop a practical cultivation technology leading to large scale farming of this seaweed in shallow coastal waters. Indeed, large scale cultivation was found to be feasible and the cultivation know-how has been licensed for commercial production of this alga in Indian coastal waters. Presently, over 1000 people are employed in seaweed cultivation (>18500 rafts) in Tamil Nadu and very recently activities to cultivate it over various places along the Gujarat coast have also taken off on a large scale. Seaweed farming is a supplementary activity to existing fishing and its ancillary activities. It can provide a regular and sustainable income source by leveraging local entrepreneurial talent and has translated into an additional annual income of up to Rs. 80,000 per person.

Raft cultivation of seaweed in sea

Given the fact that seaweeds contain more than 90% water on fresh weight basis, CSMCRI thereafter invented (US Patent No. 6,893,479) a process for liquefaction of fresh *Kappaphycus alvarezii* leading to simultaneous production of sap (80% of fresh weight) and residue rich in κ-carrageenan (polysaccharide).



Kappaphycus seaweed sap (Aqua-sap) production from commercial sap extraction plant

The former has turned out to be a promising plant nutrient. The sap is found to be rich in potash (ca. 2% w/v), micronutrients and iodine besides plant growth promoting substances. Recently quartenary ammonium compounds, Glycine betaine and choline has also been detected in it in substantial amounts. Based on limited scale preliminary trials carried out by different Agricultural Universities and organizations, it has proven to be very effective in increasing the productivity of some crops, reducing insect and disease incidences on them and also improving the quality of crop produce in some cases. The yield improvement has been found over and above the yield obtained with recommended doses of standard fertilizers.

2. Premises / Rationale/Justification/Objectives

In order to validate the results over larger agro climatic locations across whole of India, so as to reap the benefit of the low cost invention, this project was proposed to optimize the dosages of these two seaweed sap formulations and also demonstrate it over a large scale. As of now, the project is underway in collaboration with more than 40 centres of different Agricultural Universities and ICAR Institutes across 16 states in India. In the first phase, the following objectives have been targeted:

Multilocational and multicrop demonstration trials to study the efficacy of seaweed sap

1. Location-specific optimization of sap technology on different crops and studies on changes in soil fertility.
2. Study the principal constituents responsible for the observed crop improvement.
3. Effective formulation development for enhanced efficacy of sap.
4. Basic studies for development of natural surfactants.

3. Proposed work plan and Milestones

Methodology

Two types of trials are being undertaken in this project, viz., (i) Agronomic (A) or (ii) demonstration (D) trials or both as per agreed by the different partnering agricultural institutes.

Treatments imposed under Seaweed sap trial for different crops

A) Agro trial design: Randomized Complete Block Design (RBD) Replication: 3;
No of sprays: 2-4 depending on crop duration

TREATMENTS	T1	T2	T3	T4	T5
Concentration of saps (%) to be applied as foliar spray					
Cereals (Maize, Rice)	2.5 K sap+RDF	5% K Sap+RDF	10 % K Sap+RDF	15% K Sap+RDF	7.5% K Sap+50% RDF
Pulses (Blackgram, Greengram)	2.5 K sap+RDF	5% K Sap+RDF	10 % K Sap+RDF	15% K Sap+RDF	7.5% K Sap+50%RDF
Oilseeds (Soybean, Sesame)	2.5 K sap+RDF	5% K Sap+RDF	10 % K Sap+RDF	15% K Sap+RDF	7.5% K Sap+50%RDF
Sugarcrops (Sugarcane)	2.5 K sap+RDF	5% K Sap+RDF	7.5 % K Sap+RDF	10% K Sap+RDF	6.25% K Sap+50%RDF
Grass (Fodder): Lucerne	2.5 K sap+RDF	5% K Sap+RDF	7.5 % K Sap+RDF	10% K Sap+RDF	6.25% K Sap+50%RDF
Potato	2.5 K sap+RDF	5% K Sap+RDF	7.5 % K Sap+RDF	10% K Sap+RDF	6.25% K Sap+50%RDF

K sap: *Kappaphycus* sap

RDF: Recommended dose of fertilizer for the crop in respective regions (to be specified in detail including NPK doses + organic manure applications

Different concentrations of the sap are being tried across all locations. Yield, dry matter content of the produce and nutritional parameters and quality of harvest are being assessed, followed by analyzing them statistically to reach a conclusion.

B) DEMONSTRATION TRIALS

This is being conducted by taking three plots each of ½ to 1 acre (preferably as per the availability of land with the institutions) either in farmer's field or on University's/Institute's farm with following treatments:

T1: K sap with concentration and number of sprays mentioned in the following table at appropriate critical growth stages of the crops

T2: Water spray

The above trials are being done with RDF in all the three plots following all standard agro-practices.

Crops	K sap concentration	No. of sprays required
Cereals (Rice)	2.5%	3
Cereals (Maize)	12.5%	3
Pulses (Blackgram and Greengram)	5.0%	2
Oilseeds (Sesame)	5.0%	3
Oilseeds (Soybean)	12.5%	3
Sugarcrop (Sugarcane)	1% sett treatment followed by 5% foliar spray 3 times	1+3
Potato	5.0%	3
Grass (Fodder)	5.0%	3

The collaborations have been made with the following institutes (Table to the right):

Centre No.	Centre Name
1.	BCKV, Nadia, WB
2.	CRRI, Cuttack centre, Odisha
3.	CRRI, Jorhat centre, Assam
4.	CRRI, Hazaribagh centre, Jharkhand
5.	PSB, Shantiniketan, W.B.
6.	RAU, Samastipur, Bihar
7.	AAU, Jorhat
8.	ICAR Research Complex, for NEH, Meghalaya
9.	OUA & T, Bhubaneshwar, Odisha
10.	MPUA & T, Udaipur, Rajasthan
11.	SDAU,Sardar krushi nagar, Gujarat
12.	PAU, Ludhiana, Punjab
13.	NAU, Navsari, Gujarat
15.	PDKV, Akola, Maharashtra
16.	CSMCRI trials (Guj, MH, MP)
17.	Dir. Soyabean Res, Indore, MP
18.	JNKVV, Jabalpur, MP
19.	GBPUA&T, Pantnagar, Uttaranchal
20.	IISR, Lucknow (ICAR), UP
21.	CCS HAU, Hissar, Haryana
22.	CSAUA & T, kanpur, UP
23.	GKVK, Bangalore, Karnataka
24.	ANGRAU, Hyderabad, Andhra Pradesh
25.	UAS, Dharwad , Karnataka
26.	TNAU, Coimbatore, Tamil Nadu
27.	SKRAU, Bikaner, Rajasthan
28.	BAU, Ranchi, Jharkhand
29.	DBSKKV, Dapoli, Maharashtra
30.	CAU, Manipur, Imphal
31.	AAU, Anand, Gujarat
32.	SVRUAT, Meerut, UP
33.	CSKHPKV, Palampur, HP
34.	IGKV, Raipur, Chattisgarh
35.	CPRI, Shimla centre, HP
36.	CPRI, Shillong Centre, Meghalaya
37.	CPRI, Ooty Centre, Tamil Nadu
38.	CPRI, Meerut Centre, Modipuram
39.	CPRI, Jalandhar, Punjab
40.	CPRI, Patna centre, Bihar
41.	CPRI, Gwalior, MP
42.	SBI, Coimbatore, TN
43.	VSI, Pune, Maharashtra

In parallel, a comprehensive study to study the role of different constituents in sap is being done by selectively removing naturally growth hormones from the pristine sap and then correlating with crop performance. Suitable formulations are being designed for enhancing the efficacy of the sap. Further, laboratory studies would be done to prepare natural surfactants and test their performance as an additive. Finally, techno-economic assessment for the use of sap technology would be done for all the crops.

4. Results

The following section summarizes results obtained from 100 trials carried out so far in collaboration with different participating Institutes/ State Agricultural Universities and CSIR-CSMCRI who have undertaken different experiments at their centres at on-station/farmer's fields. The results which are up to March 2013 are summarized crop wise for different centres.

RICE

Effect of seaweed sap on yield of Rice

Names of Institute/ University and its location	K Sap concentration giving maximum yield	Trial Type	Test Variety	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
BCKV (Nadia, (West Bengal)	15% K sap +RDF	Agro	IET 1081	5950 **(31.9%)**	7490 **(43.2%)**
	2.5 % K sap +RDF	Demo		4950 **(14.3%)**	5590 **(10.7%)**
ICAR-CRRI (Cuttack centre)	10 % K sap +RDF	Agro	Naveen	5820 **(8.4%)**	6380 **(12.1%)**
	5% K sap +RDF	Demo		5430 **(12.7%)**	5800 **(12.4%)**
ICAR-CRRI (Assam centre)	5% K sap +RDF	Agro	Naveen	5850 **(18.2%)**	6450 **(16.0%)**
	5% K sap +RDF	Demo		5650 **(11.9%)**	ND
ICAR-CRRI (Hazaribagh, Jharkhand centre)	K sap 10.0% +RDF	Agro	Sahabhagi Dhan	2650 (NS)	3280 (NS)
	5% K sap	Demo	Abhisekh	3260**(14.4%)**	7430**(7.1%)**
PSB, (Shantiniketan, West Bengal)	10% K Sap +RDF	Agro	Swarna MTU 7029	6790 (**61.3%**)	7530 (**14.2%**)
	2.5% K sap	Demo		4830 **(28.1%)**	4790 **(14.9%)**
AAU (Jorhat, Assam)	15% K sap +RDF	Agro	Ranjit	4830 **(16.9%)**	1168 **(25.0%)**
	2.5% K sap +RDF	Demo-Site-1		4750 **(17.2%)**	ND
	2.5% K sap +RDF	Demo-Site-2		4650 **(10.7%)**	
ICAR NEH Region, Umiam, Meghalaya)	15.0% K sap + RDF	Agro	Shahsarang-1	5360 **(11.8%)**	7340 **(2.4^{NS})**
OUAT (Bhubaneswar, Odisha)	10.0 % K sap + RDF	Agro	Lalat	5094 **(10.1%)**	5953 **(2.9%^{NS})**
MPUA&T (Udaipur,Rajasthan)	15% K sap +RDF	Agro	P1121	4864 **(11.4%)**	7220 (**12.1%**)
PAU (Ludhiana, Punjab)	15.0 % K sap +RDF	Agro	PR115	6470 **(17.4%)**	6400 **(16.8%)**
RAU (Samastipur, Bihar)	10.0% K sap +RDF	Agro	Rajendra Masoori	5100 **(23.8%)**	6350 **(20.3%)**

RRRS (Vyara, Gujarat)	10% K sap +RDF	Agro	NAUR-1	6484.7 (**28.3%**)	6376.8 **(8.0%)**
CCS HAU, Kaul, Haryana	15.0% K sap +RDF	Agro	HKR-47	**7757 (1.1%^{NS})**	8180 (-0.98%^{NS})
GKVK (Bangalore, Karnataka)	15% K sap +RDF	Agro	Tanu	4886.3 **(11.2%)**	8758.8 **(12.8%)**
ANGARU (Hyderabad, Andhra Pradesh)	10% K sap +RDF	Agro	RNR 1446 Satya	6328 **(11.3%)**	6657 (**12.0%**)
UAS (Dharwad, Karnataka)	10% K sap +RDF	Agro	MTU-1001	5536 **(23.2^{NS})**	**ND**
TNAU (Coimbatore, Tamil nadu)	15 % K sap +RDF	Agro	ADT-43	6294 **(8.9%)**	7391 **(9.6%)**
BAU (Ranchi, Jharkhand)	10 % K sap +RDF	Agro	Naveen	4554.50 **(54.1%)**	5693.21**(44.1%)**

K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers
***Figures in parentheses indicate percent improvement over control (water spray+RDF) for that character**
***ND: Not done**
***NS: Not Significant**

In rice crop, application of K sap in conjunction with recommended dose of fertilizers (RDF) was found to be effective in increasing the number of tillers, number of grains per panicle, filled grains per panicle over control (RDF+water spray) in most of the places. This eventually led to higher grain yield over control. The per cent grain yield improvement over control was in the range from 8.4 to 61.3. North Eastern region centre (PSB, Birbhum, West Bengal) reported the highest grain yield improvement of 61.3% (6790 Kg ha^{-1}) by foliar spray of K sap (10% concentration). Rice variety, Naveen was employed at two centres of Central Rice Research Institute (ICAR-CRRI), at Assam and Cuttack, Odisha and it was found that it best responds at 5% concentration of the K sap in conjugation with recommended dose of fertilizers for that region. The maximum grain yield improvement by K sap at Assam and Cuttack were 8.4% and 18.2%, respectively, and the improvements were found statistically significant over control where recommended dose of fertilizers (RDF) + water spray was done. Varietal responses were also observed in some centres. In north eastern region (ICAR-CRRI, Hazaribagh centre), there was difference in yield improvement of straw using the same variety (Sahabhagi Dhan), Straw yield improvement is beneficial as fodder for cattle and it was also increased up to 44.1% (5693.21 Kg ha^{-1}) by foliar spray of K sap at 10% concentration in BAU (Ranchi, Jharkhand) centre. This was closely followed by BCKV (Nadia, West Bengal) centre with 43.2% (7490 Kg ha^{-1}) increment over control at 15% concentration of K sap.

Rice crop sprayed with K Sap by a farmer in west Bengal

Farmers benefiting from sea weed sap spray at Gerua, Assam

Large scale demonstration of K sap on rice at Hazaribhagh Jharkhand

MAIZE

Effect of seaweed sap on yield of maize

Names of Institute/ University and its location	K Sap concentration giving maximum yield	Trial Type	Test Variety	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
BCKV (Nadia, West Bengal)	15 % K sap +RDF	Agro	Disha 3502	3595 **(48.43%)**	ND
	12.5% K sap +RDF	Demo		2660 **(14.6%)**	
PSB, (Shantiniketan, West Bengal)	15 % K sap +RDF	Agro	Rajkumar	3170 **(17.8%)**	1960 **(26.4%)**
	12.5 % K sap	Demo		2850 **(10.4%)**	1600**(-14.4%)**
RAU (Samastipur, Bihar	10.0% K sap	Agro	900 M Gold	7290 **(35.2%)**	8930 **(34.7%)**
ICAR NEH Region (Umiam, Meghalaya)	15% K sap	Agro	DA 61 A	5610 **(13.1%)**	16010**(14.3%)**
GKVK (Bangalore, Karnataka)	10% K sap +RDF	Agro	Hema (NAH 1137)	7695 **(15.8%)**	11615**(15.8%)**
MPUAT (Udaipur, Rajasthan)	15% K sap +RDF	Agro	PEHM-2	4599 **(15.7%)**	7620 **(22.1%)**
CCHAU, Hisar, (Karnal), Haryana	15% K sap +RDF	Agro	HQPM1	5786 **(11.5%)**	ND
ANGARU (Hyderabad, Andhra Pradesh)	10% K sap +RDF	Agro	DHM 117	9058 **(6.4^{NS})**	ND
UAS (Dharwad, Karnataka)	15 % K sap + RDF	Agro	CP 818	12530 **(4.6%^{NS})**	7407 **(6.7$_{NS}$)**
TNAU (Coimbatore, Tamil nadu)	15% K sap+ RDF	Agro	NK 6240	7242 (**13.8%**)	8737 **(11.1%)**
BAU (Ranchi,Jharkhand)	7.5% K sap +RDF	Agro	HQPM1	4092**(21.3%)**	7534 **(14.9%)**

K-sap- ***Kappaphycus*** **RDF- Recommended dose of fertilizers *Figures in parentheses indicate percent improvement over control (water spray+RDF)*ND: Not done *NS: Not Significant**

In maize crop application of K sap was found to be effective in increasing plant height, number of rows in cob, number of grains in each row, cob length (cm) and test weight over control (RDF + water spray). The per cent grain yield improvement over control was in the range from 10 to 48.3. The maximum and minimum percent improvement by K sap was 48.43 to 10.4 respectively. The highest grain yield of 3595 kg ha^{-1} was reported by foliar spray of K sap (15% concentration) in BCKV, Nadia, West Bengal centre. This was 48.43% improvement over control. This was closely followed by RAU (Samastipur, Bihar) centre with a yield of 7290 Kg ha^{-1} (35.2% improvement over control) at 10% concentration of K sap. At Haryana, maximum 11.5% improvement in grain yield was obtained by application of sap at 15%. In general, K sap at higher concentrations performed better in most of the centres. The carbohydrate content of grains improved significantly over control by sap applications.

***Kappaphycus* sap being sprayed on maize crop at Umiam, Meghalaya**

Maize cob size significantly improved by foliar spray of seaweed sap at Udaipur, Rajasthan

BLACKGRAM

Effect of seaweed sap on seed yield of blackgram

Names of Institute/ University and its location	K/G Sap concentration giving maximum yield	Trial Condition	Test Variety	Seed yield (kg ha^{-1})
BCKV (West Bengal)	15.0% K sap +RDF	Agro	Sarada	1352 **(51.1%)**
	5 % K sap +RDF	Demo		1095.5**(21.7%)**
MPUAT, (Udaipur, Rajasthan)	10.0% K sap +RDF	Agro	PU-31	1025**(26.5%)**
	5% K + RDF (Farmer's Field)	Demo (5 Sites Avg.)		735 **(13.07%)**
NAU (Navsari, Gujarat)	15.0% K sap +RDF	Agro	GU-1	800.0 **(12.5%)**
	5% K sap	Demo		433.0 **(6.1%)**
PDKV (Akola, Maharashtra)	15% K sap +RDF	Agro	TAU-1	1349.72 **(67.3%)**
GBPUAT (Pantnagar, Uttaranchal)	10% K sap +RDF	Agro	PU-31	1901.23 **(27.4%)**
	5 % K sap +RDF	Demo	PU-31	1890 **(17.4%)**
PSB, (Shantiniketan, West Bengal)	15% K sap +RDF	Agro	Sarada WBU108	1822.08 **(43.1%)**
ANGRAU, Lam, Guntur (AP)	10% K sap +RDF	Agro	PU-31	1043 **(26.7%)**
	5 % K Sap +RDF	Demo	LBG-685	1300 **(8.3%)**
TNAU, (Coimbatore, Tamil nadu)	15% K sap +RDF	Agro	ADT 5	888.0 **(8.8%)**
UAS (Dharwad, Karnataka)	10% K sap +RDF	Agro	GVV-2	1164.71**(16.3^{NS})**

K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers *Figures in parentheses indicate percent improvement over control (water spray+RDF)*ND: Not done *NS: Not Significant

In general, blackgram responded well at higher (15%) concentrations of *Kappaphycus* sap. The per cent seed yield improvement over control was in the range from 6.1 to 51.1. The maximum and minimum percent increment by K sap was 67.3 to 8.8 respectively. Highest seed yield of 1349.7 Kg ha^{-1} (67.3% improvement over control) was reported at PDKV, Akola (Maharashtra) at 15% K sap concentration. Equal responses were also reported at Palli Siksha Bhavan (Shanthiniketan, West Bengal), Bidhan Chandra Krishi Viswavidyalaya (Nadia, West Bengal) centres with percentage improvement over control in the range of 39.2 to 51.1. At Gujarat (Navsari), 15% K sap application resulted in 12.5% improvement in grain yield.

Progressive farmers at Banswara, Rajasthan who got significant yield enhancement of *Kappaphycus* seaweed sap telling about the goodness of the product (an AcSIR effort)

Improvement in black gram being showed by *Kappaphycus* spray at Pantnagar, Uttarakhand

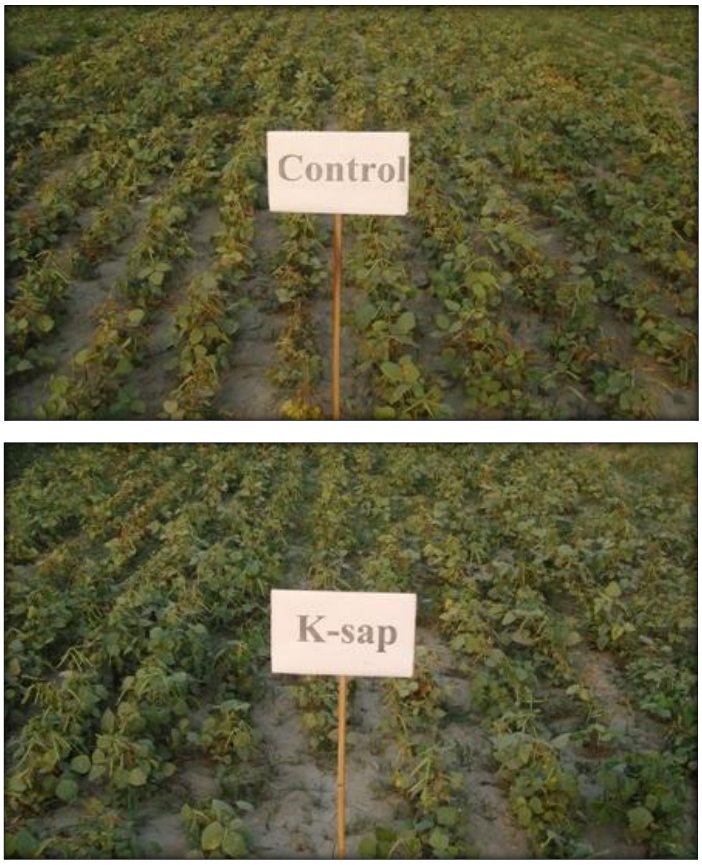
GREENGRAM

Effects of seaweed sap on seed yield of greengram

Names of Institute/ University and its location	K Sap concentration giving maximum yield	Trial Condition	Test Variety	Seed yield (kg ha^{-1})
BCKV (Nadia West Bengal)	15% K sap +RDF	Agro	Samrat	1265.0 **(39.0%)**
	5% K sap +RDF	Demo		1059.1 **(17.6%)**
MPUA&T (Bhilwara, Rajasthan)	10% K sap +RDF	Agro	K-851	825 **(25.4%)**
SDAU (S.K. Nagar, Gujarat)	5% K sap +RDF	Agro	GM-4	581 **(32.6%^{NS})**
	5% K sap	Demo		466.7 **(22.8%)**
PDKV (Akola, Maharashtra)	15% K sap +RDF	Agro	Kopergaon	873.46 **(29.2%)**
GBPUAT (Pantnagar, Uttaranchal)	10% K sap +RDF	Agro	Pant M-5	557.32 **(33.8%)**
	5% K sap + RDF	Demo	Pant M-5	600.8 **(15.2%)**
OUAT, (Bhubaneshwar, Odisha)	10% K sap +RDF	Agro	Samrat	1333 **(47.3%)**
ANGRAU (Krishna, A.P.)	10% K sap +RDF	Agro	LGG 460	741 **(10.6%)**
	5% K sap	Demo		1075 **(4.8%)**
TNAU (Coimbatore,Tamil nadu)	15% K sap +RDF	Agro	ADT 5	938 **(9.3%)**
UAS (Dharwad, Karnataka)	10% K sap +RDF	Agro		1249.4 **(21.1%^{NS})**

NB: K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers
***Figures in parentheses indicate percent improvement over control (water spray+RDF)**
***ND: Not determined *NS: Not Significant**

Application of K sap produced significant improvement in seed yield of greengram over control in majority of centres. The maximum and minimum per cent increment by K sap was 47.3 to 9.3 respectively. Green gram responded very well at higher concentrations of *Kappaphycus* and resulted in yield increase in excess of 20% in most places. Foliar application of 10% K sap produced the highest seed yield of 1333 Kg ha^{-1} (47.3% improvement over control) at OUAT (Bhubaneshwar, Odisha) centre. This was closely followed by Bidhan Chandra Krishi Viswavidyalaya (Nadia, West Bengal) centre with 1265.0 kg ha^{-1} at 15% concentration of K sap which recorded 39% increment over control. Similar responses (ca. 30%) were reported in PDKV Akola, and GBPUAT (Pantnagar, Uttaranchal) centres by application of the K saps at higher (15 or 10% concentration).



Difference being shown in greengram crop by spray of *Kappaphycus* sap on green gram at Pantnagar, Uttarakhand

Green gram crop sprayed with seaweed sap at Bhilwara, Rajasthan

SOYBEAN

Effects of sea weed sap on seed yield of soybean

Names of Institute/ University and its location	K Sap concentration giving maximum yield	Trial Condition	Test Variety	Seed yield (kg ha^{-1})
BCKV (Nadia,West Bengal)	15% K sap +RDF	Agro	PK-327	3330 **(72.5%)**
NAU (Navsari, Gujarat)	15% K sap +RDF	Agro	B.H. 18011D	878 **(11.3%)**
	12.5% K sap +RDF	Demo		1064.0 **(16.2%)**
DSR, Indore (MP)	10% K sap+RDF	Agro	JS-9560	2883 **(1.9%^{NS})**
PDKV (Akola, Maharashtra)	7.5% K Sap +RDF	Agro	JS-335	3163.43 **(45.0%)**
ANGRAU (Hyderabad A.P)	15% K sap +RDF	Agro	JS-335	3132 **(8.8%^{NS})**
	5% K sap	Demo		3150 **(22.1%)**
MPUA&T (Udaipur, Rajasthan)	15% K sap +RDF	Agro	JS-335	1824 **(16.4%)**
TNAU, (Coimbatore, Tamil nadu)	15% K sap +RDF	Agro	JS-335	1875 **(10.2%)**
UAS (Dharwad, Karnataka)	10% K sap +RDF	Agro	JS-335	4209 **(19.8%^{NS})**
BAU (Ranchi, Jharkhand)	7.5% K sap +RDF	Agro		1673.02 **(39.1%)**

NB: K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers
***Figures in parentheses indicate percent improvement over control (water spray+RDF)**
***NS: Not Significant**

Application of K sap produced significant improvement in seed yield of soybean over control in majority of centres. The highest seed yield of 3330 kg ha^{-1} at 15% concentration of K sap (72.5% improvement over control) was reported at Bidhan Chandra Krishi Viswavidyalaya (Nadia, West Bengal) centre. This was 65.3% improvement over control.

Trials of large scale soybean crop where *Kappaphycus* sap improved yield of soybean significantly at Coimbatore, Tamilnadu

Beneficial effect of seaweed sap on Soybean yield at farmer's field at Damoh, Madhya Pradesh

Soybean crop production improved at Kota, Rajasthan by seaweed sap spray

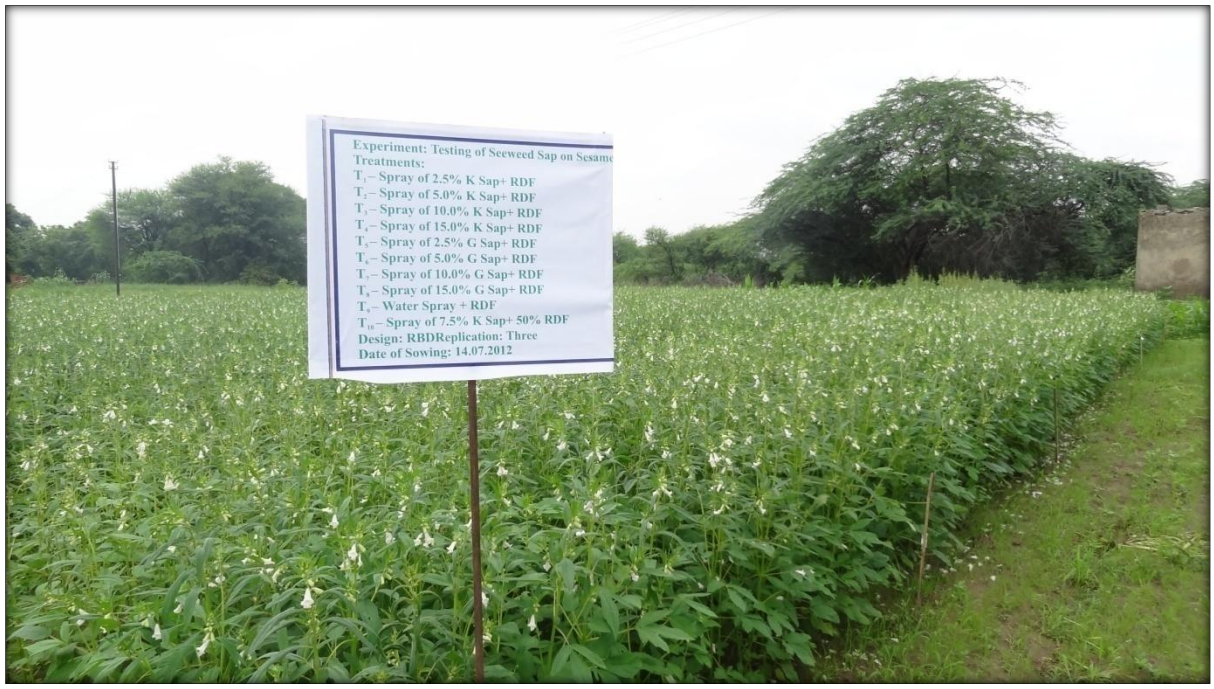
SESAME

Effects of seaweed sap on seed yield of sesame

Names of Institute/ University and its location	K Sap concentration giving maximum yield	Trial Condition	Test Variety	Seed yield (kg ha^{-1})
BCKV (Nadia,West Bengal)	15% K sap +RDF	Agro	Tillotama	902 **(19.9%)**
	5% K sap +RDF	Demo		810 **(14.1%)**
PSB, (Shantiniketan, West Bengal)	15% K sap +RDF	Agro	Rama	1890 **(4.8%)**
	5 % K sap +RDF	Demo	Rama	1950 **(19.6%)**
MPUA&T (Udaipur, Rajasthan)	15% K sap +RDF	Agro	RT-46	803.0 **(24.7%)**
SDAU (S.K. Nagar, Gujarat)	15 % K sap +RDF	Agro	GT 3	1022 **(10.5% ^{NS})**
	5 % K sap +RDF	Demo		446 **(9.9% ^{NS})**
TNAU (Coimbatore, Tamil nadu)	15% K sap +RDF	Agro	TMV-7	691.0 **(5.8%)**
BAU (Ranchi, Jharkhand)	10% K sap +RDF	Agro	Guj-Til-3	796.0 **(29.9%)**
ANGRAU (Hyderabad A.P)	10% K sap +RDF	Agro	Ylm11	291.4 **(38.4%)**
	5 % K sap +RDF	Demo		280**(33.3%)**

NB: K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers
***Figures in parentheses indicate percent improvement over control (water spray+RDF)**
***ND: Not determined *NS: Not Significant**

The maximum and minimum percent increment by K sap+RDF over control (water spray+RDF) was 38.4 to 5.8 respectively with respect to seed yield of sesame. Maximum seed yield improvement (38.4% improvement over control) was reported in ANGRAU (Hyderabad) centre by 10% concentration of K sap. Higher plant height, number of branches, number of capsule attributed to highest yield in this centre. Similar trend of responses were observed in MPUA&T (Rajasthan) and BAU (Jharkhand) centres. The per cent improvement over the control was in the range from 24.7 to 29.9. The response was maximum at higher concentration of K sap (15%). 14.3% yield improvement was observed in demonstration trial taken at farmer's field in West Bengal centres with application of 5% K sap. In PSB (West Bengal) both oil content and oil yield was significantly affected by the treatments.



Sesame crop at Bhilwara, Rajasthan

Sesame crop at West Bengal with and without K sap at BCKV, West Bengal

SUGARCANE

Effects of seaweed sap on yield of sugarcane

Assam Agricultural University

Effect of *Kappaphycus* sap on the growth parameters, cane yield and juice quality in sugarcane

K Sap concentration giving maximum yield	NMC ('000/ha)	Cane yield (t/ha)	Brix%	Sucrose (%)
5.0% K sap + RDF	66.90	**75.64 (27.0%)**	24.12	18.79
Water spray + RDF	64.01	59.55	23.99	17.15
CD(5%)	9.93	14.74	NS	1.03

NB: NMC : Number of millable cane in thousands per hectare; NS=Not significant

In north eastern region (Assam Agric. University, Jorhat, Assam), application of seaweed sap derived from *Kappaphycus* resulted in significant increase in cane yield at the spray level of 5% level and above as compared to control of water spray with recommended fertilizer dose. Similarly, number of millable cane was also significantly influenced by the application. The highest cane yield at 10% concentration yielded 74.64 t ha^{-1} (27.0% increment over control). Quality of cane juice was invariably improved due to application of seaweed sap. Sucrose content of cane juice was significantly increased due to spraying of seaweed sap as compared to water spray irrespective of level of seaweed sap application.

Improvement in sprouting of sugarcane by sett treatment with sap in sugarcane at Tamilnadu

POTATO

Effects of seaweed sap on yield of potato

Names of Institutes/ University's	K Sap concentration giving maximum yield	Trial Conditions	Test Variety	Total tuber yield (t/ha)
PSB, Shanthiniketan, West Bengal	5 % K sap +RDF	Demo	Kufri Jyoti	35.56 **(26.6%)**
JNKVV (Madhya Pradhesh)	10 % K sap +RDF	Agro	*Kufri jyoti*	18.35 **(15.2%)**
SDAU (Gujarat)	10% K sap +RDF	Agro	*Kufri badshah*	31.02 **(25.2%)**
	5 % K sap	Demo		17.2 t/acre **(7.5%)**
BCKV (Nadia,West Bengal)	15% K sap +RDF	Agro	*Kufri jyoti*	25.05 **(37.4%)**
	5 % K sap	Demo		19.67 **(23.9%)**
RAU (Samistipur, Bihar	10.0% K +RDF	Agro	*Kufri jyoti*	18.67 **(13.4%)**
PAU (Punjab)	15% K sap + RDF	Agro	Local	20.1 **(12.3%)**
TNAU (Ooty, Tamil nadu)	10 % K Sap +RDF	Agro	*Kufri Himalini*	28.33 **(16.5%)**

NB: K-sap- *Kappaphycus* sap RDF- Recommended dose of fertilizers
***Figures in parentheses indicate percent improvement over control (water spray+RDF)**

In potato, application of *Kappaphycus* sap proved better towards increasing the tuber yield in majority of cases. Highest tuber yield of 25.05 t/ha was reported in BCKV, Nadia centre which was 37.4% higher over control by application of *Kappaphycus* sap@15% concentration. This was closely followed by SDAU (Gujarat) and JNKVV (Madhya Pradesh) centre, recording 25.2 and 15.2%, respectively using K sap @ 10% concentration. In Tamil Nadu centre, the highest tuber yield of 28.33 t/ha was recorded in the treatment (100% NPK + seaweed K sap 10% spray) and the percentage of yield increase over control was 16.5. The quality parameters, i.e., dry matter, specific gravity, ascorbic acid and starch content was found to be significantly different with increasing seaweed sap concentrations in combination with recommended dose of fertilizers. In Palli Siksha bhavan (Lateritic region of West Bengal) with one of the popular potato variety *Kufri Jyoti*, the potato crop gave good responses to the spray application of seaweed sap during the critical growth stages like tuber initiation and peak tuber bulking stage. Highest tuber yield of 35.56 t/ha (26.5% improvement over control) was reported by foliar application of K sap. Interestingly, Kufri jyoti variety responded almost identically to the extent of 13.4%-15.2% by application of 10% K sap at MP and Bihar, while the same variety responded better (37.4% increase) at higher concentration (15%) and the same variety at much lower concentration of 5% recorded 26.6% improvement in tuber yield of potato. The results indicate differential response to sap concentrations because of environmental influence of the location.

Seaweed sap improved yield of potato on a large scale at Ooty, Tamilnadu

Farmers at Nadia district of West Bengal benefiting from sap spray on potato

FODDER/GRASS

Effects of seaweed sap on yield of fodder

JNKVV (Jabalpur, MP)

Table 1. Effect of RDF with different concentrations of seaweed sap on quality parameters of berseem

K/G Sap concentration giving maximum yield	Crude Protein yield (q/ha)	Crude Fiber Yield (q/ha)	Grain yield (q/ha)	Stover Yield (q/ha)
10 % K sap +RDF	12.40 **(17.7%)**	15.20 **(17.3%)**	5.03 **(36.7%)**	60.43**(30.0%)**
RDF + Water Spray	10.54	12.96	3.68	46.60

- **TV: JB-5**
- Figures in parentheses indicate percent improvement over control (water spray+RDF)

Assam Agriculture University (Jorhat, Assam)

Table 1. Effect of seaweed saps on growth and yield attributes of oat.

K Sap concentration giving maximum yield	Green Forage Yield (q/ha)	DMY (q/ha)	Crude Protien yield (q ha^{-1})
RDF + 10.0% K sap	270.54**(23.9%)**	56.81	410.88 **(29.0%)**
RDF+ water spray	218.35	45.86	319.12

NS=Not significant

K sap at 10% concentration showed significant improvement in the fodder yield and quality parameters in berseem at JNKVV, Jabalpur, (Madhya Pradesh). The increase in the concentration of K sap with recommended dose of fertilizer significantly increased the crude protein yield (CPY) and crude fiber yield (CFY). The application of 10% K sap with RDF was found superior over water spray with recommended dose of fertilizer. The higher CPY and CFY were observed by10% K sap +RDF (12.40 and 15.20 q/ha), while minimum CPY and CFY were obtained with the application of RDF + water spray alone (10.54 and 12.96 q/ha). Similarly, *Kappaphycus* sap at 10% concentration improved the green forage yield of oat by 23.9% and crude protein yield by 29% at North eastern region (Assam).

Large scale trials showing significant improvement of Yield of berseem fodder by use of different concentrations of seaweed sap at Jabalpur, Madhya Pradesh.

Studies on principal constituents of sap: The presence of quaternary ammonium compounds was detected and quantified in the *Kappaphycus* sap. In the experiments carried out at CSIR-CSMCRI, Bhavnagar on studying the role of different constituents present in the sap by studying the effect of different modified formulations of *Kappaphycus* sap on maize, sap formulation devoid of gibberellin (GA_3), auxin (Ax) and sap devoid of both (GA_3) and (Ax) on the growth of maize was investigated. Foliar spray of specific PGR free sap and pristine *Kappaphycus* sap were applied on the crop in a pot culture experiment. It was observed that GA_3 free sap formulation enhanced grain yield of maize significantly over control. But, surprisingly, **selective removal of GA_3 from the pristine sap had profound stimulating effect on total dry weight above ground biomass yield over and above the pristine sap.** The enhanced biomass yield in this treatment correlated well with gas exchange parameters, leaf thickness and gross stomatal aperture. On one hectare basis, use of GA_3 free sap can provide additional 47 GJ of energy from increased above ground biomass excluding grains (stover) while at the same time sequester additional 3 tonnes of CO_2 over the use of pristine sap. Quaternary ammonium compounds were identified in the sap and were found to influence the productivity of maize. A few ionic liquids were tested and found to be suitable as natural surfactants.