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Effect of different levels of seaweed extract and humic acid granules on soil properties and productivity of Bengal gram (*Cicer arietinum* L.) in *Alfisols*

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Abstract
A field experiment was conducted at ZARS, UAS, GKVK, Bengaluru during *Rabi*, 2021. Two species (*Ascophyllum* sp. and *Sargassum* sp.) of seaweed extract (SWE) and humic acid granules (HAG) were applied to the soil at three levels (20, 30 and 40 kg ha^{-1}) and two times (basal and 30 days after sowing) to assess the effect of these granules on soil properties and productivity of Bengal gram. The experiment was laid out in RCBD with twelve treatments replicated thrice. Soil application of 100% NPK + SWEG (*Sargassum* sp.) @ 40 kg ha^{-1} recorded significantly higher grain yield (18.65 q ha^{-1}) followed by soil application of 100% NPK + humic acid granules @ 40 kg ha^{-1} (18.40 q ha^{-1}) and both were significant over control treatment with the application of 100% NPK along with FYM @ 7.5 t ha^{-1} (16.10 q ha^{-1}) and soil application of 100% NPK + SWEG (*Ascophyllum* sp.) @ 40 kg ha^{-1} (14.15 q ha^{-1}). Absolute control recorded significantly lower grain yield (5.73 q ha^{-1}). There was no significant variation was noticed upon application of different rates of seaweed extract and humic acid granules soil reactivity, electrical conductivity and organic carbon content of the soil. Soil application of S-SWEG @ 40 kg ha^{-1} along with 100% NPK showed higher available nitrogen, phosphorus and potassium at 60 DAS and at harvest which was on par with control treatment and T_{12}: 100% NPK + HAG @ 40 kg ha^{-1}. Hence, treatment involving 100% of NPK + SWEG (*Sargassum* sp.) @ 40 kg ha^{-1} was found to be superior in improving Bengal gram productivity over all other treatments.

Keywords: Bengal gram grain yield, humic acid, seaweed extract

Introduction

Pulses occupy a unique position in every known system of farming all over the world. Among pulses chickpea (*Cicer arietinum* L.), popularly known as gram or Bengal gram is mainly grown in *rabi* season. It is the member of family *Leguminaceae* and sub family *Papilionaceae.* It is originated in the area of present-day south-eastern Turkey and adjacent Syria. It is a significant source of human food and animal feed. Chickpea is a rich source of highly digestible dietary protein (17-21%), carbohydrates (61.5%) and fat (4.5%). It is also rich in Ca, Fe, niacin, Vitamin-B and vitamin- C. It's leaves contain malic acid which is very useful for stomach ailments and blood purification (Ahmad, 2017) [1].

Conventional agricultural production systems, coupled with lower productivity of the crops, need to be improved to accomplish sustainable production. It has been realized that any advance in an agricultural system resulting in higher crop production should reduce environmental impacts and enhance the sustainability of the system as a whole. In this context, the use of bio-stimulants in improving the effectiveness of conventional mineral fertilizers may be a good choice. Among many viable options, the use of seaweed extracts and humic acid may be a possible option.

Seaweeds are macrophytic algae. They form an integral part of marine coastal ecosystems. They include the macroscopic, multicellular marine algae that commonly inhabit the coastal regions of the world's oceans where suitable substrata exist. They grow in salt water or marine environment.

They are primitive type of plants lacking true roots, stems and leaves (Krishnamurthy, 1965) [17]. Seaweeds commonly grow on coral reefs or in rocky landscape at greater depths if sunlight can penetrate through the water. The uses of seaweeds have been cited as early as 2500 years ago in Chinese literature (Tseng, 2004) [30].

Seaweed application as farmyard manure, liquid extracts obtained from seaweeds have recently gained importance as foliar sprays (Thivy, 1961) [29], soil application and for soaking of seeds before sowing as it contains growth promoting hormones such as auxins (IAA and IBA), cytokinin (Durand *et al.*, 2003), trace elements (Fe, Cu, Zn, Co, Mo, Mn, Ni), vitamins and amino acids which helps in increasing root development, mineral absorption (Jeannin *et al.*, 1991) [12], enhance plant chlorophyll content, triggers early flowering, fruit set, ripening of fruits and shelf-life of the produce in number of crop plants (Zodape, 2001) [34].

The benefits of seaweeds as sources of organic matter and plant nutrients have led to their use as soil conditioners for centuries (Temple and Bomke, 1988) [28]. The high amount of water-soluble potash, other minerals and trace elements present in seaweeds are readily absorbed by plants and control mineral deficiencies and diseases. The carbohydrates and other organic matter present in the marine algae alter the nature of soil and improve the moisture retaining capacity. The application of seaweed as a source of plant nutrients reduces the adverse effect of conventional chemical fertilizers on the soil health by reducing their quantity of application and maintains the soil flora and fauna and thus maintaining the sustainability.

Humic substances (HS) are composed of humic and fulvic acids play a significant role in soil fertility and plant nutrition, they are frequently referred as black gold of agriculture. Humic acid (HA) is derived primarily through the biochemical decomposition of plant and animal wastes as well as microbial synthesis activity and it accounts for 65-70 per cent of soil organic matter (Gulser *et al.*, 2010) [9]. Plants grown on soil with sufficient humic acid experience less stress, grow healthier and yield greater. Humic acid acts as root stimulators and increase root growth and development, improve stress tolerance in plant and also act as soil conditioner and promote aggregate stability, aeration and improve water holding and nutrient supplying capacity of soil (Pettit, 2004) [21]. In addition, humic substances promote the conversion of a number of mineral elements into forms available to plants. The HS presence in soil may exert several effects on plant functions and some of these may result, directly or indirectly, in a modulation of ion uptake (Nardi *et al.*, 2002) [20]. The HS also improves plant development by improving cell membrane permeability, respiration, photosynthesis, oxygen and phosphorus absorption and providing root cell growth (Pizzeghello *et al*., 2013) [23].

Information on optimal application rates, timing and methods needs to be developed for specific crops, geographical locations and environments (Craigie, 2010). With this backdrop, experiment entitled "Influence of different levels of seaweed extract and humic acid granules on soil properties and productivity of Bengal gram (*Cicer arietinum* L.) in *Alfisols*" was conducted.

Material and Methods

A field experiment was conducted during *Rabi* season of 2021 to study on the soil application of seaweed extracts and humic acid granules on growth and yield of Bengal gram (*Cicer arietinum* L.) at M-Block, Agroforestry, UAS, GKVK, Bengaluru. It is located in the Eastern dry zone of Karnataka. The experiment was laid out in Randomized Complete Block Design (RCBD) with twelve treatments and three replications (Table 1). Two species (*Ascophyllum* sp. and *Sargassum* sp.) of seaweed extract (SWE) and humic acid granules were applied to soil at three levels (20, 30 and 40 kg ha^{-1}) and two times (basal and 30 days after sowing) as mentioned in table 2. Detailed chemical properties of seaweed and humic acid granules used in the study were given in table 3. The haulm yield per hectare and grain yield per hectare (q) were recorded from 10 plants from each plot and statistical analysis was done as given by Gomez and Gomez (1984) [8]. The soil chemical properties *viz.*, pH, EC, organic carbon, available N, P and K were determined following standard methodologies.

Table 1: Details of experiment

Location	M-Block, Agroforestry, GKVK, Bengaluru
Season	*Rabi*-2021
Crop	Bengal gram (Desi channa)
Variety	JG 11
Recommended dose of fertilizer (RDF)	25:50:50 (N, P_2O_5, K_2O kg ha^{-1})
FYM	7.5 t ha^{-1}
Seed rate	62.5 kg ha^{-1}
Design	Randomized Complete Block Design
Number of treatments	12
Number of replications	3
Gross plot size	4.5 m x 2.8 m (12.6 m^2)
Spacing	30 cm x 10 cm

Table 2: Treatment details of the field experiment

Treatment	Treatment details
T_1	Absolute Control
T_2	100% NPK (25: 50: 50 kg ha^{-1})
T_3	100% NPK + FYM @ 7.5 t ha^{-1} (Control)
T_4	T_2 + A-SWEG @ 20 kg ha^{-1}
T_5	T_2 + A-SWEG @ 30 kg ha^{-1}
T_6	T_2 + A-SWEG @ 40 kg ha^{-1}
T_7	T_2 + S-SWEG @ 20 kg ha^{-1}
T_8	T_2 + S-SWEG @ 30 kg ha^{-1}
T_9	T_2 + S-SWEG @ 40 kg ha^{-1}
T_{10}	T_2 + HAG @ 20 kg ha^{-1}
T_{11}	T_2 + HAG @ 30 kg ha^{-1}
T_{12}	T_2 + HAG @ 40 kg ha^{-1}

Note

A-SWEG	*Ascophyllum* sp. Seaweed Extract Granules	Seaweed extract and humic acid granules applied two times (as basal and 30 DAS)
S-SWEG	*Sargassum* sp. Seaweed Extract Granules	
HAG	Humic Acid Granules	

Table 3: Chemical properties of Seaweed extract, humic acid granules and farm yard manure used in the field experiment

Parameters	Seaweed extract granules		Humic acid granules	FYM
	Sargassum sp.	*Ascophyllum* sp.		
pH	10.05	9.89	4.01	7.09 (1:10)
EC (dS m^{-1})	-	-	0.52	1.19 (1:10)
Total organic carbon (%)	14.63	11.12	14.39	15.30
Nitrogen (%)	0.87	0.71	0.84	0.53
Phosphorus (%)	1.05	0.96	0.14	0.37
Potassium (%)	1.45	1.38	0.06	0.65
Calcium (%)	0.11	0.09	0.91	1.31
Magnesium (%)	0.01	0.01	0.42	0.67
Total S (%)			0.27	0.29
Iron (mg kg^{-1})	556	484	1043	898
Manganese (mg kg^{-1})	281	242	209	156.08
Zinc (mg kg^{-1})	140	113	90	62.64
Copper (mg kg^{-1})	69	48	42	28.99
E_4/E_6 ratio			4.61	
C:N ratio				30.21

Initial soil properties of the experimental site

A composite soil sample was collected from the experimental plot at 0-15 cm depth before treatment imposition and analysed for its physico-chemical properties following standard procedures. The soil was sandy clay loam in texture with red colour. It belongs to the *Isohyperthermic* family of the sub group *Typic kandicpaleustalfs*. The pH of the soil was 6.01 (slightly acidic). The soil was low in available nitrogen (232.2 kg ha^{-1}), high in available phosphorus (58.78 kg ha^{-1}) and medium in available potassium (174.01 kg ha^{-1}). The available sulphur and DTPA extractable micronutrients content of the soil were above their respective critical levels. Details of initial soil characteristics of the experimental site are given in Table 4.

Table 4: Initial physico-chemical properties of the soil from the experimental site

Particular	Values	Method followed
A. Mechanical properties		
1. Sand (%)	54.23	International Pipette method (Piper, 1966) [22]
2. Silt (%)	21.66	
3. Clay (%)	24.11	
4. Textural classes	Sandy Clay Loam	
5. Bulk density (Mg m^3)	1.36	Keen rackzowski method (Baruah and Barthakur, 1997) [3]
6. MWHC (%)	40.48	
B. Chemical properties		
1. Soil pH (1:2.5)	6.01	Potentiometry (Jackson, 1973) [11]
2. Electrical Conductivity (dS m^{-1}) at 25°C (1:2.5)	0.043	Conductometry (Jackson, 1973) [11]
3. Organic Carbon (per cent)	0.39	Wet oxidation (Walkley and Black, 1934) [31]
4. Available N (kg ha^{-1})	232.2	Alkaline permanganate method (Subbaiah and Asija, 1956) [27]
5. Available P_2O_5 (kg ha^{-1})	58.78	Bray's extraction method (Bray and Kurtz, 1945) [5]
6. Available K_20 (kg ha^{-1})	174.01	Flame photometry (Jackson,1973) [11]
7. Exchangeable Ca [c mol (p^+) kg^{-1}]	3.70	Complexometric titration method (Jackson, 1973) [11]
8. Exchangeable Mg [c mol (p^+) kg^{-1}]	1.65	
9. Available S (kg ha^{-1})	17.90	Turbidometry extraction method (Black 1965) [4]
10. DTPA extractable Fe (mg kg^{-1})	15.20	Atomic Absorption Spectrophotometry (Lindsay and Norwell, 1978) [18]
11. DTPA extractable Mn (mg kg^{-1})	15.80	
12. DTPA extractable Zn (mg kg^{-1})	0.78	
13. DTPA extractable Cu (mg kg^{-1})	0.70	
14. Available B (mg kg^{-1})	0.39	Hot water-soluble extraction method (John *et al.*,1975) [13]
C. Biological properties		
Dehydrogenase activity (g TPF $g^{-1}hr^{-1}$)	39.25	TTC reduction technique (Casida, 1964) [7]
Acid Phosphatase activity (g PNP g^{-1} hr^{-1})	30.46	Eivazi and Tabatabai (1977)
Urease activity (g NH_4^+-N $g^{-1}hr^{-1}$)	27.43	Eivazi and Tabatabai (1977)
Biomass carbon (g g^{-1} soil)	130.37	Extraction method (Brookes *et al.*, 1982) [6]
Biomass nitrogen (g g^{-1}soil)	15.21	Extraction method (Brookes *et al.*, 1982) [6]

Results and Discussion

Haulm and grain yield (q ha^{-1})

The data on haulm and grain yield of bengal gram as influenced by soil application of seaweed and humic acid granules are presented in Table 5. Among the treatments, significantly higher haulm and yields were observed in T_9: 100% NPK + S-SWEG @ 40 kg ha^{-1} (58.72 and q ha^{-1}) followed on par with the results obtained from the treatment T_{12}: 100% NPK + HAG @ 40 kg ha^{-1} (52.69 and 18.40 q ha^{-1}). Both T_9 and T_{12} were significantly higher over control treatment which was supplied with 100% NPK along with FYM @ 7.5 t ha^{-1} (31.32 and 16.10 q ha^{-1}). Absolute control (T_1) recorded significantly lower haulm and grain yield (25.33 and 5.73 q ha^{-1}).

The yield attributes are important parameters for agricultural technology. The use of SWE increased all the yield attributes *viz.* Number of flowers $plant^{-1}$, Number of pods $plant^{-1}$, Pod weight (g $plant^{-1}$), Seed weight (g $plant^{-1}$), 100 seed weight (g) of bengal gram. This might be due to the various nutrient concentrations in the SWE. This was in conformity with the findings of Singh *et al.* (2021) [25] in rice crop where the foliar application of 2.5% K sap with100% RDF improved the yield attributes *viz*., number of productive tillers, test weight and number of grains per panicle.

The increased grain and haulm yield by the SWE application also might be due to increased plant height, no. of branches, chlorophyll, root weight and root length by the presence of versatile plant nutrients in SWE (Banakar *et al.*, 2018) [2].

Iswarya *et al*. (2019) [10] also reported more nutrient uptake, nutrient use efficiency by SWE application by triggering the plant growth and vigour in-turn reflecting the higher yield of greengram. The results attributed are phyto- hormones, amino acids, vitamins, antibiotic substances present in the SWE enhanced the root volume, biomass accretion, dispersal of photosynthates from vegetative parts to flowering and then promote the growth of plant. The results matched with Pramanick *et al.* (2017) [24] in potato, the K sap at 7.5% along with 100% RDF improved the yield over the 5% sap with 100% RDF.

Harvest index

There was no significant variation in harvest index upon application of different rates of seaweed extract and humic acid granules. However, the data on harvest index of Bengal gram varied from 0.37-0.40 (Table 5).

Table 5: Effect of seaweed extract and humic acid granules on haulm yield, grain yield and harvest index of bengal gram

Treatments	Haulm yield (q ha^{-1})	Grain yield (q ha^{-1})	Harvest index
T_1: Absolute Control	9.59	5.73	0.37
T_2: 100% NPK (25: 50: 50 kg ha^{-1})	20.88	13.92	0.40
T_3: 100% NPK + FYM @ 7.5 t ha^{-1} (Control)	24.67	16.10	0.39
T_4: T_2 + A-SWEG @ 20 kg ha^{-1}	21.36	14.15	0.40
T_5: T_2 + A-SWEG @ 30 kg ha^{-1}	22.89	15.10	0.40
T_6: T_2 + A-SWEG @ 40 kg ha^{-1}	23.81	15.61	0.40
T_7: T_2 + S-SWEG @ 20 kg ha^{-1}	25.08	16.60	0.40
T_8: T_2 + S-SWEG @ 30 kg ha^{-1}	26.82	17.78	0.40
T_9: T_2 + S-SWEG @ 40 kg ha^{-1}	29.23	18.65	0.39
T_{10}: T_2 + HAG @ 20 kg ha^{-1}	25.67	16.86	0.40
T_{11}: T_2 + HAG @ 30 kg ha^{-1}	26.42	17.53	0.40
T_{12}: T_2 + HAG @ 40 kg ha^{-1}	27.72	18.40	0.40
S.Em. ±	0.88	0.62	0.014
C.D. (0.05)	2.59	1.82	NS

Note

A-SWEG	*Ascophyllum* sp. Seaweed Extract Granules	Seaweed extract and humic acid granules applied two times (as basal and 30 DAS)
S-SWEG	*Sargassum* sp. Seaweed Extract Granules	
HAG	Humic Acid Granules	

Organic Carbon, pH and Electrical Conductivity (EC)

No significant influence was noticed upon addition of seaweed extract and humic acid granules on organic carbon content, pH and Electrical Conductivity of soil at 60 DAS and at harvest (Table 6). However, numerically higher organic carbon (4.30 and 4.30 g kg^{-1} at 60 DAS and at harvest, respectively) was noted in T_9 which received 100% NPK + S-SWEG @ 40 kg ha^{-1} and lower organic carbon (3.70 and 3.60 g kg^{-1} at 60 DAS and at harvest, respectively) was recorded in untreated plot (T_1). Similarly, numerically higher pH and electrical conductivity values were recorded in the treatment T_9 (100% NPK + S-SWEG @ 40 kg ha^{-1}) and lower values were recorded in the treatment T_1 both at 60 DAS and at harvest.

Table 6: Effect of seaweed extract and humic acid granules on OC, pH and EC in soil at 60 DAS and at harvest of bengal gram crop

Treatments	pH		EC (dS m^{-1})		Organic carbon (g kg^{-1})	
	60 DAS	At Harvest	60 DAS	At Harvest	60 DAS	At Harvest
T_1: Absolute Control	5.90	5.89	0.041	0.040	3.70	3.60
T_2: 100% NPK (25: 50: 50 kg ha^{-1})	5.92	5.90	0.041	0.042	3.70	3.70
T_3: 100% NPK + FYM @ 7.5 t ha^{-1} (Control)	5.93	5.93	0.042	0.043	4.10	4.10
T_4: T_2 + A-SWEG @ 20 kg ha^{-1}	5.93	5.90	0.042	0.042	4.00	4.00
T_5: T_2 + A-SWEG @ 30 kg ha^{-1}	5.93	5.92	0.042	0.043	4.10	4.10
T_6: T_2 + A-SWEG @ 40 kg ha^{-1}	5.93	5.92	0.042	0.043	4.10	4.10
T_7: T_2 + S-SWEG @ 20 kg ha^{-1}	5.94	5.93	0.043	0.043	4.10	4.10
T_8: T_2 + S-SWEG @ 30 kg ha^{-1}	5.96	6.23	0.043	0.043	4.20	4.20
T_9: T_2 + S-SWEG @ 40 kg ha^{-1}	5.99	6.66	0.044	0.044	4.30	4.30
T_{10}: T_2 + HAG @ 20 kg ha^{-1}	5.94	5.95	0.043	0.043	4.10	4.20
T_{11}: T_2 + HAG @ 30 kg ha^{-1}	5.95	5.96	0.043	0.043	4.20	4.20
T_{12}: T_2 + HAG @ 40 kg ha^{-1}	5.98	6.34	0.043	0.044	4.20	4.20
S.Em. ±	0.49	0.50	0.004	0.004	0.20	0.30
C.D. (0.05)	NS	NS	NS	NS	NS	NS

Note

A-SWEG	*Ascophyllum* sp. Seaweed Extract Granules	Seaweed extract and humic acid granules applied two times (as basal and 30 DAS)
S-SWEG	*Sargassum* sp. Seaweed Extract Granules	
HAG	Humic Acid Granules	

Primary nutrients status of the soil

The data pertaining to primary nutrients (kg ha^{-1}) of soil at 60 DAS and after harvest of bengal gram crop due to soil application of seaweed extract and humic acid granules is presented in Table 7.

Available nitrogen

Soil application of S-SWEG @ 40 kg ha^{-1} along with 100% NPK showed higher available nitrogen (244.34 and 240.18 kg ha^{-1} at 60 DAS and at harvest, respectively) which was on par with control treatment which received 100% NPK along with FYM @ 7.5 t ha^{-1} (237.43 and 235.15 kg ha^{-1} at 60 DAS and at harvest, respectively) and T_{12} : 100% NPK + HAG @ 40 kg ha^{-1} (243.51 and 239.42 kg ha^{-1} at 60 DAS and at harvest, respectively) (Fig. 1). On the other hand, lowest available nitrogen (223.03 and 221.29 kg ha^{-1} at 60 DAS and at harvest, respectively) was recorded in untreated plots (T_1) as there was no nitrogen source applied.

Soil available nutrients plays a major role in crop productivity So, improving available nutrients is directly related to crop productivity. Seaweed extract can stimulate the growth and activity of beneficial soil microbes, including nitrogen-fixing bacteria. These bacteria convert atmospheric nitrogen into a form that can be used by plants. Seaweed extract can also help to improve the mineralization of organic nitrogen in the soil. This process converts organic nitrogen into a form that is available to plants. In addition to that, it can help to reduce nitrogen losses from the soil through leaching and volatilization as seaweed extract can improve the soil's water-holding capacity and cation exchange capacity. Khan *et al.* (2014) [14] found that soil application of seaweed extract increased the available nitrogen content of the soil by up to 20 per cent and Zhang *et al.* (2013) [32] reported that seaweed extract increased the abundance and activity of nitrogen-fixing bacteria in the soil.

Available phosphorus

Results revealed that the soil application of S-SWEG @ 40 kg ha^{-1} along with 100% NPK showed higher available phosphorus (63.89 and 62.81 kg ha^{-1} at 60 DAS and at harvest, respectively) which was on par with control treatment which received 100% NPK along with FYM @ 7.5 t ha^{-1} (61.00 and 59.87 kg ha^{-1} at 60 DAS and at harvest, respectively) and T_{12} : 100% NPK + HAG @ 40 kg ha^{-1} (63.77 and 62.04 kg ha^{-1} at 60 DAS and at harvest, respectively) (Fig. 2). On the other hand, lowest available phosphorus (54.66 and 53.76 kg ha^{-1} at 60 DAS and at harvest, respectively) was recorded in absolute control (T_1).

Seaweed increases the activity of soil microorganisms which in turn helps to release phosphorus from bound forms in the soil, making it more available to plants. Seaweed extract can help to reduce phosphorus fixation in the soil. Phosphorus can be fixed in the soil by minerals such as iron and aluminum, making it unavailable to plants. Seaweed extract contains substances that can chelate these minerals, preventing them from binding to phosphorus and making it more available to plants (Stirk *et al.*, 2014) [26]. Du Jardin (2015) found that seaweed extract application to tomato plants increased the soil available phosphorus levels and reduced phosphorus fixation in the soil. The study also found that seaweed extract increased plant growth and yield.

Available potassium

Soil application of S-SWEG @ 40 kg ha^{-1} along with 100% NPK showed higher available potassium (182.44 and 180.23 kg ha^{-1} at 60 DAS and at harvest, respectively) which was on par with control treatment received 100% NPK along with FYM @ 7.5 t ha^{-1} (178.95 and 175.98 kg ha^{-1} at 60 DAS and at harvest, respectively) and T_{12} : 100% NPK + HAG @ 40 kg ha^{-1} (181.78 and 179.56 kg ha^{-1} at 60 DAS and at harvest, respectively) (Fig. 3). On the other hand, lowest available potassium (165.23 and 162.08 kg ha^{-1} at 60 DAS and at harvest, respectively) was recorded in absolute control (T_1).

The significant increase in available NPK content in soil could be contributed by the indirect effect of SWE on stimulating microorganisms and releasing native nutrients (Khan *et al.*, 2009) [15]. Similar findings were reported by López-Mosquera *et al.* (2011) [19] that the increased available nutrients might be due to the mineral content present in the seaweed extract which could improve the plant biomass, nutrient status and soil microbial activities. The increased K availability might be due to release of K from nonexchangeable form to exchangeable K form by the microbial activity stimulated by the SWE application. Also, the potassium mineral present in the SWE in the present study might have contributed for improved K availability.

The result is line up with Khan *et al.* (2016) [16] that, the release of K from minerals as a result of reactions of soil particles with SWE or complex reactions to the solubilizing effect caused by acids produced during the biodegradation of SOM (mainly SWE) and the release of other cations from exchange sites could be attributed to the increase in K availability. Probably the SWE of decomposed substances in the soil would have stimulated the greater NPK availability (Zhang *et al.*, 2014) [33].

Table 7: Effect of seaweed extract and humic acid granules on available N, available P_2O_5 and available K_2O in the soil at 60 DAS and after harvest of bengal gram crop

Treatments	Avail. N (kg ha^{-1})		Avail. P_2O_5 (kg ha^{-1})		Avail. K_2O (kg ha^{-1})	
	60 DAS	**At Harvest**	**60 DAS**	**At Harvest**	**60 DAS**	**At Harvest**
T_1: Absolute Control	223.03	221.29	54.66	53.76	165.23	162.08
T_2: 100% NPK (25: 50: 50 kg ha^{-1})	235.59	232.65	59.48	58.80	176.46	174.78
T_3: 100% NPK + FYM @ 7.5 t ha^{-1} (Control)	237.43	235.15	61.00	59.87	178.95	175.98
T_4: T_2 + A-SWEG @ 20 kg ha^{-1}	237.00	233.48	59.74	59.00	177.05	174.79
T_5: T_2 + A-SWEG @ 30 kg ha^{-1}	237.22	234.41	60.15	59.44	177.46	175.41
T_6: T_2 + A-SWEG @ 40 kg ha^{-1}	237.39	234.58	60.86	59.47	177.82	175.55
T_7: T_2 + S-SWEG @ 20 kg ha^{-1}	238.09	235.27	61.49	60.18	179.76	177.22

T_8: T_2 + S-SWEG @ 30 kg ha^{-1}	243.19	237.52	62.99	61.83	180.86	178.98
T_9: T_2 + S-SWEG @ 40 kg ha^{-1}	244.34	240.18	63.89	62.81	182.44	180.23
T_{10}: T_2 + HAG @ 20 kg ha^{-1}	238.22	236.01	62.05	60.52	179.83	177.52
T_{11}: T_2 + HAG @ 30 kg ha^{-1}	241.94	236.86	62.34	61.07	180.20	178.11
T_{12}: T_2 + HAG @ 40 kg ha^{-1}	243.51	239.42	63.77	62.04	181.78	179.56
S.Em. ±	3.59	3.05	1.48	1.49	2.90	3.03
C.D. (0.05)	10.52	8.96	4.34	4.36	8.49	8.89

Note

A-SWEG	*Ascophyllum* sp. Seaweed Extract Granules	Seaweed extract and humic acid granules applied two times (as basal and 30 DAS)
S-SWEG	*Sargassum* sp. Seaweed Extract Granules	
HAG	Humic Acid Granules	

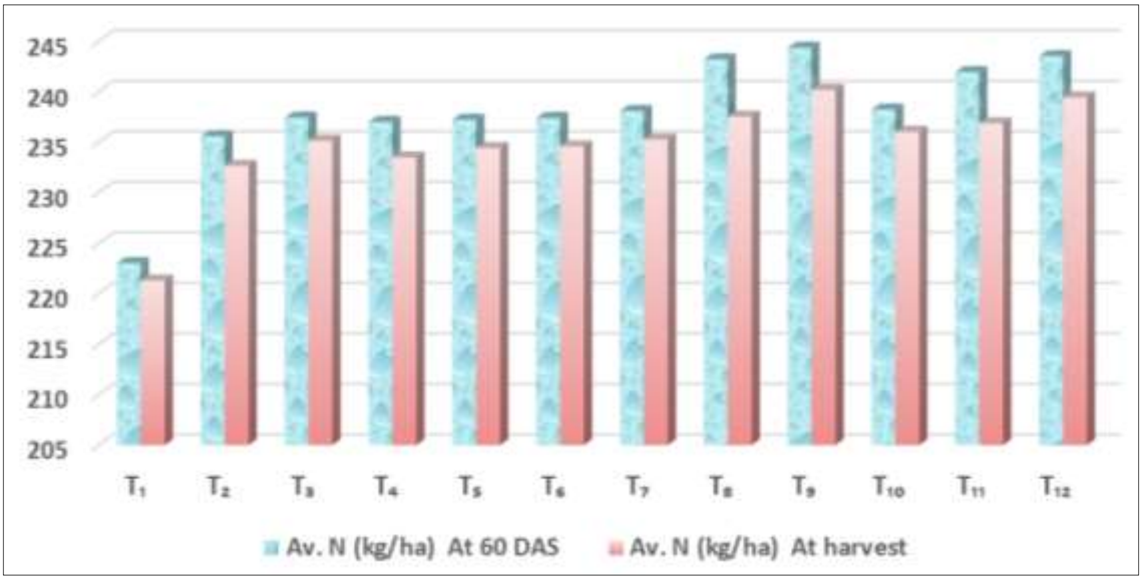

Fig 1: Effect of seaweed extract and humic acid granules on available nitrogen at 60 DAS and at harvest of bengal gram

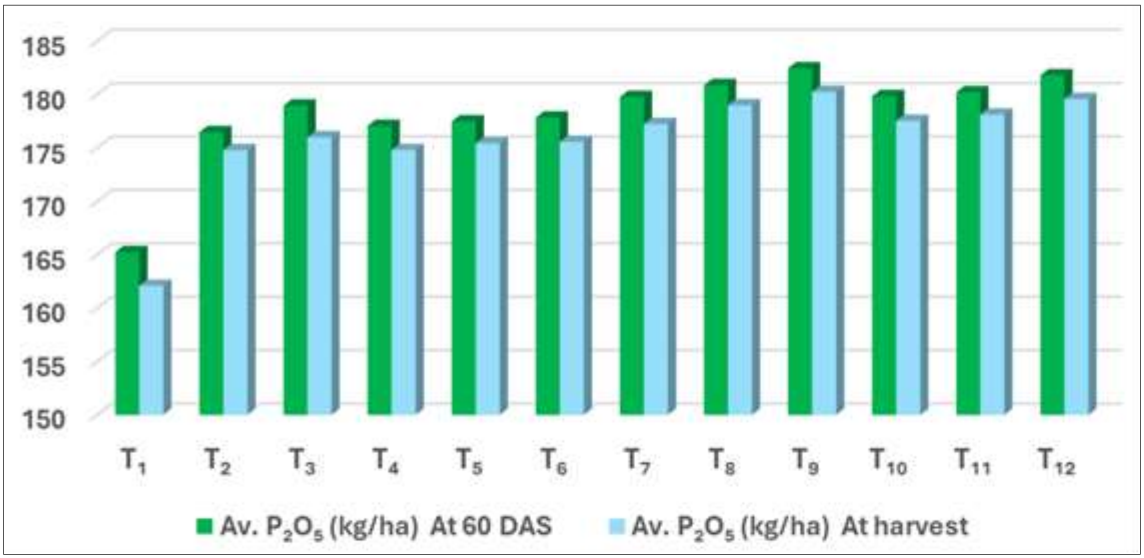

Fig 2: Effect of seaweed extract and humic acid granules on available phosphorus at 60 DAS and at harvest of bengal gram

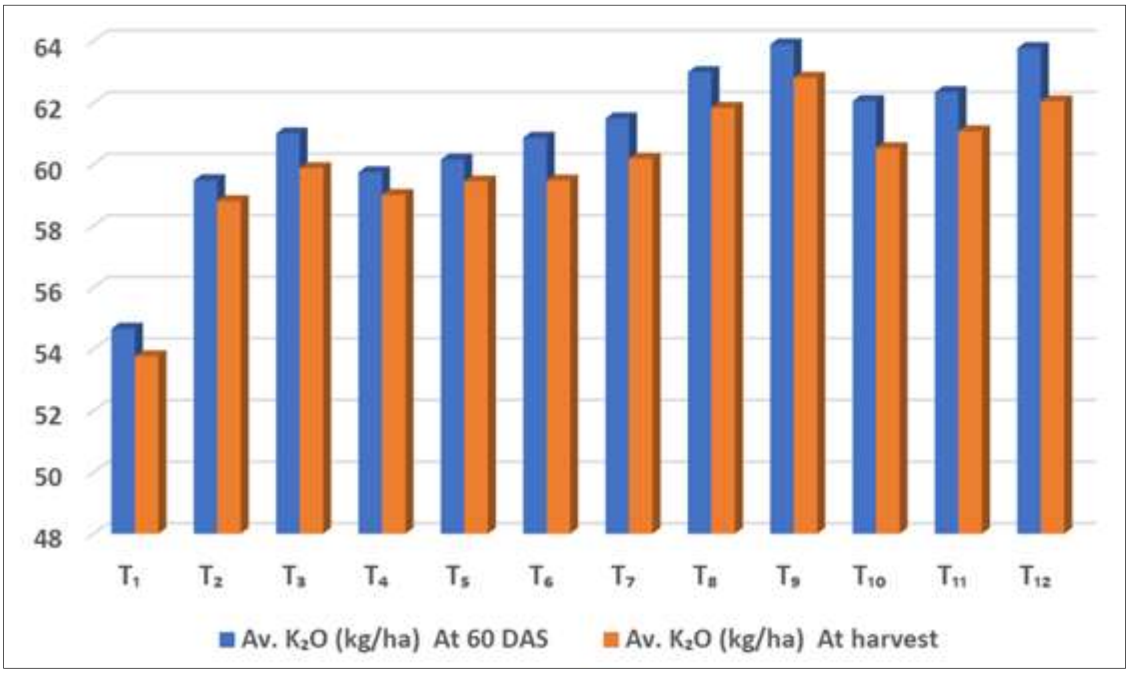

Fig 3: Effect of seaweed extract and humic acid granules on available potassium at 60 DAS and at harvest of bengal gram

Conclusion

Soil application of seaweed extract granules has a positive effect on soil properties and productivity of bengal gram. Soil application of 100% NPK + SWE Granules (*Sargassum* sp.) @ 40 kg ha^{-1} recorded significantly higher availability of major nutrients in soil and productivity of Bengal gram over control (100% NPK + FYM @ 7.5 t ha^{-1}).

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