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CROP PRODUCTION

MANUSCRIPT TITLE SEAWEED PLANT NUTRIENTS TO ENHANCE THE POPULATION AND HEALTH OF EARTHWORM *EUDRILUS EUGENIAE* ALONG WITH CROP BETTERMENT IN CHILLI *CAPSICUM ANNUM* (VAR. KKM-CH1) UNDER POT CULTURE

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Conflict of Interest
None declared.

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Abstract
In the present study, the effect of seaweed gel and seaweed fortified granules on earthworms of Eudrilus eugeniae and chilli co-cultured in pot mix was studied. The treatments were; the control (T0), which consisted only 5 kg of pot mix, in amendment 1, 0.05 gm seaweed gel (2.5 kg ha^{-1})+ 5 kg pot mix (T1), amendment 2: 0.1 gm seaweed gel (5.0 kg ha^{-1})+ 5 kg pot mix (T2), amendment 3: 0.2 gm seaweed gel (10.0 kg ha^{-1}) + 5.0 kg pot mix (T3), amendment 4: 0.5gm seaweed fortified granules (25 kg ha^{-1}) + 5.0 kg pot mix (A1), amendment 5: 1.0 gm seaweed granules (50 kg ha^{-1}) + 5 kg pot mix (A2) and amendment 6: 2.0 gm seaweed fortified granules (100 kg ha^{-1}) + 5 kg pot mix (A3). The number of cocoons and hatchlings in all treated earthworms were found significantly higher ($p < 0.05$) than control worms, similarly, in chilli, yield improvement upto 30.16 % along with increased capsaicin content were observed. The results of present study showed that both seaweed fortified granules and seaweed gel tested were found to enhance the health and population of earthworm and crop yield and quality of chilli at significant level ($p < 0.05$) and they can contribute to organic agriculture.

Keywords: *Seaweed gel; Seaweed fortified granule; Biostimulant; Earthworm; Chilli; Capsaicin.*

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1 Introduction

Modern agriculture is looking forward to new biotechnologies that would allow reduction of usage of chemical inputs without negatively affecting crop yield or the farmers' revenue (Herrera et al., 2013). Due to the presence of many bioactive substances, seaweed extracts act as plant biostimulants by improving conditions and vitality of plants (Gumul et al., 2011). Seaweed is a good source of proteins, vitamins, minerals, macro and micronutrients and can promote the growth of various vegetables, fruits and other important crops (Burtin, 2003). It improves seed germination, seedling development, increase plant tolerance to environmental stress and enhances plant growth and yield (Khan et al, 2009; Anisimov et al., 2013). Now-a-days, commercial seaweed extract products are available for use in agriculture and horticulture, and utilized in liquid form as a foliar spray, soil drench, or in granular and powder forms as soil conditioners and manure (Blunden, 1991; Zodape et al., 2011; Karthikeyan and Shanmugam, 2016). Therefore, seaweed extracts constitute an alternative to synthetic plant stimulants, the application of which very often cause environmental pollution and support to traditional fertilizer (Tuhy et al., 2013).

Earthworms play a vital role in the agricultural land and they contribute to the complex process of decomposition while affecting aeration, water transport and soil structure (Edwards and Lofty 1969; Reinecke and Viljoen, 1988). The earthworms have the ability to enhance the soil fertility. Many species of earthworm namely *Eisenia fetida*, *Lumbricus terrestris*, *Perionyx excavatus* and *Eudrilus eugeniae* are cultured in all parts of the world for agricultural purpose.

The impact of chemical fertilizer application on agricultural production is seen not only in terms of the soil quality but also for the survival of soil organisms dwelling therein. Earthworms are a major component of soil fauna in a wide variety of soils and climate are involved directly or indirectly in biodegradation and stabilization through humus formation and various soil processes. Earthworm populations are influenced by various factors like soil, temperature, moisture and pH (Baker et al., 1992). The abundance of earthworms in soils represents the health of soil ecosystems and the level of environmental safety. In the present study, the biostimulant activity of seaweed gel and seaweed fortified granules manufactured from *Sargassum swartzii* and *Kappaphycus alvarezii* on the population and health of earthworm and crop yield and capsaicin content of chilli co-cultured with earthworm under pot culture are described.

2 Materials and methods

Production and physicochemical properties of seaweed gel and seaweed fortified granule

300 kg of dry *Sargassum swartzii* (≈20 % moisture) was washed with water to remove dirt and salt and treated with alkaline water (2.0 % KOH) at 1:6 ratio at 30 – 32°C for 60min to soften it. Then alkali treated softened material was ground with a wet grinder (Kalinga Engineers, Orissa, India 60 HP motor with output capacity of 3 t h^{-1}) to get a thick pulp which was then filtered through 30 mesh to obtain a seaweed gel. Seaweed fortified granules were produced by fortifying sap manufactured from fresh biomass of *K. alvarezii* and aqueous extract of dry *S. swartzii* (1:1) with dolomite, an inert carrier material and total seaweed ratio in the granule product was at 3 % (w/w). Sap from *K. alvarezii* was produced as follows: 10.0 *t* of fresh biomass was quick washed and homogenized in a pulverizer (Fruit Juicer, Kalinga Engineer Ltd.; Capacity 2 t hr^{-1}, 600 mm dia hopper fitted with 40HP motor, Orissa, India) into slurry, which then was passed through D-canter (Pennwalt P3400 Model Super D canter Centrifuge, Pennwalt Ltd. Mumbai, India) to get liquid and wet solid residue separated, then separated liquid portion was double filtered (Sand filter and followed by ceramic filter 0.02 mm pore; A.T.E. Envirotech (P) Ltd. Mumbai, India) to obtain a clear liquid called Sap (bio-stimulant) as described by Shanmugam & Abhiram, and the *Sargassum* aqueous extract was obtained by soaking dry *S. swartzii* in water at 1:6 ratio for 60 min at room temperature (30 – 33°C) and filtered through a fine filter (pore size 0.02 mm). The pH was measured using pH meter (Model: Eutech Instrument). Elements were analyzed by flame photometers and atomic absorption spectroscopy (Association of Analytical community's 18th edition: 2005). The organic matter was burned off at 550°C for 4.0 h in a muffle furnace and determined its total content is samples gravimetrically. Plant growth regulators (PGRs) such as auxin, cytokinin and gibberellic acid were estimated using colorimetric methods as described by Prasad (Prasad et al, 2010).

2.1 Location of experiment

The experiment was conducted in the greenhouse of R&D Agri plot, AquAgri Processing Private Limited, Manamadurai, India (Latitude 9˚42′56″ N and Longitude 78˚28′2″ E) in January 2016.

2.2 Experimental design and treatments

The completely randomized design was used with 3 treatments each with seaweed gels and seaweed fortified granule and replicated 4 times. The pot, mix was made with manure, red soil and coco peat in the ratio of 2:1:0.5. The treatments were; the control (T0), which consisted only 5 kg of pot mix, amendment 1, 0.05 gm seaweed gel (2.5 kg ha^{-1})+ 5 kg pot mix (T1), amendment 2, 0.1 gm seaweed gel (5.0 kg ha^{-1})+ 5 kg pot mix (T2), amendment 3, 0.2 gm seaweed gel (10.0 kg ha^{-1}) + 5.0 kg pot mix (T3), amendment 4, 0.5gm seaweed fortified granules (25 kg ha^{-1}) + 5.0 kg pot mix (A1), amendment 5, 1.0 gm seaweed fortified granules (50 kg ha^{-1}) + 5 kg pot mix (A2) and amendment 6, 2.0 gm seaweed fortified granules (100 kg ha^{-1}) + 5 kg pot mix (A3).

2.3 Growth and reproduction of earthworms

The matured clitellate earthworms *Eudrilus eugeniae* were collected from Karthik Vermiculture farm, Vadipatti, Tamil Nadu, India and chilli nurseries (var. KKM-ch1, age 21 days) were collected from AquAgri nursery garden and used in the present study. The earthworms were removed from substrate at the time of harvest of chilli (90 d) and sieved gently and collected them using tissue paper. Number of cocoons and hatchling were counted manually and recorded. The mass of the earthworms was weighed using electronic balance and their diameter was measured with Vernier caliper meter (model: Forbes Premium, GG104646).

The matured earthworms were weighed and introduced into pot at 15 nos. per pot and transplanted chilli nursery at 2 nos. per pot. The moisture content of pots was maintained between 60±10% throughout the study period by sprinkling of water and additional dosage of seaweed gel and seaweed fortified granules were given to each test pot with dosage as mentioned above at time intervals of 30 d and 60 d.

Crop yield and capsaicin content of chilli

Vegetative growth of chilli like leaves, stem, root, plant height and yield and quality of chilli were recorded and capsaicin content of harvested chilly was estimated by using standard capsaicin (Palacio, 1977).

Analysis of the results

One-way analysis of variance (ANOVA, SYSTAT version 7) was used to determine the effect of seaweed gel and seaweed fortified granules on earthworms and chilli. Tukey's HSD test was applied for post hoc comparisons. Pearson correlation analysis was used to find out the significance in number and weight gain of earthworms and hatchlings and crop yield and capsaicin content of chili. All the statistical analysis was made using the SYSTAT version 7 (Systat, 1997).

3 Results

3.1 Physicochemical properties of seaweed gel and seaweed fortified granules

Physical and nutritional components of seaweed gel and seaweed fortified granules is given in table 1. Total organic matter of seaweed gel was 9.52 % and it was 1.19 % in seaweed fortified granules and ash content of both samples tested were 8.78 % and 70.12 % respectively. The macro nutrients nitrogen, phosphorus and potassium in seaweed gel estimated were 0.23 %, 0.01 % and 4.52 % respectively, they were 0.45 %, 0.21 % and 1.90 % in seaweed fortified granules. Seaweed gel was estimated to have 0.02 % calcium, 0.005 % of magnesium and 2.31 % sulphur as secondary nutrients and 42.31 %, 23.09 % and 0.29 % corresponded to all those 3 secondary nutrients in seaweed fortified granules. The micronutrients in seaweed gel were 7.21 ppm (Zn), 9.34 pp (Mn), 0.46 % (Na), 6.38 ppm (B), 5.0 ppm (Fe), 1.28 % (SiO_2), 0.1 % (chloride), 40.63 ppm (copper) and 1.17 % of cobalt and in seaweed fortified granules they were 0.90 ppm (Zn), 1.25 ppm (Mn), 0.90 % (Na), 0.79 ppm (B), 2.4 ppm (Fe), 0.5 % SiO_2, chloride 0.56 %, copper 5.08 ppm of copper and cobalt 0.16 ppm of cobalt. Plant growth promoters auxin, cytokinin and gibberellins were 335.5 ppm, 181.0 ppm and 488.5 ppm in seaweed gel and 41.25 ppm, 22.5 ppm, 62.5 ppm corresponded to same in seaweed fortified granules.

Table 1. Physico-chemical properties and nutrients contents of seaweed gel and seaweed granules

Physicochemical Parameters	Seaweed Gel*	Seaweed fortified granules**
Total organic matter (g $100g^{-1}$)	9.52	1.19
pH (1% solution)	8.09	9.03
Moisture content (g $100g^{-1}$)	81.70	6.60
Total ash (g $100g^{-1}$)	8.78	70.12
Bulk density (g cm^{3-1})	1.13	0.95
Macro nutrients		
Nitrogen (N) (g $100g^{-1}$)	0.23	0.45
Phosphorous (P) (g $100g^{-1}$)	0.01	0.21
Potassium (K)(as K_2O) (g $100g^{-1}$)	4.52	1.90
Secondary nutrients		
Calcium (Ca) (g $100g^{-1}$)	0.02	42.31
Magnesium (Mg) (g $100g^{-1}$)	0.005	23.09
Sulphur (S) (g $100g^{-1}$)	2.31	0.29
Micro nutrients		
Zinc (Zn) mg kg^{-1}	7.21	0.90
Manganese (Mn) (mg kg^{-1})	9.34	1.25
Sodium (Na) (g $100g^{-1}$)	0.46	0.90
Boron (B) (mg kg^{-1})	6.38	0.79
Iron (Fe) (mg kg^{-1})	5.0	2.40
Silica (SiO_2) (g $100g^{-1}$)	1.28	0.50
Chloride (Cl^-)(On Dry basis) (g $100g^{-1}$)	0.1	0.56
Copper (Cu) (mg kg^{-1})	40.63	5.08
Cobalt (Co) (mg kg^{-1})	1.17	0.16
PGR		
Auxin (mg kg^{-1})	335.5	41.25
Cytokinin (mg kg^{-1})	181.0	22.5
Gibberellin (mg kg^{-1})	488.25	62.5

* Recommended dose is 2.5 kg per hectare;
** Recommended dose is 20.0 kg per hectare

3.2 Population and growth of earthworms

The weight of mature earthworms was 5.30±0.30 g in control pot (T0) and 6.28±1.25 g, 6.53±0.85 g and 6.60±1.40 g corresponded to T1, T2 and T3 seaweed gel treated, whereas it was 5.82±0.65g, 6.10±0.35 and 6.50±0.55 g in A1, A2 and A3 of seaweed fortified granules treated pots respectively (p = 0.001). The cocoons were oval and irregular in shape and two ends of fibrous pointed and dark brown in color during the hatching period. The total number of cocoons in T0 pot was 102±8.50 and it was 160±12.0, 168±18.50 and 148± 6.80 in T1, T2 and T3 treatments and in A1, A2 and A3 it was 138±11.0, 151±15.0 and 157±15.0 respectively ($p<0.002$). The number of hatchings observed in T0 was 196± 20.15 whereas in T1, T2 and T3 it was recorded as 313± 21.50, 369±18.0 and 293±20.0 respectively with seaweed gel and 264 (11.50, 317 (21.50 and 366 (13.00 in A1, A2 and A3 respectively treated with seaweed fortified granules ($p < 0.001$). Diameter of control earthworm was 5.94±0.12 mm, T1, T2, T3 corresponded to 5.85±0.10, 6.90±0.12, 6.88 ± 0.25 mm and diameter earthworms treated with seaweed fortified granules i.e. A1, A2, A3 were 5.92±0.40, 6.26±0.15 and 6.76± 0.20 respectively (Table 3, Fig.1a-c).

Table 2. Growth and population of earthworms co-cultured with chilli treated seaweed gel and seaweed fortified granule

	Control (T0)	Treatment with seaweed gel			Treatment with seaweed fortified granule		
		T1	T2	T3	A1	A2	A3
No. of matured earthworms	27 ± 2.5^{aa}	26± 1.5^{aa}	28± 2.0^{aa}	28± 3.5^{aa}	27± 3.8^{aa}	28± 2.5^{aa}	26± 2.5^{aa}
Weight of matured earthworms	5.3± 0.3^{aa}	6.28± 1.25	6.53± 0.85	6.6± 1.40	5.8± 0.65	6.1± 0.35	6.5± 0.55
Diameter of matured earthworms	5.94± 0.12	5.24± 0.10	6.9± 0.12	6.88± 0.25	5.92± 0.40	6.26± 0.15	6.76± 0.20
No. cocoons	102± 8.5^{aa}	160± 12.0^{ab}	168± 18.5^{ab}	148± 6.8^{ab}	138± 11.0^{ab}	151± 15.0	157± 15.0
No. of hatchings	196± 20.15^{aa}	313± 21.5^{ab}	369± 18.0^{ab}	293± 20.0^{ab}	264± 11.50	317± 21.5	366± 13.0

Different letters indicate significant difference at the 0.05 level

Fig. 1 – Matured earthworms of control and treated with seaweed gel and seaweed fortified granules.

Fig. 2 – Hatchling earthworms of control and treated with seaweed gel and seaweed fortified granules.

3.3 Crop yield and capsaicin content of chilli

The number of fruits obtained per plant of chilli treated with seaweed gel was 40.80±5.0 (T1), 40.05±4.5 (T2) and 39.60 ± 6.5 (T3) ($p = 0.003$) whereas it was 41.00±3.0 (A1), 40.75±5.0 (A2) and 38.20±6.5 (A3) in chilli treatment with seaweed fortified granules ($p = 0.005$) and it was 31.5±6.5 control pot (T0). The capsaicin content estimated in T0 was 0.47±0.04 % and it was 0.52±0.02 %, 0.66±0.05 %, 0.62±0.03 % in T1, T2 and T3 respectively in significant level ($p < 0.005$) in seaweed gel treated whereas seaweed fortified granules treated plant it was 0.48±0.05 % in A1, 0.57±0.02 % in A2 and 0.57±0.03 % in A3 ($p < 0.03$) respectively. Vegetative growth of chilli like number of leaves, length and diameter of shoot and root etc. is given in Table 3.

Table 3. Vegetative growth, crop yield and capsaicin content of chilly treated with seaweed gel and seaweed fortified granule (SD±; $n = 10$)

Parameters	Control	Chilly treated with seaweed gel			Chilly treated with seaweed granules		
	T0	T1	T2	T3	A1	A2	A3
Number of leaves (no.)	21.00±5.09	31.80±9.33	28.80±8.59	28.80±1.44	31.40±7.86	23.40±11.57	23.80±5.15
Leaf thickness mm)	0.76±0.12	0.86±0.10	0.88±0.07	0.86±0.05	0.86±0.05	0.82±0.07	0.78±0.07
Leaves length (cm)	10.30±1.19	12.12±1.51	10.78±1.71	11.08±1.61	11.76±2.29	11.60±2.79	11.26±1.72
Leaf breadth (cm)	3.22±0.77	3.74±0.59	4.36±1.03	3.96±0.99	3.40±0.56	4.48±1.28	3.58±0.88
Stem dia (mm)	3.90±0.14	4.04±0.74	3.56±0.43	4.00±0.28	4.26±0.65	3.74±0.63	3.86±0.37
Root length (cm)	11.90±1.03	13.54±1.82	14.74±2.27	13.52±1.80	13.54±2.61	15.40±1.68	13.20±0.77
Root thickness (mm)	3.68±1.35	4.02±1.17	3.80±0.82	4.02±1.21	3.68±1.03	3.84±1.18	3.82±1.13
Plant height (cm)	55.34±4.65	55.58±9.70	58.96±5.41	56.14±4.95	54.88±8.69	56.02±6.38	53.62±5.89
Number of fruits / plant (no.)	31.5±6.5^{aa}	40.80±5.0^{ab}	40.05±4.5^{ab}	39.60±6.5^{ab}	41.0±3.0^{ab}	40.75±5.0^{ab}	38.20±6.5^{ab}
Yield increase over control (%)		29.52±3.5^{aa}	27.14±1.85^{aa}	25.71±2.20^{aa}	30.16±2.0^{aa}	29.37±2.5^{aa}	21.17±3.5^{aa}
Fruits length (cm)	14.04±2.58^{aa}	14.26±1.60^{aa}	14.98±1.25^{aa}	15.90±0.30^{aa}	14.40±1.78^{aa}	14.48±1.34^{aa}	16.14±0.89^{aa}
Capsaicin (w/w) (%)	0.47±0.04^{aa}	0.52±0.02^{ab}	0.66±0.05^{ab}	0.62±0.03^{ab}	0.48±0.05^{ab}	0.57±0.02^{ab}	0.57±0.03^{ab}

Different letters indicate significant difference at the 0.05 level

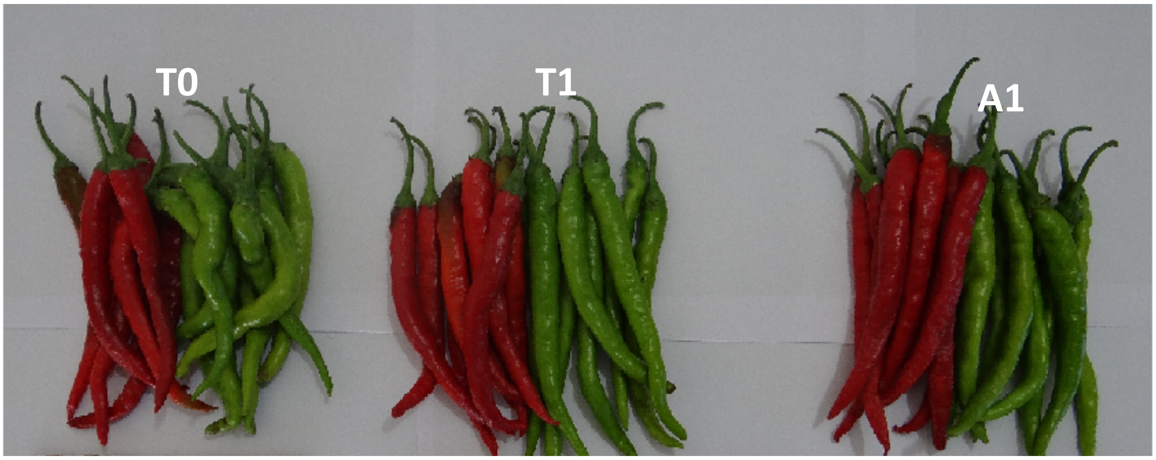

Fig. 3 - Crop yield of chilli treated with seaweed gel and seaweed fortified granules.

4 Discussion

Farming depends heavily on chemical fertilizer to increase crop production. Inorganic fertilizers are essential for high yield, but their long-term usage mischievous effects on the soil. In addition, of inorganic fertilizer to the soil, it showed negative effects on earthworms. Earthworms are a major component of soil and they involved directly or indirectly in stabilization and biodegradation and various soil processes. Overdosage of inorganic fertilizers can also kill earthworms and microorganisms in the soil, which is useful for the plant growth. Rathinamala (Rathinamala et al., 2011) observed that due to the usage of fertilizers the total number and biomass of earthworms in the cultivated land found less when compared with the non-cultivated land. Lalthanzara and Ramanujam (Lalthanzara and Ramanujam, 2010) reported that there was a radical decrease in earthworm populations and biomass in grassland soils which was treated only with nitrogenous fertilizers.

The health and population of earthworms treated with seaweed gel and seaweed fortified granule found increased with statistical level. Rai (Rai et al., 2014) observed that the weight of earthworms was found decreased steadily with the increase in the dose of urea, however, at the low concentration of urea, there was no significant change in morphology except the reduction in body weight, similarly, Edwards (Edwards et al., 1995) recorded the detrimental effect of chemical fertilizers to the earthworms. Ammonia based fertilizers can adversely affect earthworms because fertilizers with nitrogen when reacted with soil, it becomes acidic in nature and so this will be fatal for earthworms (Edward et al., 1995). Contradictory reports were also found that when there was the addition of N, it increased biological activity and enhanced earthworm growth and sexual activity to increase cocoon number and higher populations (Deibert and Lofty, 1994).

In the present study, both seaweed gel and seaweed fortified granule yield had positive effect on earthworm and chilli co-cultured in pots. In seaweed gel treatment, 56.86 % (T1), 64.71 % (T2) and 45.09 % (T3) of more cocoons were found whereas in seaweed fortified pots it was 35.29 %, 48.04 % and 58.92 % in A1, A2, A3 respectively over control. Similarly, hatchings were also found increased in seaweed treated trial as follow 59.69 % (T1), 88.27 % (T2), 49.49 % (T3), 34.69 % (A1), 61.73 (A2) and 86.73 % (A3). Edwards et al. (1995) study in New Zealand showed a 50 % increase in surface feeding earthworm species by the addition of one ton of lime per acre.

Temperature is one of the important factors for culturing earthworms. During the study period, atmospheric temperature, greenhouse temperature, pot temperatures were recorded as 30.7˚C to 36.5˚C, 29.6˚C to 35.3˚C and 24.03˚C to 25.12˚C respectively as given in table 4

Table 4. Temperature maintained during the study period

Day	Atmos. Temp (˚C)			Green House Temp (˚C)			Pot Temp ˚C		
	9.30 am	12.30 pm	4.30 pm	9.30 am	12.30 pm	4.30 pm	9.30 am	12.30 pm	4.30 pm
30	30.70 ± 1.12	34.80 ± 1.05	33.60 ± 1.67	29.67 ± 1.13	32.47 ± 1.36	32.73 ± 1.12	24.03 ± 0.64	24.97 ± 0.22	24.73 ± 0.95
60	31.62 ± 1.94	36.46 ± 1.49	34.76 ± 1.60	30.62 ± 1.90	32.38 ± 1.68	33.77 ± 1.67	24.23 ± 0.79	25.08 ± 0.99	25.12 ± 1.08
90	30.44 ± 1.85	35.18 ± 1.72	35.21 ± 1.29	29.52 ± 1.05	32.33 ± 1.75	34.10 ± 1.36	24.13 ± 0.48	24.90 ± 0.65	25.05 ± 1.12

Edwards (Edwards, 1988) reported that 20˚C reproduction of earthworm was mostly suitable at Viljoen and Reinecke (1992) recorded that the highest growth rate of *E. eugeniae* was observed at 29˚C and high mortality at 30˚C. Similarly, the rate of cocoon production of *E. eugeniae* of 3.22 cocoons was produced per earthworm per week at 25˚C was reported by Reinecke (Reinecke et al., 1992).

Karthick (Karthick et al., 2013) reported that growth rate of earthworm decreased when chemical liquid fertilizer was sprayed on them but it increased when seaweed liquid fertilizer was sprayed and similar kind of results were obtained in the present investigation that seaweed based gel and seaweed fortified granules found to stimulate the growth of earthworm *E. eugeniae* with statistically significant level ($p < 0.05$). However and Angela (However and Angela, 2011) had reported that the abundance of earthworm did not differ significantly over time as a function of seaweed treatment and also interaction effects were not detected.

Other researchers found positive effect of seaweed on other animals. Zaki (Zaki et al. 1994) reported that seaweed meals improved ration of feed conversion in common carp fish. O'Doherty (O'Doherty et al. 2010) recorded that newly weaned pigs showed the inclusion of laminarin-fucoidan extract decreased the counts of *E.coli* in the faeces and improved performance of pigs after weaning. Seaweeds contained substantial amounts of omega-3 fatty acids. The extract which contained significant levels of omega-3 fatty acid was recommended as a dietary supplement for fish nourishment (Chojnacka et al., 2012). Taher (Taher, 1986) observed that insertion of 5 % autoclaved seaweeds in the diets of broiler chicks improved their growth rate.

4.1 Yield and capsaicin content of chilli

The yield improvement in chilli treated with seaweed fortified granules and seaweed gel was 21.17% to 30.16% over control with increased capsaicin content ($p < 0.05$) (Table 3). The morphological characters of the chilli like number of leaves, length and diameter of shoot and root were found increased but not significant when compared to control plants. Thomas (2002) reported that seaweed extract (Sea Buck Thorn) improved the growth of fresh weight of vegetative and roots of Rosemary significantly. Seaweed extract found to increase the physiological activities, number and size of leaves and fruit weight in Lettuce *Lactuca sativa* (Al-Saberi 2005 **ref missing**). Gollan and Wright (Gollan and Wright, 2006) had reported that length of shoot increased due to the presence of auxins content in the seaweed extracts which had an effective role in cell division and enlargement.

Sarhan and Rasheed (Sarhan and Rasheed, 2011) observed that the cucumber treated with seaweed extract produced more by the number of distillate flowers which in turn yielded an increased number of fruits with more weight. – uniformity the fruits length shape. Sarhan and Rasheed (Sarhan and Rasheed, 2011) reported that cucumber plants treated with seaweed extracts (Alga 600 and sea force2) yielded highest value in fruit weight (126.55 g fruit^{-1}), fruit number per plant (21.73), fruit length (18.20 cm), fruit diameter (2.64 cm) and TSS (4.33 %). Also seaweeds (*Gracilaria edulis, Enteromorpha intestinalis* and *Codium linum*) tested on both gram-positive and gram-negative bacteria did not show any effect on growth, hence no adverse effects on useful microorganisms in the soil (Sarhan and Rasheed, 2011).

5 Conclusion

The results of the present study showed that both seaweed fortified granules and seaweed gel can be applied in vermiculture and organic agriculture to increase the crop yield and crop quality.

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