Use of Autochthonous Organic Inputs for Amelioration of Fluoride Toxicity and Sustainable Agriculture

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Abstract— *An assessment was undertaken to study the combating capacity of autochthonous organic inputs viz. vermicompost, compost and bacterial consortia isolated from different sources viz. oil spillage sludge of petrol pump and rhizosphere of rice plant against the fluoride toxicity under field condition. Brassica campestris L. cv.B_9 was selected as a test species. Experiments were carried out in two consecutive years 2012-2013 and 2013-2014 designed as experiment I and experiment II. One unique thing was observed that mustard which were grown under indigenous organic inputs treated plots gave maximum yield under T_1 treatment (25 mg Kg^{-1} F) and was above the control set. Moreover, autochthonous organic inputs were capable of reducing the amount of fluoride content within the different plant parts of mustard. Maximum amount of fluoride was accumulated within the leaves and minimum quantity of fluoride was accumulated within the seed but within the permissible range (< 0.3 mg Kg^{-1} as recommended by EPA, FAO and WHO). Data were significantly different at 5% level using Duncan's Multiple Range Test (DMRT). Therefore, combination of vermicompost, compost and bacterial consortia acted upon reduction of fluoride level in the crop field of mustard.*

Keywords— Vermicompost, Compost, Bacterial consortia, Fluoride, Oil spilled site, Rhizosphere.

I. INTRODUCTION

In recent years, one of the main pollutants causing much concern is fluoride. Fluoride (F) is a potential air, water, and soil pollutant and also a common phytotoxic element (Reddy and Kaur, 2008). Fluoride is a natural component of the earth crust and also found in many minerals like fluorite (CaF_2), fluoroapetite ($Ca_{10}(PO_4)_6F_2$) etc. (Tripathi and Singh, 1984; Garg et al., 1998) due to high electronegative. Problems tend to occur in places where these minerals are most abundant in the host rocks. During weathering and circulation of water in rocks and soils, fluoride leached out and dissolved in ground water and thermal gases (Brunt et al., 2004). The fluoride content of ground water varies greatly depending on the geological settings and type of rocks (Brunt et al., 2004). Climate and contact time between fluoride in ground water and aquifer minerals (Frencken et al., 1992) are also associated with high fluoride concentration in ground water. The main sources of fluoride in soil are weathering of volcanic ashes (Cronin et al., 2003), application of phosphate fertilizer in agriculture (Loganathan et al., 2011) and several industrial processes, especially the aluminum and phosphate fertilizer industries (Arnesen and Krogstad, 1998). Some soils contain a very high level of natural F (Weinstein, 1977). Plants, poorly take up the soluble F^- ions from soil solution (Brewer, 1966). Fluoride can be transported by the symplastic or apoplastic pathway in the roots. Different pathways are responsible for the variations in fluoride concentrations in the plant (Muggler, 2009). Apart from these it can also enter into the plant body through the stomata from the air (Stevens et al., 1997; Mezghani et al., 2005). It adversely affected various physiological features of plants including causing decreased plant growth, chlorosis, leaf tip burn, and necrosis of leaf tip and leaf margin (Elloumi, 2005; Klumpp et al., 2006; Miller, 1993). Fluoride has deleterious impact not only on plant species but also on human beings (Maitra et al., 2013). The accumulation of fluoride in soil has raised concern that the dietry intake by grazing animals may steadily increase to reach unhealthy levels. Not only grazing animals but dietry intake of fluoride by human beings through consumption of edible plants/ vegetables may also steadily increase to unhealthy levels. Through these a part of food chain in which it is transmitted from vegetation to herbivores and hence to the carnivores (Murray, 1981). Excessive fluoride ingestion can cause disease known as fluorosis (Kugli and Yadawe , 2010 ; Beg et al., 2011). There are numerous number of research papers which acts as an evidence of deleterious impact of fluoride upon plants (Bhargava and Bhardwaj, 2010; Datta et al., 2012; Dey et al., 2012; Ram et al., 2014). According to Bhargava and Bhardwaj, 2010 sodium fluoride had significant impact on seed germination and seedling growth of wheat. Ram et al., 2014 also reported that sodium fluoride reduced the percentage of germination(%), root and shoot length, vigor index, pigment content, chlorophyll stability index(CSI) and membrane stability index (MSI). In the present investigation *Brassica campestris* L. cv. B_9 was selected as a test species. Since rapeseed (*Brassica campestris* L. cv. B_9) is one of the most important oil yielding plant in our country and grown prevalently during winter months which can be used successfully to clean up heavy metal polluted soils if their biomass and metal There are very limited number of works so far undertaken for the amelioration of fluoride toxicity under field condition with the help of indigenous organic inputs such as use of vermicompost, compost etc (Szymanska, 2003; Alharbi, 2008). Such type of indigenous organic resources are chosen for the bioremediation measure in conventional agricultural practices. Chemical fertilizers are industrially manipulated, substances composed of known quantities of nitrogen, phosphorus and potassium and their exploitation causes air, ground and water pollution by eutrophication of water bodies (Youssef and Eissa, 2014). Vermicomposts are rich in microbial populations and diversity, particularly fungi, bacteria and actinomycetes (Moradi et al., 2013). Vermicompost enriched soil with microorganisms (adding enzymes such as phosphatase and cellulase) and improve the water holding capacity in soil. It can also increase the nutrient status in the soil specially nitrogen (Sreenivas, 2000; Kale et al., 1992; Nenthra et al., 1999). Vermicompost has a large particulate surface area that provides many microsites for microbial activity and strong retention of nutrients. Compost also have many beneficial roles such as buffering action neutralize both acid and alkaline soils, bringing pH levels to the optimum range for nutrient availability to plants.

For such above mentioned beneficial characters, in this work, vermicompost and compost both have been used to study their impact towards bioremediation of fluoride under field condition. Also there indigenous inputs has some potentiality towards the combating of stress condition as well as to reduce the uptake and transportation of toxic metals through the plant system (Lallawmsanga et al., 2012; Rangasamy et al,. 2013).Bacterial consortia in general consist of diverse naturally occurring microbes whose inoculation to the soil ecosystem advances soil physico-chemical properties, soil microbes biodiversity, soil health, plant growth and development and crop productivity (Sahoo et al., 2013). The ultimate goal of sustainable agriculture is to develop farming systems that are productive and profitable, conserve the natural resources, protect the environment and enhance health and safety (Mukhopadhyay et al., 2013).

Hence, in the present investigation, an attempt have been taken to evaluate the impact of fluoride on growth, metabolism and yield of mustard and the potentiality of different treatment combination towards sustainable agriculture along with in-situ management of fluoride.

II. MATERIALS AND METHODS

2.1 Experimental Site

Field studies were conducted at Crop Research and Seed Multiplication Farm, The University of Burdwan, West Bengal which is located at 87 º 50’ 37.35” East latitude and 23 º 15’ 7.29” North longitude with an average altitude at 30 meter above sea level during the winter season on two consecutive year i.e., 2012-2013 and 2013-2014 with rape seed or mustard (*Brassica campestris* L. cv. B_9).

2.2 Climatic condition

2.2.1 Experiment I (2012-2013)

All the field experiment conducted in randomized block design with three replicas for each treatment. The minimum and maximum relative humidity and temperature of this area were recorded during the growth period were 78.69% to 87 % and 11.75ºC to 31.89ºC respectively. Average wind speed was (1.2-7.3 Km/hr) and mean sunshine was (0.43 to 7.86 hr). No rainfall during this period.

2.2.2. Experiment II (2013-2014)

The minimum and maximum relative humidity and temperature of this area recorded during the growth period were 79.2% to 85 % and 12.5ºC to 24.7ºC respectively. Average wind speed (1.3-8.1 Km/hr) and mean sunshine (4.23 to 7.15 hr) and rainfall (3mm) were recorded.

2.3 Treatment combination and design

Experiment I was divided into two sets to compare between two treatment combination that is recommended doses of chemical fertilizers(Single super phosphate contained 10ppm fluoride) and different concentration of fluoride designated as a first set vs second set which was amended with full dose of vermicompost, compost, bacterial consortia and different concentration of fluoride. Between these first set used as treatment plot to see through what extent fluoride can impact upon mustard plant. The next set was designed for the amelioration of fluoride with the help of indigenous organic inputs.

2.3.1 Experiment I

First part

T_1= Recommended dose of chemical fertilizers (100:50:50) +25mg Kg^{-1} fluoride +Sterilized seeds

T_2= Recommended dose of chemical fertilizers (100:50:50) +50mg Kg^{-1} fluoride +Sterilized seeds

T_3= Recommended dose of chemical fertilizers(100:50:50) +100mg Kg^{-1} fluoride +Sterilized seeds

T_4= Recommended dose of chemical fertilizers (100:50:50) +200mg Kg^{-1} fluoride +Sterilized seeds

T_5 (Control **) =** Recommended dose of chemical fertilizers (100:50:50)+ Sterilized seeds

T_6= Recommended dose of chemical fertilizers (100:50:50) +300mg Kg^{-1} fluoride +Sterilized seeds

T_7= Recommended dose of chemical fertilizers (100:50:50) +400mg Kg^{-1} fluoride +Sterilized seeds

T_8= Recommended dose of chemical fertilizers (100:50:50) +500mg Kg^{-1} fluoride +Sterilized seeds

Second part

T_1= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +25 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_2= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost full dose i.e., 1.5 Kg $plot^{-1}$) +50 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_3= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +100 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_4= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +200 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_5 (Control**) =** Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +bacterial consortia treated seeds

T_6= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +300 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_7= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +400 mg/Kg fluoride +bacterial consortia treated seeds

T_8= Vermicompost (full dose i.e., 1.5 Kg $plot^{-1}$) + Compost (full dose i.e., 1.5 Kg $plot^{-1}$) +500 mg Kg^{-1} fluoride +bacterial consortia treated seeds

The all field experiments were conducted in randomized block design. The plot size was 2.5×2.5 m .Row to row and plant to plant spacing were 1.5 m and 15 cm, respectively. Irrigation channels measuring 1.0 m wide were in between the replications to ensure easy and uninterrupted flow of irrigation for each individual plot. Experimental plot was divided into 6 main plots and 48 subplots. Under 24 subplots soils were treated with recommended doses of chemical fertilizer and different concentration of sodium fluoride such as 25 mg Kg^{-1} F, 50 mg Kg^{-1} F, 100 mg Kg^{-1} F, 200 mg Kg^{-1} F, 300 mg Kg^{-1} F, 400 mg Kg^{-1} F and 500 mg Kg^{-1} F. Another 24 subplots were treated with vermicompost, compost, along with same concentration of fluoride and seeds were coated with bacterial consortia and gum (50:50). In control plots of both the treatment combinations were treated without sodium fluoride.

2.3.2 Experiment II

In the experiment II (2013-2014) we desire to study,whether vermicompost, compost of different concentration and bacterial consortia have the same beneficial impact upon plant as compared to the experiment I when they were applied in the field along with chemical fertilizers and different concentration of fluoride. In experiment I under 500 mg Kg^{-1} fluoride treatment showed stressed condition as compared to other treatments. The leaves were fully dried, yellowish and shedded quickly under such highest concentration. Therefore, in the experiment II upto 400mg Kg^{-1} fluoride concentration instead of 500mg Kg^{-1} was used.

First part

T_1= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) +Recommended dose of chemical fertilizers (100:50:50) +25 mg Kg^{-1}fluoride +bacterial consortia treated seeds

T_2= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +50 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_3= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +100 mg Kg^{-1} fluoride + bacterial consortia treated seeds

T_4= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +200 mg Kg^{-1} fluoride + bacterial consortia treated seeds

T_5 (Control**) =** Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) + bacterial consortia treated seeds

T_6= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +300 mg Kg^{-1} fluoride +bacterial consortia treated seeds

T_7= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +400 mg Kg^{-1} fluoride +bacterial consortia treated seeds

Second part

T_1= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750 g plot^{-1}) +Recommended dose of chemical fertilizers (100:50:50) +25 mg Kg^{-1} fluoride +Sterilized seeds

T_2= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750 g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +50 mg Kg^{-1} fluoride +Sterilized seeds

T_3= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750 g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +100 mg Kg^{-1} fluoride +Sterilized seeds

T_4= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750 g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +200 mg Kg^{-1} fluoride +Sterilized seeds

T_5 (Control**) =** Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750 g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) + Sterilized seeds

T_6= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +300 mg Kg^{-1} fluoride +Sterilized seeds

T_7= Vermicompost (full dose i.e., 1.5 Kg plot^{-1}) + Compost (half dose i.e., 750g plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +400 mg Kg^{-1} fluoride +Sterilized seeds

Third part

T_1= Vermicompost (half dose i.e., 750 g plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) +Recommended dose of chemical fertilizers (100:50:50) +25 mg Kg^{-1} fluoride +Sterilized seeds

T_2= Vermicompost (half dose i.e., 750g plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +50 mg Kg^{-1} fluoride +Sterilized seeds

T_3= Vermicompost (half dose i.e., 750g plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +100 mg Kg^{-1} fluoride +Sterilized seeds

T_4= Vermicompost (half dose i.e., 750g plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +200 mg Kg^{-1} fluoride +Sterilized seeds

T_5 (Control**) =** Vermicompost (half dose i.e., 750g plot^{-1}) + Compost (full dose i.e., 1.5 Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +Sterilized seeds

T_6= Vermicompost (half dose i.e., 750 g plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +300 mg Kg^{-1} fluoride +Sterilized seeds

T_7= Vermicompost (half dose i.e., 750g plot^{-1}) + Compost (full dose i.e., 1.5Kg plot^{-1}) + Recommended dose of chemical fertilizers (100:50:50) +400 mg Kg^{-1} fluoride +Sterilized seeds

Experiment was divided into three parts. Doses which were used in the field are 25 mg Kg^{-1} fluoride, 50 mg Kg^{-1} fluoride, 100 mg Kg $^{-1}$fluoride, 200 mg Kg $^{-1}$fluoride, 300 mg Kg^{-1} fluoride and 400 mg Kg^{-1} fluoride.

2.3.3 Experiment II (2013-2014)

The experimental site was prepared on 12th December, 2013. Different doses of vermicompost, compost and chemical fertilizer (at recommended dose 100:50:50, Directorate of Agriculture, Government of West Bengal for mustard) were used in the form of urea, single super phosphate (SSP) and mureate of potash (MOP) within the field on the same day. Different concentrations of sodium fluoride were applied on each treated plot except control on 14 th December, 2013. After that seeds were coated with bacterial consortia and sown in the first 21 subplot and seeds which were sown in another 42 subplots were sterilized with 0.1 % mercuric chloride .Two hand-weedings at 15-18 DAS and 38-40 DAS were carried out. The first irrigation was applied after seed sowing and after that the crop was irrigated at an intervals of 15 – 55 DAS. The crops of each plot were harvested separately on 28 th February, 2014 with golden yellow siliquae.

2.4 Data Collection

The physical, chemical and biological properties of the initial experimental soil and chemical and biological properties of vermicompost and cow dung have been represented in the Tables 1, 2 and 3.

TABLE 1
PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF EXPERIMENTAL SOIL (0-15 cm DEPTH)

Characteristics	Value
Sand (0.02-0.2 mm)(%)	39.84±0.015
Silt (0.002-0.02 mm)(%)	17.67±1.528
Clay (<0.002 mm) (%)	41.16±0.015
Moisture Content (%)	9.809±0.001
Bulk density(g cc^{-1})	0.993±0.001
Particle density(g cc^{-1})	2.67±0.01
Porosity (%)	62.75±0.05
pH	7.04±0.01
EC(ms cm^{-1})	0.016±0.001
Organic matter (%)	2.97±0.01
Available N (Kg ha^{-1})	13.402±0.001
Available P (Kg ha^{-1})	94.868±0.001
Available K (Kg ha^{-1})	36.64±0.01
Available Ca(meq 100g^{-1})	0.56±0.015
Available Mg(meq 100g^{-1})	0.21±0.01
DTPA extractable Zn(ppm)	0.47±0.01
DTPA ectractable Cu (ppm)	1.4±0.1
DTPA extractable Mn (ppm)	3.567±0.001
DTPA extractable Fe(ppm)	11.4±0.1
Fluoride (ppm)	0.18±0.01
Total Bacteria(CFU g^{-1} of soil)	15.33x10^{6}
Total Fungi CFU g^{-1} of soil)	11.67x10^{3}

TABLE 2
CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF VERMICOMPOST

Available Nitrogen (%)	Available Phosphorous (%)	Available Potassium (%)	Total bacteria (CFU g^{-1})	Total fungi (CFU g^{-1})
1.4±0.1	1.17±0.01	0.99± 0.01	61.33 x10^{6}	32.33 x10^{3}

TABLE 3
CHEMICAL AND BIOLOGICAL CHARACTERISTICS OF COMPOST (COWDUNG)

Available Nitrogen (%)	Available Phosphorous (%)	Available Potassium (%)	Total bacteria (CFU g^{-1})	Total fungi (CFU g^{-1})
0.97±0.01	1.02±0.015	0.54± 0.015	33.33 x10^6	22.33 x10^3

2.5 Parameter studied

Plant morpho-physiological attributes like root length, plant height, leaf area index were measured according to Watson, 1952. In case of yield attributes silique length and breadth, number of grains per silique, 1000 seed weight (test weight) and seed yield were determined. The numbers of plants from a one meter row length were counted at four sites in each plot. From this data, the average number of plants per meter was calculated. The total number of seeds per siliqua was recorded from the ten randomly selected plants of each plot. One thousand seeds were counted randomly from each plot and after sun-drying their weight was determined and expressed in gram(g). Plants from each plot were harvested, tied in bundles, dried and then taken to the threshing floor for threshing. After threshing, the seeds were cleaned, sun dried and their weights were recorded. The yields in gm^{-2} were converted to Kg ha^{-1}. Fluoride accumulation of mustard leaves were estimated by digestion method (Paul et al., 2011) and measured its quantity through ion selective electrode (ORION STAR A214pH/ISE meter). Texture was determined by hydrometer method, moisture content % (Saxena, 1998), Bulk density (Gupta, 2004), Particle density (Black, 1965) and Porocity (%) (Black, 1965). Soil pH (Jackson, 1972) and electrical conductivity (Trivedy and Goel, 1998) were measured by pH meter (Eutech pH.700) and conductivity meter (Systronics, Model No.-335). Available N was measured by the alkaline permanganate method (Subbiah and Asija, 1956). Available P was extracted by sodium bicarbonate according to Olsen et al., (1954). Available K was extracted by 1 M ammonium acetate (pH = 7.0) and was determined by flame photometry (Black, 1965). Soil organic carbon was determined using the wet digestion method of Walkely and Black, 1934. Available micronutrients were extracted by diethylenetriamine pentaacetic acid (DTPA) (Lindsay and Norvell, 1978), followed by atomic absorption spectorphotometry (PerkinElmer 200AA, Perkin Elmer Inc., Waltham,MA, USA). Fluoride were estimated from different vertical soil layer i.e., surface soil, 10 cm and 20 cm(Lori, 1987) and measured its quantity through ion selective electrode (ORION STAR A 214 pH/ISE meter).

2.6 Statistical Calculation

Duncan's multiple range test (DMRT) (Gomez and Gomez, 1984) at 5 % confidence interval was done with MINITAB software package (version 16) (http://www.minitab.com) to study whether the impact of different fluoride concentration on above mentioned parameters either significant or not.

III. RESULTS AND DISCUSSION

3.1 Crop morpho-physiological attributes

Present results of both experiments highlighted that the root length, plant height, fresh weight and dry weight of root, shoot and leaves, plant population and leaf area index were recorded maximum under T_1 treatment i.e., 25 mg kg^{-1}(Experiment I-Table 4, Table 5 and Table 6; Experiment II- Table 7, 8, 9 and 10). The value was above the control set. Similar results were reported by Sharma et al. 2014. They reported that the soil with VAM fungi resulted in a marked increase in the morphological features viz. root length, shoot length, leaf area, fresh and dry weight of leaf studied over the control and fluoride treated tea plants. Lowest value were recorded with T_8 (Experiment I, 500 mg Kg^{-1} fluoride; Table 4 and Table 5) and T_7 (Experiment II, 400 mg Kg^{-1} fluoride; Table 7, Table 8 and Table 9). In case of experiment I, which were grown under chemical fertilizers (recommended dose) and different concentration of sodium fluoride, highest value of above mentioned parameters were recorded with T_5(control) and lowest value were recorded with T_8(500 mg Kg^{-1}) (Table 4 and 6) . In the present investigation macromolecular level change took place within plant due to inoculation of bacterial consortia under field condition (Maitra et al., 2013). It was well documented that the presence of bioactive substances associated with low molecular weight fractions of humic acids, capable of inducing changes in plant morphology and physiology with vermicompost, which enhanced root elongation, lateral root emergence and plasma membrane H+-ATP ase activity of roots (Canellas et al., 2002). On the other hand leaf area index increased with the stimulating effect of indigenous organic resource application which could have improved the availability of nutrients and their uptake by crop plants (Saeed et al., 2002). Moreover, Bachman and Metzger (2008) reported that vermicompost increased root fresh and dry weight in French marigold, pepper, tomato and cornflower.

EXPERIMENT I (2012-2013)
TABLE 4
IMPACT OF CHEMICAL FERTILIZER AND FLUORIDE ON MORPHOLOGICAL ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Root length (cm)	Plant Height (cm)	FW (root) (g)	FW (shoot) (g)	FW (leaves) (g)	DW (root) (g)	Dw (shoot) (g)	DW (leaves) (g)
Control(T_5)	0.723^{f} 8.643^{a} 10.183^{a}	17.80^{a} 58.87^{a} 62.13^{a}	1.414^{a} 1.870^{a} 5.901^{a}	10.921^{a} 26^{a} 52.79^{a}	7.414^{a} 12.582^{a} 4.389^{a}	0.170^{a} 0.985^{a} 1.992^{a}	1.229^{a} 6.616^{a} 11.389^{a}	0.892^{a} 1.408^{a} 0.685^{a}
T_1	0.687^{e} 8.550^{a} 10.027^{a}	16.37^{b} 58.56^{a} 61.73^{a}	1.090^{ab} 1.642^{ab} 4.931^{ab}	9.682^{ab} 19.75^{b} 43.40^{b}	7.217^{a} 11.083^{b} 2.857^{b}	0.140^{ab} 0.920^{ab} 1.644^{b}	0.395^{b} 6.466^{a} 10.399^{ab}	0.794^{ab} 1.090^{b} 0.650^{a}
T_2	0.673^{e} 8.390^{ab} 9.803^{a}	15.59^{c} 57.82^{ab} 59.36^{ab}	1.012^{ab} 1.503^{bc} 4.374^{abc}	9.102^{b} 17.10^{bc} 41.07^{b}	6.025^{ab} 9.228^{c} 2.045^{bc}	0.136^{ab} 0.825^{bc} 1.462^{bc}	0.337^{bc} 6.109^{b} 9.526^{bc}	0.684^{bc} 0.934^{bc} 0.576^{ab}
T_3	0.640^{e} 8.027^{ab} 9.317^{ab}	15.17^{cd} 55.33^{bc} 57.87^{abc}	0.752^{bc} 1.257^{cd} 3.631^{bcd}	8.728^{bc} 15.35^{bc} 35.78^{bc}	5.635^{b} 7.264^{d} 1.775^{bc}	0.130^{ab} 0.810^{bc} 1.192^{cd}	0.274^{cd} 5.882^{bc} 8.150^{cd}	0.616^{cd} 0.761^{cd} 0.549^{ab}
T_4	0.623^{cd} 7.703^{abc} 8.803^{bc}	14.83^{cde} 53.62^{cd} 56.99^{bc}	0.649^{bc} 1.095^{de} 3.179^{bcd}	8.267^{bc} 14.64^{c} 31.34^{cd}	5.108^{bc} 6.659^{d} 1.737^{bc}	0.113^{b} 0.720^{cd} 1.122^{de}	0.212^{de} 5.658^{cd} 7.226^{de}	0.612^{cd} 0.679^{cd} 0.531^{ab}
T_6	0.610^{c} 7.487^{bc} 8.667^{bc}	14.48^{def} 53.02^{cd} 54.19^{cd}	0.478^{c} 0.912^{ef} 2.980^{cd}	7.905^{bc} 14.15^{c} 29.40^{cd}	4.809^{bc} 6.243^{de} 1.279^{cd}	0.102^{b} 0.710^{cd} 0.971^{de}	0.155^{ef} 5.565^{d} 6.662^{def}	0.558^{cde} 0.588^{de} 0.481^{b}
T_7	0.580^{b} 6.917^{c} 8.037^{c}	14.21^{ef} 51.70^{d} 52.32^{d}	0.431^{c} 0.765^{ef} 2.450^{d}	7.136^{cd} 13.69^{c} 26.04^{d}	4.071^{cd} 4.992^{ef} 0.731^{cd}	0.092^{bc} 0.587^{de} 0.920^{de}	0.114^{f} 5.259^{e} 6.279^{ef}	0.505^{de} 0.457^{de} 0.234^{c}
T_8	0.557^{a} 5.817^{d} 7.023^{d}	13.80^{f} 48.86^{e} 49.68^{e}	0.368^{c} 0.683^{f} 2.034^{d}	5.967^{d} 13.41^{c} 23.79^{d}	3.224^{d} 3.928^{f} 0.240^{d}	0.047^{c} 0.514^{e} 0.868^{e}	0.081^{f} 4.932^{f} 5.536^{f}	0.429^{e} 0.322^{e} 0.134^{c}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper, middle and lower value indicates data of 30 DAS, 45 DAS and 60 DAS, DAS days after sowing, FW Fresh Weight, DW Dry Weight

Not only vermicompost but compost had also beneficial characteristics. It was documented by Mehedi et al., 2012 that the application of 15 t ha^{-1} compost might have significant contribution to proper growth and development of root through optimum nutrient uptake by the crop plants. In the present investigation application of compost @ 1.5 Kg $Plot^{-1}$ might have significant contribution to increase the crop growth attributes. DMRT wordings by the different letter showed the variation among treatments which were significantly different at 5% level. On the other hand, the morpho-physiological attributes of mustard which were grown under those plots treated with indigenous organic inputs were significantly highest under T_1 treatment and significantly lowest under T_8 treatment. Moreover, in chemical fertilizer treated plots only T_5 or control and T_8 showed significant highest and lowest value. Plant population and Leaf Area Index of plants treated with indigenous inputs were significantly higher in T_1 and significantly lower in T_8. Leaf Area Index of mustard showed significant variation in T_2, T_4 and T_6 plots treated with chemical fertilizers and different concentration of sodium fluoride.

TABLE 5
IMPACT OF VERMICOMPOST, COMPOST, BACTERIAL CONSORTIUM AND FLUORIDE ON MORPHOLOGICAL ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Root length (cm)	Plant Height (cm)	FW (root) (g)	FW (shoot) (g)	FW (leaves) (g)	DW (root) (g)	Dw (shoot) (g)	DW (leaves) (g)
Control(T_5)	5.860^{bc} 8.697^{b} 10.72^{bc}	21.85^{bc} 61.54^{cd} 65.04^{bc}	1.108^{b} 2.472^{d} 7.382^{a}	14.76^{bc} 37.29^{d} 52.13^{cd}	8.298^{cd} 7.791^{cd} 4.143^{b}	0.237^{bcde} 0.942^{bc} 1.728^{de}	1.386^{abc} 9.448^{a} 13.79^{a}	0.941^{cd} 1.217^{cd} 0.808^{cd}
T_1	7.377^{a} 10.523^{a} 12.39^{a}	26.26^{a} 68.53^{a} 71.65^{a}	2.068^{a} 3.769^{a} 7.762^{ab}	26^{a} 44.78^{a} 79.20^{a}	14.481^{a} 13.884^{a} 9.691^{a}	0.574^{a} 1.255^{a} 2.478^{a}	2.206^{a} 10.098^{a} 14.49^{a}	1.461^{a} 2.917^{a} 2.241^{a}
T_2	7.290^{a} 9.843^{a} 12.02^{ab}	25.33^{a} 66.12^{ab} 71.36^{a}	1.561^{ab} 3.517^{b} 6.536^{abc}	19.75^{b} 43.39^{ab} 66.88^{b}	10.318^{b} 10.179^{b} 8.259^{a}	0.386^{b} 1.221^{a} 2.342^{ab}	2.125ab 9.959^{a} 14.31^{a}	1.199^{b} 2.302^{b} 1.447^{b}
T_3	6.353^{b} 9.050^{b} 11.10^{abc}	23.29^{b} 65.62^{b} 67.80^{ab}	1.247^{ab} 3.365^{b} 6.086^{bcd}	17.10^{b} 41.17^{bc} 62.18^{bc}	10.020^{bc} 9.591^{bc} 5.909^{b}	0.318^{bc} 1.034^{ab} 2.113^{bc}	1.694^{abc} 9.850^{a} 14.08^{a}	1.113^{bc} 2.101^{b} 0.969^{bc}
T_4	6.057^{bc} 8.887^{b} 10.96^{bc}	22.23^{bc} 63.42^{bc} 65.07^{bc}	1.170^{b} 3.070^{c} 5.641^{cde}	15.35^{bc} 38.95^{cd} 56.87^{bc}	9.520^{bc} 8.021^{bcd} 5.512^{b}	0.287^{bcd} 0.968b 1.943^{cd}	1.531^{abc} 9.619^{a} 13.87^{a}	1.011^{bcd} 1.556^{c} 0.897^{c}
T_6	5.490^{cd} 7.857^{c} 9.910^{cd}	20.68^{cd} 61.13^{cd} 61.45^{c}	0.986^{b} 2.238^{de} 5.250^{cde}	14.01^{bc} 32.49^{e} 45.81^{de}	7.237^{d} 7.190^{d} 1.927^{c}	0.182^{cde} 0.793^{bcd} 1.647^{de}	0.975^{bc} 7.151^{b} 12.65^{b}	0.844^{de} 0.943^{de} 0.470^{cde}
T_7	5.243^{d} 7.167^{c} 9.31^{de}	19.07^{d} 58.88^{d} 57.63^{d}	0.946^{b} 2.081^{e} 4.528^{de}	13.73^{bc} 28.90^{f} 42.09^{de}	6.823^{d} 7.007^{d} 1.665^{c}	0.142^{de} 0.709^{cd} 1.530^{ef}	0.791^{c} 6.777^{b} 11.93^{b}	0.626^{ef} 0.789^{de} 0.306^{de}
T_8	4.443^{e} 7.157^{c} 8.110^{e}	17.26^{e} 54.39^{e} 56.30^{d}	0.833^{b} 1.639^{f} 4.417^{e}	8.97^{c} 24.38^{g} 36.07^{e}	6.514^{d} 6.270^{d} 0.972^{c}	0.090^{e} 0.599^{d} 1.247^{f}	0.523^{c} 6.473^{b} 11.78^{b}	0.494^{f} 0.599^{e} 0.141^{e}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT) Upper, middle and lower value indicates data of 30 DAS, 45 DAS and 60 DAS, DAS days after sowing , FW Fresh Weight, DW Dry Weight

TABLE 6
COMPARATIVE STUDY BETWEEN TWO DIFFERENT TREATMENT COMBINATIONS ON LEAF AREA INDEX AND PLANT POPULATION

Treatments (mg Kg^{-1} F)	Plant Population (Chem+Fluoride)	Plant population (VC+Comp+BC+Fluoride)	LAI (Chem+Fluoride)	LAI (VC+Comp+BC+Fluoride)
Control (T_5)	160.5^{a}	153.5^{e}	7.505^{a} 5.520^{a}	5.714^{d} 3.210^{e}
T_1	151^{b}	175^{a}	7.556^{ab} 4.474^{b}	8.706^{a} 4.321^{a}
T_2	147.5^{b}	171.5^{b}	7.453^{b} 4.389^{c}	6.783^{b} 3.997^{b}
T_3	141.0^{c}	165.5^{c}	7.216^{c} 4.375^{c}	6.635^{b} 3.906^{c}
T_4	136.5^{c}	156.0^{d}	6.770^{d} 4.362^{c}	6.060^{c} 3.675^{d}
T_6	131.0^{d}	152^{e}	5.559^{e} 4.294^{d}	5.520^{d} 2.777^{f}
T_7	126.5^{de}	131.0^{f}	5.482^{ef} 4.188^{e}	5.065^{e} 2.061^{g}
T_8	124.5^{e}	120.0^{g}	5.419^{f} 3.997^{f}	5.004^{e} 2.431^{h}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper and lower value indicates data of 45 DAS and 60 DAS, DAS days after sowing , LAI Leaf Area Index, Chem Chemical fertilizer, VC Vermicompost, Comp Compost, BC Bacterial Consortium

EXPERIMENT II (2013-2014)

FIRST PART OF THE EXPERIMENT

TABLE 7

IMPACT OF VERMICOMPOST(FULL DOSE), COMPOST(FULL DOSE), BACTERIAL CONSORTIUM, CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON MORPHOLOGICAL ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Root length (cm)	Plant Height (cm)	FW (root) (g)	FW (shoot) (g)	FW (leaves) (g)	DW (root) (g)	Dw (shoot) (g)	DW (leaves) (g)
Control(T_5)	7.330^{bc} 11.73^{cd} 11.33^{c}	16.44^{bc} 39.60^{bc} 62.84^{bc}	1.012^{cd} 2.575^{b} 11.58^{b}	5.162^{c} 60.50^{bcd} 100.5^{ab}	4.701^{abc} 10.90^{bc}	0.170^{ab} 0.831^{e} 2.310^{c}	0.461^{bcd} 3.043^{a} 19.13^{cde}	0.545^{bc} 1.663^{d}
T_1	9.690^{a} 14.91^{a} 13.59^{a}	19.38^{a} 46.60^{a} 69.47^{a}	1.601^{a} 3.373^{a} 17.87^{a}	9.186^{a} 117.82^{a} 138.6^{a}	6.473^{a} 16.10^{a}	0.510^{a} 1.334^{a} 4.140^{a}	0.754^{a} 3.452^{a} 41.80^{a}	0.980^{a} 2.336^{a}
T_2	8.550^{ab} 14.02^{ab} 12.82^{ab}	16.89^{b} 45.33^{ab} 67.31^{ab}	1.462^{ab} 2.849^{ab} 13.74^{ab}	8.482^{ab} 89.86^{ab} 133.0^{a}	5.476^{ab} 13.90^{ab}	0.245^{ab} 1.092^{b} 3.295^{b}	0.563^{b} 3.325^{a} 33.58^{ab}	0.745^{b} 2.055^{b}
T_3	8.270^{ab} 13.49^{ab} 12.05^{bc}	16.84^{bc} 41.24^{abc} 64.80^{abc}	1.246^{bc} 2.774^{ab} 13.38^{ab}	6.325^{bc} 85.14^{bc} 119.7^{a}	5.114^{ab} 12.93^{b}	0.195^{ab} 1.019^{c} 3.220^{b}	0.539^{bc} 3.246^{a} 28.78^{bc}	0.600^{bc} 1.851^{c}
T_4	7.760^{b} 12.95^{ab} 11.62^{c}	16.77^{bc} 40.72^{abc} 63.02^{bc}	11.48^{cd} 2.708^{ab} 12.48^{ab}	6.057^{bc} 74.86^{bc} 107.1^{ab}	4.940^{abc} 11.01^{bc}	0.180^{ab} 0.977^{d} 2.886^{b}	0.489^{bcd} 3.226^{a} 27.24^{bcd}	0.585^{bc} 1.795^{c}
T_6	6.090^{cd} 11.03^{d} 10.02^{d}	16.06^{c} 38.12^{c} 60.60^{c}	0.897^{d} 2.494^{b} 10.72^{b}	4.773^{c} 56.98^{cd} 81.5^{ab}	4.172^{bc} 9.55^{c}	0.145^{b} 0.829^{e} 2.195^{c}	0.410^{cd} 2.310^{b} 17.79^{de}	0.435^{c} 1.458^{e}
T_7	5.570^{d} 10.06^{d} 9.43^{d}	14.53^{d} 37.07^{c} 53.64^{d}	0.848^{d} 2.428^{b} 9.21^{b}	4.516^{c} 43.56^{d} 54.1^{b}	3.100^{c} 7.88^{c}	0.115^{b} 0.783^{f} 1.520^{d}	0.360^{d} 2.225^{b} 12.60^{e}	0.380^{c} 1.225^{f}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper, middle and lower value indicates data of 30 DAS, 45 DAS and 60 DAS, in case of fresh weoght and dry weight of leaves upper and lower value indicates data of 30 DAS and 45 DAS, DAS days after sowing , FW Fresh Weight, DW Dry Weight

SECOND PART OF THE EXPERIMENT

TABLE 8

IMPACT OF VERMICOMPOST(FULL DOSE), COMPOST(HALF DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON MORPHOLOGICAL ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Root length (cm)	Plant Height (cm)	FW (root) (g)	FW (shoot) (g)	FW (leaves) (g)	DW (root) (g)	Dw (shoot) (g)	DW (leaves) (g)
Control(T_5)	6.850^{b} 10.64^{cd} 10.32^{ab}	14.59^{ab} 39.23^{ab} 57.51^{ab}	0.782^{c} 2.319^{bcd} 5.690^{ab}	3.500^{b} 19.16^{bc} 60.14^{bcd}	2.745^{bc} 7.660^{de}	0.158^{c} 0.575^{cd} 2.220^{d}	0.390^{cd} 2.935^{a} 19.77^{abc}	0.510^{cde} 1.450^{c}
T_1	9.930^{a} 14.01^{a} 12.14^{a}	17.78^{a} 44.57^{a} 66.7^{a}	1.099^{a} 2.953^{a} 9.810^{a}	6.730^{a} 26.18^{a} 117.8^{2a}	5.350^{a} 12.060^{a}	0.229^{a} 0.750^{a} 3.980^{a}	0.670^{a} 3.605^{a} 29.44^{a}	0.841^{a} 1.935^{a}
T_2	7.910^{b} 13.62^{a} 12.10^{a}	15.62^{ab} 43.73^{a} 64.98^{a}	1.072^{a} 2.788^{ab} 7.650^{ab}	4.065^{b} 21.92^{b} 88.83^{b}	3.455^{b} 10.725^{a}	0.247^{b} 0.720^{ab} 3.240^{b}	0.625^{ab} 3.255^{a} 23.67^{ab}	0.627^{b} 1.755^{ab}
T_3	7.270^{b} 12.24^{b} 10.85^{ab}	15.43^{ab} 43.18^{a} 63.62^{ab}	0.989^{ab} 2.622^{abc} 6.510^{ab}	4.065^{b} 21.17^{bc} 84.50^{bc}	3.030^{b} 9.825^{c}	0.234^{b} 0.675^{abc} 3.015^{bc}	0.505^{bc} 3.105^{a} 21.87^{abc}	0.574^{bc} 1.640^{bc}
T_4	7.070^{b} 11.63^{bc} 10.45^{ab}	14.99^{ab} 40.82^{ab} 62.65^{ab}	0.880^{bc} 2.568^{abc} 5.765^{ab}	3.925^{b} 20.77^{bc} 74.86^{bc}	2.825^{bc} 8.430^{d}	0.169^{c} 0.610^{bcd} 2.525^{cd}	0.450^{cd} 3.030^{a} 20.70^{abc}	0.529^{bcd} 1.505^{c}
T_6	6.490^{b} 10.260^{d} 9.83^{ab}	13.97^{b} 36.93^{bc} 56.37^{ab}	0.598^{d} 2.094^{cd} 4.025^{b}	2.855^{b} 18.26^{c} 56.98^{cd}	2.120^{cd} 7.395^{e}	0.155^{c} 0.553^{d} 2.135^{d}	0.370^{cd} 2.765^{a} 16.14^{bc}	0.431^{de} 1.390^{c}
T_7	6.390^{b} 10.22^{d} 8.93^{b}	13.10^{b} 33.04^{c} 51.72^{b}	0.452^{c} 1.849^{d} 3.075^{b}	2.685b 14.66^{d} 43.56^{d}	1.525^{d} 6.915^{e}	0.139^{c} 0.520^{d} 1.195^{e}	0.305^{d} 2.275^{a} 10.96^{c}	0.405^{e} 1.040^{c}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper, middle and lower value indicates data of 30 DAS, 45 DAS and 60 DAS, in case of fresh weoght and dry weight of leaves upper and lower value indicates data of 30 DAS and 45 DAS, DAS days after sowing , FW Fresh Weight, DW Dry Weight

THIRD PART OF THE EXPERIMENT

TABLE 9
IMPACT OF VERMICOMPOST(HALF DOSE), COMPOST(FULL DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON MORPHOLOGICAL ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Root length (cm)	Plant Height (cm)	FW (root) (g)	FW (shoot) (g)	FW (leaves) (g)	DW (root) (g)	Dw (shoot) (g)	DW (leaves) (g)
Control(T_5)	7.04^{bc} 9.52^{bc} 9.04^{bc}	10.77^{bc} 35.33^{c} 57.03^{bc}	0.63^{de} 2.575^{b} 4.361^{bc}	3.314^{bc} 12.4^{bcd} 58.29^{b}	0.461^{c} 4.982^{c}	0.126^{c} 0.411^{e} 1.968^{bc}	0.247^{de} 2.053^{b} 18.28^{c}	0.533^{bc} 0.663^{d}
T_1	8.71^{a} 11.12^{a} 11.55^{a}	13.1^{a} 38.8^{a} 65.94^{a}	1.315^{a} 3.373^{a} 7.957^{a}	4.941^{a} 18.84^{a} 92.53^{a}	6.978^{a} 9.439^{a}	0.181^{a} 0.687^{a} 3.370^{a}	0.364^{a} 2.968^{a} 27.84^{a}	0.808^{a} 1.806^{a}
T_2	7.94^{ab} 10.4^{ab} 10.24^{ab}	12.56^{a} 38.73^{a} 65.42^{a}	1.13^{b} 2.849^{ab} 7.763^{a}	4.065^{a} 18.52^{a} 88.69^{a}	6.236^{ab} 8.891^{ab}	0.167^{ab} 0.648^{b} 2.873^{a}	0.345^{ab} 2.572^{ab} 21.66^{b}	0.681^{ab} 1.477^{b}
T_3	7.83^{ab} 10.37^{ab} 9.61^{b}	11.46^{b} 37.66^{b} 61.29^{ab}	0.775^{c} 2.774^{ab} 5.849^{b}	3.991^{b} 16.25^{ab} 83.44^{a}	4.865^{b} 7.205^{b}	0.152^{b} 0.585^{c} 2.250^{b}	0.308^{bc} 2.335^{ab} 21.52^{b}	0.629^{bc} 1.335^{b}
T_4	7.25^{bc} 9.77^{bc} 9.36^{bc}	11.13^{b} 36.69^{b} 60.78^{abc}	0.695^{cd} 2.708^{ab} 5.048^{bc}	3.665^{b} 15.63^{abc} 78.61^{a}	0.488^{c} 5.408^{c}	0.149^{b} 0.493^{d} 2.155^{b}	0.287^{cd} 2.196^{ab} 19.39^{c}	0.569^{bc} 0.932^{c}
T_6	6.58^{cd} 9.11^{c} 7.89^{cd}	10.33^{cd} 34.63^{c} 54.67^{c}	0.505^{e} 2.494^{b} 4.272^{c}	2.742^{cd} 12.4^{cd} 47.77^{b}	0.409^{c} 4.783^{c}	0.103^{d} 0.399^{f} 1.572^{cd}	0.203^{ef} 1.853^{c} 15.57^{d}	0.435^{cd} 0.532^{d}
T_7	5.56^{d} 7.89^{d} 6.7^{d}	9.91^{d} 32.37^{d} 54.52^{c}	0.36^{f} 2.428^{b} 3.694^{c}	2.138^{d} 11.16^{d} 42.17^{b}	0.36^{c} 3.677^{c}	0.078^{e} 0.190^{g} 1.156^{d}	0.183^{f} 1.506^{c} 9.95^{e}	0.352^{d} 0.470^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper, middle and lower value indicates data of 30 DAS, 45 DAS and 60 DAS, in case of fresh weight and dry weight of leaves upper and lower value indicates data of 30 DAS and 45 DAS, DAS days after sowing , FW Fresh Weight, DW Dry Weight

TABLE 10
COMPARATIVE STUDY BETWEEN TWO TREATMENT COMBINATION ON PLANT POPULATION AND LEAF AREA INDEX

Treatments (mg Kg^{-1} F)	Plant Population (1^{st} part of the experiment)	Plant Population (2^{nd} part of the experiment)	Plant Population (3^{rd} part of the experiment)	LAI (1^{st} part of the experiment)	LAI (2^{nd} part of the experiment)	LAI (3^{rd} part of the experiment)
Control (T_5)	146^{cd}	139.5^{d}	137.5^{cd}	4.790^{cd} 5.660^{cd}	4.410^{c} 4.770^{cd}	3.185^{ab} 4.395^{cd}
T_1	172^{a}	162.5^{a}	160.5^{a}	8.495^{a} 8.593^{a}	6.520^{a} 7.090^{a}	4.315^{a} 6.925^{a}
T_2	164^{ab}	151.0^{b}	149.5^{b}	8.000^{a} 6.767^{b}	5.409^{b} 6.410^{ab}	3.995^{ab} 6.205^{a}
T_3	161^{b}	149.0^{bc}	146.5^{b}	0.695^{b} 6.435^{bc}	5.215^{bc} 6.385^{ab}	3.865^{ab} 5.900^{ab}
T_4	152.5^{c}	145.5^{c}	139.5^{c}	5.800^{bc} 5.995^{bcd}	4.940^{bc} 5.215^{bc}	3.660^{ab} 4.812^{bc}
T_6	139.5^{de}	135.5^{e}	134.5^{d}	4.440^{d} 5.480^{cd}	3.470^{d} 4.717^{cd}	2.765^{b} 4.035^{cd}
T_7	137^{e}	129.5^{f}	127^{e}	4.130^{d} 5.000^{d}	2.915^{d} 3.610^{d}	2.550^{b} 3.402^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

Upper and lower value indicates data of 45 DAS and 60 DAS, DAS days after sowing, LAI Leaf Area Index

First set, second set and third set of the experiment II, the morpho-physiological parameters viz. root length, plant height significantly highest in T_1 and significantly lowest in T_7. A similar result was found in fresh weight of root, shoot and leaves where values were significantly highest in T_1 as compared to other treatments. In case of dry weight of root, shoot and leaf were significantly highest and lowest successively under T_1 and T_7. Similar trend of the results were found with plant population and leaf area index. Values were significantly different at 5% level.

3.2 Crop Yield attributes

In the consecutive years of this field trial maximum yield occurred under T_1 treatment (25 mg Kg^{-1}). The value is above the control set. Lowest seed yield were recorded with T_8 (Table 11 and 12) and T_7 (Experiment II, 400 mg Kg^{-1} fluoride) (Table 13, 14 and 15). In experiment I, the plots which were treated with chemical fertilizers (recommended dose) and different concentration of sodium fluoride maximum and minimum yield were recorded with T_5 (Control) and T_8 (500 mg Kg^{-1} fluoride) (Table 7). DMRT wordings depicted the variation among treatments. In the present investigation some mineral element may have acted as an activator for accelerating the enzymatic activity with lowest concentration of fluoride i.e., 25 mg Kg^{-1} fluoride. Such type of action might have occurred through which high yield with low fluoride concentration took place as reported earlier (Ram et al., 2007). Bachman and Metzger, 2008 reported growth and yield improvement in different crops with vermicompost application. Theunissen et al., 2010 reported that vermicompost contains most nutrients such as phosphates, exchangeable calcium, soluble potassium and other macronutrients with a huge quantity of beneficial microorganisms, vitamins and hormones in plant available from which influence the growth and yield of plants. Atiyeh et al., 2000; Arancon et al., 2004 and Singh et al., 2008 reported that vermicompost produced significant improvements in the growth and yield of sweet corn. Not only vermicompost but also compost had a remarkable impact on yield of crops. Dietz and Krauss (1997) compared the effect of compost on yield with an unfertilized control and a recommended NPK control in a long term investigation. But at higher concentrations of fluoride under both of treatment combination due to nutrient deficiency (Sabal et al., 2006) yield were gradually decreased (Ram et al., 2014).

EXPERIMENT I (2012-2013)

TABLE 11

IMPACT OF CHEMICAL FERTILIZER AND FLUORIDE ON YIELD ATTRIBUTES

Treatments (mg Kg^{-1} F)	Silique length (cm)	Silique breadth (cm)	Grains Number	1000 seed weight(g)	Seed weight (Kg ha^{-1})	Empty pod weight (Kg ha^{-1})	Straw Weight (Kg ha^{-1})
Control(T_5)	4.423^{a}	0.723^{a}	23.67^{a}	2.478^{a}	683.3^{a}	566.7^{a}	1250^{a}
T_1	4.100^{b}	0.687^{b}	2.17^{b}	2.322^{a}	600.0^{b}	533.3^{ab}	1050^{b}
T_2	4.040^{bc}	0.673^{b}	21.70^{b}	2.304^{a}	566.7^{bc}	516.7^{abc}	983.3^{bc}
T_3	3.950^{bcd}	0.640^{c}	21.40^{b}	2.294^{a}	550.0^{bc}	466.7^{bc}	877.3^{cd}
T_4	3.867^{cde}	0.623^{cd}	21.03^{b}	2.244^{a}	533.3^{c}	450.0^{cd}	774.7^{de}
T_6	3.823^{de}	0.610^{d}	19.10^{c}	2.205^{a}	516.7^{cd}	363^{d}	664.7^{ef}
T_7	3.747^{e}	0.580^{e}	18.47^{cd}	2.193^{a}	466.7^{de}	383.3^{de}	609.0^{f}
T_8	3.520^{f}	0.557^{f}	17.40^{d}	2.126^{a}	416.7^{e}	316.7^{e}	523.7^{f}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

TABLE 12

IMPACT OF VERMICOMPOST, COMPOST, BACTERIAL CONSORTIUM AND FLUORIDE ON YIELD ATTRIBUTES

Treatments (mg Kg^{-1} F)	Silique length (cm)	Silique breadth (cm)	Grains Number	1000 seed weight(g)	Seed weight (Kg ha^{-1})	Empty pod weight (Kg ha^{-1})	Straw Weight (Kg ha^{-1})
Control(T_5)	4.083^{cd}	0.713^{c}	21.83^{cd}	2.209^{a}	751.7^{c}	760^{cd}	1350^{abc}
T_1	4.367^{a}	0.820^{a}	25.53^{a}	2.411^{a}	1016.7^{a}	1083.3^{a}	1567^{a}
T_2	4.307^{ab}	0.773^{b}	24.87^{ab}	2.39^{a}	950.0^{ab}	900.0^{b}	1533^{ab}
T_3	4.230^{abc}	0.757^{b}	23.30^{bc}	2.274^{a}	900.0^{b}	866.7^{bc}	1383^{abc}
T_4	4.170^{bc}	0.740^{bc}	21.30^{c}	2.245^{a}	816.7^{c}	816.7^{bcd}	1376^{abc}
T_6	4.083^{cd}	0.713^{c}	21.83^{cd}	2.132^{a}	665.0^{d}	733.3^{d}	1317^{bc}
T_7	3.970^{de}	0.673^{d}	20.30^{d}	2.110^{a}	586.7^{e}	616.7^{e}	1217^{c}
T_8	3.857^{e}	0.667^{d}	18.23^{e}	2.066^{a}	503.3^{f}	533.3^{e}	900^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

EXPERIMENT II (2013-2014)

FIRST PART OF THE EXPERIMENT

TABLE 13

IMPACT OF VERMICOMPOST(FULL DOSE), COMPOST(FULL DOSE), BACTERIAL CONSORTIUM, CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON YIELD ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Silique length (cm)	Silique breadth(cm)	Grains number	1000seed weight(g)	Seed weight (Kg ha^{-1})	Empty pod weight (Kg ha^{-1})	Straw weight (Kg ha^{-1})
Control(T_5)	5.325^{bc}	1.865^{a}	30.75^{bc}	2.424^{bc}	175.0^{bcd}	350.0^{cd}	725.0^{bcd}
T_1	6.380^{a}	3.425^{a}	37.95^{a}	2.734^{a}	525.0^{a}	615.0^{a}	1100.0^{a}
T_2	5.915^{ab}	3.390^{a}	35.15^{ab}	2.673^{a}	325.0^{b}	490.0^{b}	975.0^{ab}
T_3	5.855^{ab}	1.925^{a}	34.15^{ab}	2.562^{ab}	300.0^{bc}	425.0^{bc}	870.0^{abc}
T_4	5.540^{bc}	1.895^{a}	33.75^{ab}	2.530^{ab}	275.0^{bc}	420.0^{bc}	795.0^{bcd}
T_6	5.085^{cd}	1.750^{a}	28.65^{cd}	2.368^{bc}	145.0^{cd}	280.0^{d}	635^{cd}
T_7	4.620^{d}	1.715^{a}	25.35^{d}	2.266^{c}	75.0^{d}	275.0^{d}	530.0^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

SECOND PART OF THE EXPERIMENT

TABLE 14

IMPACT OF VERMICOMPOST (FULL DOSE), COMPOST (HALF DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON YIELD ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Silique length (cm)	Silique breadth(cm)	Grains number	1000seed weight(g)	Seed weight (Kg ha^{-1})	Empty pod weight (Kg ha^{-1})	Straw weight (Kg ha^{-1})
Control(T_5)	5.035^{ab}	1.375^{ab}	22.65^{c}	2.321^{cd}	200^{cd}	325^{c}	627.5^{bcd}
T_1	5.280^{a}	1.615^{a}	24.85^{a}	2.673^{a}	435^{a}	500^{a}	1025^{a}
T_2	5.205^{ab}	1.565^{ab}	24.05^{b}	2.641^{a}	400^{ab}	495^{ab}	830^{b}
T_3	5.110^{ab}	1.470^{ab}	22.95^{c}	2.503^{b}	335^{abc}	430^{ab}	754^{bc}
T_4	5.060^{ab}	1.435^{ab}	22.80^{c}	2.405^{c}	250^{bc}	400^{bc}	710^{bcd}
T_6	1.750^{a}	1.265^{ab}	21.50^{d}	2.276^{d}	75^{d}	225^{d}	550^{cd}
T_7	1.715^{a}	1.215^{b}	20.70^{e}	2.119^{e}	50^{d}	200^{d}	527.5^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

THIRD PART OF THE EXPERIMENT

TABLE 15

IMPACT OF VERMICOMPOST (HALF DOSE), COMPOST(FULL DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON YIELD ATTRIBUTES OF MUSTARD

Treatments (mg Kg^{-1} F)	Silique length (cm)	Silique breadth(cm)	Grains number	1000seed weight(g)	Seed weight (Kg ha^{-1})	Empty pod weight (Kg ha^{-1})	Straw weight (Kg ha^{-1})
Control(T_5)	4.585^{bc}	0.370^{b}	20.66^{b}	2.304^{e}	100^{d}	165^{de}	800^{bc}
T_1	5.175^{a}	0.455^{a}	22.6^{a}	2.688^{a}	377.5^{a}	475^{a}	1325^{a}
T_2	4.950^{ab}	0.40^{b}	21.05^{b}	2.625^{b}	315^{ab}	375^{b}	1025^{ab}
T_3	4.845^{ab}	0.390^{b}	21.05^{b}	2.478^{c}	260^{b}	300^{c}	1000^{ab}
T_4	4.735^{b}	0.375^{b}	20.91^{b}	2.384^{d}	177.5^{c}	200^{d}	875^{abc}
T_6	4.300^{cd}	0.360^{b}	19.71^{b}	2.202^{f}	72.5^{d}	135^{ef}	700^{bc}
T_7	4.110^{d}	0.300^{c}	18.15^{c}	2.105^{g}	50^{d}	105^{f}	400^{d}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

3.3 Fluoride accumulation in different plant parts

The present result revealed that maximum fluoride accumulation took place in the leaves and minimum quantity of fluoride within the seeds. Similar types of results were reported by Agarwal and Singh Chauhan (2014). They have reported that in

Triticum aestivum (Wheat) var. Raj 3077 under pot experiment with different concentration of fluoride solution maximum fluoride accumulated within leaves (20.64 mg Kg^{-1}) and minimum accumulation occurred within seeds (10.65 mg Kg^{-1}). In the present investigation result of fluoride accumulation within the seeds were within the permissible range (Maximum contaminant level of 4.0 mg Kg^{-1} in and the level of dose capable of causing illness which is 0.3 mg Kg^{-1} recommended by EPA, FAO and WHO) (Table 18, 19 and 20). In case of chemical fertilizer plus sodium fluoride treatment, maximum amount of fluoride accumulated compared to the indigenous organic inputs treated plots (Table 16 and Table 17). Maximum amount of fluoride accumulated within the leaves and meagre amount accumulated within the root (Agarwal and Singh Chauhan, 2014).This is perhaps due to self regulation of plant system. Fluoride may not stay in the root and it migrated either to stem or to leaves to seeds as par their suitable place for their deposition. Besides the tap root which goes inside deeper layer of the soil and active transport through the root and shoot system makes it possible for maximum amount of fluoride accumulation in the leaf and seed coat. Moreover, results of experiment I with indigenous organic inputs fluoride accumulation within root, shoot, leaf, seed coat and seed were significantly higher in T_8 and significantly lower in T_1. Under experiment II, fluoride accumulations in different parts of mustard were significantly higher in T_7 and significantly lower in T_1. The trends of the results were similar under all three sets of experiment.

EXPERIMENT I (2012-2013)

TABLE 16
IMPACT OF CHEMICAL FERTILIZER AND FLUORIDE ON DIFFERENT PARTS OF MUSTARD

Treatments (mg Kg^{-1} F)	Root(ppm)	Shoot(ppm)	Leaf(ppm)	Seed coat(ppm)	Seed(ppm)
Control(T_5)	0.002^{c}	0.005^{e}	0.007^{d}	0.012^{d}	0.008^{f}
T_1	0.008^{c}	0.017^{d}	0.026^{cd}	0.018^{d}	0.016^{e}
T_2	0.020^{b}	0.024^{c}	0.051^{cd}	0.031^{c}	0.027^{d}
T_3	0.024^{ab}	0.026^{c}	0.076^{c}	0.036^{bc}	0.029^{cd}
T_4	0.028^{ab}	0.029^{c}	0.087^{c}	0.041^{abc}	0.032^{bc}
T_6	0.030^{ab}	0.037^{b}	0.155^{b}	0.042^{ab}	0.037^{b}
T_7	0.032^{a}	0.044^{a}	0.175^{b}	0.048^{a}	0.044^{a}
T_8	0.036^{a}	0.047^{a}	0.265^{a}	0.050^{a}	0.046^{a}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

TABLE 17
IMPACT OF VERMICOMPOST, COMPOST, BACTERIAL CONSORTIUM AND FLUORIDE ON DIFFERENT PARTS OF MUSTARD

Treatments (mg Kg^{-1} F)	Root(ppm)	Shoot(ppm)	Leaf(ppm)	Seed coat(ppm)	Seed(ppm)
Control(T_5)	0^{d}	0^{d}	0^{d}	0^{d}	0^{d}
T_1	0d	0.012^{c}	0.016^{cd}	0.010^{c}	0^{d}
T_2	0.009^{c}	0.015^{c}	0.021^{cd}	0.012^{c}	0^{d}
T_3	0.012^{bc}	0.018^{bc}	0.045^{bcd}	0.015^{c}	0.003^{cd}
T_4	0.014^{bc}	0.023^{ab}	0.065^{bc}	0.016^{bc}	0.006^{c}
T_6	0.018^{ab}	0.025^{a}	0.085^{b}	0.022^{ab}	0.013^{b}
T_7	0.023^{a}	0.026^{a}	0.087^{b}	0.023^{a}	0.016^{ab}
T_8	0.024^{a}	0.028^{a}	0.155^{a}	0.026^{a}	0.017^{a}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

EXPERIMENT II (2013-2014)

FIRST PART OF THE EXPERIMENT

TABLE 18

IMPACT OF VERMICOMPOST (FULL DOSE), COMPOST (FULL DOSE), BACTERIAL CONSORTIUM, CHEMICAL FERTILIZERS(RECOMMENDED DOSE) AND FLUORIDE ON DIFFERENT PARTS OF MUSTARD

Treatments (mg Kg^{-1} F)	Root(ppm)	Shoot(ppm)	Leaf(ppm)	Seed coat(ppm)	Seed(ppm)
Control(T_5)	0.00^{b}	0.000^{e}	0.000^{f}	0.000^{e}	0.000^{d}
T_1	0.00^{b}	0.018^{d}	0.019^{e}	0.010^{d}	0.000^{d}
T_2	0.004^{b}	0.020^{cd}	$0.024d^{e}$	0.013^{cd}	0.000^{d}
T_3	0.006^{b}	0.025^{bc}	0.027^{cd}	0.013^{c}	0.000^{c}
T_4	0.007^{b}	0.027^{ab}	0.030^{c}	0.015^{c}	0.005^{c}
T_6	0.009^{b}	0.029^{ab}	0.044^{b}	0.018^{b}	0.009^{b}
T_7	0.024^{a}	0.032^{a}	0.049^{a}	0.023^{a}	0.014^{a}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

SECOND PART OF THE EXPERIMENT

TABLE 19

IMPACT OF VERMICOMPOST (FULL DOSE), COMPOST (HALF DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON DIFFERENT PARTS OF MUSTARD

Treatments (mg Kg^{-1} F)	Root(ppm)	Shoot(ppm)	Leaf(ppm)	Seed coat(ppm)	Seed(ppm)
Control(T_5)	0.000^{e}	0.000^{e}	0.000^{e}	0.000^{g}	0.000^{e}
T_1	0.004^{de}	0.024^{d}	0.015^{d}	0.012^{f}	0.002^{de}
T_2	0.005^{cd}	0.027^{cd}	0.017^{d}	0.014^{e}	0.003^{d}
T_3	0.008^{cd}	0.029^{c}	0.033^{b}	0.016^{d}	0.006^{c}
T_4	0.010^{c}	0.033^{b}	0.037^{b}	0.018^{c}	0.009^{b}
T_6	0.022^{b}	0.034^{b}	0.039^{a}	0.021^{b}	0.010^{b}
T_7	0.032^{a}	0.044^{a}	0.052^{a}	0.025^{a}	0.014^{a}

THIRD PART OF THE EXPERIMENT

TABLE 20

IMPACT OF VERMICOMPOST (HALF DOSE), COMPOST (FULL DOSE), CHEMICAL FERTILIZERS (RECOMMENDED DOSE) AND FLUORIDE ON DIFFERENT PARTS OF MUSTARD

Treatments (mg Kg^{-1} F)	Root(ppm)	Shoot(ppm)	Leaf(ppm)	Seed coat(ppm)	Seed(ppm)
Control(T_5)	0.000^{bd}	0.000^{f}	0.000^{d}	0.000^{e}	0.000^{d}
T_1	0.000^{c}	0.018^{d}	0.011^{d}	0.002^{e}	0.001^{d}
T_2	0.000^{bd}	0.025^{d}	0.033^{c}	0.013^{d}	0.005^{c}
T_3	0.016^{ab}	0.026^{d}	0.035^{c}	0.015^{c}	0.006^{c}
T_4	0.019^{a}	0.030^{c}	0.071^{b}	0.020^{b}	0.011^{b}
T_6	0.023^{a}	0.036^{b}	0.082^{b}	0.021^{b}	0.012^{ab}
T_7	0.031^{a}	0.060^{a}	0.150^{a}	0.031^{a}	0.015^{a}

Note: Means followed by the same letter within a treatment were not significantly different at 5% level using Duncan's Multiple Range Test (DMRT)

IV. CONCLUSION

In the present study with full dose of vermicompost, ½ dose of compost and bacterial consortium, it has been observed that such treatment combination, reduced the level of fluoride as compared to the recommended dose of chemical fertilizers and sodium fluoride treatment. Therefore, such treatment combination, have a positive role in combating fluoride level in such an agro-ecosystem under such soil and field condition. Again this can duplicated for other crops for reduction of fluoride under such agro ecological condition.

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REFERENCES

[1] S.A. Alharbi 2008. "In vitro solubilisation of insoluble fluorides by selected fungi," African Journal of Microbiological Research. 2: 319-321.

[2] K.R. Aneja, "Experiments in Microbiology, Plant Pathology, Tissue Culture and Mushroom Production Technology," New Age International (P) Limited, New Delhi: India, pp. 157-161, 2002.

[3] N.Q. Arancon, C.A. Edwards, P. Bierman, C. Welch, and J.D. Metzer, 2004. "Influence of vermicomposts on field strawberries : effect on growth and yields." Bioresource Technology. 93: 145-153.

[4] A.K.M. Arnesen, and T. Krogstad, 1998. "Sorption and desorption of fluoride in soil polluted from the aluminium smelter at Ardal in Western Norway," Water Air & Soil Pollution. 103: 357-73.

[5] R. Azarmi, M.T. Giglou, and R.D. Taleshmikail 2008. "Influence of vermicompost on soil chemical and physical properties in tomato (*Lycopersicum esculentum*) field," African Journal of Biotechnology. 7(14): 2397-2401.

[6] G.R. Bachman and J.D. Metzger, 2008. "Growth of bedding plants in commercial potting substrate amended with vermicompost," Bioresource Technology. 99: 3155-3161.

[7] M.K. Beg, S.K. Srivastav, E.J.M. Carranza, and J.B. De Smith, 2011. "High fluoride incidence in ground water and its potential health effects in parts of Raigarh, Chhattisgarh, India," Current Science. 100(5): 750-754.

[8] D. Bhargava and N. Bhardwaj, 2010. "Effect of sodium fluoride on seed germination and seedling growth of *Triticum aestivum*, var.Raj.4083," Journal of Phytology. 2(4): 41-43.

[9] C.A. Black, (ed), (1965).Methods of soil analysis. Part I and Part-II. Inc. Publishers, American Society of Agronomy, Madison (Wisconsin): U.S.A.

[10] R.F. Brewer, 1966. Fluorine In: H.D. Chapman (ed) (1966). "Diagnostic criteria for plants and soils," University of California: Division of Agricultural Sciences, pp. 180 -196.

[11] R. Brunt, L. Vasak and J. Griffioen, 2004. "Fluoride in ground water: probability of occurrence of excessive concentration on global scale," IGWRAC, Report nr. SP 2004-2.

[12] L.P. Canellas, F.L. Olivares, A.L. Okorokova-Facanha, and A.R. Facanha, 2002. "Humic acids isolated from earthworm compost enhance root elongation, lateral root emergence, and plasma membrane H–ATPase activity in maize roots," Plant Physiology. 130:1951–1957.

[13] S.J. Cronin, V.E. Neall, J.A. Lecointre, M.J. Hedley, and P. Loganathan, 2003. "Environmental hazards of fluoride in volcanic ash: A case study from Ruapehu volcanic, New Zealand," Journal of Volcanology Geothermal Research. 121:271-91.

[14] J.K. Datta, A. Maitra, N.K. Mondal, and A. Banerjee, 2012. "Studies on the impact of fluoride toxicity on germination and seedling growth of gram seed (*Cicer arietinum* L. cv. Anuradha)," Journal of Stress Physiology & Biochemistry. 8(1):194-202.

[15] U. Dey , N.K. Mondal, K. Das, and J.K. Datta, 2012. "Dual effects of fluoride and calcium on the uptake of fluoride, growth physiology, pigmentation, and biochemistry of Bengal gram seedlings (*Cicer arietinum* l.)," Fluoride. 45(4):389-393.

[16] T. Diez, and M. Kraus, 1997. "Wirkung langjahriger compost dung ung auf pflanzenertrag and boden fruchtbarkeit," Agribiological Research, 50(1): 78-84.

[17] S.D. Ebbs, and L.V. Kochian, 1998. "Phytoextraction of zinc by oat (*Avina sativa*), Barley (*Hordeum vulgare*), and Indian Mustard (*Brassica Juncea*)," Environmental Science & Technology, 32 : 802-806.

[18] N. Elloumi, F.B. Abdallah, I. Mezghani, I. Rhouma, and M. Boukhris, 2005. "Effect of fluoride on almond seedlings in culture solution," Fluoride, 38:193-8.

[19] J.E. Frencken (ed) (1992). "Endemic fluorosis in developing countries, causes, effects and possible solutions," Publication number 91.082, NIPG-TNO, Leiden: The Netherlands.

[20] V.K. Garg, A. Dahiya, A. Choudhary, and D. Shikha, 1998. Indian Ecol Env And Cons, 4(1-2):19-23.

[21] K.A. Gomez and A.A. Gomez, 1984. Statistical procedure for a agricultural research. (2nd ed.), Wiley: New York (NY).

[22] P.K. Gupta, 2004. "Methods in Environmental Analysis Water, Soil and Air," Agrobios, India.

[23] M.L. Jackson, 1972. "Soil chemical analysis," Prentice Hall of India Pvt. Ltd , New Delhi .

[24] C.D. Jadia, and M.H. Fulekar, 2008. "Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant," Environmental Engineering and Management Journal, 7(5): 547-558.

[25] C.P. Jordao, C.C. Nascentes, P.R. Cecon, R.L.F. Fontes, and J.L. Pereira, 2006. "Heavy metal availability in soil amended with composted urban solid wastes," Environmental Monitoring Assessment, 112:309-326.

[26] R.D. Kale, B.C. Mallesh, B. Kubra, and D.J. Bagyaraj, 1992. "Influence of vermicompost application on the available macronutrients and selected microbial populations in a paddy field," Soil Biology & Biochemistry, 24:1317-1320.

[27] G. Klumpp, C.M. Furlan, M. Domingos, and Klumpp, 2006. "Response of stress indicators and growth parameters of *Tibouchina pulchra* Cogn. Exposed to air and soil pollution near industrial complex of Cubatao, Brazil," Science of the Total Environment, 246:79-91.

[28] D.J.M.K. Lallawmsanga, M.D. Balakumaran, M.R. Kumar, and J, Jeyarathi, 2012. "Ameliorating effect of vermicompost and cow dung compost on growth and biochemical characteristics of *Solanum melongena* L. treated with paint industrial effluent," Annals of Biological Research, 3:2268–2274.

[29] W.E. Lindsay, and W.A. Norvell, 1978. "Development of a DTPA test for zinc, iron, manganese, and copper," Soil Science Society of America Journal, 42, (3):421–428.

[30] P. Loganathan, M.J. Hedley, G.C. Wallace, and A.H.C. Robert, 2011. "Fluoride accumulation in pasture forages and soils following long-term application of phosphorus fertilizers," Environmental Pollution, 115: 275-82.

[31] J.A. Lori, 1987. "Determination of some essential Minerals in the Source Soil and two cultivars of white yam (*Discrorea rotundata*)," M.Sc thesis, Zaria : Nigeria, Ahmadu Bello University.

[32] A. Khan, and F. Ishaq, 2011. "Chemical nutrient analysis of different composts(*Vermicompost* and *Pitcompost*) and their effect on the growth of a vegetative crop *sativum*," Asian Journal of Plant Science Research, 1(1):116-130.

[33] N.M.I. Kugli, and M.S. Yadawe, 2010. "Pollution of drinking water due to fluoride and dental fluorosis at hunagund taluk of Begalkot district, Karnataka," 1(2): 322-328.

[34] A. Maitra, J.K. Datta, and N.K. Mondal, 2013. "Amelioration of Fluoride Toxicity with the Use of Indigenous Inputs," Journal of Stress Physiology & Biochemistry, 9(3):207-219.

[35] C.L. Mackowiak, P.R. Grossl, and B.G. Bugbee, 2006. "Biogeochemistry of fluoride in a plant solution system," Journal of Environmental Quality, 32:2230-7.

[36] M.M. Manyuchi, A. Phiri, P. Muredzi, and T. Chitambwe, 2013. "Comparison of Vermicompost and Vermiwash Bio-Fertilizers from Vermicomposting Waste Corn Pulp," World Academy of Science, Engineering and Technology, 7(6) : 368-371.

[37] T.A. Mehedi, M.A. Siddique, and S.B. Shahid, 2012. "Effects of urea and cowdung on growth and yield of carrot," Journal of the Bangladesh Agricultural University, 10(11): 9-13.

[38] I. Mezghani, N. Elloumi, F.B. Abdallah, M. Chaieb, and M. Boukhris, 2005. "Fluoride accumulation by vegetation in the vicinity of a phosphate fertilizer plant in Tunisia," Fluoride, 38 (1): 69-75.

[39] G.W. Miller, 1993. "The effect of fluoride on higher plants: with special emphasis on early physiological and biochemical disorders," Fluoride, 26: 3-22.

[40] T. Mondal, J.K. Datta, and N.K. Mondal, 2014. "An alternative eco-friendly approach for sustainable crop production with the use of indigenous inputs under old alluvial soil zone of Burdwan ,West Bengal, India," Archives of Agronomy of Soil Science, 60: 1-14.

[41] H.M. Moradi, A. Fahramand, M. Sobhkhizi, M. Adibian, S. Noori, Abdollahi, and K. Rigi, 2014. "Effect of vermicompost on plant growth and its relationship with soil properties," International Journal of Farming & Allied Sciences, 3(3): 333-338.

[42] L. Muggler, 2009. "Fluoride in soil solution: An assessment of fluoride availability and uptake by plants in fluoride contaminated soils," Term Paper. Swiss Federal Institute of Technology, Zurich.

[43] M. Mukhopadhyay, J.K. Datta, and T.K. Garai, 2013. "Steps toward alternative farming system in rice," European Journal of Agronomy, 51:18–24.

[44] G. Murray, 1981. **"**Fluoride cycles in estuarine ecosystem," Science of Total Environment, 17**:** 233-241.

[45] N.N. Nenthra, K.V. Jayaprasad, and R.D. Kale, 1999. "China aster (*Callistephus chinensis* (L.) Ness) cultivation using vermicomposts as organic amendment," Crop Research- Hisar, 17: 209-2015.

[46] S.R. Olsen, C.V. Cole, F.S. Watnabe, and L.A. Dean, 1954. "Estimation of available phosphorous in soil by extraction with sodiumbicarbonate," U.S: Department of Agriculture circular, 1954, pp. 939.

[47] E.D. Paul, C.E. Gimba, J.A. Kagbu, G.I. Ndukwe, and F.G. Okibe, 2011. "Spectrophotometric determination of fluoride in water, soil and vegetables from the precinct of river Basawa, Zaria, Nigeria," Journal of Basic and Applied Chemistry, 1(6): 33-38.

[48] A. Ram, P. Verma, and B.R. Gadi, 2014. "Effect of fluoride and salicylic acid on seedling growth and biochemical parameters of water melon(*Citrullus lanatus)*," Fluoride, 47(1): 49-55.

[49] S. Rangasamy, B. Alagirisamy, G. Purushothaman, and M. Santiago, 2013. "Effect of vermicompost on biotransformation and bioavailability of hexavalent chromium in soil," IOSR Journal of Agriculture and Veterinary Science (IOSR- JAVS), 5(3) : 34-40.

[50] D.N. Rao, and D. Pal, 1978. "Effect of fluoride pollution on the organic matter content of soil," Plant and Soil, 49(3): 653-656.

[51] S. Rathore, 1992. "Effect of fluoride toxicity on leaf area, net assimilation rate and relative growth rate of *Hordeum vulgare* and *Zea mays*," Fluoride, 25(4) : 1-8.

[52] M.P. Reddy, and M. Kaur, 2008. "Sodium fluoride induced growth and metabolic changes in *Salicornia brachiata.*Roxb," Water Air & Soil Pollution. 188:171-9.

[53] D. Sabal, T.I. Khan, and R. Saxena, 2006. "Effect of sodium fluoride on cluster bean (*Cyamopsis tetragonoloba*) seed germination and seedling growth," Fluoride. 39(3):228-230.

[54] N. Saeed, M. Hussain, and M. Saleem, 2002. "Interactive effect of biological sources and organic amendments in the growth and yield attributes of Sunflower (*Helianthus annlus* L.)," Pakisthan Journal of Agricultural Sciences. 39:135-136.

[55] R.K. Sahoo, M.W. Ansari, M. Pradhan, T.K. Dangar, S. Mohanty, and N. Tuteja, 2014. "Phenotypic and molecular characterization of efficient native Azospirillum strains from rice fields for crop improvement," Protoplasma. doi:10.1007/s00709-013-0607-7.

[56] M.M. Saxena, 1998. "Environmental analysis Water Soil and Air," Agro Botanical Publisher, Bikaner, 1998, pp.139.

[57] G. Schwarzenbach, W. Biedermann, and F. Bangerter, 1946. Ibid. 29:811-18.

[58] R.V. Sinha, and S. Herat, 2012. "Organic farming: producing chemical-free, nutritive and protective food for the society while also protecting the farm soil by earthworms and vermicompost – reviving the dreams of sir Charles Darwin," Agricultural Science Research Journal. 2(5):217-239.

[59] C. Sreenivas, S. Muralidhar, M.S. Rao, 2000. "Vermicomposts: a viable component of IPNSS in nitrogen nutrition of ridge gourd," Annals of agricultural research. 21:108-113.

[60] D.P. Stevens, M.J. Mclaughlin, and A.M. Alston, 1997. "Phytotoxicity of aluminium –fluoride complex and their uptake from solution culture by *Avena sativa* and *Lycopersicon esculantum*" Plant and Soil. 192: 81-93.

[61] B.V. Subbiah, and G.L. Asija, 1956. "A rapid procedure for determination of available nitrogen in soils," Current Science. 25: 259-260.

[62] R.K. Suhane, 2007. "Vermicompost (In Hindi)," Pub of Rajendra Agriculture University: Pusa (Bihar), 2007, pp. 88.

[63] K. Szymanska, F. Domka, and T. Wojtowicz, 2004. Catabolic activity of *Desulfotomaculum ruminis* Bacteria in a medium containing fluorides. Polish Journal of Environmental studies. 13(1): 97-101.

[64] S.D. Takmaz-Nisancioglu, and A.W. Davison, 1988. "Effects of Al on fluoride uptake by plants," New Phytologist. 109:149-155.

[65] J. Theunissen, P.A. Ndakidemi, and C.P. Laubscher, 2010. "Potential of vermicompost prodeuced from plant waste on the growth and nutrient status in vegetable production," International Journal of Physical Sciences. 5:1964-1973.

[66] A.K. Tripathi, and R.C. Singh, 1984. Indian Journal of Environmental Protection. 16,748.

[67] R.K. Trivedy, P.K. Goel, and C.L. Trisal, 1998. Practical methods in Ecology and Environmental Science. Environmental Media Publication, Karad:India.

[68] M.M.A . Youssef , and M.F.M. Eissa, 2014. "Biofertilizers and their role in management of plant parasitic nematodes. A review," E3 J Biotechnology and Pharmaceutical Research. 5: 1–6.

[69] Walkely 1947. "Critical examination of rapid method for determining organic carbon in soils, effect of variation in digestion conditions and of inorganic soil constituents," Soil Science. 632, 251.

[70] Watson, 1952. "The physiological basis of variation in yield," Advances in Agronomy. 4:101-145.

[71] J. Weber, A. Karczewska, J. Drozd, M. Licznar, S. Licznar, E. Jamroz, and A. Kocowicz, 2007. "Agricultural and ecological aspects of a sandy soil as affected by the application of municipal solid waste composts," Soil Biology & Biochemistry. 39:1294-1302.

[72] L.H. Weinstein, 1977. "Fluoride and plant life," Journal of Occupational and Environmental Medicine, 19: 49-78.

[73] WHO (1984). Fluorine and fluorides. Geneva, World Health Organization (Environmental Health Criteria 36).