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# Impact of Compost Prepared from Invasive Alien Species in Alleviating Water Stress in Tomato (*Solanum Lycopersicum* L.)

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## ABSTRACT

Invasive alien plant species are major thread to biodiversity, climate change and environmental sustainability. Management of these invasive alien plant species become a typical task at global level. Composting can be an efficient and environment friendly solution for management of these invasive alien species. The aim of present study was to evaluate the effect of compost prepared from three invasive alien species *Cuscutareflexa*, *Eupatorium adenophorum* and *Lantana camara*on the tomato plant vigour, antioxidant and nutrient content under water deficit and irrigated (well watered) conditions. The results revealed that *Cuscutareflexa* (CR) compost treatment gave highest shoot length (23.0%, 23.7%), root length (30.0%, 21.4%), shoot fresh weight (47.9%, 52.2%), shoot dry weight (71.0%, 49.4%) and root dry weight (66.7%, 51.5%), under water stressand irrigated conditions, respectively. The application of compostCR under water stress has enhanced chlorophyll and prolinecontent over control. Similarly, antioxidant enzymes analysis showed the increased superoxide dismutase (1.33-2.17fold), peroxidase (1.38-1.82fold)) and catalase (1.06-1.73fold) activity under water deficit condition. Nutrient content such as nitrogen, phosphorus, potassium and sodiumin tomato leaf were higher under both water stress and irrigated conditions compared to their respective control. It can be concluded from above outcomes that compost prepared from invasive alien species have potential to ameliorate the negative effects of water stress and enhance the tomato growth.

**KEYWORDS**: *Water stress, compost, invasive alien species, tomato, antioxidant*

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## INTRODUCTION

Invasive alien species (IAS) are foreigner to ecosystem and are major global problem. Introduction of these species in any habitat cause economical or environmental harm to the local floral diversity and human health. In addition to being severe threat to biodiversity invasive alien species also threaten the ecosystem stability by triggering the change in biogeochemical cycles and soil nutrient content (Ehrenfeld, 2003). Among the various invasive species in Indian Himalayan region *Eupatorium adenophorum* (Crofton weed), *Lantana camara* (common lantana) and *Cuscutareflexa* (dodder) have been reported from the large area (Lamsal et al., 2018; Chandra Sekar, 2012). Their management strategies needed better research towards prevention and control because these are major drivers of global change (Pathak et al., 2019). Numbers of treatments are reported for control of invasive alien species. Several studies showed the utilization of *Lanatanacamara* for production of ethanol, cellulose, biogas, drugs and furniture (Pasha et al., 2007; Varshneyet al., 2006; Sainiet al., 2003; Sharma et al., 2007; Patel, 2011) but all methods have proved economically unviable. Composting could be an effective major for the management of invasive alien species. Suthar and Sharma (2013) studied preparation and effect of vermicompost of *Lantana camara*. Vermicompost was prepared by mixing *Lantana* and cow dung in 1:4 and 4:1 for 21 days and further treated with the *Eiseniafetida* for 2 months. This vermicompost increased the germination of *Zea mays*. Experiment on *Eupatorium adenophorum* (crofton weed), *Lantana camara* (common lantana) and *Cuscutareflexa* (dodder) showed that composting enhance theon plant growth in many crops (Li et al., 2014; Rawat and Suthar, 2014; Singh et al., 2013). However there are limited numbers of studies on the composting of these invasive alien species plants due to allelochemical content. Recently reports showed that the composting can eliminate the toxic effect of allelochemicals from these invasive alien species.

Li et al. (2014) compared un-composted and composted crofton weed and concluded that the main allelochemical of composted crofton weed, i.e., 9-b-hydroxy-ageraphorone was significantly reduced and contents of nitrogen and phosphorus also increased after composting.

Agriculture sector claims almost 70% of fresh water for irrigation, is going to sternly affected by the water stress (OECD, 2020). Water stress (drought)is a major abiotic stress that affects almost20% of agricultural land around the world and declines the crop production by means of poor seed germination and establishment, reduced plant height, stem diameter biomass and canopy, decrease the photosynthetic efficiency and generation of high amount of reactive oxygen species (ROS)(Kaya et al., 2006;Hussainet al.,2008; Zheng et al., 2016;Wahid and Rasul, 2005; Munne-Bosch and Penuelas, 2003; Chandra et al., 2020). High amount of ROS introduce oxidative damage to the DNA, proteins and cellular membrane and inactivate enzymes (Gill and Tuteja, 2010; Foyer and Noctor, 2005). During the evolution, plants developed a complex set of machinery to handle abiotic and biotic stresses. ROS are scavenged by low molecular weight enzymes such as superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT). Moreover, production of high amount of compatible solutes such as proline is also one of the most common responses towards the stress in plants (Serraj and Sinclair, 2002). High concentration of proline responsible for decrease in osmotic potential also maintains stability of proteins and membranes (Ashraf and Foolad, 2007).

To tackle water stress with sustainable and economical way, compost originated from different kinds of IAS can play vital role. Compost enhance crop tolerance and plant productivity by improving soil structure, nutrients, water holding capacity and diversity of beneficial microorganism(Zewide et al., 2018).Organic matter present in compost not only promotes plant health but also protects water evaporation and improves water holding capacity of soil. Compost containing 1% organic matter can increase soil organic matter by 10% and can hold 16,500 gallons of plant available water per acre of soil down to one foot deep (Gould, 2015). Apart from this it has been also reported in many studies that compost amendment to the soil also increase antioxidant defence system which save them from oxidative damage (Mittler, 2002). Multiple range of characteristics such as agronomical, physiological and biochemical are stimulated by compost application hence it is vital module for sustainable agriculture.

The aim of present study was to evaluate the effect of compost prepared from invasive alien species on tomato growth, antioxidant potential and nutrient content under irrigated and drought conditions.

## Materials and methods

### Soil source and characteristics of compost

Clayloam soil collected from GBPUA&T Pantnagar, Uttarakhand India, passed through 1 mm of mess size. The chemical characteristics of soil were pH-6.9, electrical conductivity (EC)-86.13 ds/m, organic carbon (OC) 2.12%, total nitrogen (N) 0.48%, available phosphorus (P) 11.31mg/kg, potassium (K) 400.00 mg/Kg, sodium (Na) 16.00 g/Kg and water holding capacity (WHC) 26.62%.Composts used in present study were prepared by tray composting method at 60% moisture content by using following ingredients: - 1. *Cuscutareflexa* (dodder) plant+ cow dung 2.tender shoot and leaves of *Eupatorium adenophorum* (Crofton weed)+ cow dung,4.*Lantana camara* (common lantana) leaves+ cow dung.

pH and EC of soil and compost was calculated by method of Jackson (1973). Organic carbon (OC) % in soil and compost was measured by the wet digestion method of Walkely and Black (1934). Total N was determined by Kjeldahl digestion method and available P was calculated according to Olsen's Method (1954). Available K and Na were calculated by flame photometry (Systronics).

### Experimental plant

For glasshouse experiment, tomato seeds (*SolanumlycopersicumL.* var. Pant T3) were purchased from GBPUA&T Pantnagar, Uttarakhand, India. Seeds were sterilized by dipping in 3% (v/v) NaOCl for 3 minutes further treated with 70% ethanol and finally rinsed with distilled water. Nursery was prepared in tray under glasshouse condition. Twenty one days old seedlings of same size were planted in plastic pots.

### Experimental design and watering details

To evaluate the effect of composts on tomato plant under water stress and irrigated (non-stress) conditions glass house experiment was conducted at temperature, light intensity and duration at 25±2 $^0$C, 400 Em$^{-2}$s$^{-1}$ and 12/12 day/light cycle, respectively. Compost was added at the rate of 12g/kg of soil. Two tomato seedlings were transplanted into pot having 9.0 cm diameter and 10.5 cm height. Complete randomized design with 4 treatments [1. Control (without compost) 2.Cuscutareflexa compost 3.*Eupatorium adenophorum* compost 4.*Lantana camara* compost] with two sets, water stress and irrigated was used. Each treatment was repeated for three times. Moisture content of both sets was kept at the water holding capacity (WHC, 26.6%) of soil for initial 30 days of experiment and then one set was exposed to the water stress (drought) by maintaining 30% of WHC until completion of experiment. Plants were harvested and analysed for various agronomical and biochemical parameters. No additional nutrient was supplemented to the pots to evaluate if the compost treatments can increase the nutrient uptake in treated plants compared to soil without treatment.

### Plant sample analysis

### Agronomical characteristics

Plant length and fresh weight were measured immediate after harvesting the plants whereas, dry biomass of shoot and root was determined after drying the plant at 60$^0$C in oven until sample weight remained constant.

### Analysis of biochemical parameters

Chlorophyll a and b content in fresh tomato leaves were calculated according to Arnon (1949).Total proline content in tomato leaves was analysed by following the procedure of Bates et al. (1973).SOD, POD and CAT activity were determined by method of Beahuchamp and Fridovich (1971), Kar and Mishra (1975) and Beers and Sizer (1952), respectively.

### Analysis of plant nutrient content

To determine the nutrient [nitrogen (N), phosphorus (P), potassium (K) and sodium (Na)] content, the plant leaf samples were dried at 60 $^0$C in oven and powdered. Total N was analysed with the help of Kjeldahl digestion method. Elements P, K and Na were determined after digestion of leaf samples in diacid ($HNO_3$:$HClO_4$) mixture. P concentration in digest was analysed according to Jackson (1973) and Kand Na were determined by flame photometry.

### Statistical analysis

All data were shown as arithmetic mean value of three replicates with standard error. ANOVA was applied to compare the effect of different treatments and both water conditions on various plant characteristics. Statistical analysis was done by using SPSS software version 20.0 and Duncan's test was applied at 5% confidence level to compare the data.

## Results

### Composting

During the composting process, temperature started to increase after 4$^{th}$ day of composting and remained at 60-70 % for 14-16 days. Composting was completed when temperature came below 40� after 44-46 days.

**Physicochemical characteristic of composts**

All physiochemical characteristics of composts were given in table 1.The pH value of matured composts was within 7.5-8.0 range. Organic carbon in all matured composts varies from 10.7-14.3%. Maximum organic matter (24.7%) was recorded in CRcompost followed by the LC compost (22.8%).Total nitrogen content(2.6%) was highest in compost made from CR followed by the LC (2.1%) compost.

**Growth characteristics of tomato**

Control plants had significantly reduced shoot and root length when compared to the plants treated with compost in both water conditions (Fig. 1). Shoot length was significantly reduced by 21.7% in water deficit condition compared to irrigated situation. Compost treatment under both conditions significantly increased shoot and root length, fresh weight and dry weight of tomato. In shoot length, maximum increment of 23.0%was recorded after application of CR compost followed by compost EA (19.2%) and LC (14.0%) as compared to un-amended control plant sunder water deficit condition(Fig. 1A). Similarly, under irrigated condition maximum shoot length was increased by compost CR, EA and LC by 23.7%, 21.3% and 18.7% respectively, over untreated ones (Fig. 1A). Under water stress condition, maximum enhancement of 30.0% in root length was achieved in plants treated with compost CR followed by EA (27.3%) and LC (25.9%) over untreated control plants whereas, under irrigated condition, maximum root length was noticed 21.4%after application of compost CR followed by EA (20.4%) and LC (15.7%) over untreated control (Fig. 1B).

Shoot fresh weight in water stress condition was maximally enhanced by compost CR (47.9%) followed by compost EA (36.4%) whereas, under well watered condition shoot fresh weight was increased by compost CR and EA by 52.2%, 47.2%,respectively, compared to untreated control plants (Fig. 2). Opposite to shoot fresh weight, shoot dry weight was maximum in water stress condition when compared to their irrigated counterpart. Highest shoot dry weight increased after treating the plants with compost CR(71.0%) followed by EA (69.8%) as compared to control one in water stress condition whereas, compost CR (49.4.8%), EA (43.3%) were efficient in irrigated condition over relative control (Fig. 3A).Root dry weight in both conditions was maximum after application of CR (66.7%, 51.5%) followed by EA (58.8%, 41.7%) and LC (52.2%, 30.9%) under water stress and irrigated conditions, respectively, when compared to their relative control (Fig. 3B).

**Chlorophyll a and b content**

Chlorophyll content analysis revealed that addition of compost significantly increased chlorophyll a (2.25 fold) and b (2.07 fold) under water stress condition as compared to its untreated water stressed plant (Table 3). However, chl a and b concentration enhanced by 2.41 and 2.62fold, respectively, by CR compost in irrigated condition when compared to its control plant.

**Proline content**

Result analysis from total proline content showed the highest proline (3.39fold) was recorded after treating the plant with compost CR under water stress condition (Table 3). Under well watered condition there was not very prominent difference inproline content.

**Antioxidant enzymatic activity**

Tomato plants treated with compost had higher (1.33-2.17fold) SOD activity as compared to untreated plants under water deficit condition (Table 3). Under irrigated condition, SOD activity was lower than its counterpart water stress set.

Water stress significantly increased leaf POD activity and this increment was further enhanced by the application of composts (Table 3). POD activity under water deficit condition was increased (1.38- 1.82fold), whereas, in irrigated condition there was negligible increment in activity when compared to the control plants. A significance enhancement in leaf CAT activity was caused by water deficit condition (Table 3). Maximum CAT activity was enhanced by 1.73fold after treatment under water deficit condition when compared to its respective untreated control plant. In irrigated set, CAT activity was lower in compost amended plants than untreated one.

**Plant nutrient analysis**

Waters stress negatively affected the leaf nutrients N, P, Kand Naintomato leaves. Nutrients analysis showed that stressed plants without any treatment had substantial reduction in the N (31.2%), P (19.4%), K (7.7%), Ca (12.6%) and Na(12.5%) level as compared to irrigated control plants (Table 4). Plants treated with compost with exhibited significant increase in N (41.0-60.7%), P (43.1-65.1%), $K^+$ (36.9-59.6%), $Na^+$ (43.0-55.0%) and Ca (25.1-31.4%) under water stress condition. Likewise, in irrigated condition, compost treatment increased N (40.1-58.4%), P (35.7-64.3%), $K^+$ (3.5-29.8%), $Na^+$ (9.3-33.8%) and $Ca^{2+}$ (23.6-32.6%) nutrient content in tomato leaves as compared to untreated control (Fig. 4).

**Discussion**

Water stress restricts the crop physiology performance and productivity thus; it is major hurdle to achieve the food security throughout the world (Kogan et al., 2018; Chandra et al., 2019). Compost has aptitude to improve the plant resistance and productivity under water stress condition. Diverse type of microorganisms present in compost stimulate substrates such as vitamins, hormones, antibiotics and nutrients which further enhances plant growth directly and indirectly (Osman and Rady,2012; Ojo et al,. 2014; Mensah and Frimpong, 2018).In present study, efficacy of composts prepared from invasive alien species on the growth of tomato plant was assayed under water stress and irrigated conditions. The maximum shoot and root length was observed in plants treated with compost CR (*Cuscutareflexa*) under water stress and irrigated conditions.

There are very few reports on organic amendments to soil and its effect on plant biomass are available. In this study, compost treatments promoted the tomato plant biomass. Soil treated with compost CR (*Cuscutareflexa*) enhanced the shoot fresh and dry biomass under water stress and irrigated conditions. Nguyen et al. (2012) also reported that compost incorporation can increase shoot-root dry biomass. Organic matter present in compost improves water holding capacity and nutrient availability to the plant hence enhance the crop biomass under water deficit condition compared to full irrigation(Curtis and Claassen, 2005; Hirich et al., 2014). Shoot length, shoot fresh weight, root length and root fresh weights were maximum in irrigated condition when compared to its water stress counterpart. Whereas, shoot and root dry weight was higher in water stress condition when compared to counterpart plants grown in irrigated condition.

The water stressed plant showed high dry biomass compared to their counterpart irrigated set. This is might be due to accumulation of potassium ion in plant tissue which finally responsible for increased total dry mass, stomatal regulation and water retention under water stress condition (Egilla et al., 2001; Marschner, 2012).

A very swift effect of water scarcity in plants mainly slow the photosynthetic rate by closing of stomata which limits the $CO_2$ uptake, impaired the photosynthetic system, enhances the leaf rolling which decrease the leaf area, and increased the disintegration of chlorophyll (Farooq et al. 2009).Tomato plants treated with composts neutralizing the negative effect of water stress and stimulate chlorophyll a and b content. Duo et al. (2018) also stated that compost had positive effect on the chlorophyll a and b content under water stress condition. Enhanced amount of nitrogen which promotes the chlorophyll content was observed in tomato plants treated with compost as compared to untreated plants. Similar types of studies are reported by many researchers where amendments of organic fertilizers significantly increased chlorophyll content in many plants under water stress condition (Khadem et al., 2010; Salehi et al., 2016; Chopra et al., 2017).

Furthermore, amendment of compost shows straight influence on proline accumulation in plants. Augmented proline content acts as sensor of drought injury in cell (Dien et al., 2019). Our results showed, proline content was higher in tomato plants received compost treatment under water deficit condition. Bokobana et al. (2019) reported that in water stress condition, compost application enhanced proline content in maize. Increased concentration of proline maintains osmotic balance and sustains protein structure and cell integrity (Chun et al., 2018; Zlatev and Lidon, 2012).It has been reported in many studies that compatible solutes proline, glycine betaineregulate cytoplasmic pH, boost energy required for the growth and survival for plants to resist abiotic stresses(KaviKishor et al., 2005; Valentovic et al., 2006;Gomaa et al., 2015).

Plants furnished with various antioxidant defence mechanism which may be enzymatic and non-enzymatic to alleviate oxidative damage caused by ROS under water stress (Miller et al.,2010).Under various stress conditions, plants produce high amount of ROS in cell organelles such as mitochondria, chloroplasts and peroxisomes (Apel and Hirt, 2004). But due to availability of sufficient amount of water, ROS concentration remains balanced. Earlier studies of Tartoura (2010) reported that increased activity of SOD and CAT by compost application under water deficit condition. In present study, compost treated tomato plants had higher concentration of antioxidant enzymes SOD, POD and CAT under water stress condition. Increased concentration of these antioxidant enzymes after compost treatment might be to neutralize effect of $H_2O_2$produce after the exposure of water stress. Presence of nutrients in organic fertilizers help in ROS detoxification by enhancing activity of antioxidants such as SOD, POD and CAT in plants (Waraich et al., 2012; Hasanuzzaman et al., 2018).

In present study**,** foliar nutrient content indicated that plants treated with compost provide adequate amount of nutrients. When compared to other nutrient mainly potassium content was high in water deficit condition after application of organic amendments. Potassium is principle ion related to stomatal regulation and turgor pressure (Marschner, 2012).

## Conclusion

The outcomes of present study suggest that addition of compost prepared from available invasive alien flora is better soil amendment to reduce the water stress. Compost enhances fertility, stability and functionality of soil which leads to the increase plant growth and productivity. These properties finally contribute to upgrading the tomato plant height and biomass. Compost prepared from invasive alien species like *Cuscutareflexa*performed better under water stress and irrigated conditions when compared to other treatments. In conclusion, this experiment opens up the opportunity to assess the probability of compost as fertilizer in alleviating the water stress confronted by the plants. Utilizing these residues for compost preparation can be a solution to get ride on noxious weeds which are threat to native vegetation community, soil structure and agricultural yield.


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## Conflict of Interest

On the behalf of all, the corresponding author declares that there is no conflict of interest in the publication.

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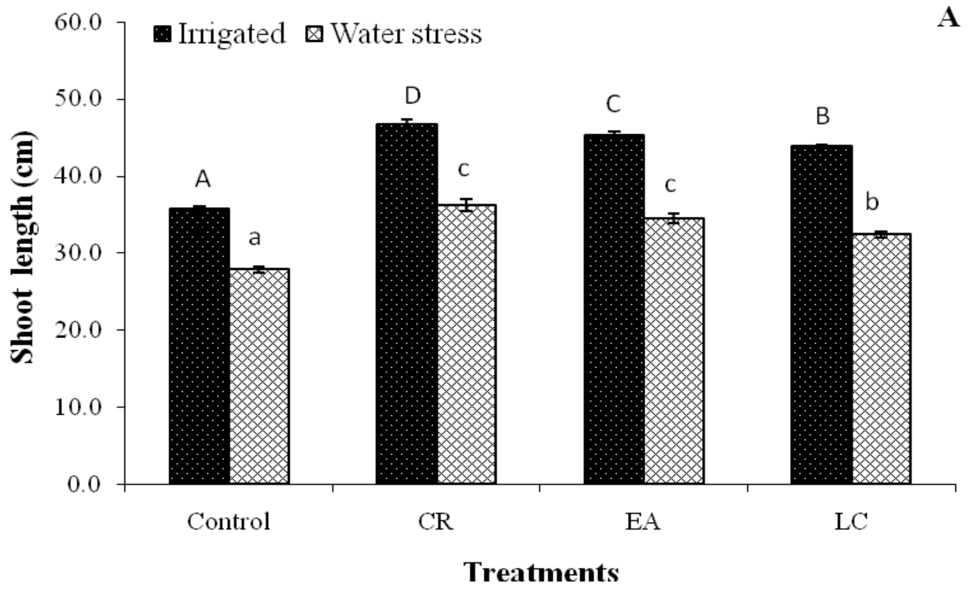
**Fig. 1: Effect of composts and rice biochar on (A) shoot length and (B) root length of tomato under irrigated and water stress conditions. Values are means of 3 replicates ± S. E. Bars sharing different alphabets differ significantly from each other at p < 0. 05 according to Duncan's test.**



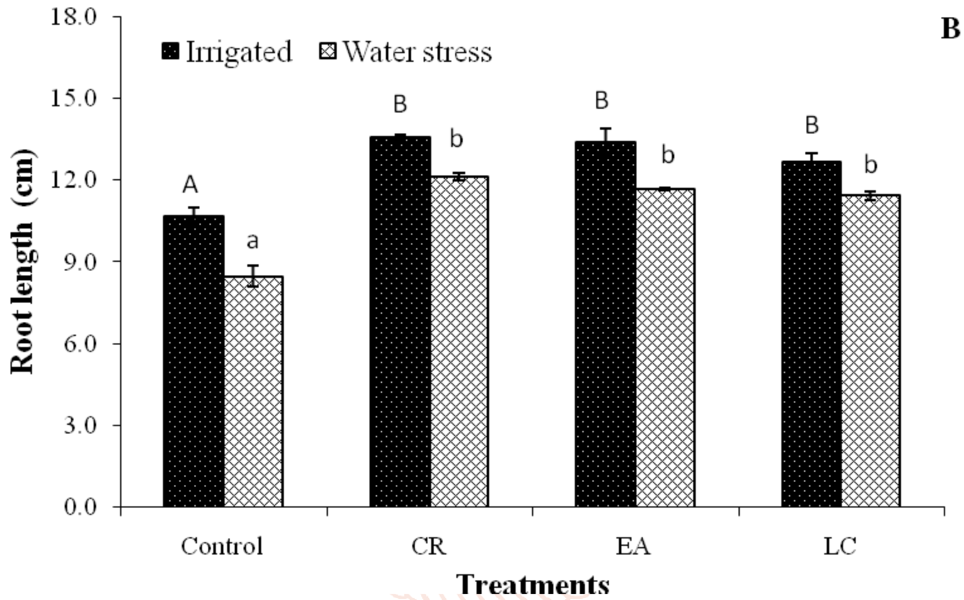
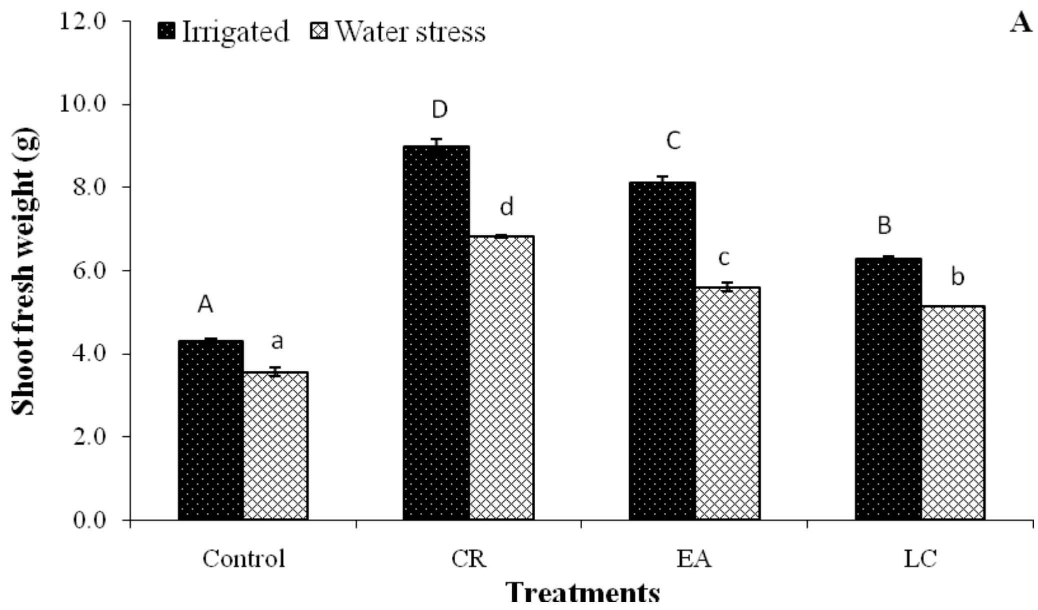




**Fig. 2: Effect of composts on (A) shoot fresh weight of tomato under irrigated and water stress conditions. Values are means of 3 replicates ± S. E. Bars sharing different alphabets differ significantly from each other at p < 0. 05 according to Duncan's test**



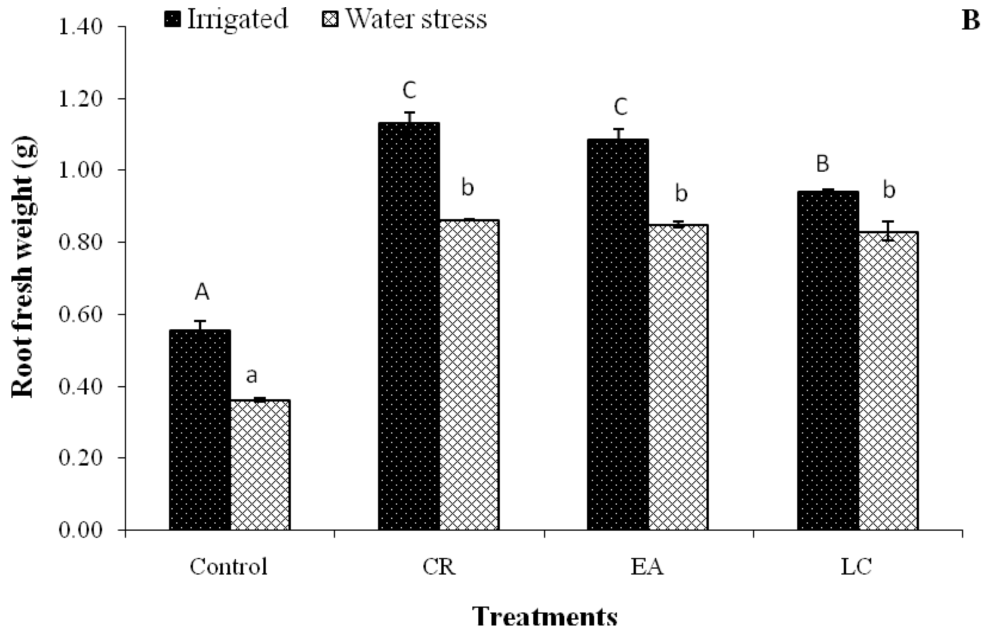
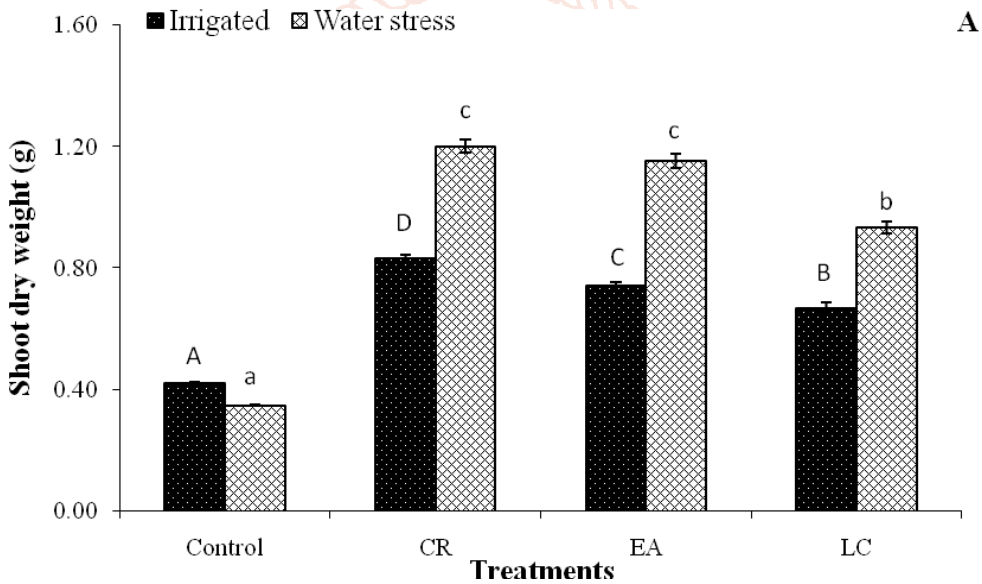



**Fig. 3: Effect of composts on (A) shoot dry weight and (B) root dry weight of tomato under irrigated and water stress conditions. Values are means of 3 replicates ± S. E. Bars sharing different alphabets differ significantly from each other at p < 0. 05 according to Duncan's test.**



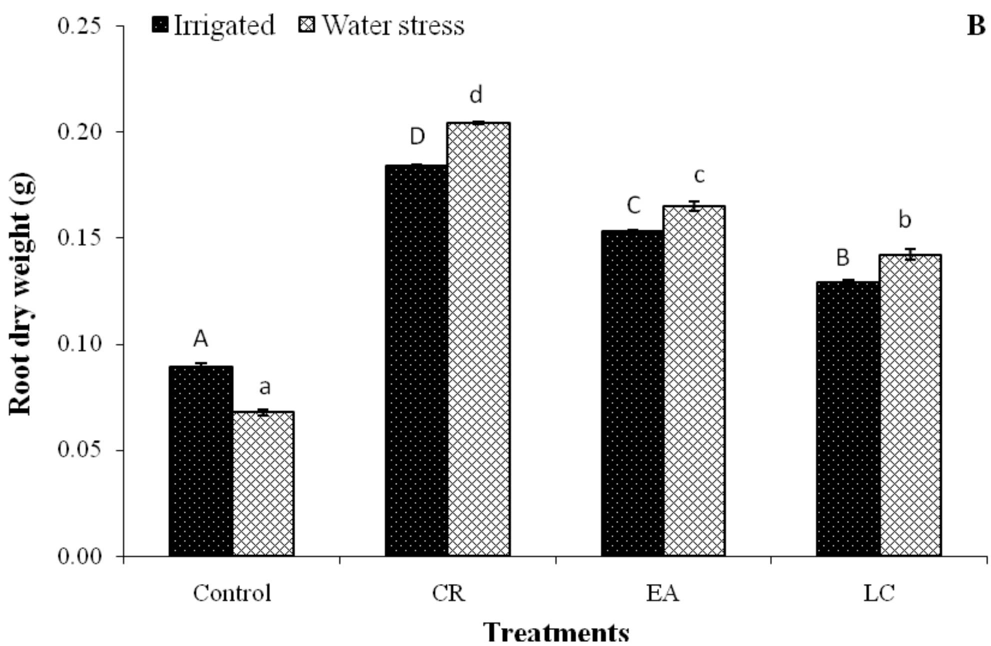



**Fig. 4: Effect of compost on foliar nutrients [nitrogen (N), phosphorus (P), potassium (K) and sodium (Na)] concentration under (A) irrigated and (B) drought conditions.**

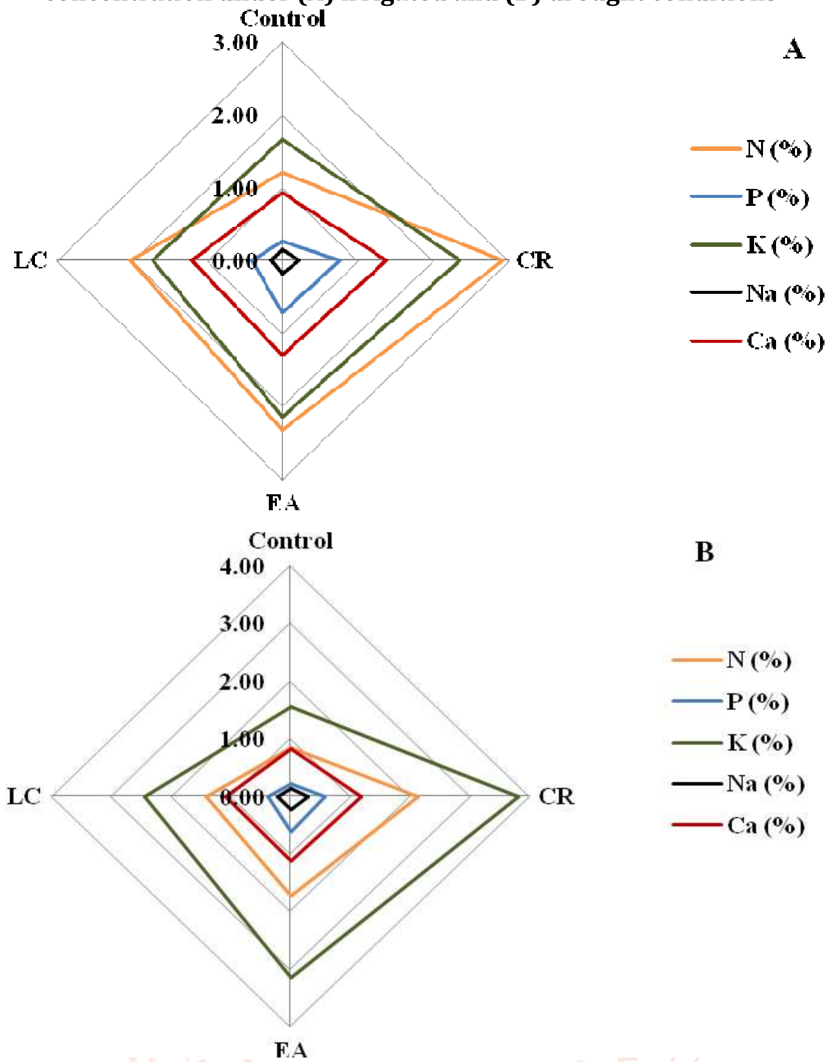



**Table 1: Physico-chemical characteristics of different compost**

| Compost/ Parameters | pH | EC (dS/m) | Moisture (%) | OC (%) | OM (%) | N (%) | P (%) | K (%) | Na (%) |
|---|---|---|---|---|---|---|---|---|---|
| C. reflexa (CR) | 8.0 | 3.06 | 23.81 | 14.34 | 24.72 | 2.65 | 0.035 | 10.00 | 0.50 |
| E. adenophorum (EA) | 7.5 | 2.54 | 29.72 | 10.69 | 18.44 | 1.32 | 0.030 | 20.00 | 0.57 |
| L. camara (LC) | 7.7 | 2.27 | 26.53 | 13.25 | 22.83 | 2.00 | 0.034 | 10.50 | 0.55 |

EC-Electrical conductivity, OC-Organic carbon, OM-Organic matter, N-Nitrogen, P-Phosphorus, K-Potassium, Na- Sodium

**Table 2: List of treatments used in glasshouse experiment**

| Treatment | Designation | Identity |
|---|---|---|
| T1 | Control | Control |
| T2 | CR | Cuscutareflexa compost |
| T3 | EA | Eupatorium adenophorumcompost |
| T4 | LC | Lantana camaracompost |

**Table 3: Effect of compost treatment on tomato chlorophyll a and b, proline, superoxide dismutase (SOD), peroxidase (POD) and catalase (CAT) concentration under irrigated and drought conditions**

| Treatment | Chl a (mg/g Fresh Weight ) | | Chl b (mg/g Fresh Weight) | | Proline (µg/ Fresh Weight) | | SOD (Unit/mg Fresh Weight) | | POD (nmol/min/mg protein) | | CAT (µmol/min/mg protein) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | D | I | D | I | D | I | D | I | D | I | D |
| Control | 0.78$^{A}$ | 0.58$^{a}$ | 0.30$^{A}$ | 0.25$^{a}$ | 1.51$^{A}$ | 1.82$^{a}$ | 2.28$^{A}$ | 2.85$^{a}$ | 12.10$^{A}$ | 15.24$^{a}$ | 6.52$^{a}$ | 7.71$^{a}$ |
| CR | 1.88$^{D}$ | 1.29$^{d}$ | 0.80$^{D}$ | 0.58$^{d}$ | 1.74$^{B}$ | 6.18$^{d}$ | 2.54$^{B}$ | 6.19$^{d}$ | 14.62$^{B}$ | 27.69$^{d}$ | 7.18$^{ef}$ | 13.32$^{d}$ |
| EA | 1.58$^{C}$ | 1.08$^{c}$ | 0.67$^{C}$ | 0.45$^{c}$ | 1.61$^{A}$ | 4.95$^{c}$ | 2.87$^{C}$ | 5.37$^{c}$ | 13.83$^{B}$ | 23.28$^{c}$ | 7.70$^{cd}$ | 8.88$^{c}$ |
| LC | 1.01$^{B}$ | 0.93$^{b}$ | 0.41$^{B}$ | 0.39$^{b}$ | 1.54$^{A}$ | 2.37$^{b}$ | 2.62$^{B}$ | 3.80$^{b}$ | 13.80$^{B}$ | 21.12$^{b}$ | 6.72$^{ab}$ | 8.17$^{b}$ |

Values are mean of three replicates. Means within columns with the different latters indicate statistically significant differences at 5% significance level after DMRT.

Chl a- Chlorophyll a, Chl b- Chlorophyll b, SOD- Superoxide dismutase, POD- Peroxidase, CAT-Catalase