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ALLELOPATHIC COMPETITIVENESS OF *TRIANTHEMA PORTULACASTRUM* L. AND *PARTHENIUM HYSTEROPHORUS* L. ON MORPHOLOGICAL AND PHYSIOLOGICAL GROWTH PARAMETERS IN OKRA

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Abstract

Okra is an essential vegetable world over, but in past decade, a reduction in per hectare yield was noted. Amongst various reasons for its low yield, weeds are the most important. These weeds reduce the crop growth by competing for resources and by allelopathic effects. During surveys of okra fields in Pakistan, amongst others, *Trianthema portulacastrum* L. and *Parthenium hysterophorus* L. were noted but no data till to date are available that show comparative allelopathic potential of these weeds in okra. So, in the recent investigation, experiments were executed to assess the allelopathic effects of these two weeds on okra. Soil amendment with *T. portulacastrum* significantly reduced the shoot length of okra up to 42%, root length up to 73%, shoot dry weight up to 84%, root dry weight up to 73% and chlorophyll a up to 48%, chlorophyll b up to 50% and carotenoid up to 19.5%. Similar inhibitory effects were observed in case of *P. hysterophorus* but with comparatively less intensity. Gas Chromatography Mass Spectrometry analysis of *T. portulacastrum* revealed the presence of compounds viz., Phytol, 11-octadecenoic acid, methyl ester, 8, 11-Octadecadienoic acid, metlyl ester and Pentadecanoic acid at the highest concentrations. While in case of *P. hysterophorus*, following compounds were present at the highest concentrations; Phorbol, 1, 2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester, Isolongifolene-7, 8-dehydro-8a-hydroxy- and 1H-cycloprop[e]azulene, 1a, 2, 3, 4, 4a, 5, 6, 7b-octahydro-1, 1, 4, 7-tetramethyl-, [1ar (1a.alpha., -4.alpha., 4a.beta.,7b.alpha.)]-. It can be concluded that these compounds may be responsible for allelopathic effects observed during the present study.

Key words: Allelelopathy, *Parthenium, Trianthema*, Weeds, Okra, GCMS.

Introduction

In recent years, there is growing trend to address food security (Uyttendaele *et al.,* 2016; King *et al.,* 2017; Hidrobo *et al.,* 2018). Pakistan is an agriculture country and number of crops are grown here to meet food security and food safety of growing population. Okra [*Abelmoschus esculentus* (L.) Moench] is popular vegetable cultivated in all parts of Pakistan and a number of other countries, but in past decade, a declining trend in its per hectare yield has been recorded (Anon., 2019). Sustainable production of vegetable crops like okra is important for the economy of any country all over the world (Pannacci *et al.,* 2017).

Amongst various reasons for low crop yield, weeds are the most important as these inflict 40% decline in yield (Ramesh *et al.,* 2017). These weeds reduce the crop growth by competing for resources and by allelopathic effects (Safdar *et al.,* 2015; Dai *et al.,* 2017; Gfeller *et al.,* 2018), thereby affecting food security negatively. *Trianthema portulacastrum* L. (Horse purslane), family Aizoaceae and *Parthenium hysterophorus* L. (*Parthenium* weed or congress weed), family Asteraceae, are two important weeds in various crops and are wide in distribution (Ara *et al.,* 2015). A number of herbicides have been recommended to combat these weeds but with little success and greater environmental and human health problems as well as herbicide resistance in number of weeds (Javaid *et al.,* 2017; Takano *et al.,* 2017). These weeds are also known to affect the physiology of crops when growing at nearby places (Barros *et al.,* 2017). At one time, *P. hysterophorus* was considered as weed of wasteland but there are number of reports indicating its presence in numerous agricultural crops including okra. Horse purslane is a problematic weed species that has been reported having infested in many agricultural crops including vegetables like okra (Kumar & Gaddeyya, 2014).

During surveys of okra fields in Gujrat, Pakistan, amongst others, *T. portulacastrum* and *P. hysterophorus* were noted but no data till to date are available that show the comparative allelopathic potential of these weeds in okra. So, in the recent investigation, experiments were planned to appraise the allelopathic effects of these two weeds; *T. portulacastrum* and *P. hysterophorus* on okra plants in soil amendment bioassays. Moreover, the present investigation was designed to determine the allelopathic efficacy of *T. portulacastrum* and *P. hysterophorus* on morphological and physiological growth parameters of *A. esculentus.* This study will help to set priorities by policy makers, researchers and stakeholders in weed management programs in okra fields.

Materials and Methods

Site description: Experiments were conducted at experimental area of University of Gujrat, Pakistan. Gujrat, Pakistan is located at 32.5731° N, 74.1005° E and lies 233 meters above sea level. Pot experiments were conducted under natural environmental conditions in open sun. The pot experiments were performed during the month of July and August, 2016. During these two months, mean rainfall was 161.35mm, mean maximum temperature was 34.9°C, mean minimum temperature was 24.6°C and humidity level as 71.75%. While, annual rain fall mean was 44.7 mm, mean maximum temperature was 31.04°C and mean minimum temperature was 16.18°C and humidity level as 59.96%. These weather data were kindly provided by Pakistan Meteorological Department, Pakistan.

Soil amendment bioassays: Soil to be used in pot experiments was collected from nearby agricultural land, mixed well manually and then fumigated/disinfested with formaldehyde for one week. After fumigation process polythene sheet was removed from soil and again mixed well and left for 3 days under open environmental conditions. Plastic pots were filled with loamy soil @ 6 kgs soil/pot. Soil analysis was done from soil and water analysis laboratory, District Mandi Bahauddin, Pakistan. Soil was loamy in texture having pH = 8, EC dsm^{-1} equal to 1.1, organic matter % age= 0.79, Avail-P= 5.6 ppm, Avail-K= 98 ppm and saturation % age equal to 34.

Test plants, *Trianthema portulacastrum* and *Parthenium hysterophorus* were collected from infested okra fields in Gujrat, Pakistan. After collection of these two weeds, these weed plants were washed under running tap water to remove attached soil particles or other impurities. After washing step, all weed plants were immediately put under fan to remove surface moisture. Then these plants were sundried for 7 days. These dried plant materials were ground to powder in pestle and mortar. Soil amendments with different concentrations (W/W) of powder of two weeds viz. *T. portulacastrum* and *P. hysterophorus* were carried out as below. Pots were arranged in Completely Randomized Design (CRD).

Treatments:
Set 1
T1= Control
T2= *T. portulacastrum* (0.375%)
T3= *T. portulacastrum* (0.75%)
T4= *T. portulacastrum* (1.5%)
Set 2
T1= Control
T2= *P. hysterophorus* (0.375%)
T3= *P. hysterophorus* (0.75%)
T4= *P. hysterophorus* (1.5%)

After mixing the plant (*T. portulacastrum* and *P. hysterophorus*) powder thoroughly into the weighed soil, these were filled into pots, watered and left for one week in open sun. Weed species emerged due to this process were removed manually by hand hoeing from all pots including control as well as treatments. After this, okra (*Abelmoschus esculentus*) variety (Pusa Green) seed sowing was done @ 6 seeds/pot. Seeds of okra variety were purchased from local market. Pots were watered as per requirement.

Harvesting and data collection: At harvesting (40 days after germination), following morphological and physiological parameters were recorded.

Morphological parameters: To investigate the allelopathic effects of two weeds, *T. portulacastrum* and *P. hysterophorus*, following growth parameters were considered. Shoot length (cm), shoot fresh and dry weight (g), root length (cm), root fresh and dry weight (g). Shoot length was measured with measuring scale. Plant fresh weight was recorded immediately after harvesting. Uprooted plants were washed under tap water to eradicate attached soil particles. After washing, excessive water from plant material was removed with blotting paper and then kept under fan for 30 minutes. Same process was repeated with all plant materials in all treatments. Then the plant material was weighed with digital balance. To record dried weight of plants in all treatments, plant materials were kept in an electric oven (Model: Memmert GmbH+Co.KG D-91126 Schwabach FRG, Germany) at 60°C till complete drying and weighed (Akbar & Javaid 2015).

Physiological parameters: Okra plant mortality % was assessed by counting the number of seeds sown in each pot and plants survived at the time of harvesting. For the determination of physiological parameters viz. chlorophyll a, b and carotenoids, following procedures were adopted.

Determination/estimation of chlorophyll: For the determination of chlorophyll a, chlorophyll b and carotenoids, procedure described by (Arnon, 1949) was adopted. 0.5 grams fresh leaves were taken from all plants from particular treatment under investigation. These leaves were grinded with 2 mL ethanol in pestle and mortar. Then added 5 mL ethanol into it and kept it overnight at room temperature. After this incubation, mixture was filtered through Whatman filter paper No.1. After this filtration the filtrate was used to record optical density (OD) with the help of spectrophotometer (Model: UV3000 Spectrophotometer). The OD was recorded at various wavelengths i.e. 663 nm, 645 nm, 480 nm and 652 nm wavelengths. Determination of chlorophyll a, chlorophyll b and carotenoids was accomplished through following formulae:

Chlorophyll a (mg/g) = [12.7 (O.D 663) - 2.69 (O.D 645)] V / 1000 x W (Sample)
Chlorophyll b (mg/g) = 22.9 (O.D 645) - 4.63 x V / 1000 x W (Sample)
Carotenoids (mg/g) = [7.6 (OD 480)- 1.49 (OD 652)] V / 1000 x W (Sample)

Gas chromatography mass spectrometry (GCMS) analysis: Biochemical constituents of organic solvent (methanolic) extract of *T. portulacastrum* showing higher allelopathic potency were probed by using GCMS, (Agilent Technologies), GC model number 7890A and MS model number 5975C. In order to compare the metabolites of two weed species, GCMS of *P. hysterophorus* was also carried out. Extraction procedure was kept same in all samples (Yue *et al*., 2018). This part of analysis was accomplished at Chemistry Department, Forman Christian University Lahore, Pakistan. GCMS instrument was equipped with column, HP-5MS (30 m × 250 µm × 0.25 µm). In this procedure, helium gas with 99.99% purity was used with constant flow rate of 1 mL/min. Test sample was employed with injection of 2µl volume (0.1 mg/mL concentration). In front injector, the temperature of heater was kept at 240°C. Oven temperature was programmed first from 60°C for 0 minute then 10°C/minute increment to 150°C for 4 minutes then 5°C/ minute to 200°C for 0 minute then 10°C/minute to 300°C for 2 minutes and total GC running time was 35 minutes. MS acquisition parameters were set at scan parameters of low mass as 50.0 and high mass as 650.0.

Data analyses: Data were analyzed by ANOVA followed by Duncan's Multiple Range Test (DMRT) using computer software CoStat.

Results and Discussion

Effect of *Trianthema* and *Parthenium* on shoot growth of okra: Soil amendment with different concentrations of dried biomass of *Trianthema portulacastrum* and *Parthenium hysterophorus* significantly reduced shoot growth parameters of okra up to varying extents. In general, the inhibitory effects of *T. portulacastrum* were more distinct as compared to inhibitory effects of *P. hysterophorus.* Soil amendments with different concentrations (0.375%, 0.75 and 1.5%) of dried powder of *T. portulacastrum* reduced the shoot length of okra to 13%, 33% and 42%, respectively. Different concentrations, 0.375%, 0.75 and 1.5% of *T. portulacastrum* caused 23%, 37% and 44% reduction in shoot fresh weight and 32%, 61% and 84% reduction in shoot dry weight of okra, respectively.

On the other hand, soil amendments with different concentrations (0.375%, 0.75 and 1.5%) of dried powder of *P. hysterophorus* also reduced the shoot length of okra to 4.3%, 10% and 19%, respectively. In this case the effect of lowest concentrations was found non significant but the effect was significant at higher concentrations employed. Different powder concentrations, 0.375%, 0.75 and 1.5% of *P. hysterophorus* caused significant reduction of 12%, 38% and 57% in shoot fresh weight and 31%, 47% and 53% significant reduction in shoot dry weight of okra, respectively (Fig. 1A-C). Such inhibitory effects of allelopathic plants on some other crops have also been reported (Kumar *et al*., 2017).

Effect of *Trianthema* and *Parthenium* on root growth of okra: Soil amendments with different concentrations of dried biomass of *T. portulacastrum* and *P. hysterophorus* significantly reduced root growth parameters of okra up to varying degrees. In general, the deleterious effects of *T. portulacastrum* were more pronounced as compared to deleterious effects of *P. hysterophorus.* Soil amendments with different concentrations (0.375%, 0.75 and 1.5%) of dried powder of *T. portulacastrum* significantly reduced the shoot length of okra to 32%, 53% and 73%, respectively. While, different corresponding concentrations of *P. hysterophorus* reduced the root length of okra upto 15%, 24% and 43%, as compared to control.

Similarly, the negative effects of *T. portulacastrum* and *P. hysterophorus* in soil amendment bioassays were evident on other root growth parameters i.e. root fresh weight and root dry weight of okra. Different concentrations (0.375%, 0.75 and 1.5%) of *T. portulacastrum* and *P. hysterophorus* caused 25%, 36% and 42% and 13%, 17% and 41% reduction in root fresh weight of okra. Similar effects were observed in case of root dry weight of okra where *T. portulacastrum* inflicted 30%, 34% and 73% reduction in root dry weight of okra corresponding to concentrations, 0.375%, 0.75 and 1.5%, respectively. On the other hand, *P. hysterophorus* caused 7%, 13% and 39% reduction in root dry weight of okra at these corresponding concentrations. These results clearly showed that inhibitory effects of *T. portulacastrum* were more intense as compared to similar effects by *P. hysterophorus* (Fig. 1D-F).

Effect of *Trianthema* and *Parthenium* on chlorophyll a, b and carotenoids concentrations of okra: Determination of the optical activity and content of photosynthetic pigments viz. chlorophyll a, b and carotenoids concentrations in leaves is one of the key techniques that authenticate the process of photosynthesis and measuring plant productivity. This technique can also be used to monitor the effects of various biotic and abiotic factors as stress especially in terms of photosynthesis in plants. These are principally valuable in calculating nitrogen content in plants because chlorophyll is one of the major sink of its accumulation (Pavlovic *et al.*, 2014). By combining the chlorophyll measurement with weighing of plant biomass of control and treated plants, correlations can be established among assimilates reallocation, photosynthesis and crop productivity (Nikolić *et al.*, 2007; Pavlović *et al.*, 2010). In the present investigation, deleterious effects of two weeds of okra, *T. portulacastrum* and *P. hysterophorus*, were investigated on the physiological function in terms of chlorophyll a, b and carotenoids. Different employed concentrations of these two weeds exhibited variable response in terms of chlorophyll a, b and carotenoids concentrations. There was significant decline of 39% and 48% in contents of chlorophyll a where 0.75% and 1.5% concentration of *T. portulacastrum* was employed, while an increase in chlrophyll a, chlorophyll b and carotenoids contents was observed in case of treatments having 0.375% concentration of both weeds, *T. portulacastrum* and *P. hysterophorus. T. portulacastrum* at concentration of 0.375% significantly increased the concentration of chlorophyll b (36%).

Increase in case of chlrophyll a (12%) and carotenoids (13%) was statistically significant as compared to control. Similar effects were observed in case of *P. hysterophorus* where its lowest concentration significantly increased the contents of carotenoids to 7%, while in case of chlorophyll a and chlorophyll b, although the results were non-significant but a slight increase was observed. As chlorophyll is the essential element of photosynthesis in plants and entire activity of photosynthesis is based on chlorophyll and therefore, by monitoring its contents in plants, we can determine the productivity of photosynthesis. A change in chlorophyll content of plant is considered as one of the most obvious symptoms of plant stress (Pavlovic *et al.*, 2014). In another study, the negative effect of allelopathic leachates on chlorophyll contents was reported. These allelochemicals from invasive weeds incur their influence by decreasing the synthesis of chlorophyll in leaves of crops (Zhang *et al.*, 2017a). In this case, low concentration of *T. portulacastrum* proved to be having stimulatory effects on the concentrations of chlorophyll a, b and carotenoids but inhibitory at higher concentrations (Fig. 2A-C). It seems possible that lower concentration of weed biomass have stimulatory effects on the efficiency of some photosynthesis related enzymes, thereby increasing chlorophyll contents. These stimulatory effects have been pointed out by (Zhang *et al.*, 2017b), where they concluded that the activities of ascorbate peroxidase (APX) and catalase (CAT) were improved at lower leachate concentrations than control but were inhibited at the highest concentration.

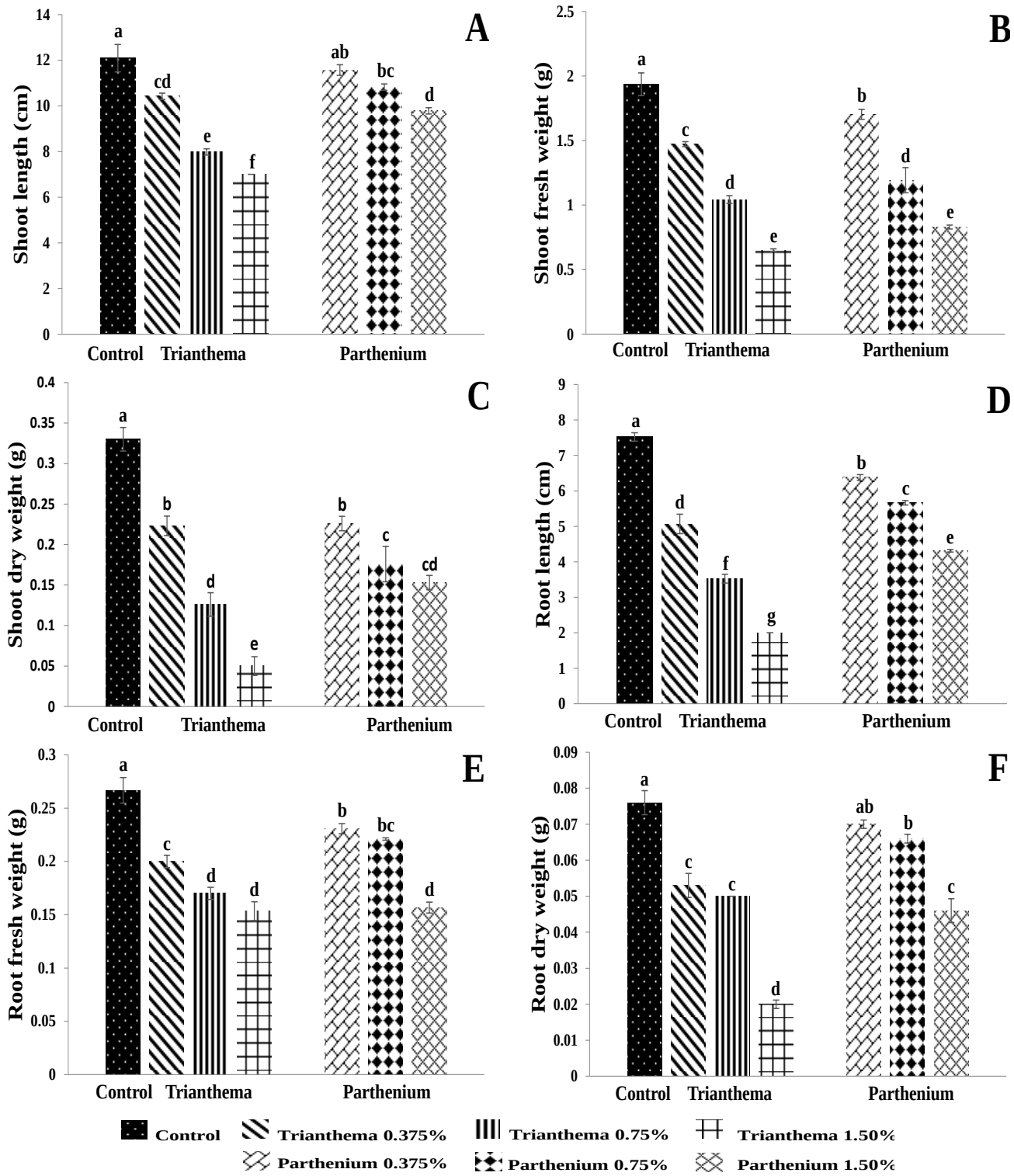

Fig. 1. Effect of different concentrations of *Trianthema* and *Parthenium* on **(A)** shoot length, **(B)** shoot fresh weight, **(C)** shoot dry weight, **(D)** root length, **(E)** root fresh weight and **(F)** root dry weight of okra.
Bars topped by the same letter do not differ significantly at $p \leq 0.05$ by Duncan's Multiple Range test.

Effect of *Trianthema* and *Parthenium* on mortality of okra: Effect of *T. portulacastrum* and *P. hysterophorus* on mortality of okra is shown in Fig. 2D. From these results, it became obvious that effect of *T. portulacastrum* was more intense in causing mortality in okra plants as compared to *P. hysterophorus. T. portulacastrum* caused 94%, 67% and 17% mortality when used at concentrations of 1.5%, 0.75% and 0.375%, respectively. On the other hand, different concentrations of *P. hysterophorus* induced 17%, 17% and 11% mortality of okra plants (Fig. 2D). There are reports on the allelopathic activity of *Melia azedarach* L. on development of *Solanum melongena* L. and okra. In that investigation, leaf aqueous extract and leaf litter inhibited the germination and seedling growth of egg plant and okra, both in laboratory and pot bioassays (Thakur *et al.*, 2017).

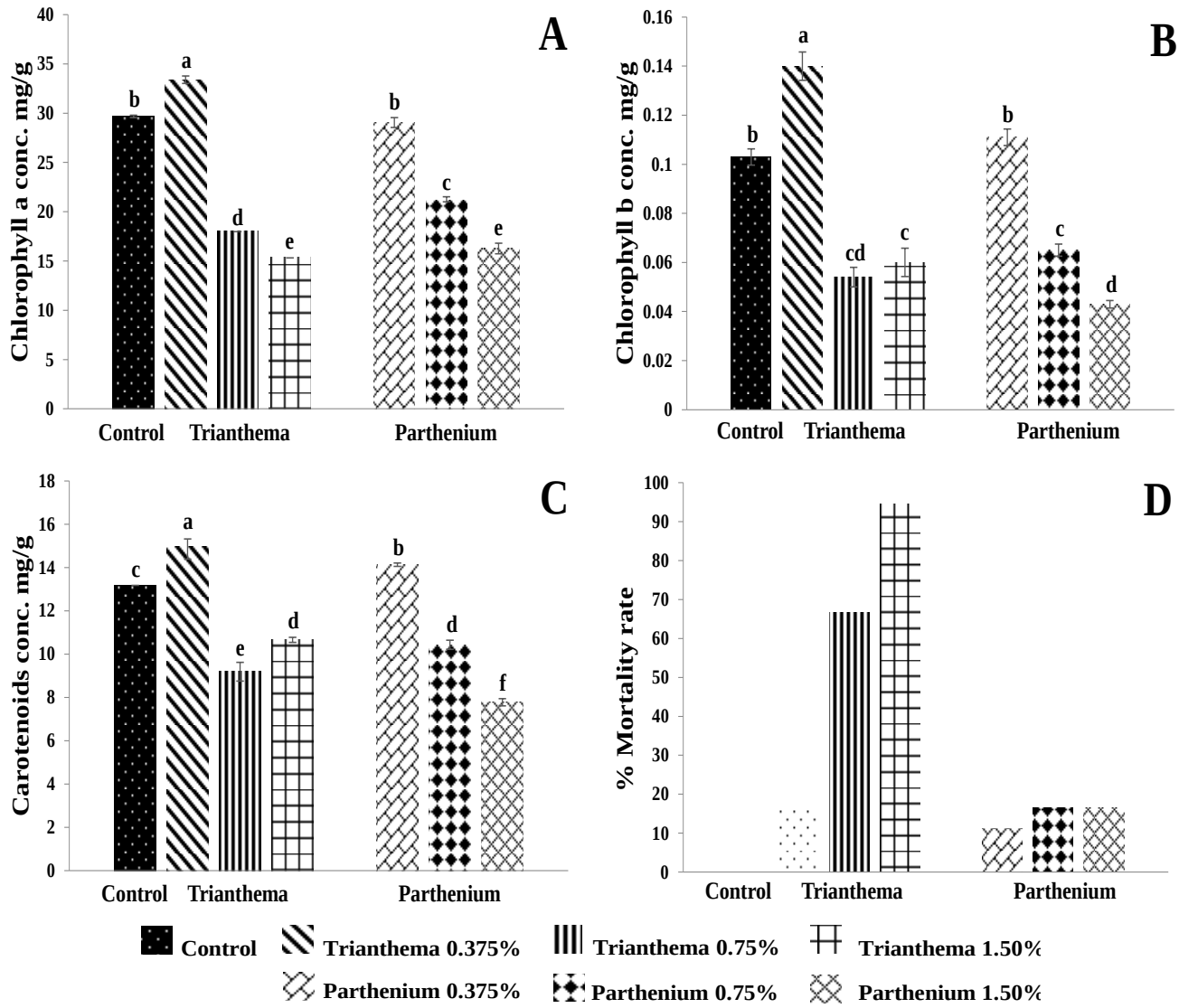

Fig. 2. Effect of different concentrations of *Trianthema* and *Parthenium* on **(A)** chlorophyll a concentration, **(B)** chlorophyll b concentration, **(C)** carotenoids concentration and **(D)** mortality of okra.
Bars topped by the same letter do not differ significantly at $p \leq 0.05$ by Duncan's Multiple Range test.

Gas chromatography mass spectrometry (GCMS) analysis: GCMS analysis of *T. portulacastrum* methanolic extract revealed the presence of compounds viz., Phytol [Retention time (R.T)] = 24.711, $C_{20}H_{40}O$, MW = 296, Concentration = 18.801%), 11-octadecenoic acid, methyl ester, 8, 11-Octadecadienoic acid, metlyl ester (R.T = 24.711, $C_{19}H_{36}O_2$, MW = 296, Concentration = 14.015%), 8, 11-octadecadienoic acid, methyl ester (R.T = 24.378, $C_{19}H_{34}O_2$, MW = 294, Concentration = 12.756%), Pentadecanoic acid, 14-methyl-,methyl ester (R.T = 21.167, $C_{17}H_{34}O_2$, MW = 270, Concentration = 11.768%) and Cholest-4-ene, 3.beta.-(methoxymethoxy)- (R.T = 33.902, $C_{29}H_{50}O_2$, MW = 430, Concentration = 11.599%), at the highest concentrations (Fig. 3A-E). On the other hand, GCMS analysis of *P. hysterophorus* depicted the presence of Phorbol, (R.T = 33.101, $C_{20}H_{28}O_6$, MW = 364, Concentration = 29.118%), 1, 2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester (R.T = 29.449, $C_{16}H_{22}O_4$, MW = 278, Concentration = 9.183%), Isolongifolene-7, 8-dehydro-8a-hydroxy- (R.T = 15.370, $C_{15}H_{24}O$, MW = 220, Concentration = 6.436%) and 1H-cycloprop[e]azulene, 1a, 2, 3, 4, 4a, 5, 6, 7b-octahydro-1, 1, 4, 7-tetramethyl-, [1ar (1a.alpha., -4.alpha., 4a.beta., 7b.alpha.)]- (R.T=11.263, $C_{15}H_{24}$, MW = 204, Concentration = 5.151%) (Fig. 4A-D). In some previous studies a number of compounds have been identified from *T. portulacastrum*, exhibiting different bioactivities but no study is available that describes these compounds as having allelopathic impact in terms of negative effects on crop morphology and physiology. As for example, some phenolic compounds were reported in the leaf and stem extract of *T. Portulacastrum* viz., P-Hydroxybenzoic acid, Caffeic acid, Vanillic acid, Ferulic acid, o-coumaric acid, Pyrogallic acid, Protocatechuic acid and trans-Cinnamic acid (Al Sherif and Gharieb, 2011). One more study indicated the presence of C-Methylflavone (5, 7-Dimethoxy-6-C-methylflavone) in methanolic extract of leaves of *T. portulacastrum* (Kavitha *et al.*, 2014). In another investigation, a tetraterpenoid named trianthenol has been isolated from the chloroform extract of *T. portulacastrum*. It's structure was established as 15-hydroxymethyl-2, 6, 10, 18, 22, 26, 30-heptamethyl-14-methylene-17-hentriacontene. A benzaldehyde derivative, a pentacyclictriterpenoid and benzoic acid derivatives were also reported from *T. portulacastrum* (Nawaz *et al.*, 2001). In another investigation, flavonoid (5, 2 dihydroxy-7methoxy- 6,8 dimethyl flavone)

and b-glucopyranosides, b-cyanin were reported (Kokpol *et al.,* 1997). Moreover, quercetin, benzoic and cinnamic acid derivatives, such as protocatechuic acid, vanillic acid, ferulic acid, caffeic acid, o-coumaric acid and pyrogallol are also reported from Trianthema (Al Sherif & Gharieb, 2011). Similarly, Beta cyanin has also been reported in *T. portulacastrum* (Sunder *et al.,* 2009). Four terpenoids have also been isolated from the chloroform extract of *T. portulacastrum* (Nawaz *et al.,* 2001). Substance, namely trianthenol (15-hydroxymethyl-2, 6, 10, 18, 22, 26, 30-heptamethyl-14- methylene-17-hentriacontene), benzaldehyde, benzoic acid derivatives, and penta cyclic terpenoids were also reported. In addition, β carotene has also been identified from the organic solvents of *T. portulacastrum* (Khare, 2007). In a recent investigation a number of chemical constituents have been identified from *T. portulacastrum* such as Beta-ecdysterone, Leptorumol, 3-Acetyl aleuritolic acid, Beta sitosterol, Stigmasterol, p-Methoxy benzoic acid, 5-Hydroxy-2-methoxy benzaldehyde, 3, 4-Dimethoxy cinnamic acid, p-Propoxy benzoic acid, 7-Hydroxy-3-methylflavone, Pyridine-3-carboxyli c acid and Ascorbic acid (Sukalingam *et al.,* 2017). In a very recent investigation, it was pointed out the presence of allelopathic/ phytotoxic compounds e.g., terpenes as a major component in the extract of *T. portulacastrum* against *Brassica tournefortii*, *Cenchrus echinatus* and *Lactuca sativa*. The major chemical constituents were hexahydro-farnesyl acetone, verbenene, incensole acetate, 3-p-manthane, cis-carvyl propanoate and trans-p-mentha-2, 8-dien-ol (Abd El-Gawad, 2016). In the present research work, 5 compounds were found having their concentration above 10% in case of GCMS of *Trianthema* but only 1 compound was identified in case of GCMS of *Parthenium* having its concentration above 10%. From this, we may conclude that more number of compounds having higher concentrations were present in *Trianthema* and these contributed towards allelopathic effects recorded in the present study. As there are few reports available depicting allelopathic compounds from *T. portulacastrum* with respect to deterioration of crop morphological and physiological parameters, it may be concluded that allelopathic effects observed during the present study were due to the presence of compounds identified on the basis of GCMS in the present study and these could be used in controlling noxious weeds as ecofriendly herbicides. Moreover, compounds identified in the present study will be useful in developing nature based herbicides.

Conclusion

The present study concludes that *T. portulacastrum* and *P. hysterophorus* have strong allelopathic effects on okra so measures should be taken to eradicate these weeds. Effect of *Trianthema* was more on morphological parameters of okra as compared to *Parthenium* and *Trianthema* causing 94% mortality in okra. Gas Chromatography Mass Spectrometry (GCMS) analysis of *T. portulacastrum* methanolic extract revealed the presence of compounds viz. Phytol, 11-octadecenoic acid, methyl ester, 8,11-Octadecadienoic acid, metlyl ester and Pentadecanoic acid,14-methyl-,methyl ester and Cholest-4-ene, 3.beta.-(methoxymethoxy)-, at the highest (more than 10%) concentrations. While in case of GCMS analysis of *Parthenium*, only 1 compound was identified having its concentration above 10%. It may be concluded that allelopathic effects observed during the present study were due to the presence of more number of allelochemicals having higher concentrations in case of *Trianthema* as compared to *Parthenium*.

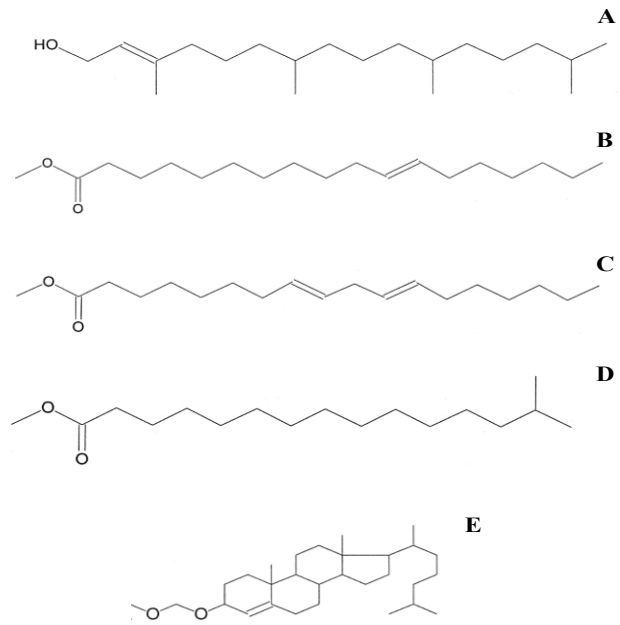

Fig. 3. Major compounds detected through Gas Chromatography Mass Spectrometry (GCMS) analysis of *Trianthema portulacastrum*; **(A)** Phytol, **(B)** 11-octadecenoic acid, methyl ester, **(C)** 8, 11-octadecadienoic acid, methyl ester, **(D)** Pentadecanoic acid, 14-methyl, methyl ester and **(E)** Cholest-4-ene, 3-beta-(methoxymethoxy).

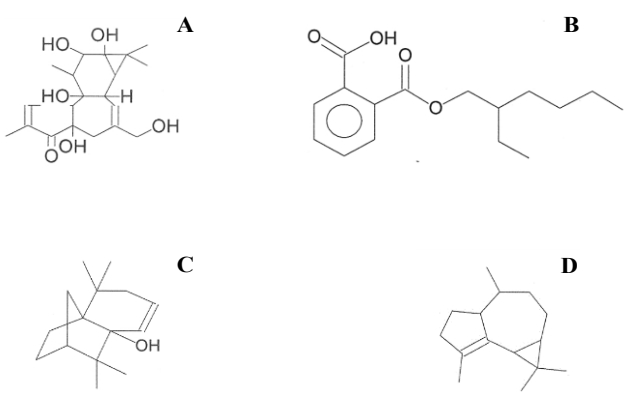

Fig. 4. Major compounds detected through Gas Chromatography Mass Spectrometry (GCMS) analysis of *Parthenium hysterophorus*; **(A)** Phorbol, **(B)** 1, 2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester, **(C)** Isolongifolene-7, 8-dehydro-8a-hydroxy- **(D)** 1H-cycloprop[e]azulene, 1a, 2, 3, 4, 4a, 5, 6, 7b-octahydro-1, 1, 4, 7-tetramethyl-, [1ar-(1a.alpha., 4. alpha., 4a. beta., 7b. alpha.)]-

Recommendations

1) In the present investigation, inhibitory effects of both *Trianthema* and *Parthenium* weeds on the morphological and physiological parameters of okra were encountered. So, steps should be taken to manage these weeds.
2) Experiments are needed to evaluate nutritional quality of okra as a result of infestation with these weeds.

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