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# Effect of Aqueous Extract of *Trianthema portulacastrum* L. on the Growth of *Zea mays* L. and its Associated Weeds

**Dalia A. Ahmed[(1)#], Dalia F. Slima[(2)]**
*[(1)]Department of Botany, Faculty of Science, Tanta University, 31527 Tanta, Egypt;*
*[(2)]Department of Botany and Microbiology, Faculty of Science, Menoufia University, Menoufia, Egypt.*

THE INTERFERENCE of weeds with economic crops is a worldwide problem. The weeds suppress the growht of the crop plants and decrease their production. As the herbicides have several hazards, health and environment safe alternatives should be seeking. In this study, water extract of *Trianthema portulacastrum* (10g $L^{-1}$) was used to control the growth of weeds associating the plantations. Nine plots (each of 25$m^2$) were prepared in a complete randomized design for different experimental treatments. The treatments were: a) Cultivated with maize without treatment (control), b) Irrigated with the extract (2 L/$m^2$) once a day for 5 days (BC) before cultivation with maize, and c) Treated before cultivation and then irrigated with the extract until harvesting (IC) for two cropping seasons (April 2017 and April 2018). After treatment, the density of each weed species was calculated, maize growth parameters and grain nutrient contents were determined. The results showed that the associated weeds were declined to 54.1%, 52.8% in BC and 75.7%, 83.3% in IC during the first and second growth seasons, respectively. Plant height, number of leaves, leaf area, ear weight, number and weight of grains, grain yield and harvest index, the nutritive value of the grains (carbohydrates, proteins, fats and minerals), and soil parameters (organic matter and NPK) of Maize plants were increased significantly in the treated sites during both seasons. During the second crop season the number and the type of weed individuals were more declined than the first crop season as a result of treatment with water extract of *T. portulacastrum*. On the other hand the growth of maize increased during the second crop season as a result of treatment with water extract of *T. portulacastrum*. Our study obviously showed that the water extract of *T. portulacastrum* can be a potential bio-fertilizer and used to control weeds.

**Keywords:** Allelopathy, Bio-fertilizers, Control weeds, Maize growth, Soil nutrient.

## Introduction

Maize (*Zea mays*) is a worldwide important crop. It originated in Central America, especially Mexico (MINFAL, 2003). It belongs to family Poaceae, it's an annual short-lived and fast growing herb. It usually develops with a single main culm with one or two lateral branches in the upper part of the stem. It is a cross pollinating species that has female and male flowers at separate parts on the plant (Parle & Dhamija, 2013). It is considered as a fodder plant, in addition to using as a human food, its raw materials can be used in many industries (oil extraction, starch production, weaving of fibers, paper making,...etc) and also can be used as a bio-fuel source (Atta et al., 2017). In the developing countries, maize is considered as a major source of income to many farmers (Imoloame & Omolaiye, 2017). The annual total world production of maize was 986, 226, 630 tons (FAOSTAT, 2019). The top three maize-producing countries are the United States, China, and Brazil; they produce approximately 563 of the 717 million metric tons/year (Ranum et al., 2014). In Egypt, the total harvested area of maize in 2016 was about 1, 239, 341 hectares with a total production about 10, 159, 906 tons

[#]Corresponding author email: dalia.ahmed@science.tanta.edu.eg, drdalia1080@yahoo.com Mobile: +201223712092
ORCID: 0000-0001-7115-9375
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of grains, and an average yield of 9.76 tones/ha (FAOSTAT, 2019).

The productivity of crops was limited by the weed growth, as they competing with the crops for nutrients, water, light and space (Asghar et al., 2013). The crop yield may be reduced by 24-47% as a result of weed competition (Afzal et al., 2014). Some weeds have allellopathic compounds that could adversely affect crop growth and production (Farooq et al., 2013). Among these weeds is *Trianthema portulacastrum*, which is one of the major maize associated weeds (Balayan & Bhan, 1989). This weed does not only reduce maize yields (Khan et al., 2016) but also affects the quality of its grain (Gricher, 2008). *Trianthema portulacastrum* is a worldwide distributed species, and is a native plant to South Africa, tropical and subtropical regions (Boulos, 2009). Regarding the worldwide distribution, *T. portulacastrum* has a pantatropical distribution. In Africa, it is known from Senegal, Egypt, Sudan, Mauritania, Upper Guinea, Cape Coast, Belgian Congo Christiansburg, Belgian Congo, Angola, Gold Coast, Gambia, Ivory Coast, Togo and Nigeria. In Asia, it is known from Tropical Arabia, West Pakistan, India, Malaya, Delhi, Java, Sri Lanka, Yemen and Aden. In South and Central America it is recorded in Cuba, West Indies, Mexico, Argentina, Paraguay and Peru. It is recorded also in Southern part of USA and in Australia, it is found in Southern and Central Queensland (Kosinová, 1984). *Trianthema portulacastrum* was known in Egypt as a very rare species recorded in Gebel Elba (Täckholm, 1974), after that, it is widely distributed northward and spread rapidly in summer crop fields, along the banks of irrigation canals and waste lands (Shaltout et al., 2013). *T. portulacastrum* is known in English as Horse purslane, black pigweed, and giant pigweed. It is an annual terrestrial succulent herb, prostrate and much branched weed, belongs to the family Aizoaceae (Bolous, 1999).

Allelopathy is a potential field of research all over the world including the harmful and beneficial interactions between the plants (Randhawa et al., 1999). In agriculture, the inhibitory effect of weeds on germination and growth of crops has been attributed to phytotoxic chemicals released from the leaf litter and roots (Natarajan & Elavazhagan, 2014). Many weeds have allelopathic effects on crops where they are associated (Randhawa et al., 1999; Sherif & Gharieb, 2011; Khan et al. 2012; Asghar et al., 2013; Abd El-Gawad, 2014). The impact of *Trianthema portulacastrum* on crops and on other weeds were studied by many investigators (Randhawa et al., 1999; Aneja et al., 2000; Randhawa et al., 2009; Saeed et al., 2010; Sherif & Gharieb, 2011; Kavitha et al., 2014; Naeem et al., 2016; Sutradhar et al. 2017). The studies aimed either to control the growth of *T. portulacastrum* and/or detecting its negative effect on the growth of different economic crops. The current study was undertaken to analyze the effect of the water extract of *T. portulacastrum* on controlling the growth of associated weeds in maize fields.

## Materials and Methods

*Preparation of Trianthema portulacastrum* water extract

Fresh *T. portulacastrum* plants were collected from the fields, the banks of irrigation canals and waste lands. The plants were washed 2-3 times with running tap water, twice with sterile distilled water, and then dried at room temperature on a sterile blotting paper. The whole plants were ground using a metal blender and stored in closed bottles for the extract preparation. For aqueous extract preparation, the dried plants were soaked in distilled water (10g $L^{-1}$) containing bottles which were plugged tightly and kept on shaker for 24hrs at room temperature (Abd El-Gawad et al., 2016). Next, the Water extract was filtered through Whatman filter paper No. 1 and stored in the refrigerator for the experiments.

*Cultivation of maize*

The experiment was carried out at cultivation field in Mit Ghamr City (30° 40′ 13.55″N and 31° 17′ 58.41″E) under natural field conditions. Three treatments were applied: a) Cultivation without treatment (control), b) Cultivation after irrigating the soil by *T. portulacastrum* water extract (2L/$m^2$) once a day for 5 days (BC), and c) Cultivation after treating soil with *T. portulacastrum* water extract and then using it in irrigation until the end of the experiment (IC). Nine plots (5x5m each) with two meters as buffer zones were prepared in a complete randomized design, and each treatment was replicated three times. All other agronomic practices for all the treatments were the same.

Maize grains (SC-30k8) were obtained from

the Main Crops Improvement Station at Kafr EI-Sheikh Governorate. The grains were surface sterilized by 3.5% sodium hypochloride for 20 minutes and washed many times with distilled water. The grains were then sown in each site for two cropping seasons in April 2017 and April 2018, at 2-3cm depth (three grains in each hole). The density was 24grain/$m^2$. Soil was treated with *T. portulacastrum* water extract (2L/$m^2$) daily for 5 days, after sowing while IC plots were irrigated (1L/$m^2$) 6-8 times with *T. portulacastrum* water extract once every two weeks until ripening and ears formed. Control and BC plots were irrigated with fresh water. The plants were thinned manually 15 days after germination to one individual per hole.

In each plot, the number of individuals of each weed species was recorded and its relative density (RD) was calculated as follow:

RD= No of individuals of one species/total No of individuals of recorded species x100

Life form of each species was recorded according to Raunkiaer (1937). The identification of the recorded species was done according to Boulos's studies (1999, 2000, 2002, 2005, 2009). Voucher speciemens were kept in Tanta University Herbarium (TANE).

*Soil Analysis*

From each plot, three composite soil samples were collected as a profile of 0-50cm below the soil surface for further physical and chemical analysis. Soil texture was carried out by Bouyoucous hydrometer method for determination the percentage of clay, silt and sand. Organic matter was determined by loss in ignition according to Piper (1947). Soil water extract (1:5 v/v) was prepared for determination of electrical conductivity (EC) and soil pH (Jackson 1962). For elemental analysis (P, N, K, Ca, Na, Mg, Cu, Zn, Fe, and Mn) in the soil samples, soil was digested using the acid digestion method adopted by Wade et al. (1993). The total soluble nitrogen (N) was determined by Kjeldahl method (Pirie, 1955) and P amount by molybdenum blue method using a spectrophotometer (Shimadzu UV 1900, Japan). In addition, K, Ca, Na and Mg were determined using Flame Photometer (CORNING M410, UK). Concentrations of total Cu, Zn, Fe and Mn in soil samples were determined using a Perkin-Elmer 5000 Atomic Absorption Spectrophotometer. All these procedures were carried out according to Allen (1989).

*Growth measurements*

For each treatment, the germination percentage was calculated after sowing (by counting the number of the emerging seedlings to the total number of the sowing grains). At the harvesting stage, twenty randomly chosen maize plants were used to measure the growth parameters: plant height, number of leaves per plant, leaf area ($cm^2$), cob length (cm) and weight (g), 1000-grain weight (g), number of grains per cob, number of grain rows per cob, and number of grains per row. Leaf area was determined for the top, middle and bottom leaves and the average of these measurements was multiplied by a factor 0.75 to give the leaf area per individual (Moll & Kamprath, 1977).

Twenty randomly selected cobs were sun dried and ground, then grain pith (grain content without external envelop) ratio was calculated as follows:

Grain/pith ratio (%)= Grain weight/pith weight x 100

The biological yield was measured by harvesting all plants in each site, air dried for 6 days and weighed with electronic balance, and then the value was converted into tons $ha^{-1}$. Grain yield was calculated by weighing all cobs, and then convert the value into tons $ha^{-1}$. Harvest index was calculated as follows:

Harvest index (%)= Grain yield/Biological yield × 100

The calculations were performed according to Khan et al. (2012).

*Chemical analysis*

The minerals content (P, N, K, Ca, Na, Mg, Cu, Zn, Fe and Mn) of the grains was determined by digesting the dry and grounded grains (5g) using mixed-acid digestion method (Lu, 2000). The digested samples were filtered and the volume was diluted to 50ml with distilled water. The minerals were determined as mentioned above in the soil analysis, and then converted into g $kg^{-1}$. Total soluble proteins and carbohydrates were measured spectrophotometrically (Shimadzu UV 1900, Japan) by using bio-Rad protein assay

(Lowry et al., 1951) and the anthrone-sulfuric acid methods (Umbriet et al., 1959), respectively. The total lipids were determined using the method described by Bligh & Dyer (1959).

*Phytochemistry of T. portulacastrum extract*

*T. portulacastrum* plant was collected and air dried then grounded to measure some secondary metabolites as total content of phenolic compounds, flavonoids, alkaloids and tannins.

*Determination of total phenolics*

A known weight of the dried plant powder (0.1g) was extracted three times by 5ml of 95% ethyl alcohol, and then filtered. The clear supernatants were collected and completed into a definite volume (20ml) with 95% ethyl alcohol.1ml from the extract was mixed with 1ml folin ciocalteau reagent and 1ml sodium carbonate (20%), then the mixture was completed to a known volume with distilled water, and the tubes were incubated in dark for 30min. The absorbance was measured at 650 nm on spectrophotometer (Shimadzu UV 1900, Japan) (Jindal & Singh, 1975).

*Determination of flavonoids*

A known weight of the dried plant powder (0.1g) was extracted by 80% ethyl alcohol and filtered. 0.5ml of the extract was mixed with 1.5ml ethyl alcohol (95%) and 0.1ml of 10% aluminum chloride then added 0.1ml of 1M potassium acetate and 2.8 ml of distilled water. After incubation at room temperature for 30min, the absorbance was measured at 415nm on spectrophotometer (Shimadzu UV 1900, Japan) according to Chang et al.(2002).

*Determination of alkaloids*

Total alkaloids were determined according to Harborne (1973). 1g of dry plant powder was extracted several times with 4:1 (v/v) of 70% ethyl alcohol and glacial acetic acid. The mixture was left to stand for 6hrs and was shacked from time to time then filtered. The alkaloids were precipitated by a drop wise addition of a concentrated ammonia solution until precipitation was completed. The precipitated alkaloids were filtered on a pre-weighted filter paper (moistened with diluted ammonia solution and dried in an oven at 60$^{o}$C to a constant weight). The alkaloids were dried in an oven at 60$^{o}$C to a constant weight and expressed as mg/g dry weight of the plant sample.

*Determination of total tannins*

One gram of dry plant powder was extracted by boiling twice for 1 hour with 100ml (1:1) (acetone : water) and then filtered. The combined extract was completed to a certain volume with distilled water then boiled. Add 30ml of 15% copper acetate with stirring. The precipitate of copper tannate was collected on ashless filter paper and washed with distilled water. The ashless filter paper containing the precipitate was ignited in a porcelain crucible (pre-ignited to a constant weight) at 550$^{o}$C for 3hrs. Few drops of nitric acid were added to the residue and reignited to a constant weight. The weight of copper oxide was determined and the percentage of tannins was calculated according to Ali (1991) by the following relation:

Each 1g of copper oxide= 1.305g of tannis.

*Data analysis*

The effect of different treatments and different growth seasons on the types of weeds and their individual number as well as maize growth parameters were assessed using repeated measurement two-way ANOVAs using SPSS 20.0 software (SPSS, 2006).

## Results

*Floristic analysis*

The floristic composition of weeds associated to *Zea mays* indicated that 37 species were recorded in control plots and only 17 species were recorded in BC during the two cropping seasons (Table 1). Only 9 species were recorded in IC during the first growth season and 6 species during the second growth season (Table 1). On the percentage basis, the reduction in weeds was 54.1% in BC and 75.7% in IC during the first growth season, and 83.3% in IC during the second growth season relative to the control.

The total number mean of weed individuals in control plots was up to 423 individual during the first season and 397 during the second season. This number was declined to 137 individual in BC during the first season and 100 individual during the second season (Table 1). In IC the total number of individuals was declined, with a reduction of 87.2% and 60.6% compared to control and BC during the first season and 91.9% and 68% during the second season (Table 1).

**TABLE 1. Relative density of weeds recorded in different treatment plots on 2017 and 2018 crop seasons, C: Control, BC: Soil treated with *Trianthema portulacastrum* water extract, IC: Soil treated with *T. portulacastrum* water extract and irrigated with it [The mean individual number of weeds is given in brackets].**

| Family | Species | Season 1 (April 2017) | | | Season 2 (April 2018) | | |
|---|---|---|---|---|---|---|---|
| | | C | BC | IC | C | BC | IC |
| | | **Therophyte** | | | | | |
| Aizoaceae | *Trianthema portulacastrum* | 5.7 (24) | 14.6 (20) | 18.5 (10) | 7.3 (29) | 25 (25) | 43.8 (14) |
| Amaranthaceae | *Amaranthus hybridus* L. | 3.8 (16) | - | - | 4.0 (16) | - | - |
| | *Amaranthus viridis* L. | 5.7 (24) | 2.2 (3) | 11.1 (6) | 4.8 (19) | 6.0 (6) | 9.4 (3) |
| Asteraceae | *Cichorium endiva* subsp. *divaricatum* Schousb. | 3.8 (16) | 3.7 (5) | - | 2.8 (11) | 2.0 (2) | - |
| | *Sonchus asper* (L.) Hill. | 0.9 (4) | 7.3 (10) | 7.4 (4) | 1.0 (4) | 5.0 (5) | - |
| | *Sonchus oleraceus* L. | 0.7 (3) | - | - | 0.8 (3) | - | - |
| | *Xanthium spinosum* L. | 0.5 (2) | - | - | 0.5 (2) | - | - |
| Brassicaceae | *Brassica tournefortii* Gouan | 1.2 (5) | - | - | 1.3 (5) | - | - |
| | *Capsella bursa-pastoris* (L.) Medik. | 1.2 (5) | - | - | 1.3 (5) | - | - |
| Chenopodiaceae | *Beta vulgaris* subsp. *maritima* (L.) Arcang. | 5.7 (24) | - | - | 5.0 (20) | - | - |
| | *Chenopodium album* L. | 1.9 (8) | - | - | 2.0 (8) | - | - |
| | *Chenopodium murale* L. | 1.7 (7) | - | - | 1.8 (7) | - | - |
| Euphorbiaceae | *Euphorbia helioscopia* L. | 3.5 (15) | 6.6 (9) | 13.0 (7) | 3.3 (13) | 5.0 (5) | 9.4 (3) |
| Fabaceae | *Medicago polymorpha* L. | 1.9 (8) | 7.3 (10) | 11.1 (6) | 1.5 (6) | 6.0 (6) | 9.4 (3) |
| Malvaceae | *Hibiscus trionum* L. | 5.7 (24) | 2.2 (3) | - | 5.0 (20) | 1.0 (1) | - |
| | *Malva parviflora* L. | 1.9 (8) | 2.2 (3) | - | 1.8 (7) | 1.0 (1) | - |
| Poaceae | *Cenchrus echinatus* L. | 2.8 (12) | - | - | 2.5 (10) | - | - |
| | *Dinebra retroflexa* (Vahl) Panz. | 7.3 (31) | - | - | 6.3 (25) | - | - |
| | *Dactyloctenium aegyptium* (L.) Willd. | 3.8 (16) | - | - | 4.0 (16) | - | - |
| | *Echinochloa colona* (L.) Link | 5.7 (24) | - | - | 5.0 (20) | - | - |
| | *Echinochloa crus-galli* (L.) P. Beauv. | 2.1 (9) | - | - | 2.3 (9) | - | - |
| | *Phalaris minor* Retz. | 0.7 (3) | - | - | 1.5 (6) | - | - |
| | *Polypogon monspelensis* (L) Desf.. | 1.9 (8) | - | - | 2.0 (8) | - | - |
| Polygonaceae | *Rumex dentatus* L. | 1.4 (6) | - | - | - | - | - |
| Portulacaceae | *Portulaca oleracea* L. | 4.5 (19) | 18.3 (25) | 18.5 (10) | 4.3 (17) | 11.0 (11) | 15.6 (5) |
| Primulaceae | *Anagallis arvensis* L. | 1 (4) | 4.4 (6) | 9.3 (5) | 1.5 (6) | 4.0 (4) | - |
| Tiliaceae | *Corchorus olitorius* L. | 6.9 (29) | 6.6 (9) | 9.3 (5) | 4.8 (19) | 7.0 (7) | - |
| Verbenaceae | *Verbena officinalis* L. | 0.2 (1) | - | - | 0.8 (3) | - | - |
| | | **Geophyte-Helophyte** | | | | | |
| Cyperaceae | *Cyperus rotundus* L. | 2.6 (11) | - | - | 2.3 (9) | - | - |
| Lamiaceae | *Mentha microphylla* C. Koch | 0.7 (3) | 6.6 (9) | 5.6 (3) | 0.5 (2) | 6.0 (6) | 12.5 (4) |
| Oxalidaceae | *Oxalis corniculatus* L. | 1.9 (8) | 1.5 (2) | - | 2.8 (11) | 2.0 (2) | - |
| Poaceae | *Cynodon dactylon* (L.) Pers. | 5.7 (24) | - | - | 3.5 (14) | - | - |
| | | **Hemicryptophyte** | | | | | |
| Convolvulaceae | *Convolvulus arvensis* L. | 5.0 (21) | 8.0 (11) | | 5.0 (20) | 9.0 (9) | - |
| Malvaceae | *Sida alba* L. | 1.9 (8) | 3.7 (5) | | 2.8 (11) | 5.0 (5) | - |
| Plantaginaceae | *Plantago major* L. | 0.7 (3) | 2.2 (3) | | 0.8 (3) | 1.0 (1) | - |
| | | **Chamaephyte** | | | | | |
| Solanaceae | *Solanum nigrum* L. | 1 (4) | 4.4 (6) | | 1,5 (6) | 4.0 (4) | - |
| Asteraceae | *Symphyotrichum squamatum* (Spreng) Nesom. | 1.9 (8) | - | - | 1.8 (7) | - | - |
| | **Total recorded species** | 37 (423) | 17 (137) | 9 (54) | 36 (397) | 17 (100) | 6 (32) |

- Types of weeds: $F_{treatment} = 33.7^{*}$, $F_{season} = 23.1^{ns}$, $F_{treatment\ x\ season} = 14.6^{*}$
- Number of weed individuals: $F_{treatment} = 153.9^{*}$, $F_{season} = 36.2^{ns}$, $F_{treatment\ x\ season} = 25.7^{*}$
- *: P< 0.001, ns: not significant.

Poaceae and Asteraceae were the most prevailed families. *Dinebra retroflexa*, *Echinochloa colona* and *Cynodon dactylon* (from poaceae), and *Sonchus oleraceus, Symphyotrichum squamatum* and *Xanthium spinosum* (from Asteraceae) were the most abundant species in maize control plots during the two cropping seasons; these species were completely disappeared in BC and IC (Table 1). Therophytes were the most abundant life form (28 species= 75.7% of the total recorded species), followed by geophytes- helophytes (4 species= 10.8%), hemicryptophytes (3 species= 8.1%) and chamaephytes (2 species= 5.4%) (Table 1).

*Soil analysis*

All the studied soil characters were increased significantly either by treating the soil with *T. portulacastrum* water extract and the effect of different seasons or by the interaction between soil treated with *T. portulacastrum* water extract and different seasons (Table 2). Organic matter percentage was significantly increased in treated plots (BC and IC), it had the highest values in IC plots during the two growth seasons (7.7% and 7.9%, respectively). Values of pH were increased up to 7.8 in IC plots during the first growth season and to 7.9 during the second growth season. The salinity of soil (EC) and macro nutrients were significantly increased compared to control plots during both seasons (Table 2, Fig. 1). Consistently, the content of N, P, K, Na, Ca, and Mg had the highest values in IC plots (Fig. 1). On the other hand, the concentration of minor nutrients (Mn, Cu, Zn and Fe) was increased significantly due to the effect of *T. portulacastrum* water extract only (Fig. 2).

*Growth parameters of the crop*

Except cob length, all the growth parameters increased significantly in response to soil treating with *T. portulacastrum* water extract (Table 3). The treated plants were taller than control by 1.5 times whereas the number of leaves per plant was almost doubled in BC and IC during both seasons (Table 3).

*Trianthema portulacastrum* water extract elevated significantly the number of grains per cob, the number of grains per row and the number of grains row per cob (Table 3). Also, there was a significant increase in grain/pith ratio percentage about two times in the plants of the treated plots compared to the control. Similarly, the biological and grain yield increased about 1.5-2 times for treated plots compared to control during the two growth seasons (Table 3). The increase in the above growth parameters occurred either by treating soil with *T. portulacastrum* water extract only or by the interaction between treating soil with *T. portulacastrum* water extract and different seasons.

*Chemical analysis*

The content of carbohydrates, proteins and total lipids concentration for the grains of the plants were increased significantly in the treated plots relative to the control in both studied seasons due to the effect of different *T. portulacastrum* water extract treatments and the interaction between *T. portulacastrum* water extract treatments and different seasons (Fig. 3). The increase in the three parameters was greater in IC than BC during the two growth seasons (Fig. 3).

**TABLE 2. Effect of *Trianthema portulacastrum* water extract treatment on soil characteristics of *Zea mays* L. cultivation.**

| Soil variables | | Season 1 (April 2017) | | | Season 2 (April 2018) | | | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Control | BC | IC | Control | BC | IC | *Trianthema* treatment | Season | Treatment x season |
| Sand | % | 39.0 ± 0.5 | 39.0 ± 0.5 | 39.0± 0.5 | 39.0 ± 0.5 | 39.0 ± 0.5 | 39.0± 0.5 | - | - | - |
| Silt | | 23.2 ± 0.7 | 23.2 ± 0.7 | 23.2± 0.7 | 23.2 ± 0.7 | 23.2 ± 0.7 | 23.2± 0.7 | - | - | - |
| Clay | | 37.8 ±.0.4 | 37.8 ±.0.4 | 37.8±0.4 | 37.8 ±.0.4 | 37.8 ±.0.4 | 37.8±0.4 | - | - | - |
| Om. | | 6.3 ±0.1 | 6.9± 0.04 | 7.7 ± 0.1 | 6.2 ±0.1 | 7.1± 0.1 | 7.9 ± 0.3 | 646.7** | 232.8* | 3549.0** |
| pH | | 7.2 ±0.1 | 7.4 ± 0.03 | 7.8 ± 0.1 | 7.2 ± 0.05 | 7.5 ± 0.1 | 7.9 ± 0.6 | 19.0* | 11.7* | 37.0** |
| EC ($mScm^{-1}$) | | 1.7 ± 0.01 | 2.4 ± 0.1 | 4.4 ± 0.1 | 1.81 ± 0.3 | 2.87 ± 0.1 | 4.1 ± 0.2 | 594.3* | 354.6* | 502.2** |

- Results of repeated measurement two-way ANOVA (F values).
- Each value is the mean±SD of three replications.
- BC, soil treated with *T. portulacastrum* water extract; IC, soil treated with *T. portulacastrum* water extract and irrigated with it; Om, organic matter.
- *P< 0.01, **: P< 0.001

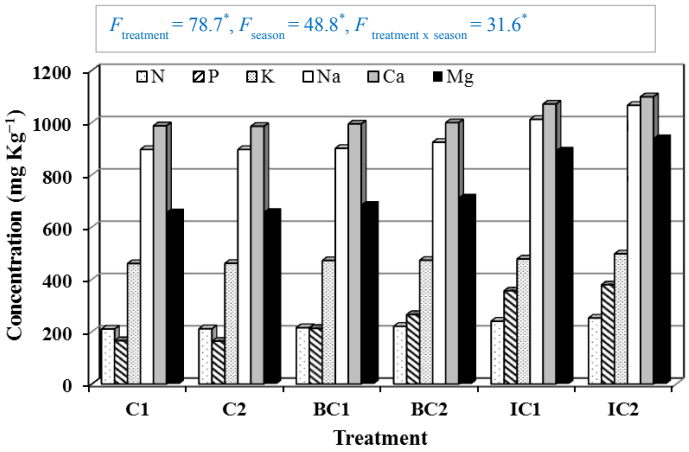


**Fig. 1. Macro nutrients concentration (mg kg$^{-1}$) in soil of different treatments of *Zea mays* L. cultivation during two cropping season (April 2017 and April 2018) (*: P < 0.001) [Treatments are coded as: C1: Control of the first season, C2: Control of the second season, BC1: Soil treated with *Trianthema portulacastrum* water extract during the first season, BC2: Soil treated with *T. portulacastrum* water extract during the second season, IC1: Soil treated with *T. portulacastrum* water extract and irrigated with it during the first season and IC2: Soil treated with *T. portulacastrum* water extract and irrigated with it during the second season. The concentration of all studied nutrients was increased significantly (at P < 0.001) due to the effect of different treatments, seasons and the interaction between them].**

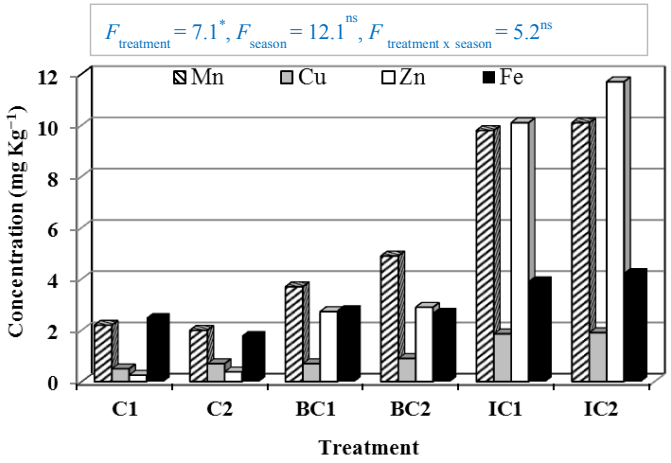


**Fig. 2. Minor nutrient concentration (mg Kg$^{-1}$) in soil of different treatments cultivated with *Zea mays* L. during two cropping season (April 2017 and April 2018) (*: P < 0.01) [Treatments are coded as: C1: Control of the first season, C2: Control of the second season, BC1: Soil treated with *Trianthema portulacastrum* water extract during the first season, BC2: Soil treated with *T. portulacastrum* water extract during the second season, IC1: Soil treated with *T. portulacastrum* water extract and irrigated with it during the first season and IC2: Soil treated with *T. portulacastrum* water extract and irrigated with it during the second season].**

*Grain elemental analysis*

Except Cu and Mn, determined inorganic nutrients were significantly increased in the treated plots due to the effect of different *T. portulacastrum* water extract treatments, then they increased (except Mg, Cu and Mn) due to the effect of different seasons and also increased (except Mg and Cu) due to the effect of the interaction between different *T. portulacastrum* water extract treatments and seasons (Table 4).

*Phytochemistry of T. portulacastrum:*

The results indicated that *T. portulacastrum* extract contains (69.8±3.3mg/g dry weight) of phenolic compounds, (58.69±3.23mg/g dry weight), of flavonoids, (25.67±1.3mg/g dry weight) of alkaloids and (15.9±0.3mg/g dry weight) of total tannins.

**TABLE 3. Growth parameters of maize (*Zea mays* L.) measured in different treatment plots in 2017 and 2018 crop seasons.**

| Growth parameters | Season 1 (April 2017) | | | Season 2 (Apil 2018) | | | Effect | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | BC | IC | Control | BC | IC | *Trianthema* treatment | Season | Treatment x season |
| Germination % | 96.3 ± 0.01 | 95.6 ± 0.04 | 95.8± 0.01 | 95.8 ± 0.1 | 97.6 ± 0.05 | 96.9 ± 0.4 | 19.58* | 130.7* | 148.4* |
| Plant height (cm) | 133.1± 1.2 | 204.5 ± 0.2 | 206.2 ± 1.6 | 134.5 ± 1.6 | 206.1 ± 0.9 | 215.6 ± 0.6 | 3131.8* | 1879.8* | 738.4* |
| No. of leaves per plant | 6.2 ± 0.5 | 10.4 ± 0.3 | 13.4 ± 0.9 | 7.2 ± 0.4 | 12.4 ± 0.2 | 17.4 ± 0.3 | 3576.0* | 872.1* | 175.8* |
| Leaf area ($cm^2$) | 250.5 ± 1.0 | 410.5 ± 0.5 | 480.1 ± 0.9 | 260.5 ± 1.1 | 430.7± 0. 5 | 495.1 ± 0.8 | 3620.82* | 3048.2* | 7177.9* |
| Cob length (cm) | 14.3 ± 0.2 | 19.8 ± 0.9 | 22.2 ± 0.8 | 15.2 ± 0.9 | 20.6 ± 0.8 | 26.8 ± 0.6 | $1.4^{ns}$ | $0.011^{ns}$ | $0. 9^{ns}$ |
| Cob weight (g) | 81.4 ± 2.1 | 184.3± 1.2 | 191.1 ± 2.4 | 85.2 ± 1.6 | 187.8 ± 0.8 | 198.6 ± 1.1 | 6984.79* | 880.3* | 1940.8* |
| 1000-grain weight (g) | 298.4 ± 2.8 | 989.6 ± 0.1 | 1054.4 ± 5.8 | 301.5 ± 1.7 | 1006.3 ± 2.5 | 1078.3 ± 6.4 | 1.85* | $1.04^{ns}$ | 1.003* |
| No. of grains per cob | 412.1 ± 0.9 | 605.9 ± 1.8 | 678.9 ± 1.9 | 427.1 ± 0.7 | 627.3 ± 1.5 | 698.7 ± 0.8 | 3908.39* | 5322.5* | 4997.7* |
| No. of grain rows per cob | 14.9 ± 1.0 | 18.1± 0.3 | 20.2 ± 0.7 | 15.1 ± 0.6 | 19.8 ± 0.08 | 23.1 ± 0.07 | 3171.6* | 852.6* | 129.5* |
| No. of grains per row | 23.2 ± 1.1 | 34.5 ± 0.8 | 41.6 ± 1.2 | 23.9 ± 0.1 | 36.2± 0.9 | 48.3 ± 2.4 | 3503.1* | 1904.8* | 865.5* |
| Grain/pith ratio (%) | 0.94 ± 0.1 | 1.81± 0.5 | 2.72 ± 0.1 | 0.98 ± 0.04 | 2.11± 0.4 | 3.12 ± 0.5 | 0.868* | $1.07^{ns}$ | 1.0* |
| Biological yield (tons $ha^{-1}$) | 19.5 | 24.8 | 29.1 | 20.5 | 26.6 b | 29.9 | 4762.2* | 135.6* | 94.1* |
| Grain yield (tons $ha^{-1}$) | 3.1 | 5.1 | 6.5 | 4.5 | 5.8 | 6.7 | 601.7* | 138.1* | 37.9* |
| Harvest index (%) | 15.9 | 20.6 | 22.4 | 21.9 | 21.8 | 22.4 | 1205.7* | 1573* | 545.0 * |

- Results of repeated measurement two-way ANOVA (F values).
- *: $P < 0.001$
- ns: Not significant
- Each value is the mean ± SD of three replications. BC, soil treated with *Trianthema portulacastrum* water extract; IC, soil treated with T. *portulacastrum* water extract and irrigated with it.

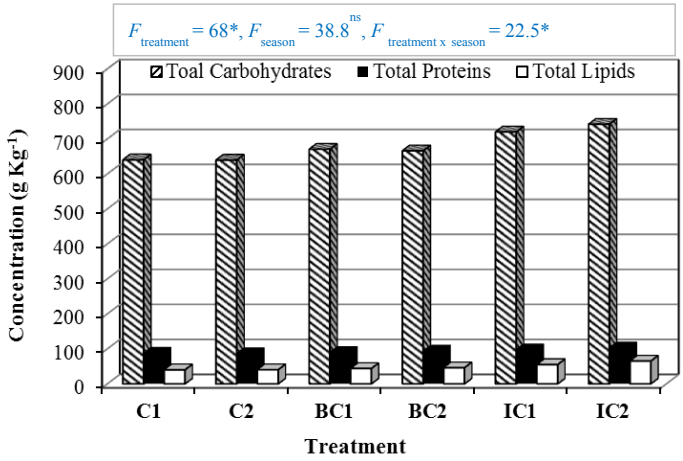


**Fig. 3. Grain organic nutrient concentrations (g kg$^{-1}$) of *Zea mays* L. of different treatments during two cropping season (April 2017 and April 2018) (*: P < 0.01) [Treatments are coded as C1: Control of the first season, C2: control of the second season, BC1: Soil treated with *Trianthema portulacastrum* water extract during the first season, BC2: Soil treated with *T. portulacastrum* water extract during the second season, IC1: Soil treated with *T. portulacastrum* water extract and irrigated with it during the first season and IC2: Soil treated with *T. portulacastrum* water extract and irrigated with it during the second season].**

**TABLE 4. Effect of *Trianthema portulacastrum* water extract on inorganic nutrient contents of maize plants.**

| Nutrients | Season 1 (April 2017) | | | Season 2 (April 2018) | | | Effect | | |
|---|---|---|---|---|---|---|---|---|---|
| | Control | BC | IC | Control | BC | IC | | | |
| | mg kg$^{-1}$ | | | mg kg$^{-1}$ | | | *Trianthema* treatment | Season | Treatment x season |
| **Macro-nutrients** | | | | | | | | | |
| Total N | 1200±1. 6 | 2200±4.3 | 2900± 3.1 | 1400±7.1 | 2500± 9.1 | 3100± 11.1 | 12.0** | 23.4* | 61.0*** |
| Total P | 1800±2.1 | 2100±5.1 | 2700±2.8 | 1700±4.6 | 2200± 8.8 | 3000±9.4 | 113.4*** | 93.9* | 120.3*** |
| K | 2100±1.1 | 2400±2.3 | 2970±4.7 | 2000±6.8 | 2600±7.2 | 3130±10.9 | 69.3*** | 26.9* | 95.9*** |
| Na | 250±0.8 | 290±1.3 | 390±1.9 | 260±3.3 | 310±9.1 | 410±9.7 | 103.9*** | 83.3** | 175*** |
| Ca | 50±0. 7 | 60±1.1 | 90±1.5 | 50±2.1 | 80±7.5 | 110±9.2 | 13.7** | 10.6* | 31.3** |
| Mg | 1100±1.9 | 1230±2.9 | 1380±1.2 | 1200±7.9 | 1310±9.5 | 1400±10.8 | 5.6* | 2.1$^{ns}$ | 3.0$^{ns}$ |
| **Micro-nutrients** | | | | | | | | | |
| Cu | 2±0.1a | 2.6±0.7 | 3.6±0.9 | 2±0.8 | 2.9±0.9 | 3.9±1.1 | 1.8$^{ns}$ | 2.1$^{ns}$ | 3.3$^{ns}$ |
| Zn | 12±1.7 | 18±1.1 | 27±1.4 | 11±1.1 | 20±1.1 | 29±0.9 | 133.1*** | 122.8** | 102.3*** |
| Fe | 14±1.2 | 21±1.9 | 38±0.8 | 14±1.0 | 28±0.7 | 45±1.7 | 211.0*** | 304.5** | 727.0*** |
| Mn | 4±0. 6 | 4.6±1.6 | 5.5±0.9 | 3.8±0.9 | 4.9± 0.03 | 6±0.5 | 3.3$^{ns}$ | 13.4$^{ns}$ | 363.0*** |

- Each value is the mean±SD of three replications.

- BC: Soil treated with *T. portulacastrum* water extract, IC: Soil treated with *T. portulacastrum* water extract and irrigated with it.
*:P< 0.05, **:P< 0.01, ***:P< 0.00

## Discussion

*Floristic analysis*

There are several physiological and biochemical effects caused by plant allelochemicals including, cell division, biosynthesis of some hormones and proteins, transport of minerals through the membranes, water relations, membranes permeability, stomatal conductance, photosynthesis, respiration, and protein breakdown in target plants (Einhellig & Rasmussen, 1979; Harper & Balke, 1981; Rice, 1984; Rizvi et al., 1992; Kruse et al., 2000; Yu et al., 2003; Batish et al., 2006; Farooq et al., 2013).

The reduction in the density of the weeds associated to maize treated with *T. portulacastrum* water extract, and also the decline in different

weed types and the number of their individuals reported in this study is supported by the finding of Farooq et al. (2013) who indicated that allelochemicals of *T. portulacastrum* affect and decrease the growth of many weeds even at low concentration and also suppressed their growth when applied at high concentration. This allelopathic activity effect of *T. portulacastrum* water extract is explained by many researchers and considered it due to the presence of some secondary metabolites as alkaloids, flavonoids, tannins and phenolic compounds that are released into the environment through volatilization, leaching and decomposition of other allelopathic plants. (Karim et al., 2011; Asghar et al., 2013; Naeem et al., 2016). The Phenolic compounds affect the permeability of cell membrane by making it non-specific permeable, disturb the ion fluctuations and hydraulic conductivity in roots. Any variations in plant membranes affect the plant water relations, photosynthesis and transpiration rates, stomatal conductance and ion balance (Einhellig et al. 1985; Gerald et al. 1992). Blum et al. (1999) confirmed that phenolic compounds cause depolarization of cell membranes and affect the ion fluctuations.

Sherif & Gharieb (2011) reported the presence of P-Hydroxybenzoic acid, Caffeic acid, Vanillic acid, ferrulic acid, o-coumaric acid, Pyrogallic acid, Protocatechuic acid and trans-Cinnamic acid in the leaves and stems of *T. portulacastrum*. These compounds play an important role in allelopathic interactions and their biological activities on growth and development n of some crop plants and weeds. In addition, Randhawa et al. (1999) indicated that *T. portulacastrum* water extract allelochemicals (especially phenolic compounds) inhibited cell division in plants and also affected on cell elongation. *T. portulacastrum* water extract contains many phenolic acids as (caffeic acid, ferulic acid, M- coumeric acid, P- coumeric acid, syringic acid, venillic acid; gallic acid and 4-Hydroxy-3- Methoxybenzoic acid) (Asghar et al., 2013).

Some phenolic compounds as (vanillic acid, ferulic acid, and *p*-coumaric acid) inhibited the synthesis of protein and photosynthesis in velvet leaf (*Abutilon theophrasti* Medik.) (Mersie & Singh, 1993). Also Hassanein et al. (2019) reported that phenols act as important regulators of many physiological processes in many plants.

The impact of allelochemicals on photosynthesis mainly restricted to the damage of the photosynthetic apparatus and photosynthetic pigments through disruption of chlorophyll synthesis pathways (Yu et al., 2003). It has been reported that the contribution of phenolic acids to allelopathy might not be due to a single phenolic acid because of the weak inhibitory activity. It has been reported that mixtures of phenolic acids have additive inhibitory action and/or synergistic inhibitory action (Einhellig, 1999).

The most abundant families associated with maize crop were Poaceae and Asteraceae which agrees with the results of Shaltout et al. (1992) who report that the most weeds associated families with maize were Poaceae, Asteraceae and chenopodiaceae. As demonstrated in the work of Shaltout et al. (1992) and in the current study the grasses were more dominant than broadleaved weeds which could more compete with maize crop than broadleaved weeds. Our interpretation is supported by the data of Imoloame & Omolaiye (2017) who show that the grass weeds are more competitive and damaging to grass-leaf crops (e.g. maize) than the broad-leaf crops. Owing to the presence of allelochemicals in the *T. portulacastrum* extract, the grass weeds were completely controlled or even disappeared in response to *T. portulacastrum* treatment (BC and IC plots) during the two cropping seasons. Our findings is in agreement with that of Farooq et al. (2013) reporting a decrease and/or suppress of the growth of many weeds, especially grass weeds by *T. portulacastrum* treatment. In the present study, the number of individuals of *Amaranthus viridis* was declined in treated plots than in control in both seasons which contrasts with the finding of Sherif & Gharieb (2011) who find a positive allelopathic effect on germination of *Amaranthus viridis* by *T. portulacastrum*. This effect may be due to the notion that *T. portulacastrum* extract increased soluble protein, amylase and total phenol of *A. viridis* and hence improved germination, which can be easily controlled by hand weeding. Similarly, Khan et al. (2013) indicate that treatment of weeds which associate the crop plant, not only caused a negative effect on the weeds, but also improved the growth of the cultivated crop. Moreover, the growth improvement of the crop would result in a prominent increase in its competitive capacity, which finally caused a consequent reduction in the growth of the weeds.

*Growth parameters and chemical analysis*

Increasing plant height, number of leaves per plant and leaf area reported in this study is very important to maize as a fodder plant, and this growth improvement might be due to prevention of weeds from interfering with the crop for a long time and hence minimizes competition between the weeds and maize for growth resources as moisture, soil nutrients and assimilation (Imoloame & Omolaiye, 2017). Water extract of *T. portulacastrum* was a source of many macro- and micro-nutrients: proteins, fats, carbohydrates, crude fibers, soluble calcium and phosphorous, riboflavin, potassium, sodium, nitrogen and iron (Khan et al., 2013; Karim et al., 2015), which essentially stimulate the growth of crops. In the same trend, Sher et al. (2016) reported that nitrogen available for crop was the most important nutrient for increasing harvest of maize, and it was vital to optimize maize grain yield and to improve grain quality. Our results agreed with those of Sher et al. (2016) that N availablity for maize was increased in soil with *T. portulacastrum* water extract treatment, leading to improvement of the grain yield and harvest index of maize.

Seed parameters, heavier ears, higher number of seed rows/ear, heavier seeds with high nutrient contents, were increased which most likely as a result of increased leaf area and number of leaves leading to elevated photosynthates. Also, weed control as a result of treatment and/or irrigation with water extract of *T. portulacastrum* may contribute to this increase in seed parameters. In support, minimizing weed competition and enhancing the utilization of growth resources for optimal production of photosynthates results in better performance in response to *T. portulacastrum* treatment (Khan et al., 2016).

*Soil characteristics*

Enhanced mineral contents of the treated soil with *T. portulacastrum* water extract is most probably due to presence of these minerals in high concentrations in the extract of *T. portulacastrum* which is also confirmed by Khan et al. (2013) who similarly reported that the aqueous extract of *T. portulacastrum* contains a relatively significant amounts of sodium, zinc iron and manganese. Soil treatment and irrigation with *T. portulacastrum* water extract led to increased organic matter and nitrogen contents as well as pH elevation leading to improvement of the soil properties and consequently increases the crop growth. Our results are in accordance with those of Tavakkoli et al. (2015) and Aziz et al. (2010) who show increased soil pH led to led to increase the amount of dissolved organic matter and nitrogen which improve soil nutrient availability for crops and thus induce maize growth and yields.

## Conclusions

The present study indicated that *T. portulacastrum* water extract had negative allelopathic effect on the growth of associated weed species with maize. The extract suppressed the germination of seeds of some weeds and decreased the growth of others without side effects on the cultivated maize. As the water extract of *T. portulacastrum* contains several organic and inorganic nutrients, treating the soil before cultivation and/or irrigation with this extract improved the soil characteristics and also enhanced the growth and productivity of maize crop. We therefore recommend *T. portulacastrum* water extract to be used as weed control and an alternative fertilizer for maize crop.

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## تأثير المستخلص المائي لنبات الرجلة البري على نمو نبات الذرة والحشائش المصاحبة له

**داليا عبد العظيم أحمد[1]، داليا فهمي سليمة[2]**

[1]قسم النبات– كلية العلوم– جامعة طنطا– طنطا– مصر ، [2]قسم النبات و الميكروبيولوجي– كلية العلوم– جامعة المنوفية– المنوفية– مصر.

يشكل نمو الحشائش مع المحاصيل الإقتصاديه مشكلة عالمية، حيث أنها تضعف نمو المحصول وتقلل انتاجيته. تهدف هـذه الدراسة إلى استخدام المستخلص المائي لنبات الرجلة الأفرنجي (تريانثيما برتيولاكسترم) بتركيز 10 جرام/لتر، في الحد من نمو الحشائش المصاحبة لمحصول الـذرة. تم إعـداد تسع مواقع (مساحة كل منها 25 م$^2$) لدراسة ثلاثة معاملات في التجربه الحقليه وهي: أ- الكنترول (الزراعة بدون استخدام المستخلص المائي للرجلة الأفرنجي، ب – الزراعة بعد معاملة التربة قبل الزراعة مرة يوميا بالمستخلص المائي للرجلة الأفرنجي (2 لتر/ م$^2$)، وجـ -الزراعة بعد معاملة التربة قبل الزراعة مرة يوميا بالمستخلص المائي للرجلة الأفرنجي والري به حتى حصاد المحصول وذلك خلال موسمين زراعيين (إبريل 2017 و2018). تم حساب كثافة كل نوع من الحشائش المصاحبة للمحصول وكذلك قياس مؤشرات النمو للمحصول والمحتوى الغذائي للحبوب. أوضحت النتائج خلال موسم الزراعة الأول انخفاض عدد أنواع الحشائش المصاحبة للمحصول بنسبة 54.1% في المعاملة الثانية و75.7% في المعاملة الثالثة، وخلال موسم الزراعة الثاني حدث إنخاض آخر بنسبة 52.8% في المعاملة الثانية و81.1% في المعاملة الثالثة. وقد زادت مؤشرات نمو محصول الذرة (نسبة الإنبات، ارتفاع النبات، عدد ومساحة الأوراق، عدد ووزن الكيزان، عدد ووزن الحبوب في كل كوز....الخ)، المحتوى الغذائي في الحبوب (كربوهيدرات، بروتين، دهون، نيتروجين، فسفور، كالسيوم، بوتاسيوم....الخ)، وخصائص التربة (كمية المادة العضوية ونسبة النيتروجين والفسفور والبوتاسيوم) زيادة معنوية ($P < 0.001$) في المواقع المعاملة بالمستخلص المائي لنبات الرجلة الأفرنجي مقارنة بالكنترول خلال الموسمين الزراعيين. ووجد أن مستخلص نبات الرجلة الأفرنجي يحتوي على مركبات فينولية (69.8 مجم/جم)، فلافينيدات (58.69 مجم/جم)، قلويات (25.67 مجم/جم) وتانينات (15.9 مجم/جم). ومن النتائج نجد أن أنواع الحشائش وأعداد أفرادها قد تناقص بدرجة كبيرة خلال موسم الزراعة الثاني، وكذلك معدلات نمو نبات الذرة قد زادت وذلك يعود إلى المعاملة بالممستخلص المائي للرجلة الأفرنجي. ومن تلك النتائج استنتج الباحثتين أنه يمكن استخدام المستخلص المائي لنبات الرجلة الأفرنجي للحد من نمو الحشائش المصاحبة لمحصول الذرة، وكذلك اسنخدامه كسماد حيوي بديلا عن الأسمدة الكيماوية.