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Aqueous Extract of The *Opuntia Ficus-indica* (L.) Fruit Peel and its Potential Against *Malva parviflora* Associated Wheat (*Triticum aestivum* L.) Plants.

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Abstract: Aqueous Extract of the *Opuntia Ficus-indica* (L.) fruit fresh Peel extract was investigated against *Malva parviflora* associated wheat (*Triticum aestivum* L). plants cv. Giza168 in the two successive winter seasons of 2021/2022 and 2022/2023 under greenhouse conditions at National Research Centre, Dokki, Egypt. The *Opuntia Ficus-indica* (L.) fruit fresh peel extract was applied to the soil at 0, 5, 10,15 and 20%. The results revealed significant inhibition in *Malva parviflora* dry weight at 40 days after sowing as well as at harvest. The results recorded more than 65% reduction at harvest with using 20% of the extract. On the other side, this reduction in weed growth was accompanied by wheat growth enhancement as well as yield and yield components. Analysis of the *Opuntia Ficus-indica* (L.) fruit fresh peel indicated the presence of phenolic and flavonoids compounds. The results suggested using the *Opuntia Ficus-indica* (L.) peel extract instead of chemical herbicides to control *Malva parviflora* associate wheat plants. A comprehensive bibliometric analysis to enhance understanding of the scientific production during last years and to show the most published authors and their countries as well as the collaborations as clusters.

Keywords: *Peel extract; Opuntia Ficus-indica; weeds-Allelopathy; flavonoids-phenolic compounds*

1. Introduction

Most of the problems in crop fields arise from the presence of weeds, which play an important role in reducing crop yield by competing with water, light and mineral uptake (Chauhan, 2020; Laita *et al*., 2024). Consequently, controlling weeds became a strategy to ensure the maximum yield. The use of chemical herbicides is considered to be an effective method for controlling weeds that realizes the target for yield increase (El-Metwally and El-Rokiek 2019). However, the persistence use of herbicides cause risks to human health (Ghazi *et al*., 2023) in addition to environmental pollution (Li *et al*., 2019; Khamare *et al*., 2022; Saludes-Zanfaño *et al*., 2024) and resistance of some weeds to chemical herbicides that arises from continuous use (Heap and Duke, 2018; Westwood *et al*., 2018; Varah *et al*., 2020).

So, the use of natural herbicides that are less toxic to human health and for clean environment have been developed (Macías *et al*., 2019). Several workers have documented that the natural

secondary metabolites extracted from some plants have bioherbicidal and allelopathic effect (Cheng and Cheng, 2015; Nornasuha and Ismail, 2017; Kremer, 2019; Sathishkumar *et al*., 2020; Khursheed *et al*., 2022; Nair *et al*., 2022; Rahaman *et al*., 2022). The allelopathic plant metabolites contain phenolic compounds, flavonoids, alkaloids that reported to have potential bioherbicidal activity (Li *et al*., 2010; Misra *et al*., 2020; Kumar *et al*., 2020; Zhao *et al*., 2021; El-Rokiek *et al*., 2022 and 2024; Shehata *et al*., 2025). Many allelochemicals that have bioherbicidal effects were identified in fruit crops (Ercisli and Turkkal 2005; Gopal *et al*., 2006; Kumar *et al*., 2009; Bhatt, *et al*., 2011; Saleem *et al*., 2013; El-Sawi *et al*., 2019; El-Rokiek *et al*., 2019; Loukili *et al*., 2022). These allelochemicals that reported as alkaloids, phenolics and flavonoids are used for weed management and suppressed completely barnyard grass (Khanh *et al*., 2008).

Opuntia, the prickly pear cactus, is a genus of flowering plants in the cactus family Cactaceae. Many cacti are known for their flavorful fruit and showy flowers. Cacti are native to the Americas and well-adapted to arid climates; however, they are still vulnerable to precipitation and temperature changes driven by climate change. The plant has been introduced to parts of Australia, southern Europe, the Middle East, and northern Africa. Actually, Scopus analysis and VOS viewer may be an excellent tool for a bibliometric study to show the profiler authors and their collaborators and their countries in mapping clusters (Costa *et al*., 2025; Hammouti *et al*., 2025; Haruna *et al*., 2025; Chakir *et al*., 2023 N'diyae *et al*., 2022; Cascajares *et al*., 2021; Nandiyanto *et al*., 2020).

Search for "Opuntia" on Scopus gave more than 6000 articles, the first one was dated in 1841, but no author was found, treated Cactus Opuntia L. and Coccus Cacti L (Not Author Found,1841). The most cited one reached more 1330 citations published in *Nature Communications* by Ju *et al*., 2012. The search is now limited to twenty years (2015-2024), more than 2400 articles were collected, and the increase in the papers is shown in **Figure 1.** The interested countries in Opuntia research are ranked in **Figure 2** and visualized by VOS viewer in **Figure 3.** The obtained mapping shows the largest nodes of Mexico at light blue color and that of Italy with a dark color, Brazil by violet, the brown color of Tunisia, Morocco pink one…

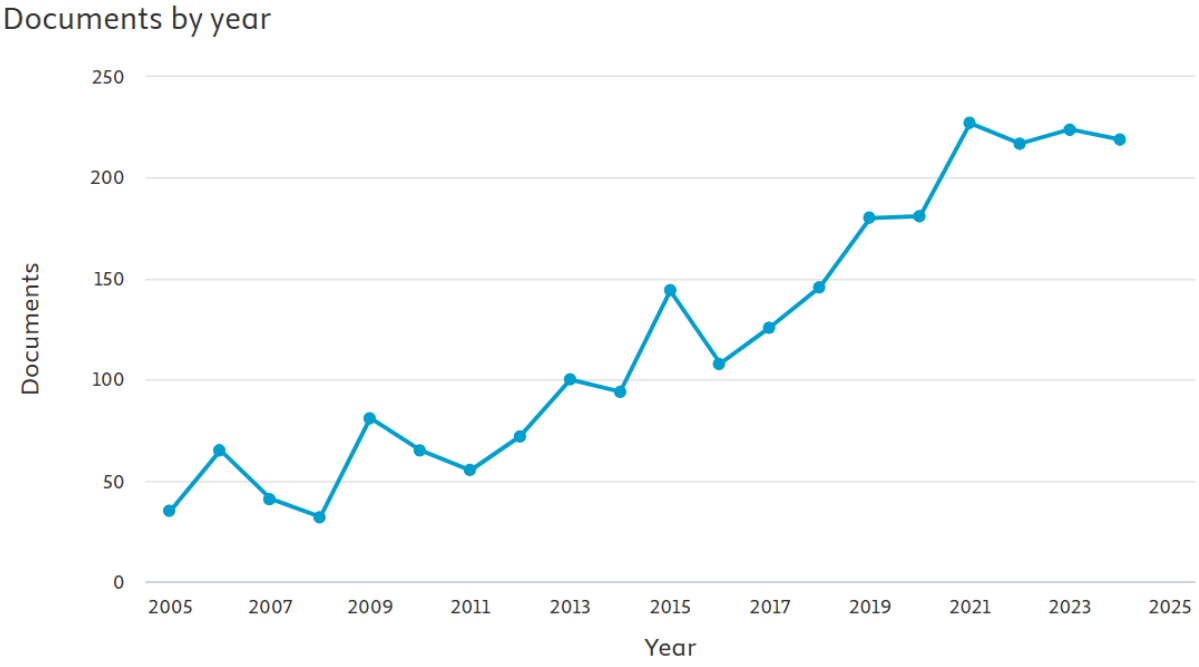

Figure 1. Evolution of the publication numbers on Opuntia

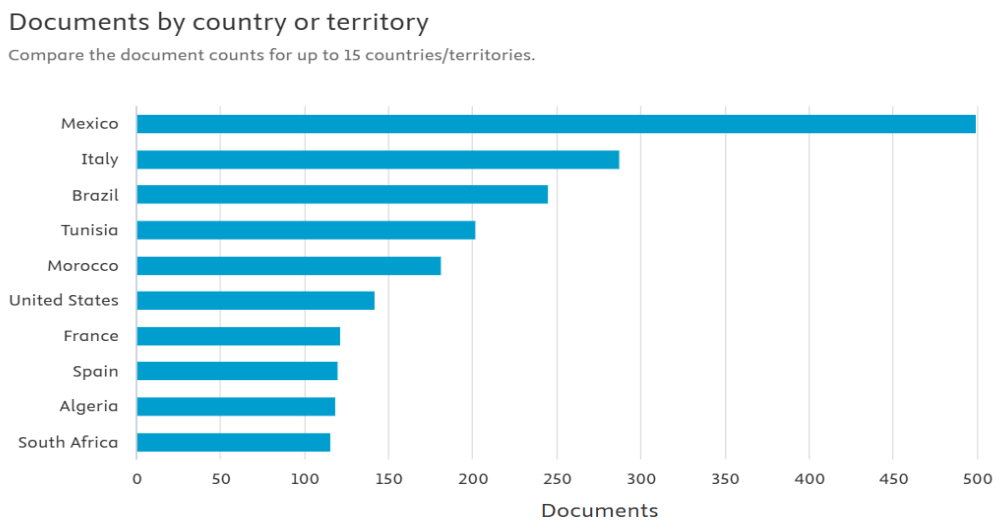

Figure 2. List of the countries on scopus

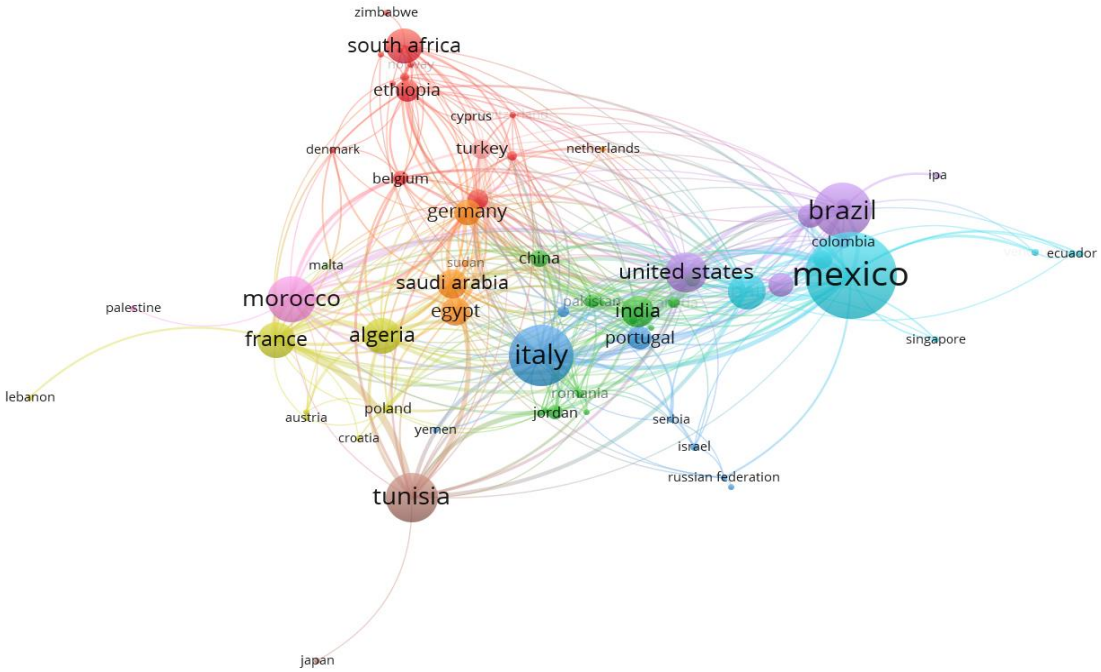

Figure 3. VOS viewer mapping of the most countries contributing to Opuntia research

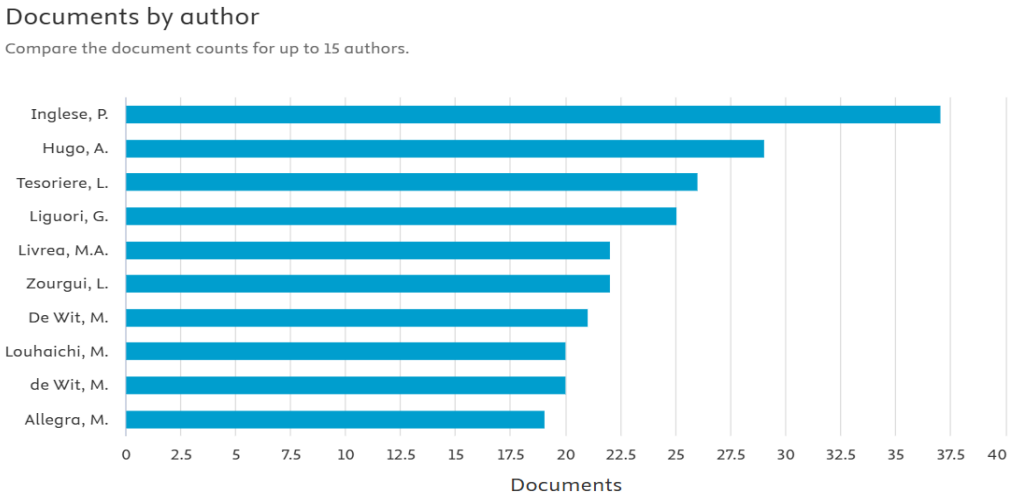

Figure 4. List of the most authors

The *Opuntia Ficus-indica* (L.) is an invasive, drought-tolerant plant from desert areas. This species is widespread throughout the whole world, including in the Mediterranean Basin as it is adapted to its climate (Iacopetta *et al*., 2021, Kadda *et al*., 2022). It has been found that several bioactive molecules include a variety of secondary metabolites such as polyphenols, flavonoids and antioxidants are present in *Opuntia Ficus-indica* (Schaffer *et al*., 2005; Osorio-Esquivel *et al*., 2011; Slimen *et al*., 2016 & 2021; Aourabi *et al*., 2021; Arroussi *et al*., 2022; Moussaoui *et al*., 2022). It has been reported that seven extracts containing *Opuntia Ficus-indica* (L.) have allelopathic inhibiting effects on *Lactaca sativa* and *Phalaris minor* plumule and hypocotyl lengths (Arroussi *et al*., 2022; Loukili *et al*., 2021.

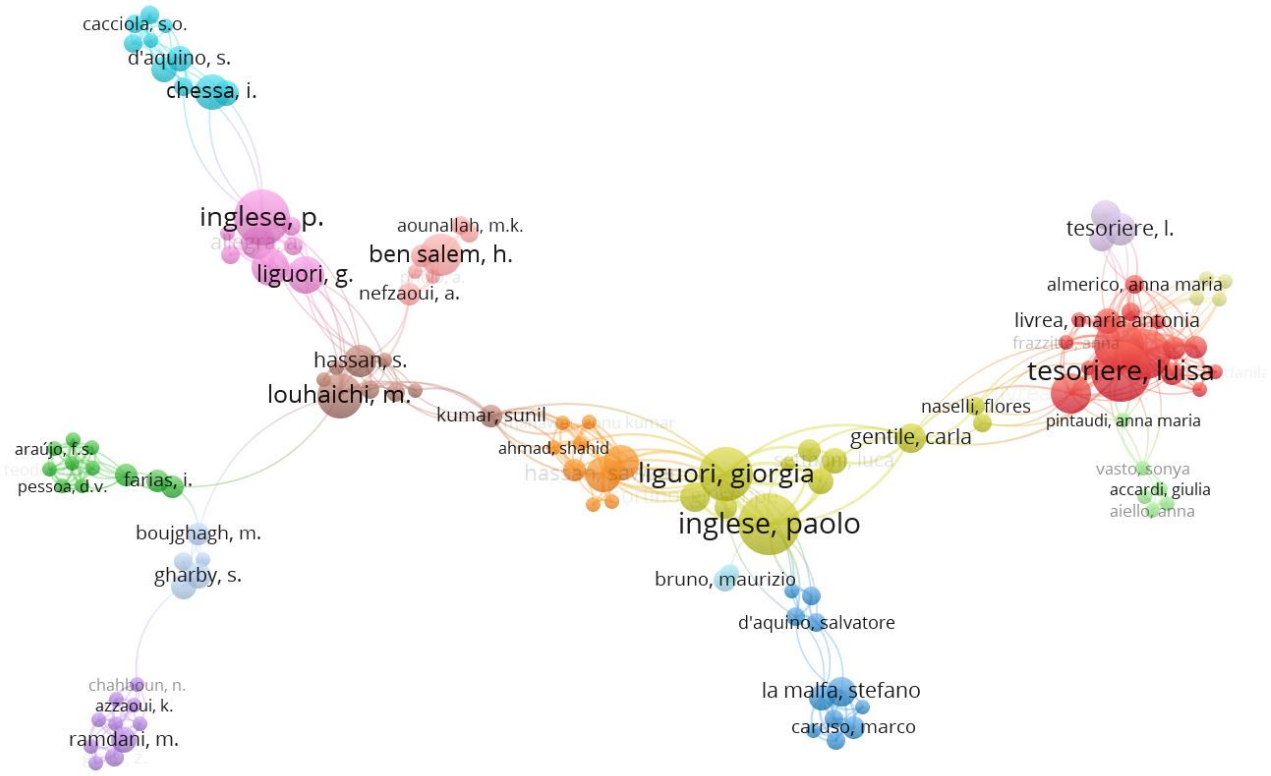

Figure 5. Network visualisation of the authors and their collaborations

The present investigation was conducted to evaluate the effect of aqueous fresh peel extract of *Opuntia Ficus indica* fruit against *malva parviflora* associate wheat plants and the net return on wheat growth and yield.

2. Methodology

2.1. Preparation of plant material and aqueous extract

Homogenous Fruits of the *Opuntia Ficus-indica* (L.) Mill (yellow orange) were selected from Egyptian fruit market in August (**Figure 6**). They were peeled and the fresh peels were washed well with tap then distilled water and kept in the freezer till use.

On the late of Novembre, the saved peels of *O. Ficus-indica* (L.) Mill were prepared for use by cutting them to very small pieces, weighted and transferred to labeled baker containing distilled water for obtaining stalk solution (concentration 20 %), left to soak for 48 hours. The extract was filtered in very fine mesh and pushed well through the mesh for complete extraction. A part of the extract was taken for use at 20% concentrations. The remaining extract was diluted to obtain 5, 10 and 15% concentrations. The process of extraction was repeated according to need.

Figure 6. *Opuntia Ficus-indica* (L.)

2.2. Pot experiments

The experiments were carried out in the two successive winter seasons 2021/2022 and 2022/2023 in the greenhouse of the National Research Centre, Dokki, Egypt. Wheat grains cv. Giza 168 were obtained from the Agricultural Research Centre, Giza, Egypt. Wheat grains were selected to be of the same size and sown 2 cm deep (eight grains in each pot). The grains were germinated in pots 30cm diameter and 30cm height which filled with sieved soil (2: 1 v/v clay and sand). All pots (except the weed free treatment) were infested at the same time with a definite weight of weed *Malva parviflora* and mixed well at a depth of 2 cm in the soil. Thinning wheat seedlings was done 2 weeks after sowing so that three homogeneous seedlings were left per pot. Irrigation and routine fertilizers were carried out. The experiment consisted of 6 treatments; each treatment was represented by 6 pots distributed at a complete random design. The prepared aqueous fresh peel extract of *O. Ficus-indica* (L.) Mill at concentrations (5-20%) were applied in soil at a rate of 250 ml /pot two times during the two weeks, starting with 15-day-old plants. The data were taken 40 DAS (days after sowing) and at harvest.

2.3. Characters studied

2.3.1. Weed data

In each season, *Malva parviflora* weed samples in the three pots were taken, representing three replicates 40 days after sowing (DAS) and at harvest (all weed samples in each pot were pulled up). The fresh weight of *Malva parviflora* at 40 DAS were recorded, then oven dried at 60°C for determination of dry weight (g/pot).

2.3.2. Wheat data

Three plants in each pot were taken 40 DAS for recording, plant height, number of leaves/plant, as well as fresh and dry weight (g/plant). At harvest, number of spikes/plant spike length, number of spikelets/spikes, weight of grain yield/plant (g/plant) and weight of 1000- grains (g) were determined.

2.3.3. Phytochemical screening of Opuntia. Ficus indica **fruit** *peelt*

2.3.3.1. Determination of total phenolic compounds content

Total phenolic compounds content was determined in fresh peel of *O. Ficus indica* fruit using the modified Folin-Ciocalteu technique (Kaur and Kapoor 2002). The concentration was represented as mg /g fresh weight.

2.3.3.2. Determination of total flavonoid content

Total flavonoid content was measured in fresh peel fruit of *O. Ficus indica* using a modified colorimetric method (Chang *et al*. 2002). The total flavonoid content was determined as mg/g fresh weight

2.4. Statistical analysis

The data obtained were subjected to Analysis of Variance (ANOVA) according to Snedecor and Cochran (1991) and the means of treatments were compared by the least significant difference at 5% probability.

3. Results

3.1. Weed

Table 1 shows that the incorporation of the aqueous fresh peel extract of *O. Ficus indica* fruit in soil has significant reduction on *M. parviflora* fresh weight at 40 DAS at 10, 15 and 20%. The reduction in dry weight 40 DAS and at harvest was significant at 5-20% as compared to their corresponding unweeded controls. The maximum reduction was obtained by using the extract at 20%. recording 65.86% reduction at harvest under unweeded control.

Table1. Effect of the aqueous fresh peel extract of *Opuntia. Ficus indica* fruit on *Malva parviflora* growth associated wheat plant (Average of the two seasons)

Treatments	Concentration. %	40 DAS		At the end of the season
		Fresh weight	Dry weight	
Weed-Free plants	0.0	0.00	0.000	0.000
Unweeded plants	0.0	6.88	1.556	40.693
Aqueous fresh peel extract of *Opuntia. Ficus indica* fruit	5.0	6.73	1.180	33.583
	10.0	5.86	1.120	31.450
	15.0	5.01	0.930	19.956
	20.0	3.02	0.540	13.890
LSD at 5%		0.39	0.210	1.156

3.2. Wheat

3.2.1. Vegetative growth

The results in Table 2 indicate increases in plant height (cm), fresh and dry weight/ (g/plant) of wheat significantly over that their corresponding unweeded controls 40DAS when the plants treated with the aqueous fresh peel extract of *O. Ficus indica* fruit (5-20%). The results also reveal a significant increase in number of leaves/plant at 15 and 20% of fresh peel extract in comparison to the unweeded control. The soil treatment at 15% recorded results more or less higher than that of free plant giving maximum significant results in all wheat growth parameters among soil tretments.

3.2.2. Yield

The results in Table 3 reveal significant increases in the number of spikes/plant, spike length, number of spiklets/spike, grain yield/plant (weight of grain/plant) and weight of 1000 grains with the soil treatments of the aqueous fresh peel extract of *O. Ficus indica* fruit at concentrations 10-20% as compared to their corresponding controls. The highest significant increase in grain yield / plant (g) reached about 58% over unweeded control with 15% of the fresh peel extract. However, the

interference of *M. parviflora* with wheat (unweeded control) reduced the grain yield/plant by 28.68% as compared to that of free plants, so, recording the least yield among all treatments.

Total phenolic compounds content in the aqueous fresh peel extract of *O. Ficus indica* fruit amounted to 17.41 and total flavonoids content recorded 2.98 (mg/ g fresh weight) as in (Table 4).

Table 2. Effect of the aqueous fresh peel extract of *Opuntia*. *Ficus indica* fruit on different parameters of wheat growth (Average of the two seasons)

Treatments	Concentration. %	Plant height (cm)	No. Leaves/ plant	Fresh weight (g/plant)	Dry weight (g/plant)
Weed-Free plants	0.0	47.44	5.77	2.80	0.860
Unweeded plants	0.0	33.33	4.77	0.30	0.082
Aqueous fresh peel extract of *Opuntia*. *indica* fruit	5.0	35.83	5.00	0.51	0.202
	10.0	39.27	5.00	1.27	0.360
	15.0	43.11	5.77	2.28	0.636
	20.0	40.22	5.33	2.25	0.538
LSD at 5%		1.55	0.400	0.21	0.109

Table 3. Effect of the aqueous fresh peel extract of *Opuntia*. *Ficus indica* fruit on yield and yield components of wheat (Average of the two seasons)

Treatments	Concentration. %	No. spikes/ plant	Spike length (cm)	No. spiklets/spike	Weight of grain /plant	Weight of.1000 grain
Weed-Free plants	0.0	6.00	6.33	20.00	6.73	41.28
Unweeded plants	0.0	5.00	5.91	16.33	4.80	34.80
Aqueous fresh peel extract of *Opuntia*. *Ficus indica* fruit	5.0	5.00	6.08	16.66	4.86	35.73
	10.0	5.33	6.41	18.00	5.16	36.93
	15.0	6.00	6.50	21.00	7.58	42.22
	20.0	5.66	6.12	19.00	5.95	38.31
LSD at 5%		0.31	0.31	1.03	0.27	1.25

Table 4. The contents of total phenolic and total flavonoids in fresh peel of *Opuntia Ficus-indica* fruit

O. Ficus indica fruit peel	Total phenolic (mg/g freshweight)	Total flavonoids (mg/g fresh weight)
	17.41	2.98

4. Discussion

Using allelopathic materials in agricultural management is a strategy for minimizing the use of herbicides to decrease their environmental damage (Prasad *et al*., 2016). It has been Documented that using allelopathy in weed management is important to protect target plants and challenges for weed resistance to the herbicides due to their continues use (Khamare *et al*., 2022). It was found that *O. Ficus indica* contain bioactive secondary metabolites that make researchers use them as allelopathic plants (Elaloui *et al*., 2019, Arroussi *et al*., 2022).

The Results in the current work indicated significant inhibition in *M. parviflora* weight when using aqueous fresh peel extract of O. Ficus indica fruit, especially at 20% concentration, after 40 days from sowing and at harvest. In accordance with the present results, Rsaissi *et al*. (2013) documented up to 100% inhibition in germination and growth of jujube by different parts of O. *Ficus*

indica. Other confirmed results were obtained by Elaloui *et al*. (2019), who reported that *Opuntia-Ficus-indica* inhibited *Triticum durum* at levels of 25% seeds germination and 93.60% shoot length. Moreover, Arroussi *et al*. (2022) mentioned that *O*. *Ficus indica* had allelopathic inhibiting effects on *Lactaca sativa* and *Phalaris minor* plumule and hypocotyl lengths. In addition, many fruit crops were found to have bioherbicidal effects (Bhatt, *et al*., 2011; Saleem *et al*., 2013; El-Sawi *et al*., 2019). In this respect, El-Rokiek *et al*. (2019) mentioned that *Citrus sinensis* peel oil inhibited *M. parviflora* growth associated wheat plants.

Like other allelopathic fruits, O. *Ficus indica* fruit peel possesses secondary metabolites such as phenolic compounds and flavonoids. These allelochemicals were reported to suppress completely barnyard grass (Khanh *et al*., 2008). Ramadan *et al*. (2021) cited that different parts (peel, pulp, and seeds) of *Opuntia* fruits generates a large number of by-products that are rich in bioactive constituents such as fibers, vitamin C, phenolic compounds, vitamin E, amino acids, minerals, and natural pigments such as betalains. So, the reduction in *M. parviflora* associated wheat plants (Table 1) by the fresh peel extract *of O. Ficus indica* fruit may be attributed to the contents of phenolic compounds and flavonoids (Table 4). This suggestion came in accordance with Rsaissi *et al*. (2013) in which they attributed the inhibition in jujube growth by *O. Ficus indica* to strong correlation between allelopathic effects and the content of phenolic**.** Many workers interpreted weed inhibition caused by allelopathic plants to the contents of phenolic compounds and flavonoids in addition to other allelochemicals such as alkaloids, tannins and antioxidants (Ghimire *et al*., 2020; Kato-Noguchi and Kurniadie 2022; Issami *et al*., 2023; El-Rokiek *et al*., 2024; Shehata *et al*., 2025).

In general, controlling weeds associated crop plants decreased the competition of these associated weeds against target plants resulting in more nutrients and water taken by the plant as have been reported by many workers (Messiha *et al*. 2021&2023; El-Rokiek *et al*. 2022, 2024 and Shehata *et al* 2025). Consequently, the increase in wheat growth and yield (Tables 2&3) due to the inhibition *M. parviflora* growth (Table 1) came in accordance with the finding of these previous workers confirming these obtained results.

Conclusion

The significant inhibition in *Malva. Parviflora* growth associated wheat plants in the present investigation by the *Opuntia Ficus-indica* (L.) fruit fresh peel extract and the net return on the yield increase in wheat suggest using the peel extract as a natural bioherbicide for controlling *Malva. Parviflora* associate wheat plants However, *Opuntia Ficus-indica* (L.) attention must be given to future research to explore more effects on other weeds.

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Compliance with Ethical Standards: This article does not contain any studies involving human or animal subjects

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