Effect of fenugreek (*Trigonella foenum-graecum* L.) seed aqueous extract on germination, growth and chlorophyll content of selected field crops

Nahla Mohammed Ali Khaleel[1], Vian Dler Ali[2] *, Raad Hussien Salih[3], Sumaya Ahmad Abdullah[3], Hiyam Younis Taha[4]

[1] Department of Nutrition and Dietetics, Hawler Medical University, Kurdistan region, Iraq. [2] Department of Horticulture and Landscape Design, College of Agricultural Engineering Science, Salaheddin University-Erbil, Kurdistan region, Iraq.
[3] Department of Field Crop and Medicinal Plant, College of Agricultural Engineering Science, Salaheddin University-Erbil, Kurdistan region, Iraq.
[4] Department of Biology, College of Science, Salaheddin University-Erbil, Kurdistan region, Iraq.
***Corresponding author email:** vian.ali1@su.edu.krd
https://doi.org/10.59658/jkas.v13i2.6624

Received:
Jan. 19, 2026

Accepted:
Apr. 23, 2026

Published:
June 15, 2026

Abstract

This research was conducted to determine that it was essential to investigate the impact of fenugreek (*Trigonella Foenum-graecum* L.) seed extract spraying on wheat, barley, oat and fenugreek plant on plant height, chlorophyll content and shoot dry weight in plastic house during December 30th, 2024 to April 24th, 2025 at Grdarasha Research Field, College of Agricultural Engineering Sciences, Salahaddin University – Erbil. For the aqueous extracts, four concentrations were used: 0, 25, 50 and 100% with three replicates and a completely randomized design (CRD) were used. The results found that significant differences between plant species for all parameters and the fenugreek seeds aqueous extract at 100% concentration give the highest efficiency in this study. Also, for the interaction between treatments, plant height statistically increased for barley by 50, 100%, chlorophyll and shoot dry weight in fenugreek plant at all concentrations. A laboratory experiment using a completely randomized design with four replicates was conducted at the same college to evaluate the germination and viability parameters of plant seeds and radicle and plumule characteristics. Findings showed that fenugreek and barely plant seeds were stimulated with using fenugreek extracts than other. Fenugreek seeds aqueous extract concentrations increased from 25 to 100%, the effect of allelopathic materials for all germination parameters was increased. For the interaction between treatments, it gave the lowest number for all parameters studied by wild oat plant and 100% of fenugreek extract.

Keywords: Fenugreek, Allelopathic, Germination, chlorophyll.

Introduction

Allelopathy, the biological phenomenon of chemical interactions between plants through the release of secondary metabolites into the environment, is becoming more and more popular as a solution to these problems, farmers are still hesitant to put this knowledge into practice, despite the fact that many essential crops are known to have allelopathic potential. [1, 2]. Due to extensive and irregular use of chemical toxins (especially herbicides) now days, allelopathic plants application and their residue in the soil have been reported for controlling undesirable plants and improving plant growth conditions [3, 4].

Allelopathy is an ecologically significant biochemical phenomenon that involves any direct or indirect negative or positive impact that one plant (donor) has on another (target) through the release of chemical compounds into the environment. The complex phenomenon known as allelopathy involves both stimulatory and inhibitory effects on plant activity brought on by the release of specific chemical compounds known as allelochemicals. Several harmful effects of allelopathic substances include: inhibition and delays in germination, seed darkening and loss of turgidity, deformation of seedlings, reduction in root, radicle, stem, and coleoptile development, swelling and necrosis of roots or radicles, paleness, absence of root hairs, and decrease in total dry matter [5,6, 7].

The fenugreek plant, *Trigonella foenum-graecum* L., is a member of the Fabaceae family and is found all over the world. With proper cultivation, irrigation, and harvesting management, yields can be significantly increased in both quantity and quality. Active ingredients found in the plant include alkaloids, flavonoids, steroids, saponins, and more [8].

Azizi et al. [9] reported that using different parts of fenugreek extracts, had a negative effect on seed germination and growth of several crops and weeds. The results indicated that not only fenugreek extract reduced seedling growth of different species, but also inhibited seed germination of crop and weed species, these responses were different to allelopathic substances due to the species nature and amount of allelopathic substances of fenugreek parts. In all species, the highest allelopathic effect was observed for seed and leaf extracts.

The germination and early growth stages are considered critical phases in the life cycle of field crops such as wheat, barley, and oat, as they directly affect plant establishment and final yield. Recently, there has been increasing interest in using natural and eco-friendly substances as alternatives to chemical treatments to enhance plant growth and physiological performance.

Fenugreek (*Trigonella foenum-graecum* L.) seeds contain various bioactive compounds, including alkaloids, flavonoids, and vitamins, which may have either stimulatory or inhibitory effects on plant physiological processes such as germination, growth, and chlorophyll formation. However, these effects are likely to vary depending on the concentration of the extract and the plant species involved.

Despite the availability of some studies on plant extracts, there is a lack of comprehensive research comparing the effects of different concentrations of fenugreek seed extract on multiple field crops under the same experimental conditions, particularly in terms of germination, growth, and chlorophyll content.

Therefore, the research problem lies in the unclear and variable response of different field crops (fenugreek, wheat, barley, and oat) to varying concentrations of fenugreek seed extract, and whether these effects are stimulatory or inhibitory. Additionally, it is not well-established which concentration may be optimal for improving physiological performance and plant growth.

The aim of this study was designed to show the effect of fenugreek seed aqueous extracts on germination and seedling development of wheat, barely, oat and fenugreek plants. It will also propose to investigate the effective allelochemical use of suitable herbicides and fertilizer based on the research results.

Materials and Methods

Two experiments were carried out in this study, the first experiment was carried out in the plastic house from December 30th, 2024 to April 24th, 2025 at Grdarasha Research Field, College of Agricultural Engineering Sciences, Salahaddin University – Erbil to study the effect of foliar application of fenugreek (*Trigonella foenum-graecum* L.) on chlorophyll content and yield of some field Crops. The experiment was conducted using pots measuring 10cm in height, 12cm in upper diameter, and 9cm for the lower diameter. A total of 48 pots were used. The pots were randomly arranged and assigned to treatments in order to reduce experimental errors. Pots were filled with soil (Table 1), two seeds per pot were sown at a depth of 3cm on December 30th, 2024 in the plastic house using a completely randomized design (CRD) with three replications. Four species of plants were used in the experiment, wheat (*Triticum aestivum* L.) Adana variety, barley (*Hordeum vulgare* L.) Aksad14 variety, wild Oat (*Avena fatua*) and fenugreek (*Trigonella foenum-graecum* L.). Moisture was maintained by adding water when needed.

Fenugreek seeds were taken to the College of Agricultural Engineering Sciences Laboratory at Salahaddin University-Erbil, where they were ground with a grinder to a fine consistency and made ready for analysis. 30 grams of powdered fenugreek seeds and 200 milliliters of distilled water were combined to make an aqueous extract, which was then put on a shaker machine to enhance mixing. The samples were then kept for two days at 35°C in an oven. Additionally, the extracts are filtered using filter paper, and distilled water is added to reach the full volume of 300 ml. Lastly, the extract was stored at 4°C in a freezer until it was used. Gas Chromatography-Mass Spectrometry (GC/MS) was done for an aqueous fenugreek seed extract sample (Table 2) according to [10 , 11].

The fenugreek seeds aqueous extract diluted with distilled water to the required concentrations (control, 25, 50 and 100%) were used for foliar application. A surfactant agent-Tween40 was added at a concentration of 0.1% to the solutions. Spraying was

carried out in two stages; the first spray was applied after two months from the sowing date and the second spray was applied after two days from the first spray. The spray was carried out early in the morning till runoff.

Two plants were selected from each pot to study the plant height two times (8/3 and 14/3 -2025) with a one week interval between them, Shoot dry weight (g.plant^{-1}), inhibition and response ratio of shoot dry weight (S.D.W.) % [12] and Chlorophyll content was measured at two times in the (3/3 and 8/3 -2025) with five days interval between them, the "Chlorophyll Meter SPAD-502 plus" was used for total chlorophyll estimation [13].

$$\textbf{Inhibition ratio of shoot dry weight\%} = \frac{\text{S.D.W. control} - \text{S.D.W. treated}}{\text{S.D.W. control}} \times 100 \quad \text{.....(1)}$$

$$\textbf{Response ratio of shoot dry weight\%} = \frac{\text{S.D.W. treated} - \text{S.D.W. control}}{\text{S.D.W. control}} \times 100 \quad \text{.....(2)}$$

Table (1): Some chemical and physical properties of the field soil of Grdarasha

Soil properties		Soil components
Particle size distribution %	Sand	12.5
	Silt	42.5
	Clay	45
Texture Class		Silty Clay
pH		7.42
Electrical Conductivity (EC) ds m^{-1}		0.2
Organic Matter (%)		0.9
Total Nitrogen (N) ppm		0.18
Total Phosphor (P) ppm		3.75
Total Potassium (K) ppm		100

*Laboratory Soil and Water Sciences Department, College of the Agricultural Engineering Sciences, University of Salaheddin University.

The second experiment was conducted at the College of Agricultural Engineering Sciences laboratory to examine the effectiveness of fenugreek seed extract on the germination and viability characteristics of plant seeds. Each plant species' 25 seeds were put in a separate, 9cm diameter petri dish lined with filter paper. Ten milliliters of fenugreek seed aqueous extract were applied to the petri dishes, which served as the treatment for petri dishes. Just 10 milliliters of distilled water were added to petri dishes for the control treatment. There were four replications of each seed species, including test and control treatments. Petri dishes were incubated at 22°C in a growth chamber. Every day, the percentage of seed germination, germination speed (seed/day)

[14], radicle and plumule lengths (cm), radicle and plumule elongation velocity(cm/day), peak value (%day) [15], mean daily germination (% day) [16], germination value [17], inhibition and response ratio of radicle and plumule % and seedling vigor index (cm/100) [18] of the sprouted seedlings, it was continued for a period of 8 days and were recorded as detailed below:

Germination percentage $\%=\frac{\text{Number of germinationed seed}}{\text{Total number of seeds sown}} \times 100$ ……..….(3)

Germination speed (seed day^{-1}) $=\sum \frac{\text{number of germinated seeds}}{\text{number of days}}$ ……...…….(4)

Radicle or plumule elongation velocity(cm/day) $= \frac{N1}{1} + \frac{N2}{2} + \frac{N3}{3} + \frac{N}{n} \times 100$ … … … ..(5)

Peak value(% day^{-1}) $= \frac{\text{Final germination percentage}}{\text{Number of days to reach maximum germination}}$ ……..(6)

Mean daily germination (% day^{-1}) $= \frac{\text{Final germination \%}}{\text{Total number of days in test}}$ ……..……..(7)

Germination value = mean daily germination % day^{-1} × peak value **%** day^{-1} ....(8)

Seedling Vigor Index (cm/100)= Germination percentage × seedling length…(9)

Inhibition ratio of radicle or plumule% $=\frac{\text{S.D.W.control}-\text{S.D.W. treated}}{\text{S.D.W. control}} \times 100$ .....(10)

Response ratio of radicle or plumule %= $\frac{\text{S.D.W. treated}-\text{S.D.W. control}}{\text{S.D.W. control}} \times 100$……..(11)

The experiments were designed according to factorial completely randomized design (CRD) with three replicates for the pot experiment and four for laboratory. Comparisons between means were made using Duncan's Multiple Range Test at 5% level for plastic house experiment. However, 1% level was used for laboratory characteristics. The statistical analysis was carried out using the SPSS (Statistical Package for Social Sciences) Program, version (22.0) in 2019 [19].

Table (2): Analysis GC-MS of an extract of fenugreek seeds

Component Name	Re-ten-tion Time	Peak Area %	Component Name	Re-ten-tion Time	Peak Area%
1-Methoxy-2,3-dimethyl-2-butene	5.153	0.21	.gamma.-Sitosterol	28.473	3.28
.alpha.,.beta.-Gluco-octonic acid lactone	5.189	0.18	1-Methylcyclohex-1-en-4-carboxylic acid	8.261	0.75
3-Nonen-1-ol, (Z)-	5.37	3.88	9,19-Cyclolanostan-3-ol, acetate, (3.beta.)-	29.722	0.73
2-Methylpyrrolidine	5.438	1.65	Megastigmatrienone	8.603	0.19
9-Azabicyclo[4,2,1]non-2-ene, 2-acetyl-9-methyl-	5.557	0.83	1-Chloro-4-(1-ethoxyeth-oxy)-2-methylbut-2-ene	8.766	0.53
Carbonic acid, propargyl 2-ethylhexyl ester	5.589	0.65	3-O-Methyl-d-glucose	9.191	17.16
Cyclotetrasiloxane, octame-thyl-	5.659	0.41	Neophytadiene	10.003	0.74
4H-Pyran-4-one, 3,5-dihy-droxy-2-methyl-	5.702	0.59	Squalene	17.548	0.27
2-Oxonanone	5.794	2.58	2-Methyltetracosane	10.461	0.2
Benzenemethanamine, N-ethyl-	5.938	0.34	Hexadecanoic acid, methyl ester	10.635	2.3
3-Amino-4,5-dimethyl-2(5H)-furanone	6.043	0.68	n-Hexadecanoic acid	10.893	2.39
2-Pentyl-cyclohexane-1,4-diol	6.182	0.35	7-Hexadecenal, (Z)-	11.196	0.26
9,19-Cyclolanost-24-en-3-ol, acetate, (3.beta.)-	31.325	1.32	.beta.-Sitosterol acetate	33.003	1.13
4-Pentenoic acid, 2-methyl-, decyl ester	6.342	0.61	9,12-Octadecadienoic acid (Z,Z)-, methyl ester	11.85	10.62
Pent-4-enoyl amide, 2-me-thyl-N-ethyl-	6.391	0.4	9,12-Octadecadienoic acid (Z,Z)-	12.131	7.14
Vitamin E	23.082	1.04	4-Morpholinopiperidine, N-trimethylacetyl-	12.314	2.98
Imidazole-4-carboxylic acid, 1-methoxymethyl-, ethyl es-ter	6.948	0.2	2- Chloropropionic acid, hexadecyl ester	12.583	0.5
dl-Citrulline	7.036	0.17	8,11,14-Eicosatrienoic acid, (Z,Z,Z)-	12.885	1.01

4-(tert-Butylamino)-3-methylbutan-2-one	7.123	0.1	2-(Dimethylamino)ethyl (9Z,12Z)-octadeca-9,12-dienoate	13.081	0.47
2H-Pyran-2-one, tetrahydro-6-undecyl-	7.173	0.27	2-((8Z,11Z)-Heptadeca-8,11-dien-1-yl)-4,5-dihy-drooxazole	13.316	3.4
(E)-2-Decenyl acetate	7.257	0.25	Oxazole, 4,5-dihydro-2-pentadecyl-	13.503	0.49
2-(Isobutoxymethyl)oxirane	7.528	8.95	5-Methyltricosane	13.731	0.79
Heptadecane, 4-methyl-	7.82	0.91	Phenol, 2,2'-meth-ylenebis[6-(1,1-di-methylethyl)-4-methyl-	13.983	0.57
(2E,4E)-2,4-Dodecadienoic acid	7.882	3.47	2-(Dimethylamino)ethyl vaccenoate	14.212	0.77
2,4-Di-tert-butylphenol	7.68	0.92	9,12-Octadecadienoic acid (Z,Z)-, 2-hydroxy-1-(hy-droxymethyl)ethyl ester	14.338	0.39
9,12-Octadecadienoic acid (Z,Z)-, TMS derivative	15.933	0.66	Swainsonine	14.548	0.78
9,12-Octadecadienoic acid (Z,Z)-, 2-hydroxy-1-(hy-droxymethyl)ethyl ester	16.232	2.34	Hexadecanoic acid, 2-hy-droxy-1-(hydroxyme-thyl)ethyl ester	14.651	1.25

*Laboratory of College of the Science, University of Salahaddin.

Results and Dissuasion

Plastic house parameters

From the results presented in table (3), the barely plant had the highest values (30.05 and 35.59cm) of plant height, while the fenugreek plant had the lowest height (14.77 and 16.90cm). The total chlorophyll amount in both measurements significantly increased in the fenugreek plant to (40.88 and 42.41 SPAD), whereas, this amount declined in wild oat plant to (29.21 and 29.15 SPAD). Shoot dry weight and inhibition rate of shoot dry weight recorded the maximum values in wheat plant by (0.52g and 19.26%), while the response rate of shoot dry weight was increased in fenugreek plant (53.84%).

They were not statistically significant for all concentrations of spray of fenugreek seed extract for all parameters except, response rate of shoot dry weight increasing with increased the fenugreek extract level and vice versa with inhibition rate of shoot dry weight. In the same table shows the interaction between plant species and fenugreek extract foliar application. Plant height significantly increased to (34.33 and 38.66cm) in the barley plant with 50% and 100% fenugreek extract, but decreased to (13.00 and 15.16cm) in the fenugreek plant with control. The maximum values of

chlorophyll content were recorded by the fenugreek plant at 25% and 50%, whilst the minimum number was obtained with the wild oat plant in the first measure and the wheat plant in the second measure at 50%. Shoot dry weight statistically improved in the fenugreek plant at 100% and declined on the same plant but with 25% fenugreek seeds extract.in addition, the highest percentage of response rate and inhibition rate were recorded for fenugreek at 100% (161.53%) and for wheat at 25% (27.68%) respectively. On the contrary, the lowest values of these parameters were obtained by fenugreek with 100% for inhibition rate and wheat at 25% for response rate. Results indicate the potential strength of fenugreek aqueous extracts towards different plant species. On the other hand, it is well known that plant species differ in responding to allelochemicals due to genetic variation properties, beside crop and weed plants included in this study showed different levels of sensitivity towards allelochemics of fenugreek plants. The chemical composition of the fenugreek seed extract components under investigation was examined using GC-MS and mass spectrometry. A total of 54 substances were shown in Table (2).

It was noted that several compounds showed up in large quantities, such as the compound 2-(Isobutoxymethyl) oxirane (8.95%) and gamma. -Sitosterol (3.28%). However, a few additional chemicals, like vitamin E (1.04%) and Megastigmatrienone (0.19%), were present at extremely small levels. The increasing plant height and content of chlorophyllin leaves, that is due to the role of fenugreek extract which contains nutrients such as potassium, an important role in the growth and development of plants, although it does not entered in any installation of cellular components as well as act as a cofactor in many biological processes as an effect in activating enzymes synthesis of proteins and it also plays an active role in organizing the osmotic pressure inside plant cells this helps to absorb water and organizing opening and closing of stomata in leaves, as well as his role in the increase of cell division and its relationship to the formation of nucleic acids as a relationship in the formation of proteins and photosynthesis [20,21,22, 23]. Dawood et al. [24] mentioned that fenugreek seeds extract including important nutrients, such as an iron element that positively affects photosynthesis and chlorophyll building.

Table (3): Influence of plant species, fenugreek seeds extract concertation and their interaction on some growth parameters in the plastic house

Plant species	Plant height FC (cm)	Plant height SC (cm)	Chloro-phyll FC (SPAD)	Chloro-phyll SC (SPAD)	Shoot dry weight (g.plant $^{-1}$)	Re-sponse ratio of shoot dry weight %	Inhibi-tion of shoot dry weight %
Wheat	25.75 b	25.57 b	33.88 b	31.50 b	0.52 a	-19.26 b	19.26 a
Barley	30.05 a	35.59 a	31.82 b	32.51 b	0.51 a	34.41 a	-34.41 b
Wild oat	21.86 c	22.52 c	29.21 b	29.15 b	0.39 ab	-5.42 b	5.42 a
Fenugreek	14.77 d	16.90 d	40.88 a	42.41 a	0.36 b	53.84 a	-53.84 b
Fenugreek extract con-centration (%)	**Plant height FC (cm)**	**Plant height SC (cm)**	**Chloro-phyll FC (SPAD)**	**Chloro-phyll SC (SPAD)**	**Shoot dry weight (g.plant $^{-1}$)**	**Re-sponse ratio of shoot dry weight %**	**Inhibi-tion of shoot dry weight %**
0	22.85 a	24.92 a	32.64 a	31.92 a	0.43 a	----------	----------
25	21.94 a	24.09 a	35.85 a	35.66 a	0.42 a	0.06 b	-0.06 a
50	23.87 a	25.35 a	32.86 a	32.82 a	0.43 a	4.27 b	-4.27 a
100	23.78 a	26.21 a	34.44 a	35.66 a	0.53 a	43.34 a	-43.34 b
Plant species × Fenugreek extract con-centration	**Plant height FC (cm)**	**Plant height SC (cm)**	**Chloro-phyll FC (SPAD)**	**Chloro-phyll SC (SPAD)**	**Shoot dry weight (g.plant $^{-1}$)**	**Re-sponse ratio of shoot dry weight %**	**Inhibi-tion of shoot dry weight %**
Wheat 0%	26.76 bc	26.60 b	35.94 a-d	29.73 c	0.61 ab	---------	-------
Wheat 25%	26.66 bc	26.33 b	28.90 cd	34.46 bc	0.57 abc	-7.79 b	7.79 a
Wheat 50%	25.33 c	24.43 bc	36.20 a-d	24.40 c	0.44 abc	-27.68 b	27.68 a
Wheat 100%	24.26 cd	24.43 bc	34.50 bcd	37.43 bc	0.48 abc	-22.31 b	22.31 a
Barley 0%	27.43 bc	33.00 a	31.60 cd	35.43 bc	0.41 abc	--------	--------

Barley 25%	27.16 bc	33.00 a	30.60 cd	33.90 bc	0.58 ab	31.70 b	-31.70 a
Barley 50%	34.33 a	36.83 a	25.66 cd	27.50 c	0.54 abc	43.08 b	-43.08 a
Barley 100%	31.26 ab	38.66 a	39.43 abc	33.23 bc	0.52 abc	28.45 b	-28.45 a
Wild oat 0%	24.20 cd	24.93 bc	30.00 cd	28.43 c	0.41 abc	--------	--------
Wild oat 25%	19.93 de	20.00 cd	34.50 bcd	27.83 c	0.31 bc	-22.35 b	22.35 a
Wild oat 50%	18.33 ef	19.83 cd	21.600 d	26.36 c	0.41 abc	0.40 b	-0.40 a
Wild oat 100%	25.00 c	25.33 bc	31.06 cd	34.00 bc	0.43 abc	5.69 a	-5.69 a
Fenugreek 0%	13.00 g	15.16 d	33.03 bcd	34.10 bc	0.26 c	---------	---------
Fenugreek 25%	14.00 fg	16.16 d	49.73 a	49.46 ab	0.25 c	-1.28 b	1.28 a
Fenugreek 50%	17.50ef g	19.83 cd	48.00 ab	53.03 a	0.26 c	1.28 b	-1.28 a
Fenugreek 100%	14.60 fg	16.43 d	32.76 bcd	36.06 bc	0.68 a	161.53 a	-161.53 b

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 5% level.
* FC – First count, SC- second count.

Germination parameters

Table (4) indicates a significant effect of fenugreek aqueous extracts on recorded data, whereas the highest values were recorded for all germination characteristics for the fenugreek plant and the lowest data for wild oat plant. With increasing the concentration of aqueous extract significantly decreases the germination parameters and the minimum rate were obvious with level 100% and germination parameters recorded the maximum data with those seeds that not take any treatment. Barley plant at the 0% level occupies the first position for germination percentage, germination speed and mean daily germination by (94.00%, 1.38 seed/day and 11.75%) respectively. In addition to that peak value and germination value significantly increased to (21.00% and 240.75) in fenugreek with 100% while, the minimum values of these parameters were obtained by wild oat with 100%.

These results elucidate the negative effect of increasing concentration of the aqueous extracts, which suggest different plant responses to concentration in such way it may be perfect evidence of its potential to be used as an herbicide for these tested weed plants due to its concentration dependent behavior [9]. The decrease in weed seed germination here is due to the inhibitory effect of fenugreek extract, which contains

substances such as phenols, tannins, and coumarin compounds, which are toxic at high concentrations, as well as, fenugreek contains chemical compounds that are soluble in water, and therefore increasing the concentration of the aqueous extract, whether through the process of seeds being soaked in water, means an increase in the amount of these compounds, which vary in their effect on cell division and elongation, and some compounds may affect the activity of some enzymes that contribute to this process, such as amylase-Q [25 and 26, 27].

Plumule, radicle and seedling vigor index parameters

Table (5) elucidates the significant effect of different concentrations of aqueous extracts of fenugreek seeds on some plumule, radicle and seedling vigor index parameters. Findings show that no significant differences between plant species of radicle elongation velocity, while the ratio in radicle inhibition statically increased to (81.73%) in wild oats and decreased to (27.77%) in fenugreek plants. In contract to, for the radicle response rate, the highest ratio (-27.77%) was recorded for fenugreek and the lowest (-81.73%) for wild oat. The plumule characteristics and seedling vigor index show the highest improvement for barely plant and minimum amount for wild oat plant, excepting, the plumule inhibition rate had a significant increase in wild oats and a decrease in barely plant. Radicle and plumule elongation velocity and seed vigor index produced the maximum rates (1.37, 1.25 and 1881.52) without using any fenugreek aqueous extract, and the lowest values obtained at 50 and 100% levels. The inhibited rate in radicle and plumule significantly increased with 100% concertation, while the response proportion of these parameters raised at 25% and declined at 100%. From the interaction data, radicle and plumule velocity and seedling vigor index increased in wild oat, fenugreek and barely with control and these parameters significantly affected interaction between treatments and showed no growth (0.00) in wild oat at 100% level, for this reason the ration of inhibition rise to 100% for these characteristics. As well as, the response ratio was (0.00 and -9.78) in radicle and plumule parts.

A decrease in average radicle and plumule lengths or death is observed, due to the inhibitory effect of fenugreek extracts, as they expose the seeds to osmotic stress and prevent the embryo from dividing and forming the radicle, which delays germination or leads to germination failure and death of the embryo within the seed [28].

Table (4): Influence of plant species, fenugreek seeds extract application and their interaction on some germination characteristics

Plant species	Germination percentage %	Germination Speed (seed day^{-1})	Peak Value (% day^{-1})	Mean Daily Germination (% day^{-1})	Germination Value
Wheat	75.25 b	1.05 b	14.80 b	9.40 b	148.48 b
Barley	87.25 a	1.23 a	15.93 ab	10.90 a	175.73 ab
Wild oat	41.50 c	0.29 c	6.95 c	5.18 c	57.35 c

Fenugreek	91.25 a	1.28 a	18.40 a	11.40 a	209.76 a
Fenugreek extract concentration (%)	**Germination percentage %**	**Germination Speed (seed day^{-1})**	**Peak Value (% day^{-1})**	**Mean Daily Germination (% day^{-1})**	**Germination Value**
0	86.75 a	1.16 a	15.48 a	10.84 a	170.36 a
25	84.50 a	1.07 ab	15.45 a	10.56 a	164.56 a
50	72.00 b	0.97 b	14.31 a	9.00 b	153.72 a
100	52.00 c	0.65 c	10.85 b	6.50 c	102.68 b
Plant species × Fenugreek extract concentration	**Germination percentage %**	**Germination Speed (seed day^{-1})**	**Peak Value (% day^{-1})**	**Mean Daily Germination (% day^{-1})**	**Germination Value**
Wheat 0%	90.00 ab	1.36 a	19.10 ab	11.25 ab	214.70 a
Wheat 25%	84.00 abc	1.20 ab	16.50 abc	10.50 abc	170.50 abc
Wheat 50%	90.00 ab	1.18 ab	14.86 a-d	11.25 ab	166.93 abc
Wheat 100%	37.00 d	0.46 c	8.76 de	4.62 d	41.81 de
Barley 0%	94.00 a	1.38 a	15.66 a-d	11.75 a	184.83 abc
Barley 25%	90.00 ab	1.31 a	16.43 abc	11.25 ab	184.58 abc
Barley 50%	89.00 ab	1.25 a	18.50 abc	11.12 ab	206.08 ab
Barley 100%	76.00 bc	0.97 b	13.33 bcd	9.50 bc	127.43 bc
Wild oat 0%	71.00 c	0.60 c	11.83 cd	8.87 c	105.58 de
Wild oat 25%	72.00 c	0.44 c	12.00 bcd	9.00 c	108.83 cd
Wild oat 50%	20.00 e	0.11 d	3.46 ef	2.50 e	14.26 e
Wild oat 100%	3.00 f	0.01 d	0.50 f	0.37 f	0.75 e
Fenugreek 0%	92.00 ab	1.31 a	15.33 a-d	11.50 ab	176.33 abc
Fenugreek 25%	92.00 ab	1.31 a	16.86 abc	11.50 ab	194.33 ab
Fenugreek 50%	89.00 ab	1.32 a	20.41 a	11.12 ab	227.62 a
Fenugreek 100%	92.00 ab	1.17 ab	21.00 a	11.50 ab	240.75 a

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

Table (5): Influence of plant species, fenugreek seeds extract application and their interaction on some radicle, plumule and seedling vigor index characteristics

Plant species	Radicle elongation velocity (cm day^{-1})	Radicle inhibition rate %	Radicle response rate %	Plumule elongation velocity (cm day^{-1})	Plumule inhibition rate %	Plumule response rate %	Seedling vigor index
Wheat	0.67 a	70.31 a	-70.31 b	1.10 a	33.26 b	-33.26 a	1313.85 b
Barley	0.65 a	69.98 a	-69.98 b	1.29 a	19.79 b	-19.79 a	1569.87 a
Wild oat	0.85 a	81.73 a	-81.73 b	0.34 b	73.50 a	-73.50 b	438.02 c
Fenugreek	0.73 a	27.77 b	-27.77 a	1.13 a	33.63 b	-33.62 a	1164.40 b
Fenugreek extract concentration (%)	**Radicle elongation velocity (cm day^{-1})**	**Radicle inhibition rate %**	**Radicle response rate %**	**Plumule elongation velocity (cm day^{-1})**	**Plumule inhibition rate %**	**Plumule response rate %**	**Seedling vigor index**
0	1.37 a	-------	-------	1.25 a	-------	-------	1881.52 a
25	0.80 b	40.83 c	-40.83 a	1.04 ab	20.30 c	-20.30 a	1253.35 b
50	0.52 c	57.17 b	-57.17 b	1.00 b	32.80 b	-32.80 b	992.72 c
100	0.20 d	89.36 a	-89.36 c	0.57 c	67.04 a	-67.04 c	358.55 d
Plant species × Fenugreek extract concentration	**Radicle elongation velocity (cm day^{-1})**	**Radicle inhibition rate %**	**Radicle response rate %**	**Plumule elongation velocity (cm day^{-1})**	**Plumule inhibition rate %**	**Plumule response rate %**	**Seedling vigor index**
Wheat 0%	1.17 b	-------	-------	1.39 a	-------	-------	2343.20 a
Wheat 25%	0.80 b-e	49.24 c	-49.24 b	1.11 ab	14.45 e	-14.45 a	1484.20 b
Wheat 50%	0.34 d-g	76.22 abc	-76.22 bcd	1.26 a	23.04 de	-23.04 ab	1167.20 bc
Wheat 100%	0.35 d-g	85.47 ab	-85.47 cd	0.63 c	62.30 bc	-62.30 cd	260.80 ef
Barley 0%	1.05 bc	-------	-------	1.36 a	-------	-------	2505.40 a
Barley 25%	0.66 b-f	57.97 bc	-57.97 bc	1.31 a	10.48 e	-10.48 a	1586.00 b
Barley 50%	0.53 c-g	68.11 bc	-68.11 bc	1.21 a	18.88 de	-18.88 ab	1327.50 b

Barley 100%	0.37 d-g	83.87 ab	-83.87 cd	1.29 a	29.99 de	-29.99 ab	859.80 cd
Wild oat 0%	2.32 a	-------	-------	0.72 bc	-------	-------	1136.50 bc
Wild oat 25%	0.81 b-e	60.86 bc	-60.86 bc	0.52 cd	41.05 cd	-41.05 bc	532.40 de
Wild oat 50%	0.28 efg	84.34 ab	-84.34 cd	0.12 de	79.47 ab	-79.47 de	83.20 f
Wild oat 100%	0.00 g	100.00 a	-100.00 d	0.00 e	100.00 a	-100.00 e	0.00 f
Fenugreek 0%	0.93 bcd	-------	-------	1.51 a	-------	-------	1541.00 b
Fenugreek 25%	0.95 bcd	-4.76 d	4.76 a	1.21 a	15.21 e	-15.21 a	1410.00 b
Fenugreek 50%	0.93 bcd	0.00 d	0.00 a	1.42 a	9.78 e	-9.78 a	1393.00 b
Fenugreek 100%	0.10 fg	88.09 ab	-88.09 cd	0.38 cde	75.86 ab	-75.86 de	313.60 ef

*The similar letters between treatments means there are no significant differences between them using Duncan's Multiple Test at 1% level.

The results indicated that crop and weed species responses were different to allelopathic substances, due to the species nature and number of allelopathic substances of fenugreek seed extract. In general, wheat and wild oats are more sensitive and fenugreek plant tolerant, than other species to allelopathic substances. However, the effect was increased with increasing the concentration of fenugreek seed extract. Treating plant species seeds with extracts of fenugreek positively affected all the studied traits, making them suitable as natural and safe growth stimulants for the fenugreek plant, and showed a high inhibitory effect on the germination characteristics and the radicle and plumule of the wild oat plant. For this reason, the results obtained from this study encourage us to be optimistic about finding safe alternatives and promising prospects for obtaining healthy agricultural products free from the negative effects of chemical substances and pesticides used in these species.

References

1) Scavo, A and Mauromicale, G. (2021). Crop Allelopathy for Sustainable Weed Management in Agroecosystems: Knowing the Present with a View to the Future. Agronomy, 11(2104): 1-23. https://doi.org/10.3390/agronomy11112104.
2) Kruse M, Strandberg M, Strandberg B. (2000). Ecological effects of allelopathic plants – a review. National Environmental Research Institute, Silkeborg, Denmark., NERI Technical Report, 315: 66 pp.

3) Abdulfatah, H. F. and Naji, E. F. (2023). The Role of Allelopathy for some Plants: A Review. Iraqi Journal of Desert Studies, 13 (2): 61-71. http://dx.doi.org/10.36531/ijds.2023.139093.1031.

4) Cordobé SF, Anton A, Scrivant I. (2023). Preliminary report on the allelopathic Potential of South American imperato Species (Poaceae: and Pogoneae). Botanical Sciences, 101 (2): 493-503. https://doi.org/10.17129/botsci.3188

5) Khamare, Y., Chen, J. and Marble, S. (2022). Allelopathy and its application as a weed management tool: A review. Plant Science, 13:1-7. https://doi.org/10.3389/fpls.2022.1034649.

6) Chaïb S, Pistevos J, Bertrand C, Bonnard I. (2021). Allelopathy and allelochemicals from microalgae: An innovative source for bio-herbicidal compounds and biocontrol research. Algal Research, 54:102213. https://doi.org/10.1016/j.algal.2021.102213

7) Sánchez-Moreiras AM, Weiss OA, Reigosa-Roger MJ. (2003). Allelopathic Evidence in the Poaceae Botanical Review, 69(3) .p. 300-319. https://doi.org/10.1663/0006-8101(2003)069[0300:AEITP]2.0.CO;2

8) Kor, Z. M. and Zadeh, J. B. (2013). Fenugreek (*Trigonella foenum-graecum* L.) As a Valuable Medicinal Plant. International journal of Advanced Biological and Biomedical Research,1(8): 922-931.

9) Azizi, G., Kondori, M. J., Siah-Marguee, A. and Alimoradi, L. (2011). Bioassay study of fenugreek extract's allelopathic effects on the germination and growth of several crops and weeds. Journal of Plant Breeding and Crop Science, 3(10): 229-239. http://www.academicjournals.org/JPBCS.

10) Godara, P., Dulara, B, Barwer, N, and Chaudhary, N. (2019). Comparative GC–MS Analysis of Bioactive Phytochemicals from Different Plant Parts and Callus of *Leptadenia reticulata* Wight and Arn. Pharmacogn Journal, 11(1): 129-140. http://dx.doi.org/10.5530/pj.2019.1.22.

11) Gopu, C., Chirumamilla, P., Daravath, S., Vankudoth, V. and Taduri, S. (2021). GC-MS analysis of bioactive compounds in the plant parts of methanolic extracts of *Momordica cymbalaria* Fenzl. Journal of Medicinal Plants Studies, 9(3): 209-218. https://doi.org/10.22271/plants.2021.v9.i3c.1289 .

12) Rasul, S. A. (2024). Influence of allelopathic potential of pomegranate peel extracts on germination and growth of some plant species. Kirkuk University Journal of Agricultural Sciences, ISSN:2958-6585, P:201-207. https://doi.org.10.58928/ku24.15424.

13) Ali, K. A., Amin, S. M. and Abdullah, R. A. (2021). Late sowing date influence on wheat and triticale crop yield as a draught management tool. Journal of the Saudi Society of Agricultural Sciences, 20. p.353-358. http://dx.doi.org/10.1016/j.jssas.2021.04.002.

14) Chebouti-Meziou, N., Merabet, N. A., Chebouti, Y., Bissaad, F. Z., Behidj-Benyounes, N. B. and Doumandji, S. (2014). Effect of cold and scarification on

seeds germination of *Pistacia atlantica* L. for rapid multiplication. Pak. J. Bot, 46(2): 441-446.

15) Khalaf, A. S. (2016) Seeds and Seed Technology. A University of Duhok Publication. p.192.

16) Prasad, S., Prasad, B. and Singh, R. K. (2012). Effect of hydropriming duration on germination and seedling vigour of rice (*Oryza sativa* L.) cv. Prasad. Journal of Crop and Weed, 8 (1):65-71.

17) Xu, Y., Cai, N., He, B., Zhang, R., Zhao, W., Mao, J., Duan, A., Li, Y. and Woeste, K. (2016). Germination and early seedling growth of *Pinus densata* Mast. Provenances. J. For. Res, 27 (2): 283-297. https://doi.org/10.1007/s11676-015-0186-x.

18) Mosalem, M., Ragab, A, El-Sayed, A., Okba, E., Nor Eldeen, M., Roshdi, M. and Abdelaal, K. (2023). Effects of Plant Extracts on Quality and Viability of Wheat Seeds during Storage. Pol. J. Environ. Stud, 32(5): 4191-4200. http://dx.doi.org/10.15244/pjoes/166188.

19) Field, A. (2009) Discovering Statistics Using SPSS. 3rd edn SAGH Publications Limited: London. UK.

20) Abbass, J. A., Al-Zurfi, M. T., Hassan, A. A. and Ali, S. M. (2016). Effect of spraying fenugreek seed extracts *Rigonella foenum– graecum* L. and salicylic acid on growth and flowering parameters of snapdragon plant (*Antirrhinum majus* L.). Agricultural Science Research Journal, 6(4): 101 – 106. https://www.researchgate.net/publication/328408008.

21) Godlewska K, Ronga D, Michalak I. (2021). Plant extracts - importance in sustainable agriculture. Italian Journal of Agronomy, 16(1851): 149-177. https://doi.org/10.4081/ija.2021.1851

22) Hussain W. S. (2020). Effects of spraying aqueous extracts of some crop plants on growth of four types of weeds Plant Archives, 20(Supplement 1): 1460-1464.

23) Ali K, Miran K. (2021). The Allelopathic Potential of Foliar Application of Aqueous Extracts of Chickpea on Growth and Yield of Chickpea. Polytechnic Journal, 11(2): 7-11. https://doi.org/10.25156/ptj.v11n2y2021.pp7-11

24) Dawood, M. G., El-Rorkiek, G. A., El-Awadi, M. E. and Sadak, M. S. (2020). Physiological effect of aqueous seed extract of fenugreek on productivity and grain quality of wheat plant. Asian Journal of Applied Sciences, 3(3): 107-113. https://doi.org/10.3923/ajaps.2020.107.113.

25) Perisoara, A., Tihauan, B., Pirvu, L., Ene. D., Pavel, M. and Cristea, S. (2023). The study of some fenugreek extract by germination bioassay. Romanian Agricultural Research, 40: 1-11. https://doi.org/10.59665/rar4054.

26) Li Z, Wang Q, Ruan X, Pan, CD and Jiang A. (2010). Phenolics and Allelopathy. Molecules, 15:8933-8952. https://doi.org/10.3390/molecules15128933

27) Meriem B, Atmane R, Houda E, Rkia M, El hassane B. (2019). Allelopathic effect of some natural plants on seed germination and growth of Phalaris canariensis

L. and Lactuca sativa L. Plant Cell Biotechnology and Molecular Biology, 20(21&22) :994–1003.

28) Alnass, S. M., Bader, M. B., and Zorab, A. E. (2024). Effect of aquatic extracts of five medicinal plant species on germination and seedling growth of Avena sativa L. The North African Journal of Scientific Publishing, 2(4): 110-118. (In Arabic).