https://doi.org/10.26651/allelo.j/2022-57-2-1410 0971-4693/94 Euro 20.00
Allelopathy Journal 57 (2): 145-160 (September, 2022) *International Allelopathy Foundation* 2022
Table: 5, Figs : 4

Allelochemicals and allelopathic effects of *Cucumis melo* L. on growth, photosynthesis and antioxidant compounds of *Brassica napus* L. and *Sinapis arvensis* L.

N. Norouzi, M. Niakan*, M. Ebadi[1] and M. Younesabadi[2]
Department of Biology, Faculty of Science, Gorgan Branch,
Islamic Azad University, Gorgan, Iran
E. Mail: neda.niakan@gmail.com

(Received in revised form: July 17, 2022)

ABSTRACT

We investigated the allelopathic effects of aqueous extracts of shoots (leaf, stem, fruits) of *Cucumis melo* L weed on the growth, photosynthetic, and antioxidant system of *Brassica napus* and *Sinapis arvensis* weeds. The fruit, leaf, and stem aqueous extracts of *Cucumis melo* L were sprayed at 0, 2.5, 5 and 10 % concentrations on the plants of *Brassica napus* and *Sinapis arvensis* at rosette stage and after one month the effects on plants were studied. The higher concentration of Donor *Cucumis melo* aqueous extracts, decreased the growth parameters in recipient *Brassica napus* and *Sinapis arvensis* weeds. The higher concentrations of *Cucumis melo* extracts increased the phenolic compounds and decreased the flavonoid compounds in both test plants and these changes were higher in *Brassica napus* than in *Sinapis arvensis*. The aqueous extracts of leaves, stems and fruits of *Cucumis melo* analyzed by GC-MS contained 30, 23 and 12 allelochemical compounds, respectively. These allelochemical compounds in extracts of leaf, stem and fruit of *Cucumis melo* influenced the morpho-physiological characteristics of *Brassica napus* and *Sinapis arvensis* weeds.

Keywords: Allelochemicals, allelopathy, aqueous extracts, *Brassica napus* L., *Cucumis melo*, GC-MS, growth, morphology, *Sinapis arvensis*

INTRODUCTION

Plants produce various secondary metabolites as allelochemicals and these play essential role in interactions among the plants e.g. allelopathic effect of weeds on crops (6). The allelochemicals are detrimental to cell division and organs development leading to reduction in leaf area (31,54). Hence, the applied allelochemicals decreased the growth of shoots and roots (16,20). The allelochemicals affects the photosynthesis by adversely affecting the function of Photosystem II (PSII) components and decomposition of photosynthetic pigments, these impairs the photosynthesis, decreases the ATP synthetase activity and ATP production, by inhibiting the electron and energy transfer (9). Damage to the photosynthetic process increases the ROS generation by interrupting the energy transfer mechanism (44).

Plants develop ROS removal mechanisms with antioxidants to deal with oxidative stress situations. One of the usual reactions to abiotic and biological stressors such as allelopathic stress in plants is the accumulation of antioxidant molecules such as flavonoids and other phenolic compounds (48), these are secondary ROS inhibitory mechanism in plants (40).

*Correspondence author, [1]Department of Chemistry, Faculty of Science, Gorgan Branch, Islamic Azad University, Gorgan, Iran, [2]Plant Protection Research Department, Golestan Agricultural and Natural Resources Research and Education Center, AREEO, Gorgan, Iran.

A. *Cucumis melo* (Donor plant)

B. *Brassica napus* (Recipient plant)

C. *Sinapis arvensis* (Recipient plant)

Figure 1. Photographs of test Donor and Recipient plants

Cucumis melo L. variety ' (family Cucurbitaceae) is weed in many crops and is native to Eurasia (43). Many members of Cucurbitaceae family have considerable allelopathic potential (18,22,36,37,42). It contains Benzoic acid, cinnamic acid which are autotoxic allelochemicals (22). These autotoxins significantly affects the ion uptake, membrane permeability, photosynthesis and phytohormones balance and can negatively affects the plant growth (9,52). The GC-MS results showed that *Cucumis melo* fruit extract contains compounds : 16-Octadecenoic the acid methyl ester, 5-hydroxy-6,7,8-trimethoxy-2,3-dimethyl-4H-chromen-4-one, 9,12-Octadecadienoic acid, 1,3,12-Nonadecatriene, Methyl (5α, 12β, 19α) -2,3-didehydro aspidospermidine-3-carboxylate, Hexadecanoic acid, 2-hydroxy ethyl ester (37). Its stem and root extracts at low concentrations stimulates the wheat growth, but high concentrations are inhibitory (18). The photographs of Donor weed *C. melo* and Recipient plants *B. napus* and s. *S arvensis* are given in Figure 1.

The *Brassica napus* L. (family Brassicaceae) is oil seed crop, called rapeseed (or canola) (29). It is major source of oil and protein for food and industrial uses. After the oil extraction its cakes is used to feed animals, or recycled (39).

Sinapis arvensis L. (wild mustard) is common weed in field crops. It is an annual broad leaf most competitive weed in spring cereal crops (52). It ranked 11th of 101 weeds in a 2002 Manitoba survey of cereal and oilseed crops (25,34).

Weeds decrease growth, yield and quality (oil content) of *Brassica napus* L. by competing for growth resources (light, water, nutrients) (41). The weed *Sinapis arvensis* reduces yields up to 20-30 % of *Brassica napus* L. (3,12). The excessive use of chemical herbicides is harmful to environment, human health and food, as well as causes development of resistance to herbicides (24). Hence, researchers are searching plants with allelopathic herbicidal potential, against weeds and least inhibitory to crops. This study aimed to investigate the allelopathic effects of *Cucumis melo* cv. agrestis extracts on the growth, photosynthetic activity and antioxidant constituents of *Brassica napus* L. and *Sinapis arvensis*. The GC-MS was used to identify the chemical compounds in *Cucumis melo* extracts.

MATERIALS AND METHODS

Soil analysis : The field studies were done in 2020 at Agricultural and Natural Resources Research Station, Gorgan, Golestan Province, Iran (latitude 36° 84′ 30″ N and longitude 54° 45′ 65″ S). Random soil sampling was done from the Experimental field upto 0-30 cm depth to determine the physico-chemical properties of soil, before the experiment. The soil was silty loam (21 % clay, 62 % silt and 14 % sand) and contents of N, P and K nutrients were 0.17, 2.2 and 197 ppm, respectively. Organic carbon was 1.77 (OC) pH was 7.6.

I. Sample collection

Cucumis melo cv Agretis was sown on August 1, 2020. Its plants were collected at maturity on September 28, 2020. The plants were washed in Tap water, to remove dirt and adhering soil on roots. Thereafter the plants were partitioned in fruit, leaf and stem. These plant parts were dried in oven at 40 ºC for 72 h, afterward these dried samples were grounded and passed through 2 mm sieve.

II. *Cucumis melo* extracts

The aqueous extracts were prepared using Narwal and Tauro method (33). Ten g of each powder was put in bottles in 100 ml distilled water (1:10 w/v) and kept in incubator at 20 ºC in dark for 3 days. The bottles were shaken several time during the incubation period. Afterwards, the solution was filtered through double layers of muslin cloths. These extracts were considered as the stock solution and stored in Refrigerator at 4 ºC until used. For bioassays, these were diluted with distilled water to prepare 2.5, 5 and 10 % concentrations (4).

III. Field experiments:

The field experiment was done in Split-Split-Plot Design in three replications. The main plot were : 2 crops (*Brassica napus* L cultivar RGS and *Sinapis arvensis*, sub-plots were *Cucumis melo* var. agrestis extracts: 3 parts (Fruit, leaf, and stem extract) and sub-sub-plot were *Cucumis melo* parts extracts concentrations: 4 (0, 2.5, 5 and 10 %). Each subplot size was (1.5 m x 5 m). The main plots, sub plots and sub-sub plots were separated from each other 5.0 m, 2.0 m and 1.0 m distances, respectively and the replications were separated by 3.0 m.

The *Brassica napus* L. and *Sinapis arvensis* seeds were sown broadcasted in pre-irrigated field on November 15, 2020. The crops were irrigated with Sprinkler system at regular intervals. The aqueous extracts of fruit, leaf and stems of *C. melo* L., (0, 2.5, 5 and 10 % concentrations) were sprayed on December 15, 2020 at 400 L/ha on *B. napus* and *S. arvensis* plants at the rosette stage. The 30-days old plants were sampled and transferred to laboratory to measure the growth indices, photosynthetic activity and antioxidant systems in their leaves and root. All morphological parameters were measured as per Bharwana *et al.* (7). These crops were harvested on May 29, 2021.

IV. Physiological studies

(i). Photosynthetic pigments: These were measured by non-maceration method as per Hiscox and Israelstam (19) using DMSO as blank. The absorption rate was determined by 2800 UV Visible Spectrophotometer at wavelengths of 663 and 645 nm for cholorophyll a, cholorophyll b and cholorophyll a+b and wavelengths of 480 and 510 nm for carotenoids and the contents of chlorophylls and carotenoids were calculated using the formulas as per Duxbury and Yentsch., MacLachlan and Zalick (13,28) as mg/g fresh weight, respectively.

(ii). Total carbohydrates: These were measured as per Loweus (26) using Antron method. Glucose was used as the standard and the absorption was read at 620 nm by spectrophotometer and the carbohydrates amount in samples was calculated using a standard graph.

(iii). Total phenolic compounds: These were measured as per Tugli *et al.* (47) using Folin Ciocalteu's method. Gallic acid was used as the standard and finally, the total phenolic compounds were evaluated in terms of milligrams of gallic acid per g of fresh weight by 2800 UV-Visible Spectrophotometer at 750 nm.

(iv). Total flavonoid content It was determined as per method of Tugli *et al.* (47) using aluminum chloride colorimetric assay. Quercetin reagent as a standard solution and the absorption of each reaction compound was read by spectrophotometer at 510 nm and reported as mg quercetin per g fresh weight.

V. Identification of allelochemical compounds using GC-MS

Gas chromatography model Agilent A 7890 along with mass spectrometer model Agilent 5975 C with a narrow column (HP-5MS with 30 m length × 0.25 mm inside diameter × 0.25 μm thickness Agilent Technologies, Santa Clara, USA) was used, and pure helium was the carrier gas at a constant flow rate of 1 ml/min. Thus, the chemical constituents of

Cucumis melo fruit, leaf, and stem extracts were identified and measured by analytical gas chromatography (GC) and GC-MS (53). For this an aqueous extract was prepared from fruit, leaves, and stem of *C. melo* at flowering stage, their water was evaporated at room temperature, the dried extracts were dissolved in ethanol ($S_{A:}$). The prepared extracts were injected into the GC-MS and related spectra of compounds were obtained (30). Two types of extracts were injected in GC-MS instrument: (i) Raw extract of S_A: $S_{A,F}$ (fruit), $S_{A,L}$ (leaves), $S_{A,S}$ (Stem) and (ii) Fractions isolated using chromatography column (S_B: $S_{B,F}$ (fruit), $S_{B,L}$ (leaves), $S_{B,S}$ (Stem). The filled chromatography column with silica gel (60 G) was loaded with 2 g dried extract. The mobile phases used were Polar to non-polar solvents. The chromatographic column was eluted with: (i) Polar mobile phase methanol and distilled water (1:1), (ii): Mixture of ethanol and methanol (3:2), (iii) Mixture of ethanol and propanol (1:1), (iv) Pure propanol as a fourth mobile phase. All the dried extracts of fruits, leaves and stems were loaded in to the chromatography column and were eluted by the above mentioned mobile phases, respectively (50).

VI. Statistical Analysis: Statistical analysis of data were performed using SAS software (ver 9.0) and the comparison of means was accomplished based on the Least Significant Difference test at levels of 1 and 5 % probability.

RESULTS AND DISCUSSION

Growth

The increased concentrations of aqueous extracts of *Cucumis melo* (fruit and leaves) decreased the growth parameters of both test plants (Table 1). The aqueous extracts of *C. melo* stem were more inhibitory to *Brassica napus* L. growth parameters than *Sinapis arvensis*. This indicated that *Brassica napus* L. was more sensitive to aqueous extract of *C. melo* stem. Several studies indicated that applied allelopathic compounds reduces the growth of plants shoots and roots (16,20). Allelochemicals have detrimental effects on cell division and thereby on organs development and reduces leaf area (51,54). Hadi *et al.* (18) studied the effects of *C. melo* extract on wheat and found it was stimulatory at low concentrations and inhibitory at high concentrations, while, the extracts of root and stem were inhibitory. El-Shora and Abd El-Gawad (14) reported the inhibitory allelopathic effects of aqueous extracts of *Portulaca oleracea* on *Brassica oleracea* growth, and the degree of inhibition was concentration dependent. Our results of this study also showed that the higher concentration of aqueous extracts of the fruit, leaves, and stems of *Cucumis melo*, increased the inhibitory effects of extracts in both target plants and the inhibitory intensity was higher in *Sinapis arvensis* growth on all parts of *Brassica napus* L.

Photosynthesis

The applied aqueous extracts of all three organs of *C. melo* did not affect the content of photosynthetic pigments in *Brassica napus*, but their inhibitory effects were significant on the content of photosynthetic pigments in *S. arvensis* at higher concentrations of extracts of all three organs (Table 2). Several studies showed allelochemicals disrupts the plant photosynthesis by breaking down photosynthetic pigments, destroying or inhibiting synthesis machinery, decreasing photosynthetic pigments by preventing electron and energy transfer, decreasing ATP synthase enzyme activity and inhibiting ATP synthesis (9). The damage to photosynthesis leads to ROS over production by disrupting the energy transfer

Table 1. Effects of aqueous extract of *C. melo* fruit, leaves and stems on growth of *Brassica napus* L. and *Sinapis arvensis*.

Extract type	Conc. (%)	Leaf number	Leaf area (cm^2)	Leaf dry weight (g)	Stem length (cm)	Stem dry weight (g)	Siliqua number
				Sinapis arvensis			
Fruit	0	37.33^{b}	3189.65^{a}	11.40^{a}	83.33^{abcdef}	8.97^{b}	141.66^{a}
	2.5	38.0^{b}	1381.88^{d}	6.77^{cd}	71.33^{j}	6.53^{cd}	138.55^{ab}
	5.0	32.33^{def}	1069.22^{fghi}	4.30^{ghij}	80.77^{cdefg}	4.67^{fghi}	110.44^{cd}
	10.0	35.33^{bcd}	945.70^{hijk}	3.93^{hijk}	71.44^{j}	5.53^{defgh}	96.78^{f}
				Brassica napus			
	0	25.33^{hi}	987.09^{ghij}	4.13^{hij}	89.78^{a}	5.73^{def}	26.66^{ij}
	2.5	24.66^{hi}	771.36^{klm}	3.43^{jklm}	86.88^{abc}	5.40^{defgh}	22.22^{jkl}
	5.0	22.0^{i}	606.14^{mno}	1.83^{n}	79.00^{efghi}	4.43^{ghi}	18.89^{klm}
	10.0	23.0^{i}	469.34^{o}	2.60^{mn}	78.77^{efghi}	3.77^{ij}	15.55^{m}
				Sinapsis arvensis			
Leaf	0	43.67^{a}	2043.23^{b}	9.17^{b}	88.33^{ab}	10.03^{b}	143.11^{a}
	2.5	31.33^{efg}	1679.10^{c}	5.23^{fg}	79.44^{efgh}	5.13^{efgh}	137.66^{ab}
	5.0	32.33^{def}	932.83^{hijk}	6.33^{de}	72.66^{ij}	5.63^{defg}	116.00^{c}
	10.0	33.33^{cde}	1058.93^{fghi}	4.47^{ghij}	81.78^{bcdefg}	5.63^{defg}	106.66^{de}
				Brassica napus			
	0	29.66^{fg}	1143.89^{efg}	9.07^{b}	86.89^{abc}	7.13^{c}	38.55^{h}
	2.5	28.0^{gh}	1114.42^{efgh}	3.73^{ijkl}	85.89^{abcd}	4.63^{fghi}	22.89^{jk}
	5.0	23.66^{i}	858.70^{jkl}	2.70^{lmn}	80.88^{cdefg}	5.07^{efgh}	18.78^{klm}
	10.0	24.0^{i}	732.42^{lmn}	2.87^{klmn}	73.22^{hij}	2.97^{j}	16.11^{m}
				Sinapsis arvensis			
Stem	0	33.0^{cdef}	1286.67^{de}	5.67^{ef}	78.66^{efghi}	6.13^{cde}	139.66^{ab}
	2.5	30.0^{efg}	1194.03^{def}	4.83^{fgh}	75.33^{ghij}	5.33^{defgh}	133.88^{b}
	5.0	36.0^{bc}	900.67^{ijkl}	4.77^{fghi}	77.11^{fghij}	5.13^{efgh}	103.11^{e}
	10.0	31.33^{efg}	983.01^{ghij}	3.70^{ijkl}	80.00^{defg}	5.33^{defgh}	86.89^{g}
				Brassica napus			
	0	24.0^{i}	1144.94^{efg}	7.60^{c}	84.66^{abcde}	13.50^{a}	29.89^{i}
	2.5	24.33^{i}	541.95^{no}	4.60^{fghi}	73.00^{hij}	4.30^{hi}	24.22^{ijk}
	5.0	24.66^{hi}	544.06^{no}	3.90^{hijk}	76.55^{ghij}	4.73^{fghi}	21.33^{jklm}
	10.0	24.33^{i}	473.55^{o}	3.50^{jklm}	75.44^{ghij}	3.80^{ij}	17.00^{lm}

Similar letters indicate no significant difference between treatments based on LSD test at 5 % level

process (44). Unal *et al*. (49) reported the negative allelopathic effects of *Palustriella falcate* extract on photosynthetic pigments of *Sinapis arvensis*. Pula *et al*. (38) studied the effects of ethanolic extract of *Helianthus annuus* L. root on photosynthetic activity of *Sinapis alba* L. cv. Barka and they found that the extracts decreased the amount of chlorophyll a and b in *Sinapis alba* leaves at each concentration than control. The aqueous extract of *Cucumis melo* leaves increased the quantity of root sugar in both target plants in this study than control and this increase was higher in *Brassica napus* L. compared to *Sinapis arvensis* (Table 2).

Table 2. Effects of aqueous extract of *Cucumis melo* fruit, leaves and stems on Physiological and Biochemical parameters of *B. napus* L and *S. arvensis*.

Extract type	Conc. (%)	Chlorophyll a*	Chlorophyll b*	Chlorophyll a+b*	Soluble sugars*		Phenolic compounds (mg Gallic acid/g FW)		Flavonoid (mg/g FW)	
					Leaf	Root	Leaf	Root	Leaf	Root
					Sinapis arvensis					
Fruit	0	7.64 [ab]	13.46 [a]	21.10 [ab]	41.05 [kl]	38.76[de]	112.56 [e]	85.49 [bc]	14.75 [f]	10.42 [c]
	2.5	7.35 [ab]	10.31 [b]	17.66 [de]	56.05 [bc]	46.78[a]	62.56[o]	90.16[b]	12.46 [i]	6.99 [g]
	5.0	6.34[cde]	10.52 [b]	16.86 [e]	59.18[a]	40.64[cd]	52.29[p]	96.16[a]	5.14 [l]	4.55 [j]
	10.0	6.16[de]	8.74 [c]	14.90 [f]	46.05 [ghi]	36.57[fg]	41.63[q]	83.89 [c]	1.96 [o]	3.10 [k]
					Brassica napus					
	0	3.64 [gh]	4.93 [defg]	8.57 [hijk]	42.09[jk]	16.57[n]	64.16 [no]	42.96 [i]	21.16 [b]	11.16 [b]
	2.5	3.60 [gh]	4.01[g]	7.60[kl]	47.82 [efg]	17.09[mn]	108.83 [fg]	44.56 [hi]	13.45 [h]	7.68 [f]
	5.0	3.03 [h]	4.55 [efg]	7.57[kl]	41.89 [jk]	16.47[n]	72.16 [m]	32.56 [k]	14.85 [f]	5.24 [i]
	10.0	2.89[h]	3.86 [g]	6.76[l]	38.14 [mn]	21.99[l]	63.63 [o]	26.03 [l]	8.68 [k]	3.30 [k]
Leaf					***Sinapsis arvensis***					
	0	7.22 [ab]	12.75 [a]	19.97 [bc]	38.55 [m]	35.84[g]	112.56 [e]	51.76 [fg]	14.25 [fg]	9.32 [d]
	2.5	6.94 [bcd]	10.32 [b]	17.26 [de]	52.41 [d]	41.26[c]	110.03 [ef]	73.23 [de]	11.36 [j]	8.63 [e]
	5.0	5.84[e]	12.82 [a]	18.66 [cd]	42.51[jk]	43.55[b]	82.29 [kl]	76.83 [d]	3.55 [n]	6.34 [h]
	10.0	4.57 [f]	5.71 [def]	10.27 [g]	36.78 [mn]	37.72[efg]	97.36 [h]	75.23 [d]	4.40 [m]	4.80 [ij]
					Brassica napus					
	0	3.49 [gh]	5.96 [de]	9.45 [ghi]	45.32 [hi]	17.93[mn]	79.76 [l]	37.49 [j]	23.55[a]	12.16 [a]
	2.5	3.45 [gh]	4.33[fg]	7.78 [jkl]	43.97[ij]	25.01[j]	150.83 [c]	38.03 [j]	13.70 [gh]	4.55 [j]
	5.0	3.37 [gh]	5.09 [defg]	8.47[hijk]	53.45 [d]	26.16[ij]	164.43 [b]	48.43 [gh]	11.36 [j]	8.03 [ef]
	10.0	3.95 [fg]	5.72 [def]	9.68 [gh]	57.41 [ab]	30.95[h]	201.23[a]	54.96 [f]	12.56 [i]	9.67 [d]
Stem					***Sinapsis arvensis***					
	0	7.86[a]	14.04 [a]	21.90 [a]	27.61[o]	27.30[i]	90.69 [i]	43.76 [hi]	12.76 [i]	8.08 [ef]
	2.5	7.15 [abc]	10.98 [b]	18.13 [de]	35.74 [n]	24.39[jk]	105.23 [g]	68.69 [e]	16.64 [e]	6.44 [gh]
	5.0	5.64 [e]	13.15 [a]	18.79 [cd]	46.78 [fgh]	31.89[h]	87.63 [ij]	86.16 [bc]	17.93 [d]	2.01 [l]
	10.0	7.08 [abc]	11.05 [b]	18.12 [de]	48.76 [ef]	37.93[ef]	95.63 [h]	82.69 [c]	12.71 [i]	0.52 [m]
					Brassica napus					
	0	3.72 [gh]	6.26 [d]	9.98 [gh]	39.07 [ml]	18.24[mn]	67.36 [n]	29.89 [kl]	21.66 [b]	10.72 [bc]
	2.5	3.65 [gh]	5.72 [def]	9.37 [ghij]	38.66 [ml]	18.76[m]	85.76 [jk]	46.56 [hi]	19.27 [c]	9.67 [d]
	5.0	3.41 [gh]	4.53 [efg]	7.93[ijkl]	54.28 [cd]	21.99[l]	129.76 [d]	38.16 [j]	16.94 [e]	7.83 [f]
	10.0	3.41 [gh]	5.91 [de]	9.32 [ghij]	49.59 [e]	22.61[kl]	163.76 [b]	47.49 [ghi]	14.85 [f]	6.79 [gh]

FW: Fresh weight, Similar letters indicate no significant difference between treatments based on LSD test at 5 % level. *$mg.g^{-1}$ DW.

Chemical composition of *B. napus* L and *S. arvensis*

(i). Phenolic compounds: The aqueous extracts of all 3-organs of *C. melo* at all concentrations significantly increased the phenolic compounds of *Brassica napus* L. compared to the control (Table 2). However, the aqueous extract of *Cucumis melo* fruit reduced the level of phenolic compounds at all doses, and the reduction was higher in *S. arvensis* than in *B. napus*. On the other hand, all doses of aqueous extract of leaves and stems of *C. melo* increased the phenolic compounds in *Brassica napus* and *Sinapis arvensis* at all doses. The phenolic compounds were higher in *B. napus* than in *S. arvensis* (Table 2).

(ii). Flavonoids: The 10 % aqueous extract of *Cucumis melo* L. fruit decreased the quantity of flavonoid compounds in both *B. napus* and *S. arvensis* and this decrease was more in *S. arvensis*. However the stem extract, enhanced these chemicals in both target plants at all doses and were higher in *S. arvensis* (Table 2). Plants develop ROS removal systems with antioxidants to resist oxidative stress. Antioxidant chemicals (flavonoids, phenolic compounds) accumulate in plants as a reaction to abiotic and biological allelopathic stress (40). Biological and non-biological stimuli impacts the phenolics content, as an indigenous antioxidant system to overcome the environmental stresses (2,17).

The amount of phenols and flavonoids in *Brassica napus* increased significantly under the allopathic extracts of *Onosma bracteatum* Wall and *Commiphora stocksiana* Engl, which may be associated with phytotoxins (1). There is a substantial association between phenols and flavonoids and allopathic potential (15,27).

All doses of aqueous extracts of all three *Cucumis melo* organs considerably increased the phenolic compounds in *Brassica napus* L. leaves and roots. Our results were supported by earlier reports which suggested the association between phenols, flavonoids and allopathic potential (27,45). Soluble sugars are osmotic protectors and increases under the allopathic stress (23,54). The aqueous extract of *C. melo* leaves increased the quantity of sugar in both target plants than control, and the intensity of this increase was higher in *Brassica napus* L. than in *Sinapis arvensis*. Chatterjee *et al*. (8) found a significant increase in soluble carbohydrates in *Sinapis arvensis* seeds treated with an allopathic extract of *Cassia occidentalis* leaves.

GC-MS Identification of allelochemical compounds

All compounds of three organs (leaf, stem, and fruit) of *Cucumis melo* in aqueous extract were identified by GC-MS (35).

Table 3. List of compounds identified in the aqueous extract of *Cucumis melo* fruit

#	RT (min)	Name of compound	Mol Weight (g/mol)	Molecular formula	Peak area (%)	Quality
1	19.54	n-Hexadecanoic acid*	256.42	$C_{16}H_{32}O_2$	16.59	99
2	23.37	9,12-Octadecadienoic acid (Z,Z)-*	280.44	$C_{18}H_{32}O_2$	65.69	99
3	23.37	Linoelaidic acid*	280.44	$C_{18}H_{32}O_2$	56.62	99
4	23.73	Linoleic acid ethyl ester	308.50	$C_{20}H_{36}O_2$	5.31	99
5	23.73	9,12-Octadecadienoic acid, ethyl ester	308.50	$C_{20}H_{36}O_2$	5.31	99
6	23.85	9,17-Octadecadienal, (Z)-	264.45	$C_{18}H_{32}O$	4.03	97
7	34.34	13-Tetradece-11-yn-1-ol	208.34	$C_{14}H_{24}O$	2.21	50
8	36.97	Cyclohexene, 4-(4-ethylcyclohexyl)-1-pentyl-	262.5	$C_{19}H_{34}$	36.39	84
9	38.06	Androstan-6-one, (5.alpha.)-	274.45	$C_{19}H_{30}O$	9.54	60
10	38.06	2(1H)-Phenanthrenone, 3,4,4a,4b,5,6,7,8,10,10a-decahydro-1, 1,4a,7,7-pentamethyl-, [4aR-4a.alpha.,4b.beta.,10a.beta.) **	274.44	$C_{19}H_{30}O$	9.54	46
11	38.06	Caparratriene	206.37	$C_{15}H_{26}$	.54	43
12	41.61	7-Pentadecyne	208.38	$C_{15}H_{28}$	2.96	96

*: Allelochemical compounds, **: Phenolic compounds

(i). Fruits: The GC-MS chromatogram of the aqueous extract of *Cucumis melo* fruits was shown as GC-MS (Figure 2). It showed the presence of 12 bioactive compounds (Table 3) and 3-allelopathic compounds (n-Hexadecanoic acid, 9,12-Octadecadienoic acid (Z,Z) and linoelaidic acid) fruits (5,46,55).

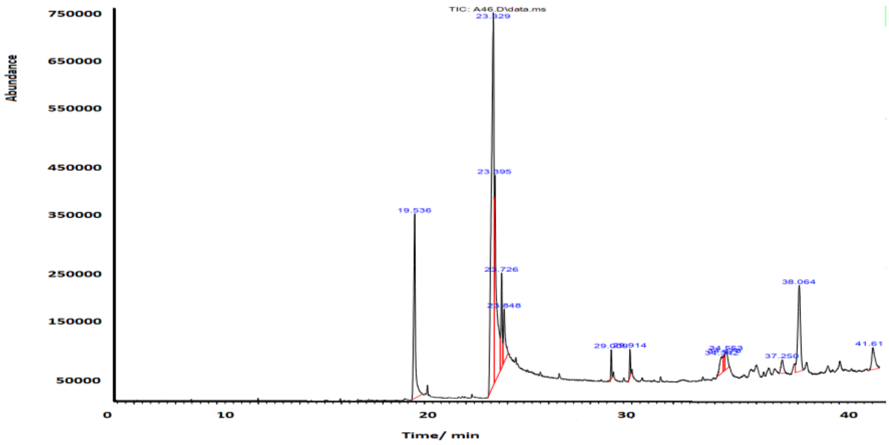

Figure 2. GC-MS chromatogram 1 of aqueous extract of *Cucumis melo* fruit in 41 minutes (horizontal axis is time and vertical axis shows frequency).

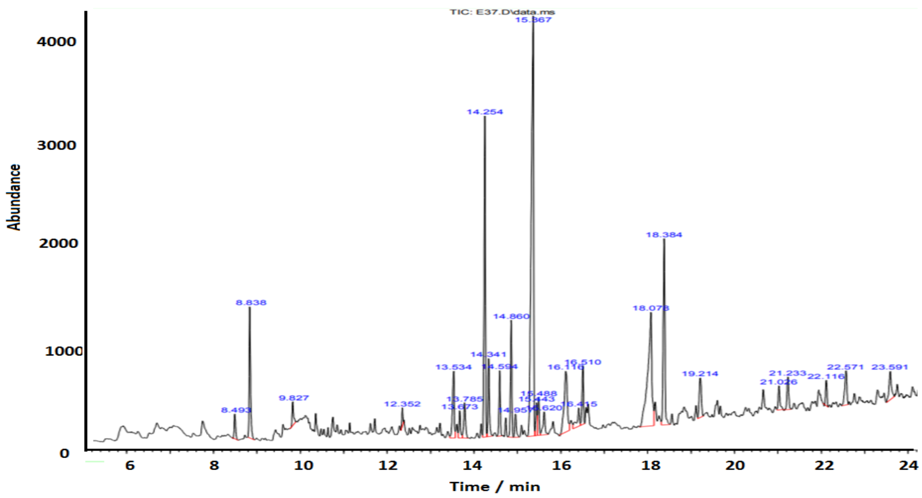

Figure 3. GC-MS chromatogram 2 of aqueous extract of *Cucumis melo* leaf in 24 minutes (horizontal axis is time and vertical axis is frequency)

(ii). Leaves: The GC-MS chromatogram of the aqueous extract of *Cucumis melo* leaves was shown in GC-MS (Figure 3). It showed the presence of 30 bioactive compounds (Table 4) and 6-allelopathic compounds [6-Hydroxy-4,4,7a-allelic, trimethyl-5,6,7,7a-tetrahydrobenzofuran-2(4H)-one, Neophytadiene, n-Hexadecanoic acid, Dibutyl phthalate, Phytol and 1-Docosene] (5,10,11,32,55).

Table 4. List of dominant compounds identified in aqueous extract of *Cucumis melo* leaves.

#	RT (min)	Name of compound	Mol. Weight (g/mol)	Mol. formula	Peak area (%)	Quality
1	8.84	1-(3,6,6-Trimethyl-1,6,7,7a tetrahydrocyclopenta[c]pyran-1-yl) ethanone***	206.26	$C_{13}H_{18}O_2$	7.14	97
2	8.84	2H-Indeno[1,2-b]furan-2-one, 3,3a,4,5,6,7,8,8b-octahydro-8,8-dimethyl***	206.00	$C_{13}H_{18}O_2$	4.52	76
3	8.84	Benzeneacetic acid, 4-(1,1-dimethylethyl)-, methyl ester	206.28	$C_{13}H_{18}O_2$	4.52	62
4	13.54	5,5,8a-Trimethyldecalin-1-one**	194.00	$C_{13}H_{22}O$	2.98	32
5	13.54	6-Hydroxy-4,4,7a-trimethyl-5,6,7,7a-tetrahydrobenzofuran-2(4H)-one ****	196.24	$C_{11}H_{16}O_3$	2.98	97
6	13.54	1-Methyl-3-n-propyl-2-pyrazolin-5-one	140.18	$C_7H_{12}N_2O$	2.98	30
7	14.25	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-, [1R-(1.alpha.,2.beta., 5.alpha.)]-	138.25	$C_{10}H_{18}$	10.89	60
8	14.24	Neophytadiene*	278.51	$C_{20}H_{38}$	20.9	94
9	14.24	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-	138.24	$C_{10}H_{18}$	11.24	55
10	14.33	2-Pentadecanone, 6,10,14-trimethyl-	268.48	$C_{18}H_{36}O$	5.38	91
11	14.34	1-Dodecanol, 3,7,11-trimethyl-	228.41	$C_{15}H_{32}O$	2.76	25
12	14.34	2-Dodecenal	182.30	$C_{12}H_{22}O$	2.76	25
13	14.59	Bicyclo[4.1.0]heptane, 3-methyl-		Unknown	2.09	53
14	14.57	1,4-Eicosadiene	278.52	$C_{20}H_{38}$	3.09	64
15	14.86	Cyclopentane, 1-methyl-1-(2-methyl-2-propenyl)-		Unknown	4.01	47
16	14.86	9-Octadecyne	250.46	$C_{18}H_{34}$	4.01	50
17	15.37	Lidocaine	234.34	$C_{14}H_{22}N_2O$	25.71	94
18	16.12	2,4,7-Trioxabicyclo[4.4.0]9-decene, 8-[4-(4-pentylcyclohexyl) cyclohexyloxy]-3-phenyl-**		Unknown	4.98	52
19	16.12	n-Hexadecanoic acid*	256.42	$C_{16}H_{32}O_2$	4.98	76
20	16.11	Dibutyl phthalate*	278.34	$C_{16}H_{22}O_4$	4.53	95
21	16.51	Hexadecanoic acid, ethyl ester	284.48	$C_{18}H_{36}O_2$	39.40	98
22	16.51	Tetradecanoic acid, ethyl ester	256.42	$C_{16}H_{32}O_2$	7.34	94
23	18.08	4(1H)-Pyrimidinone, 6-methyl-2-propyl-		Unknown	11.96	50
24	18.08	2-Cyclohexen-1-one, 4-hydroxy-3,5,5-trimethyl-4-(3-oxo-1-butenyl)- **	222.28	$C_{13}H_{18}O_3$	11.96	50
25	18.08	Orcinol**	124.14	$C_7H_8O_2$	11.96	50
26	18.38	Phytol*	296.53	$C_{20}H_{40}O$	41.60	91
27	18.38	Isophytol	296.53	$C_{20}H_{40}O$	7.92	83
28	19.25	1-Naphthalenol, decahydro-4a-methyl-**	168.28	$C_{11}H_{20}O$	2.23	70
29	19.25	13-Octadecenal, (Z)-	266.46	$C_{18}H_{34}O$	2.23	55
30	19.25	1-Docosene*	308.58	$C_{22}H_{44}$	2.23	70

*: Allelochemical compounds, **: Phenolic compounds, ***: Flavonoid compounds, ****: Both phenolic and allelochemical compounds

(iii). Stem: GC-MS chromatogram of aqueous extract of *Cucumis melo* stems was shown as GC-MS (Figure 4)**.** It showed the presence of 23 bioactive compounds (Table 5) and 6-allelopathic compounds [2-Methoxy-4-vinylphenol, Neophytadiene, 3,7,11,15-Tetramethyl-2-hexadecen-1-ol, Dibutyl phthalate,9,12-Octadecadienoic acid, methyl ester and Phytol] (10,21,22,29,55).

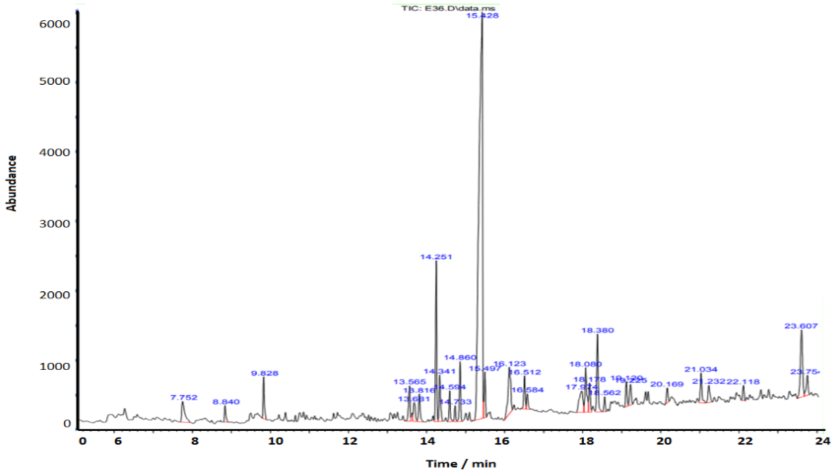

Figure 4. GC-MS chromatogram 3 of aqueous extract of *Cucumis melo* stem in 24 minutes (horizontal axis diagram is time and vertical axis is frequency)

Table 5. List of dominant compounds identified in aqueous extract of *Cucumis melo* stem

NO	RT (min)	Name of compound	Molecular Weight (g/mol)	Molecular formula	Peak area (%)	Quality
1	7.75	2-Methoxy-4-vinylphenol****	150.17	$C_9H_{10}O_2$	2.04	87
2	7.75	4-Hydroxy-3-methylacetophenone**	150.17	$C_9H_{10}O_2$	2.04	74
3	7.75	Ethanone, 1-(2-hydroxy-5-methylphenyl)- **	150.17	$C_9H_{10}O_2$	2.04	72
4	14.25	Neophytadiene*	278.52	$C_{20}H_{38}$	11.07	94
5	14.25	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-, (1α,2β,5α)-	138.25	$C_{10}H_{18}$	6.07	60
6	14.24	Bicyclo[3.1.1]heptane, 2,6,6-trimethyl-	138.25	$C_{10}H_{18}$	18.24	55
7	14.34	2-Pentadecanone, 6,10,14-trimethyl-	268.48	$C_{18}H_{36}O$	13.35	52
8	14.85	3,7,11,15-Tetramethyl-2-hexadecen-1-ol*	296.53	$C_{20}H_{40}O$	3.55	64
9	14.86	Cyclohexanol, 1-ethynyl-**	124.18	$C_8H_{12}O$	3.55	38
10	15.45	Lidocaine	234.34	$C_{14}H_{22}N_2O$	47.00	93
11	16.12	Dibutyl phthalate*	278.34	$C_{16}H_{22}O_4$	12.6	96
12	16.13	Phthalic acid, butyl tetradecyl ester**	418.00	$C_{26}H_{42}O_4$	4.01	58
13	16.13	1,2-Benzenedicarboxylic acid, butyl 2-methylpropyl ester**	278.34	$C_{16}H_{22}O_4$	4.01	53

14	17.97	11-methyl-11-aza-bicyclo[4.4.1]undecane	167.29	$C_{11}H_{21}N$	2.55	46
15	17.97	1,3-Benzenediol, 2-methyl-**	124.14	$C_7H_8O_2$	2.55	46
16	17.80	Orcinol**	124.14	$C_7H_8O_2$	5.04	50
17	18.06	9,12-Octadecadienoic acid, methyl ester	294.47	$C_{19}H_{34}O_2$	3.99	99
18	18.08	Methyl 10-trans,12-cis-octadecadienoate	294.00	$C_{19}H_{34}O_2$	2.65	99
19	18.06	9,12-Octadecadienoic acid (Z,Z)-, methyl ester*	294.47	$C_{19}H_{34}O_2$	3.99	99
20	18.36	Phytol*	296.53	$C_{20}H_{40}O$	19.45	91
21	23.61	Benzylephedrine***	255.35	$C_{17}H_{21}NO$	4.78	64
22	23.61	Benzphetamine	239.35	$C_{17}H_{21}N$	4.78	59
23	23.61	Benzenemethanamine, N-(1,1-dimethylethyl)-	163.26	$C_{11}H_{17}N$	]4.78	59

*: Allelochemical compounds, **: Phenolic compounds, ***: Flavonoid compounds, ****: Both phenolic and allelochemical compounds

It seemed that the inhibitory effects of *Cucumis melo* weed were due to the presence of many allelopathic compounds in the aqueous extract of its leaves, stem and fruits (5,10,29,55).

CONCLUSIONS

The aqueous extracts of leaves, stems and fruits of *Cucumis melo* weed contained different allelochemical compounds, which affected the morpho-physiological characteristics of *B. napus* and *S. arvensis* weeds. These 3-organs had different types and amounts of these compounds. The variations in allelochemicals present and their quantity in the aqueous extract of *C. melo* leaves, stems, and fruits may be related to the morphological and biochemical responses of *B. napus* and *S. arvensis* to these allelochemicals. The stem extract of *C. melo* was more inhibitory to *Brassica napus* growth than to *S. arvensis*. The *Sinapis arvensis* was more inhibited by the aqueous extract of *C. melo* leaves and fruits.

DECLARATION

We declare that all authors of this Ms. have made substantial contributions. We did not exclude any author who substantially contributed to this Ms. We have followed our ethical norms established by our respective institutions.

CONFLICT OF INTEREST

The authors announce that they have no conflict of interest.

ETHICAL APPROVAL

The authors declare that the study was carried out following scientific ethics and conduct. However, this study did not involve any use of animals, hence no ethical approval has been obtained from the concerned committee.

REFERENCES

1. Ali, S.I., Gaafar, A.A., Metwally, S.A. and Habba, I.E. (2020). The reactive influences of pre-sowing He-Ne laser seed irradiation and drought stress on growth, fatty acids, phenolic ingredients and antioxidant properties of *Celosia argentea*. *Scientia Horticulturae* **261**: 108989.
2. Ali, J.S., Haq, I.U., Ali, A., Ahmed, M. and Zia, M. (2017). *Onosma bracteatum* Wall and *Commiphora stocksiana* Engl extracts generate oxidative stress in *Brassica napus*: An allelopathic perspective. *Cogent Biology* **3**: 1283875.
3. Asaduzzaman, M., Pratley, J.E., Luckett, D., Lemerle, D. and Wu, H. (2020). Weed management in canola (*Brassica napus* L): A review of current constraints and future strategies for Australia. *Archives of Agronomy and Soil Science* **66**: 427-444.
4. Ashraf, R., Sultana, B., Yaqoob, S. and Iqbal, M. (2017). Allelochemicals and crop management: A review. *Current Science* **3:** 1-13.
5. Ayodele, O.O., Onajobi, F.D. and Osoniyi, O.R. (2020). Phytochemical Profiling of the Hexane fraction of *Crassocephalum crepidioides* Benth S. Moore leaves by GC-MS. *African Journal of Pure and Applied Chemistry* **14**: 1-8.
6. Bhadoria, P.B.S. (2011). Allelopathy: A natural way towards weed management. *American Journal of Experimental Agriculture* **1:** 7-20.
7. Bharwana, S.A., Ali, S., Farooq, M.A., Iqbal, N., Hameed, A., Abbas, F. and Ahmad, M.S.A. (2014). Glycine betaine-induced lead toxicity tolerance related to elevated photosynthesis, antioxidant enzymes suppressed lead uptake and oxidative stress in cotton. *Turkish Journal of Botany* **38:** 281-292.
8. Chatterjee, S., Bhattacharya, A. and Dutta, S. (2012). Allelopathic effect of *Cassia occidentalis* leaves on mustard seeds. *Trends in Biotechnology Research* **1:** 29-35.
9. Cheng, F. and Cheng, Z. (2015). Research progress on the use of plant allelopathy in agriculture and the physiological and ecological mechanisms of allelopathy. *Frontiers in Plant Science* **6**: 1020.
10. Cq, Z.H.H. and Yer, L. (2011). Inferference of *Spartina alterniflora* allelopathy on *Scirpus mariqueter*, effects of activated carbon on soil. *Procedia Environmental Sciences* **10:** 1835-1840.
11. Della Cuna, F.S.R., Calevo, J., Giovannini, A., Boselli, C. and Tava, A. (2018). Characterization of the Essential oil of the Bat-pollinated *Passiflora mucronata*. *Natural Product Communications* **13**: 1934578X1801301236.
12. Dosdall, L.M., Clayton, G.W., Harker, K.N., O'Donovan, J.T. and Stevenson, F.C. (2003). Weed control and root maggots: Making canola pest management strategies compatible. *Weed Science* **51:** 576-585.
13. Duxbury, A.C. and Yentsch, C.S. (1956). Plankton pigment monographs. *Journal of Marine Research* **15:** 19-101.
14. El-Shora, H.M. and Abd El-Gawad, A.M. (2015). Physiological and biochemical responses of *Cucurbita pepo* L. mediated by *Portulaca oleracea* L. allelopathy. *Fresenius Environmental Bulletin Journal* **24:** 386-393.
15. Fatholahi, S., Karimmojeni, H. and Ehsanzadeh, P. (2020). Phenolic compounds and allelopathic activities of ancient emmer wheats: Perspective for non-chemical weed control scenarios. *Acta Physiologiae Plantarum* **42**: 1-10.
16. Fikreyesus, S., Kebebea, Z., Nebiya, A., Zeleke, N. and Bogale, S. (2011). Allelopathic Effects of *Eucalyptus camaldulensis* Dehnh. on germination and growth of tomato. *American-Eurasian Journal of Agricultural and Environmental Sciences* **11:** 600-608.
17. Gaafar, A.A., Ali, S.I., El-Shawadfy, M.A., Salama, Z.A., Sękara, A., Ulrichs, C. and Abdelhamid, M.T. (2020). Ascorbic acid induces the increase of secondary metabolites, antioxidant activity, growth, and productivity of the common bean under water stress conditions. *Plants* **9**: 627.
18. Hadi, F., Bibi, H., Razzaq, A., Iqbal, A. and Ali, G. (2016). Allelopathic effects of *Cucumis m*elo sub-species agrestis variety Agrestis on wheat. *Pakistan Journal of Weed Science Research* **22:** 471-480.
19. Hiscox, J.D. and Israelstam, G.F.A. (1979). A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany* **57:** 1332-1334.
20. Hussain, N., Abbasi, T. and Abbasi, S.A. (2016). Transformation of toxic and allelopathic lantana into a benign organic fertilizer through vermicomposting. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy* **163:** 162-169.
21. Hussain, I.M. and Reigosa, M.J. (2011). Allelochemical stress inhibits growth, leaf water relations, PSII photochemistry, non-photochemical fluorescence quenching, and heat energy dissipation in three C3 perennial species. *Journal of Experimental Botany* **62:** 4533-4545.

22. Jabran, K. and Farooq, M. (2013). Implications of potential allelopathic crops in agricultural systems. In: *Allelopathy* (Eds., M.J. Reigosa, N. Pedrol and L. Gonzalez), pp. 349-185. Springer-Verlag, Berlin, Heidelberg.
23. Khalil, R., Yusuf, M., Bassuony, F., Gamal, A. and Madany, M. (2020). Phytotoxic effect of *Alhagi maurorum* on the growth and physiological activities of *Pisum sativum* L. *South African Journal of Botany* **131**: 250-258.
24. Lebecque, S., Crowet, J.M., Lins, L., Delory, B.M., du Jardin, P., Fauconnier, M.L. and Deleu, M. (2018). Interactions between the barley allelochemical compounds gramine and hordenine and artificial lipid bilayers mimicking the plant plasma membrane. *Scientific Reports* **8:** 1-13.
25. Leeson, J.Y., Thomas, A.G., Hall, L.M., Brenzil, C.A., Andrews, T., Brown, K.R. and Van Acker, R.C. (2005). Prairie weed surveys of cereal, oilseed and pulse crops from the 1970s to the 2000s. *Weed Survey Series* pp. 395. Agriculture and Agri-Food Canada, Saskatoon.
26. Loewus, F.A. (1952). Improvement in anthrone method for determination of carbohydrates. *Analytical Chemistry* **24** : 219 -219.
27. Macías, F.A., López, A., Varela, R.M., Torres, A. and Molinillo, J.M. (2008). Helikauranoside A., a new bioactive diterpene. *Journal of Chemical Ecology* **34:** 65-69.
28. MacLachlan, S. and Zalick, S. (1963). Plastid structures, chlorophyll concentration and free amino acid composition of a chlorophyll mutant of barley. *Canadian Journal of Botany* **41:** 1053-1060.
29. Majidi, M.M., Rashidi, F. and Sharafi, Y. (2015). Physiological traits related to drought tolerance in Brassica. *International Journal of Plant Production* **9:** 541-560.
30. Mandana, B., Russly, A.R., Farah, S.T., Noranizan, M.A., Zaidul, I.S. and Ali, G. (2012). Antioxidant activity of winter melon (*Benincasa hispida*) seeds using conventional Soxhlet extraction technique. *International Food Research Journal* **19:** 229-234.
31. Mrid, R.B., Benmrid, B., Hafsa, J., Boukcim, H., Sobeh, M. and Yasri, A. (2021). Secondary metabolites as biostimulant and bioprotectant agents: A review. *Science of the Total Environment* **777**: 146-204.
32. Mushtaq, W., Ain, Q., Siddiqui, M.B., Alharby, H. and Hakeem, K.R. (2020). Allelochemicals change macromolecular content of some selected weeds. *South African Journal of Botany* **130:** 177-184.
33. Narwal, S.S. and Tauro, P. (1996). Suggested methodology for allelopathy laboratory bioassay. *Allelopathy: Field Observations and Methodology*. Scietific Publishers, Jodhpur, India. pp 255-266.
34. Ntoanidou, S., Madesis, P., Menexes, G. and Eleftherohorinos, I. (2020). Growth rate and genetic structure of *Sinapis arvensis* susceptible and herbicide resistant populations originating from Greece. *Euphytica* **216**: 1-13.
35. Omorowa, O.G., Idu, M. and Oghale, O.U. (2015). GC-MS analysis of the aqueous extracts of *Buchholzia coriacea* Engl (Capparidaceae), seeds. *International Journal of Life Science and Pharmacy Research* **5:** 26-32.
36. Pramanik, M.H.R., Nagai, M., Asao, T. and Matsui, Y. (2000). Effects of temperature and photoperiod on phytotoxic root exudates of cucumber (*Cucumis sativus*) in hydroponic culture. *Journal of Chemical Ecology* **26:** 1953-1967.
37. Priyadharshini, S. and Nivedha, S. (2015). *In-vitro* Pharmacognostical studies and evaluation of bioactive constituents from the fruits of (*Cucumis melo* L.) (Muskmelon). *International Journal of Pharmacognosy and Phytochemical Research* **6:** 936-941.
38. Puła, J., Zandi, P., Stachurska-Swakoń, A., Barabasz-Krasny, B., Możdżeń, K. and Wang, Y. (2020). Influence of alcoholic extracts from *Helianthus annnus* L. roots on the photosynthetic activity of *Sinapis alba* L. cv. Barka plants. *Acta Agriculturae Scandinavica, Section B. Soil and Plant Science* **70:** 8-13.
39. Raboanatahiry, N., Li, H., Yu, L. and Li, M. (2021). Rapeseed (*Brassica napus*): Processing, utilization and genetic improvement. *Agronomy* **11**: 1776.
40. Rezayian, M., Niknam, V. and Ebrahimzadeh, H. (2018). Differential responses of phenolic compounds of *Brassica napus* under drought stress. *Plant Physiology* **8:** 2417-2425.
41. Salisbury, P.A., Potter, T.D., Gurung, A.M., Mailer, R.J. and Williams, W.M. (2018). Potential impact of weedy Brassicaceae species on oil and meal quality of oilseed rape (canola) in Australia. *Weed Research* **58:** 200-209.
42. Sangeetha, C. and Baskar, P. (2015). Allelopathy in weed management: A critical review. *African Journal of Agricultural Research* **10:** 1004-1015.
43. Sohrabi, S., Ghanbari, A., Mohassel, M.H.R., Gherekhloo, J. and Vidal, R.A. (2016). Effects of environmental factors on *Cucumis melo* L. subsp. agrestis var. agrestis (Naudin) Pangalo seed germination and seedling emergence. *South African Journal of Botany* **105:** 1-8.
44. Szabados, L. and Savoure, A. (2010). Proline: A multifunctional amino acid. *Trends in Plant Science* **15:** 89-97.

45. Szwed, M., Wiczkowski, W., Szawara-Nowak, D., Obendorf, R.L. and Horbowicz, M. (2019). Allelopathic influence of common buckwheat root residues on selected weed species. *Acta Physiologiae Plantarum* **41** : 1-9.
46. Torawane, S. and Mokat, D. (2020). Allelopathic effects of weed *Neanotis montholonii* on seed germination and metabolism of mungbean and rice. *Allelopathy Journal* **49:** 151-164.
47. Tugli, L.S., Essuman, E. K., Kortei, N.K., Nsor-Atindana, J., Nartey, E.B. and Ofori-Amoah, J. (2019). Bioactive constituents of waakye; A local Ghanaian dish prepared with *Sorghum bicolor* (L.) Moench leaf sheaths. *Scientific African* **3:** p.e00049.
48. Unal, B.T. (2013). Effects of growth regulators on seed germination, seedling growth and some aspects of metabolism of wheat under allelochemical stress. *Bangladesh Journal of Botany*, **42**: 65-72.
49. Unal, B.T., Islek, C., Ezer, T. and Duzelten, Z. (2017). Allelopathic effects of *Palustriella falcata* (Bryophyta) extracts on wild mustard plants. *International Journal of Agronomy and Agricultural Research* **11:** 37-45.
50. Varadharajan, R., Rajalingam, D. and Palani, S. (2016). GCMS/MS analysis and cardioprotective potential of *Cucumis callosus* on doxorubicin induced cardiotoxicity in rats. *International Journal of Pharmacy and Pharmaceutical Sciences* **8:** 239-245.
51. Wei, M., Wang, S., Wu, B., Cheng, H. and Wang, C. (2020). Combined allelopathy of Canada goldenrod and horseweed on the seed germination and seedling growth performance of lettuce. *Landscape and Ecological Engineering* **16**: 299-306.
52. Yu, J.Q. (2001). Autotoxic potential of cucurbit crops: Phenomenon, chemicals, mechanisms and means to overcome. *Journal of Crop Production* **4:** 335-348.
53. Zhang, Z., Han, X., Wu, J., Zhang, L., Wang, J. and Wang-Pruski, G. (2020). Specific response mechanism to autotoxicity in melon (*Cucumis melo* L.) roots revealed by physiological analysis combined with transcriptome profiling. *Ecotoxicology and Environmental Safety* 200, p. 110779.
54. Zhou, Y.H. and Yu, J.Q. (2006). Allelochemicals and photosynthesis. *Allelopathy: A Physiological Process with Ecological Implications* (Eds., M.J. Reigosa, N. Pedrol and L Gonzalez*)*, pp. 127-139. Springer, Dordrecht.
55. Zhu, X., Dao, G., Tao, Y., Zhan, X. and Hu, H. (2021). A review on control of harmful algal blooms by plant-derived allelochemicals. *Journal of Hazardous Materials* **401**: 123403.

PUBLISHER NOTE

Allelopathy Journal remains neutral with regard to jurisdictional claims in published Maps and Institutional Affiliations.