https://doi.org/10.17221/386/2020-PSE

Allelopathic potential of white cabbage on some plants

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Citation: Kural L., Özkan R.Y. (2020): Allelopathic potential of white cabbage on some plants. Plant Soil Environ., 66: 559–563.

Abstract: The aim of this study carried out in 2017–2018 was to determine the effect of white cabbage (*Brassica oleracea* L.), which is known to have an allelopathic effect on the germination of some weed and cultural crops seeds. In addition to weeds, *Amaranthus retroflexus* L., *Chenopodium album* L. and *Solanum nigrum* L., cultural plants such as *Zea mays* L., *Beta vulgaris* L., were used in this study. It has been shown that the seed germination rate was decreased by the increased concentration of white cabbage post-harvest leaves extractions, which were made with different concentrations of aqueous and methanol extracts (30, 40, and 50%). The methanol extract was found to be more effective in germination. According to these results, *S. nigrum* and *Z. mays* seeds were less affected than *A. retroflexus*, *C. album* and *B. vulgaris* seeds. In the light of these data, it is observed that extracts obtained from white cabbage can be effective on some weeds; however, it was concluded that in order to reach more definite conclusions, studies on the subject should be increased, and similar studies should be continued under greenhouse or field conditions.

Keywords: weed control; biochemical; Brassicaceae; glycosinolate; biopreparation

Weeds are an important factor causing a 34% yield loss in agricultural production areas in the world. Yield loss caused by weeds was determined as 23% in wheat, 37% in soybean and paddy, 40% in corn, 36% in cotton, and 30% in potato (Oerke 2006). Studies have shown that these rates are higher than losses caused by other pests in agricultural products (Oerke et al. 2012). This loss caused by weeds necessitates sustainable weed control. The variety in weed control methods provides sustainable weed control. Accordingly, it reduces the chance of developing resistance of herbicide, which is one of the biggest problems today (Jabran et al. 2015). Many studies have shown that allelopathy is an alternative to environmental pollution and herbicide resistance resulting from herbicide use (Jabran and Farooq 2013, Zeng 2014).

Plants in the Brassicaceae family contain substances such as sulfur-containing compounds, oils, glycosides, and glycosinolates. Glycosinolates (GLS, ß-thioglucoside-N-hydroxysulfates) are secondary nitrogen-containing chemicals responsible for giving their unique flavours and fragrances to vegetables such as cabbage, broccoli, radishes, and mustard (Holst and Williamson 2004). The presence of glycosinolate in all members of the Brassicaceae family caused its use as an important chemotaxonomic criterion in the classification of this family. Glycosinolates are water-soluble, anionic, non-volatile, and heat-stable compounds (Fahey et al. 2001).

Glycosinolates are hydrolysed by the action of the myrosinase enzyme naturally present in the plant when the tissue breaks down, and hydrolysis products are formed, such as isothiocyanates, thiocyanates, nitriles, oxazolidin-2-thiones, hydroxynitriles, and epithionitriles. Isothiocyanate compounds, one type of these transformations, have toxic effects on plants (Bell and Muller 1973, Haramoto and Gallandt 2005). For this reason, it has been reported that Brassicaceae family plants prevent the weeds from germinating and growing (Uygur et al. 1990, Al-Khatib and Boydston 1999, Uludag et al. 2005, Mushtaq et al.

Supported by the Institute of Science of Van Yuzuncu Yıl University, and by the Main Scientific Research Projects Department, Project No. FYL-2018-6633 of the Van Yuzuncu Yıl University.

https://doi.org/10.17221/386/2020-PSE

2010, Jafariehyazdi and Javidfar 2011, Toosi and Baki 2011, Al-Sherif et al. 2013, Walsh et al. 2014, Naeem et al. 2017).

Dişli and Nemli (2014) investigated the effect of barley, wheat, oat, vetch, canola, and white cabbage root extracts on the germination of *Sinapis alba* L. seeds. According to the results, barley stimulated the germination of *S. alba* seeds. Sunflower, vetch, and cabbage were reported to inhibit germination. In another study, different doses of some cultivated plants with allelopathic properties (sugar beet, bean, sainfoin, and white cabbage) were used to investigate the effect of *Cuscuta approximata* Bab. and *Medicago sativa* L. on germination. 3% concentration of cabbage was found to inhibit the germination of both *C. approximata* and *M. sativa* seeds (Özkan Yergin 2014)

In this study, the effect of water and methanol extracts of leaves of white cabbage (*Brassica oleracea* L.) that are left on the field after harvest was investigated on the germination of cultivated seeds of redroot pigweed (*Amaranthus retroflexus* L.), lamb's quarters (*Chenopodium album* L.) and black nightshade (*Solanum nigrum* L.) weeds and corn (*Zea mays* L.) and sugar beet (*Beta vulgaris* L.). As the allelochemical effect of cabbage is known, the results are intended to contribute to the use and development of biopreparations. They are among the alternative methods of combating weeds, which are more sensitive to human health and the environment, as well as integrated weed control.

MATERIAL AND METHODS

Material. The study was carried out in the Faculty of Agriculture, Department of Plant Protection, Van Yuzuncu Yıl University, Turkey. The main material of the study is the lower leaves of white cabbage, known to have an allelopathic effect, remained in the field after harvest. In the determination of the allelopathic effect on germination, the corn (*Zea mays* L., Pınaper seeding) and sugar beet (*Beta vulgaris* L., Agro-tek seeding) were chosen for this study, as well as the seeds of redroot pigweed, lamb's quarters, and black nightshade as weeds causing significant losses in these two cultivated plants (Tozlu and Zengin 1997, Tepe 2014). Weed seeds were collected from the Siirt Kurtalan District in July and August 2017. Seeds were stored in the refrigerator at +4 °C until use in the study. The post-harvest lower leaves of white cabbage to be used in the study were harvested from the Van Erciş district in August 2017.

Preparing plant extracts. The lower leaves of white cabbage after harvest were washed with distilled water and then dried in the shade. Distilled water and methanol (80%) were used as the solvent in the preparation of the extracts. After taking 50 g of white cabbage plant from the milled material, 100 mL of solvent was mixed and kept at 200 rpm for 24 h in an "orbital" shaker at room temperature. The resulting mixture was passed through a 4-layer sterile cheesecloth and centrifuged at 3 500 rpm for 5 min. The water extract was used immediately after it was passed through the filter paper. Unlike in the methanol extract, methanol in the mixture obtained was used immediately after removal with the help of a rotary evaporator (Ashrafi et al. 2008, Ali Athafah 2014).

Germination experiment. In germination studies, 50 weeds, 10 corns, and 30 sugar beet seeds, whose dormancy was broken, were used in each repetition. The study was carried out in 9 cm thick glass Petri dishes with 2 layers of filter paper. The resulting stock solutions were diluted to 30, 40, and 50% concentrations (Özkan Yergin 2014). The extracts were passed through 0.45 µm diameter filters, and 5 mL was applied to Petri dishes. The same amount of sterile distilled water was applied to the control. Petri dishes sown were left in incubators at an optimum germination temperature of 25 °C for *B. vulgaris* and 30 °C for other plants for 14 days. Seeds forming a 0.5 cm germ tube were considered as germinated (Üremiş and Uygur 1999).

Statistical analysis. Experiments were established with 5 replications according to the test pattern of random plots. In the study, the nonparametric two-way analysis of variance was used, and quantitative changes of the doses were subjected to the orthogonal polynomial. R (V.3.4.4) statistical analysis software was used in the evaluation of data obtained (R Core Team 2017).

The inhibition rate of applications on seeds was calculated using the following equation (Ellnain-Wojtaszek et al. 2003):

$$\text{inhibition (\%)} = C - T/C \times 100$$

where: T – mean value obtained from the application; C – mean value obtained from control.

RESULTS AND DISCUSSION

In all plants tested, it was found that the germination decreased due to the increase in the concentration

https://doi.org/10.17221/386/2020-PSE

of extracts (Table 1). It was determined that white cabbage at the concentration of 50% applied to the redroot pigweed seeds prevented germination at 95% in water extract and 98% in methanol extract. The results obtained from lamb's quarters seeds showed similarity with the redroot pigweed. Accordingly, the white cabbage plant at 50% concentration prevented germination at 93% in water extract and 97% in methanol extract. It was determined that 50% concentration of the white cabbage plant applied to the black nightshade seeds prevented germination at 34% in water extract and 44% in methanol extract. Using the 50% concentration cabbage plant applied to corn seeds showed an inhibition effect at 86% in water extract and 94% in methanol extract. 50% concentration of white cabbage plants applied to sugar beet seeds resulted in the inhibition at a rate of 94% in water extract and 97% in methanol extract.

The results of orthogonal polynomial variance analysis showed a cubic effect in red rooted rooster, lamb's quarters, corn, and sugar beet seeds. The cubic effect can be explained as the values first increasing, then decreasing and then starting to increase again. According to the orthogonal polynomial variance analysis results, the quadratic effect was observed in the water, and methanol extracts application of white cabbage plant to the black nightshade seeds. The quadratic is the beginning of the decrease following a certain increase. In addition, the difference between the extracts and concentrations was found to be significant in all tested plants (Table 2).

It was stated by many researchers that the allelopathic effects of plants from the Brassicaceae family inhibit the germination of small-seeded weeds at high rates and therefore, these plants are useful in weed control (Bialy et al. 1990, Al-Khatib and Boydston 1994, 1999, Özdemir 2007). The number of studies with white cabbage plants in the allelopathy area is lower compared to the other members of the Brassicaceae family. *Brassica juncea* (L.) Czern. was applied to the redroot pigweed seeds at concentrations of 5, 25, and 50%, and similar to our study, it was detected that germination was reduced by 23.29, 41.10, and 93.15%, respectively (Kolören 2008). Similarly, İskenderoğlu (1995) reported that the root extract of *Raphanus sativus* L. prevented the germination of the redroot pigweed seeds by 50%. The root extracts of cabbage were determined to have an inhibitory effect on the seed germination of *Sinapis alba* seeds (Dişli and Nemli 2014), and the water extracts of leaves had an inhibitory effect on *Cuscuta approximata* and *Medicago sativa* (Özkan Yergin 2014). Similarly, Uremis et al. (2009) stated that some radish extracts reduced germination in parallel with the increase in concentration on redroot pigweed and black nightshade. In our study, it was determined as the species least affected by *S. nigrum* extract application. This difference is thought to be due to the species-specific structural difference of the seed (Efil and Üremis 2019). Uygur et al. (1990), in their study, investigated the effect of Antep radish (*Raphanus sativus*) on 25 weed species and 32 cultivated seeds in order to determine the allelopathic effect in laboratory conditions. Using the Antep radish extracts, the total of 11 weed species of (*Alhagi* sp., *Alopecurus myosuroides* Huds.,

Table 1. Results of applications on the seeds tested

Concentration (%)	*Amaranthus retroflexus*		*Chenopodium album*		*Solanum nigrum*		*Zea mays*		*Beta vulgaris*	
	$\bar{x}$ ± SD	I (%)	$\bar{x}$ ± SD	I (%)	$\bar{x}$ ± SD	I (%)	$\bar{x}$ ± SD	I (%)	$\bar{x}$ ± SD	I (%)
Aqueous										
Control	47.6 ± 2.3	–	47.6 ± 2.3	–	50.0 ± 0	–	10.0 ± 0	–	26.0 ± 1.41	–
30	5.8 ± 0.83	88	5.8 ± 0.83	88	50.0 ± 0	0	4.2 ± 0.83	58	8.8 ± 0.83	66
40	4.2 ± 0.83	91	3.8 ± 0.83	92	39.0 ± 2.64	22	3.2 ± 0.83	68	4.6 ± 0.54	82
50	2.2 ± 0.83	95	3.2 ± 0.83	93	32.8 ± 3.03	34	1.4 ± 0.54	86	1.6 ± 0.54	94
Methanol										
Control	47.6 ± 2.3	–	47.6 ± 2.3	–	50.0 ± 0	–	10.0 ± 0	–	26.0 ± 1.41	–
30	3.4 ± 0.54	93	4.4 ± 0.54	91	43.4 ± 4.21	13	2.0 ± 0.70	80	3.4 ± 1.14	87
40	3.0 ± 0.70	94	3.2 ± 0.83	93	40.4 ± 4.77	19	1.2 ± 0.44	88	2.4 ± 0.54	91
50	0.80 ± 0.44	98	1.2 ± 0.83	97	28.2 ± 4.32	44	0.6 ± 0.54	94	0.8 ± 0.44	97

$\bar{x}$ – average of germination; SD – standard deviation; I – inhibition

https://doi.org/10.17221/386/2020-PSE

Table 2. Orthogonal polynomial variance analysis results of the seeds tested

Tested plant	Aqueous and methanol extract		Concentration		Linear		Quadratic		Cubic	
	F*	Pr > F***	F*	Pr > F***	F*	P**	F*	P**	F*	P**
Amaranthus retroflexus	9.12	< 0.01	2 883.32	< 0.0001	5 665.54	< 0.0001	2 442.06	< 0.0001	542.37	< 0.0001
Chenopodium album	5.56	< 0.05	2 696.70	< 0.0001	5 274.68	< 0.0001	2 357.56	< 0.0001	457.88	< 0.0001
Solanum nigrum	6.36	< 0.05	78.88	< 0.0001	227.30	< 0.0001	9.22	< 0.01	0.12	0.7322
Zea mays	46.30	< 0.0001	484.22	< 0.0001	1 153.20	< 0.0001	240.67	< 0.0001	58.80	< 0.0001
Beta vulgaris	46.30	< 0.0001	484.22	< 0.0001	3 340.28	< 0.0001	872.56	< 0.0001	162.82	< 0.0001

*F – F test statistic; **P – significance value; ***Pr > F – The P-value is the two-tailed probability computed

Cachia maritima Scop., *Capsella bursa-pastoris* L., *Convolvulus arvensis* L., *Cuscuta* sp., *Daucus carota* L., *Hirchfeldia incana* (L.) Lagr.-Foss., *Ochtodium aegyptiacum* L., *Sisymbrium polyceratium* L. and *Sorghum halepense* L.) and 4 cultivated seeds (*Lactuca sativa* ssp., *Nicotiana tabacum* L., *Phaseolus* sp. and *Trifolium* sp.) were reported to completely inhibit seed germination.

According to the data obtained, it is considered that leaf extracts of white cabbage after harvest may be an important application in integrated weed control. The fact that the applications carried out with water extracts of cabbage plants have less effect on corn increases the chance of usability in sustainable agriculture.

Although the white cabbage extracts used in the study have a very high inhibition rate, especially on weeds, it can be said that especially the water extract of cabbage contributes to the integrated weed control in terms of showing relatively low inhibition effect on cultivated plants. The fact that these results were obtained from plant residues left in the field after harvesting the white cabbage plants in the study should be considered as an economically important factor in transferring the study to the practice. Although the extracts are found to be effective *in vitro* like herbicides, it is thought that the studies on the subject should be increased, and similar studies should be continued in greenhouse or field conditions in order to reach definite judgments.

Acknowledgment. We would like to thank Hayrettin Okut (University of Kansas) for his supports during the statistical analysis.

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Received: July 28, 2020
Accepted: September 22, 2020
Published online: October 6, 2020