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). This loss caused by weeds necessitates sustainable weed control. 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

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Preventing 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 (Ashraf 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):

\[
\text{inhibition (\%)} = \frac{C - T}{C} \times 100
\]

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...
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, Iskenderoğlu (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>
<thead>
<tr>
<th>Concentration (%)</th>
<th>Amaranthus retroflexus</th>
<th>Chenopodium album</th>
<th>Solanum nigrum</th>
<th>Zea mays</th>
<th>Beta vulgaris</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x ± SD</td>
<td>1 (%)</td>
<td>x ± SD</td>
<td>1 (%)</td>
<td>x ± SD</td>
</tr>
<tr>
<td><strong>Aqueous</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>47.6 ± 2.3</td>
<td>–</td>
<td>47.6 ± 2.3</td>
<td>–</td>
<td>50.0 ± 0</td>
</tr>
<tr>
<td>30</td>
<td>5.8 ± 0.83</td>
<td>88</td>
<td>5.8 ± 0.83</td>
<td>88</td>
<td>50.0 ± 0</td>
</tr>
<tr>
<td>40</td>
<td>4.2 ± 0.83</td>
<td>91</td>
<td>3.8 ± 0.83</td>
<td>92</td>
<td>39.0 ± 2.64</td>
</tr>
<tr>
<td>50</td>
<td>2.2 ± 0.83</td>
<td>95</td>
<td>3.2 ± 0.83</td>
<td>93</td>
<td>32.8 ± 3.03</td>
</tr>
<tr>
<td><strong>Methanol</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>47.6 ± 2.3</td>
<td>–</td>
<td>47.6 ± 2.3</td>
<td>–</td>
<td>50.0 ± 0</td>
</tr>
<tr>
<td>30</td>
<td>3.4 ± 0.54</td>
<td>93</td>
<td>4.4 ± 0.54</td>
<td>91</td>
<td>43.4 ± 4.21</td>
</tr>
<tr>
<td>40</td>
<td>3.0 ± 0.70</td>
<td>94</td>
<td>3.2 ± 0.83</td>
<td>93</td>
<td>40.4 ± 4.77</td>
</tr>
<tr>
<td>50</td>
<td>0.80 ± 0.44</td>
<td>98</td>
<td>1.2 ± 0.83</td>
<td>97</td>
<td>28.2 ± 4.32</td>
</tr>
</tbody>
</table>

x – average of germination; SD – standard deviation; I – inhibition
Table 2. Orthogonal polynomial variance analysis results of the seeds tested

<table>
<thead>
<tr>
<th>Tested plant</th>
<th>Aqueous and methanol extract</th>
<th>Concentration</th>
<th>Linear</th>
<th>Quadratic</th>
<th>Cubic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F*</td>
<td>Pr &gt; F***</td>
<td>F*</td>
<td>Pr &gt; F***</td>
<td>F*</td>
</tr>
<tr>
<td>Amaranthus retroflexus</td>
<td>9.12</td>
<td>&lt; 0.01</td>
<td>2 883.32</td>
<td>&lt; 0.0001</td>
<td>5 665.54</td>
</tr>
<tr>
<td>Chenopodium album</td>
<td>5.56</td>
<td>&lt; 0.05</td>
<td>2 696.70</td>
<td>&lt; 0.0001</td>
<td>5 274.68</td>
</tr>
<tr>
<td>Solanum nigrum</td>
<td>6.36</td>
<td>&lt; 0.05</td>
<td>78.88</td>
<td>&lt; 0.0001</td>
<td>227.30</td>
</tr>
<tr>
<td>Zea mays</td>
<td>46.30</td>
<td>&lt; 0.0001</td>
<td>484.22</td>
<td>&lt; 0.0001</td>
<td>1 153.20</td>
</tr>
<tr>
<td>Beta vulgaris</td>
<td>46.30</td>
<td>&lt; 0.0001</td>
<td>484.22</td>
<td>&lt; 0.0001</td>
<td>3 340.28</td>
</tr>
</tbody>
</table>

*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., Hirschfeldia incana (L.) Lagr.-Foss., Ochthodium aegyptiacum L., Sisymbrium polyceratium L. and Sorghum halepenese 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.

REFERENCES


