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WEED CONTROL USING ALLELOPATHIC PROPERTIES OF RAPESEED RESIDUES AND CROP MANAGEMENT

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ABSTRACT

Planting date, density and allelopathic properties are important tools of crop management in controlling weeds in crops. Allelopathy refers to any direct or indirect inhibitory or stimulating effect of one plant on another through the production and release of secondary metabolites in the environment. Two experiments performed separately, in order to investigate the effect of allelopathic properties of rapeseed residues and crop management on the control of rapeseed weeds and its yield. The first experiment was conducted during two agricultural years (2018-2019 and 2019-2020) in a factorial form of a randomized complete block design with 3 replications at the Qarakhil agricultural research station (QaemShahr). The treatments were included: planting date in 3 treatment levels (October 17, November 6 and November 26), seed rate in 3 treatment levels (3, 5 and 7 kg per hectare) and weed management in 2 treatment levels presence of weed (no control) and the absence of weed (control). The second experiment was conducted as a factorial in the form of a completely random design in three repetitions in the research laboratory of the Islamic Azad University, QaemShahr branch in 2020. The experimental treatments included weeds [wild oat *(Avena fatua)*, darnel regrass *(Lolium temulentum)*, phalaris *(Phalaris minor)*] and charlock mustard *(Sinapis arvensis)*) different concentrations of rapeseed root and stalk extracts (0, 25, 50, 75 and 100%). The results of the first experiment showed that, in general, the rapeseed seed yield was affected by the planting date and density, so that the rapeseed seed yield on the delayed planting date (November 26) decreased compared to the first planting date (October 17) by 49 and 59 percent, respectively in the first and second year of the experiment, and this decrease was more intense in the second year. Also, the results showed that the highest dry weight of weeds was obtained in both years at a density of three kilograms per hectare and in the cultivation of November 26 (except for the highest dry weight of wild oats that was observed in the cultivation of October 17). While the highest weight of seed yield was obtained in both crop years at a density of 7 kg per hectare. The results of the second experiment showed that the extract obtained from the root and stem of the rape plant had a negative and significant effect on the speed, percentage and inhibition of germination in all weeds. However, no significant difference was observed between the concentration of root and stem extracts at the 5% level. A significant negative linear regression relationship was observed between the concentration of the extract (root and stem) with the percentage and speed of germination. Also, a significant positive linear regression relationship was observed between inhibition percentage and extract concentration (root and stem). Therefore, the germination and seedling growth of the seeds of all three weed species had a negative reaction to the concentration of rapeseed extract, but the highest sensitivity was observed in wild oat seeds. Therefore, according to the results, rapeseed extract can be used in the biological control of weeds. In general, the results of two experiments showed that the planting date, density and rapeseed residues can be used effectively in controlling weeds in rapeseed fields.

Keywords: allelopathic, planting date, density, germination, weed, canola.

INTRODUCTION

Rapeseed (*Brassica napus* L.) is an oil crop belonging to the *Brassicaceae* family which is the result of natural hybridization of *Brassica oleracea* L. and *Brassica rapa* L. and ranked as the second most important source of vegetable oil worldwide. It is also a potential source of specific protein and industrial raw materials including biopolymers, surfactants, adhesives and biodiesel (Asaduzzaman et al., 2020; Biabani et al., 2021). The cultivated area of rapeseed in Iran is 52.267 thousand hectares and in Mazandaran province it is 6484 hectares, which is mostly rainfed. The average yield is 1773 kg per hectare (Agricultural statistics, 2019). Allelopathy

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is a natural ecological phenomenon of interference between different products and refers to any direct or indirect, inhibitory or stimulating effect of one plant on another one through the production and release of secondary metabolites in the environment (Hayyat et al., 2020; Torawane and Mokat, 2020). The phenomenon of allelopathy is caused by the creation of biologically active compounds by plants or their residues that affect the germination, growth and development of individuals of the same species or other species (Saeedipour et al., 2021). A large number of allelopathic substances have been identified, some of which play a role in the plant's defense system, with phenolics, alkaloids, terpenes, fatty acids, and indoles being the most common in plants (Deepmala, 2019). These phenolic compounds affect different physiological processes related to growth and development in different stages of the plant (Fu et al., 2019). It has been observed that allelopathic substances in high concentrations have an inhibitory effect and in low concentrations have a stimulating effect on seed germination and plant growth (Singh, 2021). Allelopathic plants can be widely used in organic agriculture due to their potential role in improving seed germination (Findura et al., 2020). Weeds are one of the most important factors in yield determinants in crops and can significantly reduce yield in canola. They compete for resources (light, water, nutrients) and significantly reduce the growth and quantitative and qualitative yield of canola (Deligios et al., 2019). On the other hand, weeds may act as alternative hosts for various pests and diseases, thereby severely reducing yield (Inuganti et al., 2021). Allelochemical control of weeds can provide an environmentally friendly tool for weed control in cropping systems without dependence on chemical herbicides, as chemical weed control poses various risks to the environment, biodiversity, and human health. The use of allelopathic weed control through mixed cropping, planting date, density, crop rotation, cover cropping, mulch, residues, and aqueous extract alone or in combination with synthetic herbicides not only provides sustainable weed control, but also due to the positive effects of these strategies provides sustainable product production (Abbas et al., 2021). The results showed that weed management can be effective by reducing herbicide inputs with an integrated approach, but may lead to more weeds over time (Summers et al., 2021). In a study on spinach, De Cauwer et al. (2021) found that plots with a density of 400 plants per square meter had lower numbers and biomass of weeds compared to plots with a density of 300 plants per square meter. Hasam et al., (2021) reported that a 25% increase in plant density in wheat compared to the recommended amount caused a significant decrease in the number and biomass of weeds by 61.2 and 50.9%, respectively. It has been reported that in the competition of aerial parts and roots of charlock mustard with wheat, seed yield and plant height decreased by 22.10 and 69.79%, respectively, compared to the control (weed control) (Modhej, 2021). In a study conducted by Saeedipour et al. (2021) under the title of allelopathic effect of nut grass weed on the invasive weeds of morning glory and wild melon, they found that traits such as germination percentage and seedling growth were affected by different amounts of harmful combinations of residues compared to the control. The results of the experiment (Rezendes et al., 2020) on the allelopathic effects of several weed species on the parameters of germination and seedling growth of lettuce and tomato showed that the percentage of seed germination was less affected by aqueous extract than other parameters. The allelopathic effect of *Sphenoclea zeylanica Gaertn*, a broadleaf weed in rice fields in Thailand, was investigated. The results showed that aqueous leaf and stem extracts at concentrations higher than 50 grams per liter had more than 50% inhibitory effect on the germination and growth of rice seedlings compared to the control, at a concentration of 100 g/L, leaf and stem extracts completely (100%) inhibited the germination of rice seeds (Krumsri et al., 2020). There are various weeds throughout the fields of Mazandaran province, but wild oats (*Avena fatua*), darnel ryegrass (*Lolium temulentum*), phalaris (*Phalaris minor*) and charlock mustard (*Sinapis arvensis*) are major weeds in agricultural fields, especially rape fields in Mazandaran province. Therefore, one of the solutions to overcome the weeds and also one of the inevitable components of the integrated management system of weed control in the rape field is density in the area, appropriate planting date and the use of the allelopathic property of rapeseed residues (root and stem). At the same time, planning for weed management requires obtaining the necessary information about the competitive effect of weeds on the yield and yield components of crop seeds, Therefore, this research was conducted with the aim of evaluating the density, planting date and allelopathic property of rapeseed residues (root and stem), as a tool in the sustainable management of rapeseed weeds.

MATERIAL AND METHODS

First experiment

This experiment was carried out during two agricultural years (2018-2019 and 2019-2020) in the agricultural research station of Qarakhil (QaimShahr). Qarakhil is located at the 6^{th} kilometer of Qaimshahr-Babol road at 56°18’ east longitude, 36°28’ north latitude and 14.7 meters above sea level. Its average annual rainfall is 745 mm. A factorial experiment was carried out in the form of a randomized complete block design with 3 replications. The treatments include: planting date in 3 treatment levels (October 17, November 6 and November 26), seed rate in 3 treatment levels (3, 5 and 7 kg per hectare) and weed management in 2 treatment levels [presence of weeds (no control) and the absence of weed (control)].

Each plot consisted of 6 planting lines with a length of 6 meters, and the distance between the lines was fixed (30 cm). Planting was done manually and on the studied dates. Also, weeding was only done in the plots that weed should be controlled, and in the plots that should not be controlled, the weeds were present in the plot in the same way. Cultivated canola variety was Hyola-50. The soil test results showed that its texture is clay loam, the acidity of the soil is alkaline and it has pH = 7.4. The soil of the test site contains 3 percent of organic matter, 0.52 electrical conductivity, 0.17 total nitrogen, and 14.3 milligrams of phosphorus and 186 milligrams of potassium. Based on the soil test, the fertilizers used were 100 kg/ha of urea fertilizer at the time of planting, 200 kg/ha of urea fertilizer in the form of vinegar, 50 kg of triple superphosphate fertilizer/ha, and 50 kg of potassium sulfate/ha at the time of planting. During the flowering stage, spraying was done after observing pests such as aphids and pollinating beetles. The traits studied include the identification of the dominant weeds along with the dry weight of each separately, which in this experiment were wild oats (*Avena fatua*), darnel ryegrass (*Lolium temulentum*), phalaris (*Phalaris minor*) and charlock mustard (*Sinapis arvensis*). In order to measure grain yield, plants in the area of two square meters of each plot were cut from the ground, except to the margin (half a meter from the sides).

Second experiment

In order to investigate the allelopathic effect of rapeseed on the traits related to the germination of some weeds such as phalaris, darnel ryegrass and wild oats, a three-factorial experiment was carried out in the form of a completely randomized design with three replications in the Agricultural Research Laboratory, Islamic Azad University, Qaemshahr branch in the winter of 2019.

The first factor includes the seeds of three weeds, phalaris (*Phalaris minor*), darnel ryegrass (*Lolium temulentum*) and wild oats (*Avena fatua*), the second factor root and stem residues, and the third factor different concentrations of rapeseed root and stem extracts (0, 25, 50, 75 and 100 percent).

Rapeseed plant samples were collected in the physiological treatment stage from the fields of Golestan Province. They were washed for a short time to remove dust, then the root and stem were separated, and then placed inside the oven and dried for 72 hours. The dried plant was ground and passed through a sieve with holes (1 mm diameter) for homogenization. To prepare the extract from each plant, 10 grams of powder was weighed and poured into an Erlenmeyer flask and 100 ml of distilled water was added to it, the resulting mixture was placed in a shaker for 72 hours. After the required time, the resulting mixture was filtered with Whatman filter paper (number one). Different concentrations (0, 25, 50, 75 and 100%) were prepared from the obtained extracts with the help of distilled water. Petri dishes and weed seeds were disinfected with 1% sodium hypochlorite, then 50 seeds were placed in a petri dish with a diameter of 11 cm on filter paper. 5 ml of each of the extracts was applied to each petri dish separately on the weed seeds. Petri dishes were placed in the laboratory germinator with a constant temperature of 25°C for germination, and germinated seeds with roots longer than two millimeters were counted daily and it continued until no increase in germination was observed in two consecutive counts. Then traits such as germination percentage, germination speed and inhibition percentage were measured (ISTA, 2022).

Germination percentage was obtained from the equation (Agrawal, 2003).

Equation (1): Germination percentage = number of germinated seeds out of total seeds × 100 (Scott et al., 1984).

The rate of seed germination using Maguire's method (Maguire, 1962) is equal to the Ni/Ti ratio, where Ni is the number of germinated seeds per day and Ti is the number of days after sowing (first day to tenth day).

Equation (2): $Ni/Ti \sum GR$

Equation 3 was used to obtain the germination inhibition percentage:

Equation (3): $IP = [(Control – Extracts) / Control] \times 100$

Here, IP means germination inhibition percentage, Control means the number of germinated seeds in the distilled water control treatment, and Extracts means the number of germinated seeds in the extracts of different rapeseed treatments.

Data analysis

In the first experiment, the test of homogeneity of variances was performed before performing any analysis, because the analysis design was composite and it was observed that the error variance between two different years is not the same, therefore, each year was analyzed separately. In order to compare yields between density treatments and planting dates in each year in conditions of weed control and non-control t-test was used and then only weed yield and biomass were investigated in the condition of no weed control.

In the second experiment, the normality of the data was first tested. All data except germination percentage, germination inhibition was normal. Therefore, to normalize the data of germination speed, the logarithm in base 10 was used.

Finally, analysis of the variance of the data in both experiments was done using the Proc Anova procedure and the LSD test at the 5% level used for the comparison of the means in the first experiment and post-ANOVA analyzes in the second experiment were performed using the Proc reg procedure with SAS statistical software version (9.3) (Sousa et al., 2018). Excel 2013 software was also used to draw the figures.

RESULTS AND DISCUSSION

The results of the mean comparison showed that the grain yield in the condition of no weed control compared to the control condition in both crop years was significant at the level of 1%, so that the date yield in the first and second year decreased by 39 and 42% respectively in the condition of no weed control compared to its control. Therefore, according to the results, the lack of weed control in the rapeseed field had a significant effect on its yield (Table 1).

Table 1. Comparison of plant height, yield and oil percentage in canola under weed control and non-control conditions during two crop years 2017-2018 and 2018-2019

Year	Trait	Year	Number	Mean	t	P value
2017-2018	Seed yield (kg/ha)	Weed control	27	58±1311	7.18	0.0001
		No Weed control	27	45±777		
2018-2019	Seed yield (kg/ha)	Weed control	27	50±1452	7	0.0001
		No Weed control	27	69±848		

The results of analysis of variance showed that the effect of planting date and density on all studied traits (Except for the charlock mustard dry weight in the first year and the dry weight of phalaris in the second year) were significant at the 1% level. While the interaction effect between density and planting date was significant only on the dry weight of darnel ryegrass and phalaris in both crop years at the level of 1% (Table 2).

Table 2. Variance analysis of seed yield, oil percentage and canola height and dry weight of different weeds in crop years 2018-2019 and 2019-2020

2018-2019	Mean squares					
Source of variation	Df	Grain yield	Darnel ryegrass (dry matter)	Phalaris (dry matter)	Charlock mustard (dry matter)	Wild oats (dry matter)
Block	2	69999**	2.78	24.20	66.57	2.54
Planting date (Pd)	2	203978**	320**	1252**	129	558**
Density (d)	2	1242310**	919**	27.20**	2466**	827**
Pd × d	2	6806	74.64**	264**	97.60	111
Error	4	2415	15.36	37.18	78.05	18.99
Cv	16	6.32	23.62	18.64	28.19	24.84
2019-2020						
Block	2	52523**	0.25	1.33	711	911
Planting date (Pd)	2	340551**	57.72**	9.33	8400**	8304**
Density (d)	2	1242310**	75.72**	1737**	10000**	30172**
Pd × d	2	17196	4.26**	111**	400	523
error	4	5853	0.37	28.33	211	286
Cv	16	9.01	2.61	17.11	16.76	10.59

*, ** Significant at the 5 and 1% levels, respectively.

The mean comparison results among two crop years showed that the yield of rapeseed and dry weight of wild oats on the planting date of October 17 was higher compared to other planting dates, the yield difference in the delayed planting date (November 26) compared to the optimal planting date (October 17) in the crop years of 2018-2019 and 2019-2020 was 49 and 59%, respectively, and the decrease was more intense in the second year. The second crop year was drier and hotter than the first crop year. Also, the dry weight of wild oats on the optimal planting date was significant compared to the delayed planting date in both agricultural years.

Table 3. Comparison of the average grain yield and dry weight of weeds in the planting date and different densities during the crop years 2018-2019 and 2019-2020

Treatment		**2018-2019**			**2019-2020**		
		Y	DY		Y	DKh	DY
Planting date	October 17	916^{a}	26.62^{a}		10.46^{a}	60.33^{c}	24^{a}
	November 6	799^{b}	18.49^{b}		824^{b}	80.67^{b}	16^{b}
	November 26	617^{c}	7.51^{c}		657^{c}	120^{a}	16^{b}
	$LSD_{0.05}$	49	4.35		76.46	14.52	3.99
		2018-2019			**2019-2020**		
		Y	DKh	DY	Y	DKh	Y
Plant density	3 kg	570^{C}	46.19^{a}	26.62^{a}	435^{c}	120^{a}	28^{a}
	5 kg	760^{b}	34.32^{b}	18.49^{b}	956^{b}	86.67^{b}	16^{b}
	7 kg	1002^{a}	13.49^{c}	7.51^{c}	1155^{a}	53.33^{c}	12^{c}
	$LSD_{0.05}$	49	8.83	4.36	76.46	14.52	3.999

Y, grain yield Y; grain yield (kg/ha); DYM, dry weight of charlock mustard (g/m^2); DY, dry weight of wild oats (g/m^2)

Also, the mean comparison of the grain yield, dry weight of charlock mustard and wild oats among two crop years showed that the highest grain yield was 7 kg per hectare, While the highest dry weight of charlock mustard and wild oats was obtained at low density with at the 3 kg/ha treatment (Table 3).

The mean comparison of the interaction between planting date and density in both crop years showed that the highest dry weight of darnel ryegrass and phalaris was observed in three kilograms per hectare and late planting date (November 26) (Table 4).

Table 4. Mean comparison of density and planting date interaction effect of studied traits among two crop years 2017-2018 and 2018-2019

Treatment	**2017-2018**		**2018-2019**	
	Dch	Dfa	Dch	Dfa
P1d1	16.43^{c}	28.67^{de}	24.60^{c}	40.00^{ab}
P1d2	10.27^{cd}	20.60^{efg}	21.00^{d}	30.01^{bc}
P1d3	5.01^{d}	10.50^{g}	18.60^{e}	24.02^{d}
P2d1	26.93^{b}	50.17^{b}	24.60^{bc}	42.17^{ab}
P2d2	16.60^{c}	42.33^{bc}	24.00^{c}	36.33^{bc}
P2d3	6.60^{d}	12.73^{fg}	18.60^{e}	12.01^{e}
P3d1	39.37^{a}	70.03^{a}	29.40^{a}	48.03^{a}
P3d2	16.70^{c}	38.00^{cd}	25.20^{b}	36.00^{bc}
P3d3	11.43^{cd}	21.43^{ef}	24.00^{cd}	12.43^{e}
$LSD_{0.05}$	6.78	10.55	1.05	9.21

P1d1, planting date October 17 and density 3 kg/ha; P1d2, planting date October 17 and density 5 kg/ha; P1d3, planting date October 17 and density 7 kg/ha; P2d1, planting date November 6 and density 3 kg/ha; P2d2, planting date November 6 and density 5 kg/ha; P2d3, planting date November 6 and density 7 kg/ha; P3d1, planting date of November 26 and density of 3 kg per hectare; P3d2, planting date of November 26 and density of 5 kg per hectare; P3d3, planting date of November 26 and density of 7 kg/ha; Dch, dry weight of darnel ryegrass (g/m^2); Dfa, phalaris dry weight (g/m^2).

Testing two effects of aqueous extracts of rapeseed plant residues on germination and seedling growth of three weed species

Germination percentage and rate

The results of analysis of variance showed that the effect of weed, concentration of rapeseed extract, source of extract, the interaction effect of weed and source of extract, the interaction effect of weed and concentration of rapeseed extract on germination percentage and germination speed were significant at the level of 1%, but other interaction effects of extract concentration and its source on both traits were not significant, the triple interaction effect was significant only on the germination speed at the level of 1%.

Regression analysis of the relationship between germination percentage and different concentration levels of rapeseed root and stem extract for each type of weed showed that 78 to 99% of the variation in seed germination of *phalaris*, darnel ryegrass and wild oat weeds can be explained by the linear relationship. So that for each unit of increase in the concentration of rapeseed root and stem extract, on average, 0.45, 0.36 and 0.65% decrease in the germination of *phalaris*, darnel ryegrass and wild oat seeds was observed respectively. Also, according to the results at the concentration of 5%, the extracts from the roots and stems of rapeseed did not inhibit the germination progeny of any of the studied weed species, but a significant difference was observed between weeds ($P \leq 0.05$), so that, the highest decrease in germination percentage was observed in wild oats and the lowest was in darnel ryegrass.

A negative linear regression relationship was observed between the germination speed and the concentration of rapeseed root and stem extract for each weed species with a high explanatory coefficient at the level of 1%. However, no significant difference was observed between the inhibitory effect of rapeseed root and stalk extract on seed germination rate for any weed at the 5% level. The results showed that the highest decrease in germination rate with an average of 0.007 seeds per day per unit increase in extract concentration was observed in wild oats and *phalaris* (Table 2, Figure 1a), while the lowest decrease was observed with an average of 0.0052 seeds per day per unit increase in extract concentration in darnel ryegrass (Figure 1b).

Table 5. Variance analysis related traits to germination

Source of variation	Df	Germination percentage	Germination seed	Germination inhibition
Weed (W)	2	13811^{**}	8.009^{**}	0.935^{**}
Rapeseed extract concentration (C)	4	7200^{**}	1.215^{**}	9.415^{**}
Extract Source (Rs)	1	284^{**}	0.025^{*}	0.011^{ns}
C×W	8	351^{**}	0.043^{**}	0.067^{**}
Rs×W	2	336^{**}	0.151^{**}	0.033^{**}
C×Rs	4	40.87^{ns}	0.003^{ns}	0.003^{ns}
Rs×W×C	8	49.61^{ns}	0.024^{**}	0.010^{ns}
Error	60	27.91	0.005	0.006
CV	-	8.92	7.21	6.15

Germination inhibition

The results of analysis of variance showed that the effect of weed, concentration of rapeseed extract, interaction effect of weed and concentration of rapeseed extract, weed and source of extract was significant at 1% level, but the effect of extract source and other interaction effects were not significant (Table 5). The results indicated a positive and strong linear regression relationship between the percentage of inhibition with the concentration of rapeseed root and stem extracts for each weed species, at the level of 1%, yet, no significant difference was observed between the inhibitory effect of rapeseed root and stem extract on the inhibitory percentage for two weed species, phalaris and darnel ryegrass, at the 5% level. On average, per unit of increase in extract concentration, led to 0.45% and 0.39% in phalaris and darnel ryegrass inhibition percentage, respectively (Figure 1c).

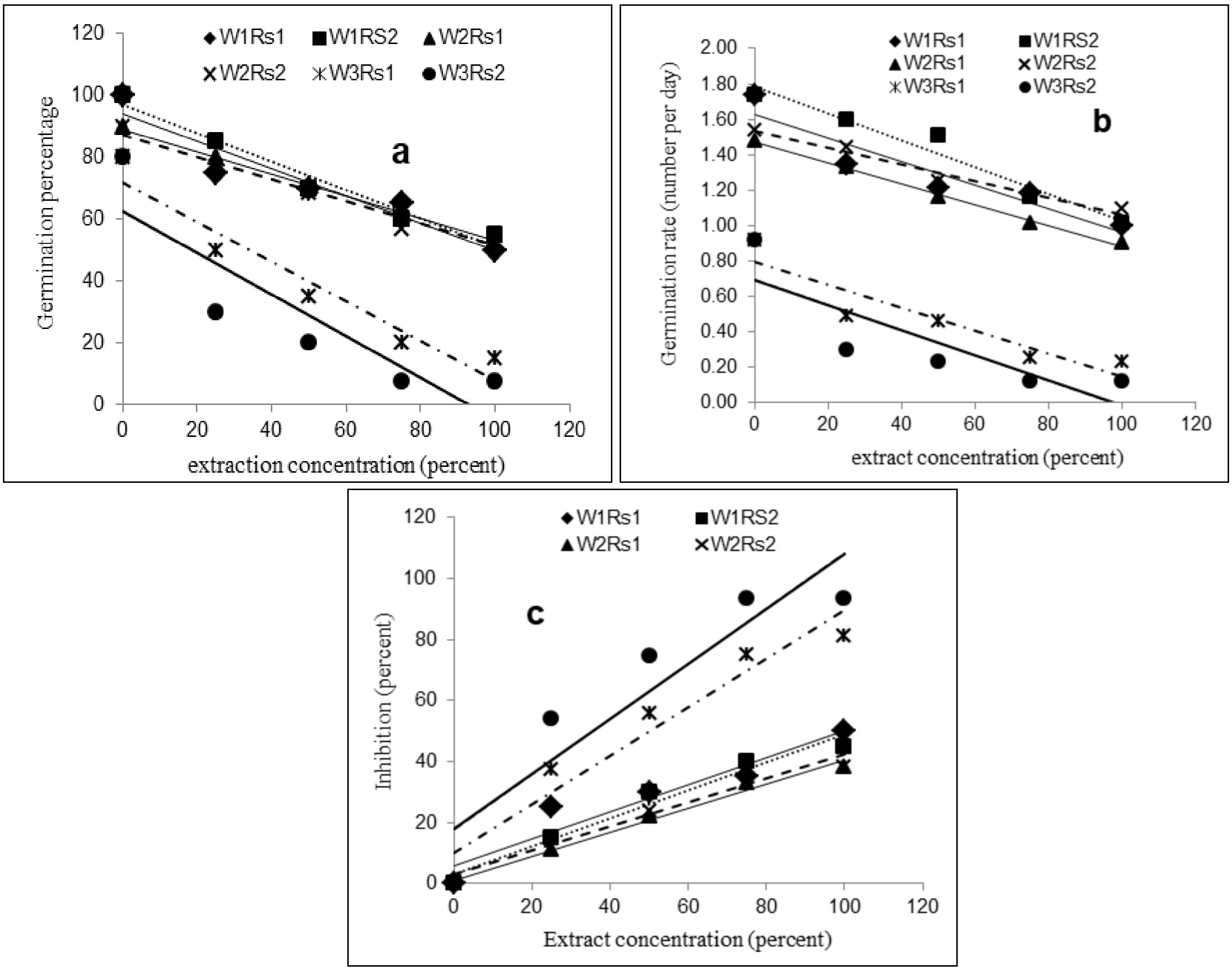

Figure 1. Relationship between extract concentration and a) germination percentage; b) germination rate (number per day); c) inhibition of germination (percentage); W1Rs1, phalaris weed with canola root extract source; W1Rs2, phalaris weed with canola stem extract source; W2Rs1, darnel ryegrass with rapeseed root extract source; W2Rs2, darnel ryegrass with rapeseed stem extract source; W3Rs1, wild oat weeds with rapeseed root extract source; W3Rs2, wild oat weeds with rapeseed extract source

The high weight of wild oats on the first planting date is due to the growth physiology and appearance of the wild oat plants compared to other weeds. Wild oats is a plant from the Gramineae family and has a branched root, and compared to rapeseed, which has a straight root system, feeds on the surface parts of the soil, so there is less competition between rapeseed and Wild oats. Also, compared to the other studied weeds in this research, the germination and greening of Wild oats begins earlier, this is the reason why this plant is more successful in the first planting date in both crop years (Table 3).

The increase in dry weight of charlock mustard with delayed planting can be attributed to the higher growth rate and wider canopy cover of charlock mustard compared to rapeseed. Planting on time and increasing the density of crop plants can be considered as an effective factor in increasing the share of crop plants from the total resources, and the competition of crop plants reduces the growth and development of weeds.

Critical period for weed control is a key component of weed management in rapeseed fields and is a period of the crop growth cycle during which weeds must be controlled to prevent reducing yield. It seems that the October 17 planting date is the best time to control darnel ryegrass, charlock mustard and phalaris, so that it has affected the grain yield and the environmental conditions would to be suitable during the time of germination, establishment and survival of the seedling.

It leads to controlling early autumn cold, pests, diseases and weeds and is of particular importance due to the use of effective climatic factors in production, such as matching the flowering time with the appropriate temperature. On the other hand, the delay in planting has reduced the number of leaves and stems in the plant and ultimately reduced the size of the canopy, which has decreased receiving and using radiation in rapeseed as a result, and has caused a decrease in yield and a decrease in the growth period. Also, in delayed planting due to the loss of the right time for growth, the plant does not reach its potential. Therefore, in delayed cultivation, due to the reduction in the size of the plant, the competition with weeds has decreased which has caused an increase in the biomass of weeds and a corresponding decrease in yield (Asaduzzaman et al., 2020). Therefore, delayed planting is effective in weed control when other techniques are used in weed control. The highest yield of rapeseed and the lowest dry weight of weeds in all four studied species were obtained at a seed rate of 7 kg per hectare, or in other words, at a higher density, conversely, the lowest yield of rapeseed and the highest dry weight of weeds were observed at low density. With increasing crop density, the availability of growth resources for weeds decreases, and on the other hand, it has caused rapeseed canopy to close faster, and led to more effective control of weeds. Therefore, it seems that increasing the density is one of the easiest agronomic ways to increase the competitiveness of the crop with weeds and therefore increasing crop density can reduce weed biomass by reducing the seed bank. Studies showed that increasing the amount of rapeseed from 100 to 150 seeds per square meter reduced the size and volume of broadleaf weeds and helped to increase the grain yield by more than 40% (Asaduzzaman et al., 2020). In a study on spinach, De Cauwer et al (2021) found that plots with a density of 400 plants per square meter had fewer weeds and less biomass than plots with a density of 300 plants per square meter. Hasam et al. (2021) reported that a 25% increase in density in wheat compared to the recommended amount caused a significant decrease in the number and biomass of weeds by 61.2 and 50.9%, respectively.

In general, the results showed that the difference in germination parameters was due to the difference in weed species and rapeseed extract concentration, but no difference was observed between the sources of the extract. This might be due to the fact that leaves are the main site of metabolism where secondary metabolites are found more often than in other plant parts (Krumsri et al., 2020), And since only the root and stem organs were used in this experiment and the leaves were not used, this difference is not observed. These results are consistent with the findings of (Rezendes et al., 2020) who investigated the allelopathic effects of several weed species on germination and seedling growth parameters of lettuce and tomato. The different response to the extract concentration between the weed species, can be due to the difference in the physiological characteristics of the three studied species and their different response to the allelopathic compounds of rapeseed. Various reasons have been stated for the reduction or even non-germination of different plant seeds in the presence of other harmful compounds. Reduction of germination percentage as a result of applying the harmful compounds in the organs of different plants might be due to increased peroxidation of cell membrane lipids as a result of oxidative stress which can lead to the death of cells and the growing embryo by increasing the deterioration and destruction of cell membranes (Tarbali et al., 2021).

On the other hand, the release of gibberellin hormone is necessary for the activity of enzymes and the conversion of stored materials into transferable materials for germination and embryo growth, and therefore, in the presence of rapeseed plant extract, the activity of enzymes and then the germination and growth of the embryo are disturbed (Dejam et al., 2017). In this study, the intensity of inhibition increased with the increase in the concentration of rapeseed extract. allelopathic substances, by reducing mitotic divisions in the root meristem, decrease the activity of enzymes that catalyze plant vital processes, such as glucose 6-phosphate dehydrogenase, glucose phosphate isomerase and aldolase related to glycolysis and pentose phosphate pathways, and by reducing the production of ATP, the absorption of mineral ions has been reduced and cause a decrease in the growth of roots and shoots. This concept was also confirmed by (Dejam et al., 2017) that the allelochemical compounds released from eucalyptus leaves reduced the absorption of nitrogen, phosphorus and potassium elements in bean and corn plants.

Many polyphenols have a catechol group, and therefore, in high concentrations, have the ability to chelate divalent and trivalent metal ions, the result of which is the high ability of phenolic compounds in preventing the absorption of nutrients, which ultimately leads to a decrease in the dry weight of the plant. In a study on wheat, the results showed that with the increase in the concentration of sickle root extract, the growth of root and stem organs decreased significantly, and the length and weight of these organs was accompanied by a significant decrease which ultimately reduced the strength of the seedling. Also, root extract significantly reduced alpha-amylase enzyme activity, but the activity of antioxidant enzymes increased at low levels of the extract and decreased at higher levels. The extract of Sickle root extract had a very strong inhibitory effect on wheat seed vigor. According to the findings of the research, the mode of action of the harmful compounds of sickle is through the induction of oxidative stress and preventing the stimulation of the seed stored materials during germination. The high sensitivity of alpha-amylase enzyme activity to harmful substances was detected in this experiment; also, the decrease in the activity of all studied enzymes in high concentrations was significant. Stearic acid and palmitic acid derivatives accounted for about 30% of the compounds, which have a strong possibility of interfering of their activity with the activity of enzymes (Tarbali et al., 2021). Singh (2021) found that all characteristics of germination and seedling growth of both studied chickpea cultivars were significantly reduced under the influence of *Ageratum conyzoides* leaf extract in different concentrations compared to the control.

CONCLUSIONS

The results showed that density and planting date play an important role in controlling rapeseed weeds. Due to the fact that the weight of weeds increased with the delay in planting and the reduction of density, and the amount of rape seed yield decreased significantly. Due to the fact that the weight of weeds increased with the delay in planting and the reduction of density, and the amount of rapeseed yield decreased significantly, Therefore, it is recommended to plant rapeseed at the first suitable time for planting and avoid the delay in planting and also the recommended amount of seed is 7 kg per hectare. On the other hand, with the increase in the concentration of rapeseed root and stem extract, the percentage of germination, and the rate of germination decreased, but the rate of inhibition of germination in each type of weed increased, however, no significant difference was observed between the sources of the extract. Among the weed species, the highest decrease in germination was observed in Wild oats. In general, the results of two experiments showed that the date of planting, density and rapeseed residues can be used effectively in controlling weeds in rapeseed fields.

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