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# CHAPTER 4. APPLICATION OF OILSEED RADISH FOR WEED CONTROL AND REDUCTION OF SEGETAL SOIL DEGRADATION

## 4.1. Potential of oilseed radish herbicide competition

An oilseed radish is a well-known culture in Europe, the USA and Canada with a multifaceted nature of implementation. The multipurpose study of this species in different soils and climatic zones made it possible to formulate the main positive features potentially inherent in this plant: unpretentious to the conditions of cultivation and precursor in crop rotation (Oliveira A. et al., 2011), highly productive and nutritious, productive in after–use and post–harvest use (McCartney et al., 2009), highly intensive functioning of the root system, relatively tolerant to changes in the sowing time, marked by the rapid growth, with a high positive reaction to mineral fertilizers (Tsytsiura, Tsytsiura, 2015), highly competitive in vegetation growing in grain fields, suitable for the productive multicomponent use within forage mixtures with a wide range of accompanying crops (Dean and Weil, 2009; Malézieux, 2009), suitable for the multipurpose use (green mass, silage, haying, green manure, grass meal) (Larkin and Griffin, 2007; Davies et al., 2008), positive impact on the phytosanitary and nutrient regime of the soil, a good meliferous plant, and it is a means of revitalizing the fertility of depleted soils as a substitute for organic fertilizers by biomass ploughing (Lehrsch and Gallian, 2010; Mazzoncini et al., 2011), with high nematode resistance (Vleugels et al, 2014; Teklu et al., 2014), highly competitive against weeds (Lawley et al., 2011; Brust et al., 2014; Kunz et al., 2016), used as feedstock for biofuel production (De Andrade Avila and Sodre, 2012; Ratanapariyanuch et al., 2013) and its honey productivity (Decourtye et al., 2010).

On the one hand, regardless the above mentioned feature of this culture to suppress weeds (Lawley et al., 2011; Brust et al., 2014; Kunz et al., 2016), the issue of the effective control over weeds in its agrophytocenoses is the topical one that seek to exploit possible technological options of wide rows growing, especially for seed purposes, a rapid growth and ripening, a tendency to lay down in the final vegetation, starting from the fruiting stage.

All these factors in growth peculiarities and crop development stipulate an intensive decrease in the competitiveness of oilseed radish plants in the second vegetation period of this radish (Tsytsiura, Tsytsiura, 2015).

On the other hand, despite the technological level of the basic crops cultivation, weeds remain a significant and complex problem that restricts the effective realization of the genetic potential of varieties and hybrids of the agricultural crops (Szumigalki et al., 2005; Fennimore et al., 2008; Yaduraju et al., 2018). However, weeds are an integrated component of the overall functional life of any agrophytocenosis, and they cannot be considered separately from the total resulting bioproductivity (Cousens et al., 1995; Mortensen et al., 2000; Rola et al., 2002; Franke et al., 2009; Shaner et al., 2014). The latter statement is determined by the nature of any crop sowing as a complete multicomponent agrophytocenosis. Moreover, it has been put foraward to use the notion of an agrocenotic gradient as a certain organized sequence of fields occupied by different cultivated plants (Mirkin, 1985; Jordan, 1993; Monaco et al., 2002; Zimdah, 2007; Bajwa et al., 2017). Separate gradations of this gradient can be distinguished as sowing of the same crop. This approach corresponds to another definition of the agrophytocenosis, according to which agrophytocenosis is a plant grouping of "an arable land, a set of cultivated plants, changing during rotation or maintained as monoculture, and weeds united in a vegetative grouping" (Grodzinski, 1992; Rao, 2017). It is the emphasis on the latter statement in terms of the vegetative grouping that presents a tendency in the modern science, regarding the formation of weed levels and their detriment (Cardina et al., 1997; Fennimore et al., 2008; Dobrzański et al., 2009; Shaner et al., 2014).

The well–known practice of the role of weeds in crops is regard as an element unnecessary in crops, which at different densities and species composition can reduce crop yields in the range from 5 to 80% (Aldrich, 1987; Bruce et al., 1992; Callaway et al., 1993; Rao, 2000; Oerke et al., 2004; Jakubiak, 2005; Týr et al., 2009; Booth et al., 2010; Kraehmer et al., 2013; Abouziena et al., 2014; Korav et al., 2018; Singh et al., 2018; Westwood et al., 2018). There is also a risk of weed spread and growth due to the climate change and the emergence of weed resistance to a number of herbicides (Zimdahl et al., 2004; Kathiresan et al., 2005; Ziska et al., 2011; Kathiresan et al., 2012; Ervin et al., 2014; Singh et al., 2015; Liebman et al., 2016; Moss et al., 2017; Jugulam et al., 2019). An integral aspect of the effective crop weed control is also taking into account the current trends in soil tillage systems, fertilizer levels and intensity of herbicide control, crop rotation systems and mechanization level, etc. (Harker et al., 2013; Singh et al., 2015; Tursun et al., 2015; Liebman et al., 2017). In addition, recent studies have shown that weeds are to be regarded as inherent components of the agrophytocenosis, which perform additional positive functions in the overall trophic structure of the connections between its components (Cardina et al., 1997; Singh et al., 2006; Burgos et al., 2015; Rana et al., 2016). A complex mechanism of allelopathic effects of weeds on cultivated plants as well as on each other within different species and biological groups has been traced (Grodzinski, 1973; Kandasamy et al., 1997; Batish et al., 2002; Khanh et al., 2005; Sangeetha et al., 2015; Jabran et al., 2015).

In brief, the weed control is one of the complex and responsible parts in the overall technological management of growing all crops.

A common tactic for weed control and a number of control measures has been developed for a fairly long period of the scientific research, and it is based on establishing a critical weed control period especially for the crop (Nieto et al., 1968; Weaver et al., 1992; Berti et al., 1996; Singh ET AL., 1996; Knezevic, 2000; Rajcan et al., 2001; Singh et al., 2002; Knezevic et al., 2002; Jakubiak et al., 2006; Knezevic et al., 2015; Swanton et al., 2015; Andrew et al., 2015). So, today this indicator has been identified and analyzed for many crops (Hall et al., 1992; Norsworthy et al., 2004; Maqbool et al., 2006; Ahmadvand et al., 2009; Cardoso et al., 2011; Karkanis et al., 2012; Tursun et al., 2016; Vaishali et al., 2018) including relatives (Brassicaceae) to oilseed radish crops – a radish, a spring rapeseed, a winter rapeseed and a mustard (Martin et al., 2001; Singh et al., 2006; Paulsen et al., 2006; Hamzei et al., 2007; Beckie et al., 2008; Roshdy et al., 2008; Qasem et al., 2009; Lemerle et al., 2010; Harris et al., 2015). The conceptually indicated methodological approach allows us to exclude specifically those periods, where the culture is the least competitive in relation to weeds, from the general period of growth and development of a crop. This indicator, based on the scientific publications, has not been portrayed for the oilseed radish.

Many scientific publications on this issue highlight that the establishment of a critical weed period allows the effective planning and implementation of an integrated weed protection system based on the determination of identified crop losses and the establishment of phases and inter–phase vegetation periods with the lowest levels of competition in relation to growing in grain fields vegetation (Rana et al., 2016). The critical period indicator also allows for effective herbicide control in terms of both the appropriateness of using chemical protection and the justification for these measures considering the cost of the harvest (Knezevic et al., 2015).

An important factor in the success of weed control in the crop coenosis is the consideration of the competitiveness of a particular crop in relation to weeds in view of the basic technological solutions for the agrophytocenosis models, such as its density (stocking density and row width). Both factors have been found to influence the intensity of growth processes of both – the crop and weed plants, causing different levels of intensity in quantitative and weight terms of competition between them (Rao, 2000; Zimdahl, 2004, 2018; Booth et al., 2010; Bajwa et al., 2017).

It should be marked that critical period of crop–weed competition (CPWC) has two aspects. First is the duration of time a crop has to be kept weed free after planting so that weeds, which will be emerging later, will not reduce the grain harvest. The second is the duration of time in which weeds emerging with the crop can remain before they begin the interference with crop growth and finally reduce the yield (Rana and Kumar, 2014). It is important to reduce the critical period of the crop–weed competition in order to maximize economic revenues. A critical period is defined as the shortest time spell during the life cycle of a crop when weeding will result in the highest yield of crop or economic returns. The unequal growth between a weed and a crop is a necessary part of creating competitive advantage in favour of a crop. The aim of the unequal growth manipulations should coincide with the rapid growth stages of a crop. Tall growing cultivars cover the soil earlier, therefore, critical period of competition is shorter. Although, a critical period of weed competition is longer for dwarf cultivars. In the case of an upland crop, CPWC is longer because of the slow growth. However, CPWC is shorter for an irrigated crop. In general, one third duration of the crop growth is critical for the weed competition. Considering the importance of developing the efficient technologies and weed control strategies, the aim of tackling the basic aspects of this problem is precisely for agrophytocenoses of oilseeds of different technological patterns, for which this indicator is not marked currently as an urgent task.

The study has been carried out on the research field of Vinnytsia National Agrarian University, namely on the dark gray forest soils – Luvic Greyic Phaeozem soils (for WRB classification). The agrochemical potential of the field corresponds to the general features of this type of soil according to the main agrochemical indicators, and it includes: humus content: 2.02–3.2%, easily hydrolyzed nitrogen 67–92, mobile phosphorus 149–220, exchange potassium 92–126 mg / kg of soil at pH 5.5–6.0. The study of the weed formation in the agrophytocenosis of the Zhuravka oilseed radish is conducted on two radically distant technological variants of its modelling at the seeding rate of 4.0 million pieces / ha of similar seeds of the ordinary row sowing (15 cm) and 0.5 million pieces / ha of similar seeds of the wide–row (30 cm) sowing. The study of both options is held on a non–fertilized background. The sowing period for both variants corresponded to the end of the first – the beginning of the second decade of April.

The hydrothermal parameters of the oilseed radish vegetation period varied, having formed certain typological features of the research years (Figure 4.1).

The conditions of 2013 and especially of 2014 can be referred to the most optimal for the growth processes of the oilseed radish due to the combination of slow rates of increase in average daily temperatures and equal precipitation in the end of May – mid–June, which is phenologically, in the study area, corresponds to the active vegetation, and the rare vegetation coincides with the interphase of the phenological stem–flowering period (BBCH 30–65) (Test Guidelines to conduct tests for the distinctness, uniformity and stability of Fodder Radish (*Raphanus sativus* L. var. *oleiformis* Pers.), 2017).

The conditions of 2015 and 2018 for the period of studies on the ratio of rainfall equality, and the nature of the average daily temperature curve should be attributed to stresful for the physiological and growth processes of the oilseed radish plants. For instance, the precipitation distribution in 2015 was uneven with the total absence during the period of the second decade of May – the second decade of June due to the intense and rapid increase of average daily temperatures during the same period at high amplitude of values. This created a double effect of the overall stress of the environmental factor in the inter–phase start of budding–flowering (BBCH 38–64) with respect to the oilseed radish plants and made it possible to effectively evaluate the studied indicators in the environmental–trait system.

A prolonged atmospheric and soil drought with a slight humidity until the second decade of June was observed for the conditions of 2018 against the background of low average daily temperatures, which, unlike the conditions of 2015, affected the magnitude of the architecture of oil radish plants from the stage of rosette formation and its further stalking (BBCH 19–38). It is for these reasons that the stressful year 2018 is the most illustrative in the assessment of stress.

The years of research 2016 and 2017 by hydrothermal parameters should be attributed to the intermediate ones in the six–year study cycle with a similar dynamic regime of average daily temperatures and uneven atmospheric humidity. In this case, the terms of 2016 are close to a number of years 2013–2014, and the conditions of 2017 – to those of 2015. Thus, the increase in the overall favorable hydrothermal regimes of the oilseed radish in the direction of reducing weather risks should be placed in the following order: 2018–2015–2017–2016–2013–2014.

The critical period of sowing weediness was determined by means of widely used methodological approaches (Knezevic, 2000; Knezevic et al., 2002. Knezevic and Datta, 2015). For this purpose, from the total area of the given technological variant, the accounting squares with an area of each 4 $m^2$ were repeated four times. In turn, accounting sites were divided into two options. The first one involved the cultivation of the weed–free radish (with their complete removal) sequentially with a period of 15–90 days after sprouting (DAS).

The second was to be keep the sites under analysis in a state of weed abundancy at the same consecutive interval of 15–90 days after sprouting (DAS). Moreover, each square is kept plowed up to a certain reporting moment (15, 30, etc. days after sprouting) and after that it was maintained in a weed–free state until harvesting. This scheme is typical for the study of the critical period of weed control on cross–flowering crops (Hamzei et al., 2007). Afterwards, we gather the crops, the harvest is taken down for every sqaure, the results of each site are compared to the yield of completely weed free one. Observation is focused on the aspects: what the weed free period is, harvest as an increasing significant and at par with treatment of weedy conditions up to a particular period.

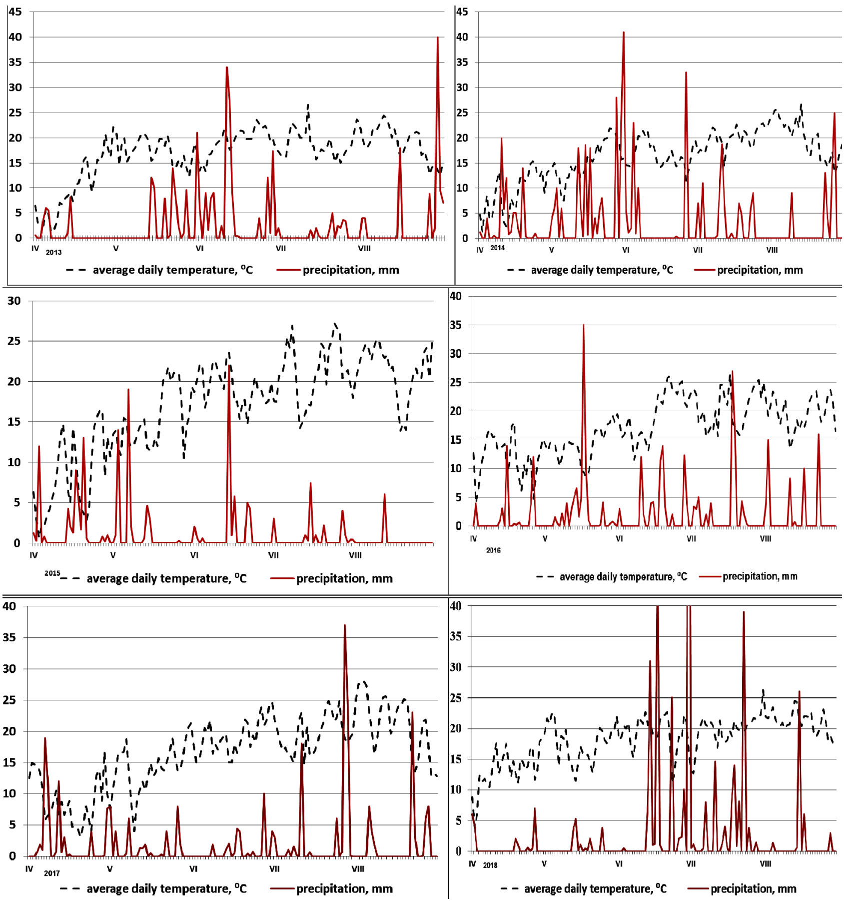



**Figure 4.1 – The hydrothermal conditions for April–August (2013–2018) in the consecutive order from left to right and from top to bottom in 2013, 2014, 2015, 2016, 2017, 2018 (Tsytsiura, 2020)**

A detailed system of weediness formation peculiarities of the oilseed radish agrophytocenosis is received in various technological ways of the pattern on the green pod phase (BBCH 75–79), on the background without taking a fertilizer or any anti–weed measures, implementing widely–used methodical approaches to recording weeds (Kosolap, 2004; Rana and Kumar, 2014), defining the following indicators (based on the initial recommendations (Curtis and Mclntosh, 1950; Misra, 1968; Dombois and Ellenberg, 1974)):

Density $D = \frac{TNI}{TNQ}$ (4.1)

TNI–Total number of individuals of a species in all squares; TNQ–Total number of squares studied

Frequency $F = \frac{TOI}{TNQ} \cdot 100$ (4.2)

where TOI–Total number of squares in which the species occurred

Abundance $Ab = \frac{TNI}{TOI}$ (4.3)

Relative density $RD = \frac{TNI}{TNS} \cdot 100$ (4.4)

where TNS–Number of individuals of all the species

Relative frequency $RF = \frac{TOI}{TOAS} \cdot 100$ (4.5)

where TOAS–Number of occurrence of all the species

Relative abundance $RAb = \frac{Ab}{TAb} \cdot 100$ (4.6)

where TAb–Total abundance of all species in all squares

Importance Value Index (Curtis, 1959) $IVI = RD + RF + RAb$ (4.7)

Summed dominance ratio $SDR = \frac{IVI}{3}$ (4.8)

The frequency classes of weed species is determined with regard to Raunkiaer (1934). There are five corresponding frequency classes, i.e. 'A' class with the species of frequency ranging from 1–20%; 'B' class 21–40%; 'C' class 41–60%; 'D' class 61–80% and 'E' class 81–100%. Furthermore, compare the weed community frequency patterns with the normal frequency pattern of Raunkiaer (A>B>C>=D<E). Based on the frequency pattern of the community, we determine the homogeneity and heterogeneity of the vegetation. If the values are high with respect to B, C and D, then the community is said to be heterogeneous where higher values of E indicates the homogeneous nature.

The layer of weed formation was determined by Maltsev's method (1962) using the tier criterion K = (H) 1/2 where H is the average quantitative value of weeds in sowing and the interval of weed height relative to the height of cultivated plants (IX). Several types of layers are distinguished according to the specified criteria: a ground layer (I) (K = 0,2; IN = 0–0,1), a lower layer (II) (K = 0,5; IN = 0,1–0,5), a middle layer (III) (K = 0.9; IN = 0.5–1.0), an upper layer (IV) (K = 1.2; IN = 1.0–2.0). Non–tiered plants (V) were attributed to coils and saline weeds, although they were assigned corresponding values by the nature of their altitude development. A generalized estimation of sowing weed (GD) was calculated on the basis of the layering indices:

$$GD = K \cdot D \tag{4.9}$$

The species composition of the weeds is determined according to the state classifiers–determinants of Ukraine (Barbarich et al., 1970; Veselovsky et al., 1988). Latin weed names are refined according to European naming rules (Williams and Hunyadi, 1988). Weed classification is conducted according to generally accepted criteria for their life expectancy, the developmental cycle, the breeding character, spreading, and the type of a weed (Kosolap, 2004; Rana and Kumar, 2014).

The current study also dwells upon indicators of the environmental plasticity (bi) and environmental stability ($Si^2$) in relation to the Ab index according to the basic approaches of their calculation (Eberhart and Russel, 1966). Oilseed radish yields were calculated using a standardized methodology for the cruciferous crop group (Saiko, 2011), using experimental statistics approaches (Sokal & Rohlf, 2012) in the form of Multivariate Analysis of Variance (MANOVA) and the statistical application programme package R (Foundation for Statistical Computing Platform version 3.5.3 (2019–03–11)), Statistica, Exel, CurveExpert Pro**:** 2.6.5.

The level of variation of indicators was conducted according to coefficient of variation (CV): very low (CV<7%); low (CV=8–12%); average (CV=13–20%); increased (CV=21–30%); high (CV=31–40%); very high (CV> 40%).

The peculiarities of weed formation of any coenosis should be considered altogether with the features of the growth and development of the main forming crop (Andrew et al., 2015). The oilseed radish has many characteristics in the vegetative development, they include the slow growth rate from the cotyledons phase to the rosette phase (BBCH 8–15), the intense reduction of stemming in the full phase of the green pod (BBCH 71–80), the cessation of any growth processes already at the phenological stage of the yellow–green pod (BBCH 75–85), the tendency to stem's laying out of the coenosis at the main fruiting stages (BBCH 76–85). This nature of the growth processes of oilseed plants causes a high level of threat from the weed growth in the early stages of its vegetation and the intensive weed growth in a slight stalk with a change in the dominance of the general vegetation in the upper layer. In addition, the extended flowering period, which is combined with a long phase of the pod formation and seed ripening against the background of the medium sowing rate, leads to increased dominance of weed plants in the microstage period of the complete yellow and brown ripeness of the pod (BBCH 75–89). Consequently, the cenosis of the oilseed radish (due to the above mentined features) is characterized by oscillation in the vertical dominance of certain biological weed groups. The total number of weed species at the maximum occurrence, found in calculations of different research years, is 48, belonging to 47 genera (Table 4.1).

Table 4.1

**The specific generic spectrum of weeds in the agrocenoses of the radish of the oil variety 'Zhuravka' in the system of averaged indicators of technological variants of modelling a cenosis on a phase of a green pod (BBCH 71–77) (on the average for 2013–2018) (Tsytsiura, 2020)**

| Family | Maximum number of species counted, spieces. | Structure, % | Maximum number of genera reported, pcs. | Structure, % |
|---|---|---|---|---|
| Asteraceae | 9 | 18.75 | 7 | 14.89 |
| Brassicaceae | 7 | 14.58 | 8 | 17.02 |
| Poaceae | 7 | 14.58 | 6 | 12.77 |
| Boraginaceae | 5 | 10.42 | 5 | 10.64 |
| Caryophyllaceae | 5 | 10.42 | 4 | 8.51 |
| Fabaceae | 4 | 8.33 | 6 | 12.77 |
| Chenopodiaceae | 5 | 10.42 | 5 | 10.64 |
| Euphorbiaceae | 3 | 6.25 | 3 | 6.38 |
| Lamiaceae | 3 | 6.25 | 3 | 6.38 |
| Total | 48 | 100.00 | 47 | 100.00 |

Among the species, the most common families are Asteraceae, Brassicaceae and Poaceae – a total of 50.0% in the overall structure of the ratio. A complex layer structure of the weediness formation of the oilseed radish agrophytocenosis in the context of its main phenological phases was also specified during the long-term evaluations (Table 4.2).

Before the phenological phase of the beginning of stalking (BBCH – 36–52), the lower layer of the oilseed radish agrocenosis is occupied by weeds such as *Elytrigia repens (L.) Gould, Equisetum arvense L., Taraxacum officinale Wigg., Polygonum scabrum Moench, Setaria glauca L., Setaria viridis L., Lamium purpureum L, Thlaspi arvense L., Capsella bursa–pastoris (L.) Medic., Stellaria media L*. There are weeds in the same altitude with the radish oil plants: *Brassica campestris L.*, *Raphanus raphanistrum L.*, *Sinapis arvensis L.*, *Chenopodium album L.*, *Amaranthus retroflexus L.*, *Echinochloa crus–galli L.*, *Galium aparine L.*, *Rocket-cress R. Br.*, *Convolvulus arvensis L.*. The leading role in the coenosis, by the altitude gradient, belong to the weeds such as Sonchus arvensis L, *Cirsium arvense L.*, *Lactuca tataricia L.*, *Artemisia absinthium L.*, *Artemisia vulgaris L.* During the ripening of the oilseed radish plants, the nature of altitude dominance changes in favour of weeds that previously occupied the middle and higher layers in relation to the height of the oilseed radish plants.

This essense of the growth processes stipulates differences in the competitiveness levels of the oilseed radish plants and determines the critical period of its susceptibility to weeds in the interphase of the germination–stalking period (microstages BBCH 10–36). It is determined that the weedy type of the oilseed radish agrocenosis is oscillatory from dicotyledonous–cereal–non–perennial in the interphase period germinate–rosette – to root–germinating–rhizome–non–perennial type in the interphase period of the green–yellow ripeness of pods (BBCH 70–84).

It should be noted that according to the nature of the agrocenosis weed types formation and the magnitude of the frequency index there can be singled out individual species, that correlates to the results of the individual studies It should be noted that according to the nature of the formation of weed types of agrocenosis and the value of the frequency index, bridges of certain species are found, which corresponds to the results of individual studies (Aldrich, 1987; Szumigalki and van Acker, 2005; Page et al., 2010; Afifi and Swanton, 2012; Harris et al., 2015; Zimdahl, 2018), a rare oilseed radish in a system of intensive planting density of standing can be attributed to crops with high competition potential in relation to the main weed species.

The results of assessments of weed vegetation dynamics indicate a gradual increase in cenotic tension due to the gradual transition of dominant weed species such as *Chenopodium album L.*, *Amaranthus retroflexus L.*, *Echinochloa crus–galli L.*, *Elytrigia repens (L.)*, *Sonchus arvensis L.*, *Cirsium arvense L.*, *Convolvulus arvensis L.* in the middle and upper sowing stages while increasing the frequency of their determination by 1.1–1.3 times. The problem of the remarkable dominance of individual weeds, including the multi–year cycle of development, is common in the aspects of the effective weed control over all cross–flowering crops (Hulting, 2004; Lososova et al., 2004; Harris et al., 2015).

As a result, the phenological periodization of weed formation in the agrocenosis of the oilseed radish and the nature of their layer development is confirmed by their basic physiological features considering the maximum dense and minimal dense technological model of the oilseed radish coenosis on the phenological phase of the crop, which corresponds to Table 4.3.

Table 4.2

**Typology of weeds dynamics of the oilseed radish agrophytocenosis in the context of the main interphase periods in the context of two technological variants of its modelling (on the average for 2013–2018) (Tsytsiura, 2020)**

| **The interphase period** | **Types of weeds growth** | **Weeds layers** | **The main representatives of weeds within each layer and the frequency (F,%) of their determination** |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| BBCH 10–19 (germination– rosette) | Non–perennial (dicotyledonous–cereal–annual) | I (II), II (H), III (C) | **Groundwater:** *Capsella bursa–pastoris* 8.5* (10.7**)%, *Stellária média* 2.4 (4.2)%, *Thlaspi arvense L.* 7.5* (9,3**)%, *Veronica hederifolia* 2.2 (1.3)%, *Poa annua L.* 0.9 (1.3)%. **Lower:** *Galium aparine L.* 1.3 (1.9)%, *Taraxacum officinale Wigg.* 1,8 (2.4)%, *Equisetum arvense L.)* (2.4 (6.7)%, *Elytrigia repens (L.) Gould* (7.5 (24.7)%, *Sonchus arvensis L* 8.4 (14.2)%, *Convolvulus arvensis L.* 12,4 (20,3)%, *Brassica campestris L.* 1.5 (6.9)%, *Raphanus raphanistrum L.)* 5.5 (6.7)%, *Sinapis arvensis L.* 2.8 (3.3)%, *Carduus acanthoides L.* 0.5 (0.8)%. **Middle:** *Rocket-cress R.Br.* 5.5 (12.8)%, *Lactuca tatarica L*) 10.8 (16.4)%, *Cirsium arvense L.* 11.8 (21.3)%. |

(End of Table 4.2)

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| BBCH 20–39 (rosette–stalking) | Non–perennial–root–sprout–rhizome | II–IV(H–B) | **Groundwater:** *Stellária média* 8.7 (6.5)%, *Veronica hederifolia* 6.8 (3.1)%, *Anagallis arvensis L. 6.3 (3.9)%.* **Lower:** *Capsella bursa–pastoris* 10.8 (12.7)%, *Thlaspi arvense L.)* 9.9 (11.8)%, *Artemisia absinthium L.* 1.2 (2.2)%, *Artemisia vulgaris L.* 0.6 (1.3) %*, Chenopodium album L.* 18.5 (27.3)%, *Polygonum scabrum Moench 7.8* (12.6)%, *Amaranthus retroflexus L.* 22.5 (30.3)%, *Echinochloa crus–galli L.*(33.8 (40.2)%, *Setaria glauca L. 37.9 (47.2)%, Setaria viridis L. 2.8* (3.5)%, *Tripleurospermum inodorum (L.) Sch. Bip.* 6.8 (10.1)%. **Middle:** *Galium aparine L.)* 2.2 (3.4)%, *Rocket-cress R. Br.* 9.3 (15.7)%*, Elytrigia repens (L.) Gould* 9.8 (30.6) %*, Sonchus arvensis L.* 12.8 (21.8)%, *Cirsium arvense L.)* 18.1 (25.7)%, *Convolvulus arvensis L.* 19.1 (22.8)%. *Lactuca tataricia L.* 12.6 (20.3)%, *Brassica campestris L.* 3.2 (7.8 %), *Raphanus raphanistrum L. 2.*6 (5.3)%, *Rocket-cress R.Br.* 2.0 (8.7) %, *Poa annua L.* 1.9 (2.8)%, *Sinapis arvensis L.* 2.7 (3.5)%, *Carduus acanthoides L.* 0.9 (1.1)%. **Uppe**r**:** *Brassica campestris L.* 6.3 (12.8 %), *Raphanus raphanistrum L. 7.6* (8.1)%, *Rocket-cress R.Br.* 4.6 (13.5) %*, Sinapis arvensis L.* 3.7 (4.9)% |
| BBCH 50–69 (budding – flowering) | Non–perennial–root–sprout–rhizome | II–IV (H–B) | **Groundwater:** (*Stellária média*) 10.6 (6.9) %, *Veronica hederifolia* 10.8 (4.2)%, *Anagallis arvensis L.* 10.5 (5.2)%*, Portulaca oleraceae L. 10.5 (7,7)%, Elytrigia repens (L.) Gould 5,6* (11.9) %. **Lower:** *Galinsoga parviflora Cav.* 16.8 (30.2)%, *Chenopodium album L.* 10.9 (16.2)%, *Elytrigia repens (L.) Gould* 4.9 (9.7) %, *Echinochloa crus–galli L.*(14.2 (17.5)%, *Setaria glauca L.* 21.6 (31.3)%, *Cynodon dactylon L.* 5.6 (8.3)%, *Lepidium ruderale L.* 4.8 (6.1)%, *Erigeron canadensis L.* 7.4 (9.1)%, *Amaranthus retroflexus L* 16.3 (22.7)%, *Setaria glauca L.)* 23.9 (33.5)%, *Echinochloa crus–galli L.* 16.7 (24.8)%, *Sonchus arvensis L* 10.8 (14.7)%, *Convolvulus arvensis L.* 9.6 (11.8)%, *Poa annua L. 2.4* (3.2)%. **Middle**: *Erigeron canadensis L.* 5.4 (7.5)%, *Chenopodium album L.)* 20.2 (34.5)%, *Polygonum scabrum Moench)* 12.6 (20.8)%, *Amaranthus retroflexus L.)* 24.6 (32,9)%, *Echinochloa crus–galli L.* 16.2 (22.7)%, *Setaria glauca L.* 27.8 (35.6) %*, (Elytrigia repens (L.) Gould* 20.8 (32.3)%*, Sonchus arvensis L* 12.9 (19.1)%, *Cirsium arvense L. 15.9* (22.7) %, *Convolvulus arvensis L.)* 15.2 (20.9) %*, Lactuca tataricia L.* 6.8 (11.4)%*, Artemisia absinthium L.* 1.5 (2.6) %, *Artemisia vulgaris L.* 1.7 (2.5)%*, Tripleurospermum inodorum (L.) Sch. Bip)* (6.4 %) *Carduus acanthoides L.* 1.1 (1.3)%, *Brassica campestris L.* 2.8 (3.7)%, *Raphanus raphanistrum L.* 1.7 (4.1)%, *Rocket-cress R.Br.* 2.8 (5.4) %*, Sinapis arvensis L.* 2.3 (3.4)%. **Uppe**r**:** *Chenopodium album L.* 18.9 (24.5)%*, Echinochloa crus–galli L.* 10.8 (15.9)%*, Sonchus arvensis L*) 5.8 (7.2) %, *Cirsium arvense L.* 6.8 (9.3) %, *Convolvulus arvensis L.* 4.2 (5.3)%, *Amaranthus retroflexus L.* 10.7 (12.2)%, *Artemisia absinthium L.* 1.8 (2.2)%, *Artemisia absinthium L.* 1.4 (1.7)%, *Carduus acanthoides L.* 1.2 (1.6)% |

* – for the technological variant 4,0 million pieces/ha of similar seeds; ** – for the technological variant 0.5 million pieces / ha of similar seeds.

Table 4.3

**The phytosociological attributes of oilseed radish weeds on average for the period 2013–2018 per a starting fruiting phase (OVS 70–74) (for the total annual number of accounted squares of 1m² 50) (Tsytsiura, 2020)**

| Name of the species | | TOI. шт | $CV_{TOI}$. % | TNI. шт | $CV_{TIN}$. % | Ab | D | F. % | Fcl | RAb. % | RD. % | RF. % | IVI. % | SDR. % | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Thlaspi* | *1** | 3.83 | 19.6 | 5.17 | 22.6 | 1.35 | 0.10 | 7.67 | A | 1.30 | 0.44 | 1.01 | 2.75 | 0.92 | 0.5 |
| *arvense L* | *2* | 10.50 | 23.1 | 12.33 | 16.7 | 1.17 | 0.25 | 21.00 | B | 0.89 | 0.60 | 2.19 | 3.68 | 1.23 | 0.5 |
| Linaria vulgaris | *1* | 2.33 | 22.1 | 2.17 | 18.8 | 0.93 | 0.04 | 4.67 | A | 0.90 | 0.18 | 0.62 | 1.69 | 0.56 | 0.9 |
| Milk | *2* | 3.50 | 53.5 | 3.50 | 53.5 | 1.00 | 0.07 | 7.00 | A | 0.75 | 0.17 | 0.73 | 1.65 | 0.55 | 0.9 |
| Xanthoxalis | *1* | 1.33 | 38.7 | 2.17 | 34.7 | 1.63 | 0.04 | 2.67 | A | 1.57 | 0.18 | 0.35 | 2.10 | 0.70 | 0.2 |
| fontana | *2* | 4.33 | 43.0 | 5.83 | 51.3 | 1.35 | 0.12 | 8.67 | A | 1.02 | 0.29 | 0.90 | 2.20 | 0.73 | 0.2 |
| Barbarea | *1* | 3.33 | 15.5 | 4.33 | 27.9 | 1.30 | 0.09 | 6.67 | A | 1.25 | 0.37 | 0.88 | 2.50 | 0.83 | 0.9 |
| vulgaris R.Br. | *2* | 11.33 | 20.6 | 16.67 | 47.3 | 1.47 | 0.33 | 22.67 | B | 1.11 | 0.81 | 2.36 | 4.28 | 1.43 | 0.9 |
| Daucus carota | *1* | 1.83 | 22.3 | 2.50 | 21.9 | 1.36 | 0.05 | 3.67 | A | 1.32 | 0.21 | 0.48 | 2.01 | 0.67 | 0.5 |
| L. | *2* | 3.67 | 44.5 | 5.33 | 64.6 | 1.45 | 0.11 | 7.33 | A | 1.10 | 0.26 | 0.76 | 2.12 | 0.71 | 0.5 |
| Lappula squarrosa | *1* | 1.33 | 38.7 | 3.17 | 23.8 | 2.38 | 0.06 | 2.67 | A | 2.29 | 0.27 | 0.35 | 2.91 | 0.97 | 0.9 |
| (Retz.) Dumort | *2* | 1.83 | 41.1 | 2.83 | 56.5 | 1.55 | 0.06 | 3.67 | A | 1.17 | 0.14 | 0.38 | 1.69 | 0.56 | 0.9 |
| Lamium | *1* | 3.00 | 21.1 | 4.67 | 17.5 | 1.56 | 0.09 | 6.00 | A | 1.50 | 0.39 | 0.79 | 2.69 | 0.90 | 0.2 |
| purpureum L | *2* | 2.50 | 55.1 | 5.17 | 62.9 | 2.07 | 0.10 | 5.00 | A | 1.56 | 0.25 | 0.52 | 2.33 | 0.78 | 0.2 |
| Berteroa | *1* | 1.17 | 35.0 | 2.17 | 18.8 | 1.86 | 0.04 | 2.33 | A | 1.79 | 0.18 | 0.31 | 2.28 | 0.76 | 0.5 |
| incana L. | *2* | 1.50 | 36.5 | 3.33 | 41.0 | 2.22 | 0.07 | 3.00 | A | 1.68 | 0.16 | 0.31 | 2.15 | 0.72 | 0.5 |
| Veronica | *1* | 6.00 | 14.9 | 11.00 | 14.1 | 1.83 | 0.22 | 12.00 | A | 1.77 | 0.93 | 1.58 | 4.28 | 1.43 | 0.2 |
| hederifolia L. | *2* | 2.33 | 22.1 | 4.83 | 49.7 | 2.07 | 0.10 | 4.67 | A | 1.56 | 0.24 | 0.49 | 2.28 | 0.76 | 0.2 |
| Carduus | *1* | 3.33 | 15.5 | 5.33 | 28.2 | 1.60 | 0.11 | 6.67 | A | 1.54 | 0.45 | 0.88 | 2.87 | 0.96 | 1.2 |
| acanthoides L. | *2* | 4.17 | 28.1 | 19.17 | 32.2 | 4.60 | 0.38 | 8.33 | B | 3.47 | 0.94 | 0.87 | 5.27 | 1.76 | 1.2 |
| Lepidium | *1* | 2.33 | 22.1 | 3.83 | 19.6 | 1.64 | 0.08 | 4.67 | A | 1.59 | 0.32 | 0.62 | 2.53 | 0.84 | 0.5 |
| ruderale L. | *2* | 4.33 | 34.7 | 11.33 | 21.4 | 2.62 | 0.23 | 8.67 | A | 1.97 | 0.55 | 0.90 | 3.43 | 1.14 | 0.5 |

(End of Table 4.3)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Erigeron canadensis L. | *1* | 5.67 | 18.2 | 10.33 | 11.7 | 1.82 | 0.21 | 11.33 | A | 1.76 | 0.87 | 1.50 | 4.13 | 1.38 | 0.9 |
| | 2 | 9.67 | 16.9 | 24.00 | 32.6 | 2.48 | 0.48 | 19.33 | A | 1.87 | 1.17 | 2.01 | 5.06 | 1.69 | 0.5 |
| Raphanus raphanistrum L. | *1* | 4.17 | 18.1 | 6.33 | 19.1 | 1.52 | 0.13 | 8.33 | A | 1.47 | 0.53 | 1.10 | 3.10 | 1.03 | 0.9 |
| | 2 | 4.17 | 18.1 | 10.67 | 29.4 | 2.56 | 0.21 | 8.33 | A | 1.93 | 0.52 | 0.87 | 3.32 | 1.11 | 0.9 |
| Amaranthus Blifoides S. Wats. | *1* | 2.33 | 22.1 | 3.33 | 31.0 | 1.43 | 0.07 | 4.67 | A | 1.38 | 0.28 | 0.62 | 2.28 | 0.76 | 0.9 |
| | 2 | 2.17 | 34.7 | 2.33 | 51.9 | 1.08 | 0.05 | 4.33 | A | 0.81 | 0.11 | 0.45 | 1.38 | 0.46 | 0.5 |
| Anagallis arvensis L. | *1* | 6.33 | 12.9 | 8.33 | 14.5 | 1.32 | 0.17 | 12.67 | A | 1.27 | 0.70 | 1.67 | 3.65 | 1.22 | 0.2 |
| | 2 | 3.00 | 29.8 | 5.17 | 41.4 | 1.72 | 0.10 | 6.00 | A | 1.30 | 0.25 | 0.63 | 2.18 | 0.73 | 0.2 |
| Brassica campestris L. | *1* | 11.17 | 18.3 | 19.17 | 14.2 | 1.72 | 0.38 | 22.33 | B | 1.66 | 1.62 | 2.95 | 6.22 | 2.07 | 0.9 |
| | 2 | 9.67 | 22.3 | 14.17 | 30.7 | 1.47 | 0.28 | 19.33 | A | 1.11 | 0.69 | 2.01 | 3.81 | 1.27 | 0.9 |
| Artemisia vulgaris L | *1* | 3.33 | 24.5 | 4.33 | 27.9 | 1.30 | 0.09 | 6.67 | A | 1.25 | 0.37 | 0.88 | 2.50 | 0.83 | 1.2 |
| | 2 | 2.83 | 34.7 | 7.83 | 14.9 | 2.76 | 0.16 | 5.67 | A | 2.08 | 0.38 | 0.59 | 3.06 | 1.02 | 0.9 |
| Artemisia absinthium L.. | *1* | 2.33 | 22.1 | 5.33 | 19.4 | 2.29 | 0.11 | 4.67 | A | 2.21 | 0.45 | 0.62 | 3.27 | 1.09 | 1.2 |
| | 2 | 2.17 | 34.7 | 3.50 | 30.0 | 1.62 | 0.07 | 4.33 | A | 1.22 | 0.17 | 0.45 | 1.84 | 0.61 | 1.2 |
| Taraxacum officinale | *1* | 5.00 | 21.9 | 8.33 | 25.9 | 1.67 | 0.17 | 10.00 | A | 1.61 | 0.70 | 1.32 | 3.63 | 1.21 | 0.5 |
| | 2 | 11.83 | 19.6 | 15.50 | 24.7 | 1.31 | 0.31 | 23.67 | B | 0.99 | 0.76 | 2.47 | 4.21 | 1.40 | 0.5 |
| Cirsium arvense L. | *1* | 21.33 | 23.1 | 114.50 | 18.6 | 5.37 | 2.29 | 42.67 | C | 5.18 | 9.67 | 5.63 | 20.48 | 6.83 | 1.2 |
| | 2 | 23.83 | 13.4 | 149.00 | 30.6 | 6.25 | 2.98 | 47.67 | C | 4.71 | 7.29 | 4.97 | 16.96 | 5.65 | 1.2 |
| Sonchus arvensis L. | *1* | 14.17 | 18.1 | 22.33 | 17.6 | 1.58 | 0.45 | 28.33 | B | 1.52 | 1.89 | 3.74 | 7.15 | 2.38 | 1.2 |
| | 2 | 17.83 | 16.0 | 27.83 | 28.3 | 1.56 | 0.56 | 35.67 | B | 1.18 | 1.36 | 3.72 | 6.25 | 2.08 | 1.2 |
| Convolvulus arvensis L. | *1* | 9.17 | 23.3 | 14.00 | 12.8 | 1.53 | 0.28 | 18.33 | A | 1.47 | 1.18 | 2.42 | 5.08 | 1.69 | 0.9 |
| | 2 | 12.33 | 19.0 | 32.00 | 26.0 | 2.59 | 0.64 | 24.67 | B | 1.96 | 1.56 | 2.57 | 6.09 | 2.03 | 0.9 |
| Equisetum arvense L. | *1* | 2.17 | 18.8 | 6.00 | 23.6 | 2.77 | 0.12 | 4.33 | A | 2.67 | 0.51 | 0.57 | 3.75 | 1.25 | 0.5 |
| | 2 | 6.17 | 19.0 | 14.83 | 13.1 | 2.41 | 0.30 | 12.33 | A | 1.81 | 0.73 | 1.28 | 3.82 | 1.27 | 0.5 |
| Cynodon dactylon L. | *1* | 5.17 | 22.6 | 11.33 | 15.5 | 2.19 | 0.23 | 10.33 | A | 2.12 | 0.96 | 1.36 | 4.44 | 1.48 | 0.5 |
| | 2 | 6.67 | 27.9 | 14.83 | 16.2 | 2.23 | 0.30 | 13.33 | A | 1.68 | 0.73 | 1.39 | 3.79 | 1.26 | 0.5 |
| Achillea millefolium L. | *1* | 2.33 | 22.1 | 4.17 | 28.1 | 1.79 | 0.08 | 4.67 | A | 1.72 | 0.35 | 0.62 | 2.69 | 0.90 | 0.9 |
| | 2 | 5.17 | 22.6 | 9.50 | 14.5 | 1.84 | 0.19 | 10.33 | A | 1.39 | 0.46 | 1.08 | 2.93 | 0.98 | 0.9 |

(End of Table 4.3)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elytrigia repens L | *1* | 27.33 | 25.6 | 70.17 | 19.4 | 2.57 | 1.40 | 54.67 | C | 2.48 | 5.92 | 7.22 | 15.62 | 5.21 | 0.9 |
| | *2* | 35.83 | 15.4 | 130.00 | 19.8 | 3.63 | 2.60 | 71.67 | D | 2.74 | 6.36 | 7.47 | 16.56 | 5.52 | 0.9 |
| *Delphinium consolida* | *1* | 6.50 | 23.3 | 10.33 | 22.6 | 1.59 | 0.21 | 13.00 | A | 1.53 | 0.87 | 1.72 | 4.12 | 1.37 | 0.5 |
| | *2* | 7.83 | 26.1 | 13.67 | 15.8 | 1.74 | 0.27 | 15.67 | A | 1.32 | 0.67 | 1.63 | 3.62 | 1.21 | 0.5 |
| Tripleuro-spermum inodorum L. | *1* | 8.17 | 32.3 | 15.17 | 13.5 | 1.86 | 0.30 | 16.33 | A | 1.79 | 1.28 | 2.16 | 5.23 | 1.74 | 0.5 |
| | *2* | 21.33 | 10.1 | 41.17 | 24.3 | 1.93 | 0.82 | 42.67 | C | 1.46 | 2.01 | 4.44 | 7.91 | 2.64 | 0.5 |
| Senecio vernalis Waldst | *1* | 5.50 | 25.1 | 7.33 | 23.9 | 1.33 | 0.15 | 11.00 | A | 1.29 | 0.62 | 1.45 | 3.36 | 1.12 | 0.9 |
| | *2* | 8.83 | 16.7 | 13.83 | 16.7 | 1.57 | 0.28 | 17.67 | A | 1.18 | 0.68 | 1.84 | 3.70 | 1.23 | 0.9 |
| *Lactuca Tatarica L.* | *1* | 5.33 | 22.7 | 6.33 | 35.5 | 1.19 | 0.13 | 10.67 | A | 1.15 | 0.53 | 1.41 | 3.09 | 1.03 | 0.9 |
| | *2* | 10.83 | 20.6 | 22.50 | 24.5 | 2.08 | 0.45 | 21.67 | B | 1.57 | 1.10 | 2.26 | 4.92 | 1.64 | 0.9 |
| *Capsella bursa pastoris L.* | *1* | 10.33 | 22.6 | 14.00 | 20.2 | 1.35 | 0.28 | 20.67 | A | 1.31 | 1.18 | 2.73 | 5.22 | 1.74 | 0.2 |
| | *2* | 10.00 | 16.7 | 23.83 | 13.4 | 2.38 | 0.48 | 20.00 | A | 1.80 | 1.17 | 2.08 | 5.05 | 1.68 | 0.2 |
| Centaurea cyanus L. | *1* | 5.50 | 15.2 | 7.33 | 22.3 | 1.33 | 0.15 | 11.00 | A | 1.29 | 0.62 | 1.45 | 3.36 | 1.12 | 0.5 |
| | *2* | 5.33 | 19.4 | 7.67 | 13.5 | 1.44 | 0.15 | 10.67 | A | 1.08 | 0.37 | 1.11 | 2.57 | 0.86 | 0.5 |
| Portulaca oleraceae L. | *1* | 8.33 | 28.1 | 16.00 | 17.7 | 1.92 | 0.32 | 16.67 | A | 1.85 | 1.35 | 2.20 | 5.40 | 1.80 | 0.2 |
| | *2* | 6.00 | 14.9 | 13.50 | 15.4 | 2.25 | 0.27 | 12.00 | A | 1.70 | 0.66 | 1.25 | 3.61 | 1.20 | 0.2 |
| Galinsoga parviflora Cav. | *1* | 12.50 | 17.3 | 16.33 | 21.1 | 1.31 | 0.33 | 25.00 | B | 1.26 | 1.38 | 3.30 | 5.94 | 1.98 | 0.5 |
| | *2* | 23.17 | 13.8 | 46.50 | 24.2 | 2.01 | 0.93 | 46.33 | C | 1.51 | 2.27 | 4.83 | 8.61 | 2.87 | 0.5 |
| Spergula vulgaris Boenn. | *1* | 2.50 | 21.9 | 5.33 | 28.2 | 2.13 | 0.11 | 5.00 | A | 2.06 | 0.45 | 0.66 | 3.17 | 1.06 | 0.5 |
| | *2* | 2.33 | 22.1 | 4.67 | 26.0 | 2.00 | 0.09 | 4.67 | A | 1.51 | 0.23 | 0.49 | 2.22 | 0.74 | 0.5 |
| Amaranthus retroflexus L. | *1* | 31.17 | 16.5 | 75.17 | 22.4 | 2.41 | 1.50 | 62.33 | D | 2.33 | 6.35 | 8.23 | 16.90 | 5.63 | 1.2 |
| | *2* | 35.83 | 13.5 | 156.00 | 18.3 | 4.35 | 3.12 | 71.67 | D | 3.28 | 7.63 | 7.47 | 18.38 | 6.13 | 0.9 |
| Polygonum aviculare L. | *1* | 1.50 | 36.5 | 2.33 | 22.1 | 1.56 | 0.05 | 3.00 | A | 1.50 | 0.20 | 0.40 | 2.09 | 0.70 | 0.2 |
| | *2* | 2.33 | 22.1 | 5.00 | 17.9 | 2.14 | 0.10 | 4.67 | A | 1.62 | 0.24 | 0.49 | 2.35 | 0.78 | 0.2 |
| Sonchus oleraceus L. | *1* | 5.50 | 19.1 | 8.17 | 16.3 | 1.48 | 0.16 | 11.00 | A | 1.43 | 0.69 | 1.45 | 3.57 | 1.19 | 1.2 |
| | *2* | 8.17 | 19.6 | 10.50 | 13.1 | 1.29 | 0.21 | 16.33 | A | 0.97 | 0.51 | 1.70 | 3.18 | 1.06 | 1.2 |

(End of Table 4.3)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Polygonum scabrum Moench. | *1* | 12.33 | 18.3 | 21.00 | 12.0 | 1.70 | 0.42 | 24.67 | B | 1.64 | 1.77 | 3.26 | 6.67 | 2.22 | 0.5 |
| | 2 | 17.17 | 15.8 | 44.00 | 20.9 | 2.56 | 0.88 | 34.33 | B | 1.93 | 2.15 | 3.58 | 7.66 | 2.55 | 0.5 |
| Echinochloa crus–galli L. | *1* | 29.33 | 22.4 | 77.83 | 16.6 | 2.65 | 1.56 | 58.67 | C | 2.56 | 6.57 | 7.74 | 16.88 | 5.63 | 1.2 |
| | 2 | 35.83 | 13.3 | 97.67 | 18.5 | 2.73 | 1.95 | 71.67 | D | 2.06 | 4.78 | 7.47 | 14.30 | 4.77 | 1.2 |
| Setaria viridis L. | *1* | 12.50 | 24.7 | 34.17 | 16.4 | 2.73 | 0.68 | 25.00 | B | 2.64 | 2.88 | 3.30 | 8.82 | 2.94 | 0.5 |
| | 2 | 8.33 | 22.3 | 19.50 | 22.6 | 2.34 | 0.39 | 16.67 | A | 1.76 | 0.95 | 1.74 | 4.45 | 1.48 | 0.5 |
| Setaria glauca L.. | *1* | 28.00 | 19.6 | 267.83 | 18.1 | 9.57 | 5.36 | 56.00 | C | 9.23 | 22.61 | 7.39 | 39.24 | 13.08 | 0.9 |
| | 2 | 31.17 | 15.2 | 690.17 | 18.6 | 22.14 | 13.80 | 62.33 | D | 16.70 | 33.75 | 6.49 | 56.94 | 18.98 | 0.5 |
| Galium aparine L. | *1* | 5.33 | 25.6 | 7.83 | 27.3 | 1.47 | 0.16 | 10.67 | A | 1.42 | 0.66 | 1.41 | 3.49 | 1.16 | 0.5 |
| | 2 | 2.50 | 21.9 | 6.00 | 21.1 | 2.40 | 0.12 | 5.00 | A | 1.81 | 0.29 | 0.52 | 2.62 | 0.87 | 0.5 |
| Chenopodium album L. | *1* | 21.33 | 16.7 | 205.33 | 14.7 | 9.63 | 4.11 | 42.67 | C | 9.29 | 17.34 | 5.63 | 32.26 | 10.75 | 1.2 |
| | 2 | 27.00 | 11.2 | 243.50 | 18.7 | 9.02 | 4.87 | 54.00 | C | 6.80 | 11.91 | 5.63 | 24.33 | 8.11 | 0.9 |
| Sinapis arvensis L. | *1* | 4.33 | 23.8 | 8.00 | 23.7 | 1.85 | 0.16 | 8.67 | A | 1.78 | 0.68 | 1.14 | 3.60 | 1.20 | 0.9 |
| | 2 | 4.00 | 22.4 | 19.33 | 21.1 | 4.83 | 0.39 | 8.00 | A | 3.64 | 0.95 | 0.83 | 5.42 | 1.81 | 0.9 |
| Polygonum convolvulus L. | *1* | 2.50 | 21.9 | 6.33 | 12.9 | 2.53 | 0.13 | 5.00 | A | 2.44 | 0.53 | 0.66 | 3.64 | 1.21 | 0.9 |
| | 2 | 2.33 | 22.1 | 1.83 | 41.1 | 0.79 | 0.04 | 4.67 | A | 0.59 | 0.09 | 0.49 | 1.17 | 0.39 | 0.9 |
| Poa annua L.. | *1* | 2.33 | 22.1 | 3.33 | 15.5 | 1.43 | 0.07 | 4.67 | A | 1.38 | 0.28 | 0.62 | 2.28 | 0.76 | 0.5 |
| | 2 | 2.33 | 22.1 | 2.00 | 44.7 | 0.86 | 0.04 | 4.67 | A | 0.65 | 0.10 | 0.49 | 1.23 | 0.41 | 0.5 |
| Stellaria media L. | *1* | 6.17 | 19.0 | 14.33 | 10.5 | 2.32 | 0.29 | 12.33 | A | 2.24 | 1.21 | 1.63 | 5.08 | 1.69 | 0.2 |
| | 2 | 4.00 | 27.4 | 10.83 | 21.4 | 2.71 | 0.22 | 8.00 | A | 2.04 | 0.53 | 0.83 | 3.41 | 1.14 | 0.2 |
| Всього | *1* | 378.8 | 22.3* | 1184.3 | 20.4* | 103.6 | 23.7 | 757.7 | – | 100.0 | 100.0 | 100.0 | 300.0 | 100.0 | 33.9 |
| | 2 | 480.0 | 24.1* | 2045.2 | 28.6* | 132.6 | 40.9 | 960.0 | – | 100.0 | 100.0 | 100.0 | 300.0 | 100.0 | 31.8 |

TOI = Total Occurrence of Individuals, $CV_{TOI}$ = coefficient of variation of the Total Occurrence of Individuals, TNI = Total Number of Individuals, $CV_{TNI}$ = coefficient of variation of the Total Number of Individuals, Ab = Abundance, D = Density, F = Frequency, Fcl = Frequency classes; RA= Relative Abundance, RD = Relative Density, RF = Relative Frequency, IVI = Importance Value Index, and SDI = Summed dominance ratio, K=tier criterion; 1 – for seeding rates of 4.0 million pieces / ha of similar seeds; 2 sowing rates of 0.5 million pieces / ha of similar seeds; *– inferior to the value of the flow.

The weed population in the agrophytocenosis of the oilseed radish of two radically remote technological variants is heterogeneous according to the given indicators. This is showed by the ratio of the frequency classes (F) A> B> C> = D <E (Raunkiaer, 1934). To be more specific, the presented indicators determine the amount of dominance in the crop, and the highest indicator is observed among such weed species as *Chenopodium album L.*, *Amaranthus retroflexus L.*, *Echinochloa crus–galli L.*, *Setaria glauca L.*, *Galinsoga parviflora Cav*. До зимуючих однорічників *Lactuca serriola L*, *Galium aparine L.*, *Rocket-cress R. Br.*, *Thlaspi arvense L.*, *Capsella bursa–pastoris (L.) Medic.*, *Tripleurospermum inodorum (L.) Sch. Bip.* i *Stellaria media L.* The marked spectrum of perennial weeds is represented in the agrocenoses of oilseed radish by the rhizome forms of *Elytrigia repens L.*, *Equisetum arvense L.*, root–sprout forms of *Sonchus arvensis L.*, *Cirsium arvense L., Convolvulus arvensis L.*, taproot forks and non–root forms *Taraxacum officinale Wigg.*, *Lactuca tataricia*, *Artemisia absinthium L.*, *Artemisia vulgaris L.* Contrary to the revealed peculiarities for a spring rapeseed (Martin et al., 2001), a white mustard (Singh, 2006), more distinctive layer differentiation of weed species is typical of the agrocenosis of the oilseed radish and strongly marked inhibition of the soil and the lower layer, especially interfacial stalking–flowering period (BBCH 25–55).

It should be noted that both quantitative and structured weed abundances in the coenosis of oilseed radish with a density of 4.0 million pieces / ha of similar seeds are substantially lower than in the version of 0.5 million pieces / ha of similar seeds. Therefore, the total weed abundance in the first variant over the study period equals 17.2 ppm less than in the second variant of the coenosis density. With the preservation of the species structure of weeds, the layering level of their formation was less than 2.1 pieces of the displaced dominant by the level coefficient (K) in the variant of 0.5 million pieces / ha of similar seeds, which indicates the increase in the vitality of the oil–radish plants for reduction in seeding rates on the one hand, and on the other, an overall increase in F of 26.7% in this embodiment indicates an overall increase in the number of weeds in the lower and middle layers. That is to say, the effect of competitiveness of weed plants in relation to weeds tends to decline as the density of their plants is reduced, but this decrease is not directly proportional, since it is limited by the redistribution of the layering structure of the weeds and the change in the vitality tactics of the oilseed radish proper. It should also be specified that within the variation in the TII and TNI indices, the number of specific weed species depended on the hydrothermal conditions of the year, since in this case the coefficient of variation determines the annual fluctuations in the number of the definite individual species. Diffrent types of weeds have different degrees of adaptаищдшен to the changing hydrothermal vegetation conditions by the magnitude of the variation coefficient from low to very high. At the same time, the variation in the number of annual plants is on average 5.6% higher than the variation in the number of perennial forms. The variability of the species composition of the weeds is 1.4 times higher than the sowing rate of 0.5 million pieces / ha of similar seeds according to the results of the average value of the variation coefficient in the TNI expression. This confirms our findings once more as to the expansion of the range of vitality tactics of weed species in the oilseed radish agrocenosis by reducing the total cenotic pressure per a unit area. The same is also proved by the Generalized Weed Estimation (GD) score for two coenosis constructs in general. This indicator averaged 22.13 pieces $m^{-2}$ in the layers for the study period for the variant of 4.0 million pieces $ha^{-1}$ of similar seeds, and the option of 0.5 million pieces $ha^{-1}$ of similar seeds embraced 29.79 units / $m^2$ in layers. This is the proof of a denser spatial orientation of the weed plants on the attenated norms of seeding of the oilseed radish and a more complete filling of the free layering niches with the vegetative parts of the weeds themselves. Such features correspond to certain general laws of phytocenology (Mirkin, 1985) and such indicators as consideration of weed vitality in determining the critical state in weediness of the agrocenosis of the respective crop (Kandasamy, 1997; Monaco et al., 2002; Rao, 2017).

Identifying the relevant indicators of the stability of weed formation in the agrocenosis of the oilseed radish is also important. As it has been specified before, the weather conditions varied during different years of the study, which allowed us to put them in order of favourability to ensure the growth processes of the oil radish. A similar dynamics in the favourability of growth processes is also found for weed plants. The years of assessment have the following indices for the index Abundance (Ab) 2018 (–0.09) –2015 (–0.26) –2017 (–0.05) –2016 (0.21) – 2013 (0.26) –2014 (0.32) according to the methodology for assessing the stability and ductility of indicators (Eberhart and Russel, 1966).

The evaluation of the environmental plasticity (bi) and the environmental stability ($Si^2$) for the two technological options for modelling the oilseed radish cenosis is showed in Table 4.4 It is known that these indices are divided into the following grouping ranks according to their value (Tai, 1971): I the indicators bi <1, Si2> 0 – have better results in the unfavourable conditions, unstable; II indicators bi <1, $Si^2 = 0$ – have better results in unfavorable conditions, stable; III indicators bi = 1, $Si^2 = 0$ – responds well to the improvement of conditions, stable; IV indicators bi = 1, $Si^2 > 0$ – responds well to the improvement of conditions, unstable; V indicators bi> 1, $Si^2 = 0$ – have better results in favourable conditions, stable; VI indicators bi> 1, $Si^2 > 0$ – have the best results in the favourable conditions.

The obtained results enable us to make many important conclusions. First, dominance among the weed species considered by the correlation bi/$Si^2$ of the I and VI rank groups indicates a clear differentiation of the weed species by resistance to unfavourable conditions. Species with rank I, which show higher abundance in unfavorable conditions, but with the unstable variant of reaction to the specified conditions, have been estimated as 26 (54.2%, of the total number of the considered species) for the first technological variant of modelling of oilseed radish agrocenosis. Species with the VI rank that respond positively to favourable weather conditions for the first variant are marked as 5 (31.3%). The marginal species of other groups include 7 (14.5%). In the case of changes in the planting density of the oilseed radish, this factor is a regularity in the system of the plasticity assessment and stability of the definite weed species, 27 species (56.3%) are assigned to the first rank, 19 (39.6%) – to rank sixth at the presence of two marginal species in the rank group (4.1%). These results confirm the fact that the competitive potential of weeds in the composition of oilseed agrocenosis in terms of the hydrothermal vegetation conditions is high, and the change of the rank from I to VI in some species for reducing the standing density of oilseed plants is a manifestation of its competitive potential as to the segetal vegetation, which complies with the concept of plasticity (Eberhart and Russel, 1966).

It is necessary to highlight that weeds of the VI rank of the grouping should be attributed to species with numbers to increase significantly when improving both edaphic conditions and the introduction of additional elements in the cultivation technology, namely the use of mineral fertilizers, the increase in feeding areas of cultivated plants and others. This is the case for the oilseed species that are dominant in the coenosis of the radish, such as *Cirsium arvense L., Elytrigia repens L., Galinsoga parviflora Cav., Amaranthus retroflexus L., Echinochloa crus–galli L., Setaria glauca L, Chenopodium album L., Erigeron canadensis L., Carduus acanthoides L.*

As a result, we have scrutinized the peculiarities of weed formation in the agrophytocenosis of the oilseed radish with different technological variants, admitting of shifting the indicator of the critical weed control period (CPWC) (Figure 4.2).

Table 4.4

**Ecological plasticity (bi) and ecological stability ($Si^2$) of Ab indicator under different technological variants of oilseed radish growing at the beginning of the fruiting phase (BBCH 70–74), 2013–2018 (Tsytsiura, 2020)**

| Name of the species | Variant of constructing agrocenosis of oilseed radish | | | | | |
|---|---|---|---|---|---|---|
| | 4.0 million pcs./ha of similar seeds | | | 0.5 million pcs./ha of similar seeds | | |
| | bi | $Si^2$ | Ранг | bi | $Si^2$ | Ранг |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| *Thlaspi arvense L.* | –0,87 | 0,09 | I | –0,56 | 0,02 | I |
| *Linaria vulgaris Milk.* | 0,60 | 0,11 | I | 0,01 | 0,00 | II |
| *Xanthoxalis fontana* | 6,03 | 0,17 | VI | –0,08 | 0,12 | I |
| *Rocket-cress R.Br.* | 0,69 | 0,11 | I | 0,87 | 0,20 | I |
| *Daucus carota L.* | –3,16 | 0,08 | I | 1,17 | 0,03 | VI |
| *Lappula squarrosa (Retz.) Dumort* | 4,58 | 1,01 | VI | 1,16 | 1,10 | VI |
| *Lamium purpureum L.* | –1,46 | 0,05 | I | 2,31 | 0,12 | VI |
| *Berteroa incana L.* | –3,05 | 0,52 | I | 0,98 | 0,72 | I |
| *Veronica hederifolia L.* | 1,76 | 0,08 | VI | 2,73 | 0,47 | VI |
| *Carduus acanthoides L.* | –1,08 | 0,06 | I | 2,30 | 0,18 | VI |
| *Lepidium ruderale L.* | 1,70 | 0,43 | VI | –0,09 | 0,37 | I |
| *Erigeron canadensis L.* | –2,20 | 0,14 | I | 1,69 | 0,05 | VI |
| *Raphanus raphanistrum L.* | 0,10 | 0,01 | II | 0,60 | 0,09 | I |
| *Amaranthus Blifoides S. Wats.* | 2,25 | 0,10 | I | –2,82 | 1,10 | I |
| *Anagallis arvensis L.* | –0,21 | 0,01 | II | 0,71 | 0,48 | I |
| *Brassica campestris L.* | –1,01 | 0,01 | II | 0,15 | 0,03 | I |

(End of Table 4.4)

| *1* | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| *Artemisia vulgaris L.* | –2,74 | 0,17 | I | 0,35 | 0,79 | I |
| *Artemisia absinthium L.* | 1,01 | 0,07 | IV | –0,76 | 0,20 | I |
| *Taraxacum officinale* | –1,08 | 0,15 | I | 0,03 | 0,04 | I |
| *Cirsium arvense L.* | 5,51 | 0,20 | VI | 5,61 | 0,56 | VI |
| *Sonchus arvensis L.* | 0,03 | 0,07 | I | 1,00 | 0,03 | IV |
| *Convolvulus arvensis L.* | –0,52 | 0,16 | I | 0,55 | 0,10 | I |
| *Equisetum arvense L.* | 4,08 | 1,00 | VI | –0,18 | 0,32 | I |
| *Cynodon dactylon L.* | –0,35 | 0,04 | I | –0,62 | 0,15 | I |
| *Achillea millefolium L.* | 1,14 | 0,05 | VI | –0,61 | 0,06 | I |
| *Elytrigia repens L.* | 0,66 | 0,06 | I | 1,33 | 0,09 | VI |
| *Delphinium consolida, Consolida regalis* | –0,36 | 0,03 | I | 0,06 | 0,22 | I |
| *Tripleurospermum inodorum L.* | 3,05 | 0,70 | VI | 1,77 | 0,17 | VI |
| *Senecio vernalis Waldst* | 3,34 | 0,01 | V | –0,16 | 0,21 | I |
| *Lactuca tatarica L.* | –0,93 | 0,04 | I | 0,66 | 0,01 | I |
| *Capsella bursa pastoris L.* | 2,42 | 0,14 | VI | 0,52 | 0,09 | I |
| *Centaurea cyanus L.* | 2,89 | 0,21 | VI | –0,31 | 0,07 | I |
| *Portulaca oleraceae L.* | 2,56 | 0,10 | VI | 0,18 | 0,04 | I |
| *Galinsoga parviflora Cav.* | 0,35 | 0,00 | II | 1,49 | 0,00 | VI |
| *Spergula vulgaris Boenn.* | –1,00 | 0,62 | I | 0,59 | 0,16 | I |
| *Amaranthus retroflexus L.* | –0,39 | 0,04 | I | 1,62 | 0,20 | VI |
| *Polygonum aviculare L.* | 1,07 | 0,72 | VI | 0,48 | 0,35 | I |
| *Sonchus oleraceus L.* | 0,36 | 0,01 | II | –0,85 | 0,01 | I |
| *Polygonum scabrum Moench.* | 0,73 | 0,04 | I | 1,37 | 0,03 | VI |
| *Echinochloa crus–galli L.* | –0,20 | 0,08 | I | 1,48 | 0,10 | VI |
| *Setaria viridis L.* | 0,21 | 0,09 | I | 0,49 | 0,45 | I |
| *Setaria glauca L.* | 11,22 | 0,63 | VI | 6,30 | 0,23 | VI |
| *Galium aparine L.* | –0,19 | 0,08 | I | 0,23 | 0,29 | I |
| *Chenopodium album L.* | 7,71 | 0,48 | VI | 5,35 | 1,19 | VI |
| *Sinapis arvensis L.* | 0,55 | 0,10 | I | 4,34 | 0,98 | VI |
| *Polygonum convolvulus L.* | –1,54 | 0,21 | I | 1,47 | 0,12 | VI |
| *Poa annua L.* | 1,15 | 0,07 | VI | 1,99 | 0,08 | VI |
| *Stellaria media L.* | 0,33 | 0,11 | I | 1,29 | 0,56 | VI |
| *Parameters* Year conditions: $F_f$ 1960,2 ($F_{0.5}$ 2,46); Ab $F_f$ 425,5 ($F_{0.5}$ 1,82); Ab x year conditions $F_f$ 96,3 ($F_{0.5}$ 1,48) | | | | | | |

We have applied the duration of the post–emergence period in the system for determining this indicator, although as observed (Beckie et al., 2008; Rana, 2016), the format of the post–emergence study of weed competition under early spring sowing is more relevant. The use of classical approaches to determining the CPWC (Knezevic et al., 2002; Norsworthy et al., 2004;

Knezevic and Datta, 2015), 5% in particular and 10% of the rate of decline. For the variant of forming the oilseed radish agrocenosis with a seeding rate of 4.0 million pieces ha$^{-1}$ of similar seeds, the rate of 5% reduction of the average crop during the study period was in the range of 5–45 DAS, 10% of the crop loss rate was in the range of 12–40 DAS. For the technological variant of 0.5 million pieces ha$^{-1}$ of similar seeds, the indicated yield reduction levels varied between 6–60 DAS and 13–50 DAS respectively. The interval itself differs from similar indicators for oilseeds close to the radish: a spring and winter rapeseed, a white mustard in particular. On the whole, the total critical period is revealed for a rape, which includes 5 and 10% crop reduction levels, the critical period is specified in the range from 15–40 DAS (Rana and Kumar, 2014) to 15–60 DAS (Beckie et al., 2008; Lemerle et al., 2010). Consequently, the oilseed radish has identical features in terms of the competitiveness to the main weeds. However, our studies have shown a number of differences. The first of these, already mentioned by us, is related to the peculiarities of the oilseed radish plant growth – these are the slow growth rates to the rosette phase of the beginning of stalking (BBW 10–30), and intensive rapid growth rates from the stem stage to the flowering one (BBW 31–50). The level of competition of weed radish plants in relation to weeds increases from the rosette stage and reaches its maximum value within budding due to these peculiarities (OVS 42–50). With the increase in the density of agrocenosis, and for the radish of oilseed in the study area, this is the maximum applied technological option, in addition to increasing the overall competitiveness of the plants in relation to weeds due to the correspondingly higher cover (Mirkin, 1985), also increased internal competition between the cultivated plants of the oilseed radish. In this case, the critical interval between 5 and 10% yield reduction levels is rstricted to 5–7 DAS instead of 9–10 DAS in the variant of 0.5 million pieces/ha of similar seeds. For this reason, the CPWC period for the first technological variant is shortened, and the intersection point of the Gompertz curve and logistics for the first variant was 24 DAS, and for the second – 33 DAS. These features have been found in other several cultures and generalized by a number of researchers (Martin et al., 2001; Zimdahl, 2004; Hamzei et al., 2007; Dobrzański and Adamczewski, 2009; Swanton et al., 2015; Rana, 2016).


**Figure 4.2 – Weed invasion in two sectors (A and B) of an oilseed radish field at full maturity in our University field in 2020). (A – weed density m$^{-2}$ – 26; B – weed density m$^{-2}$ – 41) (Tsytsiura, 2020)**

Another peculiarity of the oilseed radish is related to the nature of seed yield formation in relation to the formation of the total leafy biomass. By increasing the seeding rate to the critical maximum limit, a general decrease in the reproductive and increase of the vegetative plant architectonics is observed. For this reason, a complex proportion of the crop decline is formed both due to weeds and due to the unique features of the depressing influence of the intraspecific competition.

The opposite processes occur to the variant of critically low seeding rates. As a result, the growth curve (Gompertz Relation) has lower approximation values ($R^2$) than the logistic curve. A lot of publications highlight these observations as for the evaluation of CPWC period curves (Ahmadvand et al., 2009; Knezevic and Datta, 2015; Zimdahl, 2018).

In addition, due to the higher level of weediness and the decrease in the overall competitiveness of sowing by reducing the potential project surface coverage of the soil surface by one plant (Mirkin, 1985), the relevance of weed control extends to later phenological phases in the development of the oilseed radish plants than for the variant of denser coenoses of a crop.

The determined CPWC shows that herbicides should be applied for the effective herbicide control over the oilseed radish agrocoenosis in the period from germination to the beginning of rosette formation

(BBCH 4–12) at high technological density of the coenosis, and in the period from the beginning of rosette formation to the beginning of stalking (BBCH 10–20) in the variants of extremely low density values. This complies with the conventional weed control strategy (Anderson, 2007; Sanyal, 2008; Harker and O'Donovan, 2013; Andrew et al., 2015; Jugulam et al., 2019).

The heterogeneous qualitiy of weed formation has been determined for agrophytocenoses of the oilseed radish. The overall species diversity is represented by 48 species that constitute four consecutive layers within the height of the oil radish stalk. The nature of the weediness types changes one after another in the light of major stages of the growing season. The prevailing type of weediness in terms of the structure is non–perennial–rooting–sprouting–rhizome. The dominant forms with a higher level of competitiveness as for the oilseed radish plants are represented by cereals of the early and late spring groups (SDR = 22.4 overall for 4.0 million pieces $ha^{-1}$ of similar seeds and 25.6 for 0.5 million pieces $ha^{-1}$ of similar seeds as well as the perennial rhizome forms (SDR 5.2 and 5.5 correspondinly). The dominant role among the broad–leaved (dicotyledonous) weeds is played by the representatives of the late spring group (SDR 24.1 and 24.4 correspondinly) and the perennial rootstock group (SDR 12.6 and 11.8 correspondinly). The attributed features of weeds reported in the agrocenosis of the oilseed radish of different densities were 39.2% by species identity average representation for the technological variant of 0.5 million pieces/ha of similar seeds.

In general, the prevailing weed types belonged to groups I and VI according to the parameters of the ecological plasticity (bi) and ecological stability ($Si^2$) of the parameter Ab. CPWC depended on the technological density of the oilseed radish agrocenosis, and at its value for the level of 5% reduction in the yield of 4.0 million pieces $ha^{-1}$ of similar seeds was 5–45 DAS, which was 14 DAS less than in the version 0.5 mn pieces $ha^{-1}$ of similar seeds. This indicator was also lower for the denser study of the oilseed radish agrocenosis by 9 DAS for the level of 10% reduction in harvest. The most appropriate period of using herbicides for the effective control over their number, taking into account the criterion CPWC for the full range of technological parameters of forming the agrocenosis of oilseed radish, corresponds to the period of seedling – the start of sprouting (BBCH 4–20).

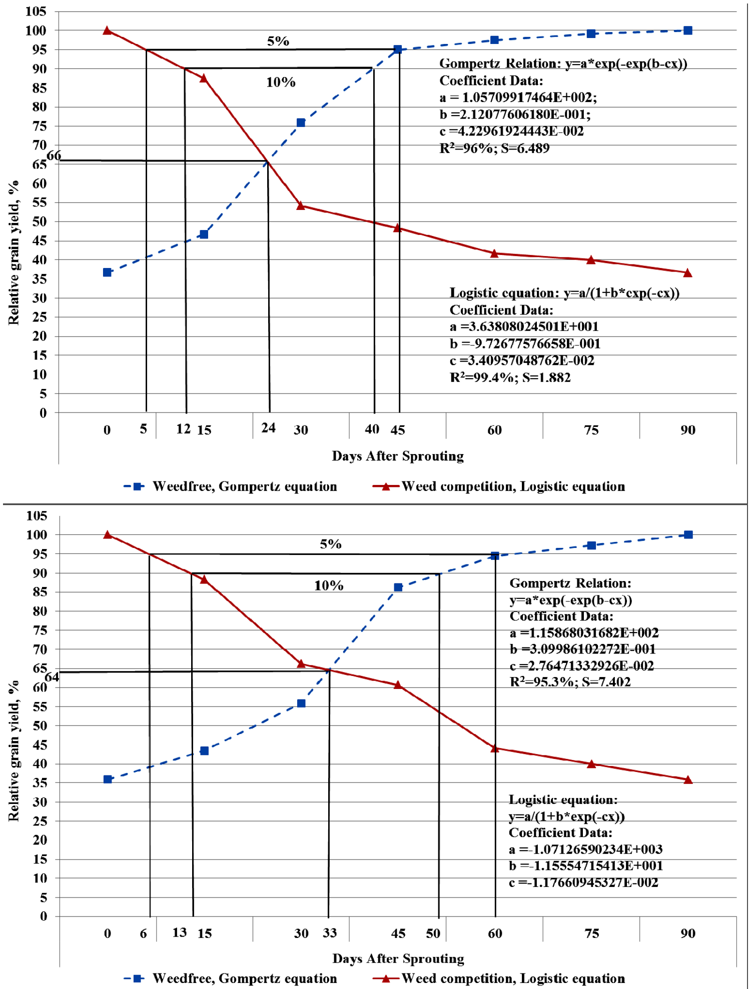



**Figure 4.3 – The critical period of the weed competition of the oilseed radish agrophytocenosis with different seeding technological model (the top position for seeding rates of 4.0 million pieces ha$^{-1}$ of similar seeds, bottom position – for seeding rates of 0.5 million pieces ha$^{-1}$ of similar seeds), 2013–2018 average (determination of graph parameters in CurveExpert Pro: 2.6.5) (Tsytsiura, 2020)**

Any agrophytocenosis of cultivated plants can be visualized as a complex system consisting of 1–2 species of cultivated plants and a multispecies complex of weeds. The efficiency of interaction between the two components determines the overall level of yield of a given crop and the level of its loss due to competition for life factors between the crop and weeds. In modern systems of agro-technologies, the main task of designing agrophytocenoses is to achieve such a density of plants per unit area, which would ensure the optimality of their growth processes, the maximum realization of the potential of their genotype and guarantee the resulting success of competitiveness in relation to the main harmful weed species. A correctly formed cenosis thus provides not only high levels of desired productivity, but also provides a significant reduction of herbicide load in the technology of cultivation of the crop. On the other hand, between cultivated plants and weeds in the cenosis there are multifactorial systemic relationships, the nature of which is determined by the properties of the life strategy of the latter, according to which violents (C), patients (S), explerents (R) and transitional strategies (CS; CR; SR; CSR). Such complexity of biologic-competitive relationships despite the relative study of biology and reproductive tactics of a number of common weeds determines the search for optimal sowing parameters for each crop separately, providing high starting levels of competitiveness of cultivated plants in relation to the main weeds with a pronounced dominant life strategy in cenoses. This confirms the relevance of our research and its significance for agrotechnological practice.

In our previous publications, we noted that oilseed radish has positive features from the position of herbocompetition, which is due to high growth rates, positive reaction of the increase in total phytomass when changing the width of row spacing and intra-row spacing, intensive branching of the stem and a high degree of denudation, intensive indicators of photosynthetic potential growth starting from the stem stage.

However, there are a number of reservations regarding oilseed radish. In particular, the cessation of growth processes during the fruiting period (especially in the phase of yellow-green and yellow pods) leads to intensive weed growth, and in case of lodging of oil radish crops – to the dominance of weed vegetation in the upper tier of stem cenosis. The crop is also characterized by an intensive reduction in the number of leaves from the phase of yellow-green pod, which also contributes to intensive weed regrowth, especially in the final stages of vegetation of the crop. It should be taken into account in the strategy of controlling the number of weeds in agrocenoses of oilseed radish and its tendency to lodging at the final stages of vegetation, starting from the microstage of phenological development when 50% of pods have reached the final size (BBCH 75). The prolonged flowering period, which is combined with a long phase of pod formation and seed ripening on the background of a medium degree of lodging of the crop leads to increased dominance of weed plants in the microstage period of green-full pod ripeness (BBCH 75–89). Due to these features, the cenosis of oil radish is characterized by oscillatory character in the vertical dominance of certain biological groups of weeds. The total number of weed species identified in the surveys in different years of research is 38, which belong to 33 genera (Table 4.5).

Among the species, the most common families are Asteraceae, Brassicaceae and Poaceae – a total of 50.0 % in the total structure of the ratio. In general, the highest occurrence (dominance) including under conditions of frequent excess of EFV level in the crop was established for such spring weed species as field cabbage (*Brassica campestris* L.), wild radish (*Raphanus raphanistrum* L.), field mustard (*Sinapis arvensis* L.), white chaff (*Chen arvensis* L.). L.), white marestail (*Chenopodium album* L.), scabrous mountain (*Polygonum scabrum* Moench), tansy (*Amaranthus retroflexus* L.), common platypus (*Echinochloa crus-galli* L.), bristlecone blue (*Echinochloa crus-galli* L.), blue bristlecone (*Setaria glauca* L.), green bristlecone (*Setaria viridis* L.), stem-branching bramble (*Lamium amplexicaule* L.), small-flowered Galinsoga (*Galinsoga parviflora* Cav.). Wintering annuals include wild lettuce, compass lettuce (*Lactuca serriola* L.), clinging mayflower (*Galium aparine* L.), common thistle (*Rocket-cress* R. Br.), field broom (*Thlaspi arvense* L.), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), chamomile (*Tripleurospermum inodorum* (L.) Sch. Bip.), *Stellaria media* (L.)).

The spectrum of perennial weeds is represented in the agrocenosis of oilseed radish by such weeds as creeping wheatgrass (*Elymus repens* (L.) Gould), field horsetail (*Equisetum arvense* L.), field thistle (*Sonchus arvensis* L.), field thistle (*Cirsium arvense* L. ), field thistle (*Convolvulus arvensis* L.), field dandelion (*Taraxacum officinale* Wigg.), Tatar lettuce

(*Lactuca tataricia*), bitter wormwood (*Artemisia absinthium* L.), common wormwood (*Artemisia vulgaris* L.).

Until the phenological phase of the beginning of stemming (BBCH 36–52) the lower tier of cenosis is occupied by such weeds as creeping wheatgrass (*Elymus repens* (L.) Gould), horsetail (*Equisetum arvense* L.),medicinal dandelion (*Taraxacum officinale* Wigg.), scabrous mountain (*Polygonum scabrum* Moench), bluebunchgrass (*Setaria glauca* L.), bristlecone green (*Setaria viridis* L.), stem-branch (*Lamium amplexicaule* L.), small-flowered Galinsoga (*Galinsoga parviflora* Cav.), field broom (*Thlaspi arvense* L.), shepherd's purse (*Capsella bursa-pastoris* (L.) Medic.), chamomile unguent (*Tripleurospermum inodorum* (L.) Sch. Bip.), middle starflower (*Stellaria media* (L.)).

Taking into account certain regularities of species structure of weed infestation of oilseed radish agrocenosis, one of the stages of our research was to study the peculiarities of formation of the number of individual weed species that belong to different growth tiers in the context of different technological approaches to pre-sowing design of oilseed radish cenosis (Table 4.5). The results obtained show that the life strategy of individual weed species differs with the influence of factors put to study in the experiment. Thus, the condition of years were the most determinant in the formation of the number of bristlewort (Setaria glauca L.) – factor A 28.38 %, and the least – for the number of wheatgrass (Elymus repens (L.) Gould) (A – 19.42 %).

Stay in the same altitudinal tier with oilseed radish plants: field cabbage (*Brassica campestris* L.), wild radish (*Raphanus raphanistrum* L.), field mustard (*Sinapis arvensis* L.), white mungbean (*Chenopodium album* L.), tansy (*Amaranthus retroflexus* L.), common chickweed (*Echinochloa crus-galli* L.), wild lettuce, compassion (*Echinochloa crus-galli* L.). L.), tansy (*Amaranthus retroflexus* L.), common chickweed (*Echinochloa crus-galli* L.), wild, compass lettuce (*Lactuca serriola* L.), tussock (*Galium aparine* L.), common thistle (*Rocket-cress* R. Br.), field creeper (*Convolvulus arvensis* L.). The dominant role in the cenosis, beyond the altitudinal gradient, is occupied by such weeds as field thistle (*Sonchus arvensis* L.), field thistle (*Cirsium arvense* L.), Tatar lettuce (*Lactuca tataricia*), bitter wormwood (*Artemisia absinthium* L.), common wormwood (*Artemisia vulgaris* L.).

Table 4.5

**Family-species spectrum of weeds in the agrocenosis of oilseed radish variety 'Zhuravka' in the system of averaged indicators of technological options of cenosis construction (average for 2013–2018 for the phase of green pod (BBCH 75–76)) (Tsytsiura, 2019)**

| Plant Genus | Number of species | | | Number of births | | |
|---|---|---|---|---|---|---|
| | $X_{av}$, units. | R, units | % | $X_{av}$, units. | R, units | % |
| Asteraceae | 7 | 4–10 | 18.42 | 5 | 3–7 | 15.15 |
| Brassicaceae | 7 | 5–8 | 18.42 | 6 | 5–8 | 18.18 |
| Poaceae | 5 | 3–7 | 13.16 | 5 | 3–6 | 15.15 |
| Boraginaceae | 4 | 1–5 | 10.53 | 4 | 3–5 | 12.12 |
| Caryophyllaceae | 3 | 2–5 | 7.89 | 2 | 1–4 | 6.06 |
| Fabaceae | 3 | 1–4 | 7.89 | 4 | 2–6 | 12.12 |
| Chenopodiaceae | 4 | 2–5 | 10.53 | 3 | 2–5 | 9.09 |
| Euphorbiaceae | 2 | 1–3 | 5.26 | 2 | 1–3 | 6.06 |
| Lamiaceae | 3 | 1–3 | 7.89 | 2 | 1–3 | 6.06 |

For the phenological interval of microstages from the green pod phase to the stage of full yellow ripeness of pods (BBCH 76–84), the character of visot dominance changes towards the weeds that previously occupied the middle and higher tier in relation to the height of oil radish plants (Fig. 4.4). The very factor of lodging of agrocenoses of oilseed radish, studied by us in a single complex of development of adaptive technological strategies of cultivation of the crop in the conditions of Praoberezhnaya Lesostepi of Ukraine (Tsitsyura, 2018), shows a high probability of lodging at a seeding rate of more than 2.0–2.5 million pieces/ha of germinating seeds on the background of full fertilization 60 and above kg/ha of active ingredient. This implies a higher probability of changes in the height dominance of weeds and a general increase in their number due to a decrease in plant competitiveness.

Taking into account certain regularities of species structure of weed infestation of oilseed radish agrocenosis, one of the stages of our research was to study the peculiarities of formation of the number of individual weed species that belong to different growth tiers in the context of different technological approaches to pre-sowing design of oilseed radish cenosis (Table 4.6).

Table 4.6

**Numbers of individual weed species in the agrocenosis of oilseed radish variety Zhuravka depending on the technological parameters of its design (average for 2013–2018) (Tsytsiura, 2019)**

| Seeding rate (mln pcs $ha^{-1}$ of germinated seeds) (factor B), sowing method (factor C) | Fertilizer rates (factor D) | Number of weeds for the period of full green pod phase (BBCH 75–79), pcs $m^{-2}$ | | | | |
|---|---|---|---|---|---|---|
| | | *Chenopodium album* L | *Amaranthus retroflexus* L | *Setaria glauca* L. | *Elymus repens* L. Gould | *Cirsium arvense* L. |
| 4,0 million, row | Without fertilizer | 4.6 ± 0.8 | 1.1 ± 0.9 | 5.4 ± 2.0 | 1.6 ± 0.3 | 2.1 ± 0.2 |
| | $N_{30}P_{30}K_{30}$ | 4.1 ± 0.9 | 1.5 ± 1.2 | 5.3 ± 2.2 | 1.4 ± 0.5 | 2.1 ± 0.3 |
| | $N_{60}P_{60}K_{60}$ | 3.7 ± 1.2 | 1.4 ± 1.0 | 5.1 ± 2.5 | 1.2 ± 0.6 | 2.3 ± 0.3 |
| | $N_{90}P_{90}K_{90}$ | 4.0 ± 1.5 | 1.8 ± 0.9 | 5.6 ± 2.7 | 1.2 ± 0.8 | 2.6 ± 0.4 |
| 3,0 million, row | Without fertilizer | 4.5 ± 1.3 | 1.1 ± 0.8 | 5.1 ± 2.4 | 1.4 ± 0.4 | 1.9 ± 0.3 |
| | $N_{30}P_{30}K_{30}$ | 4.0 ± 0.9 | 1.6 ± 1.0 | 5.5 ± 2.5 | 1.5 ± 0.5 | 2.0 ± 0.4 |
| | $N_{60}P_{60}K_{60}$ | 3.4 ± 0.8 | 1.5 ± 1.0 | 5.2 ± 2.3 | 1.5 ± 0.5 | 2.2 ± 0.4 |
| | $N_{90}P_{90}K_{90}$ | 3.7 ± 1.4. | 2.1 ± 1.4 | 5.8 ± 2.7 | 1.7 ± 0.7 | 2.4 ± 0.5 |
| 2,0 million, row | Without fertilizer | 4.4 ± 0.7 | 1.1 ± 1.0 | 5.6 ± 1.9 | 1.6 ± 0.4 | 2.2 ± 0.4 |
| | $N_{30}P_{30}K_{30}$ | 4.5 ± 0.8 | 1.4 ± 1.1 | 5.9 ± 2.5 | 1.9 ± 0.4 | 2.2 ± 0.3 |
| | $N_{60}P_{60}K_{60}$ | 5.0 ± 0.8 | 1.6 ± 1.2 | 6.7 ± 2.2 | 1.9 ± 0.5 | 2.5 ± 0.5 |
| | $N_{90}P_{90}K_{90}$ | 5.3 ± 1.0 | 2.3 ± 1.5 | 6.2 ± 2.5 | 2.2 ± 0.5 | 2.7 ± 0.5 |
| 1,0 million, row | Without fertilizer | 5.3 ± 0.5 | 1.9 ± 1.0 | 7.4 ± 2.0 | 1.8 ± 0.3 | 2.4 ± 0.4 |
| | $N_{30}P_{30}K_{30}$ | 5.7 ± 0.7 | 2.1 ± 1.2 | 8.1 ± 2.2 | 1.8 ± 0.5 | 2.5 ± 0.6 |
| | $N_{60}P_{60}K_{60}$ | 6.0 ± 0.6 | 2.7 ± 1.4 | 8.5 ± 2.5 | 2.1 ± 0.6 | 2.7 ± 0.6 |
| | $N_{90}P_{90}K_{90}$ | 6.2 ± 0.9 | 3.1 ± 1.6 | 8.7 ± 2.7 | 2.4 ± 0.6 | 2.9 ± 0.6 |
| 2,0 million, wide-row | Without fertilizer | 5.7 ± 1.2 | 1.6 ± 0.6 | 6.7 ± 1.9 | 1.7 ± 0.3 | 2.1 ± 0.4 |
| | $N_{30}P_{30}K_{30}$ | 5.5 ± 1.1 | 2.1 ± 0.8 | 6.9 ± 1.9 | 1.6 ± 0.4 | 2.3 ± 0.7 |
| | $N_{60}P_{60}K_{60}$ | 5.4 ± 1.3 | 2.4 ± 0.8 | 6.4 ± 1.8 | 1.9 ± 0.5 | 2.4 ± 0.5 |
| | $N_{90}P_{90}K_{90}$ | 6.8 ± 1.2 | 2.6 ± 1.0 | 6.6 ± 2.2 | 1.9 ± 0.6 | 2.7 ± 0.7 |

(End of Table 4.6)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,5 million, wide-row | Without fertilizer | 5.8 ± 0.8 | | 1.6 ± 0.7 | | 8.5 ± 2.3 | | 2.1 ± 0.4 | | 2.3 ± 0.5 | |
| | $N_{30}P_{30}K_{30}$ | 6.2 ± 0.7 | | 2.2 ± 1.0 | | 8.9 ± 2.0 | | 2.3 ± 0.5 | | 2.5 ± 0.5 | |
| | $N_{60}P_{60}K_{60}$ | 6.5 ± 1.4 | | 2.4 ± 0.8 | | 9.2 ± 2.4 | | 2.5 ± 0.5 | | 2.7 ± 0.7 | |
| | $N_{90}P_{90}K_{90}$ | 7.3 ± 1.9 | | 2.9 ± 1.2 | | 10.8 ± 2.4 | | 2.5 ± 0.7 | | 3.2 ± 0.7 | |
| 1,0 million, wide-row | Without fertilizer | 6.1 ± 0.7 | | 1.7 ± 0.7 | | 11.8 ± 2.7 | | 2.2 ± 0.3 | | 2.3 ± 0.6 | |
| | $N_{30}P_{30}K_{30}$ | 7.4 ± 1.5 | | 2.7 ± 1.0 | | 12.4 ± 2.9 | | 2.4 ± 0.4 | | 2.5 ± 0.7 | |
| | $N_{60}P_{60}K_{60}$ | 8.6 ± 1.7 | | 3.0 ± 0.9 | | 13.8 ± 3.1 | | 2.5 ± 0.5 | | 2.8 ± 0.7 | |
| | $N_{90}P_{90}K_{90}$ | 9.3 ± 1.9 | | 3.4 ± 1.3 | | 14.5 ± 3.3 | | 2.6 ± 0.5 | | 3.4 ± 0.8 | |
| 0,5 million, wide-row | Without fertilizer | 7.8 ± 1.2 | | 2.5 ± 1.4 | | 12.3 ± 3.2 | | 2.4 ± 0.3 | | 2.5 ± 0.7 | |
| | $N_{30}P_{30}K_{30}$ | 8.4 ±1.1 | | 2.8 ± 1.5 | | 12.9 ± 3.4 | | 2.6 ± 0.3 | | 2.7 ± 0.8 | |
| | $N_{60}P_{60}K_{60}$ | 9.6 ± 1.6 | | 3.2 ± 1.6 | | 14.2 ± 3.6 | | 2.6 ± 0.4 | | 3.2 ± 1.0 | |
| | $N_{90}P_{90}K_{90}$ | 10.4 ± 1.8 | | 4.0 ± 1.8 | | 15.8 ± 4.1 | | 2.8 ± 0.6 | | 3.5 ± 1.2 | |
| **Factor A – conditions of the year** | | **LSD$_{05}$, ps.m$^{-2}$** | **Influence of factor (%)** | **LSD$_{05}$, ps.m$^{-2}$** | **Influence of factor (%)** | **LSD$_{05}$, ps.m$^{-2}$** | **Influence of factor (%)** | **LSD$_{05}$, ps.m$^{-2}$** | **Influence of factor (%)** | **LSD$_{05}$, ps.m$^{-2}$** | **Influence of factor (%)** |
| *A* | | 0,055 | 27.50 | 0.043 | 23.82 | 0.186 | 28.38 | 0.047 | 19.42 | 0.048 | 20.15 |
| B | | 0,032 | 26.23 | 0.025 | 9.56 | 0.107 | 27.81 | 0.027 | 8.20 | 0.028 | 6.38 |
| C | | 0,045 | 17.45 | 0.036 | 8.88 | 0.152 | 17.82 | 0.038 | 7.96 | 0.039 | 6.79 |
| D | | 0,045 | 2.75 | 0.036 | 2.90 | 0.152 | 3.94 | 0.038 | 0.90 | 0.039 | 1.82 |
| AB | | 0,077 | 6.55 | 0.061 | 13.08 | 0.263 | 1.72 | 0.066 | 15.87 | 0.067 | 15.45 |
| AC | | 0,109 | 6.04 | 0.087 | 15.41 | 0.372 | 1.73 | 0.093 | 16.42 | 0.095 | 16.12 |
| AD | | 0,109 | 0.37 | 0.087 | 0.95 | 0.372 | 0.39 | 0.093 | 3.99 | 0.095 | 6.01 |
| BC | | 0,063 | 3.15 | 0.050 | 4.05 | 0.215 | 7.12 | 0.054 | 3.85 | 0.055 | 4.15 |
| BD | | 0,063 | 1.82 | 0.050 | 0.40 | 0.215 | 1.83 | 0.054 | 0.37 | 0.055 | 0.49 |
| CD | | 0,089 | 1.72 | 0.071 | 0.92 | 0.303 | 3.80 | 0.076 | 0.99 | 0.078 | 0.69 |
| ABC | | 0,155 | 4.54 | 0.123 | 14.49 | 0.525 | 0.75 | 0.132 | 15.52 | 0.135 | 15.56 |
| ABD | | 0,155 | 0.33 | 0.123 | 0.74 | 0.525 | 0.32 | 0.132 | 0.92 | 0.135 | 0.88 |
| ACD | | 0,219 | 0.74 | 0.174 | 2.13 | 0.743 | 0.78 | 0.186 | 2.57 | 0.191 | 2.42 |
| BCD | | 0,126 | 0.21 | 0.100 | 0.59 | 0.429 | 2.86 | 0.108 | 0.53 | 0.110 | 0.69 |
| ABCD | | 0,310 | 0.61 | 0.246 | 2.08 | 1.051 | 0.74 | 0.263 | 2.48 | 0.269 | 2.40 |

The results obtained show that the life strategy of individual weed species differs with the influence of factors put to study in the experiment. Thus, the conditions of the year were the most determinant in the formation of the number of bristlewort (*Setaria glauca* L.) – factor A – 28.38 %, and the least – for the number of wheatgrass (*Elymus repens* (L.) Gould) (A – 19.42 %). The greatest influence in the complex of factors B, C and D was established for the abundance of bluebunch wheatgrass (*Setaria glauca* L.) (total sum of influence 49.57 %). The least complex influence of technological factors of the experiment was observed for the number of field thistle (*Cirsium arvense* L.) – total amount of 14.99 %.

Thus, the most pronounced influence of the herb-competing effect of the oil radish cenosis was established for annual weeds with a narrow interval of biological plasticity against the background of high values of the abiotic response, which include the following weed groups: ephemerals, ardent early annuals, winter and wintering weeds with a short vegetation period in crops of cultivated plants. Other features of the formation of the weed population in oil radish crops in the study area were also established: firstly, the maximum variability of the average annual value was noted for annual weeds; secondly, the effect of fertilizers had different effectiveness for different types of weeds – with a general increase in the number of weeds against higher fertilizer backgrounds, the responsiveness of different species was significantly different. Thus, in the strategy of coupled regulation of the number of weeds and the format of seeding rates and plant density for the agrocenosis of oilseed radish, it is necessary to take into account the edaphic properties of individual weed species (for example, azotophilicity, etc.). Thirdly, the seeding rate in interaction with the row spacing of oilseed radish (factor B and C) had the most pronounced effect on the number of all presented weeds of different biological groups with a feedback nature (Figures 4.5–4.6). For this factor, the established long-term value of influence is at the level of 39–67% (the main component and its interaction).According to the presented graphs, the minimum number of each weed is noted at different intervals of the density of standing of oilseed radish plants, and the nature of the regression surface has individual features characteristic only of this type of weed. Thus, in the variant of white goosefoot (*Chenopodium album* L.), the minimum number in the average annual measurement corresponds to the interval of 3.0–3.5 million pcs./ha

**Figure 4.4 – Height dominance in oilseed radish agrocenosis of bristlewort (*Setaria glauca* L.), white mary (*Chenopodium album* L.) (top position, 2016) and field thistle (*Cirsium arvense* L.) (bottom position, 2018) by brown pod phase (BBCH 83–86) in the 1.5 million, wide-row variant on $N_{90}P_{90}K_{90}$ background (Tsytsiura, 2019)**

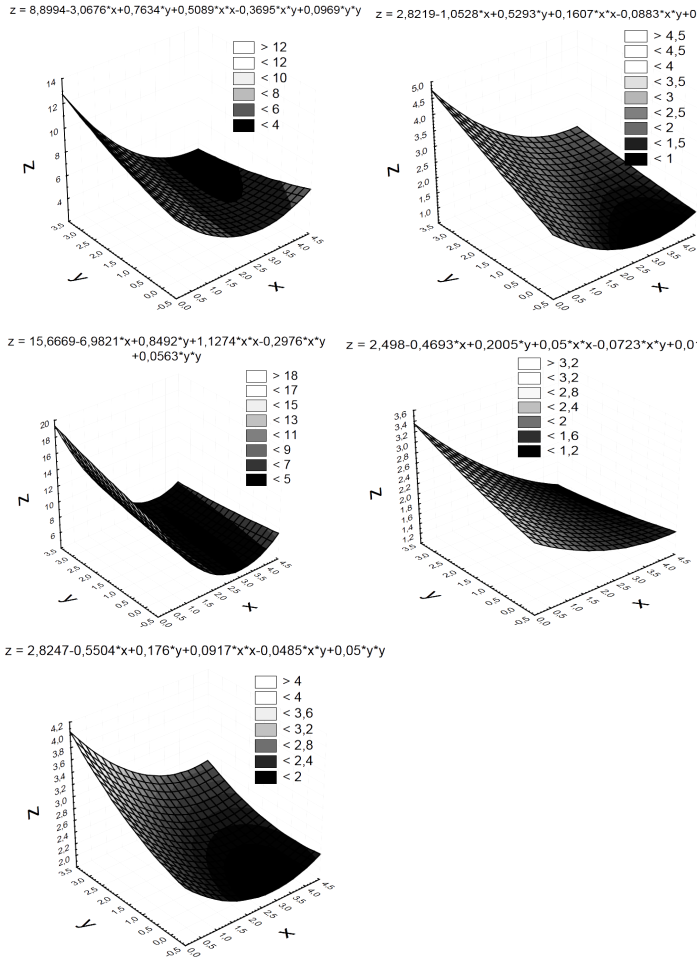



**Figure 4.5 – Graphs of the dependence of the weed population (z-axis, pcs m$^{-2}$) on the seeding rate (x-axis, million pcs ha$^{-1}$ of viable seeds) and fertilizer (y-axis, in index form: without fertilizers – 0, $N_{30}P_{30}K_{30}$ – 1; $N_{60}P_{60}K_{60}$ – 2; $N_{90}P_{90}K_{90}$ – 3.0). Consecutively from left to right and top to bottom: white goosefoot, retroflexed amaranth, glaucous foxtail, creeping wheatgrass, field thistle, average for 2013–2018 (Tsytsiura, 2019)**

**Figure 4.6 – Different types of weeds in oilseed radish agrocenosis, 2014–2024**

of viable seeds with a fertilizer index of 1.5–2.0 (45–60 kg ha$^{-1}$ of the active substance NPK). For the number of pigweed (*Amaranthus retroflexus* L.), the same minimum number is already at the parameters of seeding rates of 2.0–3.5 million pcs./ha of viable seeds and a fertilizer index of 0.0–1.5 (up to 45 kg ha$^{-1}$ of the active substance NPK). For the number of foxtail grass (*Setaria glauca* L.) 2.5–3.5 million pcs/ha of viable seeds at a fertilizer index of 0.0–1.5 (up to 45 kg $ha^{-1}$ of active substance NPK). Accordingly, for creeping wheatgrass (*Elymus repens* (L.) Gould) 3.5–4.5 million pcs/ha of viable seeds, 1.0–2.0 (30–60 kg $ha^{-1}$), and for field thistle (*Cirsium arvense* L.) – 2.0–3.5 million pcs $ha^{-1}$ of viable seeds, 0.0–2.0 (0–60 kg $ha^{-1}$).

At the same time, we have established (Tsitsyura, Ya. et al. 2015) that the forage productivity of oilseed radish in the study area is the highest at a seeding rate of 2.0–2.5 million pcs $ha^{-1}$ of viable seeds with the introduction of up to 60 kg $ha^{-1}$ of NPK, and the maximum binary yield of leaf-stem mass and seeds is in the variant of 1.5–2.0 million pcs $ha^{-1}$ of viable seeds with the introduction of the same up to 60 kg $ha^{-1}$ of NPK. Thus, taking into account the level of the ratio of the number of weeds in the radically opposite experimental variants, oilseed radish should be classified as a plant with a high level of herb competition of a wide range of use.

To obtain the effective combined effect of reducing the overall weed infestation of crops while maintaining high levels of biological yield of the crop, it is advisable to use the following technological parameters of sowing: for the row option, 2.5–3.5 million pcs. $ha^{-1}$ of viable seeds with the addition of $N_{30-60}P_{30-60}K_{30-60}$, for the wide-row option – 2.0–2.5 million pcs./ha of viable seeds with the addition of $N_{45-60}P_{45-60}K_{45-60}$.

### 4.2. Allelopathic potential of oilseed radish

Allelopathic approach in weed population control system isn't new, but it is based on biologic and physiologic regularities of agrocoenosis formation and development, which are based on the principles of vitality strategy of particular plant species and their competition both on the level of intraspecific and interspecific expression in the format of horizontal and vertical gradients (Bakhshayeshan–Agdam et al., 2015; Arroyo et al., 2018; VanVolkenburg et al., 2020). Application of the allelopathic factor is becoming more and more popular worldwide, given the intensive development of organic farming and crop production systems, and the formation of resistance in weeds to widely used active substances of herbicides. Development of this direction is also supported by aspects of climate change, which cause changes in the typology of the nature of the infestation of territories and the dominance of the most aggressive weed species, which are most adapted to the aridization of the territory's hydrothermal regime and are much more competitive than cultivated plant species (Rice, 1984; Brust et al., 2014; Duke, 2015; Jabran et al., 2015; Rueda–Ayala et al., 2015; Bhowmick et al., 2016; Hodgdon et al., 2016; Carvalho et al., 2019; Florence et al., 2019).

Allelopathic approaches are also important in considering agroecosystems towards development based on the maximal filling of ecological niches of certain species' existence and natural state of agrocenosis heterogeneity (Syed et al., 2014; Subtain et al., 2014; Singh et al., 2016; Kunz et al., 2016). Nowadays, highly specialized agroecosystems prevail, so their ability to support ecological balance through self–regulation mechanisms decreases. As a result, there is a growing environmental and genetic affliction of crops, as well as the need to use more chemical protection products on a larger scale. This inevitably enhances the process of destroying the mechanisms of natural landscape self–renewal (Blum, 2004; Reigosa et al., 2006; Macías et al., 2007).

From the standpoint of scientific study and application of allelopathic approaches to the determination of the competitiveness of cultivated plant species and dominant weeds in their cenosises have undergone a long and difficult formation period. Therefore, even though the issue is thoroughly studied, there are still many questions today without clear answers. It is well known that the carriers of allelopathic effect are physiologically active substances – collins, the chemical nature of which is extremely diverse and unstable even for one species (Grodzinsky, 1965; Rice, 1984; Inderjit and Keating, 1999; Awan et al., 2012; Iqbal & Fry, 2012; Gfeller et al., 2018). It means that even in terms of the chemistry of allelopathic activity itself, many factors determine it and can significantly limit it. The collins produced by plants themselves serve as ecological chemoregulators and are among the important environmental factors that determine the structure, dynamics and productivity of plant groupings. This biochemical phenomenon can seriously affect the germination of seeds and delay the development of further crops. At the same time, allelopathy can also have a positive effect on certain crops, which are able to inhibit the development of weeds by releasing biochemical compounds, while not harming cultivated plants. In this case, allelopathy is direct, i. e. from one crop to another (Grodzinsky, 1965; Rice, 1984; Lahdhiri et al., 2016; Sturm et al., 2016; Lemerle et al., 2017; Prinsloo and Plooy, 2018).

In modern practice, the allelopathic effect of plants is considered in terms of the following mechanisms: direct action of root exudations of a given species in the process of its growth and development (Grodzinsky, 1965; Rice, 1984; Izzet et al., 2004; Zimdahl, 2004; Yurchak, 2005; Jabran et al., 2015; Singh et al., 2016; Gfeller et al., 2018; Florence et al., 2019); the action of substances as a result of decomposition of plant residues of a given plant species in the system of technological application of sideration (Khanh et al., 2005; Hoffman and Regnier, 2006; Kruidhof et al., 2008; Hodgdon et al., 2016; Lahdhiri et al., 2016; Możdżeń et al., 2018); the artificially induced process of allelopathic impact due to the use of extracts from various parts of the plant in the process of their application for treatment of germinating seeds or their use in combination with traditional products of chemical and bioorganic origin, such as bioherbicides (Nagabhushana et al., 2001; Teasdale et al., 2003, 2007; Hoffman and Regnier, 2006; Pheng et al., 2010; Duke, 2015; Florence et al., 2019; Carvalho et al., 2019). As for the last option of the allelopathic effect, it should be noted that different parts contain different amounts of stopping substances (Grodzinsky, 1965; Rice, 1984; VanVolkenburg et al., 2020). According to Yurchak (2005), more collins are concentrated in leaves and generative organs; in the roots, their number is 1.6–9 times less, and the highest activity of plants is in the flowering phase.

Allelopathic activity of traditional cruciferous crops such as white mustard and rapeseed is known and determined by leaching and secretion of glucosinolates, and their hydrolysis to isothiocyanates inhibits germination and growth of weed seeds (Chew, 1988; Brown and Morra, 1996; Al–Khatib et al., 1997; Petersen et al., 2001; Turk and Tawaha, 2003; Norsworthy, 2003; Haramoto and Gallandt, 2004; Boydston and Al–Khatib, 2006; Lawley et al., 2012; Mohamed and El–gawad, 2014; Lemerle et al., 2017; Carvalho et al., 2019). Benzyl isothiocyanate, a product of white mustard decomposition, is phytotoxic for Abutilon theophrasti Medik. Allyl isothiocyanate, which was extracted from black mustard, inhibited germination of Bromus rigidus. Water extracts from rotten mustard residue

(Brassica kaber (D.C.)) were toxic for Echinochloa uusgalli var.Frumentacea (Roxb). Rapeseed leaves (Brassica napus L.), which had been put in the soil, suppressed the development of Chenopodium album, Amaranthus retroflexus and Echinochloa uusgal population, and their action was similar to the regular treatment with herbicides. White mustard and spring rapeseed leaves, which had been put into soil, reduced the abundance of Capsella bursa pastoris (L.) (Medic) and Kochia scoparia (L.) (Schrad). Winter rape, used as a green manure crop before planting potatoes, reduced weed density by 73–85% and biomass by 50–96% (Boydston, and Hang, 1995). In Russia, the rapeseed inclusion in crop rotation reduces the total number of weeds to 40%. Several other positive aspects regarding the impact of cruciferous crops on the number and germination of weeds were confirmed. On the other hand, there is a certain tendency for limited application of cruciferous crops in the system of allelopathic control of weeds to the already mentioned traditional white mustard, spring and winter rapeseed. As for oilseed radish, which has a full complex of beneficial features and belongs to the fodder–green–manure crops used in the system of organic (alternative) farming (Tsytsiura, & Tsytsiura, 2015), the question of allelopathy is poorly studied in comparison with other similar species*:* *Raphanus sativus* L. var. *longipinnatus*, *Raphanus sativus* var. *niger* J. Kern (Kunz et al., 2016) and even with wild radish species *Raphanus raphanistrum* (Norsworthy, 2003).

Given these factors, it is important to determine the allelopathic potential of oilseed radish as a fallow–grown and green manure component in the crop rotation for its effective application. This task has become the goal of our research. The research's working hypothesis is based on the assumption that the allelopathic potential of oilseed radish is sufficient for its effective use in farming systems with limited use of traditional herbicides, provided the appropriate realization of its allelopathic and competitive potential with respect to weeds.

Researches were carried out in laboratory conditions based on water extracts from weeds plants (water extraction method (in methodological variation Shahrokhi et al., 2011; VanVolkenburg et al., 2020)). The types of weeds used in the research are presented in Table 4.7.

Table 4.7

**Weed species used in research and its symbol from EPPO codes database (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| Coded variant number (CVN) | Water extract from weeds (latin name) | EPPO Code | Coded variant number (CVN) | Water extract from weeds (latin name) | EPPO Code |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 0 | Control (distilled water) | – | 39 | *Eryngium campestre* L. | ERXCA |
| 1 | *Capsella bursa–pastoris* L. | CAPBP | 40 | *Lepidium ruderale* L. | LEPRU |
| 2 | *Galium aparine* L. | GALAP | 41 | *Daucus carota* L. | DAUCA |
| 3 | *Ambrosia artemisiifolia* L. | AMBEL | 42** | *Sinapis alba* L. | SINAL |
| 4 | *Stellaria media* (L.) Vill. | STEME | 43 | *Lepidium draba* L. | CADDR |
| 5 | *Setaria glauca* L. | SETPU | 44 | *Lactuca serriola* L. | LACSE |
| 6 | *Erigeron canadensis* L. | ERICA | 45 | *Lepidium campestre* (L.) Brown | LEPCA |
| 7 | *Carduus acanthoides* L. | CRUAC | 46 | *Polygonum aviculare* L. | POLAV |
| 8 | *Thlaspi arvense* L. | THLAR | 47 | *Portulaca oleracea* L. | POROL |
| 9 | *Cirsium arvense* (L.) Scopoli | CIRAR | 48 | *Fumaria officinalis* L. | FUMOF |
| 10 | *Cynodon dactylon* (L.) Pers. | CYNDA | 49 | *Descurainia Sophia* (L.) Prantl | DESSO |
| 11 | *Echinochloa crus–galli* (L.) P.Beauv. | ECHCG | 50 | *Cichorium intybus* L. | CICIN |
| 12 | *Polygonum lapathifolium* (L.) Delarbre | POLLA | 51 | *Avena fatua* L. | AVEFA |
| 13 | *Papaver rhoeas* L. | PAPRH | 52 | *Bromus secalinus* L. | BROSE |
| 14 | *Brassica campestris* (L.) Janchen | BRSRA | 53 | *Lamium purpureum* L. | LAMPU |
| 15** | *Raphanus sativus* L. var. *oleiformis* Pers. | RAPSO | 54 | *Veronica hederifolia* L. | VERHE |
| 16 | *Agropyron repens* (L.) Gould | AGRRE | 55 | *Chondrilla juncea* L. | CHOJU |
| 17 | *Amaranthus retroflexus* L. | AMARE | 56 | *Crepis tectorum* L. | CVPTE |

(End of Table 4.7)

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| 18 | *Taraxacum officinale* Weber | TAROF | 57 | *Lamium amplexicaule* L. | LAMAM |
| 19 | *Sonchus arvensis* L. | SONAR | 58 | *Cyclachaena xanthiifolia* Nuttall | IVAXA |
| 20 | *Raphanus raphanistrum* L. | RAPRA | 59 | *Digitaria ischaemum* (Schreber) Muhlenberg | DIGIS |
| 21 | *Tripleurospermum maritimum* (L.) Koch | MATMA | 60 | *Achillea millefolium* L. | ACHMI |
| 22 | *Galinsoga parviflora* Cavanilles | GASPA | 61 | *Senecio vernalis* (Waldstein & Kitaibel) Alexander | SENVE |
| 23 | *Chenopodium album* L. | CHEAL | 62 | *Spergula vulgaris* L. | SPRAR |
| 24 | *Convolvulus arvensis* L. | CONAR | 63 | *Poa annua* L. | POAAN |
| 25** | *Brassica napus* L. | BRSNN | 64 | *Amaranthus blitoides* Watson | AMABL |
| 26 | *Rocket-cress* Brown | BARVU | 65 | *Plantago lanceolata* L. | PLALA |
| 27 | *Centaurea cyanus* L. | CENCY | 66 | *Acroptilon repens* (L.) de Candolle | CENRE |
| 28 | *Artemisia vulgaris* L. | ARTVU | 67 | *Erodium cicutarium* ( L.) L'Héritier | EROCI |
| 29 | *Berteroa incana* (L.) de Candolle | BEFIN | 68 | *Panicum capillare* L. | PANCA |
| 30 | *Artemisia absinthium* L. | ARTAB | 69 | *Rumex acetosella* L. | RUMAA |
| 31 | *Rumex confertus* Willdenow | RUMCF | 70 | *Sisymbrium Loeselii* L. | SSYLO |
| 32 | *Setaria viridis* (L.) Palisot de Beauvois | SETVI | 71 | *Cuscuta campestris* Yuncker | CVCCA |
| 33 | *Polytrichum commune* L. | PTYCO | 72 | *Onopordon acanthium* L. | ONRAC |
| 34 | *Sinapis arvensis* L. | SINAR | 73 | *Echium vulgare* L. | EHIVU |
| 35 | *Arctium lappa* L. | ARFLA | 74 | *Polygonum convolvulus* (L.) Löve | POLCO |
| 36 | *Equisetum arvense* L. | EQUAR | 75 | *Bunias orientalis* L. | BUNOR |
| 37 | *Consolida regalis* Gray | CNSRE | 76 | *Aethusa cynapium* L. | AETCY |
| 38 | *Plantago major* L. | PLAMA | 77 | *Solanum nigrum* L.. | SOLNI |

** – species of cultivated plants, which were studied as scavengers (contamination) form in agrophytocoenosises.

Parts of the weed plants were selected during the flowering phase, with equal participation of parts of the root system, stem, leaves, and generative part in the general sample weight (the share of each element in the weight structure is 20%). The sample thus formed was milled and dried to an air–dry mass. The obtained samples were milled in a powder–like mass using a laboratory mill. Milled samples were stored in sealed bags for extracted air samples in a dark, dry place. The extract was produced in the following concentration variants (w $v^{-1}$): 16.0%, 8.0%, 4.0%, 2.0%, 1.0%, 0,5%, 0,25%. For extraction, an appropriate amount of milled weed sample was placed in a glass container, an appropriate amount of distilled water was added, which corresponded to the desired extraction concentration according to the sample weight mass/liquid volume ratio. The container was shaken so that the plant mass was completely immersed in distilled water, preheated to 40 ◦C. The container was covered with a lid. The extraction process lasted for 1 day at +22 ° C, while the water–soluble chemical compounds penetrated the solution. For better extraction, the samples were centrifuged. After 24 hours, the extracted solution was poured into a container and filtered out using filters.

To determine the allelopathic activity of weeds concerning oilseed radish, two experiments were conducted under the recommended methodological approaches (John et al. 2006; VanVolkenburg et al., 2020). The first one provided the study of oilseed radish germination when germinating 100 seeds with a single sowing fraction in a thermostatic mode with a temperature of 25 ° C on filter paper. Indicators of seed germination in all variants of germination were determined by the 6 day, the dynamics of germination was determined from the 3rd to 9th day with a 24–hour interval after laying samples on germination under the national standard of Ukraine (Seeds of agricultural crops. 2003). In germination capacity calculations, Kader (2005) and Association of Official Seed Analysts recommendations were considered (ISTA 1985; AOSA, 1990). The experiment was repeated four times. The obtained result was compared with the control point – germination on the background of distilled water. The seeds were considered as germinating upon the appearance of 2 mm radicle as described by Association of Official Seed Analysts (ISTA 1985; AOSA, 1990).

The second laboratory experiment (simulated, given the recommendations of Fujii et al. (2005)) envisaged seed germination with the use of plastic seedling cassettes with a useful volume of one cell of 50 $cm^3$, filled with well moistened soil substrate, accompanied by water extracts of the studied weed species according to the experiment scheme with the same volume and time interval (on the first, fifth and tenth days of germination). One processing variant included 10 cells of one variant with fivefold repeatability. Watering with distilled water to regulate the humidity of the substrate was carried out on the 3rd and 7th days of germination. Distilled water irrigation option is used as a control. The overall morphological development of plants was determined by dividing the selections in non–contiguous repetitions by the 18$^{th}$ day of experiment (Figure 4.7).

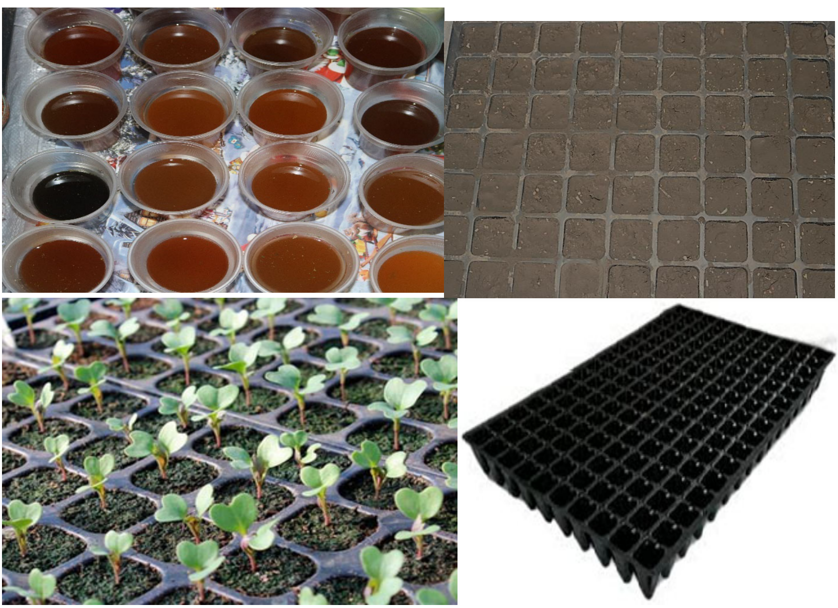


**Figure 4.7 – Extracts from weeds plants before filtration and purification (left position) and system for soil germination of oilseed radish seeds during irrigation by weed extracts of different concentration (right position) (Tsytsiura, 2022)**

The soil for the analysis was selected from the experimental field and was previously prepared for analysis according to the established methods, given the format of its use for laboratory bioindication (State standard of Ukraine, 2017). Soil substrate was selected from the Vinnytsia National Agrarian University experimental field (N 49°11′31″, E 28°22′16″) and matched the type of soil prevailing in the region, namely dark gray forest soils Luvic Greyic Phaeozem soils (IUSS Working Group WRB, 2015). Agrochemical field potential: humus content: 2,02–3,2%, lightly hydrolyzed nitrogen 67–92, mobile phosphorus 149–220, exchangeable potassium 92–126 mg $kg^{-1}$ of soil at $pH_{\text{кcl}}$ 5,5–6,0.

Intertool MT–3006 electronic caliper was used for linear measurements. Weight characteristics of plants were determined using electronic laboratory scales Certus CBA–300–0,005. The content of dry matter in plants to calculate one of the indicators was determined by the method of thermostatic drying of the summary sample of plants obtained at soil–substrate germination on all repetitions of the variants of the experiment. Acidity of solutions in the experiment was determined using the electronic pH meter Smart Sensor AS218. Periodization of the oilseed radish phenological period was carried out in accordance with the BBCH scale, which is typical for cultures (Test Guidelines…, 2017).

The speed of germination (S) of each variant was calculated by the following equation as described by Einhellig et al. (1982) and Khandakar & Bradbeer (1983) in the interpretation of El–Khatib et al. (2004):

$$S = \frac{N_1}{1} + \frac{N_2}{2} + \frac{N_3}{3} \dots \frac{N_n}{n}$$

where $N_1$, $N_2$, $N_3 \dots N_n$, ... is the proportion of seeds which germinated on day 1, 2, 3...n.

Coefficient of velocity ($CV_i$) was calculated by the adapted formula of Nasr & Mansour (2005):

$$CV_i = \left( \frac{\sum Ni}{T} \right),$$

where: N is the number of seeds germinated on day i and T is the number of days from sowing.

The rate of emergence (GR %) was determined by the formula of Marinov–Serafimov and Golubinova (2015):

$$GR_{\%} = 1 - \left[ \frac{N_t - C_n}{N_c} \right] \times 100,$$

where $N_t$ – germinated seeds in each treatment (%); $N_c$ – germinated seeds in the control treatment (%); Cn – concentration, %.

Dynamic development index (DDI) was calculated by the formula of Marinov–Serafimov et al. (2017, 2019):

$$DDI = \left[ \frac{t \log^{2}}{\log b - \log a} \right]$$

in which: a and b are the % of sprouted seeds, the root length, hypokotyl and seedlings (mm) and/or fresh biomass of the seedlings (g), accordingly in the control variant (a) and tested variants (b); t is the duration (days).

The growth and accumulation rates for fresh biomass of the root and seedlings were determined by the adapted formula of Dauta et al. (1990):

$$\mu = \left[ \frac{\ln N_t - \ln N_0}{t} \right]$$

in which: $N_t$ is the root length (mm), hypokotyl and seedlings or biomass for seedlings in the experimental variants; $N_o$ is the root length (mm), hypokotyl and seedlings or biomass for seedlings in the control variant; t is the duration (days).

Tolerance Index (TI) was determined by the adapted formula of Tahseen and Jagannath (2015):

$$TI = \frac{LS_{ET}}{LS_{CT}} \times 100$$

where $LS_{ET}$ – longest of seedlings in each experimental treatment, mm;
$LS_{CT}$ – longest of seedlings in the control treatment, mm.

The index of plant development (GI) was assessed by the formula of Gariglio et al. (2002):

$$GI = \left[ \frac{G}{G_0} \times \frac{L}{L_0} \right] \times 100 \text{ , \%}$$

where: G – germinated seeds (%) in each treatment; $G_0$ – germinated seeds (%) in the control treatment; L – average length (mm) of seedlings in treatment transformed into percentage in relation to the control treatment; $L_0$ – average length (mm) of the seedlings in the control treatment taken as 100%.

The germination root index (GRI) was assessed by the formula of Tiquia et al. (1996):

$$GRI = \left[\frac{G \times RG}{100}\right]$$

where: G – germinated seeds (%), RG – root growth (%).

Seedling vigor index (SVI) was determined using the equation poposed by Islam et al. (2009):

$$SVI = \left(\frac{S \times G}{100}\right)$$

where: S – seedling length in the treatments variant (mm); G – germinated seeds in the treatments variant (%).

Coefficient of allometry (CA) was calculated by the formula of Nasr & Mansour (2005):

$$CA = \frac{L_s}{L_r}$$

where: $L_s$ is shoot length and $L_r$ is root legth, mm.

Dry weight ratio (DWR) was calculated by the formula of Nasr & Mansour (2005):

$$DWR = \frac{DW_s}{DW_r}$$

where: DWs is dry weight of shoot (mg) and DWr is dry weight of root (mg).

Response index (RI) was determined by the equation by Williamson & Richardson (1988):

$$RI = \frac{T}{C} - 1 \text{ if } T<C; \quad RI = 1 - \frac{C}{T} \text{ if } T \geq C$$

where C – characteristic in the control treatment; T – characteristics in each treatment.

Percent inhibition (IR) was found according to the adapted formula of Surendra & Pota (1978):

$$IR = \frac{C - T}{C} \times 100 \text{ , \%}$$

where: C – parameter (length or biomass of shoot/root) in control; T – same parameter in experimental treatment.

Overall allelopathic potential (OAP) was determined by the equation of Tiquia et al. (1996) in interpretation equation of Smith (2013):

$$OAP = mean\ (IR_a + IR_b)\ /\ 100$$

where $IR_a$, a percent inhibition of the seedling growth at the lowest applied concentration of % w/v and $IR_b$ percent inhibition of the seedling growth at the highest applied concentration.

The following classes were considered by the Smith (2013): OAP Score Description 0–0.25 Non–allelopathic (NA); 0.26–0.5 Moderately allelopathic (MA); 0.51–0.75 Highly allelopathic (HA); 0.76–1.0 Extremely allelopathic (EA).

The percentage of seed germination was calculated after preliminary arcsin–transformation following the formula, forwarded by Hinkelmann & Kempthorne (1994):

$$Y = \arcsin\left(\sqrt{\frac{x\%}{100}}\right).$$

Statistical evaluation Raw data from all analyses were processed using statistical software package Statistica 10.0. for Windows. ANOVA and Student/Fisher test (Hinnkelmann and Kempthorne, 1994) were used for testing the differences of allelopathic effect, between different aqueous extracts and also between oil radish seed and seedling reaction ($p<0.05$).

The research revealed that the obtained water extracts of the plant species under study had different color, smell and different optical properties (Fig. 1). Measured indicators of the solutions' acidity of the received water extracts showed a dynamic change to the decrease of this indicator from the maximum concentration of the water extracts in 16.0% to the minimum concentration of 0.25%, according to the regularities of the pH indicator at the gradual dilution of the solution with distilled water (Table 4.8).

It should be noted that solution acidity significantly differed in the range of two presented concentrations. In the concentration variant of 16.0%, given the typical pH grouping (Slessarev et al., 2016), its gradation value changed from very strongly acidic (pH 4.5–5.0) for species such as *Thlaspi arvense* L. (8 – here and hereinafter CVN), *Papaver rhoeas* L. (13), *Taraxacum officinale* Weber (18), *Sonchus arvensis* L. (19), *Raphanus raphanistrum* L. (20), *Tripleurospermum maritimum* (L.) Koch (21), *Chenopodium album* L. (23), *Brassica napus* L. (25), *Rocket-cress* Brown (26), *Artemisia absinthium* L. (30), *Sinapis arvensis* L. (34), *Arctium lappa* L. (35), *Equisetum arvense* L. (36), *Eryngium campestre* L. (39), *Lepidium* *ruderale* L. (40), *Sinapis alba* L. (42), *Lepidium draba* L. (43), *Portulaca oleracea* L. (47), *Fumaria officinalis* L. (48), *Senecio vernalis* (Waldstein & Kitaibel) Alexander (61), *Amaranthus blitoides* Watson (64), *Acroptilon repens* (L.) de Candolle (66), *Cuscuta campestris* Yuncker (71), *Polygonum convolvulus* (L.) Löve (74) to slightly acidic level (pH 6.1–6.5) for a species such as *Carduus acanthoid*es L. (7).

The chemical composition of water extracts was not studied, but the nature of changes in pH of their environment at high concentrations indicates the heterogeneity of the environment and its general inhibitory nature due to the existing pH index. This index is lower than the biological optimum for oilseed radish culture in soil and climatic zones of its cultivation at the level of 5.5–6.5 (Tsytsiura & Tsytsiura, 2015). Despite the deviation of the pH value of water extract for many species of analyzed plants from the biological optimum, it should be noted that for oilseed radish, its seeds germinated at the level of 1.7–2.4% at pH 4.7–4.9. For example, in the variant of seed germination in water extract from *Thlaspi arvense* L. and *Taraxacum officinale* Weber.

It should also be noted that the general dynamics of seed germination level growth along with dilution of the solution with distilled water at a corresponding decrease in its concentration doesn't show stable growth. We can draw some significant conclusions from the above: firstly, the change in pH value at the corresponding dilution of an extract from a certain plant species has different interval nature, which indicates a different level of the solution's effective buffering. It's confirmed by the general features of extractive solutions of different concentrations (Slessarev et al., 2016). Secondly, such nature of seed germination formation at different levels of its acidity indicates a corresponding level of the broad adaptive response of oilseed radish plants to changes in pH conditions of growth in the interaction with substances extracted from different parts of plants. This way, the pH of the extract has a corresponding effect on seeds' laboratory germination rate. In our opinion, it has a great impact on those species in which the optimal biological interval of pH is moved from slightly acidic to a neutral level (pH 6.1–7.3). The influence of pH index of water extracts is confirmed by the nature of correlation dependence between its value at the water extract concentration of 0.25% of different plant species and indicators of oilseed radish seed germination – 0.259 ($p < 0.05$), and the growth of bond density in the concentration variant of 4% – 0.358 ($p < 0.05$).

Table 4.8

**Indicators of germination of oilseed radish seeds in water extracts of different weed species (under laboratory conditions), 2020 (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| CVN | pH at the concentr. | | Concentration, w/v (%) (water extracts) | | | | | | | Concentration, w/v (%) (soil substrate) | | | | | | | OAP (1–4%) | OAP (1–4%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.25 | 16.0 | 0.25 | 0.5 | 1.0 | 2.0 | 4.0 | 8.0 | 16.0 | 0.25 | 0.5 | 1.0 | 2.0 | 4.0 | 8.0 | 16.0 | water substrate | soil substrate |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 0 | 7.0 | 7.0 | 92.4 | 92.7 | 92.8 | 93.5 | 91.4 | 92.6 | 93.4 | 91.6 | 90.3 | 89.8 | 90.6 | 89.2 | 88.7 | 90.2 | – | – |
| 1 | 6.8 | 5.2 | 85.8 | 73.2 | 47.3 | 21.6 | 10.3 | 1.1 | 0.0 | 89.3 | 78.9 | 58.7 | 30.2 | 16.8 | 1.9 | 0.9 | 0.58 | 0.48 |
| 2 | 6.3 | 5.1 | 71.8 | 62.5 | 55.5 | 11.5 | 6.5 | 0.0 | 0.0 | 75.3 | 68.7 | 57.8 | 20.2 | 15.4 | 0.0 | 0.0 | 0.58 | 0.49 |
| 3 | 6.5 | 5.7 | 70.7 | 62.1 | 52.4 | 34.2 | 16.2 | 0.0 | 0.0 | 76.9 | 68.9 | 56.3 | 42.5 | 19.6 | 0.8 | 0.0 | 0.53 | 0.47 |
| 4 | 6.4 | 5.6 | 86.7 | 84.2 | 78.3 | 53.3 | 24.1 | 3.9 | 1.6 | 87.4 | 86.9 | 83.1 | 61.8 | 28.7 | 5.1 | 2.9 | 0.38 | 0.31 |
| 5 | 6.3 | 5.2 | 78.5 | 71.6 | 67.2 | 37.5 | 28.3 | 2.8 | 0.0 | 81.8 | 78.9 | 72.5 | 44.5 | 32.6 | 3.6 | 0.0 | 0.41 | 0.35 |
| 6 | 6.1 | 5.4 | 84.7 | 78.8 | 74.5 | 59.2 | 38.5 | 6.1 | 2.7 | 87.2 | 81.4 | 77.9 | 62.3 | 41.6 | 6.9 | 3.5 | 0.34 | 0.28 |
| 7 | 6.6 | 6.1 | 76.2 | 70.8 | 62.6 | 49.3 | 27.2 | 1.4 | 0.0 | 80.2 | 75.3 | 69.5 | 51.8 | 33.5 | 2.1 | 0.0 | 0.43 | 0.35 |
| 8 | 6.8 | 4.7 | 69.7 | 61.3 | 49.2 | 35.5 | 19.4 | 3.9 | 1.5 | 77.6 | 67.2 | 54.7 | 42.6 | 23.5 | 5.2 | 2.6 | 0.52 | 0.46 |
| 9 | 6.3 | 5.4 | 65.9 | 48.2 | 37.3 | 19.1 | 9.2 | 0.0 | 0.0 | 68.9 | 53.6 | 44.7 | 23.8 | 15.2 | 0.0 | 0.0 | 0.63 | 0.54 |
| 10 | 6.4 | 5.5 | 82.6 | 73.4 | 67.2 | 29.2 | 14.2 | 2.7 | 0.0 | 83.9 | 77.2 | 74.3 | 34.5 | 19.2 | 3.2 | 0.0 | 0.48 | 0.40 |
| 11 | 6.5 | 5.1 | 73.6 | 61.8 | 52.4 | 21.5 | 8.3 | 0.0 | 0.0 | 78.9 | 65.8 | 56.9 | 29.2 | 13.8 | 0.0 | 0.0 | 0.57 | 0.47 |
| 12 | 6.2 | 5.3 | 68.4 | 58.1 | 49.5 | 28.4 | 16.1 | 0.0 | 0.0 | 72.6 | 60.3 | 55.8 | 32.4 | 20.9 | 0.0 | 0.0 | 0.54 | 0.45 |
| 13 | 6.0 | 4.7 | 69.7 | 57.3 | 29.6 | 14.4 | 6.1 | 0.0 | 0.0 | 72.6 | 60.8 | 35.6 | 21.4 | 10.9 | 0.0 | 0.0 | 0.68 | 0.61 |
| 14 | 6.5 | 5.7 | 70.5 | 56.7 | 38.5 | 9.3 | 3.2 | 0.0 | 0.0 | 74.8 | 60.3 | 42.6 | 12.6 | 7.8 | 0.0 | 0.0 | 0.67 | 0.60 |
| 15 | 6.1 | 5.5 | 67.2 | 45.9 | 34.8 | 9.5 | 2.4 | 0.0 | 0.0 | 70.3 | 48.9 | 39.6 | 11.4 | 5.2 | 0.0 | 0.0 | 0.72 | 0.68 |
| 16 | 6.2 | 5.3 | 78.9 | 60.9 | 42.2 | 26.2 | 10.4 | 1.8 | 0.0 | 82.4 | 63.8 | 44.6 | 32.8 | 12.8 | 2.9 | 0.0 | 0.60 | 0.56 |
| 17 | 6.3 | 5.1 | 60.9 | 42.7 | 33.6 | 17.1 | 5.5 | 0.0 | 0.0 | 63.2 | 44.8 | 35.6 | 19.6 | 6.9 | 0.0 | 0.0 | 0.67 | 0.64 |
| 18 | 6.2 | 4.9 | 89.5 | 84.5 | 77.4 | 31.5 | 18.4 | 6.2 | 2.4 | 90.4 | 86.5 | 79.6 | 34.2 | 21.3 | 6.8 | 3.6 | 0.41 | 0.36 |
| 19 | 5.8 | 4.8 | 80.2 | 67.9 | 58.5 | 19.2 | 7.2 | 0.0 | 0.0 | 83.6 | 71.3 | 60.4 | 21.3 | 8.6 | 0.0 | 0.0 | 0.56 | 0.52 |
| 20 | 6.0 | 4.8 | 67.4 | 51.2 | 38.7 | 21.4 | 3.6 | 0.0 | 0.0 | 70.8 | 53.6 | 40.8 | 23.6 | 5.1 | 0.0 | 0.0 | 0.67 | 0.63 |
| 21 | 5.9 | 4.8 | 78.3 | 50.8 | 41.9 | 24.2 | 8.4 | 0.0 | 0.0 | 80.4 | 52.8 | 43.6 | 29.3 | 11.5 | 0.0 | 0.0 | 0.61 | 0.57 |
| 22 | 6.4 | 5.3 | 63.3 | 42.7 | 35.6 | 21.5 | 11.5 | 2.2 | 0.0 | 65.9 | 46.2 | 40.5 | 23.5 | 13.8 | 3.4 | 0.0 | 0.62 | 0.57 |

(End of Table 4.8)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 6.0 | 4.9 | 67.2 | 46.2 | 29.7 | 18.6 | 7.2 | 0.0 | 0.0 | 69.1 | 48.4 | 32.3 | 20.8 | 9.1 | 0.0 | 0.0 | 0.67 | 0.63 |
| 24 | 6.2 | 5.3 | 62.8 | 50.2 | 41.9 | 26.7 | 9.3 | 0.0 | 0.0 | 64.8 | 52.6 | 43.5 | 30.4 | 11.6 | 0.0 | 0.0 | 0.61 | 0.57 |
| 25 | 5.6 | 4.7 | 65.9 | 58.1 | 47.8 | 32.4 | 11.4 | 0.0 | 0.0 | 68.7 | 59.6 | 49.6 | 34.5 | 13.9 | 0.0 | 0.0 | 0.57 | 0.53 |
| 26 | 5.9 | 4.9 | 83.4 | 47.9 | 39.6 | 28.5 | 14.1 | 0.0 | 0.0 | 85.1 | 53.6 | 40.8 | 32.3 | 15.6 | 0.0 | 0.0 | 0.59 | 0.56 |
| 27 | 6.7 | 5.6 | 90.1 | 78.4 | 68.7 | 47.2 | 30.2 | 6.8 | 4.2 | 90.8 | 81.3 | 70.4 | 49.2 | 33.5 | 7.9 | 5.7 | 0.40 | 0.35 |
| 28 | 6.0 | 5.1 | 86.7 | 73.6 | 60.3 | 36.5 | 17.5 | 3.1 | 0.0 | 87.9 | 74.5 | 62.4 | 39.3 | 19.8 | 4.0 | 0.0 | 0.49 | 0.45 |
| 29 | 6.3 | 5.2 | 75.6 | 64.5 | 55.4 | 32.4 | 18.2 | 0.0 | 0.0 | 78.1 | 66.7 | 57.8 | 33.9 | 21.3 | 0.0 | 0.0 | 0.50 | 0.46 |
| 30 | 5.9 | 5.0 | 86.1 | 70.3 | 57.8 | 27.8 | 11.3 | 2.4 | 0.0 | 87.4 | 71.8 | 62.1 | 30.9 | 12.6 | 3.7 | 0.0 | 0.53 | 0.49 |
| 31 | 6.0 | 5.2 | 90.1 | 82.6 | 78.2 | 44.2 | 9.6 | 1.1 | 0.0 | 90.8 | 83.9 | 80.4 | 45.8 | 10.9 | 1.8 | 0.0 | 0.46 | 0.42 |
| 32 | 6.2 | 5.1 | 75.2 | 66.3 | 51.5 | 36.5 | 17.2 | 4.1 | 0.0 | 77.6 | 67.4 | 53.8 | 38.4 | 19.6 | 4.9 | 0.0 | 0.52 | 0.48 |
| 33 | 6.3 | 5.3 | 64.3 | 51.7 | 37.8 | 18.5 | 9.3 | 1.5 | 0.0 | 66.8 | 52.6 | 39.3 | 20.6 | 11.4 | 2.4 | 0.0 | 0.62 | 0.59 |
| 34 | 5.7 | 4.8 | 69.4 | 57.8 | 45.5 | 19.3 | 3.2 | 0.0 | 0.0 | 70.8 | 59.3 | 47.2 | 20.8 | 3.9 | 0.0 | 0.0 | 0.64 | 0.62 |
| 35 | 5.9 | 5.0 | 89.6 | 84.2 | 72.6 | 56.4 | 10.4 | 1.7 | 0.0 | 90.4 | 85.6 | 73.9 | 57.8 | 11.8 | 2.1 | 0.0 | 0.48 | 0.44 |
| 36 | 5.6 | 4.9 | 84.7 | 71.3 | 52.4 | 38.8 | 5.1 | 0.0 | 0.0 | 80.4 | 70.6 | 51.2 | 37.6 | 4.8 | 0.0 | 0.0 | 0.60 | 0.59 |
| 37 | 6.3 | 5.2 | 84.1 | 60.9 | 32.5 | 21.4 | 11.3 | 3.9 | 1.8 | 85.6 | 62.5 | 34.8 | 22.6 | 12.8 | 5.2 | 2.6 | 0.63 | 0.60 |
| 38 | 5.6 | 5.3 | 83.9 | 62.8 | 34.7 | 19.2 | 8.4 | 1.5 | 0.0 | 84.8 | 63.6 | 35.8 | 20.6 | 8.9 | 2.6 | 0.0 | 0.64 | 0.62 |
| 39 | 5.5 | 4.5 | 90.8 | 85.2 | 74.4 | 36.6 | 11.5 | 1.9 | 0.0 | 91.8 | 86.5 | 75.2 | 37.8 | 12.6 | 2.5 | 0.0 | 0.46 | 0.43 |
| 40 | 5.8 | 4.7 | 90.2 | 86.2 | 78.6 | 39.1 | 12.4 | 0.0 | 0.0 | 91 | 87.3 | 80.1 | 40.9 | 13.8 | 0.0 | 0.0 | 0.44 | 0.40 |
| 41 | 6.3 | 5.5 | 86.3 | 78.5 | 64.5 | 37.4 | 21.6 | 4.2 | 1.8 | 82.8 | 76.5 | 69.6 | 42.3 | 25.6 | 5.6 | 2.7 | 0.45 | 0.39 |
| 42 | 5.8 | 4.8 | 56.9 | 47.2 | 38.7 | 27.5 | 9.3 | 0.0 | 0.0 | 58.1 | 48.4 | 39.8 | 29.2 | 10.6 | 0.0 | 0.0 | 0.62 | 0.59 |
| 43 | 5.7 | 4.9 | 68.7 | 59.3 | 47.2 | 31.4 | 12.5 | 0.0 | 0.0 | 70.1 | 60.9 | 48.6 | 32.5 | 13.6 | 0.0 | 0.0 | 0.57 | 0.54 |
| 44 | 6.7 | 5.5 | 88.7 | 82.8 | 79.3 | 57.6 | 21.7 | 3.7 | 1.1 | 90.9 | 84.1 | 80.5 | 60.2 | 22.6 | 4.5 | 1.9 | 0.39 | 0.35 |
| 45 | 6.1 | 5.2 | 92.0 | 90.2 | 84.2 | 67.4 | 32.2 | 3.3 | 3.4 | 91.2 | 90.8 | 85.7 | 70.1 | 35.6 | 5.2 | 4.5 | 0.32 | 0.27 |
| 46 | 6.6 | 5.7 | 91.4 | 82.6 | 69.5 | 48.4 | 14.1 | 5.3 | 1.6 | 92.4 | 83.6 | 70.8 | 50.2 | 15.9 | 6.7 | 2.9 | 0.47 | 0.43 |
| 47 | 5.7 | 4.9 | 78.9 | 60.8 | 48.5 | 31.7 | 6.3 | 0.0 | 0.0 | 79.3 | 61.8 | 50.2 | 33.6 | 7.8 | 0.0 | 0.0 | 0.60 | 0.57 |
| 48 | 5.9 | 4.8 | 74.5 | 59.6 | 41.4 | 27.5 | 8.4 | 1.4 | 0.0 | 75.8 | 60.2 | 39.8 | 26.3 | 8.9 | 1.6 | 0.0 | 0.62 | 0.60 |
| 49 | 6.5 | 5.2 | 86.9 | 74.2 | 59.6 | 29.2 | 11.2 | 2.2 | 0.0 | 88.9 | 75.6 | 61.2 | 30.8 | 12.9 | 2.6 | 0.0 | 0.53 | 0.49 |
| 50 | 6.4 | 5.5 | 80.2 | 60.8 | 42.4 | 34.1 | 19.4 | 2.8 | 1.5 | 81.7 | 62.3 | 44.5 | 35.6 | 19.8 | 3.2 | 1.8 | 0.55 | 0.52 |
| 51 | 6.5 | 5.6 | 83.2 | 67.8 | 54.5 | 34.5 | 18.3 | 3.1 | 1.8 | 81.9 | 65.6 | 55.8 | 32.5 | 17.8 | 2.5 | 1.6 | 0.51 | 0.49 |
| 52 | 6.3 | 5.5 | 86.9 | 79.6 | 68.3 | 54.2 | 25.1 | 5.3 | 2.9 | 84.5 | 78.4 | 66.8 | 53.2 | 23.6 | 4.8 | 2.6 | 0.42 | 0.41 |
| 53 | 6.2 | 5.4 | 87.8 | 77.9 | 69.4 | 51.5 | 24.3 | 6.9 | 2.2 | 89.2 | 78.7 | 71.2 | 50.8 | 21.3 | 5.5 | 1.8 | 0.42 | 0.40 |

(End of Table 4.8)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 6.4 | 5.6 | 86.3 | 70.5 | 62.5 | 46.4 | 27.8 | 8.1 | 3.8 | 87.4 | 72.8 | 63.5 | 45.8 | 25.6 | 7.4 | 3.6 | 0.43 | 0.42 |
| 55 | 6.1 | 5.3 | 74.2 | 61.2 | 49.5 | 37.8 | 14.2 | 2.5 | 1.4 | 78.7 | 60.3 | 50.8 | 35.9 | 15.2 | 2.3 | 1.7 | 0.55 | 0.52 |
| 56 | 6.3 | 5.3 | 85.2 | 70.8 | 63.2 | 38.3 | 18.6 | 2.3 | 1.1 | 83.8 | 72.4 | 61.8 | 40.5 | 19.6 | 2.6 | 1.3 | 0.47 | 0.45 |
| 57 | 6.1 | 5.2 | 87.2 | 74.5 | 58.7 | 42.7 | 21.5 | 6.7 | 3.1 | 86.3 | 75.5 | 57.6 | 42.8 | 23.8 | 5.6 | 3.2 | 0.47 | 0.45 |
| 58 | 5.7 | 4.8 | 74.1 | 60.2 | 49.6 | 28.6 | 11.7 | 0.0 | 0.0 | 75.6 | 62.3 | 50.9 | 29.8 | 12.6 | 0.0 | 0.0 | 0.56 | 0.53 |
| 59 | 6.3 | 5.5 | 80.5 | 69.8 | 57.5 | 39.2 | 19.3 | 4.1 | 2.9 | 78.9 | 70.4 | 58.6 | 40.8 | 18.6 | 3.8 | 2.7 | 0.49 | 0.47 |
| 60 | 6.4 | 5.4 | 90.8 | 85.6 | 77.6 | 58.7 | 26.4 | 8.2 | 4.5 | 90.5 | 85.3 | 78.4 | 60.3 | 27.8 | 8.6 | 5.1 | 0.37 | 0.34 |
| 61 | 5.7 | 4.9 | 76.9 | 65.8 | 56.4 | 32.1 | 14.2 | 1.1 | 0.0 | 77.4 | 63.9 | 54.8 | 33.4 | 15.1 | 1.3 | 0.0 | 0.52 | 0.50 |
| 62 | 6.2 | 5.3 | 86.9 | 80.7 | 71.8 | 48.4 | 22.5 | 7.3 | 4.2 | 88.5 | 82.4 | 72.3 | 49.6 | 24.5 | 7.7 | 4.3 | 0.42 | 0.38 |
| 63 | 6.3 | 5.5 | 90.8 | 82.3 | 79.7 | 58.6 | 34.3 | 8.9 | 5.4 | 88.9 | 83.6 | 80.4 | 59.6 | 35.6 | 9.3 | 5.3 | 0.33 | 0.29 |
| 64 | 5.5 | 4.7 | 67.8 | 52.6 | 40.5 | 19.1 | 8.6 | 0.0 | 0.0 | 68.4 | 54.7 | 39.6 | 18.7 | 9.2 | 0.0 | 0.0 | 0.62 | 0.60 |
| 65 | 6.3 | 5.5 | 77.9 | 62.3 | 48.4 | 29.3 | 14.7 | 3.6 | 2.3 | 78.2 | 61.8 | 50.1 | 30.6 | 15.5 | 4.2 | 2.6 | 0.55 | 0.52 |
| 66 | 6.1 | 5.0 | 62.4 | 50.2 | 32.6 | 16.4 | 7.3 | 0.0 | 0.0 | 63.8 | 52.6 | 33.6 | 15.2 | 6.8 | 0.0 | 0.0 | 0.66 | 0.65 |
| 67 | 6.3 | 5.5 | 89.3 | 82.9 | 73.7 | 52.1 | 27.4 | 6.2 | 5.1 | 87.5 | 80.6 | 69.8 | 53.8 | 29.6 | 6.7 | 4.8 | 0.39 | 0.37 |
| 68 | 6.4 | 5.3 | 86.8 | 78.9 | 69.2 | 47.8 | 26.2 | 7.1 | 3.9 | 85.3 | 77.4 | 70.8 | 51.3 | 27.8 | 8.3 | 4.2 | 0.41 | 0.37 |
| 69 | 6.3 | 5.5 | 82.9 | 75.3 | 62.5 | 46.2 | 14.7 | 2.5 | 1.4 | 83.4 | 77.5 | 63.9 | 42.8 | 13.8 | 2 | 1.2 | 0.49 | 0.47 |
| 70 | 6.0 | 5.1 | 74.1 | 56.9 | 47.7 | 32.5 | 11.1 | 2.1 | 0.9 | 75.2 | 57.1 | 49.2 | 33.6 | 12.5 | 2.5 | 1.2 | 0.57 | 0.54 |
| 71 | 5.6 | 4.8 | 60.9 | 42.5 | 29.3 | 16.7 | 6.5 | 0.0 | 0.0 | 56.4 | 40.3 | 28.4 | 15.2 | 5.8 | 0.0 | 0.0 | 0.68 | 0.68 |
| 72 | 5.2 | 5.5 | 69.7 | 59.6 | 44.5 | 29.5 | 12.5 | 0.0 | 0.0 | 70.8 | 60.3 | 45.2 | 28.4 | 11.8 | 0.7 | 0 | 0.58 | 0.56 |
| 73 | 6.5 | 5.7 | 82.6 | 70.9 | 57.8 | 36.4 | 19.3 | 2.7 | 1.2 | 83.8 | 72.5 | 59.6 | 35.6 | 18.4 | 2.3 | 1 | 0.49 | 0.47 |
| 74 | 6.3 | 5.0 | 63.2 | 50.8 | 41.4 | 21.7 | 10.4 | 0.0 | 0.0 | 64.5 | 52.6 | 43.2 | 20.3 | 9.8 | 0.0 | 0.0 | 0.60 | 0.58 |
| 75 | 6.2 | 5.4 | 82.6 | 75.9 | 61.3 | 41.4 | 16.5 | 2.4 | 0.0 | 83.6 | 77.8 | 62.6 | 39.8 | 15.2 | 2.1 | 0.0 | 0.49 | 0.47 |
| 76 | 5.8 | 5.1 | 66.3 | 54.7 | 41.6 | 29.5 | 18.3 | 1.7 | 0.0 | 72.8 | 62.3 | 48.9 | 27.2 | 15.4 | 1.3 | 0.0 | 0.56 | 0.53 |
| 77 | 6.2 | 5.5 | 81.4 | 68.9 | 50.7 | 31.7 | 12.4 | 3.9 | 1.1 | 83.2 | 67.1 | 49.8 | 32.8 | 12.9 | 3.3 | 1.5 | 0.55 | 0.54 |
| Average | *6,2* | *5,2* | *78,4* | *66,4* | *54,8* | *34,4* | *16,0* | *3,5* | *2,1* | *79,8* | *68,2* | *56,8* | *36,4* | *17,7* | *3,7* | *2,3* | *0,53* | *0,49* |
| $SSD_{0.05}$ | 0.1 | 0.3 | 1.8 | 1.6 | 1.4 | 1.2 | 1.0 | – | – | 1.9 | 1.8 | 1.7 | 1.5 | 1.4 | – | – | 0.036 | 0.047 |
| Tukey's test: total number of comparable comparison pairs 3003, number of comparison pairs that were not included in 95% confidence interval ($p_{adj}$=0.492–1.000) 543 (18.08% of values that do not differ significantly in the 95% confidence interval) | | | | | | | | | | | | | | | | | | |

SSD – The smallest significant difference between the values according to LSD test для $p< 0.05$; CVN – coded variant number.

It was also found that oilseed radish is very sensitive in terms of allelopathic effect. It is confirmed by laboratory germination results both in water and soil substrate already from the extract concentration level of 0.25%. At the same time, the extremely high concentration of the extract for most species is limited to 4.0%, with an interval of a significant decrease in laboratory germination of 1.0–4.0% (Fig. 2).

According to Grodzinsky (1965), this nature of reaction indicates both high allelopathic sensitivity of the species and its adaptive vitality tactics in the formation of its own cenosis in the overall cenosis of interactions between species diversity of competing plant species. In many studies (Inderjit, Keating K.I. 1999; Khanh et al., 2005; Izzet et al., 2006; Jabran et al., 2006; Kunz et al., 2016; Lahdhiri and Mekki, 2016), an allelopathic reaction in the range from 0.1% to 32.0 was observed for many plant species. At the same time, the reaction to an intensive decrease in seed germination is already determined from 0.5–1.5%. In some early studies (Grodzinsky, 1965), it is noted that the degree of the allelopathic reaction manifestation is conditioned both by the species introduction in terms of the time of its cultivation, and by the proximity to typical representatives of weed vegetation. In long–term agricultural use, the species spectrum of allelopathic reaction narrows to the most aggressive species, and vice versa, with limited territorial cultivation, the allelopathic sensitivity is higher. This is confirmed in our studies, given the fact that the intensity of oilseed radish cultivation in many regions is limited.

The nature of formation of the oilseed radish germination also differed at germination on filter paper (trivial water substrate of germination) and, respectively, in the variant of approximate imitation to field conditions – on the soil substrate. The presented averaged data show a general decrease in allelopathic effect on oilseed radish germination exactly when grown on the soil substrate by 0.2–2.0% depending on the extract concentration. The maximum difference is noted when comparing two germination variants in the concentration range of 0.25–2%, and the minimum one in the range of 8–16%. Moreover, the value of such reduction is species–specific. So, for the species *Capsella bursa–pastoris* L. (1) it ranged from 0.9 to 10.4%, for the species *Agropyron repens* (L.) Gould (16) 1.1–3.5%, and for the species *Polygonum aviculare* L. (46) 1.0–1.8%. This nature of allelopathic effect has also been noted in the researches of several scientists (Blum, 2004; Fujii et al., 2005; Subtain et al., 2014).

In these researches it is explained by the absorption and adsorption of a number of substances extracted into the solution during the extraction process. In fact, this confirms the statement that the allelopathic potential of a particular weed species is determined both by its stage phenological development and by the edaphic conditions of its growth and development, which determine both the vegetation intensity of the species, its vitality index, and the degree of influence of its root excretions, given the favorable soil fertility conditions for the species itself.

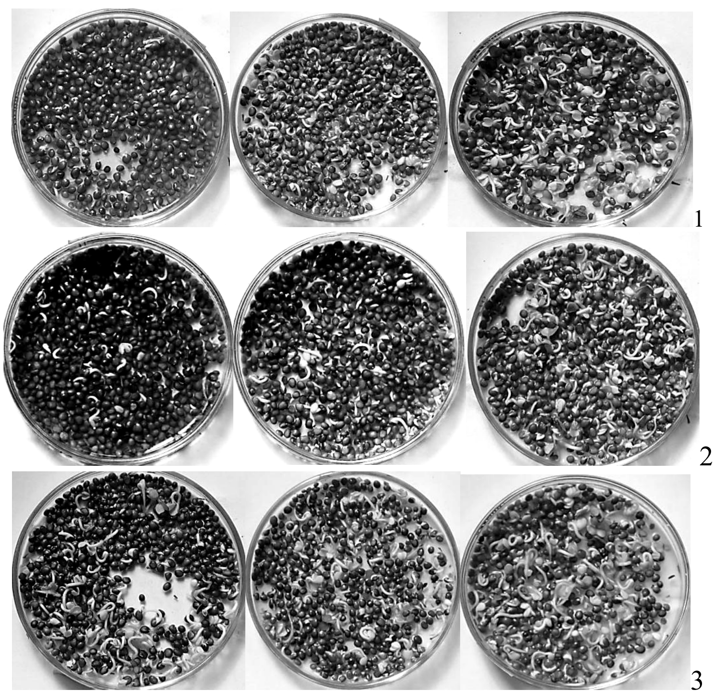



**Figure 4.8 – As an example, from the overall totality of studied types of oilseed radish germination in water extracts of weeds of various concentrations (sequentially from left to right: 4.0, 2.0 and 1.0%) (1 – *Ambrosia artemisiifolia* L.; 2 – *Galium aparine* L.; 3 – *Carduus acanthoides* L.). (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

In our opinion, the difference in the allelopathic impact on seed germination for the two variants is a measure of the importance of soil conditions for the manifestation of herbal competition of this species in relation to the oilseed radish. We consider the fact that in its cycle of development, critical period for weed control (CPWC) is typical for the period from 5–7 to 12–15 days of vegetation (Tsytsiura, 2020), which determines a specific competition of this species in relation to other plant species (Lawley et al., 2012). An actual evidence of the dynamic nature of the formation of oilseed radish seed germination at changing concentration levels and its dependence on the nature of germination are the results of calculating such an indicator as the rate of emergence (GR %) (Table 4.9).

According to this indicator, the nature of changes in the oilseed radish laboratory germination has significant differences in comparison of soil and water germination substrate with an increase in favor of the soil substrate. The maximum oilseed radish sensitivity at germination stage with minimum extract concentration (0.25%) is noted for such weeds as Amaranthus retroflexus L. (17), Convolvulus arvensis L. (24), Acroptilon repens (L.) de Candolle (66), Polygonum convolvulus (L.) Löve (74) with the GR level in the range of 65.6–71.7%. The minimum indicator in the 96.6–99.9 range was observed in such weeds as *Taraxacum officinale* Weber (18), *Centaurea cyanus* L. (27), *Rumex confertus* Willdenow (31), *Arctium lappa* L. (35), *Eryngium campestre* L. (39), *Lepidium ruderale* L. (40), *Lepidium campestre* (L.) Brown (45), *Achillea millefolium* L. (60), *Poa annua* L. (63). That is, the minimum sensitivity at seed germination in oilseed radish is observed for weeds, the occurrence frequency of which in its cenosis is minimal. The very nature of the germination dynamics had a heterogeneous nature and species specificity from a slow–down nature to a nature with leap–scopic decline, which points in favor of the biochemical causes (Reigosa et al., 2006; Florence et al., 2019).

For a more detailed assessment of the nature of this dynamics, two indicators of speed of germination (S) and coefficient of velocity ($CV_i$) were used for the soil–free germination variant, which, as we found, is more biologically aggressive and needs to be evaluated typologically for the nature of similarity formation on an allelopathic background. These indicators are rarely applied to such research systems, but are very informative (Nasr & Mansour (2005)), as they demonstrate both the overall

Table 4.9

**The rate of emergence (GR, %) of oilseed radish seeds in water extracts of different weed species (under laboratory conditions), 2020 (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| CVN | Concentration, w/v (%) (water extracts) | | | | | Concentration, w/v (%) (soil substrate) | | | | | CVN | Concentration, w/v (%) (water extracts) | | | | | Concentration, w/v (%) (soil substrate) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0.25** | **0.5** | **1.0** | **2.0** | **4.0** | **0.25** | **0.5** | **1.0** | **2.0** | **4.0** | | **0.25** | **0.5** | **1.0** | **2.0** | **4.0** | **0.25** | **0.5** | **1.0** | **2.0** | **4.0** |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 39 | 98.0 | 91.4 | 79.1 | 37.0 | 8.2 | 99.9 | 95.2 | 82.6 | 39.5 | 9.6 |
| 1 | 92.6 | 78.4 | 49.9 | 21.0 | 6.9 | 97.2 | 86.8 | 64.3 | 31.1 | 14.3 | 40 | 97.3 | 92.4 | 83.6 | 39.7 | 9.2 | 99.1 | 96.1 | 88.1 | 42.9 | 11.0 |
| 2 | 77.4 | 66.9 | 58.7 | 10.2 | 2.7 | 81.9 | 75.5 | 63.3 | 20.1 | 12.8 | 41 | 93.1 | 84.1 | 68.4 | 37.9 | 19.3 | 90.1 | 84.2 | 76.4 | 44.5 | 24.2 |
| 3 | 76.2 | 66.5 | 55.4 | 34.4 | 13.3 | 83.7 | 75.7 | 61.6 | 44.7 | 17.5 | 42 | 61.3 | 50.4 | 40.6 | 27.3 | 5.8 | 63.2 | 53.0 | 43.2 | 30.0 | 7.4 |
| 4 | 93.6 | 90.3 | 83.3 | 54.9 | 22.0 | 95.1 | 95.7 | 91.4 | 66.0 | 27.7 | 43 | 74.1 | 63.4 | 49.8 | 31.4 | 9.3 | 76.3 | 66.9 | 53.0 | 33.7 | 10.8 |
| 5 | 84.7 | 76.7 | 71.3 | 38.0 | 26.6 | 89.0 | 86.8 | 79.6 | 46.9 | 32.1 | 44 | 95.7 | 88.8 | 84.4 | 59.5 | 19.4 | 99.0 | 92.6 | 88.5 | 64.2 | 20.9 |
| 6 | 91.4 | 84.5 | 79.2 | 61.2 | 37.7 | 94.9 | 89.6 | 85.6 | 66.6 | 42.2 | 45 | 99.3 | 96.8 | 89.7 | 69.9 | 30.9 | 99.3 | 100 | 94.3 | 75.2 | 35.4 |
| 7 | 82.2 | 75.8 | 66.4 | 50.6 | 25.4 | 87.3 | 82.8 | 76.3 | 55.0 | 33.1 | 46 | 98.6 | 88.6 | 73.8 | 49.6 | 11.1 | 100.6 | 92.0 | 77.7 | 53.2 | 13.3 |
| 8 | 75.2 | 65.6 | 51.9 | 35.8 | 16.8 | 84.4 | 73.9 | 59.8 | 44.8 | 21.9 | 47 | 85.1 | 65.0 | 51.2 | 31.8 | 2.5 | 86.3 | 67.9 | 54.8 | 34.9 | 4.3 |
| 9 | 71.0 | 51.5 | 39.1 | 18.3 | 5.7 | 74.9 | 58.8 | 48.7 | 24.1 | 12.6 | 48 | 80.4 | 63.8 | 43.5 | 27.3 | 4.8 | 82.5 | 66.1 | 43.2 | 26.8 | 5.5 |
| 10 | 89.1 | 78.6 | 71.3 | 29.1 | 11.2 | 91.3 | 84.9 | 81.6 | 35.9 | 17.0 | 49 | 93.8 | 79.5 | 63.1 | 29.1 | 7.9 | 96.8 | 83.2 | 67.0 | 31.8 | 10.0 |
| 11 | 79.4 | 66.1 | 55.4 | 20.9 | 4.7 | 85.9 | 72.3 | 62.2 | 30.0 | 11.0 | 50 | 86.5 | 65.0 | 44.6 | 34.3 | 16.8 | 88.9 | 68.4 | 48.4 | 37.1 | 17.7 |
| 12 | 73.8 | 62.1 | 52.3 | 28.2 | 13.2 | 79.0 | 66.2 | 61.0 | 33.6 | 18.9 | 51 | 89.8 | 72.6 | 57.7 | 34.8 | 15.6 | 89.1 | 72.1 | 61.0 | 33.7 | 15.5 |
| 13 | 75.2 | 61.3 | 30.8 | 13.3 | 2.3 | 79.0 | 66.8 | 38.5 | 21.4 | 7.7 | 52 | 93.8 | 85.3 | 72.5 | 55.8 | 23.1 | 92.0 | 86.3 | 73.3 | 56.5 | 22.0 |
| 14 | 76.0 | 60.6 | 40.4 | 7.8 | –0.9 | 81.4 | 66.2 | 46.3 | 11.7 | 4.3 | 53 | 94.8 | 83.5 | 73.7 | 52.9 | 22.2 | 97.1 | 86.6 | 78.2 | 53.9 | 19.4 |
| 15 | 72.5 | 49.0 | 36.4 | 8.0 | –1.8 | 76.5 | 53.6 | 43.0 | 10.4 | 1.3 | 54 | 93.1 | 75.5 | 66.3 | 47.5 | 26.0 | 95.1 | 80.1 | 69.6 | 48.3 | 24.2 |
| 16 | 85.1 | 65.2 | 44.4 | 25.9 | 7.0 | 89.7 | 70.1 | 48.6 | 34.0 | 9.9 | 55 | 80.0 | 65.5 | 52.3 | 38.3 | 11.2 | 85.6 | 66.2 | 55.5 | 37.4 | 12.6 |
| 17 | 65.6 | 45.5 | 35.1 | 16.1 | 1.6 | 68.7 | 49.1 | 38.5 | 19.4 | 3.3 | 56 | 91.9 | 75.8 | 67.0 | 38.8 | 16.0 | 91.2 | 79.6 | 67.7 | 42.5 | 17.5 |
| 18 | 96.6 | 90.6 | 82.3 | 31.6 | 15.8 | 98.4 | 95.2 | 87.5 | 35.5 | 19.4 | 57 | 94.1 | 79.8 | 62.2 | 43.5 | 19.1 | 93.9 | 83.1 | 63.0 | 45.0 | 22.2 |
| 19 | 86.5 | 72.7 | 62.0 | 18.4 | 3.5 | 91.0 | 78.4 | 66.1 | 21.3 | 5.2 | 58 | 79.9 | 64.4 | 52.4 | 28.4 | 8.4 | 82.3 | 68.4 | 55.6 | 30.7 | 9.6 |
| 20 | 72.7 | 54.7 | 40.6 | 20.7 | –0.4 | 77.0 | 58.8 | 44.3 | 23.8 | 1.2 | 59 | 86.9 | 74.8 | 60.9 | 39.8 | 16.7 | 85.9 | 77.4 | 64.1 | 42.8 | 16.4 |
| 21 | 84.5 | 54.3 | 44.1 | 23.7 | 4.8 | 87.5 | 57.9 | 47.4 | 30.1 | 8.4 | 60 | 98.0 | 91.8 | 82.5 | 60.6 | 24.5 | 98.5 | 93.9 | 86.2 | 64.3 | 26.7 |
| 22 | 68.2 | 45.5 | 37.3 | 20.9 | 8.2 | 71.7 | 50.6 | 44.0 | 23.7 | 11.0 | 61 | 83.0 | 70.4 | 59.7 | 32.2 | 11.2 | 84.2 | 70.2 | 59.9 | 34.7 | 12.4 |

(End of Table 4.9)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 72.5 | 49.3 | 30.9 | 17.8 | 3.5 | 75.2 | 53.0 | 34.9 | 20.8 | 5.7 | 62 | 93.8 | 86.5 | 76.3 | 49.6 | 20.2 | 96.3 | 90.7 | 79.4 | 52.5 | 23.0 |
| 24 | 67.7 | 53.6 | 44.1 | 26.4 | 5.8 | 70.5 | 57.7 | 47.3 | 31.3 | 8.5 | 63 | 98.0 | 88.2 | 84.8 | 60.5 | 33.2 | 96.8 | 92.0 | 88.4 | 63.6 | 35.4 |
| 25 | 71.0 | 62.1 | 50.4 | 32.5 | 8.1 | 74.7 | 65.4 | 54.1 | 35.9 | 11.1 | 64 | 73.1 | 56.2 | 42.6 | 18.3 | 5.0 | 74.4 | 60.0 | 43.0 | 18.4 | 5.8 |
| 26 | 90.0 | 51.1 | 41.6 | 28.3 | 11.1 | 92.6 | 58.8 | 44.3 | 33.4 | 13.0 | 65 | 84.0 | 66.7 | 51.1 | 29.2 | 11.7 | 85.1 | 67.9 | 54.7 | 31.6 | 12.9 |
| 27 | 97.2 | 84.0 | 73.0 | 48.3 | 28.7 | 98.9 | 89.5 | 77.3 | 52.1 | 33.1 | 66 | 67.3 | 53.6 | 34.1 | 15.4 | 3.6 | 69.4 | 57.7 | 36.3 | 14.6 | 3.1 |
| 28 | 93.6 | 78.9 | 63.9 | 36.9 | 14.8 | 95.7 | 81.9 | 68.4 | 41.2 | 17.7 | 67 | 96.4 | 88.9 | 78.3 | 53.6 | 25.6 | 95.3 | 88.7 | 76.6 | 57.2 | 28.7 |
| 29 | 81.5 | 69.0 | 58.6 | 32.5 | 15.5 | 85.0 | 73.3 | 63.3 | 35.2 | 19.4 | 68 | 93.7 | 84.6 | 73.5 | 49.0 | 24.3 | 92.8 | 85.2 | 77.7 | 54.4 | 26.7 |
| 30 | 92.9 | 75.3 | 61.2 | 27.6 | 8.0 | 95.1 | 79.0 | 68.0 | 31.9 | 9.6 | 69 | 89.4 | 80.7 | 66.3 | 47.3 | 11.7 | 90.8 | 85.3 | 70.0 | 45.0 | 11.0 |
| 31 | 97.2 | 88.6 | 83.2 | 45.1 | 6.1 | 98.9 | 92.4 | 88.4 | 48.3 | 7.7 | 70 | 79.9 | 60.8 | 50.3 | 32.6 | 7.8 | 81.8 | 62.7 | 53.7 | 34.9 | 9.5 |
| 32 | 81.1 | 71.0 | 54.4 | 36.9 | 14.4 | 84.4 | 74.1 | 58.8 | 40.2 | 17.5 | 71 | 65.6 | 45.3 | 30.5 | 15.7 | 2.7 | 61.3 | 44.1 | 30.5 | 14.6 | 2.0 |
| 33 | 69.3 | 55.2 | 39.7 | 17.6 | 5.8 | 72.7 | 57.7 | 42.7 | 20.5 | 8.3 | 72 | 75.2 | 63.8 | 46.9 | 29.4 | 9.3 | 77.0 | 66.2 | 49.2 | 29.1 | 8.7 |
| 34 | 74.8 | 61.8 | 48.0 | 18.5 | –0.9 | 77.0 | 65.1 | 51.4 | 20.8 | –0.1 | 73 | 89.1 | 75.9 | 61.2 | 36.8 | 16.7 | 91.2 | 79.7 | 65.3 | 37.1 | 16.1 |
| 35 | 96.7 | 90.3 | 77.2 | 58.2 | 7.0 | 98.4 | 94.2 | 81.2 | 61.6 | 8.7 | 74 | 68.1 | 54.3 | 43.5 | 21.1 | 7.0 | 70.1 | 57.7 | 47.0 | 20.2 | 6.5 |
| 36 | 91.4 | 76.4 | 55.4 | 39.4 | 1.2 | 87.5 | 77.6 | 55.9 | 39.3 | 0.9 | 75 | 89.1 | 81.3 | 65.0 | 42.1 | 13.7 | 91.0 | 85.6 | 68.6 | 41.7 | 12.6 |
| 37 | 90.7 | 65.2 | 33.9 | 20.7 | 8.0 | 93.2 | 68.7 | 37.6 | 22.7 | 9.9 | 76 | 71.5 | 58.5 | 43.8 | 29.4 | 15.6 | 79.2 | 68.4 | 53.3 | 27.8 | 12.8 |
| 38 | 90.5 | 67.2 | 36.3 | 18.4 | 4.8 | 92.3 | 69.9 | 38.8 | 20.5 | 5.5 | 77 | 87.8 | 73.8 | 53.6 | 31.8 | 9.2 | 90.6 | 73.8 | 54.3 | 34.0 | 10.0 |

germination intensity and its dynamic nature for each additional day of the germination period. With respect to the first indicator (Fig. 4.9), significant differences were found with a concentration fluctuation of 4.0% from 9.10 for *Ambrosia artemisiifolia* L. (3) by 16.88 for *Achillea millefolium* L. (60). For water extract concentration of 1.0% – from the minimum value of 14.10 for *Raphanus sativus* L. var. *oleiformis* Pers. (15) (i.e. for the culture itself) up to the maximum value of 17.21 for *Papaver rhoeas* L. (13) at level 16.48 on control.

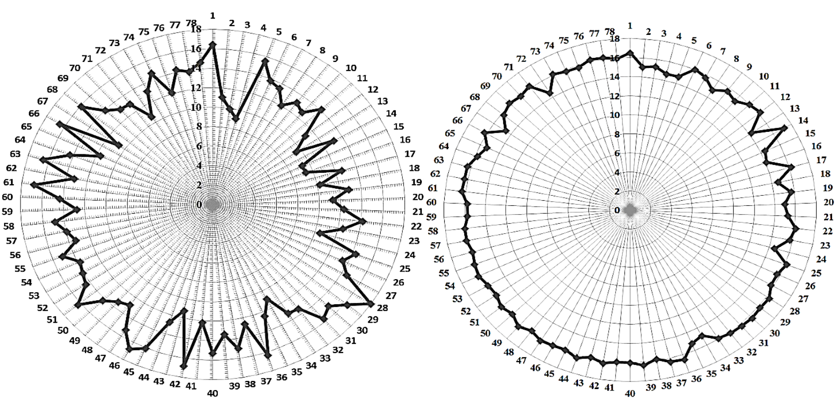



**Figure 4.9 – The speed of germination (S) of each variant at concentrations of water extract 4% (left position) and 1% (right position), 2020. (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

The obtained values of speed of germination (S) allowed to identify several types of oil radish seed germination rate under the impact of water extracts from various weeds. According to our estimates, the indicator can be functionally divided into three groups: 13–17 units – the majority of germinated seeds appear on 3–5 days of germination (typical group representatives: *Stellaria media* (L.) Vill. (4), *Cynodon dactylon* (L.) Pers. (10), *Convolvulus arvensis* L. (24), *Rocket-cress* Brown (26), *Artemisia vulgaris* L. (28), *Artemisia absinthium* L. (30), *Arctium lappa* L. (35), *Daucus carota* L. (41), *Lepidium campestre* (L.) Brown (45), *Achillea* *millefolium* L. (60); 11–13 units – the majority of germinated seeds appear on 5–7 days (typical group representatives: *Capsella bursa–pastoris* L. (1), *Raphanus raphanistrum* L. (20), *Equisetum arvense* L. (36), *Sinapis alba* L. (42), *Portulaca oleracea* L. (47), *Amaranthus blitoides* Watson (64), *Cuscuta campestris* Yuncker (71), *Polygonum convolvulus* (L.) Löve (74)); 8–11 units – an extended nature of similarity dynamics is formed with a shift from 5 to 9 days (typical group representatives: *Galium aparine* L. (2), *Ambrosia artemisiifolia* L. (3), *Echinochloa crus–galli* (L.) P.Beauv. (10), *Polygonum lapathifolium* (L.) Delarbre (12), *Brassica campestris* (L.) Janchen (14), *Amaranthus retroflexus* L. (17), *Chenopodium album* L. (23)). According to our observations, the latter variant is also characterized by the effect of the so–called sleeping seed, i.e. swollen forms with evident signs of germination initiation. For example, it is clearly demonstrated by the extreme left position 1 of Figure 4.8 in case of applying an extract from *Ambrosia artemisiifolia* L. (3). We have found that the weeds, which are dominant in oilseed radish agrophytocoenosises in the research area, belong to both the third and the second classification group of the indicator of speed of germination (S).

The typology of the conducted grouping is confirmed by the evaluation of the coefficient of velocity ($CV_i$) for two contrast concentrations of 4.0 and 1.0% at soil–free germination. This coefficient also allows estimating the interval rates of germinated seed formation (Nasr & Mansour, 2005). Statistical interpretation of the total array of variants by $CV_i$ indicator in the interval of 3–9 days of germination for two concentrations of water extracts of 4.0 and 1.0% (Fig. 4.10) showed significant differences in each interval period under study. At the same time, the maximum range of values for both concentration variants is determined on the 3rd and 4th day of germination. The decrease in the concentration of the applied extract reduces the allelopathic pressure and normalizes the variable dynamic curve of germinated seed formation to the biologically optimal maximum similarity on the 3–5th day in the absence of allelopathic extracts, which agrees with a number of studies (Rice, 1984; Inderjit and Keating, 1999; Izzet et al., 2004; John et al. 2006; Golubinova & Ilieva, 2015; Duke, 2015), and the example for different types of weeds is clearly shown in Figure 4.11.

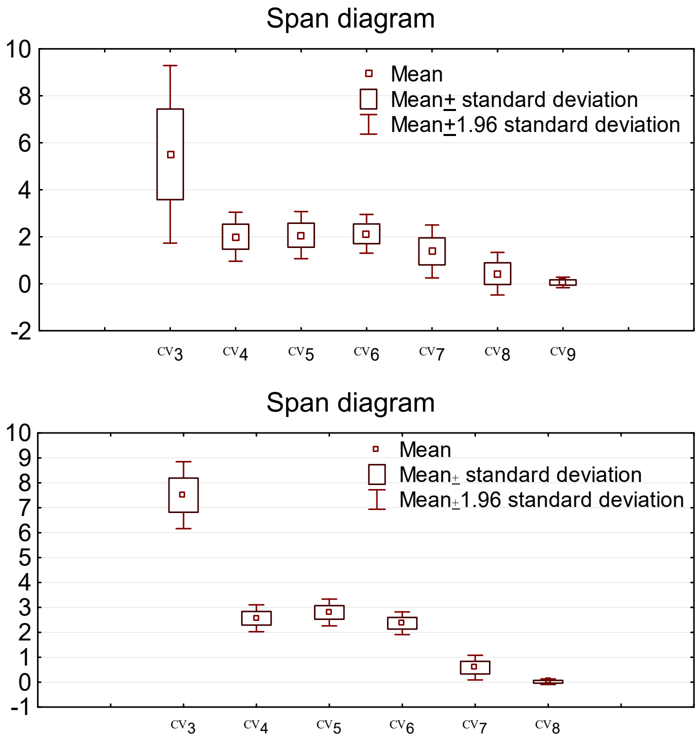
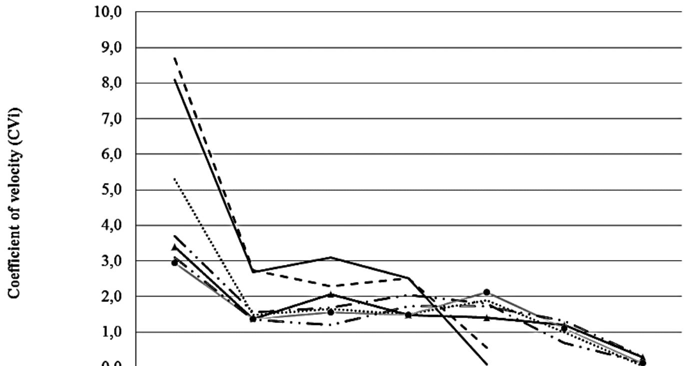



**Figure 4.10 – The range of values for the coefficient of velocity ($CV_i$) for the studied group of weeds in the context of the third ($CV_3$) and the ninth day ($CV_9$) of germination using water extraction of weeds (concentration of 4.0% upper position, concentration of 1.0% lower position) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

Obviously, given the large array of processed data, it is difficult to analyze each species in the system of similarity changes with different concentrations of the extract, but according to the results of recent studies (Smith, 2013; Jain et al., 2017; Możdżeń et al., 2018), such analysis can be successfully substituted by the evaluation of the species by the Overall allelopathic potential indicator (OAP) (Table 4.10).




| | CV3 | CV4 | CV5 | CV6 | CV7 | CV8 | CV9 |
|---|---|---|---|---|---|---|---|
| Control | 8,1 | 2,7 | 3,1 | 2,5 | 0,1 | | |
| Echinochloa crus-galli (L.) P.Beauv. | 3,4 | 1,4 | 2,1 | 1,5 | 1,4 | 1,2 | 0,3 |
| Taraxacum officinale Weber | 5,3 | 1,5 | 1,7 | 1,5 | 1,9 | 1,0 | 0,1 |
| Lepidium campestre (L.) Brown | 8,7 | 2,7 | 2,3 | 2,5 | 0,6 | | |
| Amaranthus blitoides Watson | 3,7 | 1,6 | 1,7 | 2,0 | 1,8 | 0,7 | 0,1 |
| Acroptilon repens (L.) de Candolle | 3,0 | 1,4 | 1,6 | 1,5 | 2,1 | 1,1 | 0,1 |
| Cuscuta campestris Yuncker | 3,1 | 1,4 | 1,2 | 1,7 | 1,7 | 1,3 | 0,3 |

**Figure 4.11 – Coefficient of velocity ($CV_i$) in the context of the third ($CV_3$) and the ninth day ($CV_9$) of germination using water extraction of weeds (concentration of 4.0%) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

Calculation of this indicator within the studied weed species confirmed our conclusions regarding the difference in the expression of allelopathic effect depending on the variant of seed germination. For most weed species, this difference corresponded to the transition to the lowest value interval, except for species such as *Setaria glauca* L. (5), *Cynodon dactylon* (L.) Pers. (10), *Capsella bursa–pastoris* L. (1), *Cirsium arvense* (L.) Scopoli (9), for which the difference is determined in two gradations. It should be noted that these species, based on the results of our previous studies (Tsytsiura, 2020), belong to the herbological forms with a dominant vitality tactics in all tiers of high–altitude plant development, in particular in the phase of seedlings – the formation of the rosette in the oilseed radish (BBCH 14–20), the middle tier in the phase of stem formation – beginning of budding of oilseed radish plants (BBCH 26–50).

During the maturation period (BBCH 83–89), such species as *Setaria glauca* L. and *Cirsium arvense* (L.) Scopoli occupy the dominant upper tier, which classifies them as being associated with development in relation to the crop and explains the nature of OAP formation, as described in certain conclusions of other studies (Duke, 2015; Carvalho et al., 2019). It should be noted that the provided grouping results (Table 4.10) indicate another important pattern. The highest OAP values with respect to the indicator of the oilseed radish laboratory germination were noted for the species most common in the agrophytocoenosises of this crop in the research region, as well as among weeds of similar species. In fact, the first group includes all types of weeds with the OAP range of 0.56–0.70, excluding *Portulaca oleracea* L. (47), *Aethusa cynapium* L. (76), *Plantago major* L. (38), *Cuscuta campestris* Yuncker (71), *Polytrichum commune* L. (33), the presence of which in the oilseed radish cenosis is minimal. The second group should include species from the same interval, covering both regular weeds and culturally related species, which are studied in the self–seeding or fallen format – *Brassica napus* L. (25), *Rocket-cress* Brown (26), *Sinapis arvensis* L. (34), *Brassica campestris* (L.) Janchen (14), *Raphanus raphanistrum* L. (20). At the same time, the maximum OAP value at germination on both substrates was noted in the variant of using oilseed radish extracts (*Raphanus sativus* L. var. *oleiformis* Pers. (15)) – 0.68–0.72, which emphasizes the high degree of allelopathic self–incompatibility of the species at the stage of germination, and it's confirmed in studies conducted by Brown and Morra (1996), Norsworthy (2003), Haramoto (2004), Lawley et al. (2012).

Thus, the efficiency of the oilseed radish application with respect to plant species from the cruciferous family and species with OAP above 0.60 is determined by the seeding rate and the level of potential contamination of the field. The majority of plant species under study with the OAP interval of 0.26–0.50 have a low and average frequency level of occurrence in the agrophytocoenosis of oilseed radish, which rationally correlates with the theory of remote allelopathy for species that belong to different levels of introduction and vitality tactics of their existence (Novak et al., 2018) (for example, *Achillea millefolium* L. (60), *Centaurea cyanus* L. (27), *Erigeron canadensis* L. (6)), and with a low level of allelopathic competition due to the formation of morphotypes typical for terrestrial or lower tier in the vertical structure of the oilseed radish cenosis (for example, *Stellaria media*

(L.) Vill. (4), *Poa annua* L. (63), *Lepidium campestre* (L.) Brown (45)). As for such plants, the allelopathic competition with oilseed radish in the same phase is low, which makes it possible to apply it as a biological method of controlling the number and prevalence of these weed species at appropriate technological parameters of sowing. Such a conclusion of our research differs from the classical recommendations on the principles of selection of green manure crops for biological control of the field contamination level (Hoffman et al., 2006, Hodgdon et al., 2016) and allows the effective application of oilseed radish depending on the type of species contamination of the field at the beginning of vegetation–growth of the latter.

Table 4.10

**Grouping of weed species according to their allelopathic potential (OAP) of impact oilseed radish seed germination (BBCH 01–05) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| OAP interval | Weed species, which belong to the interval group | | Number of species in the group | |
|---|---|---|---|---|
| | water substrate | soil substrate | water substrate | soil substrate |
| 1 | 2 | 3 | 4 | 5 |
| 0.26–0.30 | – | *Lepidium campestre* (L.) Brown, *Poa annua* L. | – | 2 |
| 0.30–0.35 | *Erigeron canadensis* L., *Lepidium campestre* (L.) Brown, *Poa annua* L. | *Stellaria media* (L.) Vill., *Setaria glauca* L., *Erigeron canadensis* L., *Carduus acanthoides* L., *Centaurea cyanus* L., *Lactuca serriola* L., *Achillea millefolium* L. | 3 | 7 |
| 0.36–0.40 | *Stellaria media* (L.) Vill., *Centaurea cyanus* L., *Lactuca serriola* L., *Achillea millefolium* L., *Erodium cicutarium* ( L.) L'Héritier | *Cynodon dactylon* (L.) Pers., *Taraxacum officinale* Weber, *Lepidium ruderale* L., *Daucus carota* L., *Lamium purpureum* L., *Spergula vulgaris* L., *Erodium cicutarium* (L.) L'Héritier, *Panicum capillare* L. | 5 | 8 |

(End of Table 4.10)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 0.41–0.45 | *Setaria glauca* L., *Carduus acanthoides* L., *Taraxacum officinale* Weber, *Lepidium ruderale* L., *Daucus carota* L., *Bromus secalinus* L., *Lamium purpureum* L., *Veronica hederifolia* L., *Spergula vulgaris* L., *Panicum capillare* L. | *Polygonum lapathifolium* (L.) Delarbre, *Artemisia vulgaris* L., *Rumex confertus* Willdenow, *Arctium lappa* L., *Eryngium campestre* L., *Polygonum aviculare* L., *Bromus secalinus* L., *Veronica hederifolia* L., *Crepis tectorum* L., *Lamium amplexicaule* L. | 10 | 10 |
| 0.46–0.50 | *Cynodon dactylon* (L.) Pers., *Artemisia vulgaris* L., *Berteroa incana* (L.) de Candolle, *Rumex confertus* Willdenow, *Arctium lappa* L., *Eryngium campestre* L., *Polygonum aviculare* L., *Crepis tectorum* L., *Lamium amplexicaule* L., *Digitaria ischaemum* (Schreber) Muhlenberg, *Rumex acetosella* L., *Echium vulgare* L., *Bunias orientalis* L. | *Capsella bursa–pastoris* L., *Galium aparine* L., *Ambrosia artemisiifolia* L., *Thlaspi arvense* L., *Echinochloa crus–galli* (L.) P.Beauv., *Berteroa incana* (L.) de Candolle, *Artemisia absinthium* L., *Setaria viridis* (L.) Palisot de Beauvois, *Descurainia Sophia* (L.) Prantl, *Avena fatua* L., *Digitaria ischaemum* (Schreber) Muhlenberg, *Senecio vernalis* (Waldstein & Kitaibel) Alexander, *Rumex acetosella* L., *Echium vulgare* L., *Bunias orientalis* L. | 13 | 15 |
| 0.51–0.55 | *Ambrosia artemisiifolia* L., *Thlaspi arvense* L., *Polygonum lapathifolium* (L.) Delarbre, *Artemisia absinthium* L., *Setaria viridis* (L.) Palisot de Beauvois, *Descurainia Sophia* (L.) Prantl, *Cichorium intybus* L., *Avena fatua* L., *Chondrilla juncea* L., *Senecio vernalis* (Waldstein & Kitaibel) Alexander, *Plantago lanceolata* L., *Solanum nigrum* L. | *Cirsium arvense* (L.) Scopoli, *Sonchus arvensis* L., *Brassica napus* L., *Lepidium draba* L., *Cichorium intybus* L., *Chondrilla juncea* L., *Cyclachaena xanthiifolia* Nuttall, *Plantago lanceolata* L., *Sisymbrium Loeselii* L., *Aethusa cynapium* L., *Solanum nigrum* L. | 12 | 11 |

(End of Table 4.10)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 0.56–0.60 | *Capsella bursa–pastoris* L., *Galium aparine* L., *Echinochloa crus–galli* (L.) P.Beauv., *Agropyron repens* (L.) Gould, *Sonchus arvensis* L., *Brassica napus* L., *Rocket-cress* Brown, *Equisetum arvense* L., *Lepidium draba* L., *Portulaca oleracea* L., *Cyclachaena xanthiifolia* Nuttall, *Sisymbrium Loeselii* L., *Onopordon acanthium* L., *Polygonum convolvulus* (L.) Löve, *Aethusa cynapium* L. | *Brassica campestris* (L.) Janchen, *Agropyron repens* (L.) Gould, *Tripleurospermum maritimum* (L.) Koch, *Galinsoga parviflora* Cavanilles, *Convolvulus arvensis* L., *Rocket-cress* Brown, *Polytrichum commune* L., *Equisetum arvense* L., *Consolida regalis* Gray, *Sinapis alba* L., *Portulaca oleracea* L., *Fumaria officinalis* L., *Amaranthus blitoides* Watson, *Onopordon acanthium* L., *Polygonum convolvulus* (L.) Löve | 15 | 15 |
| 0.61–0.65 | *Cirsium arvense* (L.) Scopoli, *Tripleurospermum maritimum* (L.) Koch, *Galinsoga parviflora* Cavanilles, *Convolvulus arvensis* L., *Polytrichum commune* L., *Sinapis arvensis* L., *Consolida regalis* Gray, *Plantago major* L., *Sinapis alba* L., *Fumaria officinalis* L., *Amaranthus blitoides* Watson | *Papaver rhoeas* L., *Amaranthus retroflexus* L., *Raphanus raphanistrum* L., *Chenopodium album* L., *Sinapis arvensis* L., *Plantago major* L., *Acroptilon repens* (L.) de Candolle | 11 | 7 |
| 0.66–0.70 | *Papaver rhoeas* L., *Brassica campestris* (L.) Janchen, *Amaranthus retroflexus* L., *Raphanus raphanistrum* L., *Chenopodium album* L., *Acroptilon repens* (L.) de Candolle, *Cuscuta campestris* Yuncker | *Raphanus sativus* L. var. *oleiformis* Pers., *Cuscuta campestris* Yuncker | 7 | 2 |
| 0.71–0.75 | *Raphanus sativus* L. var. *oleiformis* Pers. | – | 1 | – |

Certain peculiarities of influence on germination have stelting (*Convolvulus arvensis* L. (24), *Polygonum convolvulus* (L.) Löve (74) and parasitic species of weeds (*Cuscuta campestris* Yuncker (71)), which emphasizes their biological versatility in relation to the possibility of growth and development with the coverage of all tiers of plants and aggressive biology in relation to other plant species for parasitic studied forms, which is confirmed by studies of Marinov–Serafimov et al. (2017).

It is pointed out (Iqbal and Fry, 2012; Fragasso et al., 2013; Golubinova and Ilieva, 2014; Gfeller et al., 2018) that the allelopathic effect of plant extracts affects not only the indicators of seed germination and the indicator formation speed, but also the growth processes of plants. The intensity of this impact depends on the phenological phase of application of such substances. According to Jabran et al. (2015) and Marinov–Serafimov and Golubinova (2015), the assessment of allelopathic effects in plant relationships must be accompanied by an analysis of growth processes in the system of relevant indicators and growth correlations, which will give a complete picture of the target effect of the relevant plant extracts on growth and development of the test object. Given these statements, during the second experiment in the format of oilseed radish cultivation on the soil substrate with the addition of extracts of the studied plant species, we analyzed a number of indicators related to the analysis of growth rates. Significant differences for the majority of comparison pairs according to Tukey's criterion in terms of the influence of allelopathic extracts on the growth and development of oilseed radish plants at the initial stages of vegetation (BBCH 01–12) have been determined. The data of such research is presented in Table 4.11 for the extract concentrations in the range of 4.0–1.0%, and for some variants of the experiment in Figure 4.12. It was found that the impact of extracts on growth processes had a species–specific nature with differences in the impact on the root system and stem (above–ground) parts, which is evidenced by the ratio between the formation of dry matter of the stem and root systems in the DWR index format and its comparison with the control version, as well as the value of Coefficient of allometry (CA) in the context of the studied plant species. Overall, the evaluation of the above ratios between morphological parameters of the aboveground and root systems is an important factor in allelopathic analysis, since each plant species is characterized by a certain ratio index between stem and root system development. Certainly, this ratio changes depending on vegetation conditions, soil and climate parameters, but in certain intervals it is relatively constant. This factor in the allelopathic analysis is pointed out in the studies of Grodzinsky (1965), Macías et al., (2007), Duke (2015). This criterion adequately reflects the intensity and specificity of growth processes of plants, distributing them into certain types. At the same time, the allelopathic pressure between species is higher if the growth ratio of above–ground and underground parts of the plant is of the same type, and the biological and chemical influence of the allelopathic substances will affect this ratio (Rice, 1984).

In studies, such processes have been confirmed. Extracts of different types of weeds had different impact both on the amount of alometric and on the amount of weight (by dry matter accumulation index) coefficients in comparison to control. Even in the absence of significant morphological differences (see Fig. 4.12) between the concentration variants of the applicable water extract, there is a general decrease in the area of seed lobe, a decrease in the diameter of hypocotyl, as well as some deformation of the above–ground part. As for the root systems, certain morphological peculiarities of development have also been determined for the test plants – from the general elongation of the root system without explicit lateral branching (variant of *Sonchus arvensis* L. (19)) to intensive radial branching with minimal linear elongation (variant of *Erigeron canadensis* L. (6)).

As a result, we found that reducing the concentration of water extract from weed plants from 4.0% to 1.0% reduces the disparity between the ratio of stem and root parts coming closer to the control variant indicator and provides the formation of greater above–ground mass and corresponding dry matter value. Such dynamics of ratios indicates the dominant influence of extracts on the formation of the root system, and for species with high allelopathic potential and associated intensive impact both on the root and stem parts. But with a generally defined tendency of changes in indicators, there are also relevant exceptions.

Table 4.11

**Allelopathic effect of water extracts from weeds on the oilseed radish growing processes (*Raphanus sativus* L. var. *oleiformis* Pers.) (when germinating on a soil substrate) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| CVN | Length, mm | | | | Seedling | | | | | | | | | | | | GRI | | CA | | DWR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | root | | stem | | DDI | | TI (%) | | μ 10⁻² | | GI (%) | | SVI | | RI | | | | | | | |
| | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 | 4.0 | 1.0 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| 0 | 30.2 | 30.2 | 80.2 | 80.2 | – | – | 1.00 | 1.00 | – | – | – | – | 98.5 | 99.1 | – | – | 33.5 | 33.8 | 2.7 | 2.7 | 5,1 | 5,1 |
| 1 | 10.5 | 17.0 | 64.2 | 71.0 | –4.8 | –8.3 | 0.68 | 0.80 | –2,2 | –1,3 | 12.8 | 40.6 | 12.6 | 51.7 | –0.32 | –0.20 | 2.8 | 14.1 | 6.1 | 4.2 | 7.1 | 10.2 |
| 2 | 13.8 | 23.9 | 44.9 | 72.7 | –3.0 | –14.1 | 0.53 | 0.88 | –3,5 | –0,7 | 9.2 | 52.3 | 9.1 | 55.8 | –0.47 | –0.12 | 4.7 | 19.0 | 3.3 | 3.0 | 4.2 | 7.1 |
| 3 | 10.9 | 15.9 | 41.4 | 58.3 | –2.5 | –4.7 | 0.47 | 0.67 | –4,1 | –2,2 | 10.4 | 37.9 | 10.3 | 41.8 | –0.53 | –0.33 | 5.1 | 15.3 | 3.8 | 3.7 | 5.3 | 8.3 |
| 4 | 8.0 | 13.4 | 42.8 | 56.7 | –2.4 | –4.1 | 0.46 | 0.64 | –4,3 | –2,5 | 14.8 | 53.6 | 14.6 | 58.3 | –0.54 | –0.36 | 5.4 | 19.7 | 5.3 | 4.2 | 6.6 | 9.5 |
| 5 | 13.6 | 25.4 | 34.0 | 61.0 | –2.2 | –7.7 | 0.43 | 0.78 | –4,7 | –1,4 | 15.7 | 56.7 | 15.5 | 62.7 | –0.57 | –0.22 | 13.0 | 30.2 | 2.5 | 2.4 | 2.9 | 5.4 |
| 6 | 8.2 | 14.6 | 40.8 | 60.1 | –2.3 | –4.8 | 0.44 | 0.68 | –4,5 | –2,2 | 20.7 | 54.3 | 20.4 | 58.2 | –0.56 | –0.32 | 8.4 | 18.9 | 5.0 | 4.1 | 6.3 | 9.3 |
| 7 | 7.7 | 16.3 | 36.9 | 54.0 | –2.1 | –4.2 | 0.40 | 0.64 | –5,0 | –2,5 | 15.2 | 42.9 | 14.9 | 48.8 | –0.60 | –0.36 | 7.0 | 20.9 | 4.8 | 3.3 | 5.3 | 7.5 |
| 8 | 10.0 | 20.5 | 35.5 | 58.4 | –2.1 | –5.6 | 0.41 | 0.72 | –4,9 | –1,9 | 10.9 | 37.9 | 10.7 | 43.2 | –0.59 | –0.28 | 6.6 | 19.2 | 3.5 | 2.8 | 4.9 | 6.4 |
| 9 | 11.0 | 15.4 | 29.4 | 46.9 | –1.9 | –3.3 | 0.37 | 0.56 | –5,6 | –3,2 | 6.2 | 22.7 | 6.1 | 27.8 | –0.63 | –0.44 | 5.7 | 14.6 | 2.7 | 3.1 | 3.9 | 6.9 |
| 10 | 5.9 | 20.1 | 25.2 | 40.5 | –1.5 | –3.1 | 0.28 | 0.55 | –7,0 | –3,3 | 6.1 | 39.8 | 6.0 | 45.0 | –0.72 | –0.45 | 4.5 | 36.9 | 4.3 | 2.0 | 3.6 | 4.6 |
| 11 | 6.9 | 13.9 | 40.7 | 54.8 | –2.2 | –4.0 | 0.43 | 0.62 | –4,7 | –2,6 | 6.7 | 35.1 | 6.6 | 45.2 | –0.57 | –0.38 | 2.4 | 16.7 | 5.9 | 3.9 | 6.2 | 8.9 |
| 12 | 13.9 | 24.8 | 30.4 | 53.1 | –2.1 | –5.4 | 0.40 | 0.71 | –5,1 | –1,9 | 9.4 | 37.7 | 9.2 | 47.0 | –0.60 | –0.29 | 9.5 | 28.1 | 2.2 | 2.1 | 2.9 | 4.9 |
| 13 | 15.9 | 26.0 | 31.9 | 55.3 | –2.2 | –6.1 | 0.43 | 0.74 | –4,7 | –1,7 | 5.3 | 23.5 | 5.2 | 28.9 | –0.57 | –0.26 | 5.4 | 16.7 | 2.0 | 2.1 | 2.7 | 4.8 |
| 14 | 10.1 | 13.6 | 36.5 | 48.9 | –2.2 | –3.3 | 0.42 | 0.57 | –4,8 | –3,2 | 3.7 | 23.5 | 3.6 | 26.6 | –0.58 | –0.43 | 2.2 | 11.9 | 3.6 | 3.6 | 5.3 | 8.1 |
| 15 | 9.6 | 15,7 | 23.1 | 41.8 | –2.0 | –4.3 | 0.39 | 0.65 | –5,3 | –2,4 | 2.3 | 24.3 | 2.2 | 28.3 | –0.68 | –0.47 | 2.7 | 19.9 | 2.4 | 2.7 | 2.4 | 4.5 |
| 16 | 11.4 | 18.2 | 41.3 | 46.4 | –2.5 | –3.5 | 0.48 | 0.58 | –4,1 | –3,0 | 6.9 | 26.6 | 6.8 | 28.8 | –0.52 | –0.42 | 3.5 | 17.4 | 3.6 | 2.6 | 5.2 | 5.8 |
| 17 | 8.0 | 14.0 | 37.2 | 45.7 | –2.1 | –3.1 | 0.41 | 0.54 | –5,0 | –3,4 | 3.2 | 19.6 | 3.1 | 21.3 | –0.59 | –0.46 | 1.5 | 10.9 | 4.7 | 3.3 | 5.7 | 7.4 |
| 18 | 14.2 | 24.4 | 24.5 | 37.9 | –1.8 | –3.3 | 0.35 | 0.56 | –5,8 | –3,2 | 8.4 | 47.1 | 8.2 | 49.6 | –0.65 | –0.44 | 12.3 | 51.3 | 1.7 | 1.6 | 2.1 | 3.5 |
| 19 | 17.6 | 27.0 | 47.0 | 57.9 | –3.5 | –7.2 | 0.59 | 0.77 | –3,0 | –1,5 | 5.6 | 48.5 | 5.6 | 51.3 | –0.41 | –0.23 | 3.2 | 28.2 | 2.7 | 2.1 | 3.8 | 4.8 |
| 20 | 12.0 | 23.2 | 40.5 | 56.3 | –2.5 | –5.7 | 0.48 | 0.72 | –4,1 | –1,8 | 2.7 | 30.0 | 2.7 | 32.4 | –0.52 | –0.28 | 1.5 | 16.8 | 3.4 | 2.4 | 3.9 | 5.5 |
| 21 | 18.9 | 28.1 | 27.8 | 43.9 | –2.2 | –4.4 | 0.42 | 0.65 | –4,8 | –2,4 | 5.5 | 29.4 | 5.4 | 31.4 | –0.58 | –0.35 | 7.8 | 27.9 | 1.5 | 1.6 | 2.1 | 3.5 |
| 22 | 10.2 | 27.9 | 21.6 | 37.2 | –1.5 | –3.6 | 0.29 | 0.59 | –6,9 | –2,9 | 4.5 | 22.6 | 4.4 | 26.4 | –0.71 | –0.41 | 6.6 | 30.4 | 2.1 | 1.3 | 2.5 | 3.0 |

(End of Table 4.11)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 11.7 | 23.9 | 32.3 | 56.4 | –2.0 | –5.9 | 0.40 | 0.73 | –5,1 | –1,8 | 4.1 | 23.3 | 4.0 | 25.9 | –0.60 | –0.27 | 3.3 | 13.7 | 2.8 | 2.4 | 2.7 | 5.4 |
| 24 | 15.8 | 18.0 | 31.3 | 53.4 | –2.2 | –4.3 | 0.43 | 0.65 | –4,7 | –2,4 | 5.6 | 29.2 | 5.5 | 31.1 | –0.57 | –0.35 | 5.9 | 14.7 | 2.0 | 3.0 | 3.2 | 6.7 |
| 25 | 7.8 | 12.1 | 22.0 | 42.1 | –1.4 | –2.6 | 0.27 | 0.49 | –7,3 | –3,9 | 4.2 | 25.3 | 4.1 | 26.9 | –0.73 | –0.51 | 4.9 | 14.3 | 2.8 | 3.5 | 3.8 | 7.8 |
| 26 | 6.9 | 22.9 | 31.0 | 39.4 | –1.8 | –3.3 | 0.34 | 0.57 | –5,9 | –3,2 | 6.0 | 24.1 | 5.9 | 25.4 | –0.66 | –0.43 | 3.5 | 23.7 | 4.5 | 1.7 | 4.2 | 3.9 |
| 27 | 8.1 | 15.9 | 39.3 | 46.8 | –2.2 | –3.3 | 0.43 | 0.57 | –4,7 | –3,1 | 16.1 | 42.0 | 15.9 | 44.1 | –0.57 | –0.43 | 6.9 | 23.9 | 4.8 | 2.9 | 6.1 | 6.7 |
| 28 | 11.1 | 17.7 | 32.6 | 43.2 | –2.0 | –3.2 | 0.40 | 0.55 | –5,1 | –3,3 | 8.8 | 35.8 | 8.7 | 38.0 | –0.60 | –0.45 | 6.8 | 25.6 | 2.9 | 2.4 | 3.8 | 5.5 |
| 29 | 15.2 | 23.0 | 31.2 | 56.3 | –2.2 | –5.7 | 0.42 | 0.72 | –4,8 | –1,8 | 10.1 | 42.9 | 9.9 | 45.9 | –0.58 | –0.28 | 10.4 | 23.7 | 2.1 | 2.4 | 3.1 | 5.5 |
| 30 | 11.4 | 20.2 | 41.8 | 55.1 | –2.6 | –4.9 | 0.48 | 0.68 | –4,1 | –2,1 | 6.8 | 42.5 | 6.7 | 46.7 | –0.52 | –0.32 | 3.4 | 22.7 | 3.7 | 2.7 | 4.5 | 6.2 |
| 31 | 14.2 | 23.9 | 40.9 | 62.9 | –2.7 | –7.8 | 0.50 | 0.79 | –3,9 | –1,3 | 6.1 | 66.3 | 6.0 | 69.8 | –0.50 | –0.21 | 3.8 | 30.6 | 2.9 | 2.6 | 3.7 | 5.9 |
| 32 | 12.0 | 21.0 | 40.5 | 50.5 | –2.5 | –4.3 | 0.48 | 0.65 | –4,1 | –2,4 | 10.5 | 35.9 | 10.3 | 38.4 | –0.52 | –0.35 | 5.8 | 22.4 | 3.4 | 2.4 | 4.5 | 5.4 |
| 33 | 11.1 | 18.8 | 39.9 | 54.1 | –2.4 | –4.5 | 0.46 | 0.66 | –4,3 | –2,3 | 5.9 | 26.9 | 5.8 | 28.7 | –0.54 | –0.34 | 3.2 | 13.7 | 3.6 | 2.9 | 4.8 | 6.5 |
| 34 | 9.4 | 18.7 | 36.7 | 51.8 | –2.2 | –4.2 | 0.42 | 0.64 | –4,8 | –2,5 | 1.8 | 31.3 | 1.8 | 33.3 | –0.58 | –0.36 | 1.0 | 17.0 | 3.9 | 2.8 | 4.3 | 6.3 |
| 35 | 13.2 | 26.9 | 48.3 | 60.4 | –3.2 | –8.0 | 0.56 | 0.79 | –3,3 | –1,3 | 7.4 | 61.9 | 7.3 | 64.5 | –0.44 | –0.21 | 3.2 | 32.9 | 3.7 | 2.2 | 4.0 | 5.1 |
| 36 | 11.8 | 20.3 | 32.5 | 40.3 | –2.1 | –3.1 | 0.40 | 0.55 | –5,1 | –3,3 | 2.2 | 31.0 | 2.1 | 31.0 | –0.60 | –0.45 | 1.7 | 25.8 | 2.7 | 2.0 | 3.5 | 4.5 |
| 37 | 12.0 | 20.3 | 34.7 | 48.9 | –2.2 | –4.0 | 0.42 | 0.63 | –4,8 | –2,6 | 6.1 | 22.0 | 6.0 | 24.1 | –0.58 | –0.37 | 4.4 | 14.4 | 2.9 | 2.4 | 3.5 | 5.5 |
| 38 | 14.8 | 22.4 | 42.2 | 58.9 | –2.8 | –6.1 | 0.52 | 0.74 | –3,7 | –1,7 | 5.2 | 27.5 | 5.1 | 29.1 | –0.48 | –0.26 | 3.1 | 13.6 | 2.8 | 2.6 | 3.9 | 5.9 |
| 39 | 13.1 | 26.0 | 29.2 | 46.6 | –2.0 | –4.5 | 0.38 | 0.66 | –5,3 | –2,3 | 5.4 | 52.8 | 5.3 | 54.6 | –0.62 | –0.34 | 5.6 | 42.0 | 2.2 | 1.8 | 2.7 | 4.1 |
| 40 | 11.3 | 23.7 | 37.6 | 51.4 | –2.3 | –4.9 | 0.44 | 0.68 | –4,5 | –2,1 | 6.9 | 57.6 | 6.7 | 60.1 | –0.56 | –0.32 | 4.1 | 36.9 | 3.3 | 2.2 | 3.8 | 4.9 |
| 41 | 7.9 | 16.0 | 42.8 | 55.7 | –2.4 | –4.4 | 0.46 | 0.65 | –4,3 | –2,4 | 13.2 | 45.2 | 13.0 | 49.9 | –0.54 | –0.35 | 4.7 | 20.1 | 5.4 | 3.5 | 6.2 | 7.9 |
| 42 | 7.3 | 14.2 | 22.9 | 40.6 | –1.4 | –2.7 | 0.27 | 0.50 | –7,2 | –3,9 | 3.2 | 20.7 | 3.2 | 21.8 | –0.73 | –0.50 | 3.4 | 13.9 | 3.1 | 2.9 | 3.5 | 6.5 |
| 43 | 5.8 | 11.5 | 29.3 | 39.6 | –1.6 | –2.4 | 0.32 | 0.46 | –6,4 | –4,3 | 4.8 | 23.5 | 4.8 | 24.8 | –0.68 | –0.54 | 2.7 | 14.1 | 5.1 | 3.4 | 5.2 | 7.8 |
| 44 | 10.0 | 16.2 | 29.8 | 40.1 | –1.8 | –2.8 | 0.36 | 0.51 | –5,7 | –3,7 | 9.1 | 43.5 | 9.0 | 45.3 | –0.64 | –0.49 | 7.6 | 32.5 | 3.0 | 2.5 | 3.9 | 5.6 |
| 45 | 12.0 | 20.8 | 35.1 | 56.6 | –2.2 | –5.3 | 0.43 | 0.70 | –4,7 | –2,0 | 17.0 | 63.6 | 16.8 | 66.3 | –0.57 | –0.30 | 12.2 | 31.5 | 2.9 | 2.7 | 3.8 | 6.2 |
| 46 | 10.3 | 19.1 | 31.2 | 54.8 | –1.9 | –4.7 | 0.38 | 0.67 | –5,4 | –2,2 | 6.7 | 50.1 | 6.6 | 52.3 | –0.62 | –0.33 | 5.3 | 24.7 | 3.0 | 2.9 | 3.8 | 6.5 |
| 47 | 12.0 | 22.3 | 27.2 | 35.2 | –1.8 | –2.9 | 0.36 | 0.52 | –5,7 | –3,6 | 3.1 | 27.2 | 3.1 | 28.8 | –0.64 | –0.48 | 3.4 | 31.7 | 2.3 | 1.6 | 2.8 | 3.6 |
| 48 | 8.1 | 17.4 | 21.6 | 38.8 | –1.4 | –2.8 | 0.27 | 0.51 | –7,3 | –3,7 | 2.7 | 22.7 | 2.6 | 22.4 | –0.73 | –0.49 | 3.3 | 17.9 | 2.7 | 2.2 | 2.7 | 5.0 |
| 49 | 10.1 | 18.1 | 24.3 | 36.5 | –1.6 | –2.7 | 0.31 | 0.49 | –6,5 | –3,9 | 4.5 | 31.7 | 4.4 | 33.4 | –0.69 | –0.51 | 5.4 | 30.4 | 2.4 | 2.0 | 3.5 | 4.6 |
| 50 | 14.4 | 19.9 | 31.8 | 44.1 | –2.2 | –3.4 | 0.42 | 0.58 | –4,8 | –3,0 | 9.3 | 26.5 | 9.1 | 28.4 | –0.58 | –0.42 | 8.9 | 20.1 | 2.2 | 2.2 | 3.4 | 5.0 |
| 51 | 11.1 | 21.7 | 26.9 | 38.3 | –1.8 | –3.1 | 0.34 | 0.54 | –5,9 | –3,4 | 6.9 | 31.9 | 6.8 | 33.5 | –0.66 | –0.46 | 7.3 | 31.6 | 2.4 | 1.8 | 2.7 | 4.0 |
| 52 | 14.8 | 16.9 | 32.2 | 42.9 | –2.2 | –3.1 | 0.43 | 0.54 | –4,7 | –3,4 | 11.3 | 39.9 | 11.1 | 39.9 | –0.57 | –0.46 | 10.8 | 26.3 | 2.2 | 2.5 | 3.9 | 5.7 |
| 53 | 11.1 | 19.2 | 27.3 | 45.0 | –1.8 | –3.5 | 0.35 | 0.58 | –5,9 | –3,0 | 8.3 | 43.5 | 8.2 | 45.7 | –0.65 | –0.42 | 8.7 | 30.5 | 2.5 | 2.3 | 3.4 | 5.3 |

(End of Table 4.11)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 13.7 | 17.8 | 24.2 | 45.1 | –1.8 | –3.3 | 0.34 | 0.57 | –5,9 | –3,1 | 9.8 | 38.4 | 9.7 | 40.0 | –0.66 | –0.43 | 14.5 | 25.1 | 1.8 | 2.5 | 2.6 | 5.7 |
| 55 | 9.7 | 15.9 | 33.7 | 47.2 | –2.0 | –3.4 | 0.39 | 0.57 | –5,2 | –3,1 | 6.7 | 30.5 | 6.6 | 32.1 | –0.61 | –0.43 | 4.4 | 17.1 | 3.5 | 3.0 | 4.3 | 6.7 |
| 56 | 10.3 | 17.2 | 36.7 | 54.8 | –2.2 | –4.4 | 0.42 | 0.65 | –4,8 | –2,4 | 9.3 | 44.4 | 9.2 | 44.5 | –0.58 | –0.35 | 5.5 | 19.3 | 3.6 | 3.2 | 4.0 | 7.2 |
| 57 | 11.4 | 18.4 | 37.4 | 59.1 | –2.3 | –5.3 | 0.44 | 0.70 | –4,5 | –2,0 | 11.8 | 44.4 | 11.6 | 44.6 | –0.56 | –0.30 | 7.2 | 17.9 | 3.3 | 3.2 | 4.2 | 7.3 |
| 58 | 8.1 | 13.1 | 25.3 | 38.7 | –1.6 | –2.5 | 0.30 | 0.47 | –6,6 | –4,2 | 4.3 | 25.1 | 4.2 | 26.3 | –0.70 | –0.53 | 4.1 | 17.2 | 3.1 | 3.0 | 4.2 | 6.7 |
| 59 | 8.8 | 16.8 | 30.1 | 40.1 | –1.8 | –2.8 | 0.35 | 0.52 | –5,8 | –3,7 | 7.4 | 31.9 | 7.2 | 33.3 | –0.65 | –0.48 | 5.4 | 24.6 | 3.4 | 2.4 | 3.5 | 5.4 |
| 60 | 10.7 | 19.1 | 45.2 | 59.2 | –2.8 | –5.5 | 0.51 | 0.71 | –3,8 | –1,9 | 15.8 | 59.3 | 15.5 | 61.4 | –0.49 | –0.29 | 6.6 | 25.3 | 4.2 | 3.1 | 5.5 | 7.0 |
| 61 | 8.3 | 15.4 | 33.2 | 41.4 | –1.9 | –2.8 | 0.38 | 0.51 | –5,4 | –3,7 | 6.4 | 31.3 | 6.3 | 31.1 | –0.62 | –0.49 | 3.8 | 20.4 | 4.0 | 2.7 | 5.1 | 6.1 |
| 62 | 11.2 | 19.4 | 41.8 | 60.6 | –2.6 | –5.8 | 0.48 | 0.72 | –4,1 | –1,8 | 13.2 | 56.1 | 13.0 | 57.8 | –0.52 | –0.28 | 6.6 | 23.1 | 3.7 | 3.1 | 4.7 | 7.1 |
| 63 | 14.0 | 20.1 | 35.0 | 45.7 | –2.3 | –3.6 | 0.44 | 0.60 | –4,5 | –2,9 | 17.7 | 51.2 | 17.4 | 52.9 | –0.56 | –0.40 | 14.3 | 35.4 | 2.5 | 2.3 | 3.6 | 5.1 |
| 64 | 7.4 | 14.3 | 25.2 | 42.4 | –1.5 | –2.8 | 0.30 | 0.51 | –6,8 | –3,7 | 3.0 | 22.4 | 3.0 | 22.4 | –0.70 | –0.49 | 2.7 | 13.4 | 3.4 | 3.0 | 4.3 | 6.7 |
| 65 | 14.7 | 20.6 | 41.5 | 51.2 | –2.8 | –4.4 | 0.51 | 0.65 | –3,8 | –2,4 | 8.8 | 33.9 | 8.7 | 36.0 | –0.49 | –0.35 | 5.5 | 20.1 | 2.8 | 2.5 | 3.7 | 5.6 |
| 66 | 6.7 | 14.1 | 21.4 | 31.5 | –1.4 | –2.1 | 0.25 | 0.41 | –7,6 | –4,9 | 1.9 | 14.5 | 1.9 | 15.3 | –0.75 | –0.59 | 2.1 | 15.1 | 3.2 | 2.2 | 3.8 | 5.0 |
| 67 | 12.2 | 18.5 | 39.3 | 54.2 | –2.5 | –4.5 | 0.47 | 0.66 | –4,2 | –2,3 | 15.5 | 52.3 | 15.2 | 50.7 | –0.53 | –0.34 | 9.2 | 23.8 | 3.2 | 2.9 | 4.0 | 6.6 |
| 68 | 12.4 | 20.5 | 38.8 | 50.7 | –2.4 | –4.3 | 0.46 | 0.65 | –4,3 | –2,4 | 14.5 | 48.1 | 14.2 | 50.4 | –0.54 | –0.35 | 8.9 | 28.6 | 3.1 | 2.5 | 3.8 | 5.6 |
| 69 | 13.4 | 20.1 | 35.9 | 42.4 | –2.3 | –3.3 | 0.45 | 0.57 | –4,5 | –3,2 | 6.9 | 38.1 | 6.8 | 39.9 | –0.55 | –0.43 | 5.1 | 30.2 | 2.7 | 2.1 | 3.8 | 4.8 |
| 70 | 8.3 | 15.2 | 40.4 | 56.7 | –2.3 | –4.4 | 0.44 | 0.65 | –4,5 | –2,4 | 6.2 | 33.5 | 6.1 | 35.4 | –0.56 | –0.35 | 2.6 | 13.2 | 4.9 | 3.7 | 5.7 | 8.4 |
| 71 | 6.7 | 14.4 | 20.7 | 37.0 | –1.3 | –2.5 | 0.25 | 0.47 | –7,7 | –4,3 | 1.6 | 14.7 | 1.6 | 14.6 | –0.75 | –0.53 | 1.9 | 11.0 | 3.1 | 2.6 | 3.6 | 5.8 |
| 72 | 7.7 | 16.4 | 30.6 | 39.5 | –1.8 | –2.8 | 0.35 | 0.51 | –5,9 | –3,8 | 4.6 | 24.3 | 4.5 | 25.3 | –0.65 | –0.49 | 3.0 | 18.8 | 4.0 | 2.4 | 4.3 | 5.4 |
| 73 | 11.1 | 17.7 | 33.5 | 50.0 | –2.1 | –3.8 | 0.40 | 0.61 | –5,0 | –2,7 | 8.3 | 38.2 | 8.2 | 40.4 | –0.60 | –0.39 | 6.1 | 21.0 | 3.0 | 2.8 | 3.8 | 6.4 |
| 74 | 12.0 | 16.1 | 27.8 | 42.6 | –1.8 | –3.0 | 0.36 | 0.53 | –5,7 | –3,5 | 4.0 | 23.7 | 3.9 | 25.4 | –0.64 | –0.47 | 4.2 | 16.3 | 2.3 | 2.6 | 3.9 | 6.0 |
| 75 | 8.8 | 15.1 | 42.2 | 57.8 | –2.4 | –4.5 | 0.46 | 0.66 | –4,3 | –2,3 | 7.9 | 43.6 | 7.8 | 45.6 | –0.54 | –0.34 | 3.2 | 16.4 | 4.8 | 3.8 | 6.3 | 8.7 |
| 76 | 7.4 | 17.7 | 31.4 | 55.5 | –1.8 | –4.6 | 0.35 | 0.66 | –5,8 | –2,3 | 6.1 | 29.7 | 6.0 | 35.8 | –0.65 | –0.34 | 3.6 | 15.5 | 4.3 | 3.1 | 5.2 | 7.1 |
| 77 | 8.6 | 18.1 | 41.9 | 59.3 | –2.4 | –5.3 | 0.46 | 0.70 | –4,3 | –2,0 | 6.6 | 38.3 | 6.5 | 38.5 | –0.54 | –0.30 | 2.6 | 15.2 | 4.9 | 3.3 | 5.4 | 7.4 |
| SSD (LSD test) | 0.9 | 1.1 | 1.3 | 1.5 | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| Tukey's test: total number of comparable comparison pairs 3003, number of comparison pairs that were not included in 95% confidence interval ($p_{adj}$=0.516–1.000) 689 (22.94% of values that do not differ significantly) | | | | | | | | | | | | | | | | | | | | | | |

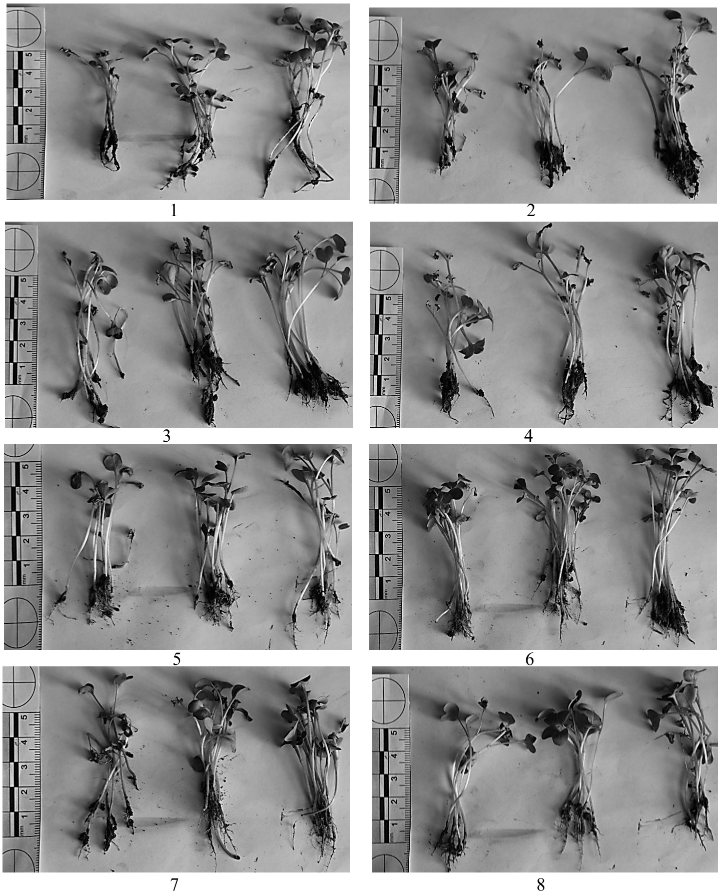



**Figure 4.12 – Oilseed radish plants when grown in the soil substrate, obtained in the variants of three water extracts of weeds at a successive concentration of the solution (from left to right) 4.0, 2.0 and 1.0% (1 – *Berteroa incana* (L.) de Candolle (29); 2 – *Cynodon dactylon* (L.) Pers. (10); 3 – *Echinochloa crus–galli* (L.) P. Beauv. (11); 4 – *Polygonum lapathifolium* (L.) Delarbre (12); 5 – *Lepidium campestre* (L.) Brown (45); 6 – *Polygonum aviculare* L. (46); 7 – *Portulaca oleracea* L. (47); 8 – *Fumaria officinalis* L. (48)) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

Thus, the growth of the CA indicator at a decrease in concentration was noted under the influence of such species as *Cirsium arvense* (L.) Scopoli (9), *Cirsium arvense* (L.) Scopoli (13), *Convolvulus arvensis* L. (24), *Brassica napus* L. (25), *Berteroa incana* (L.) de Candolle (29), *Bromus secalinus* L. (52), *Veronica hederifolia* L. (54), *Polygonum convolvulus* (L.) Löve (74). Equal values of the CA indicator for both concentrations, which testifies to the unidirectional effect of influence on growth processes of aboveground and underground parts was noted under the influence of such species as *Brassica campestris* (L.) Janchen (14), *Taraxacum officinale* Weber (18), *Tripleurospermum maritimum* (L.) Koch (21), *Cichorium intybus* L. (50), *Lamium amplexicaule* L. (57). According to Reigosa et al. (2006), Kunz et al. (2016), such influence nature indicates an appropriate level of physiological activity of the extract substances in relation to the test object.

A grouping informative indicator that combines such intermediate calculated indices as DDI, SVI, CA, TI, μ is index of plant development (GI). According to Marinov–Serafimov et al. (2013), it is a certain alternative to the overall allelopathic potential indicator (OAP). In our studies, this has been effectively confirmed. Thus, variants with low GI values (in the range of 3–23% depending on the concentration of water extract) have the highest estimated OAP gradation (Table 4.12) according to the Smith scale (2013) and the grouping performed (Table 4.13).

It should be noted that the OAP indicator was different for the root system and stems of oilseed radish plants under the action of the corresponding weed extract. It confirms our earlier conclusions about the CA indicator in the system of evaluating the allelopathic activity of the studied plant species, predetermining the need to calculate the integral (average) OAP indicator.

The obtained data allowed us to divide the whole totality of analyzed plant species and divide them by allelopathic activity. In various scientific researches (Rice, 1984; Williamson and Richardson, 1988; Izzet et al., 2004; Zimdahl, 2004, 2018; Kader et al., 2005; Yurchak, 2005; John et al., 2006; Anwar et al., 2013; Smith, 2013; Brust et al., 2014; Syed et al., 2014; Bakhshayeshan-Agdam et al., 2015; Rueda-Ayala et al., 2015; Boydston and Al–Khatib, 2016; Marinov-Serafimov et al., 2017; Arroyo et al., 2018), it was noted that the OAP indicator is a measure of the overall allelopathic effect of relationships in the system weed–tester plant, and in the variant of determining the indicators of allelopathic pressure by laboratory germination indicators and initial growth, showing the level of competitiveness of the tester plant in relation to a particular type of weed ignoring the rate of vegetative growth of the tester, the level of its vitality tactics and other factors. But it clearly divides species by thresholds values of important starting competition, which determines the subsequent success of the formation of agrophytocoenosis of any crop plant.

According to the proposed gradation of Smitha (2013) and the assessments of other scientists (Grodzinsky, 1965; Ivanov, 1973; Rabotnov, 1982; Rice, 1984; Matveev, 1994; Inderjit, 1999; Syed et al., 2014), in terms of the ratio of weeds with the OAP level above and below 5.0, oilseed radish can be attributed to species with high herbal competition potential, where this indicator was 0.75.

This grouping confirms our previous studies on the peculiarities of weed cenosis formation in the general agrophytocoenosis of oilseed radish (Tsytsiura, 2020), since the majority of weed species, which are classified in the category with the OAP level more than 0.5, are dominant in different periods of growth and development of oilseed radish plants in the context of different cenosis tiers. In particular, these species include *Cirsium arvense* (L.) Scopoli, *Echinochloa crus–galli* (L.) P. Beauv., *Chenopodium album* L., *Polygonum convolvulus* (L.) Löve, *Amaranthus retroflexus* L., *Agropyron repens* (L.) de Candolle, *Galinsoga parviflora* Cavanilles. The species botanically similar to the oilseed radish and the oilseed radish itself (*Raphanus sativus* L. var. *oleiformis* Pers., *Brassica napus* L., *Sinapis alba* L.) have also demonstrated a high allelopathic potential in relation to the impact on growth processes of the oilseed radish test plants. The highest OAP potential (0.64–0.66) was recorded for two weed species *Cuscuta campestris* Yuncker and *Acroptilon repens* (L.) de Candolle, although the prevalence of these species is low for oilseed radish agrophytocoenosises in the region.

Table 4.12

**Overall allelopathic potential of weeds in relation to growth processes of oilseed radish plants (*Raphanus sativus* L. var. *oleiformis* Pers.) (for a concentration ratio of 4.0% to 1.0% when growing on the soil substrate) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| CVN | Root | | Stem | | Seedling | | Integrated OAP Score | CVN | Root | | Stem | | Seedling | | Integrated OAP Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OAP | OAP Score | OAP | OAP Score | OAP | OAP Score | | | OAP | OAP Score | OAP | OAP Score | OAP | OAP Score | |
| 1 | 0.54 | HA | 0.16 | NA | 0.26 | MA | 0.32 | 40 | 0.42 | MA | 0.45 | MA | 0.44 | MA | 0.43 |
| 2 | 0.37 | MA | 0.27 | MA | 0.30 | MA | 0.31 | 41 | 0.60 | HA | 0.39 | MA | 0.45 | MA | 0.48 |
| 3 | 0.56 | HA | 0.38 | MA | 0.43 | MA | 0.45 | 42 | 0.64 | HA | 0.60 | HA | 0.62 | HA | 0.62 |
| 4 | 0.64 | HA | 0.38 | MA | 0.45 | MA | 0.49 | 43 | 0.71 | HA | 0.57 | HA | 0.61 | HA | 0.63 |
| 5 | 0.35 | MA | 0.41 | MA | 0.39 | MA | 0.38 | 44 | 0.57 | HA | 0.56 | HA | 0.57 | HA | 0.57 |
| 6 | 0.62 | HA | 0.37 | MA | 0.44 | MA | 0.48 | 45 | 0.46 | MA | 0.43 | MA | 0.44 | MA | 0.44 |
| 7 | 0.60 | HA | 0.43 | MA | 0.48 | MA | 0.51 | 46 | 0.51 | HA | 0.46 | MA | 0.48 | MA | 0.48 |
| 8 | 0.49 | MA | 0.41 | MA | 0.44 | MA | 0.45 | 47 | 0.43 | MA | 0.61 | HA | 0.56 | HA | 0.53 |
| 9 | 0.56 | HA | 0.52 | HA | 0.53 | HA | 0.54 | 48 | 0.58 | HA | 0.62 | HA | 0.61 | HA | 0.60 |
| 10 | 0.57 | HA | 0.59 | HA | 0.58 | HA | 0.58 | 49 | 0.53 | HA | 0.62 | HA | 0.60 | HA | 0.58 |
| 11 | 0.65 | HA | 0.41 | MA | 0.47 | MA | 0.51 | 50 | 0.43 | MA | 0.53 | HA | 0.50 | MA | 0.49 |
| 12 | 0.36 | MA | 0.48 | MA | 0.45 | MA | 0.43 | 51 | 0.46 | MA | 0.59 | HA | 0.56 | HA | 0.54 |
| 13 | 0.31 | MA | 0.46 | MA | 0.42 | MA | 0.39 | 52 | 0.47 | MA | 0.53 | HA | 0.52 | HA | 0.51 |
| 14 | 0.61 | HA | 0.47 | MA | 0.51 | HA | 0.53 | 53 | 0.50 | MA | 0.55 | HA | 0.53 | HA | 0.53 |
| 15 | 0.58 | HA | 0.65 | HA | 0.62 | HA | 0.62 | 54 | 0.48 | MA | 0.57 | HA | 0.54 | HA | 0.53 |
| 16 | 0.51 | HA | 0.45 | MA | 0.47 | MA | 0.48 | 55 | 0.58 | HA | 0.50 | HA | 0.52 | HA | 0.53 |
| 17 | 0.64 | HA | 0.48 | MA | 0.53 | HA | 0.55 | 56 | 0.55 | HA | 0.43 | MA | 0.46 | MA | 0.48 |
| 18 | 0.36 | MA | 0.61 | HA | 0.54 | HA | 0.50 | 57 | 0.51 | HA | 0.40 | MA | 0.43 | MA | 0.44 |
| 19 | 0.26 | MA | 0.35 | MA | 0.32 | MA | 0.31 | 58 | 0.65 | HA | 0.60 | HA | 0.61 | HA | 0.62 |
| 20 | 0.42 | MA | 0.40 | MA | 0.40 | MA | 0.40 | 59 | 0.58 | HA | 0.56 | HA | 0.57 | HA | 0.57 |
| 21 | 0.22 | NA | 0.55 | HA | 0.46 | MA | 0.40 | 60 | 0.51 | HA | 0.35 | MA | 0.39 | MA | 0.42 |
| 22 | 0.37 | MA | 0.63 | HA | 0.56 | HA | 0.52 | 61 | 0.61 | HA | 0.53 | HA | 0.55 | HA | 0.57 |
| 23 | 0.47 | HA | 0.55 | HA | 0.51 | HA | 0.43 | 62 | 0.49 | MA | 0.36 | MA | 0.40 | MA | 0.42 |
| 24 | 0.44 | MA | 0.47 | MA | 0.46 | MA | 0.46 | 63 | 0.43 | MA | 0.50 | MA | 0.48 | MA | 0.47 |
| 25 | 0.67 | HA | 0.60 | HA | 0.62 | HA | 0.63 | 64 | 0.64 | HA | 0.58 | HA | 0.60 | HA | 0.60 |
| 26 | 0.50 | MA | 0.56 | HA | 0.55 | HA | 0.54 | 65 | 0.42 | MA | 0.42 | MA | 0.42 | MA | 0.42 |
| 27 | 0.60 | HA | 0.46 | MA | 0.50 | MA | 0.52 | 66 | 0.65 | HA | 0.67 | HA | 0.67 | HA | 0.66 |
| 28 | 0.52 | HA | 0.53 | HA | 0.53 | HA | 0.53 | 67 | 0.49 | MA | 0.42 | MA | 0.44 | MA | 0.45 |
| 29 | 0.37 | MA | 0.45 | MA | 0.43 | MA | 0.42 | 68 | 0.45 | MA | 0.44 | MA | 0.45 | MA | 0.45 |
| 30 | 0.48 | MA | 0.40 | MA | 0.42 | MA | 0.43 | 69 | 0.45 | MA | 0.51 | HA | 0.49 | MA | 0.48 |
| 31 | 0.37 | MA | 0.35 | MA | 0.36 | MA | 0.36 | 70 | 0.61 | HA | 0.39 | MA | 0.45 | MA | 0.49 |
| 32 | 0.45 | MA | 0.43 | MA | 0.44 | MA | 0.44 | 71 | 0.65 | HA | 0.64 | HA | 0.64 | HA | 0.64 |
| 33 | 0.50 | MA | 0.41 | MA | 0.44 | MA | 0.45 | 72 | 0.60 | HA | 0.56 | HA | 0.57 | HA | 0.58 |
| 34 | 0.53 | HA | 0.45 | MA | 0.47 | MA | 0.48 | 73 | 0.52 | HA | 0.48 | MA | 0.49 | MA | 0.50 |
| 35 | 0.34 | MA | 0.32 | MA | 0.33 | MA | 0.33 | 74 | 0.53 | HA | 0.56 | HA | 0.55 | HA | 0.55 |
| 36 | 0.47 | MA | 0.55 | HA | 0.53 | HA | 0.51 | 75 | 0.60 | HA | 0.38 | MA | 0.44 | MA | 0.47 |
| 37 | 0.46 | MA | 0.48 | MA | 0.47 | MA | 0.47 | 76 | 0.58 | HA | 0.46 | MA | 0.49 | MA | 0.51 |
| 38 | 0.38 | MA | 0.37 | MA | 0.37 | MA | 0.38 | 77 | 0.56 | HA | 0.37 | MA | 0.42 | MA | 0.45 |
| 39 | 0.35 | MA | 0.53 | HA | 0.48 | MA | 0.45 | $SSD_{0.05}$ | 0.038 | | 0.045 | | 0.037 | | – |

SSD – The smallest significant difference between the values according to LSD test for $p < 0.05$.

Table 4.13

**Grouping of weed species according to their allelopathic potential (OAP) of oilseed radish impact on initial growth processes (BBCH 01–12) (Tsytsiura, 2022; Tsytsiura and Sampietro, 2024)**

| OAP interval | Weed species, which belong to the interval group | Numer of species in the group |
|---|---|---|
| 0.30–0.35 | *Capsella bursa–pastoris* L., *Galium aparine* L., *Sonchus arvensis* L., *Arctium lappa* L. | 4 |
| 0.36–0.40 | *Setaria glauca* L., *Papaver rhoeas* L., *Raphanus raphanistrum* L., *Tripleurospermum maritimum* (L.) Koch, *Plantago major* L., *Rumex confertus* Willdenow | 6 |
| 0.41–0.45 | *Ambrosia artemisiifolia* L., *Thlaspi arvense* L., *Polygonum lapathifolium* (L.) Delarbre, *Berteroa incana* (L.) de Candolle, *Artemisia absinthium* L., *Setaria viridis* (L.) Palisot de Beauvois, *Polytrichum commune* L., *Eryngium campestre* L., *Lepidium ruderale* L., *Lepidium campestre* (L.) Brown, *Lamium amplexicaule* L., *Achillea millefolium* L., *Spergula vulgaris* L., *Plantago lanceolata* L., *Erodium cicutarium* (L.) L'Héritier, *Panicum capillare* L., *Solanum nigrum* L. | 18 |
| 0.46–0.50 | *Stellaria media* (L.) Vill., *Erigeron canadensis* L., *Agropyron repens* (L.) Gould, *Taraxacum officinale* Weber, *Convolvulus arvensis* L., *Sinapis arvensis* L., *Consolida regalis* Gray, *Daucus carota* L., *Polygonum aviculare* L., *Cichorium intybus* L., *Crepis tectorum* L., *Poa annua* L., *Rumex acetosella* L., *Sisymbrium Loeselii* L., *Echium vulgare* L., *Bunias orientalis* L. | 16 |
| 0.51–0.55 | *Carduus acanthoides* L., *Cirsium arvense* (L.) Scopoli, *Echinochloa crus–galli* (L.) P. Beauv., *Brassica campestris* (L.) Janchen, *Chenopodium album* L., *Amaranthus retroflexus* L., *Galinsoga parviflora* Cavanilles, *Rocket-cress* Brown, *Centaurea cyanus* L., *Artemisia vulgaris* L., *Equisetum arvense* L., *Portulaca oleracea* L., *Avena fatua* L., *Bromus secalinus* L., *Lamium purpureum* L., *Veronica hederifolia* L., *Chondrilla juncea* L., *Polygonum convolvulus* (L.) Löve, *Aethusa cynapium* L. | 18 |
| 0.56–0.60 | *Cynodon dactylon* (L.) Pers., *Lactuca serriola* L., *Descurainia Sophia* (L.) Prantl, *Digitaria ischaemum* (Schreber) Muhlenberg, *Senecio vernalis* (Waldstein & Kitaibel) Alexander, *Amaranthus blitoides* Watson, *Onopordon acanthium* L., *Fumaria officinalis* L. | 8 |
| 0.61–0.65 | *Raphanus sativus* L. var. *oleiformis* Pers., *Brassica napus* L., *Sinapis alba* L., *Lepidium draba* L., *Cyclachaena xanthiifolia* Nuttall, *Cuscuta campestris* Yuncker | 6 |
| 0.66–0.70 | *Acroptilon repens* (L.) de Candolle | 1 |

The data obtained is also confirmed by the level of allelopathic effect on other cultivated plants from a number of weed species under study, including the representatives of theConvolvulaceae (COVF) family in the studies of Marinov–Serafimov et al. (2017), Dadkhah and Rassam (2016); Brassicaceae (1CRUF) family species in the studies of Boydston and Hang (1995), Al–Khatib et al. (1997), Petersen et al. (2001), Turk and Tawaha (2003), Norsworthy (2003), Uremis et al. (2004), Haramoto and Gallandt (2004), Boydston and Al–Khatib (2006), Awan et al. (2012), Lawley et al. (2012), Syed et al. (2014), Mohamed and El–gawad (2014), Lemerle et al. (2017), Marinov–Serafimov et al. (2019); Poaceae (1GRAF) family species in the studies of Einhellig et al. (1982), Awan et al. (2012), de Bertoldi et al. (2012), Anwar et al. (2013), Fragasso et al. (2013), Golubinova and Ilieva (2014); Apiaceae (1UMBF) family species in the studies of Yurchak (2005), Syed et al. (2014), Singh et al. (2016); Asteraceae (1COMF) family species in the studies of Izzet et al. (2004), Awan et al. (2012), Możdżeń et al. (2018), Marinov–Serafimov et al. (2019); Amaranthaceae (1AMAF) family species in the studies of Shahrokhi et al. (2011), Iqbal and Fry (2012), Bakhshayeshan-Agdam et al. (2015), Gfeller et al. (2018), Prinsloo and Plooy (2018), Carvalho et al. (2019), VanVolkenburg et al. (2020); Polygonaceae (1POLF) family species in the studies of Anwar et al. (2013). According to the research results of the above–mentioned authors, the highest level of allelopathic potential was noted for the Asteraceae and Poaceae family representatives, and among the parasitic representatives of the Convolvulaceae family, in particular the Cuscuta (1CVCG) genus. Unlike other crops, which were studied in the above publications, oilseed radish has a high level of tolerance both in the assessment of the formation of laboratory germination capacity, and from the position of initial growth processes, although the nature of allelopathic impact on the basic indicators in relation to other crops has certain similarities.

The data obtained also allow us to determine the most harmful type of contamination for oilseed radish agrophytocoenosises, which is based on estimates of the level of competitive and allelopathic pressure, given the previously studied vitality tactics of a variety of weed species in the oilseed radish cenosises of different technological density (Tsytsiura, 2020), as well as estimates made in other studies (Smith, 2013; Zimdahl, 2004, 2018) on the formation of competitive relationships and the degree of dominance of weed agrophytocoenosises. In this regard, for oilseed radish in view of the OAP of the studied species, the total harmfulness of the types of infestation will increase in the following order: young – rhizomatous – young–rhizomatous, soboliferous, young–soboliferous – rhizomatous–soboliferous – young–soboliferous–rhizomatous. At the same time, the maximum allelopathic pressure will be noted by analogy with the coenotic pressure in cenosis (Zimdahl, 2004, 2018) provided that participation in the formation of stem and cenosis tiers of one–third of species with OAP from 0.5.

Thus, oilseed radish has a sensitive reaction to water extracts from 77 species of weeds in the range of concentrations from 0.25% to 16% (w $v^{-1}$) with a boundary value of formation of the minimum level of laboratory seed germination at a concentration of 4.0%. It was found that the soil substrate alleviates the allelopathic impact of water extracts from weeds plants with a decrease in the OAP value by one or two steps of the classification gradation of the indicator in the 0.26–0.75 interval.

Based on the OAP indicator in relation to the formation of laboratory germination of seeds, 10 groups were formed from 0.26 to 0.75 with 0.04 step. In the OAP 0.5–0.75 interval, which corresponds to the impact of species with high allelopathic potential, 35 species out of 77 studied were included. Depending on the determined OAP indicator (in the interval ratio between water and soil germination substrates) and given the prevalence of the main weed species in the oilseed radish agrophytocoenosises in terms of allelopathic potential with respect to the formation of the level of laboratory germination, it can be placed in the following orde: *Setaria glauca* L. (OAP 0.35–0.41) – *Polygonum lapathifolium* (L.) Delarbre (0.45–0.54), *Setaria viridis* (L.) Palisot de Beauvois (0.48–0.52) – *Ambrosia artemisiifolia* L. (0.47–0.53) – *Sonchus arvensis* L. (0.52–0.56) – *Echinochloa crus-galli* (L.) P.Beauv. (0.47–0.57) – *Agropyron repens* (L.) Gould (0.56–0.60) – *Polygonum convolvulus* (L.) Löve (0.58–0.60) – *Equisetum arvense* L. (0.59–0.60) – *Convolvulus arvensis* L. (0.57–0.61) – *Galinsoga parviflora* Cavanilles (0.57–0.62) – *Cirsium arvense* (L.) Scopoli (0.54–0.63) – *Chenopodium album* L. (0.63–0.67) – *Amaranthus retroflexus* L. (0.64–0.67) – *Acroptilon repens* (L.) de Candolle (0.65–0.66) – *Cuscuta campestris* Yuncker (0.68).

There are 8 classification groups from 0.30 to 0.70 with an interval step of 0.04 according to the OAP indicator in relation to the initial growth processes of oilseed radish plants. 33 plant species out of 77 analyzed (42.9%) are classified among those with OAP value of 0.50 and higher. By the size of the total allelopathic potential and given again the prevalence of certain species in the oilseed radish agrophytocoenosis, the main harmful weed species can be placed in the following order: *Sonchus arvensis* L. (integral OAP 0.31) – *Setaria glauca* L. (0.38) – *Polygonum lapathifolium* (L.) Delarbre (0.43) – *Chenopodium album* L. (0.43) – *Ambrosia artemisiifolia* L. (0.45) – *Convolvulus arvensis* L. (0.46) – *Agropyron repens* (L.) Gould (0.48) – *Carduus acanthoides* L. (0.51) – *Echinochloa crus–galli* (L.) P.Beauv. (0.51) – *Equisetum arvense* L. (0.51) – *Galinsoga parviflora* Cavanilles (0.52) – *Cirsium arvense* (L.) Scopoli (0.54) – *Polygonum convolvulus* (L.) Löve *(0.55) – Amaranthus retroflexus* L. (0.55) – *Lactuca serriola* L. (0.57) – *Cynodon dactylon* (L.) Pers. (0.58) – *Lepidium draba* L. (0.63) – *Cuscuta campestris* Yuncker (0.64) – *Acroptilon repens* (L.) de Candolle (0.66).

Considering the obtained allelopathic potential rows, the maximum harmfulness of weed cenosis in the oilseed radish agrophytocoenosises will be noted if at least one third of representatives of the specified allelopathic row are combined during the vegetation of the crop with the maximum allelopathic effect of influence in case of young–soboliferous-rhizomatous type of infestation.

### 4.3. Effectiveness of weed control using oilseed radish

Plant mulch of cruciferous siderates covers the soil from the sun's rays, which are activators of the process of germination of certain groups of weeds, and exerts allelopathic inhibition on the germination of annual weeds (Brust et al., 2014; Didon et al., 2014), which reduces the need to use herbicides. By wrapping the siderate phytomass, cultivated plants increase their phytomass faster, which increases their competitiveness against weeds, due to the improvement of the agrochemical, agrophysical, and microbiological condition of typical black soil.

The research was carried out in a short-rotation crop rotation: peas – winter wheat – sugar beets – barley. The sugar beet fertilization scheme included:

– Control (wrapping only post-harvest remains of winter wheat).

– Post-harvest siderate of oilseed radish.

– Post-harvest siderate of phacelia.
– Post-harvest siderate of buckwheat.
– Wrapping 25 t/ha of manure.
– Wrapping of mineral fertilizer $N_{125}P_{63}K_{150}$.

Before sowing siderates, surface peeling was carried out for 4–6 cm. After plowing with green manure, in the following years 2001–2006, sugar beets (Umansky ChS-97 hybrid) were grown according to the technologies recommended for the location of the experiment

Among the post-harvest sowings of siderates, compared to the control without siderate, the lowest number of weeds was found for oil radish – 4.8 pcs. $m^{-2}$ and their weight – 28.1 g $m^{-2}$, which differed by 73 and 81% from the control without siderate, where the total number of weeds was determined at the level of 17.8 pcs. $m^{-2}$, and biomass – 150 g $m^{-2}$ (Table 4.14). A smaller decrease in the number of weeds was established for the pygmy-leaved facies.weight – by 64%, and weight – by 51%, compared to the control, and the lowest – for seed buckwheat – 39 and 51%, respectively.

Sowing of green fertilizers most noticeably reduced, compared to the control (without siderate), weediness by annual summer weeds, which, compared to wintering and perennial weeds, were the most common. Thus, in siderat crops, the number of early spring weeds decreased by 3.8–6.4 pcs. $m^{-2}$, and late spring weeds – by 1.6–3.8 pcs. $m^{-2}$. Their mass differed from the control without siderate – by 35.4-52.4 g $m^{-2}$ and 15.4–23.2 g $m^{-2}$, respectively. A significant reduction in weight weediness due to wintering weeds – by 15.4–23.2 g $m^{-2}$ and perennial weeds – by 3.2–5.8 g $m^{-2}$, and quantitative – only by perennial weeds – by 0, 8–1.4 pcs. $m^{-2}$.

Siderate of oil radish most suppressed seedlings and subsequent growth and development of weeds due to the densest cover of green mass. It was here that the strongest feedback was established between the above-ground mass of siderate and the number of weeds – r = -0.55 and their mass – r = -0.56.

Under a less powerful cover of the post-harvest sowing of siderate of Phacelia pygmylum, the correlation between the above-ground mass of siderate r = –0.53 and the number and mass of weeds – r = –0.51 was weaker.

The stem of the post-harvest buckwheat siderate was the least dense at the time of plowing, as this heat-loving culture stopped vegetation under the influence of low temperatures, which caused the highest weediness among the siderate crops. A correlation between the above-ground mass of buckwheat and its weediness was not established.Thus, during the cultivation of siderats, the post-harvest sowing of oil radish was the least weedy, and the sowing of buckwheat was the most weedy. After the overwintering of plowed organic and mineral fertilizers compared to the control without them, differences in the distribution of weed seeds in the soil were determined (Table 4.14).

At the beginning of the growing season, the number of all weed seeds in the 0–30 cm soil layer on the background of green fertilizers was significantly lower – by 5.4–13.1 million seeds $ha^{-1}$ or 4.7–11.5%, compared with control without siderate, where it is set at the level of 114.3 million units $ha^{-1}$.

Table 4.14

**Number and mass of weeds before plowing post-harvest siderates, average for 2000–2004 (Mishchenko and Zakharchenko, 2019)**

| Variant | Number of weeds, pcs. $m^{-2}$ | | | | | Mass of weeds, g $m^{-2}$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | biological groups of weeds | | | | In total | biological groups of weeds | | | | In total |
| | spring early | spring late | wintering | perennial | | spring early | spring late | wintering | perennial | |
| Without siderate (control) | 9.0 | 5.6 | 1.6 | 1.6 | 17.8 | 65.2 | 53.0 | 25.4 | 6.2 | 150 |
| Post-harvest siderate of oilseed radish | 2.6 | 1.8 | 0.2 | 0.2 | 4.8 | 12.8 | 12.7 | 2.2 | 0.4 | 28.1 |
| Post-harvest siderate of Phacelia tansy | 3.6 | 2.2 | 0.2 | 0.4 | 6.4 | 21.8 | 15.0 | 2.4 | 1.6 | 40.8 |
| Post-harvest siderate of sowing buckwheat | 5.2 | 4.0 | 0.8 | 0.8 | 10.8 | 29.8 | 30.6 | 10.0 | 3.0 | 73.4 |
| $LSD_{05}$ | 1.7 | 1.3 | 3.4 | 0.7 | 3.4 | 11.1 | 12.0 | 9.1 | 2.7 | 26.5 |

Plowing with 25 t $ha^{-1}$ of manure increased the potential clogging of the 0-30 cm soil layer at the beginning of the growing season by 29 million units $ha^{-1}$ or 25%; for the application of mineral fertilizers, it was at the control level – 114.6 million pcs. $ha^{-1}$.

The distribution of weed seeds by siderates contributed to the reduction of the potential clogging of the upper soil layer. Thus, for oil radish, the lowest share of seed stocks was found in the 0–5 cm layer – 14% and 5–10 cm – 14.8%, and the highest – after plowing with 25 t $ha^{-1}$ of manure and mineral fertilizers $N_{125}P_{63}K_{150}$ – 16.4 and 16 %.

The reduction of potential weediness against the background of green fertilizers is explained by the effect of two factors: 1) pre-sowing soil cultivation and subsequent rolling of the soil under intermediate crops of siderates stimulated the germination of weed seeds; 2) plowing of plant biomass activated the activity of soil biota, which ensured intensive destruction of organic matter and weed seeds. This explains that with the plowing of the largest amount of radish siderate phytomass, the most significant difference in the number of weed seeds of the upper layers of the soil 0–5 cm – by 3.4 million units/ha and 5–10 cm – by 4.6 million. units/ha to the control without siderate, where weed seed reserves were 18.8 million units/ha in the 0–5 cm layer, and 18.2 million units $ha^{-1}$ in the 5–10 cm layer. Plowing of oil radish also provided the most significant reduction of weed seed reserves in the 10–20 cm soil layer – by 2.1 million pieces/ha and in the 20–30 cm layer – by 3.0 million pieces/ha, compared with the control without siderate, where their number was 38.8 and 38.5 million pcs. $ha^{-1}$.

In the siderate of the pygmy leaf phacelium, the potential clogging at the time of vegetation recovery was significantly higher, compared to oil radish, in the soil layer of 0–5 cm – by 0.8 million units/ha, 5–10 cm – by 0.7 million . pcs. $ha^{-1}$, and in the arable (0¬30 cm) layer – by 3.0 million pcs./ha, and compared to the control – it decreased noticeably – in the range of 1.4–10.2 million pcs. $ha^{-1}$. Against the background of post-seeded buckwheat siderate, the highest potential clogging of the soil layer 0–30 cm was established – 108.9 million pcs. $ha^{-1}$ among green fertilizers, but it significantly decreased, compared to the control without siderate, in the soil layer – 0–5 cm – by 2.5 million pieces/ha, 5–10 cm – by 1.7 million pcs. $ha^{-1}$, and in the arable (0–30 cm) layer – by 5.0 million pcs. $ha^{-1}$.

Among the post-harvest siderates, the phytomass of oil radish had the most significant effect on reducing the potential clogging of the soil layer 0–30 cm – $r = 0.9$. The correlation coefficient was slightly lower for the siderate of the phacelium pygmy – 0.87, and the smallest for the siderate of the buckwheat – r = 0.77.

The phytomass of oil radish siderate had the greatest positive effect on reducing the number of weed seeds in the soil layers – 70.0–92.5%, the phytomass of phacelia had a lesser effect – 63.0–87.3%, and the least buckwheat – 51.0–63.2% (Table 4.15).

Table 4.15

**Potential soil clogging at the beginning of the growing season under different fertilization backgrounds, average for 2001–2005, million units ha$^{-1}$ (Mishchenko and Zakharchenko, 2019)**

| Variant | Soil layer, cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | | 5–10 | | 10–20 | | 20–30 | | 0–30 |
| | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | In total, million units ha$^{-1}$ |
| Without siderate (control) | 18.8 | 16.4 | 18.2 | 15.9 | 38.8 | 33.9 | 38.5 | 33.7 | 114 |
| Post-harvest siderate of oilseed radish | 14.2 | 14.0 | 14.8 | 14.6 | 35.8 | 35.4 | 36.4 | 36.0 | 101 |
| Post-harvest siderate of Phacelia tansy | 15.0 | 14.4 | 15.5 | 14.9 | 36.5 | 35.1 | 37.1 | 35.6 | 104 |
| Post-harvest siderate of sowing buckwheat | 16.3 | 15.0 | 16.5 | 15.2 | 37.9 | 34.8 | 38.2 | 35.1 | 109 |
| 25 t ha$^{-1}$ manure | 23.5 | 16.4 | 22.9 | 16.0 | 48.6 | 33.9 | 48.4 | 33.8 | 143 |
| Mineral fertilizers $N_{125}P_{63}K_{150}$ | 18.8 | 16.4 | 18.3 | 16.0 | 38.8 | 33.9 | 38.7 | 33.8 | 115 |
| $LSD_{05}$ | 0.4 | | 0.6 | | 1.0 | | 1.2 | | 1.0 |

It was established (Mishchenko and Zakharchenko, 2019) that green fertilizers had a noticeable effect on the distribution of weed seeds in the 0–30 cm soil layer. If manure and mineral fertilizers were applied, weed seeds were distributed in the soil as well as in the control without siderate – the largest their share was 16.4% in the upper layers of the soil 0–5 cm and 16.0% in 5–10 cm, then with oil radish siderate, compared to the control without it, the share of seeds of potential litterers decreased in the upper soil layer by 0– 5 cm – by 2.4% and in the 5–10 cm layer – by 1.3%, for pygmy phacelia – by 2.0 and 1.0%, and for buckwheat – by 1.5 and 0.8% . The decrease in the number of weed seeds is due to the activation of the natural processes of destruction of soil organic matter and the lack of replenishment of the seed fund of polluters, established by the application of manure (Table 4.16).

Table 4.16

**The share of influence of the type of siderate on the potential clogging of soil layers, % (Mishchenko and Zakharchenko, 2019)**

| Variant | Soil layer, cm | | | | |
|---|---|---|---|---|---|
| | 0–5 | 5–10 | 10–20 | 20–30 | 0–30 |
| Post-harvest siderate of oilseed radish | 70.0 | 72.5 | 81.3 | 92.5 | 81.3 |
| Post-harvest siderate of Phacelia tansy | 63.0 | 69.0 | 78.0 | 87.3 | 76.4 |
| Post-harvest siderate of sowing buckwheat | 51.0 | 55.7 | 59.5 | 63.2 | 59.8 |

Since the majority of weeds germinate from a layer of up to 10 cm, this distribution of them in the soil subsequently caused a lower actual weediness of sugar beet crops on the background of siderates, compared to the control without them. Thus, against the background of oil radish siderate, both the number of weeds – 19.2 pcs./$m^2$ and their mass – 354 g/$m^2$ was determined to be the lowest in sugar beet crops (Table 4.17).

Against this background, the most significant reduction in the number of weeds in sugar beet crops was established – by 39% and their weight – by 23%, compared to the control, where the number of weeds was 31.4 pcs. $m^{-2}$, and their weight was 460 g $m^{-2}$.

In comparison with the control without siderate, the number of weeds in sugar beet crops was significantly lower by 31% and their weight by 18%.

Buckwheat green fertilizer among siderates ensured a significantly higher number of weeds in sugar beet crops – 27.6 pcs. $m^{-2}$ and their weight – 436 g $m^{-2}$. In general, weediness on the background of seeded buckwheat siderate was significantly lower, compared to the control without siderate, in terms of the number of weeds in sugar beet crops – by 12%.

Since the greatest potential clogging was determined in the upper 0–10 cm soil layer when 25 t $ha^{-1}$ of manure was applied during vegetation recovery, the sugar beet crops had the highest number of weeds –

40.0 pcs./m$^2$ and their mass – 731 g m$^{-2}$, which significantly exceeded both the control and green manure backgrounds.With the introduction of mineral fertilizer $N_{125}P_{63}K_{150}$ under sugar beets, there was no significant increase in the number of weeds compared to the control without siderate, however, their weight in sugar beet crops increased significantly by 141 g to 601 g m$^{-2}$.

Table 4.17

**Distribution of biological groups of weeds in sugar beet crops under different fertilization backgrounds, average for 2001–2005 (Mishchenko and Zakharchenko, 2019)**

| Variant | Biological group of weeds | | | | | | | | | | | | In total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | spring early | | | spring late | | | wintering | | | perennial | | | | |
| | million units ha$^{-1}$ | % to total | g m$^{-2}$ | million units ha$^{-1}$ | % to total | g m$^{-2}$ | million units ha$^{-1}$ | % to total | g m$^{-2}$ | million units ha$^{-1}$ | % to total | g m$^{-2}$ | ps. m$^{-2}$ | g m$^{-2}$ |
| Without siderate (control) | 15.9 | 50.7 | 200 | 10.8 | 34.4 | 177 | 2.1 | 6.6 | 43.9 | 2.6 | 8.3 | 40.0 | 31.4 | 460 |
| Post-harvest siderate of oilseed radish | 9.9 | 51.4 | 165 | 7.9 | 41.0 | 155 | 0.7 | 3.8 | 19.1 | 0.7 | 3.8 | 15.7 | 19.2 | 354 |
| Post-harvest siderate of Phacelia tansy | 11.1 | 50.9 | 174 | 8.9 | 41.1 | 162 | 0.9 | 4 | 22.3 | 0.9 | 4.0 | 17.8 | 21.8 | 376 |
| Post-harvest siderate of sowing buckwheat | 14.1 | 51.1 | 203 | 10.3 | 37.3 | 173 | 1.5 | 5.5 | 34.1 | 1.7 | 6.0 | 26.3 | 27.6 | 436 |
| 25 t ha$^{-1}$ manure | 19.3 | 48.2 | 308 | 15.1 | 37.8 | 308 | 2.9 | 7.2 | 67.1 | 2.7 | 6.8 | 48.8 | 40.0 | 731 |
| Mineral fertilizers $N_{125}P_{63}K_{150}$ | 15.7 | 48.0 | 241 | 12.5 | 38.2 | 263 | 1.9 | 5.9 | 49.1 | 2.6 | 8.0 | 47.9 | 32.7 | 601 |
| $LSD_{05}$ | 1.7 | | 23.4 | 1.7 | | 35.2 | 0.8 | | 18.0 | 0.6 | | 10.2 | 3.3 | 52.6 |

Fertilization backgrounds had almost no effect on the species composition of sugar beet weeds, their crops were characterized by the early-year weed type – from 91 to 96% of early-year weed: common sedge (*Amaranthus retroflexus* L.), flat common (*Echinochloa crusgalli* L.), mouse green, (*Setaria viridis* L.), white quinoa (*Chenopodium album* L.), field sedge (*Thlaspi arvense* L.), Canadian sedge (*Erigeron canadensis* LJ; among perennial weed species, weakly developed yellow thistles (*Sonchus arvensis* L. ) and field birch (*Convolvulus arvensis* L.).

In the structure of weediness of sugar beet crops grown on the background of siderate of oil radish or Phacelia pysmofolia, the share of wintering and perennial weeds decreased to 4%, while in the control without siderate it fluctuated within 8%. The most noticeable increase in the structure of weediness was the increase in the share of late spring weeds when grown on the background of siderate of oil radish and phacelia pysmolys of sugar beet – up to 41%, for their share in the control without siderate at the level of 34%.

Against the background of siderates, compared to the control without them, an increase in the share of monocotyledonous weeds from the biological group of early spring weeds was noted – within 1–2%, and a decrease in the share of dicotyledonous weeds. When manure was applied, compared to the control without siderate, on the contrary, the share of monocotyledonous weeds decreased by 1–3% and, accordingly, the share of dicotyledonous weeds increased.

Determination of the dynamics of weediness of sugar beet crops established its peak in the middle of the growing season. For plowing with 25 t/ha of manure, both the number of weeds at the time of closing the rows of sugar beets was the highest – 56 pcs. $m^{-2}$, and their weight – 1214 g $m^{-2}$, which prevailed over the control without siderate in terms of the number of weeds on 27%, and by their weight – by 62%.

In the crops of sugar beets against the background of siderate of oil radish and Phacelia pysmolystia, significantly less weediness was determined with a difference to the control in the range of 20–50%.

The highest rates of weediness in the middle of the growing season (in June and July) are due to sufficient heat and precipitation and the slow formation of phytomass in sugar beets in the first half of the growing season, which did not ensure phyto-coenotic suppression of weeds.At the time of the emergence of sugar beet seedlings, the smallest number of weeds was determined for the siderate of oil radish – 14.2 pcs. $m^{-2}$ and their weight – 41.7 g $m^{-2}$. This is due to the mechanical loosening of the inter-rows in the sugar beet crops and the inhibition of weed seed germination under the action of the decomposition products of the phytomass of the green fertilizer.

Setting the minimum mass of weeds at the time of emergence from 41.7 to 108 g $m^{-2}$ is due to the shortest period of their vegetation and the low weight of representatives of each species.

At the time of harvesting of sugar beets, weed plants in crops reached the largest mass, because their vegetation was the longest, however, due to the lowest density of weeds, their mass was lower than during the recording in the middle of the vegetation and ranged from 439 to 821 g $m^{-2}$.

The least weedy crops of sugar beets were under the green manure of oil radish, which differed significantly from the background of seeded buckwheat siderate, control without siderate and plowing of traditional fertilizers. The high efficiency of oil radish siderate in terms of reducing actual weediness is due to the presence in cruciferous plants of a herbistatic effect from the decomposition products of plowed phytomass. This confirms the established inverse closest correlation between the mass of oil radish siderate and the number of weeds – $r = -0.82$ and their mass – $r = -0.89$, and the highest share of the influence of the phytomass of green fertilizer on weediness indicators – respectively 67 and 80%.

The proportion of the influence of phytomass on the number of weeds was 59% and 72% for the siderate of *Phacelia pygmaeus*, and the lowest for the siderate of buckwheat was 48 and 62%, respectively. Due to the improvement of the nutrition background, the weight of one weed plant increased with the application of fertilizers: on the background of the siderate of oil radish for the cultivation of sugar beets – by 3.8 g, the application of manure – by 3.6 g, and mineral fertilizers – by 3.7 g.

At the time of harvesting sugar beets, the largest decrease was found, compared to the count at the beginning of their cultivation, in the number of weed seeds in the 0–30 cm soil layer when using oil radish siderate – by 2.5 to 98.5 million pieces $ha^{-1}$).

The reduction of weed seed stocks occurred due to its destruction in the soil, germination and avoidance of ripening of weeds, the seedlings of which were destroyed in sugar beet crops by mechanical processing.

Thus, the lowest potential weediness of the 0–30 cm soil layer was established on the background of the siderate of oil radish during the cultivation of sugar beets – 98.5 million units $ha^{-1}$, which differed significantly from the rest of the fertilization backgrounds, and decreased most noticeably – by 12%, compared to the control without siderate, where the number of weeds was 112.3 million units $ha^{-1}$.

The number of weed seeds in the 0-30 cm soil layer was significantly reduced by 9% compared to the control without siderate before harvesting sugar beets, and by 5% with buckwheat siderate.

Application of 25 t $ha^{-1}$ of manure provided the largest number of weed seeds in the 0-30 cm soil layer before harvesting sugar beets – 140.7 million pieces $ha^{-1}$, which exceeded the control without siderate by 25%. Plowing of mineral fertilizer $N_{125}P_{63}K_{150}$ formed potential clogging at the level of control without siderate – 112.5 million units $ha^{-1}$. (Table 4.18).

In the surface (0–10 cm) layer of the soil, a smaller number of weed seeds was determined on the background of green manure in the range of 12–24%, compared to the control without it. The lowest number of weeds was determined for the siderate of oil radish in the upper layer of 0–5 and 5–10 cm under the sugar beet crops – 13.6 and 14.2 million units/ha, which provided the smallest share of the number of weeds in these soil layers Yanivs – between 13.8 and 14.4%.

Under siderates of the phacelia of pygmaeus and buckwheat, the share of seeds in the upper layers increased to 14–15%, and in the control and against the background of plowing with 25 t/ha of manure or mineral fertilizer $N_{125}P_{63}K_{150}$, it fluctuated within the range of 15.8–16.4%. Such dynamics of seed distribution in the surface (0–10 cm) layer indicates the appearance of possible weed seedlings in smaller quantities against the background of green fertilizers.

The closest inverse correlation was established between the phytomass of the post-harvest siderate and the potential clogging of the arable (0–30 cm) soil layer at the time of harvesting sugar beets after oil radish r = –0.9, and the lowest – when using buckwheat siderate – r = -0 ,77.

Between the phytomass of the post-harvest siderate of Phacelia and the potential clogging of the soil, the correlation was determined at the level of 0.87, which indicates a lower anti-weed efficiency than that of oil radish.

Table 4.18

**Potential soil clogging before harvesting sugar beets under different fertilization backgrounds, average for 2001–2005, million units ha$^{-1}$ (Mishchenko and Zakharchenko, 2019)**

| Variant | Шар грунту, см | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0–5 | | 5–10 | | 10–20 | | 20–30 | | 0–30 |
| | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | million units ha$^{-1}$ | % to total | In total, million units ha$^{-1}$ |
| Without siderate (control) | 18.3 | 16.3 | 17.7 | 15.8 | 38.1 | 33.9 | 38.2 | 34.0 | 112.3 |
| Post-harvest siderate of oilseed radish | 13.6 | 13.8 | 14.2 | 14.4 | 34.9 | 35.4 | 35.8 | 36.3 | 98.5 |
| Post-harvest siderate of Phacelia tansy | 14.5 | 14.3 | 14.9 | 14.7 | 35.7 | 35.1 | 36.6 | 36.0 | 101.7 |
| Post-harvest siderate of sowing buckwheat | 15.8 | 14.8 | 16.0 | 15.0 | 37.1 | 34.8 | 37.7 | 35.4 | 106.6 |
| 25 t ha$^{-1}$ manure | 22.8 | 16.2 | 22.2 | 15.8 | 47.6 | 33.8 | 48.1 | 34.2 | 140.7 |
| Mineral fertilizers $N_{125}P_{63}K_{150}$ | 18.5 | 16.4 | 17.8 | 15.8 | 38.0 | 33.8 | 38.2 | 34.0 | 112.5 |
| $LSD_{05}$ | 0.5 | | 0.7 | | 1.0 | | 1.2 | | 1.0 |

In the studies of Perchuk (2008), the cultivation of the green mass of oil radish by shelf cultivation contributed to the reduction of the number of weeds and their mass in the sowing of corn for grain by 40–60% (Table 4.19).

In continuation of the above, Babych et al.(2011) emphasizes that in order to increase the anti-weed and anti-nematode effectiveness of crop rotations, it is necessary to saturate them with cabbage crops as much as possible.

At the same time, it is recommended to increase the sowing rate by 20–25% to the recommended one. Their research established that the thickened crops of intermediate cabbage crops reduced the total weediness with small and perennial weeds, including creeping wheatgrass, by up to 60%. Two-time cultivation of oil radish reduced the number of growing weeds by 72–85% (Table 4.18). Based on the presented results, the authors concluded that the cultivation of cruciferous crops in intermediate crops should be considered not only as a factor in strengthening the forage base of farms, but also as a technique that has a positive effect on the phytosanitary situation in crop rotation. This is especially important for the mobilization of natural resources that determine the high productivity of agrophytocenosis.

Table 4.19

**The influence of sideration and main tillage on the weediness of corn crops, pcs. m$^{-2}$ (Perchuk, 2008)**

| Variant | Number of weeds, pcs. m$^{-2}$ | Efficiency, % | | Mass of weeds, kg m$^{-2}$ | Efficiency, % | |
|---|---|---|---|---|---|---|
| | | from processing | from siderates | | from processing | from the side-ration |
| Plow on 25–27 cm | | | | | | |
| Root and stubble remains of winter wheat (control) | 165 | 0 | -18 | 3,6 | 0 | -13 |
| Manure – 40 t ha$^{-1}$ | 201 | +22 | 0 | 4,1 | +15 | 0 |
| Oilseed radish | 82 | -50 | -59 | 1,6 | -54 | -61 |
| Oats + peas | 138 | -8 | -31 | 3,1 | -14 | -25 |
| Straw – 4 t ha$^{-1}$ | 178 | +8 | -11 | 3,4 | -6 | -18 |
| Chisel on 25–27 cm | | | | | | |
| Root and stubble remains of winter wheat (control) | 225 | 0 | -10 | 3,7 | 0 | -15 |
| Manure – 40 t ha$^{-1}$ | 250 | +11 | 0 | 4,4 | 0 | 0 |
| Oilseed radish | 98 | -43 | -61 | 2,1 | -44 | -52 |
| Oats + peas | 200 | -9 | -20 | 3,1 | -17 | -29 |
| Straw – 4 t ha$^{-1}$ | 236 | +5 | -6 | 3,3 | -11 | -24 |
| Flat-cut on 25–27 cm | | | | | | |
| Root and stubble remains of winter wheat (control) | 200 | 0 | -13 | 4,0 | 0 | -8 |
| Manure – 40 t ha$^{-1}$ | 230 | +15 | 0 | 4,3 | +8 | 0 |
| Oilseed radish | 90 | -45 | -61 | 2,6 | -35 | -40 |
| Oats + peas | 182 | -9 | -21 | 3,5 | -12 | -18 |
| Straw – 4 t ha$^{-1}$ | 195 | -1 | -15 | 3,5 | -11 | -18 |
| $LSD_{05}$ | 51 | | | 0,7 | | |

We came to the same conclusions in our research on the herboregulatory effectiveness of oil radish in the system of biological control of weediness (Table 4.20–4.21, Figures 4.13–4.15).

The presented data prove that oil radish as a precursor provides 1.6–1.7 times higher levels of phytosanitary purity of crops compared to the most recommended predecessors – soybeans and peas. This, in turn, emphasizes the importance of horseradish for herbicide-free weed control.

The analysis of the effectiveness of the use of cruciferous crops, including oil radish, in the control of the number of weeds was made in the studies of Lawley et al. (2012). Both winter annual and summer annual weed species were selected for the bioassay as the type and duration of forage radish weed suppression was unknown at the time. We hypothesized that decomposing forage radish residues would reduce the spring emergence of planted weed seeds relative to a no cover crop treatment if allelopathy was the dominant mechanism ofweed suppression. Weed and lettuce emergence was not suppressed by forage radish relative to the no cover crop control or the oat cover crop treatment regardless of weed type (summer vs. winter annual) or species (Figure 4.16). Weed emergence was higher in the forage radish treatment for several of the weeds species planted, including common chickweed, common lambsquarters, redroot pigweed, and common ragweed. Emergence of lettuce occurred much earlier (February) in forage radish treatments than the other two treatments (April) (Figure 4.16).

Stimulation of lettuce and weed seed emergence may have been due to higher soil nitrate levels in the forage radish treatment (Figure 4.16). Some weed species, such as common lambs-quarters, use nutrients as a signal to promote germination.

Table 4.20

**The influence of oil brassicacea crops on weediness by cereal weeds (on average over 5 years) (Babych et al., 2011)**

| Variant | Number of grass weeds before harvesting*, pieces $m^{-2}$ | | |
|---|---|---|---|
| | I | II | III |
| Control – winter wheat without sowing intermediate crops | 37.6 | 51.3 | 62.4 |
| Winter wheat + oilseed radish g/f | 38.1 | 21.8 | – |
| Winter wheat + spring rapeseed g/f | 38.4 | 23.9 | – |
| Winter wheat + mustard g/f | 36.9 | 27.8 | – |
| Oilseed radish + oilseed radish g/f | 23.7 | 14.3 | – |
| Winter wheat + oilseed radish g/f + oilseed radish g/fz | 37.2 | 20.6 | 12.7 |
| Winter rye + oilsed radish g/f + oilseed radish g/fz | 32.5 | 17.1 | 9.6 |

* I, II, III – harvesting of the main and intermediate crops, respectively;

g/f, g/fz – green fodder and green fertilizer.

Table 4.21

**Total littering of crops of winter wheat varieties depending on the predecessor (average for 2010–2012) (Tsytsiura, 2014)**

| Predecessor | Myronivska 67 | | Donetska 48 | |
|---|---|---|---|---|
| | g $m^{-2}$ | in total phytomass, % | g $m^{-2}$ | in total phytomass, % |
| Oilseed radish for green fodder (sowing rate of 3.0 million pieces $ha^{-1}$ of similar seeds, row sowing) | 51.4 ± 2.9 | 10.4 | 53.6 ± 3.2 | 9.6 |
| Oily radish for seeds (sowing rate of 1.5 million pcs. $ha^{-1}$ of similar seeds, inter-row sowing) | 62.3 ± 2.3 | 12.4 | 68.6 ± 3.3 | 11.3 |
| Corn for green fodder | 106.8 ±3.4 | 29.2 | 112.4 ± 2.7 | 31.3 |
| Soybean | 81.9 ± 2.7 | 13.2 | 79.4 ± 2.1 | 12.7 |
| Winter rape | 96.3 ± 1.8 | 25.1 | 94.2 ± 3.3 | 23.8 |
| Pea | 91.7 ± 3.6 | 17.2 | 89.3 ± 2.4 | 16.4 |
| $LSD_{05}$ | 3.2 | – | 3.7 | – |

**Figure 4.13 – Active inhibition of weed development in oil radish crops due to high growth rates and intensive development of the assimilation surface (the upper position – in the phase of the beginning of flowering, the lower position – during the period of active fruiting, when due to the reduction or complete attenuation of growth processes and intensive reduction of foliage, weeds intensify their growth) (Tsytsiura, 2015)**

**Figure 4.14 – Ecological niche (lower tier) of weeds in oil-stemmed radish of the Zhuravka variety at the sowing rate of 2.0 million pieces/ha of similar seeds (Tsytsiura, 2015)**

**Figure 4.15 – Single plants of oil radish on an intensively weeded area on the experimental field of VNAU, 2014 (the number of weeds is more than 450 plants/m2, due to the active growth rates, the plants compete effectively and continue to vegetate, entering the reproductive phase of development) (Tsytsiura, 2015)**

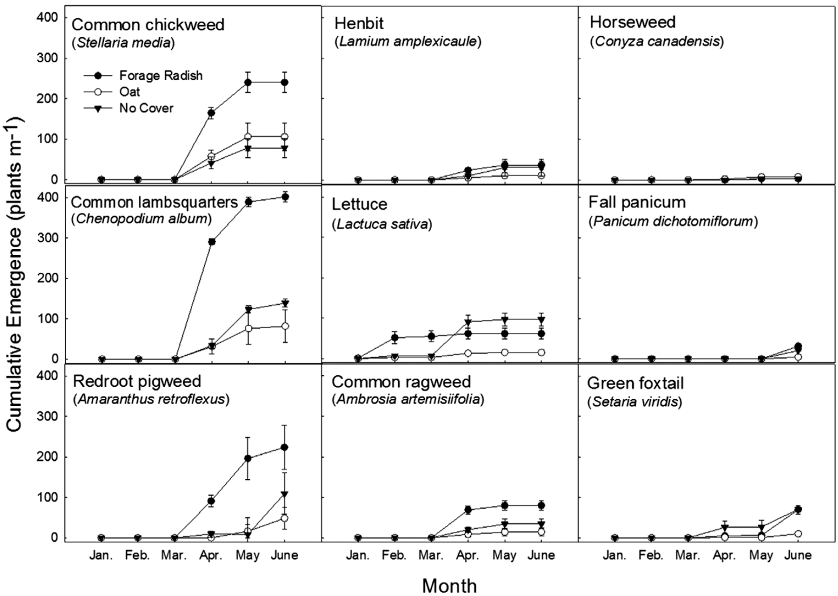



**Figure 4.16 – Mean cumulative weed emergence of planted weed seeds and lettuce seeds below decomposing forage radish cover crop, decomposing oat cover crop, and no cover crop control treatments in 2006 at the USDA Beltsville Agricultural Research Center North Farm. Data points are an average of four observations. Error bars represent standard error of the mean (Lawley et al., 2012)**

The results of these field bioassays agree with these earlier observations in 2 out of 3 site-years (Figure 4.17). The stimulatory effect of forage radish cover crops on winter annual weed species observed in this field bioassay contrast with the results of other field experiments (Lawley et al., 2011). In field experiments, Lawley et al. (2011) observed that forage radish cover crops delayed emergence of winter annual weeds relative to no cover crop. One of the differences between these field experiments and the field bioassay was the timing of weed seed introduction and germination. In the field bioassay, winter annual weeds in both forage radish and no cover control plots were forced to germinate in the spring, whereas many would naturally germinate and establish during the fall, as occurred in the no cover crop plots in the field experiments. The winter introduction date in the field bioassay also meant that planted weeds in the forage radish treatment were influenced only by residue decomposition and not by the fall cover crop growth as occurred in the field experiments. This further supports the hypothesis that forage radish weed suppression is the result of fall cover crop weed suppressiondue to rapid canopy development, rather than allelopathy.

Author hypothesized that if forage radish was allelopathic, lettuce or tomato germination and seedling growth under controlled environment conditions would be reduced in soils sampled below decomposing forage radish residues relative to a no cover crop control. We also hypothesized that the allelo-pathic effects of forage radish cover crops would be greater in soils collected during the time of most active radish decomposition in January than in soils collected during March. However, we reject both hypotheses based on assay results. In all but one case the significant differences between no cover crop and forage radish treatments indicated a stimulatory effect of forage radish, rather than an inhibitory effect, causing improved lettuce seedling biomass or tomato seed germination (Figure 4.17).

Tomato seed germination was greater in forage radish treatments relative to the no cover crop control in January and March for soils sampled at BARC-SF. Lettuce seedling DM was greater in forage radish treatments than in the no cover crop control in both January and February. These stimulatory effects of forage radish on lettuce and tomato agree with the findings of Exp. 2 and provide evidence to reject allelopathy as the mechanism of forage radish weed suppression. The stimulation of tomato seed germination and lettuce seedling DM in forage radish treatments could be due to the higher nitrate content of the soil sampled from the forage radish treatment (Figure 4.17).

One potential limitation of this experimental approach is higher temperature and moisture in the test chambers than in the field which could have caused loss of volatile allelochemicals, such as many ITCs. Petersen et al. (2001) conducted soil bioassays to evaluate the allelopathic effect of turnip-rape (B. rapa (Rapifera Group)-*B. napus* L.) mulch and identified ITCs present in both the plant tissue and soil. The ITC concentration in their study was 2300 times lower in the soil than in plant tissues and their disappearance from the soil was enhanced by saturated soil conditions and high temperatures. Sampling of soil for the bioassay also resulted in the separation of soil and plant residues, the potential source for a continued supply of newly forming ITCs as these residues decomposed. However, if allelopathy was responsible for the strong weed suppression observed in the field, we would have expected to observe some suppressive activity in these soils, despite the potential attenuating conditions of this assay.

Author hypothesized that if allelopathy was the mechanism of forage radish weed suppression, then aqueous extracts of forage radish tissues would inhibit lettuce seed germination and root growth. Extracts of both forage radish shoot and root tissues were included in the experiment to differentiate the location of potential allelopathic compounds. The allelopathic potential of living forage radish plant tissues was compared to plant residues by preparing aqueous extracts of plant residues harvested in November before frost damage and decomposing plant residues harvested the following March. Oat was included as a treatment because it is another frost sensitive cover crop that is also reported to have allelopathic properties.

Aqueous extracts of living forage radish tissues harvested before frost in November had an inhibitory effect on lettuce germination and root length relative to a distilled water control treatment (Figure). Aqueous extracts of forage radish residues harvested in March had a stimulatory effect on relative lettuce root length and an inhibitory effect on relative lettuce germination only at the highest extract concentration. Plant tissue extracts had little effect on the relative shoot length of lettuce in both November and March (data not shown).

Despite differences in color and odor of the two extracts (forage radish root extracts had a very pungent odor and dark color), both shoot and root tissues of forage radish had similar effects on relative lettuce germination and relative root growth (Figure 4.18). Thus, no differential response was observed between forage radish roots and shoots. Aqueous extracts of living oat tissue harvested in November had similar effects on lettuce germination and root growth to those observed with forage radish shoot extracts (Figure 4.19). Extracts of oat residues harvested in March had no effect on relative lettuce germination. Extracts of oat residue harvested in March had the same stimulatory effect on lettuce roots length that was observed with forage radish residues.

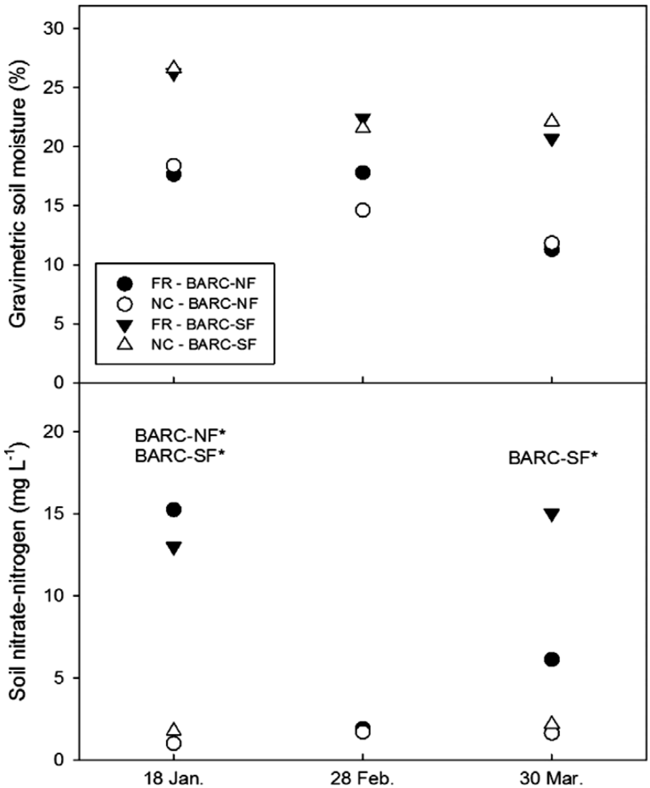



**Figure 4.17 – Initial gravimetric soil moisture and soil nitrate-nitrogen content of soils sampled from forage radish (FR) and no cover crop (NC) treatments at the USDA Beltsville Agricultural Research Center North Farm (BARC-NF) and South Farm (BARC-SF). Data points are an average of four observations. Significant differences between pairs of FR and NC treatments within a site are indicated by BARC-NF* or BARC-SF* (*P < 0.05*). No samples were available from the BARC-SF to measure soil nitrate-N for the 28 February sampling date (Lawley et al., 2012)**

Relative lettuce seed germination and relative root length increased with the dilution of the full strength plant tissue extracts for all tissues sampled in November 2005 (Figure ). The largest decline in relative germination occurred in forage radish root and shoot tissue extracts in proportions at or above 0.5 of the full strength extract. For extracts prepared from plant residues collected in March, lettuce germination declined only in full strength extracts prepared from forage radish root and shoot tissues. Extracts prepared from plant residue in March had a stimulatory effect on the relative root length of lettuce seedlings at extract proportions of 0.125 and 0.25 (Figure 4.20–4.21).

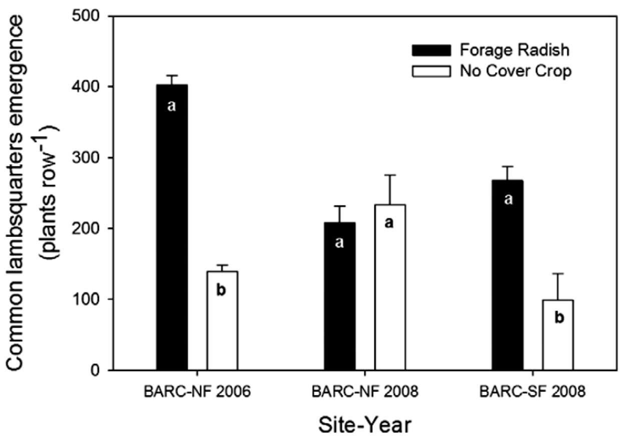



**Figure 4.18 – Mean emergence of common lambsquarters below decomposing forage radish residues and a no cover crop control for 3 site-years at the USDA Beltsville Agricultural Research Center North Farm (BARC-NF) and South Farm (BARC-SF). Bars represent an average of four observations. Bars topped with different letters indicate significant treatment differences at the p = 0.05 level within a site-year. Error bars represent stand error of the mean (Lawley et al., 2012)**

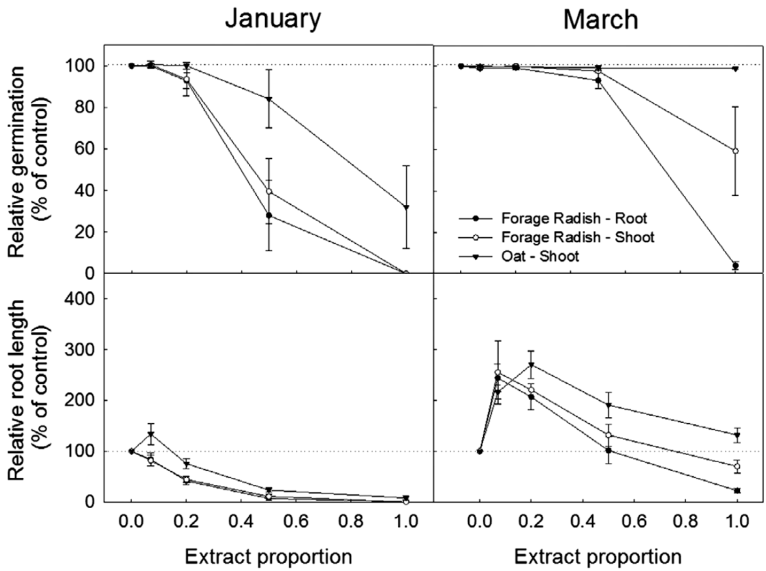



**Figure 4.19 – Relative germination and root length of lettuce seedlings grown in aqueous plant tissue extracts. Germination and root lengths are expressed as a percent of the distilled water control. Extracts were prepared from fresh forage radish shoot, forage radish root, and oat shoot tissues collected on 7 Nov. 2005, and from plant residues collected on 24 Mar. 2006. Data points are an average of four observations. Error bars represent standard error of the mean**

Although these results might suggest allelopathic potential, it is likely that the negative effects of full-strength forage radish and oat extracts on lettuce germination and root growth were due to the osmotic potential of the extract solutions. Regardless of whether the extract was prepared from plant tissue vs. residues or prepared from oat vs. forage radish, there was a general trend of decreasing lettuce seed germination and root length with increasing electrical conductivity, with a threshold between 2 and 4 dS $m^{-1}$ (Figure 4.22). Both types of forage radish tissue extracts also had high electrical conductivity. The root tissue extract had a higher electrical conductivity and more inhibitory effect on lettuce seedlings than the shoot tissue extract.

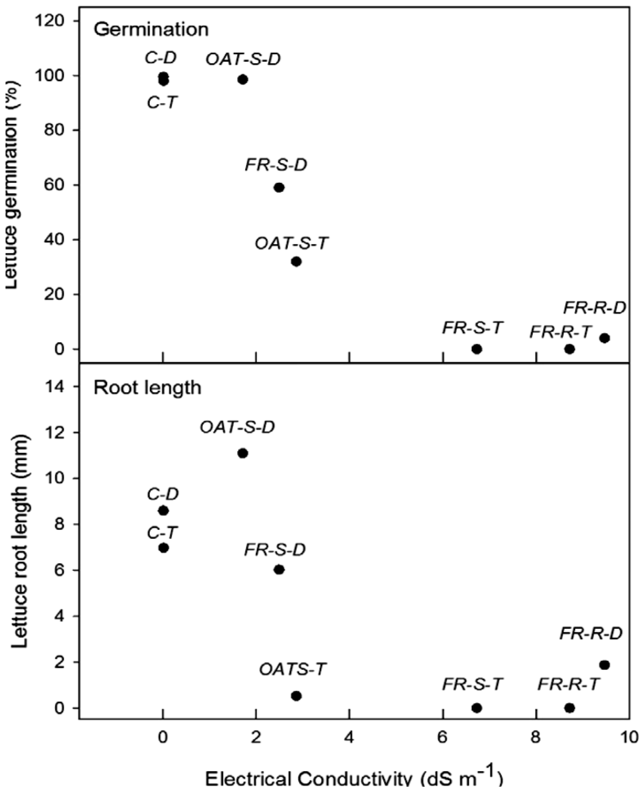



**Figure 4.20 – Relationship between lettuce performance and electrical conductivity of aqueous plant tissue extracts and a distilled water control. Extracts were prepared from forage radish root (FR-R), forage radish shoot (FR-S), and oat shoot (OAT-S) and were compared to a distilled water control (C). Plant tissues (T) were harvested November 2005 and residues (D) harvested 24 Mar. 2006. Lettuce root length and germination are averages of four observations. Electrical conductivity was measured on one extract (Lawley et al., 2012)**

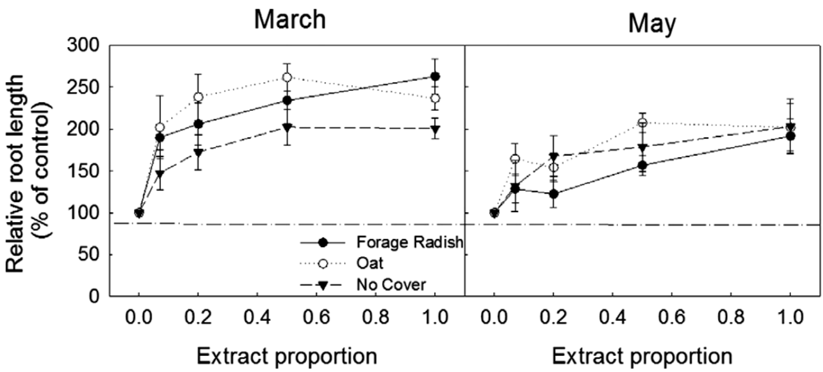



**Figure 4.21 – Relative root length of lettuce seedlings grown in aqueous soil extracts. Root lengths are expressed as a percent of the distilled water control. Soil extracts were prepared from surface soil samples (0-5 cm) collected from forage radish, oat, and no cover crop field treatments on 28 Mar. and 30 May 2006. Data points are an average of four observations. Error bars represent stand error of the mean (Lawley et al., 2012)**

Soil extracts were included in this experiment to test for potential retention of allelochemicals in the soil that could have a residual effect on weed seed germination and seedling growth. Because weeds naturally encounter allelochemicals within the soil environment, it was thought that soil extracts would provide a more realistic bioassay treatment than those prepared from plant tissues. We hypothesized that soil sampled beneath decomposing forage radish residues would decrease lettuce seed germination as well as root and shoot growth. We also hypothesized that these effects would be greater in March, when weed suppression was previously observed in the field by Lawley et al. (2011), than in May, when no weed suppression was observed.

Contrary to our hypotheses, the extracts prepared from cover crop-amended soil did not reduce lettuce seed germination or root growth. However, both cover crop treatment extracts as well as the no cover crop control extract had a stimulatory effect on lettuce root length relative to the distilled water control in March and May (Figure 4.22). Unlike extracts prepared from plant tissues, relative root length of lettuce seedlings increased with increasing soil extract proportion. The soil extracts had very low electrical conductivity (EC) (<0.1 dS $m^{-1}$). Soil extracts did not have an effect on relative shoot length or lettuce seed germination (data not shown). These results suggest that there were no or very low concentrations of allelochemicals present in the soil extracts and that noncover crop factors were the cause of lettuce stimulation, such as nutrients released by organic matter decomposition or from the soil cation exchange.

Results from the bioassay of plant tissue extracts can be explained by high EC levels, and thus only weakly suggest any potential for allelopathy. Certainly the results of the soil extract bioassay suggest that any inhibitory affect, whether due to allelopathy or osmotic potential, were not realized in the soil. Thus, aqueous extract bioassays did not present strong evidence in support of the allelopathy hypothesis for the occurrence of weed suppression following forage radish winter cover crop.

The author of the study draws the following conclusions: By employing multiple experimental approaches, the results of the four experiments in this study point to a common conclusion that early and competitive fall growth of forage radish is the dominant mechanism for weed suppression. Results of the forage radish residue-transfer experiment supported the hypothesis that fall cover crop weed competition due to rapid canopy development is the mechanisms of weed suppression following forage radish cover crops. The presence or absence of decomposing residue after winter-kill had relatively little effect on weed suppression. Field and controlled environment bioassays using cover crop-amended soil and aqueous extracts of cover crop tissues and amended soil did not reveal any allelopathic activity limiting seed germination or seedling establishment. In fact, forage radish-amended soils stimulated seedling growth in both types of bioassays.

Cover crop management strategies to maximize weed suppression following forage radish cover crops should ensure that crop rotations allow for early planting of forage radish cover crops. If factors such as late planting, drought, low soil fertility, or early frost limit the rapid canopy development of forage radish in the late summer or early fall, alternative pre-plant weed control is likely to be required the following spring. The results of this study along with the findings presented in Lawley et al. (2011) demonstrate that a competitive fall forage radish cover crop stand can achieved a relatively weed-free and residue-free seedbed in early spring to facilitate early crop planting operations. The seed bed following forage radish cover crops may be of special interest to organic farmers looking to eliminate or reduce spring tillage for direct seeding of subsequent vegetable or grain crops.

The use of oilseed radish to reduce weed infestation of potato agrocenoses proved to be effective (Mishchenko et al.m, 2019). The rate of early spring weeds increased and the winter annual weeds significantly decreased after green manure intercorporation-spring early weeds by number and weight (respectively, by 15 and 22%) and decreased wintering and perennial (11.5 and 22.0 and 2.0 and 2.3% respectively) (Figure 4.22). Compared with the control, under the cover of oil radish, the number of early weeds decreased by 4.2 plants $m^2$, and by weight-wintering-by 40 $gm^{-2}$, and the smallest number and weight of perennial weeds, respectively 2.4 plants $m^{-2}$ and 13.4 $gm^{-2}$.

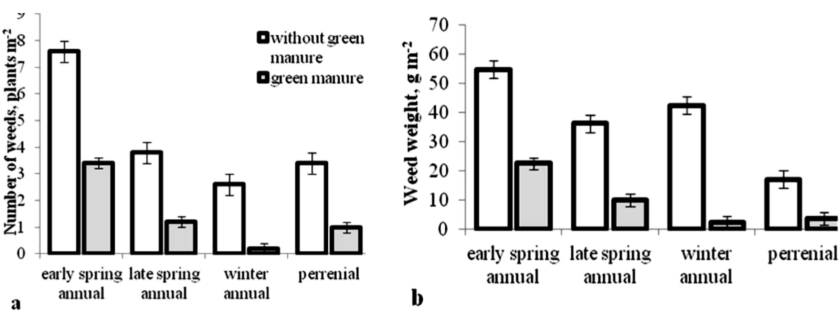



**Figure 4.22 – Amount and weight of weeds before the primary soil tillage (x ± SE, n=10). *difference between variant without the incorporation of green manure iand with is statistically reliable P<0.05 (Mishchenko et al.m, 2019)**

At the time of the growth recovery of weeds in the soil layer 0–30 cm deep after ploughing, we observed a proportional distribution of weed seeds within 30–40 % (Table 4.22). It has to say that potential infestation is the number of viable seeds in the soil and actual weed infestation is the number of weeds or their weight per unit area.

Table 4.22

**Potential weed infestation of soil after green manure incorporation and tillage (April 2006–2010), mln pcs.ha$^{-1}$ (Mishchenko et al.m, 2019)**

| Treatment | | Soil layer, cm | | | | Total |
|---|---|---|---|---|---|---|
| Green manure | Tillage system | 0–5 | 5–10 | 10–15 | 20–30 | 0–30 |
| without green manure | control (moldboard ploughing 28–30 cm) | 20.8 ± 0.41 | 19.4 ± 0.28 | 36.7 ± 0.44 | 30.7 ± 0.24 | 107.6 |
| | sweep ploughing 28–30 cm | 24.5 ± 0.64* | 35.1 ± 0.40* | 25.7 ± 0.52* | 21.9 ± 0.29* | 107.2 |
| | disking 13–15 cm | 25.5 ± 0.33* | 36.2 ± 0.36* | 24.0 ± 0.34* | 21.6 ± 0.18* | 107.3 |
| | disking 6–8 cm | 28.1± 0.42* | 35.0± 0.31* | 22.6± 0.47* | 21.5± 0.45* | 107.2 |
| green manure-incorporation | control (moldboard ploughing 28–30 cm) | 19.9 ± 0.25 | 18.8 ± 0.22 | 36.0 ± 0.40 | 30.1 ± 0.38 | 104.8 |
| | sweep ploughing 28–30 cm | 23.5± 0.40* | 33.5± 0.26* | 25.4± 0.33* | 21.7± 0.46* | 104.1 |
| | discing 13–15 cm | 24.5± 0.32* | 35.3± 0.21* | 23.1± 0.75* | 21.4± 0.32* | 104.3 |
| | discing 6–8 cm | 26.8± 0.24* | 33.4± 0.30* | 22.4± 0.62* | 21.2± 0.14* | 103.8 |

*difference between variant without green manure and with is statistically reliable $p<0.05$

Oilseed radish green manure application on all types of soil tillage reduced the potential weed infestationat a depth of 20 cm to 0.2–1.6 mln. pcs.ha$^{-1}$. In the soil layer 20–30 cm deep, the potential weed infestation decreased by 0,6 million plants ha$^{-1}$ only when using the method of green manure incorporation and conventional ploughing. Weed infestation was reduced by 2.8–3.4 mln.pcs.ha$^{-1}$ in the soil layer 0-30 cm deep because of the use of green manure.

The actual weed infestation during the potato growing period determined the potential weed infestation in the upper layers of the soil. The smallest amount of weed seeds in the upper layer was set in the plots with green manure, and the smallest amount and weight of weeds in the field was observed – 10.6–20.8 plants m$^{-2}$ and 132.4–728.0 gm$^{-2}$ (Figure 4.23).

Based on data from the weed infestation, the result most similar to moldboard ploughing of 28–30 cm deep was sweep ploughing. The difference between these two methods in weed weight at the time of the seedlings emergence (1.3 gm$^2$) was not significant under the green manure application. During the potato growing period using discing at a depth of 13–15 cm, the amount and the weight of weeds, compared with mouldboard ploughing and sweep ploughing methods on both nutrients backgrounds, substantially increased by 5.0–20.8 plants m$^{-2}$ and 33.0–346.8 gm$^{-2}$, respectively. The largest actual weed infestation was seen when discing at 6-8 cm; in comparison with other variants, the amount and weight of weeds increased significantly to 23.8–77.8 plants m$^{-2}$ and 209.9–1089.8 gm$^{-2}$.

The smallest quantity of weeds were observed at the time of the potato harvest-10.6–36.2 plants m$^{-2}$, because it was the end of growing period. The smallest amount of weeds was observed at the sprouting of the potato seedlings – 132.4–209.9 gm$^{-2}$.

This could be explain by the short vegetation period, which was interrupted by mechanical soil loosening. The deeper the tillage, the smaller was the infestation of weeds in the potato crops. This was confirmed by the inverse correlation dependence of the average force between the depth of ploughing and the amount and weight of weeds r=-0.68–0.66.

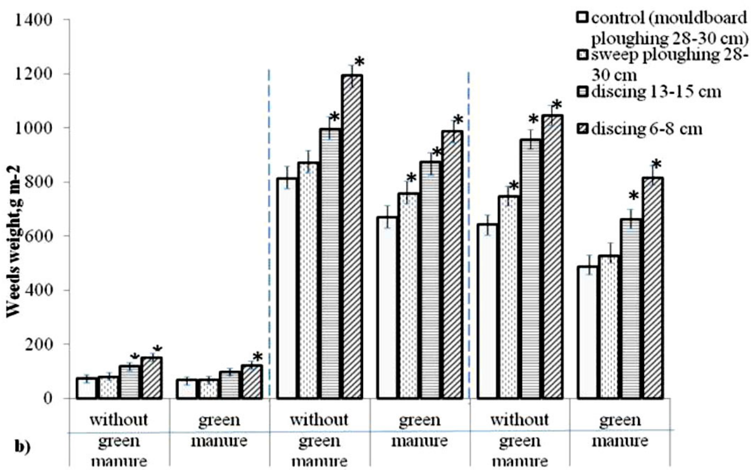



**Figure 4.23 – Impact of green manure and soil tillage on the dynamics of amounts and weight of weeds in potato crops (Mishchenko et al.m, 2019)**

Reducing the amount and weight of weeds during the potato's growing season had the largest effect on methods that involve an application of green manure in addition to the use of mouldboard ploughing and sweep ploughing at the same depth of 28–30 cm. The inverse correlation between application of green manure phytomass and the amount and weight of weeds in the potato crops was within r=-0.76 and -0.75, -0.59 and -0.55, respectively. Discing at the depths 13–15 cm and 6-8 cm was less effective in reducing the amount and weight of weeds; the proportion of the effect of phytomass green manure was 54–48 and 17–12%. The use of oil radish as incorporated green manure significantly decreased the number of biological groups of weeds and their mass during the potato growing period (Table 4.23).

The use of green manure cover crop effectively reduced the amount and weight of early and late spring weeds during the cultivation of potatoes – by 5.0–5.8 plants $m^{-2}$ and 51.3–96.9 g $m^{-2}$, respectively, and the difference with the method without green manureby wintering weeds was the smallest – 0.9–1.5 plants m – 2 and 8.3–23.6 $gm^{-2}$.

Replacing conventional ploughing with sweep ploughing and disk ploughing led to an increase in the weed infestation in the potato crop, primarily in the early spring group – 3.8–12.4 plants $m^{-2}$ and 57.9–184.1 $gm^{-2}$ respectively. There was an insignificant change in the amount and weight of the late spring and perennial weeds when usings weep ploughing at a depth of 28–30 cm. Discing at 13–15 cm caused an insignificant increase in the amount of perennial weeds, compared with mouldboard ploughing. The amount and weight of all biological groups of weeds significantly increased in both nutrients backgrounds under discing at 6–8 cm.

The application of oilseed radish as green manure contributed to a significant reduction in the amount of weed seeds in the root soil layer at a depth of 0–30 cm to 3.3–4.0 million plants $ha^{-1}$during the potato growing period; the reduction in potential weed infestation is not significant; only in the 20–30 cm deepsoil layerunder sweep and discing (Table 4.24).

Table 4.23

**Distribution of biological groups of weed in agrocenosis Solanum tuberosum (x ± SE, n=15) (Mishchenko et al.m, 2019)**

| Treatment Green manure incorporation | Tillage system | Biological group of weeds | | | |
|---|---|---|---|---|---|
| | | Early spring | Late spring | Wintering | Pirennial |
| | | Amount of weeds, plant $m^2$ | | | |
| Without green manure | control (mouldboard ploughing 28–30 cm) | 13.7 ± 0.92 | 15.9 ± 0.44 | 2.6+ 0.24 | 2.2+ 0.22 |
| | sweep ploughing 28–30 cm | 18.3 ± 1.02* | 16.2 ± 1.22 | 3.0 ± 0.12* | 2.1 ± 0.16 |
| | discing 13–15 cm | 22.8 ± 0.88* | 18.3 ± 0.90* | 4.0 ± 0.12* | 2.6 ± 0.44 |
| | discing 6–8 cm | 26.1 ± 0.89* | 19.9 ± 1.06* | 5.1± 0.52* | 3.5 ± 0.47* |
| Green manure of oilseed radish | control (mouldboard ploughing 28–30 cm) | 8.7 ± 1.08 | 7.9 ± 0.76 | 1.73± 0.21 | 1.7 ± 0.25 |
| | sweep ploughing 28–30 cm | 12.5 ± 0.58* | 7.1 ± 0.82 | 1.5 ± 0.36 | 1.3 ± 0.24 |
| | discing 13–15 cm | 17.5 ± 0.92* | 9.4 ± 0.94* | 2.6 ± 0.28* | 1.9 ± 0.32 |
| | discing 6–8 cm | 20.5 ± 1.11* | 12.3 ± 1.06* | 3.3 ± 0.22* | 2.7 ± 0.34* |
| | | Weight of weeds, g $m^2$ | | | |
| Without green manure | control (mouldboard ploughing 28–30 cm) | 196.0 ± 9.6 | 298.2 ± 10.2 | 25.5 ± 2.5 | 47.9 ± 1.2 |
| | sweep ploughing 28–30 cm | 253.9 ± 8.4* | 302.1 ± 11.6 | 34.4 ± 1.8* | 48.4 ± 1.5 |
| | discing 13–15 cm | 328.4 ± 10.6* | 350.7 ± 6.3* | 45.1 ± 1.4* | 65.3 ± 2.0* |
| | discing 6–8 cm | 380.1 ± 8.6* | 373.1 ± 6.5* | 53.2 ± 2.1* | 77.9 ± 3.2* |
| Green manure of oilseed radish | control (mouldboard ploughing 28–30 cm) | 133.3 ± 9.0 | 237.1 ± 9.2 | 17.2 ± 2.0 | 21.7 ± 1.0 |
| | sweep ploughing 28–30 cm | 202.6 ± 8.4* | 248.72 ± 8.5* | 14.4 ± 3.4 | 21.5 ± 2.5 |
| | discing 13–15 cm | 247.4 ± 8.6* | 265.3 ± 9.8* | 24.6± 3.1* | 32.4 ± 0.7* |
| | discing 6–8 cm | 283.2 ± 9.3* | 280.9 ± 10.2* | 29.6± 3.8* | 45.5 ± 2.2* |

*significant at $p<0.05$

Table 4.24

**Potential weed propagation on harvest potato time, million pcs ha$^{-1}$ (x ± SE, n=10) (Mishchenko et al.m, 2019)**

| Treatment | | Soil layer, < cm | | | | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Green manure incorporation** | **Tillage system** | **0-5** | | **5-10** | | **10-15** | | **20-30** | | |
| Without green manure | control (mouldboard ploughing 28–30 cm) | 19.9 | ± | 18.2 | ± | 36.0 | ± | 30.3 | ± | 104.4 |
| | | 1.01 | | 1.04 | | 0.56 | | 0.65 | | |
| | sweep ploughing 28–30 cm | 23.5 | ± | 33.8 | ± | 25.0 | ± | 21.6 | ± | 103.9 |
| | | 0.98 | | 1.81* | | 0.36* | | 0.52 | | |
| | discing 13–15 cm | 24.4 | ± | 34.8 | ± | 23.4 | ± | 21.4 | ± | 104 |
| | | 0.90 | | 0.96* | | 0.45* | | 0.50 | | |
| | discing 6–8 cm | 26.9 | ± | 33.6 | ± | 22.1 | ± | 21.2 | ± | 103.8 |
| | | 1.0* | | 2.00* | | 0.86* | | 0.8* | | |
| Green manure ofoilseed radish | control (mouldboard ploughing 28–30 cm) | 18.7 | ± | 17.7 | ± | 35.1 | ± | 29.6 | ± | 101.1 |
| | | 0.97 | | 1.52 | | 0.74 | | 0.38 | | |
| | sweep ploughing 28–30 cm | 22.3 | ± | 32.5 | ± | 24.1 | ± | 21.3 | ± | 100.2 |
| | | 0.82 | | 1.22* | | 0.44* | | 0.44 | | |
| | discing 13–15 cm | 23.1 | ± | 34.0 | ± | 22.1 | ± | 21.1 | ± | 100.3 |
| | | 0.74 | | 1.20* | | 0.26* | | 0.81 | | |
| | discing 6–8 cm | 25.3 | ± | 32.0 | ± | 21.6 | ± | 20.9 | ± | 99.8 |
| | | 1.01 | | 1.35* | | 0.33* | | 0.74 | | |

significant at $p<0.05$

Between the phytomass of radish oilseed and the amount of weed seeds from all methods of soil tillage a close-to-value strong inverse correlation dependencies was found-r=-0.76–0.7 with probability 70–76 %.

Tillage without soil overturning also contributes to reducing the total amount of weed seeds in the soil layer 0–30 cm deep. But the difference in the potential weed infestation compared with mouldboard ploughing was significant by discing 6-8 cm, conducted in conjunction with the application of oilseed radish green manure and was 1.3 million plants per hectare. As the soil layers 0–30 cm are not intensively mixed when using sweep ploughing and discing, a significantly smaller amount of weed seeds were observed compared with the mouldboard ploughing technique in soil layers 10–20 cm deep – by 11.0–13.9 million psc. ha$^{-1}$ and 20–30 cm – at 8.3–9.1 million psc. ha$^{-1}$ for both backgrounds. Using ploughless tillage contributes to a concentration of substantially larger amounts of weed seeds in the upper layers – 0-5 and 5–10 cm deep to 3.6–7.0 and 14.316.6 million psc.ha$^{-1}$, respectively.

A close inverse correlation was determined between the increase of the depth of tillageand the amount and weed seeds in the soil layer 0–10 cm deep (r=-0.71), and the straight line correlation was set in the lower layers 10–20 and 20–30 cm deep (r=0.96, and 0.64).

Tillage impact on the actual weed infestation of potatoes crop was in range 34-46% and has to be said the influence of different methods of tillage on the amount of weeds was larger than on its weight (Figure 4.24).

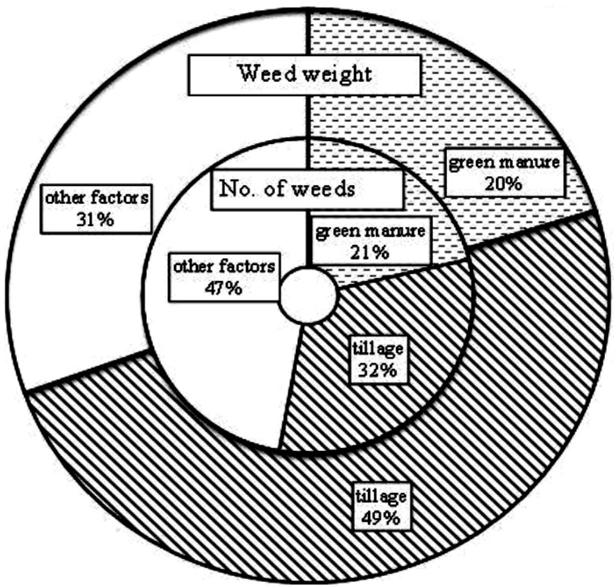



**Figure 4.24 – Impact fraction of green manure and method of tillage on weed infestation in potato crops (Mishchenko et al.m, 2019)**

Green manure made from oilseed radish plants also had a higher impact on the number of weeds-39% than its weight – 29%. The primary tillage technique had the largest impact on the potential weed infestation in the layer 10–20 cm deep (66.4%), and the least – 0–10 cm deep (46.1%). But method of application of green manure from oilseed radish had a larger impact on the potential weed infestation of the entire soil root layer 0–30 cm deep than the different methods of tillage. The green manure incorporation had a larger effect on the number of weed seeds in the upper soil layer- 0.81% more than in the deep layers – 0.43 and 0.2% (Figure 4.25).

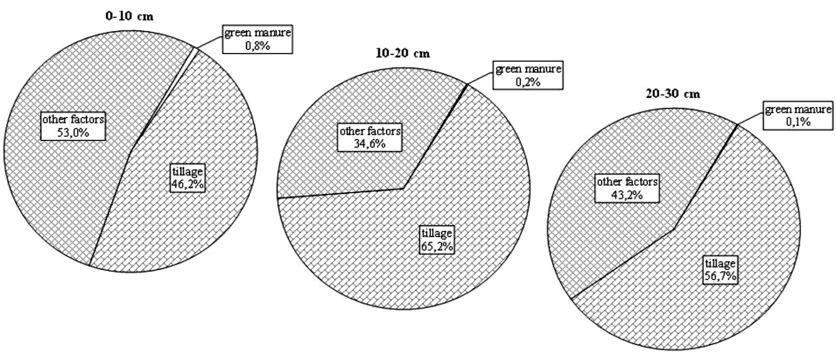



**Figure 4.25 – Impact fraction of tillage and oilseed radish incorporating on the potential weed infestation in the soil layers 0-30 cm (average for 2006-2010). (Mishchenko et al.m, 2019)**

The growth of the smallest amount of weeds produced the highest yields of 30.3 t ha$^{-1}$ using the green manure application method and ploughless tillage method 28–30 cm deep (Figure 4.26).

Reducing the depth of plougless tillage and the non-application of green manure significantly reduced the yield of potato tubers-by 1.8–5.1 tha$^{-1}$, and 3.9–6.2 t ha$^{-1}$, respectively.

Based on the of herbological monitoring of potato crops, the most effective method of weed control is using green manure made from oilseed radish incorporation in addition to sweep ploughing at a depth of 28–30 cm. Using these methods, potential weed infestation in the soil layer 0–30 cm deep has been reduced overall, and the smallest amount of weed seeds was observed in the soil layer 0–10 cm deep, compared with other ploughless treatments. Quantitatively-weighed weed infestation under sweep ploughing was similar to the mouldboard ploughing method. The highest potato tuber yield 30.3 t ha$^{-1}$ was obtained under the incorporation of oilseed radish green manure and using of sweep ploughing at 28–30 cm deep.

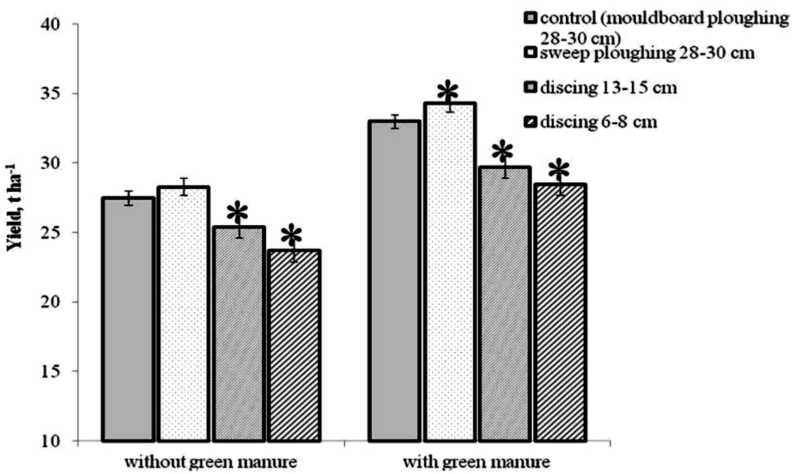



**Figure 4.26 – Influence of green manure incorporation and methods of tillage on potatoes yield, t ha$^{-1}$ (average for 2006-2010). *-significant at p<0.05 (Mishchenko et al.m, 2019)**

Similar results were obtained in the study by Sturm et al. (2017). For the two treatments, where oilseed radish was sown before the winter wheat harvest (3 WBH and 5 WBH), oilseed radish cv. Farmer was sown in the pre-existing winter wheat crop with 25 kg ha$^{-1}$ of coated seeds (149 seeds m$^{-2}$) (Feldsaaten Freudenberger, Krefeld, Germany) with a pneumatic fertilizer spreader (Aero, Rauch Landmaschinen GmbH, Sinzheim, Germany). The oilseed radish coat consisted of different layers containing humic acid, lime, plant strengthening agents and protection layers. Coated oilseed radish seeds were developed to allow an optimum cover crop emergence and growth. The increased seed weight compared to conventional seeds allows an increased flight distance and more homogeneous sowing, while sowing with a pneumatic fertilizer. The included humic acids, plant strengthening agents (Biplantol®), lime for the pH regulation and the increased water storage can improve the oilseed radish germination and development. For treatments sown at harvest (H), one (1 WAH) and three (3 WAH) weeks after harvest, a flat stubble cultivation (4 cm) (Dyna Drive, Bomford, Worcestershire, UK) was performed prior to sowing. Then un-coated oilseed radish cv. Farmer was sown in 2 cm depth with 25 kg seeds $ha^{-1}$ (198 seeds $m^{-2}$) with a pneumatic sowing machine (D82, Agrarmarkt Deppe GmbH, Bad Lauterberg, Germany). Calcium-ammonium-nitrate (27% N, 2% S) fertilizer was applied in half of the plots (Aero, Rauch Landmaschinen GmbH, Sinzheim, Germany) at cover crop sowing dates with 45 kg N $ha^{-1}$ ($N_{45}$). Two controls with no cover crop sowing (NCC) and fertilization ($N_0$) were included. Predominant weed species were *Alopecurus myosuroides* Huds. (11% and 16%), *Veronica pérsica* Poir. (14% and 18%), *Matricaria chamomilla* L. (8% and 10%), *Lamium purpureum* L. (24% and 2%), *Galium aparine* L. (10% and 5%) and *Volunteer wheat* (31% and 46%) in the untreated controls in 2015 and 2016, respectively. Cover crop and weed biomass were measured by harvesting two 0.25 $m^2$ quadrats within each plot at 7 WAH and 12 WAH. Collected biomass was washed and dried in a drying chamber at 80°C for 48 h. The reductions of weed density, cover crop and weed dry biomass were calculated, relative to the untreated control.

Table 4.25

**Different oilseed radish treatments and sowing dates of the field experiments in two experimental years (Sturm et al., 2017)**

| Treatment | Sowing date | 2015 | 2016 |
|---|---|---|---|
| No cover crop (NCC) | no cover crop | - | - |
| 5 WBH (weeks before harvest) | five weeks before winter wheat harvest | June 29th | July 6th |
| 3 WBH | three weeks before winter wheat harvest | July 13th | July 20th |
| Harvest (H) | at winter wheat harvest | August 3rd | August 10th |
| 1 WAH (weeks after harvest) | one week after winter wheat harvest | August 11th | August 17th |
| 3 WAH | three weeks after winter wheat harvest | August 24th | August 31th |

In 2015, oilseed radish biomass ranged from 5.6 to 4083.2 kg ha$^{-1}$ measured at 7 WAH and 12 WAH (Table 4.25). The highest crop biomass was achieved in treatment 1 WAH at 7 WAH (100 kg ha$^{-1}$) and 12 WAH (3069 kg ha$^{-1}$), respectively. The highest weed biomass was measured in treatment NCC (73 kg/ha) and treatments 5 WBH (81 kg ha$^{-1}$) and 3 WBH (163 kg ha$^{-1}$) at 7 WAH and 12 WAH. The highest weed control efficacy was achieved by treatment 1 WAH with 89% and 80% at 7 WAH and 12 WAH across both fertilization levels ($N_0$ and $N_{45}$), respectively.

Reversed oilseed radish biomass was measured among all sowing treatments in 2015 compared to 2016. In 2015, the highest biomass was measured in treatment 1 WAH compared to 5 WBH and 3 WBH in 2016. This could be contributed to insufficient precipitation, which resulted in unfavourable field conditions for cover crop germination and growth at the early beginning (Table 4.26). The lower precipitation (-55%) with higher mean temperature (+11%) in 2015 during the vegetation period of treatments 5 WBH and 3 WBH led to lower oilseed radish germination, which resulted in a reduced biomass production in 2015 compared to 2016. Especially in 2016, the treatments 5 WBH and 3 WBH provided high weed suppression, due to the early sowing and fast oilseed radish development under favorable field conditions. Moreover, the similar oilseed radish biomass in treatments 5 WBH (2238 kg ha$^{-1}$) and H (2081 kg ha$^{-1}$) showed different weed control efficacies at 12 WAH, which can be attributed to an earlier light interception due to a faster soil coverage and weed shading. After wheat harvest, the stubble area was already covered with the cover crop. This growth advantage compared to weeds led to higher weed suppression, especially in the pre-harvest treatments (5 WBH and 3 WBH) in 2016. It was found a linear relationship between weed and cover crop biomass in 2015 (Table 4.27). In the following year, no significant correlation was calculated at 7 WAH and 12 WAH without fertilization.

Further, it was observed a linear relationship between weed biomass and density in 2016 ($R^2$ = 0.4406, $P < 0.05$), however this relationship was much weaker and not significant in 2015 ($R^2$ = 0.252). It is assumed that the competition of the weeds with the cover crop biomass played a major role in weed biomass suppression in 2015. In 2016, weed emergence, which illustrates weed density, was highly suppressed by the cover crop and consequently reduced the weed biomass. Beside competitive effects of oilseed radish on the overall weed suppression, the family of Brassicaceae is well documented for the active and passive release of allelochemicals, as isothiocyanates, in the environment.

Table 4.27

**Dry biomass of oilseed radish and weeds without (N0) and with (N45) fertilization 7 and 12 weeks after harvest (WAH) across all treatments in 2015 and 2016 (Sturm et al., 2017)**

| Year | Date | Treatment | Oilseed radish biomass (kg/ha) | | Weed biomass | (kg/ha) |
|---|---|---|---|---|---|---|
| | | | $N_0$ | $N_{45}$ | $N_0$ | $N_{45}$ |
| 2015 | 7 WAH | NCC | $0^{bA}$ | $0^{bA}$ | $82^{abA}$ | $62^{abA}$ |
| | | 5 WBH | $6^{bA}$ | $10^{bA}$ | $85^{aA}$ | $82^{aA}$ |
| | | 3 WBH<br>H | $18^{bA}$<br>$56^{abA}$ | $20^{bA}$<br>$35^{abA}$ | $76^{abA}$<br>$28^{bcA}$ | $68^{abA}$ $44^{abA}$ |
| | | 1 WAH | $100^{aA}$ | $128^{aA}$ | $10^{cA}$ | $6^{bA}$ |
| | | 3 WAH | $29^{abA}$ | $24^{bA}$ | $34^{abcA}$ | $42^{abA}$ |
| | 12 WAH | NCC | $0^{cA}$ | $0^{bA}$ | $78^{abA}$ | $70^{abcA}$ |
| | | 5 WBH | $439^{bA}$ | $436^{bA}$ | $83^{abA}$ | $74^{abA}$ |
| | | 3 WBH<br>H | $1501^{abA}$<br>$1563^{abA}$ | $637^{bA}$ $1412^{abA}$ | $88^{aA}$<br>$29^{bcA}$ | $94^{aA}$ $63^{abcA}$ |
| | | 1 WAH | $3069^{aA}$ | $4083^{aA}$ | $9^{cA}$ | $21^{cA}$ |
| | | 3 WAH | $827^{bA}$ | $1532^{abA}$ | $40^{abcA}$ | $42^{bcA}$ |
| 2016 | 7 WAH | NCC | $0^{cA}$ | $0^{cA}$ | $328^{aA}$ | $223^{aA}$ |
| | | 5 WBH | $1883^{aA}$ | $2247^{aA}$ | $11^{bA}$ | $24^{bA}$ |
| | | 3 WBH | $1115^{abB}$ | $1995^{aA}$ | $19^{bA}$ | $41^{bA}$ |
| | | H | $906^{abA}$ | $1764^{abA}$ | $68^{bA}$ | $26^{bA}$ |
| | | 1 WAH | $410^{abA}$ | $242^{bcA}$ | $30^{bA}$ | $8^{bA}$ |
| | | 3 WAH | $81^{bA}$ | $131^{cA}$ | $15^{bA}$ | $32^{bA}$ |
| | 12 WAH | NCC | $0^{cA}$ | $0^{bA}$ | $721^{aA}$ | $1142^{aA}$ |
| | | 5 WBH | $1760^{aB}$ | $2715^{aA}$ | $6^{cA}$ | $9^{bA}$ |
| | | 3 WBH<br>H | $962^{abB}$<br>$1583^{aA}$ | $1353^{aA}$ $2579^{aA}$ | $4^{cA}$ $139^{abA}$ | $8^{bA}$<br>$44^{bA}$ |
| | | 1 WAH | $630^{abA}$ | $1215^{aA}$ | $105^{abA}$ | $45^{bA}$ |
| | | 3 WAH | $383^{bB}$ | $1216^{aA}$ | $60^{bcA}$ | $51^{bA}$ |

Lowercase letters are used to compare the oilseed radish and weed biomass among the different treatments and the uppercase letters are used to compare the oilseed radish and weed biomass between the two fertilization levels ($N_0$, $N_{45}$). Means with identical letters within the table do not differ significantly based on the Tukey's *HSD* (honest significant difference) test ($P < 0.05$); NCC – no cover crop; WBH – weeks before harvest; H – harvest

The weed density varied between 9 and 202 plants m$^{-2}$ across the experimental years 2015 and 2016. In 2015, the highest weed density reduction of the monocotyledons, dicotyledons and volunteer wheat was observed in treatments H and 1 WAH with 72, 65, 69 and 83, 86, 80%, respectively, compared to NCC across both measurement dates and fertilization levels (Figure 4.27).

In the following year, the weed density was reduced by all treatments compared to the untreated control. The most effective weed control efficacy was achieved by treatments 3 WBH and 5 WBH with up to 91, 84, 83 and 86, 90, 85% on monocotyledons, dicotyledons and volunteer wheat compared to NCC at 12 WAH, respectively (Figure 4.28). Effective weed density reductions by fall-sown cove

Table 4.28

**Coefficients of determination of the Pearson's correlation between cover crop (kg ha$^{-1}$) and weed (kg/ha) biomass (Sturm et al., 2017)**

| Year | Date | $N_0$ | $N_{45}$ |
|---|---|---|---|
| 2015 | 7 WAH 12 WAH | -0.6134*** -0.5954*** | -0.3111** -0.4481*** |
| 2016 | 7 WAH 12 WAH | -0.1127$^{ns}$ -0.0988$^{ns}$ | -0.1685* -0.3655** |

**P < 0.05; **P < 0.01; ***P < 0.001*; ns – not significant; WAH – weeks after harvest

In both years, there was no significant interaction between the factors fertilization and sowing date on cover crop and weed biomass and weed density. Cover crop fertilization did not demonstrate any changes on oilseed radish and weed biomass 7 WAH and 12 WAH in 2015 (Table 4.28). The low effects of the fertilization can be attributed to exceptional weather conditions in 2015 with low precipitation during the experimental period (Table 4.26). Water shortage and the C:N ratio increased by wheat straw decomposition can decrease nitrogen availability for cover crop plants within the field. Furthermore, an increased duration and intensity of drought are associated with a decreased N mineralization into the soil.

In the following year, the oilseed radish biomass was significantly increased by 54, 41 and 218% in treatments 5 WBH, 3 WBH and 3 WAH, respectively, at 12 WAH due to fertilization. The soil sample observation measured an Nmin content of 20.9 kg N ha$^{-1}$ (0–90 cm) at the beginning of the experiment. The increased biomass can be attributed to the missing soil nutrients after 7 WAH. No differences were detected for weed biomass between $N_0$ and $N_{45}$ at 7 WAH and 12 WAH. Furthermore, higher nutrient uptake efficacy and the influence of allelopathic compounds by cover crops can lead to lower effects of fertilization on weed growth.

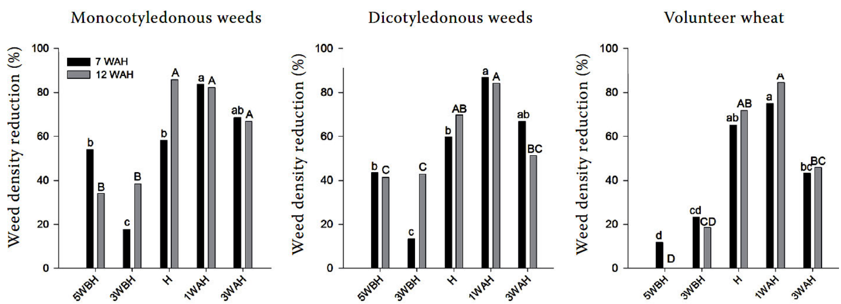



**Figure 4.27 – Weed density reduction (%) of monocotyledonous and dicotyledonous weeds and volunteer wheat (*Triticum aestivum*) at five different sowing dates of oilseed radish cover crop measured at 7 WAH (weeks after harvest) and 12 WAH in 2015. Means with identical letters within the table do not differ significantly based on the Tukey's HSD (honest significant difference) test (*P < 0.05*); WBH – weeks before harvest; H – harvest (Sturm et al., 2017)**

The fertilization of the oilseed radish revealed insignificant changes in weed density in both years.

Different weeds are able to compensate a constant or reduced weed density by higher biomass production per plant.

This study (Sturm et al., 2017) assumed that the weed suppressive ability of coated oilseed radish cover crops depends on sufficient precipitation for germination and growth. Further studies should be conducted to proof the influence of the soil water availability on cover crop and weed biomass accumulation. An early cover crop sowing can provide higher cover crop biomass and increased weed control efficacy as observed in 2016. The use of coated cover crops combined with a pre-harvest sowing can prolong the cover crop vegetation period in the field, reduce the workload peaks during and after winter wheat harvest and suppress weeds more effectively compared to conventionally sown cover crops. More research with further coated cover crops needs to be conducted to investigate the full potential of a prolonged cover crop vegetation period.

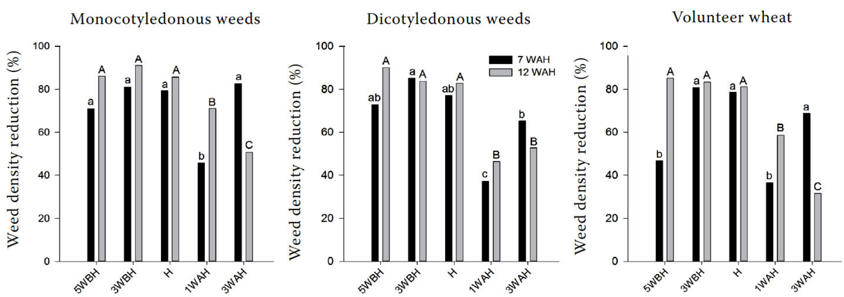



**Figure 4.28 – Weed density reduction (%) of monocotyledonous and dicotyledonous weeds and volunteer wheat (*Triticum aestivum*) at five different sowing dates of oilseed radish cover crop measured at 7 WAH (weeks after harvest) and 12 WAH in 2016. Means with identical letters within the table do not differ significantly based on the Tukey's HSD (honest significant difference) test (*P < 0.05*); WBH – weeks before harvest; H – harvest (Sturm et al., 2017)**

Important from the point of view of green manure and biofumigation application of oil radish is its resistance to the action and aftereffects of herbicides, which is important from the point of view of its long-term use in crop rotation. Thus, in the studies of Brooker et al. (2019) In the PRE field experiment (Table 4.29), the Group 2 herbicides flumetsulam and rimsulfuron caused the greatest reduction (>70%) in oilseed radish stand at both interseeding timings (Table 4.30). When oilseed radish was interseeded into corn at the V3 stage, applications of mesotrione, pyroxasulfone, and acetochlor also resulted in reduced stands, whereas at the V6 stage, pyroxasulfone and saflufenacil were the only other herbicides that caused a reduced stand compared with the no-herbicide control. In the greenhouse study, atrazine and mesotrione were the only PRE herbicides that caused a 50% reduction in oilseed radish biomass at rates that were less than field-use rates (Table 4.31). Herbicides applied PRE that reduced oilseed radish biomass by 10% at rates lower than field-use rates included atrazine, mesotrione, isoxaflutole, acetochlor, dimethenamid-P, flumetsulam, saflufenacil, and pyroxasulfone (Table 4.31). In the POST field experiment, the time ofinterseeding did not affect oilseed radish response to herbicides applied POST to V2 to V3 corn; therefore, data were combined over interseeding timings (Table 4.32). Applications of atrazine (1,120 g $ha^{-1}$), tembotrione, topramezone, mesotrione + atrazine (571 and 1,120 g $ha^{-1}$), thiencarbazone + tembotrione, and S-metolachlor + mesotrione + glyphosate all resulted in unacceptable oilseed radish stands. In the greenhouse study, none ofthe herbicides applied POST resulted in reduced oilseed radish biomass compared with the no-herbicide control (Table 4.33); however, slight bleaching symptoms (<10%) were observed when any of the Group 27 herbicides (mesotrione, tembotrione, or topramezone) were applied (data not shown).

Table 4.29

**PRE and POST herbicide common name, application timings, herbicide sites of action (SOA), and field use rates applied in the field and greenhouse experiments from 2016 to 2018 (Brooker et al., 2019)**

| Common name | Trade name | Application timing | SOA | Rate (g ai $ha^{-1}$) |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| Flumetsulam | Python[a] | PRE | 2 | 56 |
| Rimsulfuron | Resolve SG[a] | PRE | 2 | 22 |
| Clopyralid | Stinger[a] | PRE | 4 | 105 |
| Atrazine | AAtrex[b] | PRE, POST (0.5X, 1X)[g] | 5 | 1,120, 571, 1,120 |
| Saflufenacil | Sharpen[c] | PRE | 14 | 75 |
| Acetochlor | Harness[d], Warrant[d] | PRE, POST | 15 | 2,455, 1,262 |
| Dimethenamid-P | Outlook[c] | PRE | 15 | 942 |
| Pyroxasulfone | Zidua[c] | PRE | 15 | 179 |
| S-metolachlor | Dual II Magnum[e] | PRE | 15 | 1,424 |
| Bicyclopyrone | comp. of Acuron[e] | PRE | 27 | 50 |
| Isoxaflutole | Balance Flexx[d] | PRE | 27 | 105 |
| Mesotrione | Callisto[e] | PRE, POST | 27 | 210, 105 |
| Bromoxynil | Buctril[d] | POST | 6 | 421 |
| Fluthiacet | Cadet[f] | POST | 14 | 1.7 |

(End of Table 4.29)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Tembotrione | Laudis[d] | POST | 27 | 92 |
| Topramezone | Armezon[c] | POST | 27 | 18 |
| Mesotrione + atrazine | - | POST (0.5X)[g] | 27 + 5 | 105 + 285 |
| Mesotrione + atrazine | - | POST (1X)[g] | 27 + 5 | 105 + 509 |
| Dicamba + diflufenzopyr | Status[c] | POST | 4 +19 | 140 + 56 |
| Dimethenamid-P + topramezone | Armezon PRO[c] | POST | 15 + 27 | 920 + 17 |
| Thiencarbazone + tembotrione | Capreno[d] | POST | 2 + 27 | 27 + 77 |
| S-metolachlor + mesotrione + glyphosate | Halex GT[e] | POST | 15 + 27 + 9 | 1,068 + 105 +1,042 |

[a]Corteva Agriscience, Wilmington, DE, https://www.corteva.com; [b]Land O'Lakes, Inc., Arden Hills, MN, https://www.landolakesinc.com; [c]BASF Corporation, Florham Park, NJ, https://www.basf.com; [d]Bayer CropScience LP, St. Louis, MO, https://www.cropscience.bayer.com; [e]Syngenta International AG, Basel, Switzerland, https://www.syngenta.com; [f]FMC Corporation, Philadelphia, PA, http://www.fmc.com; [g]Applied at different field use rates as indicated.

Table 4.30

**Annual ryegrass and oilseed radish stand reduction (%) caused by PRE herbicides in the field experiment (Brooker et al., 2019)**

| Herbicide | Site of action | Annual ryegrass[2] | Oilseed radish[b] | |
|---|---|---|---|---|
| | | V3 + V6 | V3 | V6 |
| Stand reduction (%) | | | | |
| Flumetsulam | 2 | 46* | 74* | 100* |
| Rimsulfuron | 2 | 33* | 73* | 74* |
| Clopyralid | 4 | 6 | 12 | 29 |
| Atrazine | 5 | 8 | 13 | 18 |
| Saflufenacil | 14 | 4 | 23 | 36* |
| Acetochlor | 15 | 67* | 44* | 7 |
| Dimethenamid-P | 15 | 71* | 28 | 6 |
| Pyroxasulfone | 15 | 86* | 48* | 41* |
| S-metolachlor | 15 | 68* | 27 | 9 |
| Bicyclopyrone | 27 | 7 | 6 | 16 |
| Isoxaflutole | 27 | 6 | 28 | 16 |
| Mesotrione | 27 | 17* | 56* | 15 |
| No herbicide | | 0 | 0 | 0 |
| ±SEM[d] | | (± 8) | (± 10) | (± 10) |

[a]Annual ryegrass data are combined across site years and the V3 and V6 interseeding timings. [b]Oilseed radish data were combined over site years.[c]Treatment means followed by an asterisk (*) indicates significantly reduced cover crop stand compared with the no-herbicide control at a = 0.05 within each column using Fisher's least significant difference test. [d]Standard error of the mean.

Table 4.31

**Annual ryegrass and oilseed radish stand reduction (%) caused by POST herbicides in the field experiment.[3] (Brooker et al., 2019)**

| Treatment | Site of Annual action | Ryegrass | Oilseed radish |
|---|---|---|---|
| Stand reduction (%) | | | |
| Atrazine (571 g $ha^{-1}$) | 5 | 14 | 20 |
| Atrazine (1120 g $ha^{-1}$) | 5 | 12 | 34* |
| Bromoxynil | 6 | 13 | 11 |
| Fluthiacet | 14 | 26* | 19 |
| Acetochlor | 15 | 91* | 24 |
| Mesotrione | 27 | 9 | 18 |
| Tembotrione | 27 | 60* | 37* |
| Topramezone | 27 | 76* | 44* |
| Mesotrione + atrazine (285 g $ha^{-1}$) | 27 + 5 | 16 | 59* |
| Mesotrione + atrazine (509 g $ha^{-1}$) | 27 + 5 | 23* | 60* |
| Dicamba + diflufenzopyr | 4+19 | 48* | 31 |
| Dimethenamid-P + topramezone | 15 + 27 | 76* | 4 |
| Thiencarbazone + tembotrione | 2 + 27 | 87* | 47* |
| S-metolachlor + mesotrione | 15 + 27 + 9 | 92* | 41* |
| + glyphosate | | | |
| No herbicide | | 0 | 0 |
| ±SEM[c] | | (±9) | (±12) |

[a]Data are combined across site years and the V3 and V6 interseeding timings. [b]Treatment means followed by an asterisk (*) significantly reduced cover crop stand compared with the no herbicide control within each column at a = 0.05 using Fisher's least significant difference test. [c]Standard error of the mean.

Table 4.32

**PRE herbicide rates to cause 10% biomass reduction (BR10) and 50% biomass reduction (BR50) using Equations 1 and 2 in the text to annual ryegrass, oilseed radish, and crimson clover in the greenhouse from 2016 to 2018 (Brooker et al., 2019)**

| Herbicide | Site of action | Field use rate g ai $ha^{-1}$ | Annual | ryegrass | Oilseed radish | | Crimson clover | |
|---|---|---|---|---|---|---|---|---|
| | | | BR10 | BR50 | BR10 | BR50 | BR10 | BR50 |
| | | | % of field use rate[a] | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Flumetsulam | 2 | 56 | >100 | >100 | 18.3 | >100 | 0.05 | >100 |
| Rimsulfuron | 2 | 22 | 74.0 | >100 | >100 | >100 | 89.3 | >100 |

(End of Table 4.32)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| Clopyralid | 4 | 105 | >100 | >100 | >100 | >100 | 13.9 | 77.4 |
| Atrazine | 5 | 1,120 | 24.6 | >100 | 20.0 | 86.1 | 1.9 | 7.7 |
| Saflufenacil | 14 | 75 | >100 | >100 | 0.04 | >100 | 86.3 | >100 |
| Acetochlor | 15 | 2,455 | 5.0 | 11.4 | 96.0 | >100 | 0.3 | 7.8 |
| Dimethenamid-P | 15 | 942 | 3.0 | 9.3 | 0.01 | >100 | 18.6 | 55.5 |
| Pyroxasulfone | 15 | 179 | 15.5 | 28.1 | 79.9 | >100 | 88.5 | >100 |
| S-metolachlor | 15 | 1,424 | 0.8 | >100 | >100 | >100 | 1.7 | 24.2 |
| Bicyclopyrone | 27 | 50 | >100 | >100 | >100 | >100 | 0.01 | >100 |
| Isoxaflutole | 27 | 105 | 79.6 | >100 | 0.9 | >100 | 81.0 | 93.8 |
| Mesotrione | 27 | 210 | >100 | >100 | 19.3 | 91.4 | 0.01 | >100 |
| [a]Rate of herbicide sprayed as a fraction of the field use rate. | | | | | | | | |

Table 4.33

**Annual ryegrass, oilseed radish, and crimson clover aboveground biomass reduction caused by postemergence (POST) herbicides in the greenhouse (Brooker et al., 2019)**

| Herbicide | Site of action | Rate[a] | Annual ryegrass | Oilseed radish | Crimson clover |
|---|---|---|---|---|---|
| | Aboveground biomass (g pot$^{-1}$) | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| Atrazine (571 g ha$^{-1}$) | 5 | 0.5 | 0.49 | 1.25 | 0.23 |
| | | 1 | 0.55 | 1.31 | 0.17* |
| Atrazine (1,120 g ha$^{-1}$) | 5 | 0.5 | 0.45 | 1.08 | 0.14* |
| | | 1 | 0.62 | 1.30 | 0.09* |
| Bromoxynil | 6 | 0.5 | 0.71 | 1.45 | 0.36 |
| | | 1 | 0.62 | 1.29 | 0.46 |
| Fluthiacet | 14 | 0.5 | 0.77 | 1.34 | 0.36 |
| | | 1 | 0.73 | 1.42 | 0.49 |
| Acetochlor | 15 | 0.5 | 0.38 | 1.28 | 0.49 |
| | | 1 | 0.30* | 1.36 | 0.48 |
| Mesotrione | 27 | 0.5 | 0.59 | 1.14 | 0.39 |
| | | 1 | 0.51 | 1.12 | 0.29 |
| Tembotrione | 27 | 0.5 | 0.52 | 1.28 | 0.43 |
| | | 1 | 0.51 | 1.19 | 0.31 |
| Topramezone | 27 | 0.5 | 0.56 | 1.30 | 0.39 |
| | | 1 | 0.67 | 1.50 | 0.42 |
| Mesotrione + atrazine (285 g ha$^{-1}$) | 27 + 5 | 0.5 | 0.57 | 0.86 | 0.38 |
| | | 1 | 0.67 | 1.23 | 0.42 |

(End of Table 4.33)

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Mesotrione + atrazine (509 g ha$^{-1}$) | 27 + 5 | 0.5 | 0.68 | 1.12 | 0.37 |
| | | 1 | 0.49 | 1.17 | 0.37 |
| Dicamba + diflufenzopyr | 4+19 | 0.5 | 0.58 | 1.03 | 0.21 |
| | | 1 | 0.35 | 1.27 | 0.14* |
| Dimethenamid-P + topramezone | 15 + 27 | 0.5 | 0.31* | 1.45 | 0.28 |
| | | 1 | 0.24* | 1.21 | 0.14* |
| Thiencarbazone + tembotrione | 2 + 27 | 0.5 | 0.47 | 1.35 | 0.28 |
| | | 1 | 0.55 | 1.04 | 0.23 |
| S-metolachlor + mesotrione + glyphosate | 15 + 27 + 9 | 0.5 | 0.15* | 1.26 | 0.22 |
| | | 1 | 0.11* | 1.13 | 0.11* |
| No herbicide | | | 0.63 | 1.56 | 0.34 |
| ±SEM[c] | | | (±0.20) | (±0.83) | (±0.14) |

[a]Rate of herbicide sprayed as a fraction of the 1x rate; [b]Treatment means followed by an asterisk (*) indicates significantly reduced cover crop biomass compared with the no-herbicide control within each column at a = 0.05 using Fisher's least significant difference test. [c]Standard error of the mean.

Oilseed radish can be interseeded into corn at the V3 or V6 growth stages following PRE application of clopyralid, S-metolachlor, or bicyclopyrone. In the field experiments, atrazine and isoxaflutole also did not reduce oilseed radish stand, but when these herbicides were applied in the greenhouse experiment closer to oilseed radish seeding, at least 10% biomass reduction occurred. Additionally, isoxaflutole degradation is accelerated in biologically active soils. Greenhouse soils in this experiment were sterilized, so degradation was likely slowed. Delaying oilseed radish interseeding until corn is at the V6 growth stage may reduce injury and biomass reduction if acetochlor, dimethenamid-P, or mesotrione are applied. In this experiment, there was variability in oilseed radish injury following a saflufenacil application, with more injury occurring at V6 compared with V3. Seeding oilseed radish at either V3 or V6 following an application of saflufenacil likely causes some stand reduction, but this may be acceptable if weeds are controlled. Oilseed radish can be interseeded into V3 or V6 corn following POST applications of atrazine (571 g ha$^{-1}$), bromoxynil, fluthiacet, acetochlor, mesotrione, dicamba + diflufenzopyr, and dimethenamid-P + topramezone.

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