Weed Community Dynamics Under Conservation Agriculture Practices – Mechanisms and Implication

Dinamika korovne zajednice u konzervacijskoj poljoprivredi – mehanizmi i značaj

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WEED COMMUNITY DYNAMICS UNDER CONSERVATION AGRICULTURE PRACTICES – MECHANISMS AND IMPLICATION

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SUMMARY

Conservation agriculture is considered a sustainable production system, based on three main principles: minimal soil disturbance, permanent soil cover, and crop rotation. These principles modify environmental conditions, disturbance regimes, and resource availability, thereby influencing weed emergence, growth, establishment, and competition with crops. This review aims to summarize the main findings on weed community dynamics under conservation agriculture practices and emphasizes their effects on weed infestation in agricultural fields. Conservation tillage affects the weed seed bank and often increases seed presence in the topsoil, while permanent soil cover influences weed germination and emergence through physical and chemical mechanisms. Crop rotation introduces variability in cropping systems, influences weed life cycles, and leads to changes in weed community composition. The interaction of these practices leads to different weed community responses, depending on weed species characteristics, environmental conditions, and management. Conservation agriculture often causes a transition in weed communities, favoring species adapted to reduced disturbance and surface soil conditions. Effective weed management in these systems requires an integrated and adaptive approach. Understanding the combined and long-term effects of these practices is essential for predicting potential challenges and developing sustainable weed management strategies.

Keywords: conservation tillage, soil covering, crop rotation, weed infestation

INTRODUCTION

Conservation agriculture is generally recognized as an important approach for improving the sustainability and resilience of agricultural production systems under increasingly pronounced climate change conditions. This production system is based on three main principles: minimal soil disturbance, permanent soil cover, and varied crop rotations (FAO, 2016). The integration of these practices improves important soil ecosystem functions by enhancing soil structure, increasing water-holding capacity, stimulating soil biological activity, and contributing to carbon sequestration (Hobbs et al., 2008; Corsi et al., 2012).

As a result, conservation agriculture helps maintain long-term soil fertility, stabilize crop productivity, and improve agroecosystem sustainability (Hobbs et al., 2008; Palm et al., 2013).

In addition to their positive effects on soil and crop productivity, conservation agriculture practices also modify ecological conditions in cropping systems. Reduced soil disturbance, permanent presence of crop residues or cover crops on the soil surface, and diverse crop rotation influence several environmental factors that regulate weed germination, emergence, and competition with crops, thereby affecting weed population dynamics and community composition (Derksen et al., 2002; Chauhan et al., 2012; Nichols et al., 2015). Weed community dynamics refers to changes over time and space in weed species composition, their abundance, and characteristics, influenced by environmental conditions and management practices. Understanding how conservation agriculture affects weed community dynamics is important because weeds remain one of the main constraints in crop production.

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Even with many available weed control measures, weeds still cause significant yield losses and reduce crop quality (Oerke, 2006). Weed communities change over time and between locations depending on management and environmental conditions, with rapid adaptation to changing environmental and agricultural conditions (Marshall et al., 2003; Sosnoskie et al., 2006). Despite the increasing adoption of conservation agriculture worldwide, weed management remains one of the main threats for its wider adoption (Derksen et al., 2002; Farooq et al., 2011), and understanding weed dynamics in these systems is therefore particularly important (Derrouch et al., 2020). In recent years, conservation tillage has been increasingly implemented by farmers in Croatia (Jug et al., 2025). As a key component of conservation agriculture, conservation soil tillage often represents the first stage in the conversion from conventional to conservation-based production systems (Andersson and D'Souza, 2014). Considering these trends, it can be expected that conservation agriculture will become more widely integrated into Croatian agricultural production in the future.

In Croatia, the major weed species generally include annuals such as *Chenopodium album* L., *Amaranthus retroflexus* L., *Ambrosia artemisiifolia* L., *Echinochloa crus-galli* L. P. Beauv., *Xanthium strumarium* L., and *Abutilon theophrasti* Medik., as well as perennials such as *Cirsium arvense* L. Scop, *Convolvulus arvensis* L., *Calystegia sepium* L. R. Br, and *Sorghum halepense* L. Pers. (Dujmović Purgar and Hulina, 2008; Štefanić et al., 2020). Mentioned weed species differ in ecological traits such as seed size, dormancy, and response to soil disturbance, influencing their adaptability to conservation agriculture systems. Conservation agriculture can improve weed management in Croatia by reducing soil disturbance, maintaining soil cover, and using cover crops and crop rotation to suppress dominant weed species. However, studies regarding weed community dynamics under conservation agriculture in Croatian agroecological conditions remain limited.

As conservation agriculture expands in Croatia, weed management will become an increasingly important issue with the necessary further improvement of sustainable weed management measures in cropping systems.

Although many studies have focused on the effects of individual components of conservation agriculture on weed community dynamics, fewer studies have included multiple practices within the same system, and their combined effects remain insufficiently understood (Farooq et al., 2011; Chauhan et al., 2012). Investigating how conservation tillage, permanent soil cover, and crop rotations function together within the same system is therefore important for improving weed management in conservation agriculture. The aim of this review is to explain how conservation agriculture practices affect weed community dynamics, with a focus on key processes and their implications for sustainable weed management.

CONSERVATION TILLAGE AND WEED COMMUNITY DYNAMICS

Soil tillage is a main agronomic practice that includes soil disturbance in order to prepare the seedbed, suppress weeds, and manage crop residues (Hobbs et al., 2008).

Tillage practices strongly influence weed seed bank dynamics by altering their size and the vertical distribution of weed seeds within the soil profile, which affects weed emergence, growth, reproduction, and ultimately the composition and occurrence of weeds (Nichols et al., 2015; Navi et al., 2024). For example, small-seeded species such as *Amaranthus retroflexus*, *Chenopodium album,* and *Setaria spp.*, which tend to accumulate near the soil surface under reduced tillage, are more likely to germinate and emerge successfully, while large-seeded annual weeds such as *Xanthium strumarium* and *Abutilon theophrasti* are more likely to emerge from deeper soil layers and are therefore more commonly associated with conventional tillage systems (Clements et al., 1996; Dorner et al., 2024).

The weed seed bank includes all viable weed seeds present in the soil and on the soil surface, including recently produced seeds and those that have remained viable for a longer time (Skuodienė et al., 2013), and together with the above-ground weed community forms the overall weed infestation in the agricultural fields (Radosevich et al., 1997). Its size is determined by the balance between processes that add seeds, such as seed production and dispersal, and those that reduce the seed bank, including germination, seed predation, and natural decay, and represents a major factor in weed ecology. The effect of tillage on the size of the weed seed bank is complex and depends on various factors, including the duration of the study, timing of tillage operations, long-term field management, and environmental conditions (Zimdahl, 2007). Consequently, studies report contrasting results, with some authors indicating that reduced tillage may either decrease (Murphy et al., 2006) or increase weed seed bank size (Sosnoskie et al., 2006), while others report no significant effect (Barberi, 2002).

Modification in tillage intensity influences the vertical dispersion of weed seeds within the soil profile. Similar seed movement has been described under different tillage methods using predictive models (Colbach et al., 2014). Compared with conventional tillage, which involves ploughing and causes a more uniform distribution of weed seeds throughout the soil profile (within the upper 20 cm), conservation tillage systems limit the incorporation and vertical distribution of weed seeds. In no-tillage systems, most weed seeds remain concentrated in the shallow upper soil layer (up to 5 cm) with a decreasing trend with the soil depth, whereas in other reduced tillage systems, seed distribution varies (Clements et al., 1996; Feledyn-Szewczyk et al., 2020). Soil tillage generally works as a key factor of vertical weed distribution through dislodging, destruction of storage organs, burial at greater depths, and soil mixing (Shrestha et al., 2002). Changes in the vertical distribution of seeds caused by reduced tillage intensity can lead to increased seed predation by granivore fauna (insects, birds, and rodents), which can be an effective method for reducing the soil seed bank (Chauhan et al., 2012). The noticed changes in vertical seed distribution may lead to reduced seed viability due to desiccation of seeds in the upper soil layers, especially under dry and high-temperature conditions. Environmental conditions have been identified as a key factor influencing weed emergence, with their variability often having a greater impact on weed species diversity and density than tillage practices (Alarcón et al., 2019). Species such as *Echinochloa crus-galli* are favored by warm and moist conditions, while *Chenopodium album* can tolerate a wider range of temperatures but requires sufficient soil moisture for successful emergence. In contrast, small-seeded species such as *Amaranthus retroflexus* may be more sensitive to drought and high temperatures in the upper soil layer, which can limit their germination and survival (Šoštarić et al., 2021).

Differences in seed distribution within the soil profile, based on the degree of tillage reduction, can affect weed germination and emergence, as soil layers at different depths vary in moisture content, temperature fluctuations, exposure to light, and seed predators. Moreover, the accumulation of seeds in the topsoil can create favorable conditions for the germination of some weed species, especially those whose germination is promoted by light (Chauhan et al., 2012).

Findings from various studies suggest that weed communities may respond differently to conservation tillage (Nichols et al., 2015; Travlos et al., 2018; Romaneckas et al., 2021; Brozović et al., 2023; Winkler et al., 2023). The composition of the weed community is complex and dynamic, varying across time and space as well as under different management practices, and is strongly influenced by environmental factors. As reported by Legere et al. (2005), tillage practices have a limited influence on weed diversity, as reflected by diversity indices, but still have a significant role in influencing weed community composition.

Changes in weed populations are specific to each tillage system due to their sensitivity to different agronomic practices and agroecological conditions (Brozović et al., 2023). Conservation tillage can cause a higher occurrence of perennial weeds; however, it may also promote the presence of annual weeds and increase overall weed species richness. An increase in the average number of perennial weeds in conservation tillage systems, with the dominance of species such as *Calystegia sepium*, *Cirsium arvense*, *Convolvulus arvensis*, and *Symphytum officinale* L., has been reported in two different agroecological areas in Croatia, along with an increase in the abundance of annual weed species, including *Ambrosia artemisiifolia*, *Chenopodium polyspermum* L., *Echinochloa crus-galli*, *Setaria spp*., and *Xanthium strumarium* during the maize growing season (Brozović et al., 2023). Still, perennial weeds tend to become more dominant under reduced tillage compared to conventional systems. (Armegot et al., 2016).

Variations in tillage intensity can determine weed density, biomass, and cover, with a general increase observed as tillage depth decreases (Travlos et al., 2018; Brozović et al., 2023; Winkler et al., 2023). Such responses are not universal and are strongly dependent on environmental and management conditions, often accompanied by shifts in weed community composition.

SOIL COVER EFFECTS: CROP RESIDUES AND COVER CROPS

Permanent soil cover is an essential component of conservation agriculture systems, with significant effects on weed population dynamics. Soil cover is maintained through the holding of crop residues on the soil surface, ensuring a minimum coverage of 30%, including through the use of cover crops. According to Chauhan et al. (2012), crop residues are widely recognized as an effective and accessible component of weed management strategies. Crop residues influence weeds through physical effects (e.g., reduced light, changes in temperature) and chemical effects such as allelopathy.

The positive effect of crop residues on reducing weed occurrence is a result of the potential creation of unfavorable conditions for weed seed germination, emergence, and growth. Crop residues physically reduce weed seed germination by moderating soil temperature and limiting the amount of light reaching the soil surface. By altering microclimatic conditions in the surface soil layer, they can delay weed germination and emergence (Chauhan et al., 2012; Nichols et al., 2015; Navi et al., 2024). However, moisture retention under crop residues in drier conditions may promote weed germination and emergence, whereas in areas with sufficient water availability, this effect is generally limited or may lead to higher seed mortality. Some species may germinate better under low light conditions, others at lower temperatures, and some only under high humidity, suggesting a significant influence of ecological conditions on seed germination and emergence (Zimdahl, 2007; Chauhan et al., 2012; Baskin and Baskin, 2014). For example, *Amaranthus retroflexus* is stimulated by light, and *Chenopodium album* requires light for germination. *Galium aparine* L. can germinate under low light and lower temperatures, while *Echinochloa crus-galli* is favored by warm and moist conditions (Baskin and Baskin, 2014; Chauhan, 2012), indicating a strong influence of ecological factors on weed emergence in Croatian agroecosystems. These effects vary depending on residue type, climate, and soil conditions. In addition, crop residues may express chemical effects on weed development, as the release of allelopathic compounds can inhibit weed growth and development.

Allelopathy refers to the direct or indirect, beneficial or harmful effects of one plant species on the germination, growth, and reproduction of another through the release of chemical compounds (Rice, 1984). In agricultural systems, allelopathic plants can be integrated into crop rotations or used as mulches and living cover crops, while their residues may be incorporated into the soil, thereby suppressing weed germination and growth (Khamare et al., 2022). Crop residues releasing allelochemicals can suppress weed seed germination, particularly in small-seeded species, with greater effectiveness observed when residues remain on the soil surface compared to incorporation (Roth et al., 2000). Allelopathic effects are species-specific and environmentally dependent, and certain crops may suppress particular weed species. For example, *Hordeum vulgare* L. suppresses *Echinochloa crus-galli* (Dhima et al., 2006), while *Secale cereale* L. inhibits *Amaranthus retroflexus* (Reberg-Horton et al., 2005). *Sorghum spp*. suppresses *Convolvulus arvensis* (Al-Bedairy et al., 2013), and *Helianthus annuus* L. affects *Chenopodium album* (Anjum and Bajwa, 2008).

Cover crops, through their multiple positive effects on agroecosystems, are integrated into the principles of conservation agriculture, encompassing agronomic practices related to soil, crops, and pest management (Barberi, 2002). They contribute to the diversification of crop rotations in conservation systems, permanent soil cover, the efficiency of reduced or no-tillage systems, soil nutrient status, and integrated pest management (Lal, 2021; Biswakarma, 2022). Cover crops are widely acknowledged as an effective approach to weed suppression and represent one of their key agronomic advantages (Teasdale, 1996; Chauhan et al., 2012). Their suppressive effects are achieved through several mechanisms, including competition for light, water, nutrients, and vegetation space, as well as physical interference resulting from biomass production and soil surface coverage (Fernando and Shrestha, 2023). Cover crops can affect weed dynamics through allelopathic interactions, whereby the release of chemical compounds may inhibit weed seed germination and subsequent growth (Khamare et al., 2022). Allelopathic cover crops occur in several plant families, especially *Poaceae* and *Asteraceae*, with *Brassicaceae* and *Fabaceae* also well represented. Commonly studied species include crops such as *Secale cereale* L., *Triticum aestivum* L., *Sorghum spp*., *Hordeum vulgare*, and *Avena sativa* L. In addition, species such as *Brassica napus* L., *Medicago sativa* L., *Vicia faba* L., and *Vicia villosa* Roth also show allelopathic effects (Scavo and Mauromicale, 2021). A cover crop mixture composed of multiple species, including *Raphanus sativus* var. *oleiformis* Pers and *Sinapis alba* L., *Fagopyrum esculentum* Moench (*Polygonaceae*), and *Guizotia abyssinica* (L.f.) Cass has been shown to differ in its suppressive effects on weed species. In particular, species belonging to the *Brassicaceae* family exhibited a stronger inhibitory effect on germination and early growth of weeds such as *Ambrosia artemisiifolia*, *Echinochloa crus-galli,* and *Setaria spp*. compared to species from other families. This suggests that the inclusion of *Brassicaceae* species in cover crop mixtures may enhance weed suppression, likely due to their allelopathic potential, and explains their frequent use in multispecies cover crop systems (Šćepanović et al., 2023). Multi-species cover crop mixtures are increasingly used because they can improve weed suppression, mainly through higher biomass production, which increases competition for key resources such as light, water, and nutrients. In addition, greater species diversity within mixtures may enhance allelopathic effects, potentially allowing suppression of a wider range of weed species. However, the effectiveness of these mixtures depends on species composition and environmental conditions, and their effects are not always consistent (Baraibar et al., 2018). The mechanisms of weed suppression by cover crops involve both the growth of living cover crops and the use of surface-placed or incorporated cover crop residues (Brennan and Smith, 2005; Lemessa and Wakjira, 2014).

The implementation and cover crop practices can contribute to both direct (competition) and indirect (physical) weed suppression across multiple stages of the weed life cycle, including seed germination, seedling emergence, and plant growth. The effectiveness of weed control achieved by cover crops varies with multiple management factors, including cover crop species selection, timing of sowing and termination, termination method, and tillage practices (Osipitan et al., 2019). When grown alongside the main crop, cover crops can contribute to weed suppression through competition for light, water, and nutrients (Teasdale et al., 2007). However, this competition may also negatively affect crop performance. Consequently, the choice of suitable cover crop species is crucial, favoring those with rapid establishment, short growth duration, and lower canopy height to reduce competition for light. Moreover, sufficient soil moisture is required to limit competition for water between cover crops and the main crop.

Living cover crops are typically sown in autumn, early or late winter, or during summer, depending on the sowing time of the subsequent main crop following their termination. In some systems, they may also be grown simultaneously with the main crop. They contribute to weed suppression primarily through competition for key resources, thus resulting in reduced weed biomass, seed production, and soil seedbank (Fernando and Shrestha, 2023). One of the main limitations of living cover crops grown alongside the main crop is their lack of selectivity, since high biomass-producing species can also compete with the crop for key resources (Scavo et al., 2022). The effectiveness of weed suppression, particularly for summer annual weed species, is closely connected to cover crop biomass amount, with higher biomass levels generally associated with greater weed control (Fernando and Shrestha, 2023). During fallow, when winter cover crops are grown between main cropping periods, early sowing is particularly important to ensure rapid development of aboveground biomass. This promotes effective soil cover already in autumn and improves subsequent weed control during the spring period. Winter cover crops such as *Vicia villosa* and *Secale cereale*, as well as their mixtures, are frequently reported as effective in producing adequate biomass (Brozović et al., 2020). Early establishment of effective ground cover in spring can suppress weed germination and emergence by limiting light penetration to the soil surface and moderating temperature fluctuations in the upper soil layers, thereby creating less favorable conditions for weed development.

Further suppression may occur following cover crop termination, as accumulated biomass can create physical barriers that limit weed establishment. After the termination of cover crops, if their residues are left on the soil surface, they function as a dead mulch and can effectively contribute to weed suppression (Blanco-Canqui et al., 2015; Scavo et al., 2022; Fernando and Shrestha, 2023). The success of weed control by cover crop residues depends on the amount of biomass produced and its uniform distribution across the soil surface (Osipitan et al., 2018). Higher biomass production and more even soil coverage generally result in more effective weed suppression (Mirsky et al., 2011; Osipitan et al., 2018). The amount of biomass produced by cover crops depends on the species used, environmental conditions during their growth (such as water availability and temperature), and the duration of the cover crop growing period (Blanco-Canqui et al., 2015; Scavo et al., 2022).

By covering the soil surface and limiting light penetration, cover crop residues can reduce weed seed germination and early growth (Teasdale, 1996; Chauhan et al., 2012; Fernando & Shrestha, 2023). Surface mulch is particularly effective against small-seeded, light-sensitive species, while also acting as a physical barrier that restricts seedling emergence (Teasdale, 1996; Baskin and Baskin, 2014).

Mulch additionally modifies soil microclimatic conditions by reducing temperature fluctuations and influencing soil moisture (Blanco-Canqui et al., 2015; Scavo et al., 2022). In temperate regions, residues can decrease daily temperature variability, which may limit germination in species that rely on temperature changes to break dormancy (Zimdahl, 2007; Baskin and Baskin, 2014). Increased soil moisture under mulch, due to reduced evaporation and enhanced infiltration, may further suppress germination in some species (Blanco-Canqui et al., 2015; Scavo et al., 2022). However, the effectiveness of weed suppression depends on weed community composition, as perennial and large-seeded species are generally less affected by mulch (Chauhan et al., 2012; Nichols et al., 2015).

Incorporated cover crop residues can reduce weed growth through the release of allelopathic compounds during decomposition, which may inhibit weed seed germination and establishment (Kruidhof et al., 2009). In addition, these residues can delay seedling emergence and reduce early plant growth (Teasdale et al., 2007). The effectiveness of weed suppression by incorporated cover crops is largely influenced by the quantity and quality of the biomass, as these factors influence decomposition rates (Liebman and Mohler, 2001). For that reason, when selecting cover crop species for this aim, it is important to consider their biomass production potential, allelopathic properties, and environmental conditions.

CROP ROTATION AND WEED COMMUNITY RESPONSE

Crop rotation represents a key preventive measure in weed management. It limits the accumulation of weed populations and reduces changes in weed community composition, as many weed species are adapted to specific cropping conditions and tend to expand in systems with comparable conditions for growth (Liebman and Davis, 2000; Derksen et al., 2002). Introducing variability through crop rotation disrupts these adaptations and contributes to more balanced weed communities (Nichols et al., 2015).

Different crops are associated with varying agronomic practices, which can disrupt weed life cycles and reduce the dominance of specific weed species as well as increase weed diversity (Locke et al., 2002). An appropriate selection of crops within a rotation can result in a significant reduction in weed density and biomass in cropping systems. Weeds compete with crops for key resources, including light, water, and nutrients. When these resources are scarce, and both crops and weeds utilize the same growing conditions at the same time, competitive interactions become more intense, resulting in greater yield losses (Adeux et al., 2019).

Crop rotation affects weed infestation through both physical and chemical effects (Derksen et al., 2002). Additionally, variability in resource competition also plays an important role (Nichols et al., 2015). The physical effects are mainly related to competition between crops and weeds, which occurs both below the soil surface for water and nutrients, and above the soil surface for light and space (Chauhan et al., 2012). One of the main principles of weed control in cropping systems is to create conditions where weeds have limited access to light and space, especially light, which is essential for plant growth. Crops with dense canopies, greater height, and vigorous growth can suppress weeds by shading them and partly through mechanical effects.

The chemical effect of crop rotation is mainly related to allelopathy (Khamare et al., 2022). These effects may include reduced germination, slower growth and development, and lower seed production in certain weed species. In addition, more diverse crop rotations can lead to the use of different tillage practices and herbicides with different modes of action, which can influence weed populations and help reduce the risk of herbicide resistance (Chauhan et al., 2012). However, weed communities are usually reduced only to a certain extent, since weeds can persist and regenerate through the soil seed bank or by regrowth from vegetative organs in perennial species (Radosevich et al., 1997).

Crop rotation affects several key aspects of weed dynamics, including the size of the weed seed bank, seed germination, and seed production, as well as the composition and diversity of weed communities (Nichols et al., 2015). Different crop rotations are associated with different tillage practices, which further influence weed dynamics, as the mechanisms of tillage effects on weeds have been described previously. In conservation tillage systems, volunteer crops (pre-crop volunteers) can also be an important part of weed communities. These plants originate from seeds of the previous crop and can compete with the main crop for resources, similar to weeds. Their presence is often more noticeable under reduced tillage due to lower soil disturbance and limited seed burial. Control of volunteer crops is therefore important and is usually achieved by mechanical measures or by using non-selective herbicides before crop establishment. (Jhala et al., 2021). For this reason, their management should be included as part of integrated weed management in conservation agriculture systems.

The response of weed species to crop rotation also depends on their species characteristics, such as seed size, dormancy, and life cycle, which influence their ability to adapt to changing conditions. While crop rotation can reduce the dominance of certain weed species, it may also increase weed diversity in general (Radosevich et al., 1997). In conservation agriculture systems, crop rotation plays an important role in regulating weed populations, particularly in systems with reduced soil disturbance.

INTEGRATED EFFECTS OF CONSERVATION AGRICULTURE PRACTICES ON WEED COMMUNITIES

Agronomic practices create selection pressures that lead to changes in weed community composition (Derksen et al., 2002). In conservation agriculture, three main principles act together to shape weed communities. Reduced tillage, permanent soil cover, and crop rotation influence weed communities through multiple interacting mechanisms at different stages of the weed life cycle.

These practices influence several processes at the same time, including seed bank dynamics, weed emergence, and crop–weed competition, which together determine weed community composition.

Long-term conservation agriculture often leads to shifts from annual to perennial weed species, especially grasses (Chhokar et al., 2021). Conservation agriculture modifies tillage, crop establishment, and management practices, thereby influencing the soil environment and weed communities. As a result, weed emergence, seed bank characteristics, dispersal, and competition are affected (Nichols et al., 2015). The effects of tillage intensity on weed infestation vary depending on the cropping system and agroecological conditions, while in conservation agriculture, they are closely associated with soil cover and crop rotation (Sosnoskie et al., 2006; Brozović et al., 2023).

These effects can be reduced by crop residues and cover crops, which limit light availability, modify soil temperature and moisture, create a physical barrier that can reduce weed emergence, and suppress weeds through competition for essential resources (Chauhan et al., 2012; Navi et al., 2024; Fernando and Shrestha, 2023).

Crop rotation leads to changes in weed communities over time by altering crops, management practices, and periods of competition. This can break weed life cycles and reduce the dominance of species adapted to specific cropping conditions. When combined with reduced tillage and permanent soil cover, crop rotation increases variability in selection pressures and influences weed community composition (Nichols et al., 2015).

For example, tillage affects not only seed distribution in the soil but also weed emergence patterns, while crop rotation influences weed communities through changes in crop types, management practices, and seasonal conditions, including shifts between winter and summer weed species.

The interaction of these practices can affect weed infestation in agricultural fields in both positive and negative ways. Reduced tillage may increase the presence of certain weed species, especially perennials or those adapted to shallow seed placement. However, cover crops and crop residues can help control these species by limiting their emergence, early growth, and establishment. On the other hand, if cover crop biomass is insufficient, their suppressive effect may be reduced. Together, these practices influence key processes such as seed bank dynamics, germination, and crop–weed competition. As a result, conservation agriculture leads not only to changes in weed infestation but also to shifts in weed community composition, favoring species better adapted to these conditions.

CONCLUSION

Conservation agriculture influences weed communities through reduced soil disturbance, permanent soil cover, and crop rotation. These practices do not necessarily reduce weed infestation, but more often lead to changes in weed community composition, favoring species adapted to reduced disturbance and surface soil conditions.

Weed community response varies depending on environmental conditions, management practices, and species traits. Because of this, conservation agriculture is not equally effective under all conditions and requires site-specific management.

Effective weed management in these systems depends on combining different practices, including crop rotation, cover crops, and herbicides with different modes of action, in order to reduce selection pressure and delay herbicide resistance.

In Croatia, research on weed dynamics under conservation agriculture is still limited. More long-term studies under local agroecological conditions are needed, especially those focused on species-specific responses and functional traits, as well as on practical combinations of management practices that can improve weed control while maintaining crop productivity.

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DINAMIKA KOROVNE ZAJEDNICE U KONZERVACIJSKOJ POLJOPRIVREDI – MEHANIZMI I ZNAČENJE

SAŽETAK

Konzervacijska poljoprivreda prepoznata je kao održiv način proizvodnje temeljen na trima glavnim principima: minimalnome narušavanju tla obradom, trajnoj pokrovnosti tla i plodoredu. Ovi principi mijenjaju okolišne uvjete, narušavaju režim i dostupnost resursa te time utječu na klijanje, rast, razvoj i kompeticiju korova s usjevima. Ovaj rad temelji se na objedinjavanju ključnih spoznaja o dinamici korovne zajednice u uvjetima primjene konzervacijske poljoprivrede te naglašava njihov utjecaj na zakorovljenost poljoprivrednih površina. Konzervacijska obrada tla utječe na banku sjemena korova i često dovodi do nakupljanja sjemena u površinskome sloju tla, dok trajna pokrovnost tla utječe na klijanje i nicanje korova putem fizikalnih i kemijskih mehanizama. Plodored unosi varijabilnost u proizvodne sustave, utječe na životne cikluse korova i dovodi do promjena u sastavu korovne zajednice. Interakcija ovih praksa rezultira promjenjivim odgovorom korovne zajednice, ovisno o svojstvima korovnih vrsta, okolišnim uvjetima i načinu gospodarenja. Konzervacijska poljoprivreda često dovodi do promjena u korovnim zajednicama, favorizirajući vrste prilagođene konzervacijskoj obradi tla i uvjetima u površinskome sloju tla. Učinkovito suzbijanje korova u sustavima konzervacijske poljoprivrede stoga zahtijeva integriran i prilagođen pristup. Razumijevanje interakcije i dugoročnih učinaka ovih praksa ključno je za predviđanje potencijalnih izazova i razvoj održivih strategija upravljanja korovima.

Ključne riječi: konzervacijska obrada tla, pokrivenost tla, plodored, zakorovljenost

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