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The role of weeds as a source of beneficial microorganisms

Jelena Ilic

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Abstract Weeds are undesirable and not subject to cultivation. It is known that weeds can host pathogens, however, their role as a source of beneficial organisms is poorly studied and only in individual cases. This paper is a short review of the available literature on the role of weeds as hosts of beneficial microorganisms. Some of the fungi mentioned in this review belong to *Fusarium, Alternaria, Aspergillus* and *Trichoderma* genera, while bacterial genera include *Bacillus* and *Pseudomonas*. The conclusion is that weeds are an excellent potential source of microbial organisms that can help plant development and resistance to plant diseases.

Keywords Weeds · Beneficial microorganisms · Herbicide resistance · Plant growth promotion · Disease resistance

Introduction

Weeds

There are many different definitions of weeds (Zimdahl, 2007). The Weed Science Society of America (WSSA) states that weeds are undesirable where they grow, can cause economic losses or damage, and create health problems for humans or animals (https://wssa.net).

In agriculture, weeds influence the development of cultivated crops, take nutrients from them, and take up space and shade them (Javaid et al., 2022). However, just like other plants, weeds provide some benefits. There are many important roles of weeds, from maintaining biological diversity, being used for shelter and food by different animals, for cooking, traditional herbal remedies, for the remediation of the environment, even as future biofuels (Ferdosi et al., 2021). According to Adeux et al. (2019) leaving weeds to grow among crops is beneficial to soil quality and the yield of the cultivated plant. Weeds support soil fertility and biodiversity (Jordan & Vatovec, 2004; Ziska & Dukes, 2011). Today, balancing biodiversity and crop productivity should be one of the main aims of agriculture.

Beneficial plant microorganisms

Beneficial plant microorganisms include fungi, bacteria, protozoa, and other organisms that positively influence plant development, disease resistance, and adaptation to environmental stress (Javaid et al., 2021). Characteristics of the biological control agent are restricted to the strain level and not to genera or even species. Outof the thousands of isolates, only a few turn out to be potential biocontrol candidates. Many papers deal with the research of beneficial microorganisms (Khalil et al., 2021), but less attention is paid to the research of organisms isolated from weeds. Compant et al. (2010) state that plant microbiota supports plant growth and development, and, according to them, microorganisms have been shown to have great potential as biopesticides or biofertilizers. However, their field application tends to be limited. Authors divide microbiota into two major groups: below-ground plant microbiota and above-ground microbiota, where the latter

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J. Ilic (✉)
Faculty of Agrobiotechnical Sciences Osijek, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia
e-mail: jilic@fazos.hr

includes endosphere and phyllosphere microorganisms. The rhizosphere is considered to be one of the most complex ecological systems with very diverse microbial activity. In agricultural production, beneficial microorganisms can improve crop yield, increase photosynthesis, produce secondary metabolites, and improve soil chemical and physical properties. The best exploitation of their activity is recommended to be through repeated application for several years together with organic fertilization (Javaid, 2010). The importance of beneficial microorganisms arose as a consequence of the increased use of pesticides and artificial fertilizers. Disadvantages in the application of biocontrol organisms against plant pathogens can include poor survival, lack of adaptation to environmental conditions, and variable colonization rates. Successful colonization of biocontrol agents includes the maintenance of adequate populations which are needed for effective biological control and duration of their threshold population (Gupta, 2012). According to Thoms et al. (2021), one of the crucial steps is microorganisms' ability to evade or suppress host immunity. Once the microorganism is present, a plant chooses either to tolerate it, engage in mutual symbiosis, or initiate an immune response. Also, specific microbes are recruited by plants that can produce signals to attract them and secrete molecules that are toxic to others.

Beneficial microorganisms isolated from weeds

Microorganisms and weeds are most often mentioned together in the context of using microorganisms for weed suppression, and many papers have been written about this (Kennedy et al., 1996; Sindhu & Sehrawat, 2017). There are few papers on the isolation of beneficial microorganisms from weeds, and they usually refer only to certain narrow geographical areas and a few types of weeds. Postic et al. (2012) isolated *Fusarium* species from weeds and tested their pathogenicity on wheat and maize (Ilic et al., 2012). In addition to being pathogenic, they found that certain isolates of *F. solani*, *F. oxysporum* and *F. subglutinans* and *F. verticillioides* have a positive impact on the yield of wheat and maize. With the same *Fusarium* isolates, the research was repeated on cherries and wine grapes (Ilic et al., 2017; Jelenic et al., 2021) and it was found that endophytic *Fusarium* species have a favorable effect on the growth of blackberry plants and reduce symptoms caused by *Botrytis cinerea* on wine grapes. Donayre and Dalisay (2016) have studied endophytic fungi isolated from barnyard grass weed (*Echinochloa glabrescens*) in the Philippines. They have isolated 8 different genera of fungi, of which two genera could not be identified (Table 1). Mukhtar et al. (2010) investigated the diversity of epiphytic and endophytic microorganisms isolated from several dominant weeds in Pakistan. Five fungal genera were common in all weed samples: *Alternaria*, *Aspergillus*, *Cladosporium*, *Drechslera*, and *Penicillium*, with their frequency differing significantly among weeds. Sturz et al. (2001) studied rhizobacteria isolated from weeds and their role in the promotion of agricultural plant growth. Bacterial communities were isolated from six weed species with *Stenotrophomonas maltophilia* being the species recovered most frequently (Table 1). According to the authors, examination of crops and soil treatments should include examination of weed species, because of their possible beneficial influence and their improvement to soil quality. There is proof of a greater dependence of weeds on beneficial plant–microbe interactions and a more efficient association with microorganisms than crop plants, where bacteria isolated from weeds can show a higher richness compared to bacterial microbiota of cultivated plants growing in the same field. Modern crop plants may have lost the ability to recruit some of the microbial species that remain associated with weeds (Samad et al., 2017).

The relationship between weeds and beneficial microorganisms

Weeds might be crucial for the establishment of microbial communities in agricultural systems, and even have an important role as service crops rather than being only a worrying element in agricultural fields (Trinchera and Warren Raffa, 2023). It has been proven that the microorganism-plant relationship is not short-lived and one-time, but that the positive influence of isolated microorganisms can be extended to other plant species (Ilic et al., 2017; Jelenic et al., 2021).

Massenssini et al. (2014) analyzed the role of soil microorganisms in the interactions between crops and weeds. In their opinion, the agricultural environment has favorable conditions for short life cycles and rapid growth of weeds. This gives weeds an advantage over

Table 1 Summary of mentioned weed species and associated beneficial microorganisms

Weed names	Beneficial microorganism(s)	Reference
Chenopodium album, Abutilon theophrasti, Sonchus arvensis	*Fusarium solani, Fusarium oxysporum, Fusarium subglutinans, Fusarium verticillioides*	Ilic et al., 2017
Echinochloa glabrescens	*Alternaria, Arthrinium, Bipolaris, Curvularia, Nigrospora*, and *Stemphyllium*	Donayre and Dalisay (2016)
Chenopodium album, Euphorbia helioscopia, Parthenium hysterophorus and *Convolvulus arvensis*	*Alternaria, Aspergillus, Cladosporium, Drechslera*, and *Penicillium*	Mukhtar et al. (2010)
Echinochloa crus-galli, Spergula arvensis, Sonchus sp., Lolium multiflorum, Chenopodium album, and *Agropyron repens*	*Bacillus* sp., *Arthrobacter* sp., *Stenotrophomonas* sp., *Acinetobacter* sp., and *Pseudomonas* sp.	Sturz et al. (2001)
Portulaca oleraceae, Hedyotis corymbosa, Cleome rutidosperma, Commelina diffusa, Cyperus kyllingia, Euphorbia hirta, Eleusine indica, Echinocloa colona, Brachiarya mutica, Peperomia pellucida, Borreria, Ipomoea acquatica, Rottboellia cochinchinensis, Phyllantus amarus and *Vernonia cineria*	*Lasiodiplodia theobromae, Trichoderma asperellum* and *Ceratobasidium* sp.	Catambacan and Cumagun (2021)
Lamium amplexicaule, Veronica arvensis, Lepidium draba and *Stellaria media*	*Pseudomonas* sp., *Arthrobacter* sp., *Bacillus* sp., *Flavobacterium* sp., *Rhizobium* sp., *Microbacterium* sp. and *Variovorax* sp.	Samad et al. (2017)

cultivated plants to establish short and long-term interactions with soil microbes.

Wang et al. (2020) reported a mechanism of disease control involving an endophyte gene, Fhb7, against *Fusarium* spp. in wheat, which was probably transferred from an *Epichloë* spp. through horizontal gene transfer. In their opinion, endophytes' participation in biocontrol is complex and only starting to be developed. Endophytes isolated from weeds growing in banana fields had an antifungal influence on banana pathogen *Fusarium oxysporum* f. Sp. *Cubense* TR4, with high inhibitory activity by *Lasiodiplodia theobromae, Trichoderma asperellum* and *Ceratobasidium sp.* (Catambacan & Cumagun, 2021). When comparing the interaction between the arbuscular mycorrhizal fungi and weeds in cropping and unmanaged ecosystems, many weed species exhibited enhanced biomass and growth effects after colonization with fungi (El Omari & El Ghachtouli, 2021). Vatovec et al. (2005) investigated the influence of arbuscular mycorrhizal fungi on the growth of 14 weed species growing in crop fields in temperate agroecosystems. They determined that *Ambrosia artemisifolia* and *Cirsium arvense* showed a significant positive effect of fungal inoculation. According to Kurle and Pfleger (1994), enhanced weed fitness might be related to a higher degree of responsiveness of some weed species to fungal inoculation or their increased availability around the roots (Hendrix et al., 1995). Offspring of some weed species had increased vigor after being colonized by fungi (Koide & Lu, 1992). The plant growth promoting activities of the microbiome of grapevine and four weed species, growing in proximity in the same vineyard, has been compared (Samad et al., 2017). The microbiome of the weed isolates showed more plant growth-promoting characteristics compared with isolate from the grapevine (Table 1).

Weeds have beneficial effects on the diversity and abundance of microorganisms. They enhance sporulation and root colonization compared to crop species (Kurle & Pfleger, 1994) and influence differences in dominant fungal species enabling a wider spectrum of fungi to colonize crop roots (Radić et al., 2012, Säle et al., 2022.). A higher amount of fungi in the soil enables early colonization of the following crop that will be planted (Kubota et al., 2015), while non-controlled weeds maintain mycorrhizal infectivity (Plenchette, 1989). The presence of weeds with fungal colonization may provide grasses with an increased ability to extract water from the soil (Allen and Allen, 1984; Trinchera and Warren Raffa, 2023), confirming that interaction between beneficial microorganisms and weeds may improve soil characteristics (Jordan et al., 2000).

Conclusion

Weeds are an excellent, but underrated source of beneficial microorganisms that need further investigation.

Declarations

Competing interests The author has no financial or proprietary interests in any material discussed in this article.

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