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ORIGINAL RESEARCH PAPER

The weed composition in an orchard as a result of long-term foliar herbicide application

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Abstract

The weed composition and the dominance of individual species occurring in an orchard were assessed at the Research Station of the Wrocław University of Environmental and Life Sciences, Poland, during the first 10 years after orchard establishment. 'Ligol' apple trees were planted in the spring of 2004 (3.5 × 1.2 m). Foliar herbicides were applied in 1 m wide tree rows twice or three times per each vegetation period. In the inter-row spaces, perennial grass was maintained.

Ten years of maintenance of herbicide fallow contributed to a change in the weed composition in the orchard. It changed as a result of different responses of the most important weed species to the foliar herbicides. Total suppression of *Elymus repens* was observed in the first year after planting the trees. *Convolvulus arvensis*, *Cirsium arvense*, and other perennial weeds, completely disappeared in the succeeding periods. The maintenance of herbicide fallow did not affect the abundance of *Taraxacum officinale*. The percentage of the soil surface covered by *Trifolium repens* and *Epilobium adenocaulon*, perennial weeds with considerable tolerance to post-emergence herbicides, increased during the fruit-bearing period of the trees. The abundance of these weeds was significantly reduced only in the rows with the stronger growing trees on the semi-dwarf P 2 rootstock. *Stellaria media* was the dominant annual weed. *Senecio vulgaris*, *Poa annua*, *Capsella bursa-pastoris*, and *Lamium* spp. were also frequently observed. A significant increase in the abundance of annual and perennial weeds was found in the tree rows as a result of improved water availability after a period of high precipitation.

Keywords

apple tree; rootstock; weed; herbicide fallow; glyphosate

Introduction

The species richness of weeds is higher in an orchard than in a crop field that is plowed every year [1]. According to Lipecki [2,3], however, in the temperate climate only 20 species play an important role in orchards and berry fruit plantations. Among 186 taxa found in orchards of Mazovia, 27 were determined to be specific for fruit production [4]. Similar populations were identified by Mika [5] in the same region, Lipecki [6] in eastern Poland, Zawieja et al. [7] and Licznar-Małańczuk [8,9] in Lower Silesia. When applied for many years, foliar herbicides can be an optimal method of weed suppression in fruit tree rows [10,11], bringing an overall reduction of the weed species number [12]. Herbicide fallow favors hemicryptophytic weeds [13] and can even contribute to invasion by perennial weed species. In the periods between herbicide applications, abundant populations of annual species, therophytes, tend to appear in the orchard [8,14].

In agriculture [15], including fruit production [16,17], one can currently observe the trend towards reduced use of chemical substances in favor of alternative weed control methods. The floor management system that has been prevalent in Polish orchards involves perennial grass cover between the tree rows only, whereas herbicide fallow still remains the most common solution applied to the tree rows [9]. This is because, in comparison with various other ground cover options, chemical weed control is effective as well as economical, at the same time ensuring proper conditions for tree growth [14]. Foliar herbicides (glyphosate or glufosinate ammonium) are recommended as relatively safe for the environment [3].

In the successive years of an orchard life cycle, dynamical changes within the weed composition take place. The populations of certain species grow or shrink [18,19]. The weeds, for example *Conyza canadensis* [20], can develop resistance mechanisms to counteract the chemical control method [3], responding to repeated applications of a single herbicide [21]. Some weed species can be present in the orchard only in certain vegetation periods, whereas other ones are observed every year and show a nearly constant frequency [18,19]. As the diameter of the tree canopy increases, the number of weeds found under the tree shrinks [22]. From the point of view of fruit production, it is important to determine the weed abundance levels beyond which particular weed species become harmful for the agricultural landscape [23].

The aim of the study was to estimate the composition and abundance of weed species present during the first 10 years after planting apple trees on three different rootstocks and maintained under a long-term foliar herbicide application regime.

Material and methods

The weed composition and the dominance of individual species occurring in the orchard was assessed. The evaluation began in the year of orchard establishment (2004) and continued for ten years (2013). Apple trees (*Malus domestica* Borkh. 'Ligol') on three rootstocks: P 22 (super-dwarf), P 16 (dwarf), and P 2 (semi-dwarf), were planted in the spring of 2004 at a distance of 3.5 × 1.2 m (2380 trees ha^{-1}) on a haplic luvisol derived from silty light loam at the Fruit Experimental Station (51°06′12″ N, 16°49′52″ E), which belongs to the University of Environmental and Life Sciences in Wrocław, Poland. The experiment was established according to a Randomized Block Design in four replications with five trees per plot surface area (6 m^2). The assessment involved 24 plots.

The herbicide fallow was maintained by 10-year application of foliar herbicides in 1 m wide tree rows. It was based on a mix of glyphosate and MCPA (2-methyl-4-chlorophenoxyacetic acid) at a rate of 4 + 2 L ha^{-1}, with the exception of the autumn of 2008 (only glyphosate – 8 L ha^{-1}). The weeds were treated in spring (in April or May) and summer (mostly in July) and in certain years also in autumn (mostly in November). In the spring and autumn of the year of orchard establishment, only glyphosate (4 L ha^{-1}) was applied, whereas at the end of June the herbicide mix was used.

A permanent grass sod was introduced between the tree rows in the first year after planting the trees. It was mowed several times per vegetation season. The trees were trained into the form of a slender spindle. Fertilization and plant protection were carried out in accordance to the recommendations of the current agronomic methods and the orchard protection program 2015 [24].

The degree of soil coverage by weeds was assessed as the percentage of the total plot surface area (6 m^2) occupied by the individual species. The coverage was estimated in each plot. A non-invasive method for estimation of plant populations, conforming to the methodology of Lipecki and Janisz [19], was employed. The assessments were performed separately for each weed species, while in some cases for the genus. Underrepresented taxa were omitted. The fraction of the plot surface occupied by each species was expressed using a discrete percentage scale: 0, 20, 40, 60, 80, and 100%. As the share of each species was assessed independently, it was impossible to express the relationship between the total percentage of all weed populations at a scale of 100%. The evaluation of the weed cover was made each year in July, before the second application of the herbicides in the vegetative period. The only exception was the year

2011 when the data collection was omitted. The nomenclature of vascular plants was based on Erhardt et al. [25].

The increment of trunk cross-sectional area was calculated based on the diameter of the trunk. The diameter was recorded 30 cm above the soil level on each tree, towards north-south and east-west directions, every year after the tree growth period. The total number of annual shoots was determined only on one tree per plot, every year until the spring of 2008.

The data obtained in the year of orchard establishment and the averaged data from the subsequent 2- or 4-year periods pertaining to the degree of soil coverage by weeds and the growth of the trees were analyzed using one-way analysis of variance for a randomized block design. Prior to the analysis, the data related to the plot coverage by weeds were angularly transformed (by the Bliss function). Additionally, in order to fulfill, at least approximately, the assumptions of analysis of variance exponential transformations were applied to some of the continuous data. The multiple comparisons were performed at the 5% significance level using the Duncan's multiple range test.

Results

In the successive 10 years (2004–2013), the diversity of weed species was observed, which was correlated to precipitation, especially in May and June (Tab. 1, Tab. 2). The total number of observed species was 24, among which eight annual and three perennial species were most frequently noted. The increase in the soil surface covered by weeds was affected by wet weather conditions in the sixth year after tree planting (2009). *Stellaria media* was most dominant among the annual species in the herbicide fallow. *Senecio vulgaris*, *Poa annua*, *Capsella bursa-pastoris*, and *Lamium* spp. were less frequently found. Since the year of orchard establishment, a complete decline of *Elymus repens* was noted. In the subsequent years after planting the trees, *Convolvulus arvensis* and *Cirsium arvense* also completely disappeared. In contrast, the foliar herbicides did not reduce the soil surface coverage by *Taraxacum officinale*. Moreover, the foliar herbicides also significantly increased the growth of *Trifolium repens* and *Epilobium adenocaulon* in the succeeding periods (Tab. 3). In the young orchard, *Chenopodium album* and *Echinochloa crus-galli* were among the most important annual weeds. The presence of these species was significantly lower in the subsequent two-year periods in the fruit-bearing period.

The weed composition in the year of orchard establishment, which included for example *Elymus repens* and *Chamomilla* spp., was determined in comparison to the other periods (Tab. 4). In the next years, the dominance of annual species was observed. During the peak fruit-bearing period, despite several years of maintenance of the herbicide fallow, an increase of the soil surface area covered by perennial weeds was noted. The apple trees on the rootstock P 2 grew stronger in comparison to those on P 16 and P 22 not only during the fruit-bearing period but also in the young orchard (Tab. 5). It was confirmed by a significant increase in the trunk cross-sectional area increment. Regardless of the type of rootstock, up to the spring of 2008 the total length of shoots in the canopy was still similar. It did not affect the weed population in the young orchard. From 2009 the differences in the occurrence of the most important weeds depending on rootstock were not considerable (Tab. 6). The only significant decrease in the population of *Epilobium adenocaulon* and *Trifolium repens* was observed under the canopies of the trees on the semi-dwarf P 2 rootstock in relation to P 22. In contrast, the only mean percentage of the soil surface occupied by the annual weed *Poa annua* was significantly higher in the orchard in the fruit-bearing period.

Discussion

After 10 years of foliar herbicide application, total elimination of some perennial weeds as well as an increased occurrence or almost constant occurrence of some

Tab. 1 Total precipitation during the first six months of the growing season in 2004–2013 (mm).

Year after tree planting	Year	Month						Total I–VI	Total V–VI
		I	II	III	IV	V	VI		
1st – orchard establishment	2004	47.4	40.4	63.4	21.7	33.1	38.7	244.7	71.8
2nd	2005	25.9	44.8	2.9	26.2	122.8	28.8	251.4	151.6
3rd	2006	55.0	33.4	24.9	48.6	16.3	69.1	247.3	85.4
4th	2007	45.8	41.2	48.6	8.2	52.3	104.2	300.3	156.5
5th	2008	57.7	15.0	36.5	74.5	50.5	32.9	267.1	83.4
6th	2009	35.0	67.0	43.8	11.5	87.8	165.9	411.0	253.7
7th	2010	26.0	8.5	32.4	33.2	107.5	34.0	241.6	141.5
8th	2011	22.0	6.5	32.0	26.7	66.0	49.3	202.5	115.3
9th	2012	45.6	32.6	11.8	25.4	26.2	79.4	221.0	105.6
10th	2013	33.0	20.8	24.6	35.3	97.6	98.0	309.3	195.6

Tab. 2 Percentage of the soil surface covered by weed species in the tree rows from the year of orchard establishment (2004) up to the tenth year after planting the trees (2013), mean for the rootstocks.

No.	Specification	Year after tree planting								
		1st – orchard establishment	2nd	3rd	4th	5th	6th	7th	9th	10th
	Annuals									
1	*Amaranthus retroflexus*									
2	*Capsella bursa-pastoris*									
3	*Chamomilla* spp.									
4	*Chenopodium album*									
6	*Conyza canadensis*									
5	*Echinochloa crus-galli*									
7	*Erophila verna*									
8	*Fallopia convolvulus*									
9	*Fumaria officinalis*									
10	*Galinsoga parviflora*									
11	*Geranium* spp.									
12	*Lamium* spp.									
13	*Medicago lupulina*									
14	*Poa annua*									
15	*Polygonum aviculare*									
16	*Polygonum persicaria*									
17	*Senecio vulgaris*									
18	*Stellaria media*									

Tab. 2 Continued

No.	Specification	Year after tree planting								
		1st – orchard establishment	2nd	3rd	4th	5th	6th	7th	9th	10th
19	*Veronica* spp.	≤20%	≤20%	≤20%	–	–	≤20%	–	–	≤20%
20	*Vicia* spp.	≤20%	–	–	–	–	–	–	≤20%	–
21	*Viola arvensis*	≤20%	≤20%	–	–	≤20%	–	–	≤20%	≤20%
Perennials										
1	*Cirsium arvense*	≤20%	≤20%	≤20%	≤20%	–	–	≤20%	–	–
2	*Convolvulus arvensis*	20–40%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	–	–
3	*Elymus repens*	60–80%	–	–	–	–	–	–	–	–
4	*Epilobium adenocaulon*	–	–	≤20%	≤20%	≤20%	≤20%	20–40%	20–40%	≤20%
5	*Equisetum arvense*	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%
6	*Malva sylvestris*	–	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%
7	*Plantago major*	≤20%	≤20%	–	≤20%	≤20%	–	–	–	–
8	Poaceae – different species	–	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%
9	*Rumex crispus*	–	–	–	≤20%	≤20%	–	–	–	≤20%
10	*Sonchus arvensis*	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%	≤20%
11	*Taraxacum officinale*	≤20%	≤20%	20–40%	20–40%	20–40%	60–80%	20–40%	40–60%	≤20%
12	*Trifolium repens*	≤20%	≤20%	≤20%	≤20%	20–40%	60–80%	60–80%	20–40%	20–40%
13	*Tussilago farfara*	≤20%	–	–	–	–	–	–	–	–

Species occurring:

- (≤20%) – in small numbers up to 20% of soil surface cover
- (20–40%) – between 20–40% of soil surface cover
- (40–60%) – between 40–60% of soil surface cover
- (60–80%) – numerously – between 60–80% of soil surface cover
- (>80%) – dominantly – over 80 up to 100% of soil surface cover
- (–) – absence of the species.

other perennial weeds were observed in the apple orchard. As early as 1 year after the establishment the orchard, *Elymus repens* was eliminated, and several years later – *Convolvulus arvensis*. These two are the most important weed species predominant in orchards in the temperate climate [2,3]. *Convolvulus* spp. also occur in warmer Mediterranean regions where fruit trees are grown [26], in particular on soils of higher organic carbon content [1]. In her Bulgarian study, Tasseva [12] showed that the application of glyphosate only once a year in combination with tillage was insufficient to contain the weed population. Glyphosate-based herbicides, while effective in controlling *Elymus repens* [2], have a small impact on *Taraxacum officinale* [27] – another species that is considered as one of the most notorious weeds found in the orchards of Central and Eastern Europe [4–7] both within and between rows [23]. The occurrence of *Taraxacum* spp. clearly disappears towards the southern [12,26] and south-western parts of the continent [13]. Similarly as in the study by Lisek [27], instead

Tab. 3 Changes in the mean percentage of the soil surface covered by the most important weed species in the tree rows in the succeeding periods during 2004–2013, mean for the rootstocks.

Period		Weed species										
		annual								perennial		
		Capsella bursa-pastoris	*Chenopodium album*	*Echinochloa crus-galli*	*Erophila verna*	*Lamium* spp.	*Poa annua*	*Senecio vulgaris*	*Stellaria media*	*Epilobium adenocaulon*	*Taraxacum officinale*	*Trifolium repens*
1st year – orchard establishment		23.3*	65.0 ^{c}	35.0 ^{c}	16.7 ^{b}	26.7*	35.0*	13.3 ^{a}	80.0 ^{b}	-	13.3 ^{a}	6.7 ^{a}
Young orchard	2nd–3rd year mean	29.2	30.0 ^{b}	55.0 ^{d}	5.0 ^{a}	30.8	29.2	47.5 ^{bc}	35.8 ^{a}	1.7 ^{a}	24.2 ^{b}	10.0 ^{a}
	4th–5th year mean	32.5	35.0 ^{b}	27.5 ^{bc}	-	30.0	26.7	31.7 ^{b}	43.3 ^{a}	17.5 ^{b}	25.8 ^{bc}	25.0 ^{b}
Fruit-bearing period	6th–7th year mean	21.7	13.3 ^{a}	19.2 ^{ab}	15.8 ^{ab}	26.7	49.2	50.8 ^{c}	73.3 ^{b}	23.3 ^{c}	49.2 ^{d}	68.3 ^{c}
	9th–10th year mean	18.3	10.0 ^{a}	9.2 ^{a}	24.2 ^{b}	37.5	29.2	38.3 ^{bc}	47.5 ^{a}	20.0 ^{bc}	33.3 ^{c}	34.2 ^{b}

Within individual columns, the means marked with different letters differ significantly according to Duncan's test at the confidence level of 95%. * No significant differences.

of bringing about complete elimination, the application of foliar herbicides in the conditions of Lower Silesia only resulted in annual suppression of this species. A similar problem, occurring primarily during the fruit-bearing period in the orchard, applied to a large population of *Trifolium repens*, a weed commonly occurring in orchards [4], especially between rows of trees [23]. Also Harrington et al. [14] considered the suppression of *Trifolium repens* by glyphosate as insufficient, given the invasive character shown by this species in herbicide fallow. Likewise, during the fruit-bearing period a gradual increase of *Epilobium adenocaulon* was observed. This is a reason for concern, since control of this weed by glyphosate-based herbicides is less effective than in case of *Taraxacum officinale* and the plants regrow as early as within 2 months following the application [27].

The suppression of selected annual species by glyphosate reaches a level of 85–100% and no regrowth is observed [27]. However, in the presented 10-year study, each year a substantial proportion of therophytes was noted in the whole weed population. *Stellaria media* and *Senecio vulgaris* were the dominant species, followed by *Poa annua* and *Lamium* spp. In Europe, the specific composition of annual weed populations varies within the boundaries of a single fruit tree-growing region [12,13]. Three years of observations were sufficient to show that the population size remains constant or fluctuates in consecutive vegetation periods [12,26]. In the presented study, the abundance of *Stellaria media* was relatively stable. According to Lipecki [2], it tends to increase its dominance in herbicide strips, yet does not compete with the trees, especially older ones, to a large degree. Nevertheless, together with *Chenopodium album*, *Chamomilla* spp., and *Elymus repens*, the population of this species probably contributed to significant retardation of tree growth in the first year after planting the orchard. This impact was particularly pronounced in case of the super-dwarf P 22 and dwarf P 16 rootstocks, as none of the dwarfing rootstocks that are currently in use are resistant to weed competition, diseases, pests, and drought occurring together at the same time [28].

The high precipitation, which characterized the sixth year after the planting of the apple trees (2009), significantly contributed to an increased dominance of the most important weed species. Notable was the percentage of *Stellaria media*, with the dominance amounting to nearly 100%, followed by two perennial species: *Taraxacum officinale* and *Trifolium repens*. As weeds easily compete with cultivated

Tab. 4 Changes in the mean percentage of the soil surface covered by the most important weed species in the tree rows in the individual periods during 2004–2013, mean for the rootstocks.

No.	Weed species	Period	
		1st year – orchard establishment	
1	*Chamomilla* spp.	63.3 [b]	
2	*Chenopodium album*	65.0 [b]	
3	*Echinochloa crus-galli*	35.0 [a]	
4	*Elymus repens*	65.0 [b]	
5	*Lamium* spp.	26.7 [a]	
6	*Poa annua*	35.0 [a]	
7	*Stellaria media*	80.0 [b]	
		Young orchard	
		2nd–3rd year mean	4th–5th year mean
1	*Capsella bursa-pastoris*	29.2 [a]	32.5*
2	*Chenopodium album*	30.0 [a]	35.0
3	*Echinochloa crus-galli*	55.0 [c]	27.5
4	*Lamium* spp.	30.8 [a]	30.0
5	*Poa annua*	29.2 [a]	26.7
6	*Senecio vulgaris*	47.5 [bc]	31.7
7	*Stellaria media*	35.8 [ab]	43.3
		Fruit-bearing period	
		6th–7th year mean	9th–10th year mean
1	*Epilobium adenocaulon* *Erophila verna***	23.3 [a]	24.2*
2	*Lamium* spp.	26.7 [a]	37.5
3	*Poa annua*	49.2 [b]	29.2
4	*Senecio vulgaris*	50.8 [b]	38.3
5	*Stellaria media*	73.3 [c]	47.5
6	*Taraxacum officinale*	49.2 [b]	33.3
7	*Trifolium repens*	68.3 [bc]	34.2

Explanation: see Tab. 3. * No significant differences. ** *Epilobium adenocaulon* – 6th–7th year mean; *Erophila verna* – 9th–10th year mean.

plants [3], an increase in the population of the former one probably resulted in higher water and nutrient intake. This is confirmed by Lehoczky et al. [29] who found a negative correlation between weediness and soil water content. The rootstock factor, determining the fruit tree crown size, had a much smaller influence on the level of weed infestation than the water conditions. The phenomenon of significant weed suppression under a large tree canopy, reported by Silva et al. [22], was observed in the present study only in case of *Epilobium adenocaulon* and *Trifolium repens*. These two species became dominant late during the fruit-bearing period. The significant suppression of their populations that occurred at that time under the trees grafted on the semi-dwarf P 2 rootstock could have resulted from the larger shadow cast by their crowns than in case of the super-dwarf P 22 rootstock. In contrast, no such suppression was observed in the populations of *Taraxacum officinale* and the annual species. The only exception was *Poa annua*. This weed, which is characterized by low site requirements [2], showed significantly higher dominance in the rows of the P 2 apple trees than in the herbicide strips of the smaller trees on the P 16 and P 22 rootstocks.

Similarly as in the case of other recommended methods of orchard floor management, when used in isolation, herbicide fallow is not a sufficiently effective, economical and easy to apply approach to orchard weed control [3]. This has been confirmed by the observations of the segetal flora occurring under the apple trees growing in the Lower Silesia region. Consistently maintained herbicide fallow did not significantly suppress the populations of three notorious perennial weeds. In addition, between subsequent applications of the herbicides, abundant populations of several annual species were noted. The elimination of certain weeds cannot be based only on herbicide fallow. In order to prevent the development of a weed flora that is resistant to repeated application of a single weed control method, various approaches should be used in alternation [3,30].

Tab. 5 Growth of 'Ligol' apple trees depending on the rootstock in 2004–2013.

Rootstock	Increment in trunk cross-sectional area (cm^2) period			Total length of annual shoots (m)
	1st year – orchard establishment (spring 2004 – spring 2005)	young orchard (spring 2005 – spring 2009)	fruit-bearing period (spring 2009 – spring 2013)	young orchard (spring 2004 – spring 2008)
P 22 super-dwarf	0.08*	3.61 [a]	6.15 [a]	5.91*
P 16 dwarf	0.05	2.99 [a]	4.86 [a]	7.27
P 2 semi-dwarf	0.12	6.95 [b]	15.51 [b]	10.94

Explanation: see Tab. 3. * No significant differences.

Tab. 6 Changes in the mean percentage of the soil surface covered by the most important weed species in the tree rows depending on the rootstock during the fruit-bearing period, 6th–10th year mean (2009–2013).

Rootstock	Weed species: annual								perennial		
	Capsella bursa-pastoris	*Chenopodium album*	*Echinochloa crus-galli*	*Erophila verna*	*Lamium* spp.	*Poa annua*	*Senecio vulgaris*	*Stellaria media*	*Epilobium denocaulon*	*Taraxacum officinale*	*Trifolium repens*
P 22 super-dwarf	20.0*	11.3*	12.5*	13.8*	33.8*	30.0 [a]	37.5*	63.8*	33.8 [b]	38.8*	52.5 [b]
P 16 dwarf	17.5	13.8	12.5	20.0	33.8	36.3 [a]	51.3	57.5	15.0 [a]	43.8	63.8 [b]
P 2 semi-dwarf	22.5	10.0	17.5	26.3	28.8	51.3 [b]	45.0	60.0	16.3 [a]	41.3	37.5 [a]

Explanation: see Tab. 3. * No significant differences.

Conclusions

Ten years of foliar herbicide application within the tree rows contributes to a change in the weed species composition of plants occurring in an orchard; depending on the species, it leads to the elimination or reduction of annual or perennial weeds at a varying degree, or has no influence on their abundance.

As a result of improved water conditions, a significant increase in dominant weeds is noted in the apple tree rows.

Due to the changed growth conditions for plants occurring in the rows under the apple trees on the semi-dwarf P 2 rootstock, a significant reduction in soil surface covered by *Epilobium adenocaulon* and *Trifolium repens*, perennial, foliar herbicide-tolerant weed species, can be achieved compared to the super-dwarf P 22 rootstock.

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Skład gatunkowy chwastów w sadzie pod wpływem długotrwałego stosowania dolistnych herbicydów

Streszczenie

Skład gatunkowy ugoru herbicydowego był oceniany na terenie Stacji Badawczo-Dydaktycznej Uniwersytetu Przyrodniczego we Wrocławiu w pierwszych dziesięciu latach po założeniu sadu. Drzewa odmiany 'Ligol' na podkładkach półkarłowej P 2, karłowej P 16 i superkarłowej P 22 wysadzono wiosną 2004 roku w rozstawie 3.5 × 1.2 m. Aplikację dolistnych herbicydów prowadzono corocznie, dwu- lub trzykrotnie w okresie wegetacji w rzędach drzew jabłoni o szerokości 1 m. W międzyrzędziach utrzymywano murawę.

Dziesięcioletnie utrzymywanie ugoru herbicydowego przyczyniło się do zmiany składu fitosocjologicznego roślin w sadzie. Skład gatunkowy chwastów pozostawał w zależności od reakcji poszczególnych gatunków na aplikację herbicydów dolistnych. W pierwszym roku po posadzeniu jabłoni obserwowano całkowitą eliminację *Elymus repens*, a w latach następnych również innych wieloletnich chwastów – *Convolvulus arvensis* i *Cirsium arvense*. Utrzymywanie ugoru herbicydowego nie wpłynęło na ograniczenie *Taraxacum officinale*. W okresie pełni owocowania drzew wzrastał udział powierzchni gleby pokrytej przez rośliny w znacznym stopniu tolerujące herbicydy dolistne – *Trifolium repens* i *Epilobium adenocaulon*. Populacja tych chwastów była jednak istotnie ograniczana w rzędach silniej rosnących drzew na półkarłowej podkładce P 2 w porównaniu z P 22. Dominującym chwastem jednorocznym była *Stellaria media*. Najczęściej towarzyszyły jej: *Senecio vulgaris*, *Poa annua*, *Capsella bursa-pastoris* i gatunki z rodzaju *Lamium*. Istotny wzrost liczebności populacji dominujących jedno- i wieloletnich chwastów w rzędach drzew notowano w sezonach wegetacyjnych z opadami powyżej normy i wiązało się z poprawą warunków wodnych w sadzie.