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INFLUENCE OF ROOTSTOCK AND SOIL CONDITIONER OF THE GROWTH AND YIELD OF YOUNG APPLE TREES PLANTED IN VARIOUS PLACES CHARACTERIZED BY DIVERSE LONG-TERM METHOD OF SOIL MANAGEMENT

Summary

Intensified production of apples makes a fruit grower establish an orchard immediately after grubbing up an old one. Then, if replanting does not occur, stands for new trees can be significantly affected by soil properties conditioned by a long- term way of its management. Another problem in horticulture is water deficit. Due to diminishing water reserves there is a need to improve sorption capacity of soils. The use of polymer supersorbents provides one of possible solution to the mentioned problem.

The aim of the work was the assessment of the effect of a long- term application of herbicide fallow, black foil, black agrotextile and pine bark in trees rows in an old orchard, on growth and fruiting of apple trees 'Ligol' planted immediately after grubbing up the old trees. Research also involved potential modification of the above effect caused by rootstock type: M.9, M 26 and P 60, as well as by additionally applied agrogel. The growth and yielding of young trees 'Ligol', related to a long-term system of soil management in the old orchard, was highly diversified and depended on the type of rootstock and agrogel applied. Yielding of the trees was also connected with the year of cultivation.

Key words: *Malus*, agrogel, herbicide fallow, folia, polypropylene fabric, pine bark

INTRODUCTION

Recently, it has been a common practice to establish a new orchard replacing the old one. In that case soil properties conditioned by previous long-term way of soil cultivation can be of the highest importance.

Conducting research on the effect of a long-term application of herbicide fallow on soil properties there was recorded insignificant increase in soil acidity and diminished soil porosity. Yet continuity of interstices was preserved and the newly-formed crust on soil surface was not an obstacle for soil aeration and water percolation capacity due to wide cracks featuring that soil. Organic mulches reduce water loses from the soil. Water retention in the soil increases according to the increase in organic residues on soil surface [Szewczuk, 2004]. Application of natural mulches provides for elevated values of humus content and, therefore, improves soil fertility. Pine bark mulch favoured undesired soil acidity, while the influence of organic mulches on the content of mineral components and their accessibility for plants seemed to be not a univocal one [Licznar et al., 2000]. The mentioned conditions bring about higher enzymatic and microbiological activity of soil environment. Due to intensive development of soil fauna, mulching with straw in the rows of cherry trees contributed to the occurrence of highly advantageous aggregate structure of the soil [Słowińska-Jurkiewicz and Paluszek, 2001]. Synthetic mulches reduce evaporation from the soil, and therefore they increase water content in the soil, as well as facilitate mineralization of humus, increasing accessibility of mineral components. Moreover, synthetic materials do not cause the decrease in nitrogen level in the soil. However, the results regarding enzymatic activity of the soil seem to be highly diverse [Bielińska and Lipecki, 1998].

Soil management should provide and support soil fertility. Traditional methods of improving structure and physical properties consist in increasing its content of organic substance, and of waterproof character of soil aggregates, as well as soil retention and permeability. All those traditional treatments can be enhanced by introduction of special synthetic preparations, like macromolecular polymers and agrogels [Leciejewski, 2008]. These substances, also called soil conditioners, are able to bound elementary molecules into waterproof soil aggregates. Agrogel is a non-toxic polymer of acrylic acid, polyvinyl alcohol featuring strong absorption and accumulation both of water solutions of such substances as fertilizers or pesticides and of water itself. Due to its sorptive abilities agrogel has been applied in different fields of gardening. 95% of water absorbed and accumulated by supersorbents is available for plants root system because water loses, resulting from evaporation and percolation to deeper soil layers, are reduced to minimum. Apart from absorbing high amounts of water, agrogels are permanent and not toxic to plants. For this reason polymeric sorbents can be used to control the results of replantation disease. Appropriately introduced polymers provide for higher yields of plants by from a few to several tens per cent. Permanent aggregates can affect soil compaction, water – air conditions, as well as physico-chemical, chemical and biological properties of the soil which are decisive, as far as soil fertility and yielding potential are concerned [Paluszek, 2003].

The aim of the work was the assessment of the effect of a long-term soil management system in trees rows on growth and yielding of apple trees 'Ligol' cv., planted immediately after grubbing up of the old apple trees orchard. Research also involved an attempt to determine if the type of a rootstock and additionally used polymeric sorbent could modify the mentioned effect.

MATERIALS AND METHODS

The experiment was conducted in the years 2006-2009 in Research Station, belonging to Department of Horticulture at Wrocław University of Environmental and Life Sciences. Two-year-old apple trees of 'Ligol'cv., as knipboom type, on M.9, M 26, P 60 rootstock were planted in the spring 2006, in 3.5 x 1.0 m spacing, exactly on the same plots where the following soil cultivation systems in trees rows had been applied for 11 years: herbicide fallow, agrotextile, black foil and pine bark. The second factor of the experiment was application of agrogel in the form of granules of 0.5-0.7 g/cm^3 density, placed inside geotextile in the form of 10-cm wide tape and the length adjusted to that of a plot. Agrogel, closed in geotextile and swollen as a result of water absorption, does not cause any deterioration of mechanical properties of the soil, nor of its permeability. This preparation also allows roots to have free access to absorber water and is easy to apply.

The experiment was established according to randomized split-block method, in three replications, with three trees on each plot. The trees were fruiting as early as in the year they were planted. Fruit yield and mean fruit weight were recorded for each tree. Plant vigour was assessed taking into account the increase in cross section area of tree trunk, the number of one-year shoots and the sum of their length. To determine the relation between trees growth and their yielding there was estimated a crop efficiency index. The results were subjected to statistical analysis with the use of analysis of variance and t-Duncan test was applied to estimate significance of differences at 5% significance level.

RESULTS AND DISCUSSION

Reaction to the examined factors depended on the type of a rootstock and the age of trees. Trees on M.9 rootstock, growing at the stand previously cultivated with the use of pine bark there was recorded significant decrease in yielding in the first year of cultivation. Application of agrogel affected the increase in fruit yield in the year of planting trees, although it brought about decreased yielding in the fourth year of cultivation (Table 1). In the case of trees on M 26 rootstock, the influence of interaction on the side of the examined factors could be observed in the third year of trees cultivation.

Table 1. Influence of agrogel and long-term methods of soil management on yield of apple trees on M.9 rootstock

Treatment	Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Yield, kg · tree^{-1}, in 2006					
Control	0.29 ABa	0.23 ABa	0.34 Ba	0.10 Aa	0.24 A
Agrogel	0.45 Aa	0.40Aa	0.38 Aa	0.27 Aa	0.37 B
Mean	0.37 B	0.31 B	0.36 B	0.19 A	*
Yield, kg · tree^{-1}, in 2007					
Control	1.33	2.00	1.44	2.63	1.85
Agrogel	2.52	3.03	1.88	2.73	2.54
Mean	1.93	2.51	1.66	2.68	**
Yield, kg · tree-1, in 2008					
Control	3.82	3.33	2.96	2.64	3.19
Agrogel	3.36	4.54	2.68	2.97	3.38
Mean	3.59	3.94	2.82	2.81	**
Yield ,kg · tree^{-1}, in 2009					
Control	6.17	3.94	5.02	5.48	5.15 b
Agrogel	3.47	1.83	3.47	2.09**	2.71 a
Mean	4.82 A	2.89 A	4.24 A	3.78 A	
Total yield, kg · tree^{-1}, for 2006-2009					
Control	11.61	9.50	9.78	10.86	10.43
Agrogel	9.79	9.80	8.41	8.06	9.02
Mean	10.70	9.64	9.09	9.49	**

* Means marked with the same letter do not significantly differ at $\alpha = 0.05$;
A for method of soil management, a for agrogel
** No significant differences for soil management x agrogel

Considering control treatment, significantly higher yield was obtained from trees growing at the stand after agrotextile in comparison to trees planted at the stand where foil and pine bark had been used for many years. Regarding the use of agrogel, trees growing at the stand after agrotextile and pine bark featured more advantageous yielding than those planted on previously applied herbicide fallow. In the third year of cultivation agrogel favourably influenced the yielding of trees growing at the stand after pine bark. Agrogel also enabled higher yield from trees on M 26 rootstock growing at the place where black foil mulch had been used in an old orchard (Table 3). For trees on P 60 rootstock response to the examined factors could be observed in the second, third and fourth year of cultivation. The second and the fourth year featured better fruiting for trees growing at the stand after herbicide fallow than trees planted where pine bark and agro-textile had been applied (only in the second year). Agrogel resulted in increased yielding in the third year of trees growth, especially at the stand after black foil and organic mulch. When agrogel was introduced, trees growing on previous herbicide fallow characterized worse yielding than those occupying the stand after pine bark (Table 5). The factors subjected to examination did affect

the weight of fruits from trees on M.9 and P 60 rootstock (Table 2). From trees on M.9 rootstock growing at the stand after foil there were harvested, within four-year-lasting cultivation, fruits featuring higher weight than fruits from trees planted at the stand after agrotextile, at the same level of yielding.

Table 2. Influence of agrogel and long-term methods of soil managementon mean fruit weight of apples

Treatment		Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Mean fruit weight 2006-2009 (g)						
M.9	Control	236 ABa*	253 Ba	220 Aa	220 Aa	233 a
	Agrogel	245 ABa	234 ABa	223 Aa	258 Bb	241 a
	Mean	241 AB	243 B	222 A	239 AB	
M 26	Control	252	236	247	244	245
	Agrogel	251	247	219	235	238
	Mean	252	241	233	239	**
P 60	Control	244 Ba	204 Aa	216 ABa	224 ABa	222 a
	Agrogel	264 Aa	217 Aa	251 Ab	237 Aa	242 b
	Mean	254 C	211 A	234 BC	231 AB	

*For explanation, see Table 1.

Table 3. Influence of agrogel and long-term methods of soil management on yield of apple trees on M 26 rootstock

Treatment	Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Yield, kg · tree^{-1}, in 2006					
Control	0.68	0.47	1.00	0.58	0.68
Agrogel	1.16	1.29	0.56	0.82	0.96
Mean	0.92	0.88	0.78	0.70	**
Yield, kg · tree^{-1} in 2007					
Control	1.77	2.34	1.24	2.31	1.92
Agrogel	2.26	2.48	1.58	1.80	2.03
Mean	2.01	2.40	1.41	2.06	**
Yield, kg · tree^{-1}, in 2008					
Control	5.10 ABCa	3.00 Aa	5.89 Ca	3.98 ABa	4.49 a
Agrogel	3.19 Aa	4.88 ABa	5.20 Ba	6.42 Bb	4.92 a
Mean	4.14 A	3.94 A	5.55 A	5.19 A	
Yield, kg · tree^{-1}, in 2009					
Control	2.02	1.97	1.56	3.91	2.37
Agrogel	4.46	5.17	3.46	1.79	3.72
Mean	3.24	3.57	2.51	2.85	**
Total yield, kg · tree-1, for 2006-2009					
Control	9.57 Aa	7.79 Aa	9.70 Aa	10.77 Aa	9.46 a
Agrogel	11.07 Aa	13.82 Ab	10.80 Aa	10.82 Aa	11.62 a
Mean	10.32 A	10.80 A	10.25 A	10.80 A	

For explanation, see Table 1.

As far as control conditions are concerned, fruit from trees growing at the stand after foil reached higher weight as compared to those cultivated at the stand where agrotextile and pine bark were previously applied. In the conditions of agrogel usage, fruit of higher weight were recorded for trees planted at the stand after pine bark as compared to those growing where agro-textile was previously used. In the case of trees on P 60 rootstock, significantly higher fruit weight was obtained for trees coming from previous herbicide fallow in comparison to trees planted at the stand after long-term usage of foil and pine bark. Differences in the weight of fruit from trees planted after herbicide fallow and black foil application proved to be significant. Considering control conditions, agrogel advantageously affected the weight of fruits originating from trees growing at the stand after agro-textile.

The assessment of trees growth made it possible to conclude that the examined factors did not influence on radiation growth of 'Ligol' cv. on M 26 rootstock in the years 2006-2009 (Table 4). A long-term cultivation system in an old orchard evidently affected the increase in cross section area of tree trunk regarding apple trees on the remaining rootstock. Trees on M.9 rootstock featured the weaker growth at the stand after pine bark usage. Trees on P 60 rootstock characterized the weakest growth when planted where herbicide fallow and agrotextile were previously applied. Agrogel had influence on stronger radiation growth of trees on P 60 rootstock, growing at the stand after black foil and pine bark. The analyzed factors did not affect the value of crop efficiency index for trees on M26 rootstock (Table 6). The trees on M.9 rootstock, growing at the stand after foil, featured significantly lower crop efficiency index as compared to trees planted where pine bark had been used. Agrogel advantageously affected this index in case of trees on P60 rootstock. Cultivation of those trees at the stand after herbicide fallow, especially when compared to trees cultivated where agro-textile had been used.

Table 4. Influence of agrogel and long-term methods of soil management on mean increment in TCSA of apple trees since spring 2006 to autumn 2009

Treatment		Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Mean increment in TCSA 2006-2009 (cm · tree^{-2})						
M.9	Control	5.15 Ba	5.85 Ba	6.54 Ba	3.97 Aa	5.38 a
	Agrogel	6.52 Ba	6.10 Ba	5.14 ABa	4.04 Aa	5.45 a
	Mean	5.84 B	5.98 B	5.84 B	4.00 A	
M 26	Control	8.56	7.90	8.66	8.52	8.41
	Agrogel	8.38	8.28	7.62	7.00	7.81
	Mean	8.47	8.09	8.14	7.76	**
P 60	Control	7.28 Aa	7.81 Aa	7.30 Aa	7.70 Aa	7.52 a
	Agrogel	7.86 Aa	9.81 Bb	8.02 Aa	10.17 Bb	8.96 b
	Mean	7.57 A	8.80 B	7.66 A	8.94 B	

* For explanation, see Table 1.

Table 5. Influence of agrogel and long-term methods of soil managementon yield of apple trees on P 60 rootstock

Treatment	Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Yield, kg · tree^{-1}, in 2006					
Control	0.68	0.97	0.55	0.54	0.69
Agrogel	0.83	1.60	1.01	1.26	1.17
Mean	0.76	1.28	0.78	0.90	**
Yield ,kg · tree^{-1}, in 2007					
Control	1.50	1.58	1.27	1.70	1.51 a
Agrogel	2.74	2.19	1.51	1.36**	1.95 a
Mean	2.12B	1.89 AB	1.39 A	1.53 A	
Yield, kg · tree^{-1}, in 2008					
Control	4.88 Aa	2.90 Aa	4.75 Aa	3.76 Aa	4.07 a
Agrogel	4.16 Aa	5.23 ABb	5.36 ABa	6.42 Bb	5.29 b
Mean	4.52 A	4.07 A	5.06 A	5.09 A	
Yield, kg · tree^{-1} in 2009					
Control	6.44	3.55	4.81	2.74	4.39 a
Agrogel	5.84	4.63	2.52	2.95**	4.00 a
Mean	6.14 B	4.09 AB	3.67 AB	2.85 A	
Total yield, kg · tree^{-1}, for 2006-2009					
Control	13.51	9.00	11.40	8.73	10.66
Agrogel	13.56	13.65	10.39	12.03	12.41
Mean	13.54	11.33	10.90	10.38	**

* For explanation, see Table 1.

Table 6. Influence of agrogel and long-term methods of soil management on mean crop efficiency index of apple trees in 2006-2009 years

Treatment		Herbicide fallow	Black foil	Agro-textile	Pine bark	Mean
Mean crop efficiency index (kg· cm^{-2})						
M.9	Control	0.64 Aa	0.53 Aa	0.59 Aa	0.75 Aa	0.63 a
	Agrogel	0.56 Aa	0.58 Aa	0.58 Aa	0.66 Aa	0.60 a
	Mean	0.63 AB	0.56 A	0.59 AB	0.71 B	
M 26	Control	0.50	0.44	0.52	0.52	0.49 a
	Agrogel	0.57	0.67	0.51	0.53	0.57 a
	Mean	0.54	0.56	0.52	0.53	**
P 60	Control	0.62 Ba	0.50ABa	0.46 Aa	0.43 Aa	0.50 a
	Agrogel	0.64 Ba	0.62 ABa	0.50 Aa	0.62 ABa	0.59 b
	Mean	0.63A	0.56 A	0.48 A	0.53 A	

* For explanation, see Table 1.

Results obtained in the experiment, regarding the yielding of young apple trees ‘Ligol’ cv. on the examined rootstocks, are of lower values as compared to those reported by Bielicki et al., [1999], but comparable to the results obtained

by Gudarowska. et al., [2006]. Moderate yielding could result from trees fruiting in the year they are planted. The obtained yield size could also be a consequence of cultivation introduced immediately after grubbing up the old orchard.

Observed influence of a long-term system of soil cultivation in rows, applied in the old orchard, on growth and yielding of trees in the new orchard proves high diversity of soil environment, resulting from a long-term usage of herbicide fallow and mulches. Investigations by Licznar et al. (2000) showed that after six years of application of different cultivation methods in trees rows, the best stand occurred to be that after pine bark usage. Soil mulched with pine bark featured the highest level of C-org. and considerable richness in N-org. The lowest amount of C-org., yet the highest of quantity of N-org., was recorded for the stand after agro-textile. The lowest values of N-org content were determined at the stand where black foil mulch had been used. A long-term mulching using pine bark and black foil resulted in the increase in acidity of the examined soil [Szewczuk and Licznar-Małańczuk, 1998]. The effect of a long-term application of the same treatments in monoculture lasting for a number of years on soil properties can be definitely prolonged. That statement can be confirmed by research results by Szewczuk [2004], who observed continuously advancing trees growth in spite of the fact that mulching with pine bark had been abandoned.

CONCLUSIONS

1. The growth and yielding of young trees ‘Ligol’, related to a long-term system of soil management in the old orchard, was highly diversified and depended on the type of rootstock and agrogel applied.
2. Yielding of the trees was also connected with the year of cultivation. Moderate yielding could result from trees fruiting in the year they are planted.
3. Obtained yield size could also be a consequence of cultivation introduced immediately after grubbing up the old orchard.
4. The effect of a long-term application of the some treatments in monoculture lasting for many years on soil properties can be definitely prolonged.

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