Annals of the Academy of Romanian Scientists
Series on Agriculture, Silviculture and Veterinary Medicine Sciences
ISSN 2344-2085 Volume 1, Number 1/2012

INFLUENCE OF THE SOIL MANAGEMENT SYSTEM ON SOME CHEMICAL COMPONENTS IN 3 SOIL TYPES FROM A HIGH DENSITY APPLE ORCHARD

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Abstract. Among technological measures practiced in intensive orchards the soil management systems presents a special importance both because of modification of soil properties and because of their evident influence of trees behaviour. To quantify the effects of soil management system from an apple intensive orchard with the Starkrimson cultivar grafted on MM 106, on some soil chemical components, in the period 1985-2005, some investigations were done inside of Research Institute for Fruit Growing Pitesti, Romania. It was organized the following experimental scheme: A Factor, soil type, with 3 graduation; B Factor, soil management system, with two graduation on average on the two soil management systems and 0-60 cm soil depth, on the eutricombosol with colluvic characters, versus typical eutricombosol, the humus content was higher by 23%, the potassium content by 57%, the base exchange materials by 69% and hidrolytic acidity by 33%. On average on three soil types and 0-60 cm soil depth, maintenance of sod strips versus cultivated soil, determined an increase of humus content by 17% and of base status by 8%. Between the studied 8 soil chemical components significant correlations were established with a higher intensity on 0-20 cm soil depth.

Key words: humus, phosphorus, potassium, mowed sod strips

1. Introduction

Among the technological practices applied in the high density orchards, the soil management systems are particularly important both due to the modification of soil properties and also for the obvious influence on the trees behavior. The effects of the soil management systems on the soil chemical modification in the fruit orchards were reported in many works (Haynes, 1980; Haynes and Goh, 1980, 1980 a; Hogue and Nielsen, 1987; Merwin, 1991; Welker and Glenn, 1988; Merwin and Stilles, 1994, Lipecki and Berbec, 1997, Scribbs and Scroch, 1986, etc.).

The studies of the authors above – mentioned dealed generally with one type of soil found particularly on flat lands, the investigations taking a relatively short time. To sum up the effects of soil management systems for a longer period (20 years) on the chemical components some investigations on 3 soil types in a high density apple orchard located on a slope land were carried out (at the Research Institute for Fruit Growing Piteşti - Mărăcineni).

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2. Material and method

The investigations were carried out in a high density apple orchard, situated on a hillside with a length of line on the greatest slope of 200 m and a slope of 6-12%. The trees were planted at 3.6 m between rows and 1.5 m between trees on the row. It was organized the following experimental scheme:

Factor A - soil type, with the following graduations: a_1 = eutricombosol with colluvic character (CE), a_2 = slightly eroded eutricombosol (SEE) a_3 = typical eutricombosol (TE). *Factor B* – soil management system between tree rows: b_1 = cultivated, performed by a fall plowing to 12-14 cm and repeated disking during the vegetation period, b_2 = 2.4 – 2.6, wide mowed sod strips performed by sowing of *Lolium perenne*. Soil samples were taken from each of the graduations of the experimental factors. Samples were collected on depths 0-20 cm, 20-40 cm, 40-60 cm. It was determined humus - %, phosphorus - ppm, potassium - ppm, pH, total exchangeable bases - me, hydrolytic acidity -me , cation exchange capacity - %, base status - %.

3. Results

3.1. Soil and management system influence on the values of chemical components analyzed (average values of graduation of A, B experimental factors).

3.1.1. Soil influence

On the average, for the two soil management systems and for the 3 sampling depths, the humus content in CE soil was higher by 22-23% versus to the value of the same characteristic in SEE and TE soils. Under the same conditions, the value of K content in CE soil was higher by 10% versus the value recorded in SEE soil and by 57% versus. the value of TE soil. Also, the value of hydrolytic acidity in CE soil was higher by 15% versus the value recorded in SEE soil and by 33% versus that recorded in TE soil.

Towards the above order, where the 3 soil types studied were classified, for the chemical components related to humus, K and hydrolytic acidity, contents for the other chemical components related to pH values, total exchange bases, cation exchange capacity and base status, the classification of the 3 soil types was differently. Therefore, on the average for the 2 soil management systems and 3 soil sampling depths, pH value of SEE soil was 2% higher versus. the values of CE and TE soils. At the same time, the value of total exchangeable bases recorded on SEE soil was higher by 6% than that of CE soil and by 79% than on TE soil. Similarly, the value of cation exchange capacity recorded on SEE soil was higher by 4% versus the value recorded on CE soil and by 52% versus that on TE soil. Also, the base status recorded on SEE soil was higher by 2% versus that on CE soil and by 36% versus that on TE soil.

In case of P, the classification of the 3 soil types studied was differently than that of the two groups of chemical component mentioned above. Thus, in case of P, on the average for the two soil management systems and 3 soil sampling depths, the highest value of this chemical components was recorded on TE soil (5.63%) which was 6% higher than that recorded on CE soil and by 14% than SEE soil.

Table 1. The influence of management system on some chemical components on three soil types in an intensive apple orchard (average values for graduations of A/B experimental factors)

Chemical component	**Soil depth cm**	**Graduations of A/B experimental factors**				
		a_1	**a_2**	**a_3**	**b_1**	**b_2**
1	0-20	2,165	2,370	3,045	2,25	2,803
	20-40	1,915	1,300	0,690	1,240	1,363
	40-60	1,305	0,745	0,630	0,850	0,937
2	0-20	5,75	7,75	8,90	8,21	6,72
	20-40	6,00	3,50	4,00	8,20	6,73
	40-60	4,25	3,50	4,0	3,67	4,17
3	0-20	153,0	156,8	121,3	150,0	137,4
	20-40	117,2	102,8	65,3	107,3	82,9
	40-60	146,4	119,2	79,4	117,5	112,5
4	0-20	4,98	5,08	4,83	4,98	4,95
	20-40	4,92	5,01	5,11	5,01	5,02
	40-60	5,02	6,12	4,98	5,09	4,99
5	0-20	11,70	13,50	7,40	10,27	11,47
	20-40	9,10	11,6	5,20	8,27	9,00
	40-60	16,80	14,80	9,70	15,87	11,67
6	0-20	6,54	5,73	6,23	5,49	6,85
	20-40	6,50	5,58	3,14	5,04	5,10
	40-60	6,61	5,82	5,42	6,19	5,70
7	0-20	16,18	18,80	13,93	16,47	16,14
	20-40	15,30	17,44	11,01	14,20	14,97
	40-60	22,90	20,34	12,20	19,92	17,05
8	0-20	72,90	71,29	53,24	66,10	71,10
	20-40	59,46	66,32	50,66	68,70	71,39
	40-60	73,46	72,55	50,66	48,39	54,65

Soil type: a_1 = eutricombosol with colluvic character (CE); a_2 = slightly eroded eutricombosol (SEE); a_3 = typical eutricombosol (TE). Factor B – soil management system between tree rows: b_1 = cultivated, performed by a fall plowing to 12-14 cm and repeated disking during the vegetation period, b_2 = 2.4 – 2.6, wide mowed sod strips, performed by sowing of *Lolium perenne*.

Chemical component: 1 = humus - %, 2 = phosphorus - ppm, 3 = potassium - ppm, 4 = pH, 5 = total exchangeable bases - me, 6 = hydrolytic acidity - me, 7 = cation exchange capacity - %, 8 = base status - %

3.1.2. Influence of soil management system

On the average, for the 3 soil types and 3 soil sampling depths, the soil management as sod strips between the tree rows versus its management as clean cultivation, determined a raise of humus content by 17%, of hydrolitic acidity by 6% and of base status by 8%. At the same time, the soil management as clean cultivation between the tree rows versus that of sod strips, determined a raise of P content by 14%, of K content by 13%, of pH values by 0.8%, of total exchangeable bases by 7% and of cation exchange capacity by 5% (table 1).

3.2. Influence of soil management systems on some chemical components per 3 soil types (interaction of A/B experimental factors)

3.2.1. Influence of soil on some chemical components within each of the 2 soil management systems

On the average, for 3 soil sampling depths, the differences between the extreme values recorded with the 3 soil types for 6 of 8 chemical components analyzed (P, K, ph, total exchangeable bases, hydrolytic acidity and cation exchange capacity) were higher by 15% in case of grass strips versus the clean cultivation management system.

In return, under the same conditions, the differences between the extreme values, for the 3 soil types showed that for 2 of 8 chemical components (humus content and base status) were higher by 6.8% in case of clean cultivation versus the grass trips management system (table 2).

3.2.2. Influence of the soil management systems on some chemical components within each of 3 soil types.

On the average, for 3 soil sampling depths, the values of humus content, hydrolytic acidity and base status were higher in case of sod strips versus the clean cultivation in 8 of 9 cases investigated, representing 89% of the number of these cases. The other 5 chemical properties recorded higher values in case of clean cultivation system versus the sod strips in 10 of 15 cases investigated, recording 66%.

Table 2. The influence of management system on some chemical properties on three soil types in an intensive apple orchard (interaction graduations of experimental factors A/B)

Chemical components	Soil depth cm	a_1		a_2		a_3	
		b_1	b_2	b_1	b_2	b_1	b_2
1	0-20	2,08	2,25	2,02	2,72	2,65	3,44
	20-40	1,79	2,04	1,24	1,36	0,69	0,69
	40-60	1,15	1,46	0,77	0,72	0,63	0,63
2	0-20	5,50	6,00	10,50	5,00	8,63	9,17
	20-40	6,00	6,00	4,00	3,00	5,00	5,00
	40-60	4,00	4,5	3,00	4,00	4,00	4,00
3	0-20	143,8	162,2	196,7	117,0	109,6	133,0
	20-40	124,8	109,5	117,9	87,8	79,3	51,3
	40-60	135,7	157,0	135,3	103,2	81,6	77,2
4	0-20	5,10	4,87	5,10	5,06	4,74	4,92
	20-40	4,94	4,90	4,98	5,04	5,11	5,11
	40-60	5,04	5,01	5,15	5,10	5,10	4,86
5	0-20	12,2	11,2	11,2	15,8	7,4	7,4
	20-40	8,6	9,6	11,0	12,2	5,2	5,2
	40-60	18,0	15,6	16,8	12,8	12,8	6,6
6	0-20	5,60	7,49	5,59	5,88	5,27	7,19
	20-40	6,11	6,89	5,88	5,27	3,14	3,14
	40-60	6,94	6,28	5,87	5,81	5,81	5,02
7	0-20	18,02	14,34	16,79	20,82	14,59	13,27
	20-40	14,71	15,88	16,88	18,01	11,01	11,01
	40-60	24,94	20,87	22,62	18,07	12,20	12,20
8	0-20	67,70	78,10	66,70	75,88	50,72	55,76
	20-40	58,46	60,45	65,16	67,47	47,23	54,09
	40-60	72,17	74,74	74,27	70,83	47,23	54,09

Soil type: a_1 = eutricombosol with colluvic character (CE); a_2 = slightly eroded eutricombosol (SEE); a_3 = typical eutricombosol (TE). Factor B – soil management system between tree rows: b_1 = cultivated, performed by a fall plowing to 12-14 cm and repeated disking during the vegetation period, b_2 = 2.4 – 2.6, wide mowed sod strips, performed by sowing of *Lolium perenne*.

Chemical component: 1 = humus - %, 2 = phosphorus - ppm, 3 = potassium - ppm, 4 = pH, 5 = total exchangeable bases - me, 6 = hydrolytic acidity - me, 7 = cation exchange capacity - %, 8 = base status - %

3.3. Influence of soil management systems on the deep distribution of some chemicals in soil

On the average, for the 3 soil, the distribution per depth of 8 chemical components was differently related to the soil management system. The data in table 3 show that the most obvious difference between the 2 soil management systems regarding the values of chemical components was recorded on 0-20 cm soil profile, where there are developed the most roots of the grass strips. Thus, the humus content in the grass strips versus the clean cultivation was higher by 24.6% on 0-20 cm depth versus 17% recorded on 0-60 cm depth. On the other hand P content in the sod strips system versus clean cultivation was lower by 18.2% on 0-20 cm depth versus 12.3% on 0-60 cm depth. K content showed a similar tendency.

Table 3. Influence of soil management system on distribution by depth of some chemical components

Chemical Component	Soil Depth -cm-	Soil Management System		
		b_1	b_2	b_2 versus b_1 (%)
Humus %	0-20	2.25	2.803	124.6
	20-40	1.24	1.363	109.9
	40-60	0.85	0.937	110.3
	0-60	1.446	1.701	117.6
Phosphorus ppm	0-20	8.21	6.72	81.8
	20-40	8.20	6.73	82.1
	40-60	3.67	4.17	123.4
	0-60	6.69	5.87	87.7
Potassium ppm	0-20	150.0	137.4	91.6
	20-40	107.3	82.9	77.3
	40-60	117.5	112.5	95.7
	0-60	124.9	110.9	88.8

b_1 = cultivated, performed by a fall plowing to 12-14 cm and repeated disking during the vegetation period, b_2 = 2.4 – 2.6, wide mowed sod strips, performed by sowing of *Lolium perenne*.

3.4. Nature and intensity of correlations between some chemical components for 3 soil types, 2 soil management systems and 3 soil sampling depths

Table 4 shows that for 3 soil types, 2 soil management systems and 3 soil sampling depths, of the 8 chemical components studied, the highest number of significant correlations (6) was recorded with the characteristic of soil pH. That represented 86% of the total number of calculated correlations for this soil chemical characteristic. In the second place was the hydrolytic acidity with 5 significant correlations, representing 71% of the total number of calculated correlations. In the 3rd place, with 4 significant correlations, representing 57% of the total number of calculated correlations were 4 chemical characteristics (humus content, total exchangeable bases, cationic exchange capacity and base status). A lower number of significant correlations was recorded with K content (2) and P content (1).

Table 4. The nature and intensity of correlations between some chemical components for tree soil types, 2 soil management systems and tree soil sampling depths (0-20 cm; 20-40 cm;40-60 cm)

Chemical components	2	3	4	5	6	7	8
1	0,482*	0,722**	0,620**	NS	0,602**	NS	NS
2		NS	NS	NS	NS	NS	NS
3			0,505*	NS	NS	NS	NS
4				0,628**	0,671**	0,564*	0,663**
5					0,646**	0,978***	0,942***
6						0,655**	0,689**
7							0,840***

Chemical components: 1= Humus%; 2=pH; 3= phosphorus - ppm, 4 = potassium 5 = Total exchange bases (me), 6 = Hidrolitic acidity (me); 7 = Cation exchange capacity (%); 8 = Base status (%)

3.5. Influence of soil management systems on the nature and intensity of correlations between some chemicals components for 3 soil sampling depths

For the 3 soil types and 3 soil sampling depths, the highest number of significant correlations (10) among the 8 characteristic determined was recorded with the clean cultivation as soil management system. Thys number represented 36% of the total number of calculated correlations (table 5).

Table 5. The influence of soil management system as clean cultivation on the nature and intensity of correlations between some chemical components on three soil types and 3 soil sampling depths

Chemical components	2	3	4	5	6	7	8
1	NS	0,6417**	NS	NS	NS	NS	NS
2		NS	NS	NS	NS	NS	NS
3			NS	NS	NS	NS	NS
4				0,717*	NS	0,673*	0,753*
5					0,819**	0,992***	0,973***
6						0,808**	0,773*
7							0,926***

Chemical components: 1= Humus%; 2 = phosphorus - ppm, 3 = potassium ppm; 5= Total exchange bases (me), 6 = Hidrolitic acidity (me); 7 = Cation exchange capacity (%); 8 = Base status (%)

Under the same conditions, in case of soil management system as sod strips, the number of significant correlations was 8, representing 29% of the total number of calculated correlations (table 6).

Table 6. The influence of soil mowed sod strips system on the nature and intensity of correlations between some chemical components on three soil types and 3 soil sampling depths

Chemical components	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	NS	0,613*	0,4894*	NS	0,561*	NS	NS
2		NS	NS	NS	NS	NS	NS
3			NS	NS	NS	NS	NS
4				NS	0,6499*	NS	0,4517*
5					NS	0,9434***	0,942***
6						NS	NS
7							0,825**

Chemical components: 1 = Humus%; 2 = phosphorus – ppm, 3 = potassium ppm; 5= Total exchange bases (me), 6 = Hidrolitic acidity (me); 7 = Cation exchange capacity (%); 8=Base status (%)

3.6. Influence of soil sampling depths on the nature and intensity of correlations intensity for 3 soil types and 2 management systems

For the 3 soil types and 2 management systems, among the values of soil chemical characteristics determined on 0-20 cm, only 2 significant correlations were recorded, represented 7% of the total number of calculated correlations (table 7).

Table 7. The influence of management system on nature and intensity of correlations between some chemical components on three soil types (values for 0-20 cm soil depth)

Chemical components	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	NS	NS	NS	NS	NS	NS	NS
2		NS	NS	NS	NS	NS	NS
3			NS	NS	NS	NS	NS
4				NS	NS	NS	NS
5					NS	0,902*	0,881*
6						NS	NS
7							NS

Chemical components: 1= Humus%; 2 = phosphorus - ppm, 3 = potassium ppm; 5 = Total exchange bases (me), 6 = Hidrolitic acidity (me); 7 = Cation exchange capacity (%); 8 = Base status (%)

At the same time, among the values of 8 soil chemical characteristic determined on 20-40 cm depth, 12 significant correlations were recorded, represented 43% of the total number of calculated correlations (table 8).

Table 8. The influence of management system on nature and intensity of correlations between some chemical components on three soil types (values for 20-40 cm soil depth)

Chemical components	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	0,958**	NS	0,811*	NS	0,974***	NS	NS
2		NS	0,895*	NS	0,971***	NS	NS
3			NS	NS	NS	NS	NS
4				NS	0,864*	NS	NS
5					0,864*	0,998*	0,999*
6						0,868*	0,853*
7							0,997***

Chemical components: 1= Humus%; 2 = phosphorus - ppm, 3 = potassium ppm; 5 = Total exchange bases (me), 6 = Hidrolitic acidity (me); 7 = Cation exchange capacity (%); 8 = Base status (%)

4. Discussion

It is well known that the erosion of the soil superior horizons, generally brings about a decrease in the content of the major chemical components of soil both on the arable lands (Moţoc, 1963, Iancu, 1968) and also in the fruit orchards ((Popa, and Bor, 1975, Iancu, 1967, Iancu et all, 1967, Neamţu 1980). Data regarding the humus and K contents as well as the values of hydrolytic acidity mentioned in this paper proved this general tendency, especially for 20-40 cm and 40-60 cm soil depths. For 0-20 cm depth, the values of humus and K contents recorded on CE soil were lower than those recorded on SEE soil, probably because the soil layer on 0-20 cm depth of CE soil originated of the last eroded materials from the slope. Moreover, for the values of the other chemical components described in this paper (total exchangeable bases, pH values, cationic exchange capacity, base status) recorded on 0-60 cm depth of CE soil were lower versus those recorded on SEE soil. Regarding the influence of soil management on the values of its chemical components, the data above mentioned showed that in case of sod strips, the values of humus content, hydrolytic acidity and base status were higher than those with clean cultivation. Regarding the organic matter in soil (Haynes, 1980) it is reported that in the untiled soils, the highest content of organic matter is found in the superficial soil layers and it is gradually decreased with the depth increase. By maintaining the sod in the orchard this tendency is amplified due to organic matter result from grass growing. An increase of the organic matter content in soil as a results of grass growing was also reported by Greenhan (1983) quated by Hogue and Nielsen (1987). The greatest increase of organic matter content is mainly seen on the first 5 cm from soil surface but due to disintegration of grass roots, this increase, rather lower, can be observed on the whole depth explored by roots. These effects can be obviously in this paper, the data showing that in the sod strips system versus to the tilled soil, the increase of the organic matter content in soil was observed even on 40-60 cm depth. As Greenham (1965) reported (quoted by Hogue and Nielsen 1987), the soil managed as sod versus the clean cultivation managed by tilling does not seem to determine a raise of extractible P content. Data in this paper go to prove this conclusions. Nevertheless, the data reported by Deist et al (1973), quoted by Hogue and Nielsen (1987), showed the value of P content increased in the deeper layers of sod soil.

By disintegration of herbs results great K amounts, which according to some authors varied from 321 to 608 kg in New Zeeland (Haynes and Goh, 1980). Nevertheless, the data in this paper showed a lower content in case of sod strips system versus the clean cultivation. Hogue and Nielsen (1987), quoting different authors shows that the values of base status on the soils managed as sod strips versus the cultivated ones were higher especially due to a lower washing of Ca and Mg contents from the absorbent complex of sod soils. Data in this paper showed also higher values of the base status up to 60 cm depth in the sod strips system versus to clean cultivation. Comparatively to sod strips, the clean cultivation soil management system determined an obvious decrease of organic matter content in soil: Merwin, 1991; Welker and Glen, 1988, Merwin and Stiles, 1994. This decrease is mainly due to the increase, as a result of improving of mineralization speed, of organic matter in case of this management system owing to improvement of the soil physical and biological conditions for a short period. Also, by the soil tillage for maintaining the clean cultivation, the organic matter in the superficial layer is redistribute on the depth of tilled layer having greater chance of its decomposition. As Hogue and Nielsen (1987) reported, the effects of soil management as clean cultivation on some chemical components in soil (P, K, Ca, Mg) are less clear, suggesting that the soil management as clean cultivation may not be a major factor which can significantly alter the content of these elements.

Conclusions

On the average, for the 2 soil management systems and 3 soil sampling depths, the content of the 8 chemical components analyzed varied obviously among the 3 soil types analyzed.

On the average, for the 3 soil types and 3 soil sampling depths, soil management between the tree rows as sod strips, versus its management as clean cultivation, determined a raise in humus content by 17%, of hydraulic acidity by 6% and of base status by 8%. However, under the same conditions, the soil management as

clean cultivation versus the sod strips system determined an increase of P content by 14%, of K content by 13%, of pH values by 0,2%, of total exchangeable bases by 7% and of cationic exchange base by 5%.
On the average, for the 3 soil types, the most obvious difference between the 2 soil management systems regarding the value of chemical components was recorded on 0-20 cm depth.
Between the value of chemical component analyzed some positive correlations of various intensities related to the soil management system and soil sampling depth were recorded.

References

Haynes R.J., 1980, -"Influence of Soil management practice on the orchard agro-ecosystem", Agro-ecosystems, N. 6: 3-32;

Haynes, R.J., and K.M. Goh, (1980a). “Some effects of orchard soil management on sward composition, levels of available nutrients in the soil, and leaf nutrient content of mature ‘Golden Delicious’apple trees” SCI Hortic. 13:15-25;

Haynes, R.J., and K.M. Goh, (1980b). “Some observation on surface soil pH, base saturation and leaching of cations under three contrasting orchard soil management practices. Plant Soil 56:429-438.

Hogue E.J., Neilsen G.H., 1987, -"Orchard floor vegetation management", Horticulture Revue, Vol. 9;

Iancu M., (1967). Comportarea plantaţiilor tinere de păr pe terase. Revista de Horticultură şi Viticultură, nr. 10;

Iancu M., (1968) “Influenta unor msuri agrotehnice asupra porduictiei la principalel plante de cultura pe solurile din platforma Cotmeana”. Analele ICCPT Fudulea, Vol. XXXIV, seria B, p. 89-97;

Iancu M., Mariana Negoiţă and I. Neamţu (1996). The effect of topographycal modification of hilside apple orchards on the physical and chemical characteristics of the soil. Acta Hortic. 451.

Lipecki J., S. Berbec, 1997, -Soil management in perennial crops: „orchards and hope gardens”, Soil Tillage Research, 43: 169-184;

Merwin I.A., 1991, -"Orchard ground cover management", Proceedings of 136th Annual Meeting of Horticulture Society, Vol. 136: 71-84;

Merwin I.A., Stilles W.C., 1994, -"Orchard ground cover management on apple trees growth and yield and nutrient availability and uptake", Journal of American Society for Horticulture Sciences, N. 119 (2): 209-215;

Motoc M., (1963) “Eroziunea solului pe terenurile agricole si combaterea ei”. ED. Agrosilvica – Bucuresti;

Neamtu. I. (1980) “Influenta plantatiilor pomicole asupra procesului de eroziune a solului” – Teza de doctorat ASAS Bucuresti;

Popa V., Bor I., (1975) " Studiul influentei formelor de relief si a sistemului de amenajare asupra cresterii in primi sapte ani, a pomilor din soiul de mar Jonathan altoit pe paduret, in conditiile terenurilor in panta din N-E Transilvaniei". Lucrarile stiintifice, Vol. II, p.127-134:

Shribbs J.M., Skroch W. A., 1986, -"Influence of 12 ground cover systems on young 'Smothee Golden Delicious' apple trees. II. Nutrition.", Journal of American Society for Horticulture Sciences, N. 11 (4): 529-533;

Wekler W.V. jr. and Glenn D. M., (1988) -"Growth responses of young peach trees and changes in soil characteristics with sod and conventional planting systems", Journal of American Society for Horticulture Sciences, N. 113 (5): 652-656.