Thesis of doctoral (PhD) dissertation

THE EFFECT OF COMPOST TREATMENTS ON THE VEGETATIVE AND GENERATIVE PERFORMANCE OF APPLE TREES
(*Malus domestica* Borkh.)

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1. INTRODUCTION

Hungary, like all EU member countries, has a responsibility to carry out the environmental, economic and social sustainability. Chance needs to be provided for the next generation to live a „liveable life" they are entitled to.

Nowadays recycling of the side-products produced by agriculture is getting more emphasis on (SIMÁNDI, 2008), because the amount of the produced biomass is around 30 million ton per year (OHT II, 2009). In the meantime, the number of livestock keeps becoming sparse and the amount of the available manure is consistently reducing (LAZÁNYI, 2006).

Almost the quarter of the agriculturally utilized soils (2.2 million hectare) is acidic in Hungary (AGRONAPLÓ, 2008). The regular and proper fertilization is essential not only for the soils with low fertility, but all the soils.

With the application of the compost products in the horticultural culture not only the recycling of biological degradable organic side-products and wastes originated from the agriculture, food industry, households and public places can be realised, but also the increase of soil fertility (ELFOUGHI et al., 2010), therefore the positive effect on the crop size and quality can be seen (GIGLIOTTI et al., 1966; KÁDÁR and MORVAI, 2007; KESERŰ, 2007). While the nutrient content of the mineral fertilizers is easily uptakeable for the plants, and it may be mobile in the soils and move to the surface or underground water (ANTAL et al., 1999), the huge advantage of the composts is that they contain the necessary nutrients in bound form, however, they are uptakeable for the plants in the rate of degradation (KÁRPÁTI, 2002).

The compost application experiments were carried out under controlled environmental conditions in a greenhouse (2009-2012) and under field conditions in an apple tree orchard (2010-2012). Humic sandy soil was used as experimental soil in all cases. In the greenhouse experiments the amount of the biomass of ryegrass *(Lolium perenne L.)*, sowed into the pots indicated the variable effect of the different compost products. The effect of a certain compost product on soil parameters and the vegetative and generative performance of the fruit of *Golden Delicious* and *Pinova* apple trees in an organic and integrated cultivated orchard were examined.

2. MATERIALS AND METHODS

The controlled pot experiments were conducted in the greenhouse of the University of Debrecen, Centre for Agricultural and Applied Economic Sciences, Institute of Agricultural Chemistry and Soil Sciences. The field experiments were carried out in the RISF Farm and Regional Research Institute Research Field of Pallag, as well as the chemical analysis of the soil, plant and fruit samples took place in the laboratories of the Institute of Agricultural Chemistry and Soil Sciences.

2.1. Applied experimental plants

2.1.1. In the greenhouse experiments

During the greenhouse experiments ryegrass *(Lolium perenne L.)* was sowed as an experimental plant.

2.1.2. In the field experiments

In case of the field experiment the more sensitive *Golden Delicious* (M26) variety (with is however often demanded by consumers and called the world's most successful apple variety) and the more resistant vital *Pinova* (M26) which is created by the crossbreeding of *Golden Delicious* and *Clivia* were chosen.

2.2. The conditions of the pot experiments

2.2.1. The origin of the soils applied in the pot experiments

The sandy soils used in the pot experiments originated from the area of Debrecen-Pallag (Hajdú-Bihar county), from the cultivated topsoil (0-30 cm). (Soil type: without "kovárvány"). In case of composts 1-6 the (strongly) acidic humic sandy soil [pH($CaCl_2$) = 4.41] was applied and in case of compost 7 the (slightly acidic) humic sandy soil [pH($CaCl_2$) = 6.01] was used.

2.2.2. The origin of the composts applied in the pot experiments

Compost products applied in the experiments were provided by a partner company of the University of Debrecen. Most of these composts were produced for experimental purposes (facing consumer circulation) therefore both the production technology and the compound of these composts are confidential. (All composts were free of sewage sludge.)

2.2.3. The measured chemical parameters of the soils and composts applied in the pot experiments

During the examination of the element content of the sandy soil, the compost and the nutrient samples prepared from their mixture, we measured their wet and 0.01 M $CaCl_2$ pH, the forms of N (including NO_3-N, NH_4-N, organic-N and total-N), the P, K and Mg content, ammonium lactate acid (AL) soluble P, K, Ca and Mg content were measured.

2.2.4. The treatments applied in the pot experiments

The sieved composts were mixed with the control sandy soils of Pallag volume proportionately in different ratios (the ratios were 0, 5, 10, 25 and 50 % in case of the compost experiments 1-4, while in the case of compost experiments 5-7 these were 0, 5, 10, 20, 30, 40 and 50 %). The number of repetitions was four. After mixing, the 2.5 liter culture pots were placed on wagons randomly and allowed to stand for a week, in order to avoid possible scorching effect. The mixing ratio (v/v %, referred to as %) and amount (l) of each treatments are shown in **Table 1**.

Table 1 The amount and mixing ratio of the treatments applied

Experi-ment	Compost		Sandy soil
	Mixing ratio (%)	Amount (l)	Amount (l)
Compost 1-4	0	0.000	2.500
	5	0.125	2.375
	10	0.250	2.250
	25	0.625	1.875
	50	1.250	1.250
Compost 5-7	0	0.000	2.500
	5	0.125	2.375
	10	0.250	2.250
	20	0.500	2.000
	30	0.750	1.750
	40	1.000	1.500
	50	1.250	1.250

2.2.5. The conditions of plant growing in the greenhouse

Table 2 chronologically summarizes the settings of the compost experiments, the sowing and hatching of grass seeding, the watering of the pots and the harvest of the experiment.

Table 2 Date of the main work operations of the compost experiments

	Sort of composts				
	1-3	**4**	**5**	**6**	**7**
Set up of the experiments	**2009**	**2009**	**2010**	**2011**	**2012**
	June 8	**September 2**	**July 2**	**April 29**	**May 3**
Sowing of seeds	June 15	September 7	July 9	May 6	May 10
Hatching of seeds	June 23	September 13	July 12	May 12	May 16
Watering to $FC_{60\%}$	June 29	September 21	July 16	May 18	May 22
Harvest	July 27	October 15	August 11	June 16	June 19

A week after mixing 1.5 g grass seed was spread per pot. After that the pots were watered with 200 ml distilled water per pot. The soil surface was loosened before the sowing. After these the soil surface was compacted and covered. After the hatching of grass seed the pots were irrigated every day to 60 % of the field capacity in order to replace the daily evapotranspiration.

After harvesting the experiments the fresh mass of the shoots was cut and put into bags, and then the weight was measured by OHAUS ADVENTURER PRO AV2102C type analytical balance. After 1-2 weeks drying on open air the samples were sieved with stainless steel CISA 018067.10 type (Ø < 2 mm) sieve, the plant samples were minced with a German type FRITSCH PULVERISETTE 14 (the dry weight of samples and bags were measured before), preheated LABOR MIM L^{o}-809 type oven was used to dry them to constant weight.

During the analysis of the plant samples the fresh and dry (dried on 60 °C to constant weight) shoot weight was measured. Furthermore the samples were digested with sulfuric acid and hydrogen peroxide to measure their P and K content and after digestion with hydrogen peroxide the Mg, Ca, Mn and Zn contents were determined.

2.3. The circumstances of the field experiment

2.3.1. The soil applied in the field experiment

The field experiment was carried out in the research station of Debrecen-Pallag on a humic sandy soil [pH($CaCl_2$) = 6.06] in organic and integrated apple orchards planted in 2008.

2.3.2. The origin of the compost applied in the field experiment

The required amount (≈350 kg) of proprietary composition compost product originated from one of the partner companies of the University of Debrecen.

2.3.3. The chemical parameters of the soil and compost applied in the field experiment

There was a comprehensive soil analysis in 2010 in the area of the orchard were the field experiments took place. After this the parameters of the 0-30 and 30-60 cm layers of the soil profile and the element contents of the compost were measured every year according to the method described in chapter the 2.2.3.

2.3.4. The treatments applied in the field experiment

The nitrate regulation (Government Decree No. 81/2007. (IV. 25.)) was considered at the determination of the compost doses, because the integrated cultured orchards were fertilized with basic mineral fertilizer in a uniform way: in autumn 2010, one portion of 300 kg ha^{-1} NPK (15:15:15), in spring 2011, divided portions of 200 kg ha^{-1} (34 % NH_4NO_3), as well as in spring 2012, 200 kg ha^{-1} (11:11:26) NPK mineral fertilizers were dispersed.

The total and easily uptakeable N content of the compost was examined (total N_{CaCl2} = 726 mg kg^{-1}), then the compost doses per m^2 were determined based on this. The N active substance (kg/ha) of the compost applied were the following: 0, 10, 25, and 50 while the corresponding quantities (kg/m^2) were: 0, 1.4, 3.5 and 6.9. These compost doses were applied for 7 trees per treatment (1 tree floor area per m^2). **Table 3** shows the amounts of the N-substance applied during the 3 years.

Table 3 The amount of N active substances applied with compost and with mineral fertilizer between 2010 and 2012

Treatment	Production technology	Apple varieties	N active substance applied													
			2010				2011				2012				*In total during the 3 years*	
			Autumn				Spring				Spring					
			with Compost		with Fertilizer		with Compost		with Fertilizer		with Compost		with Fertilizer			
			kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)	kg ha^{-1}	kg m^{-2} (1 tree)
1	Organic	*Golden D.*	0.00	0.0000	-	-	0.00	0.0000	-	-	0.00	0.0000	-	-	***0.00***	***0.0000***
3			10.00	0.0010	-	-	10.00	0.0010	-	-	10.00	0.0010	-	-	***30.00***	***0.0030***
4			25.00	0.0025	-	-	25.00	0.0025	-	-	25.00	0.0025	-	-	***75.00***	***0.0075***
5			50.00	0.0050	-	-	50.00	0.0050	-	-	50.00	0.0050	-	-	***150.00***	***0.0150***
6		*Pinova*	0.00	0.0000	-	-	0.00	0.0000	-	-	0.00	0.0000	-	-	***0.00***	***0.0000***
8			10.00	0.0010	-	-	10.00	0.0010	-	-	10.00	0.0010	-	-	***30.00***	***0.0030***
9			25.00	0.0025	-	-	25.00	0.0025	-	-	25.00	0.0025	-	-	***75.00***	***0.0075***
10			50.00	0.0050	-	-	50.00	0.0050	-	-	50.00	0.0050	-	-	***150.00***	***0.0150***
11	Integrated	*Golden D.*	0.00	0.0000	45.00	0.0045	0.00	0.0000	68.00	0.0068	0.00	0.0000	22.00	0.0022	***135.00***	***0.0135***
12			10.00	0.0010	45.00	0.0045	10.00	0.0010	68.00	0.0068	10.00	0.0010	22.00	0.0022	***165.00***	***0.0165***
14			25.00	0.0025	45.00	0.0045	25.00	0.0025	68.00	0.0068	25.00	0.0025	22.00	0.0022	***210.00***	***0.0210***
15			50.00	0.0050	45.00	0.0045	50.00	0.0050	68.00	0.0068	50.00	0.0050	22.00	0.0022	***285.00***	***0.0285***
16		*Pinova*	0.00	0.0000	45.00	0.0045	0.00	0.0000	68.00	0.0068	0.00	0.0000	22.00	0.0022	***135.00***	***0.0135***
18			10.00	0.0010	45.00	0.0045	10.00	0.0010	68.00	0.0068	10.00	0.0010	22.00	0.0022	***165.00***	***0.0165***
19			25.00	0.0025	45.00	0.0045	25.00	0.0025	68.00	0.0068	25.00	0.0025	22.00	0.0022	***210.00***	***0.0210***
20			50.00	0.0050	45.00	0.0045	50.00	0.0050	68.00	0.0068	50.00	0.0050	22.00	0.0022	***285.00***	***0.0285***

2.3.5. The main characteristics of the experimental orchard

The main features of the trees of the orchard: installation in 2008, M26 rootstock, 1.5 m planting distance and slender spindle crown shape. **Table 4** summarizes further data about of the plantation, the location of the orchard and the type of the tested apple varieties.

Table 4 The characteristics the orchard

Studied orchards	**Organic**		**Integrated**	
Studied apple variety	***Golden D.***	***Pinova***	***Golden D.***	***Pinova***
Crown structure	slender spindle		slender spindle	
Plantation date	2008		2008	
Planting material	1 year old nursery material		1 year old nursery material	
Rootstock	M26		M26	
Distance between rows (m)	4		4	
Distance between trees (m)	1,5		1,5	
Number of trees (1 ha)	1666		1666	
Row orientation	NW-SE		NW-SE	
Irrigation	Drip		Drip	
Fertilizer application	wasn't		was	

2.3.6. The circumstances of the trees grown in the orchard

The composting experiment was set up in cooperation with the Horticultural Science Institute on 22nd July 2010. Then compost was applied in every spring: 28th April 2011, 02nd May 2012. The compost was delivered in big bags to the orchard and was put on a disc attached to the tractor with a hydraulic lift, then pulled between the lines where the compost doses were measured with MICRA BASIC AUTONOMA scale. After the application of the compost it was mixed into the soil and irrigated with a drip device built into the wall.

The **soil samples** were always taken before compost application (April-May) and the harvest (September) from 0-30 cm and 30-60 cm depth; they were analyzed in 4 replicates. The 0.01 M $CaCl_2$ and AL-soluble element contents were measured, as well as the plasticity index and humus content.

The **morphological parameters indicating** the condition of the trees were measured in spring each year. The following parameters were measured/calculated: wood strain area (cm^2), number- (pieces), and size- (mm) of fruit, number (pieces) and cross-section (mm) of primary branches and length (cm) of shoots. The measurements were carried out with 0-150 mm DIGITAL ELECTRONIC CALIPER and measuring tape (cm).

Leaf samples, the main in indicators of nutrient availability, were collected each year before the harvest (September) from well-lighted, developed, healthy shoots of the same branch level at shoulder height, from the middle of the closed apical buds with petiole in case of 3-3 tree of each treatment. The N, P, K, Ca, Mg, Mn and Zn content of the leaves were measured.

The **fruit samples** were taken in 3 replicates from control and the trees treated with the highest compost doses in case of both production technology (bio/eco and integrated) and both species (*Golden Delicious* and *Pinova*). The sampling times were the following: 12nd September 2010, 13th September 2011 and 16th September 2012. Subsequently, the most important fruit quality parameters were measured: dry matter-, ash-, total acid-, vitamin C-, sugar contents and nutrient contents.

2.3.7. The characterization of the weather of the years examined

The mean of the annual precipitation between 1971 and 2000 (according to the National Weather Service) was 568 mm. Considering **the annual rainfall** data of the experimental years provided by the Agro-meteorological Observatory of the University of Debrecen it can be stated, that 2010 was a very rainy (1100 mm), 2012 was a drought year (430 mm) and the year of 2011 can be considered as an average year (535 mm).

Observing **the temperatures** it can be concluded that similar mean values can be seen in all the three experimental years, the warmest month was July. It is important to note that the temperature was below 0 °C several times at the measuring station in 2011 (between 1-10 March).

2.4. Determination of the soil parameters

2.4.1. The determination of the plasticity index according to Arany of the soil samples

The physical type of the soils was determined based on the plasticity index according to Arany (K_A) (FILEP, 1995).

2.4.2. Determination of the total humus content of the soil samples

The humus content of the composts and the soil samples were determined according to SZÉKELY (1964). The clear solution was measured colorimetric with a METERTEK SP-850 spectrophotometer at 580 nm.

2.4.3. Determination of the H_2O and 0.01 M $CaCl_2$ pH of the soil samples

The **wet** and 0.01 M **$CaCl_2$ pH** of the soil samples were determined from the air dried samples according to the method of HOUBA et al. (1990). The measurement was performed with HANNA INSTRUMENTS HI-8521 digital pH measuring equipment after calibration.

2.4.4. Determination of the N forms of the soil samples with 0.01 M $CaCl_2$ soil extraction method

The soil samples were shaken with $CaCl_2$ extractant (soil:extractant ratio 1:10) according to the method of HOUBA et al. (1990) 0.01 M. The N forms of the extracts were measured with a continuous analyzer SCALAR SAN-PLUS SYSTEM.

2.4.5. Determination of the P, K, Mg and Mn content of the soil samples with 0.01 M $CaCl_2$ soil extraction method

The determination of the P, K, Mg and Mn contents of soil samples was done with 0.01 M $CaCl_2$ soil extraction method based on the method of HOUBA et al. (1990). The **K content** was determined with UNICAM SP95B AAS instrument via flame emission spectrophotometry. The **P-forms** were measured by CONTIFLOW ANALYSIS (CFA) Skalar tool. The determination of **Mg and Mn contents** of the extracts was performed with a VARIAN SPEKRAA 20 PLUS atomic absorption spectrophotometer.

2.4.6. Determination of the P, K, Ca and Mg content of the soil samples with AL extractant

The determination of the soluble P, K, Ca and Mg content of the samples was performed with ammonium lactate acidic (AL) extractant (1:20 soil:extractant ratio) based on the description of EGNER et al. (1960). The **determination of P** was conducted at 730 nm wavelength with a METERTEK SP-850 spectrophotometer, the **measurement of K** was performed at 740 nm via flame emission photometric method (FES) with a UNICAM SP90B AAS spectrophotometer, while the **determination of the Ca and Mg** was carried out with a VARIAN SPECTRAA 20 PLUS type atomic absorption spectrophotometer.

2.4.7. Determination of the water soluble total salt content of the soil samples

The salt content of the soil samples were determined with an ORION (MODEL 105 A+) type salt measuring equipment based on the electrical conductivity (FILEP, 1995).

2.5. Determination of the indicators showing the vegetative properties of the trees

2.5.1. The strain area of the trees (cm^2)

The value of the strain field area was determined by measuring the diameter (2r) of the trains of the trees and calculated by using the formula of the area ($T = r^2\pi$).

2.5.2. The thickness of the first-order branching (cm^2)

The diameter of first-order branch of the treated trees was yearly measured with a digital Caliper. The area of the branches (cm^2) close to the trunk was calculated from the measured values, and this data provided the reference for the values of the number and length of shoots measured in the further two years.

2.5.3. The specific shoot length (cm/branching cm^2)

The measurement of the length of the shoots was carried out on the 1-3 primary junction of the marked 3 trees per treatment every year, then the measured values were calculated to the cross section of the branching (cm^2).

2.5.4. The specific shoot number (piece/branching cm^2)

While measuring the length of the shoots, their number (piece) was also recorded and calculated to the cross-section of the branching (cm^2).

2.5.5. The average shoot length (cm/piece)

With the help of the length (cm) and the number (piece) of the shoots the average length of the shoots could be determined.

2.5.6. Leaf area (cm^2)

In 2010 and 2012 the length and cross-section of 50-50 randomly collected control apple leaves were examined and the values of the leaf area were calculated with their multiplication.

2.5.7. Leaf area per running meter shoot (cm^2)

Knowing the length (cm/piece) and the leaf area (cm^2/shoot) of each shoots the leaf area per running metre shoot (cm^2/m) could be determined.

2.6. Determination of the parameters indicating generative properties of the trees

2.6.1. Fruit number per trees (piece/tree)

All the fruits of 7 selected trees per treatment were counted two times (July and September) each year.

2.6.2. The specific fruit load (piece/cm^2)

After counting the number of fruits per tree the values were calculated to the strain field of the certain tree.

2.6.3. The weight of the fruits (g/piece)

The average weight of a piece of apple (g/piece) was calculated from the total weight of 10-10 apples originating from the control treatment and the treatment with the highest compost doses.

2.6.4. The specific weight of fruits (g/cm^2)

The total weight of apples per tree (g) was determined based on the 10-10 apples originating from the control and the highest dose compost treatment, then this value was calculated to the strain field area of the trees (cm^2).

2.7. Analysis of the plant samples

2.7.1. Determination of the dry matter content of the plant samples

The determination of dry matter content of **ryegrass**, **apple leaves and apple** was performed according to the ISO 1026:2000 standard. The **ryegrass and the apple leaf** samples were dried in a LABOR MIM L^o-809 type dryer, and the **apple samples** were dried in a LABOR MIM 122-1086 type oven.

2.7.2. Determination of the P and K content of the plant samples

The **P content** of plant samples dried at constant weight and milled (**ryegrass**, **apple leaves**, **apple**) was determined with ammonium molybdate-vanadate color-forming reagent according to the description of TAHMM et al. (1968) and then it was measured with a METERTEK SP-850 spectrophotometer at 400 nm wavelength. The **K content** of plants was measured with a UNICAM SP95B AAS equipment at a wavelength of 740 nm with flame emission spectrophotometry.

2.7.3. Ddetermination of the Ca, Mg, Mn and Zn content of the plant samples

0.5 g of the plant samples (ryegrass, apple leaves, apple) dried to constant weight was digested in 10 cm^3 65 % HNO_3. The **Ca, Mg, Mn and Zn** contents were determined with VARIAN SPEKRAA 20 PLUS atomic absorption spectrophotometer.

2.8. Nutritional examination of the fruits

2.8.1. Determination of the ash content of the apple samples

The determination of the ash content of the samples was performed according to the ISO 5520:1994 standard. The samples were incandesced in an OMSZÖV OH-63 type electric furnace.

2.8.2. Determination of the sugar content of the apple samples

A few grams of 3-3 apples per treatment were grated to a watch-glass, and a few drops of the juice of the samples were pressed onto the prism of the Universal Hand BRIX refractometer. The International Sugar Chemical Company (ISC) has developed a changeover table, which provided an opportunity to convert the refractometry determined water-soluble BRIX % value to sugar content given in g dm^{-3} (KÁLLAY, 2006).

2.8.3. Determination of the total acid content of the apple samples

Determination of the total acidity of the apple samples was made according to the ISO 750:2001 standard.

2.8.4. Determination of vitamin C content of the apple samples

The determination of the vitamin C content of the apple samples was performed according to BRUGOVITZKY (1956).

2.9. The statistical evaluation of the experimental data

The measured data were evaluated with a macro program written in Microsoft® Excel 2007 and developed by L. Tolner with using two or three factor analysis of variance (AYDINALP et al., 2010).

3. RESULTS AND DISCUSSION

3.1. Results of the greenhouse experiments (2009-2012)

One of the aims of our research was to qualify the different experimental composts after determining (in accordance with the limits set out in 36/2006. (V. 18.) Regulation of the Ministry of Agriculture) their nutrient content, test the effect of each compost on the plant biomass production in a pot experiment, and finally, to determine the optimal dose of compost to apply.

3.1.1. Characterization of the experimental sandy soils

Table 5 demonstrates the nutrient contents of the sandy soils and sieved composts.

Table 5 The measured parameter of the experimental sandy soils and compost products applied

	Humic sandy soil		**Compost products**							
	strongly acidic	**mildly acidic**	**1.**	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**Unit**
Hu	0.7	1.3	18.1	18.7	7.2	17.8	18.1	17.9	17.9	%
K_A	26	29	-	-	-	-	-	-	-	-
pH H_2O	5.6	-	7.0	6.9	6.2	7.6	7.2	7.3	7.1	-
pH $CaCl_2$	4.4	6.0	6.5	7.1	6.3	7.0	6.9	6.6	6.5	-
AL-P	83.2	119.6	8704.7	8782.1	2508.5	17345.9	7517.9	1697.8	1557.9	mg kg^{-1}
AL-P_2O_5	190.6	274.0	19933.7	20111.9	5744.4	39722.2	17216.2	3887.8	3567.8	mg kg^{-1}
AL-K	179.5	236.9	6965.0	7164.1	617.1	1677.3	6170.8	4456.9	4316.5	mg kg^{-1}
AL-K_2O	217.2	286.6	8427.7	8668.6	746.7	2029.5	7466.6	5392.9	5222.9	mg kg^{-1}
AL-Ca	1011.6	1185.0	28600.0	53000.0	4800.0	12760.0	50100.0	9907.5	9438.1	mg kg^{-1}
AL-Mg	88.0	117.0	3990.0	3990.0	598.0	5700.0	4471.9	3990.0	3530.7	mg kg^{-1}
$CaCl_2$-N_{total}	22.9	15.6	484.3	483.4	138.2	1926.0	725.5	861.7	790.2	mg kg^{-1}
$CaCl_2$-NO_3	2.1	6.2	314.7	315.3	118.4	88.8	459.8	596.2	479.5	mg kg^{-1}
$CaCl_2$-NH_4	15.7	1.9	20.9	13.5	8.5	685.0	0.0	0.0	0.0	mg kg^{-1}
$CaCl_2$-$N_{organic}$	-	-	148.7	154.7	11.4	1152.2	265.7	265.5	310.7	mg kg^{-1}
$CaCl_2$-P	1.8	-	24.6	8.3	3.4	24.0	137.8	43.1	93.7	mg kg^{-1}
$CaCl_2$-K	116.0	-	2694.0	4036.8	450.5	1247.1	2368.6	2935.5	2509.7	mg kg^{-1}
$CaCl_2$-Mg	39.5	9.7	947.5	867.5	276.5	1072.5	765.8	642.5	583.5	mg kg^{-1}

The N supply of the strongly acidic sandy soil (cultivation area category 4) [pH($CaCl_2$) = 4.4] was low, the P supply was good and the K supply was medium. The N supply of the mildly acidic humic sandy soil [pH($CaCl_2$) = 6.0] was good, the K and P supply was considered very good (MÉM NAK, 1979).

3.1.2. Qualification of the experimental composts based on the operative Regulation of the Ministry of Agriculture

The dry matter-referred N-, P_2O_5, K_2O, Ca- and Mg-content of all the examined seven experimental compost products was high above the minimum specified limit values that can be found in the 36/2006. (V. 18) Regulation of the Ministry of Agriculture **(Table 6)**. In case of compost number 3 the pH(H_2O) was outstanding, it did not reach the lower limit of the optimum range; the other products met the regulations.

Table 6 Limit values of the composts according to the 36/2006. (V. 18.) Regulation of the Ministry of Agriculture

Name of parameter	Limit values	Unit
pH(H_2O)	6.5-8.5	-
volume weight	< 0.9	kg/dm^3
dry matter content	> 50.0	m/m%
organic matter content	> 25.0	m/m% d.m.
water-soluble total salt content	< 4.0	m/m% d.m.
grain size distribution under 25.0 mm	> 100.0	-
N-content	> 1.0	m/m% d.m.
P_2O_5-content	> 0.5	m/m% d.m.
K_2O-content	> 0.5	m/m% d.m.
Ca-content	> 1.2	m/m% d.m.
Mg-content	> 0.5	m/m% d.m.

3.1.3. Qualification of the experimental composts based on the effect on the biomass production of the indicator plant

During the greenhouse/pot experiments we came to the following conclusions: although highest plant dry matter contents were measured due to **compost 1 and 4**, the 50 % rate of compost dose resulted a significant decrease in the dry weight, presumably due to its excessive nutrient content. In **compost experiment 2** the plant production was lower, and the 50 % compost dose also caused a decrease in the dry weight of the ryegrass. **Compost 3** did not meet the Regulation; its effect was the lowest comparing to the composts mentioned before. In case of the application of **compost number 5** it was observed, that the amount of the biomass production already reached its maximum at the 10 % dose. The results of the **compost experiments 6 and 7** (6: strongly acidic humic sandy soil, 7: mildly acidic humic sandy soil) showed that the biomass increasing effect of compost is higher in case of the modest soil conditions. The biomass

production increased with the increase of the compost doses, although the increase of the plant yield was lower in case of treatments with higher than 20 % compost.
The analysis of variance demonstrated that the **dispensed compost doses and the plant productions showed close (P = 0.1 %) correlation** (in case of compost 5 the error probability level of significance was P = 1.0 %).

3.1.4. Justification for the choice of the compost preparation

After examining and qualifying the nutrient content of the applied experimental compost products, and based on the effect of their 10 % amount on the biomass production, **compost number 5** was chosen to apply in the apple orchard **(Figure 1)**. The reason of the choice was that this compost had a neutral $CaCl_2$ pH and its humus content and organic N-content were considered significant. Proven by literature, the plant damaging effect of composts due to their high P content is often experienced. The AL-P content of this compost was average comparing to the other composts. Its AL-K content was significant, which is a favourable parameter in the aspect of the K-needs of the ryegrass and the fruits as well. The AL-Ca content of this compost was one of the highest among the compost products, while its AL-Mg content was significant, but the lowest comparing to the other products.

Figure 1 The effect of compost number 5 on the plant biomass production (SZABÓ, 2010)

3.1.5. Determination of the optimal compost doses

Based on the pot experiments it was concluded, that the different compost products had a plant dry matter increasing effect. This increase depended on the quality and the quantity of the compost product. All the tested composts had a favourable effect on the pH of the soil, they increased the lowed pH close to the range of neutral. In the terms of plant growing, the optimal doses of each compost products were different (10, 25, 30 and 50 %). Considering the feasibility and economicalness of the compost application, an average optimal dose (4-8 kg m^{-2}) was determined, of which effect was considered favourable in gardening cultures.

3.2. The results of the field experiment (2010-2012)

The effect of a certain compost product on soil parameters and the vegetative and generative performance of *Golden Delicious* and *Pinova* apple trees was examined in an organic and an integrated orchard.

3.2.1. The soil parameters of the orchard

Table 7 contains the soil parameters of the 0-30 and 30-60 cm layers of the soil profile examined (2010).

Table 7 The measured parameters of the experimental soil and compost applied (2010)

Experimental soil and compost				
	Soil of Pallag		Compost	Unit
	0-30 cm	30-60 cm		
Hu	1.17	1.01	18.1	%
K_A	26	26	-	-
pH H_2O	-	-	7.2	-
pH $CaCl_2$	6.1	5.5	6.9	-
salt %	0.009	0.008	-	-
AL-P	118.9	54.9	7517.9	mg kg^{-1}
AL-P_2O_5	272.3	125.7	17216.2	mg kg^{-1}
AL-K	130.8	124.2	6170.8	mg kg^{-1}
AL-K_2O	158.3	150.3	7466.6	mg kg^{-1}
AL-Ca	864.5	805.5	50100.0	mg kg^{-1}
AL-Mg	142.5	103.1	4471.9	mg kg^{-1}
$CaCl_2$-N_{total}	5.9	4.7	725.5	mg kg^{-1}
$CaCl_2$-$N_{organic}$	4.5	4.3	265.7	mg kg^{-1}
$CaCl_2$-NO_3	0.7	0.4	459.8	mg kg^{-1}
$CaCl_2$-NH_4	0.7	0.0	0.0	mg kg^{-1}
$CaCl_2$-P	7.5	2.2	137.8	mg kg^{-1}
$CaCl_2$-K	53.9	63.7	2368.6	mg kg^{-1}
$CaCl_2$-Mg	105.3	63.6	765.8	mg kg^{-1}

The soil type in the examined depth was sand, the plasticity index according to Arany was 26. Considering the growing site category it was sandy soil. The soil of the experimental are is mildly acidic, the pH($CaCl_2$) decreased with the depth. The organic matter content of the soil was low, humus content decreased with the depth. Its nitrogen supply capacity based on its humus content was medium. The AL soluble P supply of the topsoil (0-30 cm) was quite good, which halved with the depth. The AL soluble K supply is quite good; the amount shows a slight decrease with depth. Nitrogen and phosphorus data suggested that the majority of nutrients applied with fertilization concentrated in the topsoil. The vertical movement of the nutrients between the layers was low in spite of the sandy structure. The magnesium content of the soil was very good. The salinity of the soil was < 0.1 %, which should not be considered salty.

Nutritional differences were observed between the different production technologies year by year (the integrated orchard received basic mineral fertilization as well, while the organic orchard received compost treatments only). It was experienced that the compost treatments affected the soil parameters not only in the integrated orchard, but the organic orchard as well. Primarily, the amount of easily available nutrients (such as nitrate-, ammonia-, organic-N, $CaCl_2$ Mg) was increased or held at level by them, but they also increased the AL-K and Ca-reserve of the soil.

In our country, only a modest number of researches focus on observing and comparing the nutrient content of organic and integrated orchards yet. HOLB and NAGY (2004) were the first to publish about the changes of the measurable nutrient contents in the soil of apple orchards. In case of our experiment several times better nutrient levels and better nutrient supply were found in soil of the integrated cultured trees than in case of the organic orchard.

3.2.2. Changes of the parameters indicating the vegetative properties of the trees

Changes in strain field area

The strain field area of *Golden Delicious* and *Pinova* apple trees can be considered a kind of variety-specificity, which provides a characterization for the vigour of the varieties. Despite of the differences between the varieties, similar trends were experienced in the strain field areas and all the other analyzed parameters in both production technologies. Therefore, the sequence of the figures shown follows the technologies (and not the varieties). The strain field area of the *Golden Delicious* apple trees cultured in the organic orchard is displayed in **Figure 2.**

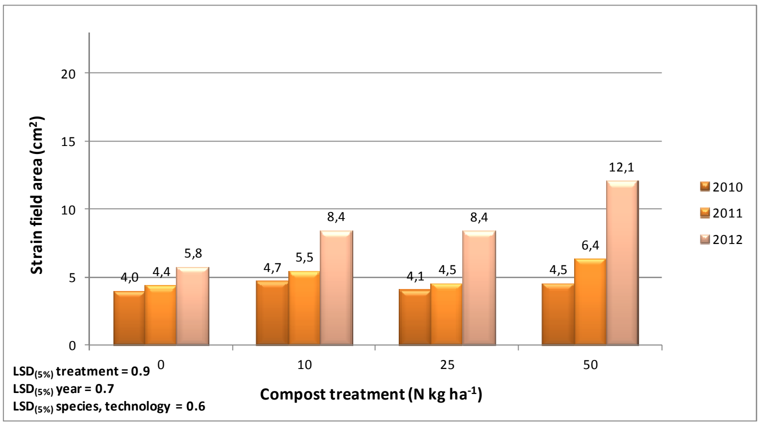

Figure 2 Strain field area of the *Golden Delicious* apple trees cultured in the organic orchard
(Debrecen-Pallag, 2010-2012)

In the starting year (2010) no significant increase in the strain field area of the trees due to the increase of the compost doses could be observed. At this time composting effect did not appear. In 2011 the strain field area of the trees treated with 10 and 50 kg N ha^{-1} significantly increased in comparison to the strain field area of the control. In 2012 the strain field areas significantly increased in case of all compost treatments. Within a certain treatment, in 2012 the average annual trunk area increased by an average 64 % (in the order of the treatments: 31, 52, 86 and 89 %) comparing to the previous year's increase. **Figure 3** demonstrates the strain field area of the *Pinova* apple trees cultured in the organic orchard.

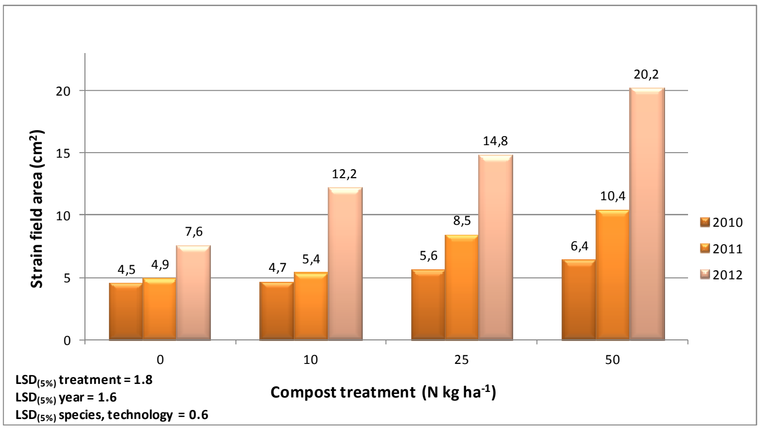

Figure 3 Strain field area of the *Pinova* apple trees cultured in the organic orchard
(Debrecen-Pallag, 2010-2012)

The growth of the strain field area of the *Pinova* apple trees followed a similar trend as the *Golden Delicious* trees'. In 2010, there was a small increase in this parameter in parallel with the increase of the compost doses and in 2011 there was a more stronger increase (the 25 and the 50 kg N ha^{-1} is significantly different in comparison to the control), while in 2012, an obvious trend-like increase could be observed in case of all compost treatments. The trunk areas measured in 2012 were higher with an average of 87 % (in the order of the treatments: 55, 125, 74 and 94 %) comparing to the previous year's increase. The strain field area of the *Golden Delicious* apple trees cultured in the integrated orchard is demonstrated in **Figure 4.**

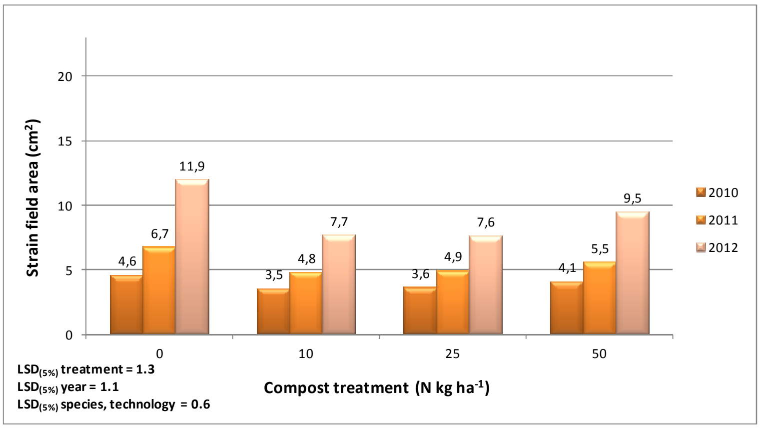

Figure 4 Strain field area of the *Golden Delicious* apple trees cultured in the integrated orchard *(Debrecen-Pallag, 2010-2012)*

There was no significant difference in the strain field area with the increase of the compost amounts in 2010 and 2011, while in 2012 significantly lower values were observed comparing to the control. Within the certain treatments in 2012, the annual trunk areas increased with on average of 66 % (in the order of the treatments: 77, 60, 55 and 72 %) comparing to the previous year's increase. **Figure 5** shows the strain field area of the *Pinova* apple trees cultured in the integrated orchard.

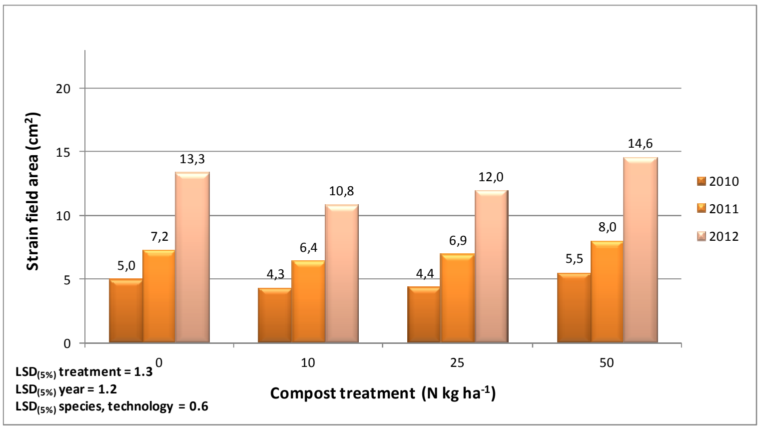

Figure 5 Strain field area of the *Pinova* apple trees cultured in the integrated orchard *(Debrecen-Pallag, 2010-2012)*

In 2010 and 2011 the increasing compost doses had no effect on the strain field area, while in 2012 significant decrease was observed (in case of the 10 and 25 kg N ha^{-1} treatments) comparing to the control (except the 50 kg N ha^{-1} where the strain field area significantly increased). The annual trunk areas measured in 2012 were bigger with

77 % (in the order of the treatments: 84, 68, 74 and 82 %) than the previous year's increase.

At the start of the experiment the strain field area of the marked control and treated trees did not differ from each other (except in case of the 50 kg N ha^{-1} treatment in the organic Pinova), therefore their strength could be considered statistically uniform.

The average shoot length

Figure 6 illustrates the average length of shoots being on the first-order branches of the organic cultured *Golden Delicious* trees.

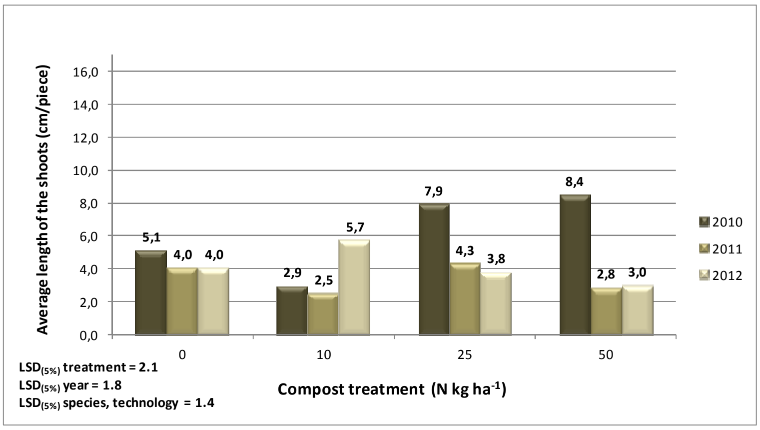

Figure 6 Average length of the shoots being on the first-order branches of the organic cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

In 2010, there was no compost effect, however in case of the 25 and 50 kg N ha^{-1} treatments longer shoots were measured comparing to the control. The increasing compost doses had no significant effect on the shoot length in 2011 and 2012. **Figure 7** illustrates the average length of shoots being on the first-order branches of the organic cultured *Pinova* trees.

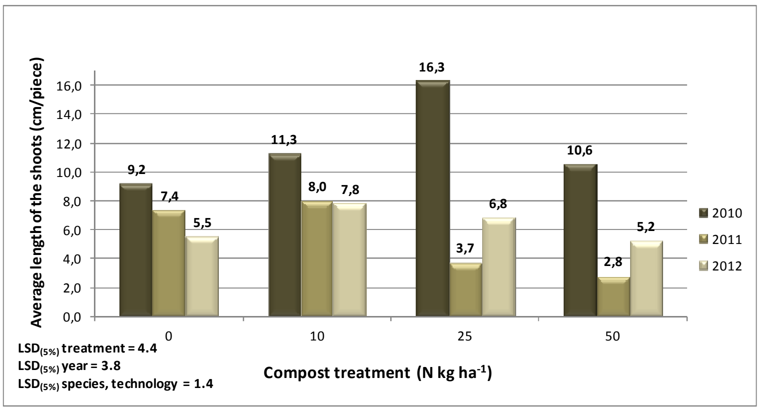

Figure 7 Average length of the shoots being on the first-order branches of the organic cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

In case of the *Pinova,* similarly to the *Golden Delicious,* the longest shoot lengths were measured in 2010. In case of the 25 kg N ha^{-1} treatment a high average value was measured (16.3 cm), which can be explained with that a relative big shoot length associated to the low shoot number. With the increase of the compost amounts significant decrease of shoot length could be observed in 2011, while in 2012 there was no significant difference comparing to the control. **Figure 8** demonstrates the number of the average length of the shoots being on the first-order branches of the integrated cultured *Golden Delicious* trees.

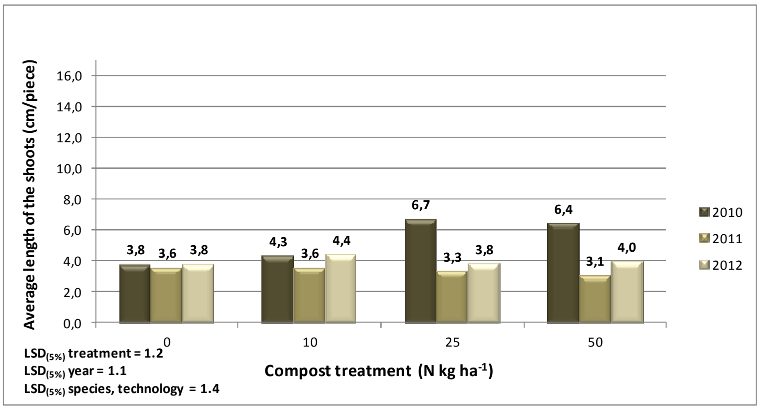

Figure 8 Average length of the shoots being on the first-order branches of the integrated cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

Similarly to the shoot length of the organic cultured *Golden Delicious* trees in 2010; in case of the two biggest compost doses a significant difference could be observed. There was no significant difference between the shoot lengths in 2011 and 2012. **Figure 9** displays the average length of the shoots being on the first-order branches of the integrated cultured *Pinova* trees.

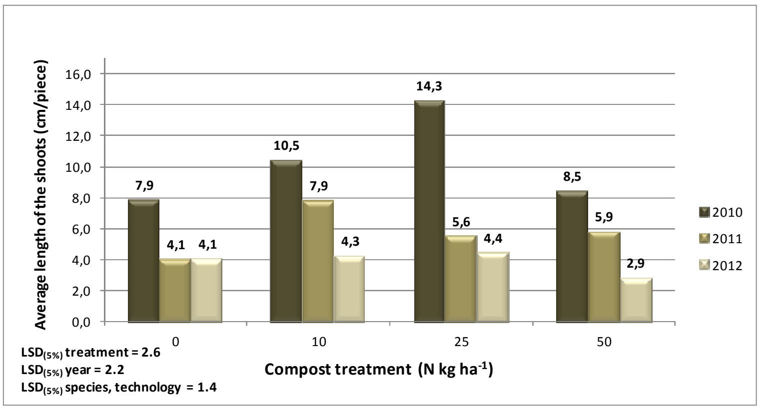

Figure 9 Average length of the shoots being on the first-order branches of the integrated cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

In case of the organic *Pinova* trees, a tendency similar to the integrated *Pinova* trees could be observed. In 2010, very high average shoot lengths were measured and in 2011 and in 2012 shorter shoots could be observed, which did not differ from the control.

With the increase of the age of the trees, decrease was observed in the shoot length.

The relationship between the total shoot length and the number of the shoots** was also examined. A close correlation between the total shoot length (cm) and the number of the shoots (pieces) was experienced (the value of the correlation coefficient was $R^2 > 0.9096$ in most cases). This means that the higher total shoot length coupled with higher shoot number. The closest relationship was found between the total shoot length and number of shoots in case of the integrated cultured Golden Delicious apple trees* ***(Figure 10).

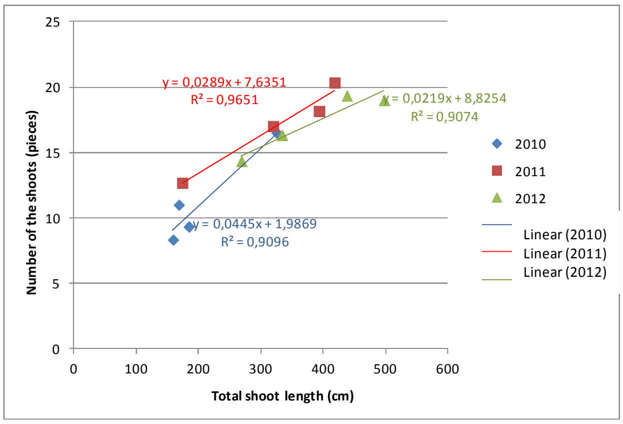

Figure 10 Relationship between the total shoot length and the number of shoots in case of the integrated cultured *Golden Delicious* apple trees *(Debrecen-Pallag, 2010-2012)*

Based on this it can be concluded that these factors are directly proportional with each other and the average shoot length (cm/piece) calculated from their quotient was opposite. Where the length or the number of the shoots was higher, the mean values were lower. This data is important in terms of the K contents of the leaves.

Leaf area in 2010 and 2012

Figure 11 illustrates the average leaf area of the control and treated trees of organic and the integrated cultured *Golden Delicious* and *Pinova* apple trees.

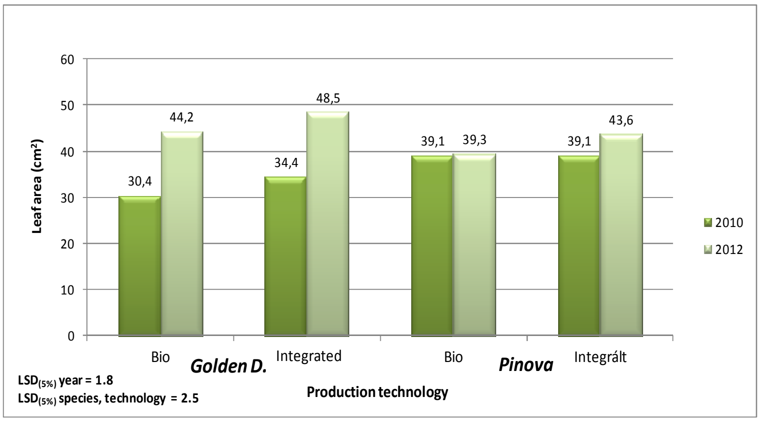

Figure 11 Average leaf area of the organic and integrated cultured *Golden Delicious* and *Pinova* apple trees *(Debrecen-Pallag, 2010 and 2012)*

As it can be seen in the figure the leaves of organic cultured *Golden Delicious* were the smallest in 2010. In 2012 a significant increase could be observed. In 2010, the leaves of the integrated *Golden Delicious* trees were significantly bigger comparing to the leaves of the organic cultured trees. In 2012 the biggest leaf areas were measured. In 2010 the leaf area of the organic *Pinova* leaves did not change, and the leaf area of the integrated leaves did not differ significantly, although in 2012 the mineral fertilization caused a significant increase.

The integrated cultured trees had bigger leaf areas than the organic cultured trees.

The leaf area of the Golden Delicious trees showed a stronger reaction to the compost treatments, while the leaf area of the Pinova trees showed a slight correlation with the amount of precipitation.

3.2.3. Changes of the parameters indicating the generative properties of the trees

Number of fruits per tree

The amount of apples harvested from the organic cultured *Golden Delicious* trees can be seen on **Figure 12**.

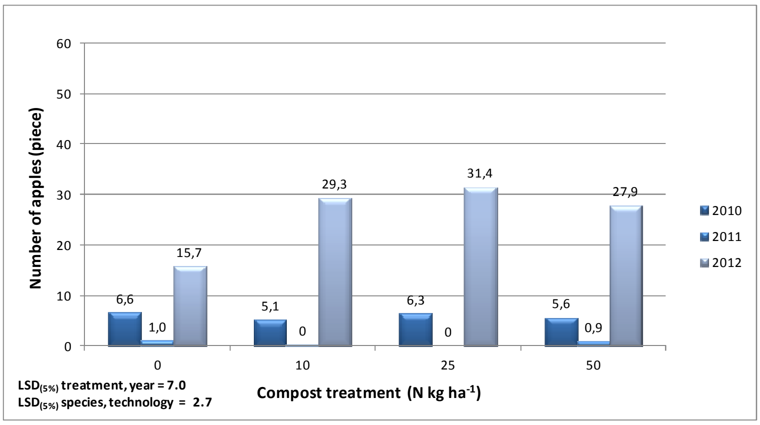

Figure 12 Number of apples per tree harvested from the organic cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

In 2010 there was no relationship between the compost treatments and the number of the apples (compost was applied after the first crop binding). An average of 5-6 apples were counted per tree. In 2011, due to several days of spring frost damage (based on the data of the DE Agro-meteorological Observatory), significant yield loss was observed. In 2012, significant increase was experienced in the number of the apples due to the compost doses; it should be noted that the trees (31.5 pieces) treated with 25 kg N ha^{-1} had an average twice as many apples as it was counted on the control trees (15.7 pieces). **Figure 13** illustrates the number of apples harvested from the organic cultured *Pinova* trees.

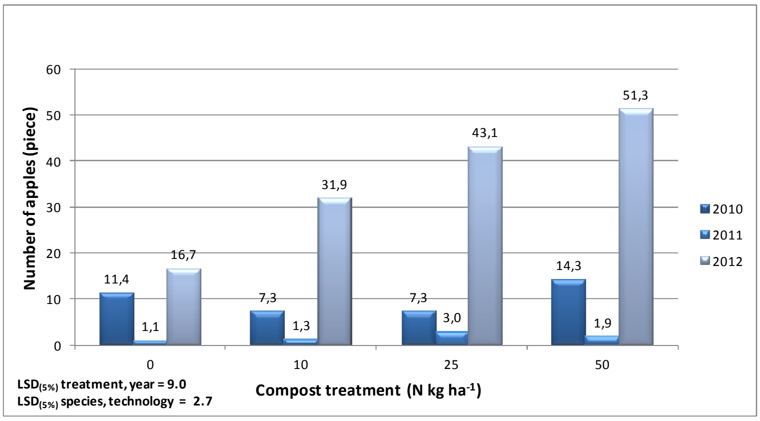

Figure 13 Number of apples per tree harvested from the organic cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

It can be concluded that in 2010 the number of the *Pinova* apples not increased yet, in 2011 there was not at all because of the frost at flowering, however in 2012 the compost doses significantly increased the number of the apples in case of all treatment in comparison to the control. The number of *Golden Delicious* apples harvested from the integrated cultured orchard can be seen in **Figure 14.**

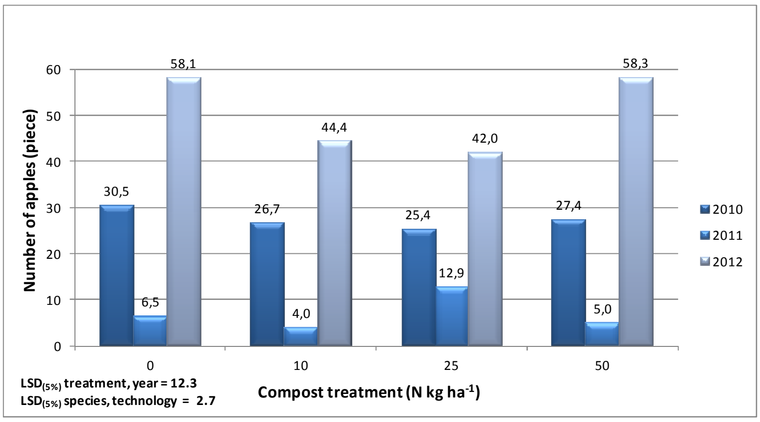

Figure 14 Number of apples per tree harvested from the integrated cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

In case of the integrated technology, besides the applied compost doses the effect of the mineral fertilization on the number of the apples could also be observed. In 2010, there was no significant difference in the number of the apples between the treated trees. In 2011, due to frost damage, a low but countable number of apples were on the trees. In 2012, with the trees turning to bear fruit, the number of the fruits suddenly increased, although there were no significant differences in the number of the apples. **Figure 15** displays the number of apples harvested from the integrated cultured *Pinova* trees.

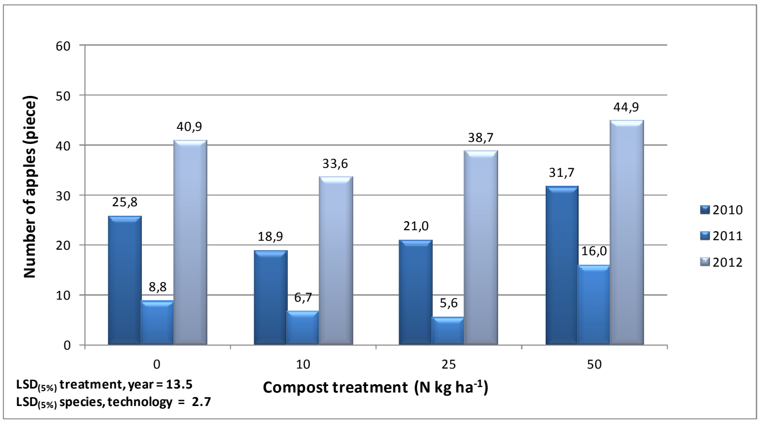

Figure 15 Number of apples per tree harvested from the integrated cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

The trend of the number of the integrated *Pinova* apples was similar to the number of the integrated *Golden Delicious* apples: in 2010 the compost had no effect yet, in 2011 there was a small effect of compost treatments on the nutrient supply (there were some countable apple on the trees comparing to the organic trees), while in 2012 a sudden, statistically not significant result could be seen, which primarily refers to the effect of the mineral fertilization.

In 2010 no composting effect could be effect observed (the first application was performed after the crop binding). In 2011, there were no apples on the trees. The reason of the crop failure was the early spring frost, which caused damage during the period of flowering. In 2012, a significant increase was observed in the number of apples in parallel with the increase of the compost doses (primarily in the organic).

3.2.4. Results of the leaf analysis

<u>Dry matter content of the leaves</u>

The dry matter content of the leaves of the organic cultured *Golden Delicious* trees is illustrated in **Figure 16.**

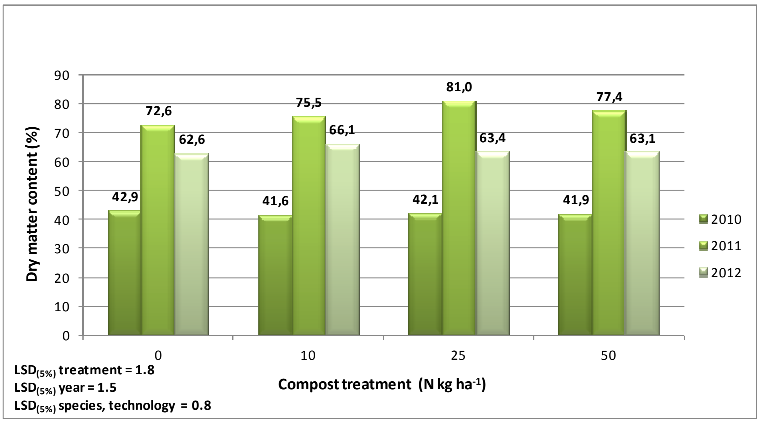

Figure 16 Dry matter content of the leaves of the organic cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

The differences among the treatments are relatively modest, significant increase was observed in 2011 in case of the 25 and 50 kg N ha^{-1} treatments, and also in 2012, in case of the 10 kg N ha^{-1} treatment comparing to the control. The dry matter content of the leaves of the organic cultured *Pinova* trees can be seen in **Figure 17.**

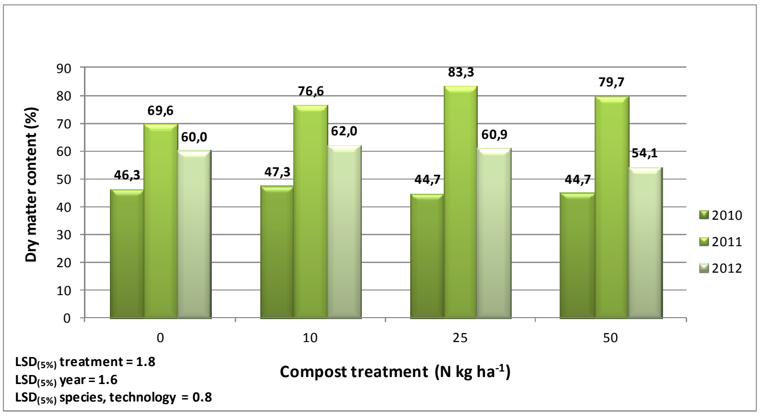

Figure 17 Dry matter content of the leaves of the organic cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

In 2011, significant differences were measured in the dry matter content of the leaves comparing to the control, in parallel with the increase of the compost doses, probably due to the lack of the crop. In 2012 the dry matter content of the leaves treated with 10 kg N ha^{-1} was significantly higher than the control. The dry matter content of leaves of the integrated cultured *Golden Delicious* trees is displayed in **Figure 18.**

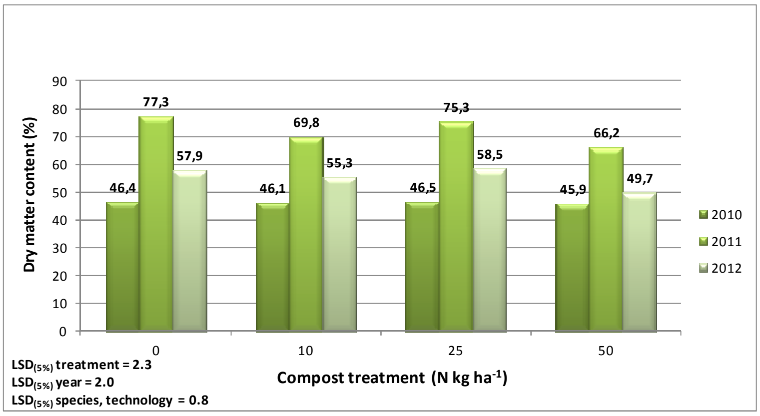

Figure 18 Dry matter content of the leaves of the integrated cultured *Golden Delicious* trees *(Debrecen-Pallag, 2010-2012)*

No (in 2010), or not significantly decreasing effect could be observed among the compost treatments comparing to the control (2011 and 2012). The dry matter content of the leaves of the integrated cultured *Pinova* trees is illustrated in **Figure 19.**

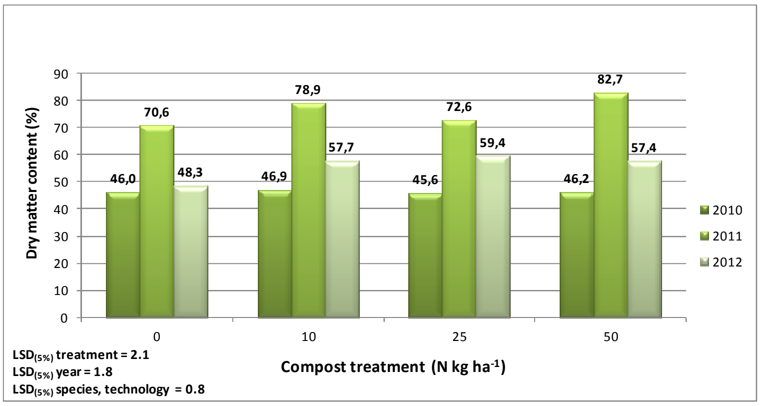

Figure 19 Dry matter content of the leaves of the integrated cultured *Pinova* trees *(Debrecen-Pallag, 2010-2012)*

In 2011 and 2012 all the treatments differed significantly from the control. Within a certain treatment the effect of the year and perhaps the lack of the crops could be seen.

In 2010 the compost probably did not have an effect on the nutrient content of the leaves yet. In 2011 the effect of the compost could be observed, but there were no fruits on the trees. In 2012, besides a fruit load on increase in the dry matter contents was measured.

About the evolution of the dry matter content of the leaves trend-like statements could be made due to the annual precipitation. The dry matter content was lower in 2010 (≈43 %), higher in 2011 (≈74 %) and in 2012 mean values of the mentioned two years (≈60 %) could be observed.

<u>K content of the leaf samples</u>

The K content of the organic cultured *Golden Delicious* leaves is illustrated in **Figure 20.**

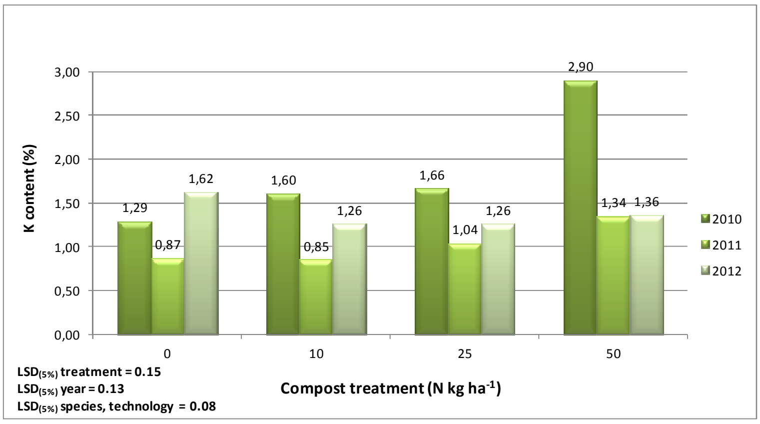

Figure 20 K content of the organic cultured *Golden Delicious* leaves *(Debrecen-Pallag, 2010-2012)*

The highest K contents were measured in the initial year, probably due to the wet year. In 2010 and 2011, a significant increase in the K content of the leaves was experienced in parallel with the increase of the compost doses comparing to the control. In case of low fruit load the vegetative overweight was relatively higher. In 2012, on the contrary, there was a decrease in the element contents, possibly due to the increase in fruit load and the drought. Within the certain treatments there was a relationship between the K content of the leaves and the average length of the shoots being on the first-order branches **(Figure 6)**. It was found that the K content of the leaves was higher, where longer average shoot lengths (cm/piece) were measured. **Figure 21** demonstrates the K content of the organic cultured *Pinova* leaves.

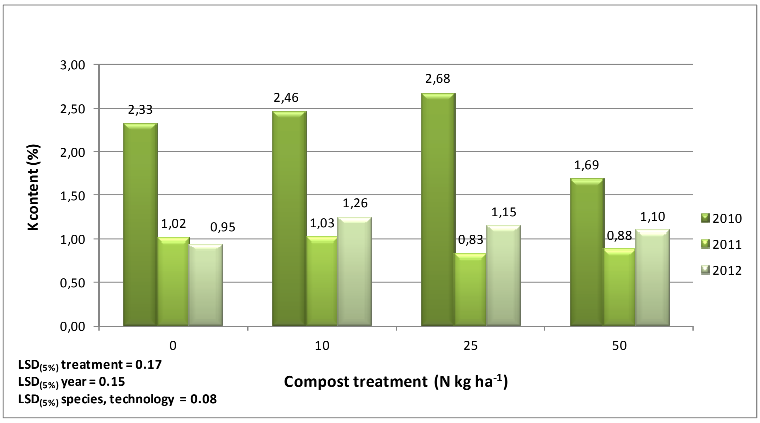

Figure 21 K content of the organic cultured *Pinova* leaves
(Debrecen-Pallag, 2010-2012)

In 2010, heavy rainfall was likely to increase the K uptake of the trees; and outstanding element contents were measured comparing to the other years. Initially, a significant increase in the K content could be observed due to the increasing compost doses comparing to the control, then in case of the 50 kg N ha^{-1} treatment statistically proven decrease could be observed. This tendency also correlated with the average length of the shoots (**Figure 7**). In 2011 and 2012, stagnation could be seen in the element contents. The K content of the integrated cultured *Golden Delicious* leaves is illustrated in **Figure 22.**

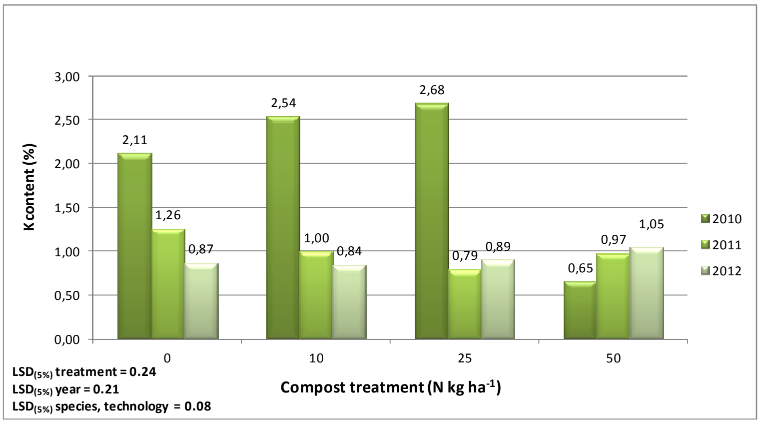

Figure 22 K content of the integrated cultured *Golden Delicious* leaves
(Debrecen-Pallag, 2010-2012)

The K contents measured in the first year were the highest (except the 50 kg N ha^{-1} treatment). In 2010, the K content increased significantly then decreased in 2011 and stagnation was experienced in 2012 in parallel with increasing the compost doses. Within a certain treatment the K content decreased as the years passed (except the 50 kg N ha^{-1} treatment), which only partially followed the evolution of the average shoot lengths (**Figure 8**). The K content of the integrated cultured *Pinova* leaves can be seen in **Figure 23.**

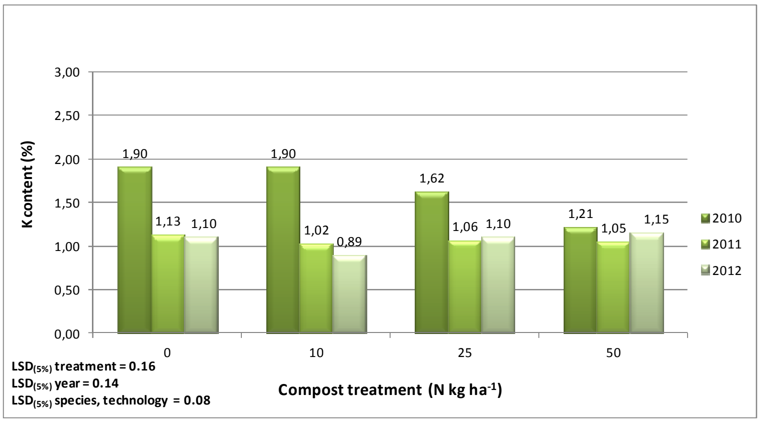

Figure 23 K content of the integrated cultured *Pinova* leaves
(Debrecen-Pallag, 2010-2012)

K contents measured in the initial year were also over to the mean of the other years. In 2010, the K contents significantly decreased in parallel with increasing of the amount of the compost. In 2011 and 2012, no significant change due to the compost treatments was experienced. Within the same treatment significant decrease in the K contents was measured comparing to the first experimental year and this partially follows the average length of the shoots (**Figure 9**).

Examining the K-supply of the leaves it can be stated that the initial year the highest (> 2.0 %), and in the following year the lowest (≈1.0 %) K-contents were measured. According to BÚZÁS (1983) the first case shows over-supply and the last case shows slight-supply.

In 2011 and 2012, in the rainfall poor years, the effect of the vintage factors on the K content were more prominent in the organic cultured orchard, than the integrated technology. Lower values were measured in all cases in the drought year, but the rate of decrease was lower in the integrated technology. HOLB and NAGY (2004) had similar findings based on their leaf-diagnostic measurements. They detected significantly higher K content in the leaves of the integrated cultured the apples varieties than in the leaves of the organic cultured trees (NAGY, 2009).

Ca content of the leaf samples

The Ca contents of the organic cultured *Golden Delicious* leaves can be seen in **Figure 24.**

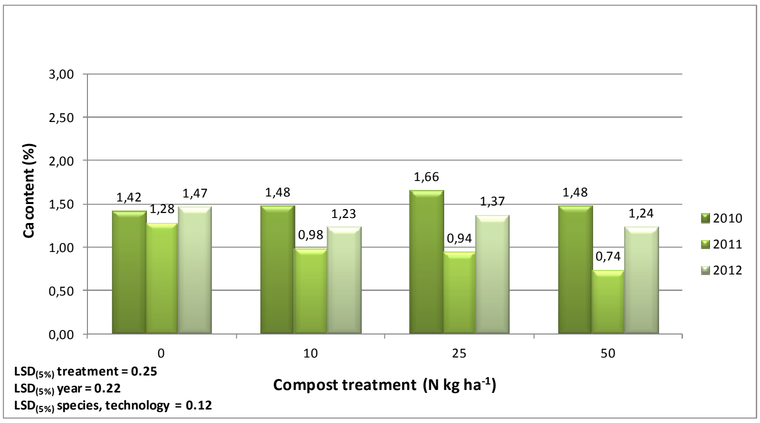

Figure 24 Ca content of the organic cultured *Golden Delicious* leaves
(Debrecen-Pallag, 2010-2012)

In 2010, no statistically justified increase of Ca content was found in parallel with increasing the compost treatments. In 2011 a significant, and in 2012 a mild decrease was observed in the Ca content of the leaves comparing to the control. Within a certain treatment different levels of decrease in the Ca content cold be observed comparing to the initial year. The lowest Ca contents were measured in the frost damaging year and the highest in the wet year. The changes of the element contents are likely to be associated with the vintage effect or the change in the dry matter content (**Figure 16**). The Ca content of the organic cultured *Pinova* leaves is illustrated in **Figure 25.**

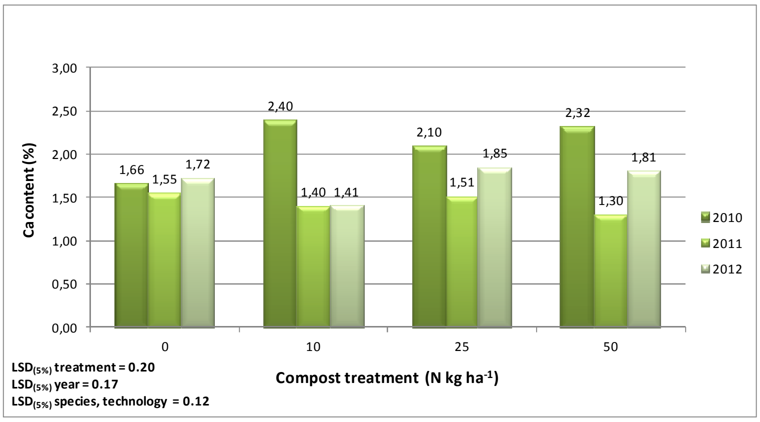

Figure 25 Ca content of the organic cultured *Pinova* leaves
(Debrecen-Pallag, 2010-2012)

In 2010, significant increase in the element content was observed comparing to the control treatment due to the raise of compost doses. In 2011 significantly lower values were measured in case of the 50 kg N ha^{-1} treatment and in 2012 in case of the 10 kg N ha^{-1} treatment comparing to the control. Within the certain treatments the highest Ca contents were measured in 2010, and the lowest in 2011, as well as the annual rainfall trends. The Ca content and the dry matter content showed an inverse relationship

(**Figure 17**). The Ca content of the integrated cultured *Golden Delicious* leaves can be seen in **Figure 26.**

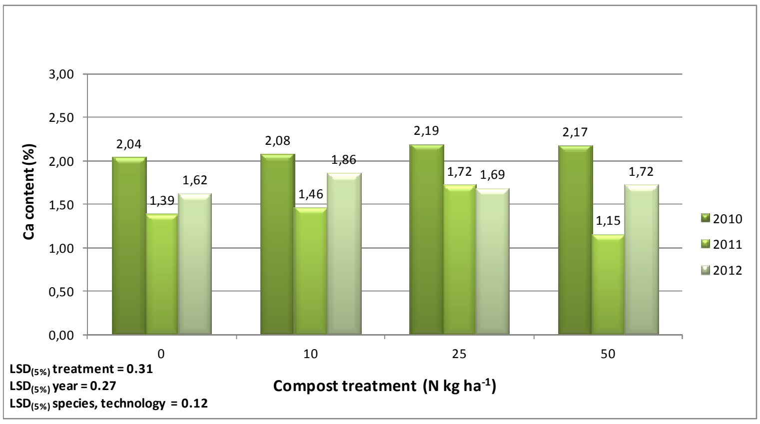

Figure 26 Ca content of the integrated cultured *Golden Delicious* leaves *(Debrecen-Pallag, 2010-2012)*

There was no significant increase observed in the Ca content due to the compost dose comparing to the element content of the control leaves. Within a certain treatment the highest Ca contents were measured in the starting experimental year, while the lowest contents were measured in the crop deficient year. The inverse evolution of the dry matter content and Ca content is reflected again (**Figure 18**). The Ca content of the integrated cultured *Pinova* leaves is illustrated in **Figure 27.**

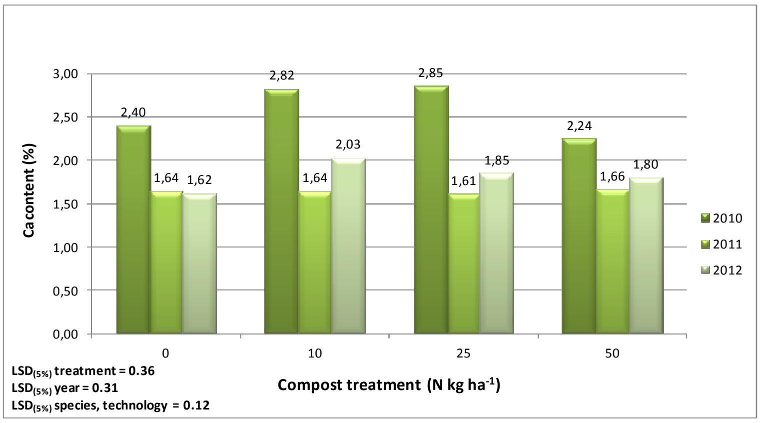

Figure 27 Ca content of the integrated cultured *Pinova* leaves *(Debrecen-Pallag, 2010-2012)*

The amount of compost did not influence the Ca content of the leaves. There were no significant differences among the treatments in any of the years comparing to the control. Within a certain treatment it can be observed that the changes in the Ca-levels reflected the fluctuation of the annual rainfall, and at the same time it was inverse proportion to the dry matter content (**Figure 19**).

The Ca content of the leaves could be considered favourable at 1.2-1.8 % (SZŰCS, 1999). In case of our experiment in the leaves of the integrated cultured trees (in 2010) in a rainy year element contents above the limit (> 2.0 %), in 2011, optimal amounts (1.4-1.6 %) were measured (when the Ca content of the leaves was the lowest). The Ca-level of the organic leaves was lower, than in the integrated orchard.

Considering the vintage effect it can be concluded that in a rainy year the Ca content maybe lower and in arid and crop deficient year the Ca content can be higher.

4. NEW AND NOVEL SCIENTIFIC RESULTS

1. **Druing the three years of the field experiment we concluded that, all the compost doses justifiably increased the strain field area – the complex index of vegetative performance of the trees – in case of both apple varieties in the organic cultivation (where mineral fertilization is excluded).**

2. **In the integrated culture, where the trees inherently had a bigger growth potential (as a result of the mineral fertilization), it was concluded that the compost did not have strain field-increasing effect.**

3. **It was concluded that regardless of the production method, there was a close relationship between the lengths and number of the shoots in case of both apple varieties, which was proven by the value of the correlation coefficient ($R^2 > 0.9096$). Accordingly, a higher total shoot length coupled with higher shoot number.**

4. **It was demonstrated that the trees integrated orchard trees had significantly higher leaf area in case of both varieties, than the organic trees had.**

5. **According to the results it was confirmed that the dry matter and Ca content of the apple leaves were inversely proportional to each other.**

6. **It was concluded that the K content of the apple leaves shows a direct proportional context with the average shoot length (cm/piece).**

7. **It was demonstrated that the compost doses and the bigger nutrient source together could favourably offset the decreasing effect of spring frost on fruit**

binding in the integrated culture and this effect could not be observed in the organic culture.

8. **It was concluded that the compost increased the weight of the *Golden Delicious* apples in the organic orchard only in the drought year, while the weight of the *Pinova* apples was increased by the compost treatment in all the examined three years.**

5. PRACTICAL SCIENTIFIC RESULTS

1. Based on the experiences of our pot experiments, considering the feasibility and efficiency of the application of compost an average application dose was determined, of which effect was considered more favourable in the horticulture (4-8 kg m^{-2}).

2. During the examination period it was found that the compost treatments increased the nutrient content not only in the organic culture but also in the soil of the integrated culture. Primarily, the amount of easily uptakeable nutrients (such as nitrate, ammonia, organic-N, $CaCl_2$ Mg) increased, but the AL-K and Ca-resource of the soils increased as well.

3. Considering the specific number of shoots of the trees treated with compost it was stated that more shoots developed in case of the integrated cultured trees, than in case of the organic orchard, which was directly associated to a productive type of growth form and plant condition.

4. Better nutrient levels and ratio were found in more cases in the apple leaves of the integrated culture, then in the organic culture (e.g. Mg content, K/Ca ratio), suggesting that the modest nutrient content of the soil of organic orchard and its uncertain uptake possibilities raise awareness of the critical importance of regular nutrient supply.

5. It was concluded, that from the two apple varieties the *Pinova* is the less sensitive to the unfavourable soil nutrient supply conditions. Its growth and yield characteristics are more balanced comparing to the *Golden Delicious* proving its better applicability for the organic cultivation.

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