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Original Paper

Bioefficacy of *Moringa oleifera* and *Anacardium occidentale* against insect pests of watermelon (*Citrullus lanatus* Thumb) and their effects on watermelon fatty acid profile

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This experiment was carried out at Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeriaduring the late and early planting seasons of 2011 and 2012 to determine the efficacy of *Moringa oleifera* (L) and *Anacardium occidentale* (L) extracts on major insect pests of pests of watermelon and their effects on fatty acid compound of watermelon. This experiment was arranged in a randomized complete block design and each treatment was replicated three times. Each of the plant extracts was applied at three different concentrations (5, 10 and 20% v/v). Gas chromatography was used to determine the level of fatty acid composition of the harvested watermelon. The results showed that the applied plant extracts exhibited insecticidal action against *Aulocophora africana* (Weise) and *Dacus cucurbitae*(Coquillet), with *M. oleifera* proved to be more effective than *A. occidentale* extracts in the control of the observed insects. Although, none of the plant extracts significantly($P >0.05$) performed better than synthetic insecticide (Lambdacyhalothrin) against the studied insects during the raining season fruits obtained from extracts treated-plots had higher number of fatty acid compounds than those of the synthetic insecticide treated-plots. Therefore, the use of botanical extracts in the management of insect pests of watermelon improved the fatty acid contents of watermelon fruit.

Keywords: *Moringa oleifera*, *Anacardium occidentale, Aulocophora africana*, *Dacus cucurbitae*, Lambdacyhalothrin, watermelon

1 Introduction

Watermelon (*Citrullus lanatus* Thumb) belongs to the Cucurbitacea family which includes about 118 genera and 825 species (Dane, 2007). It originated from Kalahari and Sahara deserts in Africa (Schippers, 2000) and now found in Tropical and subtropical climates worldwide. It has been reportedly cultivated for a long time in Africa and in the middle East and Egypt (Huh, 2008).

According to Schippers (2000), the fruit reportedly contains 95% water, 5 mg Carbohydrate, 8 mg Calcium, 0.64 g vitamins, 9 mg Phosphorous and 8 mg ascorbic acid per 100 g of edible portion. It has highest Lycopene, content among fresh fruits and vegetables, containing 60% more Lycopene than tomato. Lycopene has been reported to prevent heart attack and certain cancers (Perkins-Veazie, 2001). Rind of watermelon contains an important natural compound called Citrulline, an amino acid that is required by human body. Citrulline is found in high concentration in liver and is involved with athletic ability and functioning of immune system (Perkins-Veazie, 2001). Also, it is a good source of fiber which is important for keeping digestive tract operating properly by preventing constipation, hemorrhoids and diverticular disease

Cultivation of watermelon in Nigeria especially in Southern part of the country is low due to the high level of insect infestations during early season (Alao et al., 2015). Insect pests such as, *Aulocophora africana*, *Zonocerus variegatus*, *Phylothreta cruciferae*, *Dacus cucurbitae* etc. have been implicated to cause various degree of damage to this crop (Olaifa, 1987). Also, most of these insects are responsible for the transmission of diseases (Webb, 2010).

In order to obtain high fruit yield, protection of this crop against aforementioned insects is highly necessary. In developing countries, farmers apply synthetic insecticides to combat the insect pest attack of watermelon. Synthetic insecticides have quick action against the insect pest infestation but they are not easily degraded in the environment thereby resulting into environmental

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pollution (Isman, 2006). Some of these insects have been reported to develop resistance to the application of synthetic insecticides. Consumers as well as farmers are not saved from the use of synthetic insecticides. In view of these facts, alternatives to the use of synthetic insecticide should be initiated and such alternatives must be affordable, effective and environmentally friendly (Isman, 2008).

Several research works have been conducted on the use of plant secondary metabolites, which have been found to be effective against insect pests of some crops (Adebayo, 2003; Akhtare et al., 2008; Olaniran et al., 2013; Alao, 2015) *Moringa oleifera* also known as Horseradish tree, is a pan-tropical species that is known by such regional names as benzolive, drumstick tree, kelor, marango, saijhan and sajna (Fashey, 2005). *M. oleifera* can be grown in a variety of soil conditions preferring well-drained sandy or loamy soil that is slightly alkaline (Abdul, 2007; Anjorin et al., 2010). The main constituents of Moringa plant are oleic, palmitic and stearic acid, saponins, glycoside, gum, protein, vitamins A (8855iuper 100g), B1, B2, B3, C, Minerals: calcium, iron, phosphorus, magnesium (Mitta et al. 2007, Anjorin et al., 2010, Mehta et al., 2011). The medicinal effect of the plant was ascribed to their possession of anti-oxidants, which are known to suppress formation of reactive oxygen species and free radicals (Sofidiya et al., 2006; Ogbunugafor et al., 2011). It is a good source of nectar used by the honey bees for production of honey (Babarinde, 2009). Its insecticidal potentials against many insect pests have been reported by several authors (Babarinde et al., 2011; Ashfaq and Ashfaq, 2012; Santos et al., 2018). Cashew nut shell liquid (CNSL) contains a high proportion of phenolic compound, Anarcadic acid and Cardole (Oparaeke et al., 2005; Olotuah and Ofuya, 2010; Mukhopadyay et al.,2010). Ethanolic extract of cashew nut shell liquid was effective as synthetic insecticide (Cymbush) against field insect pests of cowpea (Olotuah and Ofuya, 2010). In addition to that insecticidal activities on stored insect pests have also been documented. For instance, Oparaeke and Bunmi (2006) observed that cashew nut shell caused 100% mortality of *Callosobruchus subannotatus* within 48 hours pot application.

However, most of these researchers did not consider the impacts of botanical insecticides on the nutritional contents of their particular studied crops. This has become necessary because the some crops are capable of absorbing the foreign materials into their body system which could generate a reaction on the phytochemical compounds inherent in the plant part. Therefore, this research was carried out to evaluate the insecticidal efficacy of *Moringa oleifera* and *A. occidentale* and their impact on the fatty acid compound of watermelon fruits.

2 Material and methods

2.1 Study site

The field experiment was conducted in the cropping season of 2013 and 2014 at Ladoke Akintola University of Technology (LAUTECH) Teaching and Research Farm, Ogbomoso, Nigeria. This region is on longitude 4° 3′ E and latitude 10° 5′ N. The region can be described as humid tropical falls in Southern Guinea Savannah of Nigeria.

2.2 Experimental design and management

The experimental land was ploughed and harrowed once. There were four treatments and each of the treatment was replicated three times in a Randomized Complete Block Design (RCBD). The plot size was 3 m by 3 m and each plot had four plant rows. Poultry manure was applied at 10 t/ha to all treated and untreated plots to ensure uniform distribution of the soil nutrients. This was done prior to the sowing of the watermelon seeds. The test crop was watermelon (variety Baby sugar). Two to four seeds were sown per hole which was later thinned after 14 days to achieve one plant per stand. Weeding was done manually.

2.3 Preparation of plant extracts

The leaves of *M. oleifera* and *A. occidentale* were air-dried for two days and each of the plant material was crushed separately with mortar and pestle. Five hundred grams (500 g) of the crushed plant materials were weighed separately with sensitive scale after which each of the paste was put into a separate 10-litre plastic buckets containing 1000 ml of water. The soaked materials were allowed to stay overnight. The filtration was done with muslin cloth and filtrates collected were stored in a 5-litre plastic keg as stock solution. One litre of each of the plant extracts was measured out from the stock solution of which three concentrations (5, 10 and 20%) were calculated (Alao and Adebayo, 2016).

2.4 Treatment application

Application of the treatment commenced three weeks after planting and this was done early in the morning with 2-litre capacity hand held sprayer. Each of the concentrations of the plant extracts and synthetic insecticide were further diluted with 1,000 ml of clean water to achieve the same spraying volume. Untreated plots were sprayed with ordinary water and synthetic insecticide was applied at 400 ml per ha. Spraying was done at seven- day intervals and four- weekly observations were made.

2.5 Data collection and analysis

Population densities of adult *Phyllotreta cruciferae*, *Aulocophora africana*, *Diabrotica undecimpunctata* and *D. cucurbitea* were made by visual observation and this was done a day after each weekly treatment. Random sampling of the insects was done from the two middle plant rows. This was done early in the morning when they were relatively inactive (Alao and Adebayo, 2016).

Data were also collected on matured fruit damaged, defoliated flowers and young fruit damaged using the method described by Alao and Adebayo (2016).

Three months after planting, the matured fruits were harvested and weighed on the field with manual scale in kilogram (kg) which was later calculated in ton per hectare (t/ha). Collected data were subjected to analysis of variance (ANOVA) and significant means were separated using Ducan multiple range text at 5% probability.

2.6 Extraction of fatty acid compounds

The fatty acid methyl esters were extracted thrice from the mixture with redistilled n-hexane. A 50 mg portion of the extracted oil (extracted with n-hexane boiling point of 40–60 °C using Soxhlet apparatus). The sample collected was esterified for five minutes at 95 °C with 3.4 ml of the 0.5 M KOH in dry methanol. The mixture was neutralized by using 0.7 M HCL and 3 ml of 14% boron triflouride in methanol. The mixture was heated for 5 minutes at the temperature of 90 °C to achieve complete methylation process. The content was concentrated to 10 ml for gas chromatography analysis and 1 µl was injected into the injection port of GC. The fatty acids were identified by comparing their retention times with those of standards. The content of the fatty acids was expressed as percentage of total fatty acids.

2.7 Quantification of fatty acid compounds

Presence of fatty acid in the treated and untreated watermelon fruit was determined with the aid of gas chromatography with column dimensions 30 m × 0.25 mm × 0.25 µm, column type Agilent 19091-433HP-5MS 5% phenyl methyl silox. The Machine model was 7890A GC system, 5675C Inert MSD with triple Axis detector. GC-MS conditions were ion source temperature (EI), 250 °C. interface temperature; 300 °C, pressure; 16.2 psia, out time, 1.8 mm, lµl injector in Split mode with split ratio 1:50 with injection temperature of 300 °C the column temperature started at 100 °C for 1min and changed to 200 °C at the rate of 4 °C per min, the temperature was raised to 230 °C at the rate of 2 °C per min and the temperature was then raised to 280 °C at the rat of 8 °C per min and held for 15 min and helium as a carrier gas. The total elution was 62.25 min. This was done at University of Ilorin Kwara state, Nigeria. MS Solution software provided by supplier was used to control the system and to acquire the data; Identification of the compounds was carried-out by comparing the mass spectra obtained with those of the standard mass spectra from NIST library (NIST, 2005).

3 Results and discussion

3.1 Effect of botanical extracts and synthetic insecticides on Dacus cucurbitae populations

The results presented in Table 1 shows that the two tested plant extracts had the same insecticidal effects at 1 week after treatment (WAT) but there were not significantly effective as Lambdacyhalothrin in both planting seasons. Similar result was obtained at 2 WAT during early season. Application of *M. oleifra* at 20% v/v significantly performed better than other tested concentrations at 3 WAT. Although *A. occidentale* extract at 20% v/v was not aseffective as *M. oleifera* at the same rate. The latter significantly controlled *D. cucurbitae* than 10 and 5% v/v at 3 WAT during early season. *A. occidentale* sprayed at 5 and 10% v/v failed to control *D. cucurbitae* when compared with populations of *D. cucurbitae* observed on the unsprayed plots in the early season.

Applied plant extracts at 20% v/v significantly proved effective in the control of *D. cucurbitae* compared

Table 1 Population of *Dacus cucurbitae* on watermelon plots treated with botanical extracts and synthetic insecticide

		Weeks After treatment (Early Season)				Weeks After treatment (Late Season)			
Treatments	Rate	1	2	3	4	1	2	3	4
Lambdacyalothrin		1.4^{b}	1.0^{b}	0.7c	0.7c	1.0^{a}	0.7^{b}	0.7c	0.7^{b}
Control		2.2^{ab}	2.5^{a}	2.3^{a}	2.4^{a}	1.7^{a}	1.7^{a}	1.8^{a}	1.7^{a}
Moringa oleifera	5	2.1^{ab}	2.1^{a}	1.9^{ab}	1.9^{ab}	1.2^{a}	1.4^{a}	1.2^{ab}c	1.4^{ab}
	10	2.0^{ab}	2.2^{a}	1.9^{ab}	1.9^{ab}	1.2^{a}	1.3^{ab}	1.0c	1.3^{ab}
	20	2.0^{ab}	2.1^{a}	1.6^{b}	0.7c	1.2^{a}	1.2^{ab}	0.9c	1.0^{ab}
Anacardium occidentale	5	2.3^{a}	2.2^{a}	2.4^{a}	2.0^{ab}	1.4^{a}	1.4^{a}	1.7^{ab}	1.7^{a}
	10	2.0^{ab}	2.2^{a}	2.3^{a}	1.9^{ab}	1.4^{a}	1.5^{a}	1.3^{ab}c	1.4^{ab}
	20	2.1^{ab}	2.3^{a}	2.1^{ab}	1.7^{b}	1.3^{a}	1.3^{ab}	1.1^{b}c	1.3^{ab}

Means with the same superscript along the column are not significantly different at 5% probability using DMRT

Table 2 Population of Aulocophora africanaon watermelon plots treated with botanical extracts and synthetic insecticide

Treatments	Rate	Weeks After treatment (Early Season)				Weeks After treatment (Late Season)			
		1	2	3	4	1	2	3	4
Lambdacyalothrin		1.9^{b}	1.4^{c}	1.0^{d}	0.7^{e}	1.2^{b}	1.0^{b}	0.7^{d}	0.7^{b}
Control		2.6^{a}	2.8^{a}	2.5^{a}	2.2^{a}	2.0^{a}	2.3^{a}	2.3^{a}	1.5^{ab}
Moringa oleifera	5	2.2^{ab}	2.3^{ab}	1.9^{abc}	1.3^{cd}	1.7^{ab}	1.8^{ab}	1.5^{bcd}	1.2^{ab}
	10	2.2^{ab}	1.9^{abc}	1.4^{cd}	1.0^{de}	1.6^{ab}	1.8^{ab}	1.1^{cd}	1.0^{ab}
	20	1.9^{ab}	1.9^{bc}	1.3^{cd}	0.9^{de}	1.5^{ab}	1.6^{ab}	1.0^{cd}	0.7^{b}
Anacardium occidentale	5	2.4^{ab}	2.3^{ab}	2.1^{ab}	1.9^{ab}	2.0^{a}	2.0^{a}	2.0^{ab}	1.8^{a}
	10	2.4^{ab}	2.3^{ab}	2.1^{ab}	1.7^{bc}	1.9^{a}	2.0^{a}	1.9^{ab}	1.6^{ab}
	20	2.2^{ab}	2.1^{abc}	1.7^{bcd}	1.3^{cd}	1.8^{ab}	1.9^{ab}	1.7^{abc}	1.2^{ab}

Means with the same superscript along the column are not significantly different at 5% probability using DMRT

Table 3 Effect of botanical extracts and synthetic insecticide on Yield

Treatments	Rate	Yield Parameters (Early Season)					Yield Parameters (Late Season)				
		yield (t/ha)	fruit damage (%)	aborted fruit (%)	defoliated flower (%)	defoliated leave (%)	yield (t/ha)	fruit damage (%)	aborted fruit (%)	defoliated flower (%)	defoliated leave (%)
Lambdacyalothrin		34.0^{a}	17.4^{e}	17.2^{f}	8.4^{c}	13.8^{d}	25.6^{a}	8.4^{c}	13.8^{d}	3.8^{c}	8.9^{c}
Control		8.11^{c}	45.4^{a}	49.5^{a}	38.8^{a}	34.0^{a}	12.0^{c}	38.8^{a}	33.8^{a}	33.9^{a}	43.0^{a}
Moringa oleifera	5	13.9^{c}	36.6^{bc}	33.3^{cde}	23.1^{bc}	24.7^{bc}	17.2^{bc}	23.1^{bc}	24.7^{bc}	28.7^{ab}	30.8^{ab}
	10	18.8^{bc}	31.9^{cd}	31.7^{de}	20.5^{bc}	22.8^{c}	18.6^{abc}	20.5^{bc}	22.8^{c}	24.6^{ab}	28.1^{abc}
	20	26.8^{ab}	30.5^{d}	27.2^{e}	18.9^{bc}	22.3^{c}	22.0^{ab}	18.9^{bc}	22.3^{c}	18.9^{b}	21.1^{bc}
Anacardium occidentale	5	10.8^{c}	40.9^{ab}	42.8^{ab}	25.3^{ab}	31.8^{ab}	13.4^{c}	25.3^{ab}	31.8^{ab}	29.4^{ab}	40.8^{ab}
	10	14.3^{bc}	37.3^{bc}	39.3^{bc}	26.2^{ab}	25.5^{abc}	14.8^{c}	26.2^{ab}	25.5^{abc}	27.0^{ab}	35.2^{ab}
	20	20.7^{bc}	33.7^{cd}	35.2^{cd}	21.5^{bc}	25.6^{abc}	18.8^{abc}	21.5^{bc}	25.6^{abc}	24.2^{ab}	31.0^{ab}

Means with the same superscript(s) along the column are not significantly different at 5% probability using DMRT.

with other concentrations and *A. occidentale* (5, 10 and 20%) during early planting season at 4 WAT. In the early planting season, *M. oleifera* sprayed at 20% v/v competed effectively with Lambdacyhalothrin in the control of *D. cucurbitae*. All the applied plant extracts had significant efficacy when compared with control except *A. occidentale* applied at 5% v/v.

3.2 Effect of botanical extracts and synthetic insecticide on *Aulocophora africana* populations

The result presented in Table 2 shows that the tested plant extracts had the same significant insecticidal effects on *A. africana* irrespective of their concentrations at 1 WAT during early season. During the late planting season, *M. oleifera* had significantly higher effect than *A. occidentale* on *A. africana* except the plots treated with *A. occidentale* at 20% v/v. However, *A. occidentale* applied at 5 and 10% v/v did not exhibit insecticidal action during late planting season at 1 WAT.

The plots treated with *M. oleifera* at 20% v/v had the least *A. africana* population compared with other tested concentrations and *A. occidentale* during early planting season at 2 WAT. No significant difference was detected between the efficacy of *A. occidentale* applied at 5 and 10% v/v in both planting seasons at 2 WAT. At 3 WAT, plots sprayed with *A. occidentale* at 5 and 10% v/v had highest infestations when compared with *M. oleifera* (5, 10 and 20% v/v) and *A. occidentale* at 20% v/v but all the applied plant extracts exhibited insecticidal action against *A. africana* when compared with the control in both seasons. Plots treated with *M. oleifera* at 10 and 20% v/v had significantly lower *A. africana* population than plots treated with *A. occidentale* (5, 10 and 20% v/v) and *M. oleifera* treated with 5% v/v during early planting season at 4 WAP. However, during late planting season applied *A. occidentale* at 10 and 20% v/v had the same insecticidal potential with *M. oleifera* at 5% and 10% v/v.

3.3 Effect of botanical extracts and synthetic insecticide on watermelon agronomic parameters

Table 3 shows that pants sprayed with *M. oleifera* had significantly highest yield (26.8 and 22 t/ha respectively) in the both planting seasons when compared with other plant extracts tested concentrations and unsprayed plants (8.11 and 12.0 t/ha, respectively). No significant difference was observed in the yield obtained in *M. oleifera* treated plants at 10% v/v and *A. occidentale* treated plots at 10 and 20% v/v during early planting season but during late planting season, the obtained yield was significantly higher in *M. oleifera* treated plants than what was obtained in the plots treated with *A. occidentale*. However, yield obtained in the unsprayed plants (12.0 t/ha) was significantly the same as that of plots sprayed with *A. occidentale* at 5 and 10% v/v (13.4 and 14.8 t/ha respectively).

The least percentage of fruit damaged was recorded in Lambdacyhalothrin sprayed plants (8.4%) compared with applied treatments and unsprayed plants which had significant highest damaged fruit (38.8%) during late planting season. The result obtained in the early planting season follows the same trend as in the case of late planting season. Among the tested concentrations (5, 10 and 20% v/v), plots treated with *M. oleifera* at 20% had the lowest percentage fruit damaged during early planting season; but during late planting season, plots treated with *A. occidentale* and *M. oleifera* highest concentration had the least fruit damaged (21.5 and 18.9% respectively).

In respect to aborted fruit, untreated plants had highest percentage of aborted fruits in both seasons followed by the plots sprayed with the least plant extracts concentrations. *M. oleifera* extracts performed better in the prevention of aborted fruits than *A. occidentale*. None of these plant extracts exhibited higher level of prevention of abortion of young fruits as obtained in Lambdacyhalothrin- treated plants.

Number of defoliated flower observed in the Lambdacyhalothrin statistically compared to other treated plants and untreated plants during both planting seasons. Plants sprayed with *M. oleifera* at 20% v/v had the least defoliated flower in both planting seasons when compared with other plant extracts concentrations.

M. oleifera applied at 10% v/v competed effectively with *M. oleifera* at 20% v/v in respect to number of defoliated leaves. *M. oleifera* was more effective in the protection of leaves from being defoliated compared with *A. occidentale*.

Table 4 shows the effects of insecticides application on different unsaturated/saturated fatty acid compounds on watermelon fruits. Three fatty acid were observed in the synthetic insecticide Lambdacyhalothrin-treated fruits, which were Heptadecanoic acid, Nonadecanoic acid and Heneicosanic acid. However, five fatty acid Pentadecanoic, Heptadecanoic, Nonadecanoic, Heneicosanoic and Tricosanoic acids were detected in the fruits obtained from the plots treated with plant extracts and untreated fruits. Among the fatty acid, Heptadecanoic acid had highest percentage composition whereas Tricosanoic had the least composition in *A. occidentals* and untreated watermelon fruits but Pentadecanoic acid had the least composition in *M. oleifera*-treated fruits.

This experiment demonstrates the effectiveness of *M. oleifera* and *A. occidentale* in the control of *D. cucurbitae* and *A. africana*. Meanwhile, there was variation in

Table 4 Fatty acids profile of watermelon fruits obtained from plots treated with botanical extracts and synthetic pesticide

Source	Peak	Retention time RT	Compound Name	Chemical formula	% Composition
Lambdacyhalothrin	1-Absent				
	2	16.099	Heptadecanoic acid, methylester	$C_{18}H_{36}O_2$	55.1
	3	21.722	Nonadecanoic acid, methylester	$C_{20}H_{40}O_2$	15.9
	4	26.855	Heneicosanoic acid, methylester	$C_{22}H_{44}O_2$	30
	5-Absent				
Control	1	10.091	Pentadecanoic acid, methylester	$C_{16}H_{32}O_2$	5.12
	2	16.093	Heptadecanoic acid, methylester	$C_{18}H_{36}O_2$	57.7
	3	21.729	Nonadecanoic acid, methylester	$C_{20}H_{40}O_2$	15.4
	4	26.873	Heneicosanoic acid, methylester	$C_{22}H_{44}O_2$	20.2
	5	31.561	Tricosanioc acid, methylester	$C_{24}H_{48}O_2$	4.66
Moringa oleifera	1	10.11	Pentadecanoic acid, methylester	$C_{16}H_{32}O_2$	2.41
	2	16.098	Heptadecanoic acid, methylester	$C_{18}H_{36}O_2$	42.8
	3	21.72	Nonadecanoic acid, methylester	$C_{20}H_{40}O_2$	9.09
	4	26.87	Heneicosanoic acid, methylester	$C_{22}H_{44}O_2$	16.1
	5	31.567	Tricosanioc acid, methylester	$C_{24}H_{48}O_2$	8.79
Anacardium occidentale	1	10.091	Pentadecanoic acid, methylester	$C_{16}H_{32}O_2$	7.68
	2	16.089	Heptadecanoic acid, methylester	$C_{18}H_{36}O_2$	57.5
	3	21.733	Nonadecanoic acid, methylester	$C_{20}H_{40}O_2$	15.1
	4	26.881	Heneicosanoic acid, methylester	$C_{22}H_{44}O_2$	15.1
	5	31.572	Tricosanioc acid, methylester	$C_{24}H_{48}O_2$	4.62

the efficacy of the tested plant extracts against the observed insects. During the early planting *M. oleifera* had higher efficacy (57%) against the observed insects than *A. occidentale* which had 43% efficacy. This is an indication that *M. oleifera* exhibited higher insecticidal potential than *A. occidentale*. This observation is in line with earlier report by Alao (2015) who reported that *A. occidentale* extracts had the least insecticidal potential when compared with other selected plant extracts against insect pests of watermelon.

There was a significant reduction in the level of insect infestation in the plots treated with plant extracts compared with unsprayed plots. This suggests that the observed insects were susceptible to Quercetin and Kampeferol (Pace-Asciak et al., 1995) derived from *M. oleifera* and Anacardic acid and Cardanols (Rehm and Espig, 1991) which have been reported as insecticidal compounds in cashew nut extract. None of the applied plant extracts proved to be effective as the synthetic insecticide (Lambdacyhalothrin) during early planting season. This could be attributed to photo-stability of synthetic insecticide and environmental factors such as wind, sunlight and temperature which reduced the insecticidal potential of the plant based-insecticides (Eileen and Sydney, 2013). Meanwhile, the tested plant extracts compete effectively with Lambdacyhalothrin in the control of *A. africana* and *D. cucurbitae* in the late planting season this might have been due to low infestation rate of the target insects. Also, variation in the chemical composition of the plant extracts used due to seasons and weather factors can be another factor. Studies have shown that the variations in the secondary metabolites of botanicals occur in respect to age, locations and seasons and collection time (Isman, 2006; Usman et al., 2017). The efficacy of each of the tested plant extracts depended on the rate of application (Alao et al., 2011). These data suggest that the higher applied concentration exerted lower level of insect infestation. This observation concurs with earlier reports by Seljasen and Meadow (2005) and Alao and Adebayo (2015) who reported that the applied plant extracts acted in a dose- dependent manner in the control of insect pests.

The ultimate aim of every poor-resource farmers is high yield (Adebayo, 2003). However, the major factor militating against fruit yield is the insect infestation which affects both physiological and morphological structure of the target crop (Alao et al., 2016). *D. cucurbitae* has been implicated for the premature falling of young fruits and damage of matured ones (Dihllion et al., 2005). Therefore, the low yield obtained in the unsprayed plants clearly showed that the rate of insect infestation was higher in unprotected plants than protected plots. Lambdacyhalothrin-treated plants had low insect infestations with corresponding higher yield than botanical treated plants.

Fatty acids are widely occurring in natural fats and dietary oils and theyplay an important role as nutritious substances and metabolites in living organisms (Cakir, 2004). It was observed that application of Lambdacyhalothrin resulted into reduction in fatty acid composition of watermelon despite the fact that it had the highest yield of watermelon fruits. Meanwhile, plant extracts treated fruits were very rich in fatty acids. This implies that botanical insecticides had positive impact in the fatty acid profile of watermelon fruits when compared with Lambdachyalothrin. Polyunsaturated fatty acids have been described as the major nutritional contents which responsible for the proper functioning of the brain, eyes and entire nervous system. Although, uncontrolled intake of dietary lipids constitute a major health risk factor (Ntsomboh-Ntsefong 2016). Meanwhile, significant variation detected among the treated fruits revealed that the applied plant extracts and synthetic insecticide were absorbed from the soil and translocated to other part of the plant thereby impacting negatively or positively in the nutritional content of watermelon fruits.

4 Conclusions

The results indicate that the applied treatements were observed into the plant physiological systems and influenced the chemical composition of the treated plants. Lambdacyhalothrin controlled the target insects but decreased the fatty acid composition whereas botanical insecticide exhibited insecticidal action on the major insect pests and also improved the fatty acid profile of the treated watermelon fruits, It shows the potentials of the botanical insecticide on the improvement of the health of the consumers. Also, the safety of the environment through the use of plant extracts is assured. Therefore, the use of secondary metabolites of botanical origin in the pest control schemes should be encouraged among the rural farmers.

References

ABDUL, D.A.S. (2007) *Economic importance of Moringa oleifera in Tafa Local Government Area of Niger State. NDE project.* Kaduna: Federal College of Forestry Mechanization.

ADEBAYO, T.A. (2003) *Efficacy of mixture formulations of synthetic and botanical insecticides in the control of insect pests of okra and cowpea: Ph.D. Thesis.* Ogbomosho: Ladoke Akintola University of Technology.

AKHTAR, Y., YEOUNG, V.R. and ISMAN, M.B. (2008) Comparative bioactivity of selected extracts from Meliaceac and some commercial botanical insecticides against two noctuid caterpillar. *Trichoplusia* and *Pseudaletiaunipuncta*. *Phytochemistry Reviews*, vol. 7, pp. 77–88.

AKHTAR Y. and ISMAN, M.B. (2004) Comparative growth inhibitory and antifeedant effects of plant extracts and pure allelochemicals on four phytophagous insect species. *Journal of Applied Entomology,* vol. 128, pp. 32–38.

ALAO, F.O. (2009) *Insecticidal principle of allellochems derived from Tephrosia vogelli and petiverian alliacea on post flowering insect pests of cowpea: M. Tech Dissertation.* Ogbomoso: Ladoke Akintola University of Technology.

ALAO, F.O. (2015) *Effects of plant extracts in the control of field insect pests associated with watermelon: Ph.D. thesis.* Ogbomosho: Ladoke Akintola University of Technology.

ALAO, F. O. and ADEBAYO, T. A. (2015) Comparative efficacy of *Tephrosia vogelii* and *Moringa oleifera* against insect pests of watermelon (*Citrulus lanatus* Thumb). *International letters of natural sciences,* vol. 36, pp. 71–78.

ALAO, F.O. et al. (2016) Population density of insect pests associated with watermelon (*Citrullus lanatus* Thumb) in southern guinea savanna zone, Ogbomoso. *Journal of Entomology and Zoology Studies,* vol. 4, no. 4, pp. 257–260.

ALAVANJA, et al. (2004) Health effects of chronic pesticide exposure: cancer and neurotoxicity. *Annual Review of Public Health,* vol. 25, p. 155.

ALLWOOD, A.J. et al. (1999). Host plant record of fruit flies (*Diptera*; *Tephritidae*) in southeast Asia. *The Raffles Bulletin in zoology supplies,* vol. 7, 92 p.

ANJORIN, T.B. et al. (2010) Mineral composition of *Moringa oleifera* leaves, pods and seeds from two regions in Abuja, Nigeria. International. *Journal of Agriculture and Biology,* vol. 12, pp. 431–434.

ANJORIN, T.S. et al. (2010) Mineral composition of *Moringa oleifera* leaves, pods and seeds from two regions in Abuja, Nigeria. *International Journal of Agriculture Biology,* vol. 12, pp. 431–434.

ASOGWA, E.U. et al. (2007) Evaluation of cashew nut shell liquid (CNSL) as a potential natural insecticide against termites (soldiers and workers Castes). *Research Journal of Applied Sciences,* vol. 2, no. 9, pp. 939–942.

BABARINDE, S.A. (2009) Tree bees use – *Moringa oleifera*. *Bees for Development Journal,* vol. 92, p. 11.

BABARINDE, S.A. et al. (2011) Bioactivity of *Piper guineense* Schum. & Thonn seed and *Moringa oleifera* Lam. leaf powder against *Trogoderma granarium* Everts (Coleoptera: Dermestidae). *Archives of Phytopathology and Plant Protection,* vol. 44, no. 3, pp. 298–306.

CAKIR, A. (2004) Essential oil and fatty acid composition of the fruits of *Hippophae rhamnoides* L. (Sea Buckthorn) and *Myrtus communis* L. from Turkey. *Biochem. System. Ecol.,* vol. 32, pp. 809–816.

BAMISHAIYE, E.I. et al. (2011) Proximate and Phytochemical composition of *Moringa oleifera* leaves at three stages of maturation. *Advance Journal of Food Science and Technology,* vol. 3, no. 4, pp. 233–237.

DANE, F. and LIU, J. (2007) Diversity and origin of cultivated and Citron type watermelon (*Citrullus lanatus*). *Genet Resour Crop Evol,* vol. 54, pp. 1255–1265.

DE LIMA, S.G. et al. (2008) Effects of immature cashew nut-shell liquid (*Anacardium occidentale*) against oxidative damage in *Saccharomyces cerevisiae* and inhibition of acetylcholinesterase activity. *Genetics and Molecular Research,* vol. 7, no. 3, pp. 806–818.

DENT, D. (1991) *Yield loss assessment.* In: Insect pest management. Wiltshire: C.A.B. International, Redwood Press.

DERKE, E.C. and DEHNE, H.W. (2004) Safeguarding Production losses in major crops and the role of crop protection. *Crop Protection.* vol. 23, pp. 275–285.

DHILLION, M.K., et al. (2005) The melon fruits fly, *Bactrocera cucurbitae*: a review of its biology and management. *Journal of Insects Science,* vol. 5, p. 40.

FASHEY, J.W. (2005) *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *Trees Life J.,* no. 1, p. 5.

EILEEN, A.B. and SYDNEY, G.P.B. (2013) Natural products for managing landscaping and garden pests in Florida. EDIS.

GICHIMU, B.M. et al. (2009) Morphological characterization of some wild andcultivated watermelon (Citrullus sp.) accession in Kenya. *ARPN Journal of Agricultural and Biological Science,* vol. 4, pp. 1990–6145.

HASYIM, A. et al. (2008) Population fluctuation of the adult males of the fruits fly, *Bactrocera tau* Walker (*Diptera*: *Tephritidae*) in passion fruit orchards in relation to abiotic factors and sanitation. *Indones*. *J. Agric. Sci*., vol. 9, no. 1, pp. 29–33.

INDRA, P.S. and KAMINI, V. (2003). *Control of flea beetle, Phyllotreta nemorum L. (Coleoptera: Chrysomelidae) using locally available natural resources.* Tribhuvan: Central Department of Zoology, Tribhuan University, Kathmandu, Nepal.

ISMAN, M.B. (2006) Botanical insecticides, deterrents and repellents in modern agriculture and increasingly regulated world. *Annual Review of Entomology,*vol. 51, pp. 45–66.

ISMAN, M.B. (2008) Perspective Botanical Insecticides: for richer for poorer. *Pest Management Science,* vol. 64, pp. 8–11.

KHAN M, et al. (2007) Effect of Neem leaf dust and a commercial formulation of a neem compound on the longevity, fecundity and ovarian development of the melon fly, *Bactrocera cucurbitae* (Coquillet) and the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (*Diptera*: *Tephritidae*). *Pakistan Journal of Biological Sciences,* vol. 10, pp. 3656–3661.

MUKHOPADHYAY, et al. (2010) Larvicidal properties of cashew nut shell liquid (*Anarcardium occidentale* L.) on immature stages of two mosquito species. *Journal of Vector Borne Disease*, vol. 47, pp. 257–260.

MITTAL, M., et al. (2007) Pharmacognostical and phytochemical investigation of antidiabetic activity of *Moringa oleifera* Lam leaf. *Ind. Pharm.,* vol. 6, pp. 70–72.

OBERLIES, et al. (1997) Structure activity relationships of diverse *Annonacers acetogenins* against multidrug resistant human mammary *adennocarcinnoma. Journal medical chemistry*, vol. 40, pp. 2012–2106.

OGBUNUGAFOR, H.A. et al. (2011) Physic-chemical and antioxidant properties of *Moringa oleifera* seed oil. *Pakistan Journal of Nutrition,* vol. 1, no. 5, pp. 409–414.

OLAIFA, J.I. and ADEBAYO, T.A. (2003) Procedure for evaluation of toxicity and dosage and plant based pesticides. *Journal of Annals of Agriculture Sciences,* vol. 3, no. 2, pp. 31–37.

OLANIRAN, et al. (2013) Control of foliage pests of roselle (*Hibscus sabdariffa* L.) using plant extracts of *Tephrosia vogelii* and *Azardiractha indica* in Ogbomoso Nigeria. *Transnational Journal of Science and Technology,* vol. 3, no. 6, pp. 51–62.

OLOTUAH, O.F.and OFUYA, T.I. (2010) Comparative protection of cowpea, *Vigna unguiculata* L.) Walpers against field insect pests using cashew nut shell liquid and Cypermethrin (Cymbush). *Pakistan Journal of Nutrition,* vol. 9, no. 2, pp. 158–161.

OPARAEKE, A.M., Bunmi (2006) Insecticidal potential of cashew (*Anacardium occidentale* L.) for control of the beetle, *Callosobruchus subinnotatus* (Pic) (*Bruchidae*) on bambara groundnut (*voandzeis subterranean* L.). Verde *Archives of Phytopathology and Plant Protection,* vol. 39, no. 4, pp. 247–251.

PERKINS-VEAZIE, J. (2001) *In search of High Lycophene watermelon.* Washington: USDA-ARS, South Central Agric. Research Centre Lane.

PRABHU, K. and MURUGAN, A. (2011) Larvicidal and repellent potential of *Moringa oleifera* against malarial vector, *Anopheles stephensi* Liston (Insecta: *Diptera*: Culicidae). *Asian Pac. J. Trop. Biomed.,* pp. 124–129.

NAVA-DIAZ, et al. (2000) Organismos association a chirmoyo (A. Chermola M:Il) *Agrociencia*, vol. 34, pp. 217–226.

REHM, S. and ESPIG, G. (1991) *The cultivated plants of the tropics and subtropics.* Munchen: Verlag Josef Margraf, Weikersheim.

SCHIPPERS, R.R. (2000) African indigenous vegetable. In: An *overview of the cultivated species Chatthan,* pp. 56–60.

SELJASEN, R., and MEADOW, R. (2006) Effect of neem on oviposition and egg and larval development of *Mamestra brassicae* L: Dose response, residential activity. Repellent effect and systemic activity in cabbage plants. *Crop Protection,* vol. 25, pp. 238–345.

SINGH, R.N, and SARATCHANDRA, B. (2005) The development of botanical products with special refrence to seri-ecosyetem. *Caspain Journal Environmental Science*, vol. 3, no. 1, pp. 1–8.

SINGH, R.N, and SARATCHANDRA, B. (2002) An integrated Approach in the Pest Management in the sericulture. *International Journal Industries Entomology*, no. 5, pp. 141–151.

SOFIDIYA, M.O. et al. (2006) Free-radical scavenging activity of some Nigerian medicinal plant extracts. *Pakistan Journal of Biological Science*, vol. 9, no. 1, pp. 1438–1441.

WEEMS, H.V. and HEPPNER, J.B. (2001) *Melon fruit fly, Bactrocera cucurbitae Coquillet (Insecta: Diptera:Tephritidae)*. Florida Department of Agriculture and consumer Services, Division of plant industry and T.R. Fasulo, University of Florida. University of Florida publication EENY-199.

WHEELER, D. and ISMAN, M.B. (2001) Antifeedant and toxic activity of *Trichilia americana* extracts against the larvae of Spodoptera litura. *Entomologia Experimentals Applicata*, vol. 98, p. 9.

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Original Paper

Influence of tillage on soil physical properties and three varieties of sesame (*Sesamum indicum* L.) in Ogbomoso, southwestern Nigeria

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A two year field experiment was conducted to investigate the effect of different tillage practices on soil physical properties and agronomic properties of three varieties of sesame (*Sesamum indicum* L.) in 2013 and 2014 cropping seasons. The study was a split plot in randomized complete block design (RCBD). Tillage was the main treatment having three types; manual clearing (MC), ploughed twice (PT) followed by ridged (RT) while the sub plot was sesame varieties; 03L+ Tithonia, Ex-Sudan and E8. The result showed that soil physical properties and sesame varieties were not generally affected by tillage practices during the two years of the experiment. However, there was significant interaction of tillage and sesame varieties on soil microporosity and available water content (AWC) in 2013. RT increased AWC in 2013 and 2014 compared to MC and PT although, the treatments were statistically similar. RT significantly increased stem girth, number of leaves, and number of branches of sesame in 2013. Ex- Sudan variety produced significantly higher number of leaves and branches in 2013. However, E8 produced higher number of capsules per plant and seed yield. In 2013, interaction between tillage practices and sesame variety were significant on microporosity, available water content and plant height. Ridge tillage and E8 variety gave the best result in terms of improved soil physical properties and yield, therefore it is recommended in this study area.

Keywords: tillage, soil physical properties, sesame variety, yield

1 Introduction

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid et al., 2006). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). In humid tropics where most farmers are poor and fertilizer is expensive, soil working and tillage methods can temporarily serve as an alternative to fertilizer application (Adekiya and Ojeniyi, 2002).

There has been mixed reports from tillage research over the years. Many see the need to reduce the amount and intensity of tillage operations to reduce erosion, improve soil structure, and ease flooding by increasing the infiltration of water into the soil water system by quantitatively characterizing soil structural properties (Braudeau et al., 2004; Braudeau and Mohtar, 2008). Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared with conservation and no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance (Khan et al., 2001). Tillage practices profoundly affect soil physical properties. Therefore, it is essential to select a tillage practice that sustains the physical properties required for successful growth of agricultural crops (Jabro et al., 2009). The changes produced by tillage on soil physical properties differ among management practices and varies over a wide range of soils and climatic conditions (Elder and Lal, 2008).

Tillage practices are beneficial in Nigeria due to some land that have low clay activity, inherent low fertility,

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various nutrient imbalance, pure structural stability, low water holding capacity and susceptibility to erosion (Opara-Nadi, 1990).The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. It has been noted that soil tillage is among the important factors affecting soil physical properties and crop yield.

Sesame (*Sesame indicum* L.) production is an important component of Nigeria's food security strategy. It is quite extensively grown in Nigeria and according to Alegbejo et al. (2003), it is more widely grown in the northern states of Nigeria such as: Nasarawa, Jigawa, Benue, Yobe, Kano, Taraba, Kastina, Kogi, Gombe, Kebbi, Zamfara and Niger. The crop has the potential to generate employment for the teeming unemployed youths and also generate income from exports. The utilizations of sesame among others include human consumption, health treatments, beautification, livestock feeding and industrial uses (Sharma, 2005; El- Habbasha et al., 2007). Sesame as a vegetative crop has been introduced under different cropping systems and agro-ecology. Considering its importance, there is a need to bridge the gap in knowledge on appropriate tillage and variety of sesame that will thrive best in Ogbomoso, south west Nigeria. Therefore, the objective of this study was to determine the effect of tillage practices on physical properties of soil, growth and yield of three sesame varieties.

2 Material and methods

2.1 Description of study site

The field experiment was conducted between 2013 and 2014 at the Teaching and Research Farm, Ladoke Akintola University of Technology Ogbomoso, Nigeria on a soil which had been under continuous cultivation for more than 5 years. Ogbomoso lies between latitude 8° 10' N and longitude 4° 10' E in the Southern guinea savanna ecological zone of Nigeria. The site has an altitude of 340 m above sea level. The rainfall pattern is bimodal and averages 1,400 mm per annum. Rainfall peaks occur in June and September. There are two growing seasons; an early season runs from March/April to August and late season, from mid-August to October/November. Annual temperatures range from 29.8 to 19.7 °C. The soil of the area was Gambari series (Smith and Montgomery, 1962) derived from highly weathered metamorphic materials, typically referred to as basement complex rocks. The soil was classified as an Alfisol under the order Udic Paleustalf according to the USDA classification (Soil Survey Staff, 2006).

2.2 Field experiment

The experimental design was a split-plot laid out in a Randomized Complete Block Design. Tillage practice was the main treatment and sesame variety as sub plot treatment. Each treatment was replicated three times. The tillage practices were -Manual clearing (MC), Ploughed twice (PT) and Ridged (RT). The sesame varieties – 03L + Tithonia, Ex-Sudan and E8 were sourced from Institute of Agricultural Research & Training (IAR &T), Ibadan. The area of land used for the experiment measured 0.648 ha with a plot size of 54 × 12 m and sub-plot measuring 3 × 4 m (12 m^2) with 1 m border to separate each plot from another whereas the individual plots were separated by 0.5 m. Manual plots were cleared manually with cutlass and hoe while Ploughed plots were ploughed twice with a disc plough to a depth of 30 cm and Ridged plots were ploughed once and ridged with disc tractor mounted ridger. The same land preparation for tillage treatments were carried out in both 2013 and 2014. Sesame seeds were sown at the rate of three seeds per hole at a spacing of 60 × 10 cm. The seedlings were later thinned to one plant per stand at two weeks after sowing which gave 16,667 plants ha^{-1}. Data were collected at 2- week interval for 12 weeks on the following growth parameters; plant height, number of leaves, stem girth, number of branches. At harvest, data on number of capsules per plant and seed yield in kg ha^{-1} were determined.

The initial soil samples were taken at 0–15 cm depth for routine analysis to determine soil texture and chemical properties of the soil according to IITA 1982. Particle size analysis of the soil was determined by hydrometer method (Gee and Or, 2002). Soil pH was determined in water using 1 : 1, available P was determined in the soil using Bray P-1 method (Bray and Kurtz, 1945). Organic carbon was analyzed by dichromate wet oxidation method of Nelson and Sommers (1982). Exchangeable K, Na, Ca, and Mg were extracted with 1 M NH_4OAc at pH 7, and determined by atomic absorption spectrophotometer. Effective Cation Exchange Capacity (ECEC) was calculated by summing up the exchangeable bases plus the exchangeable acidity. Cation Exchangeable Capacity (CEC) was determined by neutral, 1 N Ammonium acetate method. Determination of Total Nitrogen was done by the Macro Kjeldahl method as described by Bremner and Mulvaney (1982).

Soil samples were taken after harvesting to determine physical properties of the soil at 14 weeks after sowing.

Bulk density was estimated by dividing the oven-dried mass of the soil by the volume of the soil as described by Grossman and Reinsch (2002). This was computed by dividing the oven-dried mass of the soil by the volume of the core.

$$bulk\ density\ (g\ cm^{-3}) = \frac{mass\ of\ soil\ (oven\ dried)}{total\ volume\ of\ soil} = \frac{Ms}{V_T} \quad (1)$$

Volume of soil sample = volume of core (cylinder) = πr^{2h}

where:
h – height of the cylinder
r – internal radius of the cylinder.

Total porosity (TP) was calculated from the parameters of bulk density and particle density using an assumed value of 2.65 g cm^{-3} for particle density in the formula:

$$TP = 1 - \left(\frac{Pb}{Ps}\right) \times 100 \quad (2)$$

where:
Pb – the bulk density
Ps – the particle density

Pore size distribution was calculated using the water retention data and capillary rise equation as described by Flint and Flint (2002). Macropores (pores >30 µm), taken as drain pores were estimated at 10 k Pa matric potential.

$$Ow = \frac{Ww}{Vw} \quad (3)$$

where:
Qw – macroporosity
Ww – the difference between wet and oven dry soil
Vw – volume of the soil

Microporosity of the soil was determined by subtracting macro porosity from the total porosity.

Soil available water was determined as described by Reynolds et al. (2002)

Data were subjected to analysis of variance (ANOVA) test based on Randomized Complete Block Design according to SAS (2002) version. Means were compared using Fisher's least significant difference at 5% level of probability.

3 Results and discussion

The soil physical and chemical properties of the field used for the experiment are presented in Table 1. Textural class of the soil was sandy loam, with neutral pH (6.9), very low in organic carbon, total nitrogen and available phosphorus. The exchangeable cations range from low (K and Ca) to medium (Mg and Ca) (Esu, 1991). The general low nutrient status of the soil might be due to continuous cultivation of the land prior to cropping.

Table 1 Initial soil physical and chemical properties of the field used for the experiment

Parameters	Values
Sand (g kg^{-1})	795.60
Silt (g kg^{-1})	87.80
Clay (g kg^{-1})	116.60
Textural class	sandy loam
pH H_20 (1 : 2)	6.90
Total N (g kg^{-1})	0.07
Organic carbon (g kg^{-1})	0.69
Available P (mg kg^{-1})	2.02
Exchangeable cations (cmol kg^{-1})	
K^{2+}	0.16
Ca^{2+}	1.47
Mg^{2+}	0.39
Na^{2+}	0.15
EA	0.14
ECEC	2.31
Micronutrients (mg kg^{-1})	
Zn	3.29
Cu	0.73
Fe	102.31
Mn	100.27

The effect of tillage practices and sesame variety on soil bulk density and total porosity for 2013 and 2014 cropping seasons are presented in Table 2.

Tillage practices had no significant influence on bulk density and total porosity in both years, the values ranged from 1.60 Mg m^{-3} Ridge tillage (RT) to 1.66 Mg m^{-3} Ploughed (PT) in 2013 and 1.45 Mg m^{-3} (RT) to 1.48 Mg m^{-3} (PT) in 2014. Also, total porosity was not affected by tillage practices in both years. The values ranged from 33.10% (PT) to 40.28% in 2013 and 34.06% (PT) to 40.48% (RT). In the same way, bulk density and total porosity had similar effect among sesame varieties in 2013 and 2014 cropping seasons.

Tillage practices influence on soil microporosity (MIC), macroporosity (MAC) and available water content (AWC) after 2013 and 2014 cropping seasons are shown in Table 3. Generally, there was no significant difference among tillage practices on these soil properties. Mean values over the two years ranged from 16.38–17.07%, 6.37–10.75% and 0.117–0.131 M^{-3} m^{-3}, respectively, for MIC, MAC and AWC. Similarly, these soil properties did not differ among sesame variety. The interaction between tillage practices and sesame variety treatments were significant (P <0.05)

Table 2 Influence of tillage and three sesame variety on bulk density and as total porosity at 0–15 depth after 2013 and 2014 cropping seasons

Treatment	Bulk density (Mg m^{-3})			Total porosity (%)		
	2013	2014	mean	2013	2014	mean
Tillage (T)						
Manual	1.64	1.47	1.55	33.10	35.50	34.3
Ploughed	1.66	1.48	1.57	30.39	34.06	32.23
Ridged	1.60	1.45	1.52	40.28	40.48	40.38
$LSD_{(0.05)}$	ns	ns		ns	ns	
Variety (V)						
03L + Tithonia	1.63	1.51	1.57	31.52	37.98	34.75
Ex-Sudan	1.67	1.49	1.58	38.49	35.54	37.02
E8	1.60	1.41	1.51	33.74	34.51	34.13
$LSD_{(0.05)}$	ns	ns		ns	ns	
Interaction						
T × V	ns	ns		ns	ns	

ns – not-significant, * significant at 5% probability level

on MC and AWC in 2013 cropping season. The result indicates that tillage effect on MC and SAW has led to the effect on sesame variety.

The lower bulk density of the tilled plots specifically ridge tillage though not significant has led to the increase in total porosity of the soil. This may be attributed to the repackaging of the soil that has improved the soil structure. For any given soil, the lower the bulk density, the less compacted the soil and the more the pore space as observed in this study. The observation of non-significance effect of tillage practices on soil physical properties may be due to the short duration of the study. This result is in line with the report of (Buschiazzo et al., 1998) that a period of 2–3 years was not enough for tillage to affect most properties of sandy loam and other soils in Argentinean Pampas. Also, Anikwe et al. (2007) noted that in an experiment under no-till and tilled with plastic mulch at 95 days after planting, no significant treatment differences in soil dry bulk density were found between various treatments. Non-significance of tillage effect on bulk density over time has also been reported by Osunbitan et al. (2005). Gomez et al. (2001) observed that it took five years before changes in some of the physical properties (structure and aggregate stability, which are indicators of bulk density) could be detected as a result of the soil management practices. The full effect of tillage can only be observed after four or five years and this could not be obtained in this short term study.

Also, the increase in microporosity, macroporosity and available water content of the ridged plots although not significant can be related to the improved soil structure. This might have provided ease of water movement into the soil and subsequently increased the available water content of the soil. The increase in MIC (water filled pores) under tilled plots has led to increase in available water content which invariably promoted growth of sesame. The result also implies that tillage has influenced water storage. The result of this study could be corroborated by Katsvairo et al. (2002) that macroporosity and total porosity of soil has no significant difference amongst moldboard, plow, chisel, and ridge tillage systems on a silt loam soil near Aurora.

Result of the effect of tillage practices on growth parameters of the three sesame varieties are presented in Table 4. In 2013 cropping season, all the growth parameters were significantly (P = 0.05) affected by tillage practices. Ridge tillage (RT) produced significantly taller plant by 65% and 68% than manual clearing (MC) and ploughed tillage (PT) respectively, while RT and PH were not statistically different from each other. No significant difference was observed among sesame variety. However, there was significant interaction between tillage practices and sesame variety on plant height. RT and PT produced significantly wider stem than MC by 53% and 42%, respectively. The order of number of leaves among tillage practices was RT > PT > MC. The result also indicates that, RT and PT significantly increased number of branches compared to MC while no significant difference was observed between RT and PT plots. Number of branches indicated significant difference among three varieties of sesame (Table 4). 03L + Tithonia and Ex-Sudan produced significantly

Table 3 Effect of tillage and three sesame varieties on microporosity, macroporosity and available water content after 2013 and 2014 cropping seasons

Treatment	Microporosity (%)			Macroporosity (%)			Available water content ($m^3 m^{-3}$)		
	2013	2014	mean	2013	2014	mean	2013	2014	mean
Tillage (T)									
Manual	6.37	27.14	16.51	26.14	6.37	16.55	0.108	0.127	0.118
Ploughed	7.08	25.47	16.38	23.39	6.59	14.99	0.109	0.124	0.117
Ridged	4.40	29.73	17.07	30.13	10.75	20.44	0.133	0.129	0.131
$LSD_{(0.05)}$	ns	ns		ns	ns		ns	ns	
Variety (V)									
03L + Tithonia	5.56	25.82	15.96	25.48	10.16	17.82	0.110	0.120	0.115
Ex-Sudan	6.12	28.70	17.41	27.13	6.68	16.91	0.122	0.156	0.139
E8	6.67	27.83	17.25	27.06	27.68	27.37	0.117	0.123	0.120
$LSD_{(0.05)}$	ns	ns		ns	ns		ns	ns	
Interaction									
T × V		*	ns		ns	ns		*	ns

ns – non-significance, * significant at 5% probability level

Table 4 Effect of tillage practices on growth parameters of three sesame varieties at 12 weeks after sowing

Treatment	Plant height (cm)			Stem girth (cm)			Number of leaves			Number of branches		
	2013	2014	mean	2013	2014	mean	2013	2014	mean	2013	2014	mean
Tillage												
MC	39.68	78.50	59.09	2.10	3.47	2.29	26.24	47.28	36.76	6.30	6.76	6.53
Ploughed	112.02	97.20	115.16	3.65	3.97	3.81	57.24	58.77	58.01	9.02	8.42	8.72
Ridged	126.07	118.30	122.19	4.53	4.54	4.54	76.76	74.96	75.8	10.00	11.80	10.9
$LSD_{(0.05)}$	28.67*	14.33*		0.62*	0.48*		35.93*	11.07*		1.77*	4.27*	
Variety (V)												
03L + Tithonia	29.90	98.54	64.22	3.22	4.06	3.64	52.60	59.74	56.17	8.71	8.27	8.49
Ex-Sudan	32.70	104.38	64.54	3.50	4.07	3.79	56.71	64.51	60.61	8.86	7.77	8.32
E8	33.44	91.19	62.32	3.54	3.86	3.70	50.93	56.77	58.69	7.76	10.93	9.35
$LSD_{(0.05)}$	ns	ns		ns	ns	5.72*	ns	ns	64*	ns		
T × V	*	ns		ns	ns		ns	ns		ns	ns	

ns – non- significance,

higher number of branches than E8, but 03L + Tithonia and Ex-Sudan had similar effect on number of branches.

In 2014 cropping season, tillage practices significantly influenced plant height, stem girth, number of leaves and number of branches of sesame (Table 4). Plant height was in order of RT > PT > MC among tillage practices. Similarly, RT (4.54 cm^2) recorded wider stem than MC (3.47cm^2). Also, PT plots (3.97 cm^2) recorded wider stem girth than MC plots. The result follow similar trend on number of leaves. It showed significantly higher number of leaves (between 59 and 75) in both RT and PT plots when compared to the corresponding MC plots.

No significant difference in number of branches was found among tillage practices. There was no significant difference on number of branches among varieties of sesame. However, the means over the two years revealed that E8 had higher number of branches than the other two varieties. Tillage practices significantly influenced number of capsules per plant (NCPP) in both years of study (Table 5).

In 2013 cropping season, RT and PT produced significantly higher NCPP than MC. The increase was in the order of RT > PT > MC. There was no significant difference in NCPP among sesame variety. RT plots significantly recorded

Table 5 Effect of Tillage practices on yield component and seed yield of sesame varieties at 14 weeks after sowing

Treatment	Number of capsules (Plant^{-1})			Seed yield (kg ha^{-1})		
	2013	2014	mean	2013	2014	mean
Tillage (T)						
Manual	14.10	18.99	16.56	199.42	663.50	431.46
Ploughed	56.46	25.48	40.97	450.12	567.30	508.71
Ridged	93.01	50.90	71.96	583.27	719.19	651.23
$LSD_{(0.05)}$	32.39*	8.08*		ns	ns	
Variety (V)						
03L + Tithonia	59.67	31.44	45.56	239.00	643.90	441.45
Ex-Sudan	51.93	32.72	42.33	187.43	508.80	348.12
E8	52.07	31.20	41.64	351.01	797.20	574.11
$LSD_{(0.05)}$	ns	ns		ns	210.00*	
Interaction						
T × V	ns	ns		ns	*	

ns – non- significance, * significant at 5% probability level

higher NCPP than MC plots by 62% in 2014 cropping season, while no significant difference in NCPP was found between PH and MC plots. The results also indicate no significant difference in seed yield among tillage practices in both years of study. However, RT and PT increased mean grain yield of sesame by 15 and 34% than MC, respectively, over the two years. In 2013 cropping season, variety has no influence on seed yield of sesame. Conversely in 2014, E8 variety produced significantly higher seed yield of 797.2 kg ha^{-1} and lower yield from 03L + Tithonia (643.9 kg ha^{-1}) and Ex-Sudan (508.8 kg ha^{-1}) which were not different from each other. Tillage practices and sesame variety has significant interaction on seed yield of sesame in 2014 cropping season. In all the tillage practices investigated, ridge tillage provided better enabling environment for superior growth than MC and PT plots. The improved soil structure and tilth afforded the plant for greater access to water and nutrients leading to taller plants, wider stems and higher number of branches that transformed to better crop growth. Similarly, Sarder and Rosario (1995) observed that tillage resulted in a higher plant height (14–20%) than no-till methods in sesame planted after wet land rice. In this study, increase in number of capsules of sesame obtained on RT and PH plots compared to MC plots could be explained from better growth recorded on tilled plots which produced better number of capsules. The values of obtained under RT and PH were higher than that of MC resulting in higher seed yield in the RT and PH. The higher seed yield on the tilled plots though statistically similar accrued from better soil condition that promoted growth and later led to production of more seed. Bennett et al. (1998) reported that no-till methods had a low seed yield compared to the other tillage methods. They found that sesame seed yield in conventional tillage plots increased approximately 2-fold in comparison to no-till plots. Yol et al. (2010) reported that number of capsules per plant and height are the most important characters that affect seed yield in sesame. In contrast, these two parameters did not follow a consistent trend among the three sesame varieties studied.

The benefit derived from improved soil physical properties accruing from tillage such as reduced bulk density, increased available soil water content brought about superior number of capsule per plant and grain yield under tilled plots. Generally, the significant (P <0.05) higher seed yield of E8 variety compared with and 03L + Tithonia and Ex-Sudan may be attributed to the adaptability of the study area. The two varieties E8 and 03L + Tithonia showed superior growth particularly in number of branches, which transformed to higher grain yield.

4 Conclusions

The study revealed that the physical constraint of soil can be responsible for the performance of crop to its optimum level. Ridge tillage gave the optimum soil condition among tillage practices for best sesame production. It was observed that E8 variety produced the highest grain yield than the other two varieties. In order to get optimum growth and yield of sesame, it is therefore recommended that ridge tillage and E8 variety should be adopted in Ogbomoso south-west, Nigeria.

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References

ADEKIYA, A. O. and OJENIYI, S. O. (2002) Evaluation of tomato growth and soil properties under methods of seedling bed preparation in an Alfisol in the rainforest zone of southwest Nigeria. *Soil Till. Res.,* vol. 64, pp. 275–279. doi: https://doi.org/10.1016/j.jssas2016.01.006

ALEGBEJO, M. D. et al. (2003). Sesame production: A Potential Industrial and Export Oil Seeds Crop in Nigeria. *Journal of sustainable agriculture,* vol. 23, no. 1, p 59–76.

ANIKWE, et al. (2007) Tillage and plastic mulch effects on soil properties and growth and yield of cocoyam (*Colocasia esculenta*) on an ultisol in southeastern Nigeria. *Soil Till. Res.*, vol. 93, pp. 264–272. doi: https://doi.org/ 10.1016/j.still.2006.04.007

BRAYR.H. and KURTZ, L.T. (1945) Determination of total organic carbon and available forms of phosphorus in soils. *Soil Science,* vol. 59 pp. 39–45.

BENNETT, M. et al. (1998) Sesame Research Report 1996-97. Wet season. Katherine Northern Territory. *Technical Bulletin of Australian Department of Primary Industries and Fisheries,* no. 274.

BREMNER, J. and MULVANEY, C. (1982) *Nitrogen – Total: Chemical and Microbiological properties.* Madison: ASA and SSSA, pp. 595–624.

CHUDE, V.O. et al. (2011) *Fertilizer use and management practices for crops in Nigeria.* 4th edition. Abuja: Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development.

EL- HABBASHA, S. F. et al. (2007) Response of two Sesame varieties (*Sesamum indicum* L.) to partial replacement of chemical fertilizers. *Research Journal of Agriculture and Biological Sciences,* vol. 3, no.6, pp. 563–571.

ELDER, J.W. and LAL, R. (2008) Tillage effect on physical properties of agricultural organic soils of North Central Ohio. *Soil Till. Res.,* vol. 98, no. 2, pp. 208–210. doi: https://doi.org/10.1016/j.still.2007.12.002

ESU, I.E. (1991) *Detailed soil survey of NIHORT Farmat Bunkure, Kano State, Nigeria.* Zaria: Institute for Agricultural Research, Amadu Bello University.

FLINT, L.A. E. and FLINT, A. L. (2002) Porosity. In: Dane, J. H, Topp, G. C. (Eds.). *Methods of Soil Analysis, Part 4 Physical Methods*. Madison: SSSA, pp. 241–254.

GEE, G. W. and OR, D., 2002. Partide size distribution. In: Dane, J. H, Topp, G. C. (Eds.). *Methods of Soil Analysis, Part 4. Physical Methods.* Madison: SSSA, pp. 255–293.

GOMEZ, E. et al. (2001) Changes in some soil properties in a Vertic Argiudoll under short term conservation tillage. *Soil Till. Res.,* vol. 6, no. 3–4, pp. 179–186. doi: https://doi.org/10.1016/s0167-1987601/00193-3

GROSSMAN, R. B. and REINSCH, T.G. (2002) Bulk density and extensibility: Core method. In: Dane, J.H, Topp, G.C. (Eds.). *Methods of Soil Analysis, Part 4. Physical Methods.* Madison: SSSA, pp. 208–228.

IITA (International Institute for Tropical agriculture). (1982) Selected Methods for Soil and Plant Analysis. International Institute of Tropical Agriculture, Ibadan, Nigeria. *IITA Manual Series,* no. 7, pp. 53–56.

KATSVAVAIRO, T. et al. (2002) Tillage and rotation effects on soil physical characteristics. *Agronomy Journal,* vol. 94, pp. 299–304.

KHURSHID, K. et al. (2006) Effects of tillage and mulch on soil physical properties and growth of maize. *Int. J. Agri. Biol.*, vol. 5, pp. 593–596.

LAL, R. (1993). Tillage effects on soil degradation. Soil resilience: soil quality and sustainability. *Soil Till. Res.,* vol. 51, pp. 61–70. doi: https://doi.org/10.1016/0167-1987(93)90059-x

NELSON, D.W. and SOMMER, L.E. (1996) Total carbon, organic carbon, and organic matter. In: Sparks, D.L. (Ed.). *Methods of Soil Analysis Chemical Methods.* Madison: American Society of Agronomy, pp. 961–1010.

OPARA-NADI, O. A. (1990) Tillage practices and their effects on soil productivity. *Organic-Matter management and Tillage in Humid and Sub-humid Africa. IBSRAM Proceedings,* no.10, pp. 87–111.

OSUNBITAN, J.A. (2005) Tillage effects on bulk density, hydraulic and strength of a loamy sand soil in southwestern Nigeria. *Soil Till. Res.,* vol. 82, no. 1, pp. 57–64. doi: https://doi.org/10.1016/j.still.2004.05.007

RASHIDI, M. and KESHAVARZPOUR, F. (2007) Effects of different tillage methods on soil physical properties and crop yield of melon (*Cucumis melo*). *ARPN Journal of Agricultural and Biological Sciences,* vol. 3, no. 2, pp. 41–46.

REYNOLDS, W. D. et al. (2002) Soil water content. In: Dane, J.H, Topp, G.C. (Eds.). *Methods of Soil Analysis, Part 4. Physical Methods.* Madison: SSSA, pp. 802–817.

SAS Institute. (2002) *SAS/STAT User's Guide. Version 8.2.*, SAS Institute Cary, NC.

SHARMA, P. B. (2005) Fertilizer Management in Sesame (*Sesamum indicum* L.) based inter-system in Tawab Command area. *Journal of Oil Seeds Research*, vol. 22, pp. 63–65.

SMYTH, A. J. and MONTGOMERY, R.F. (1962) *Soils and Land Use in Central Western Nigeria.* Ibadan: Government Printer.

SOIL SURVEY STAFF. (2006) Key to soil taxonomy. 20th ed. Washington: United States Department of Agriculture, Natural Resources Conservation Service, DC.

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Original Paper

The long-term different tillage and its effect on physical properties of heavy soils

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Between 2006 and 2015 years the effect of different tillage of heavy clay loamy soils on their physical properties were studied. Field treatments were carried on Experimental workplace in Milhostov, in central part of the East Slovak Lowland. Conventional tillage, reduce tillage and no-tillage practises were examined. Soil samples were taken from topsoil in natural conditions without irrigation in spring time by Kopecky's rollers. From basic physical soil properties, the bulk density, total porosity and maximum capillary water capacity were analysed by known methods. The linear trend analysis was used for testing of long-term application of different soil tillage in relation to soil properties. Bulk density was in range 1,331–1,623 kg m^{-3}, the lowest average values (in aver. 1,466 kg m^{-3}) was found for reduce tillage. Total porosity answered to bulk density and its values was from 38.12% to 49.26%, higher values were at conventional and reduce tillage and lower at no-tillage practise. Maximum capillary water capacity values in range 31.65–42.03% reached level of values typical for heavy soils of the East Slovak Lowland. The trend analysis of 10-years-time series indicate decreasing of bulk density at conventional and reduce tillage variants, but its increasing for no-tillage variant. The time course of the total porosity had the opposite course than bulk density. Mainly for no-tillage variant, trend of decreasing of total porosity influence the possibility of air and water regimes changes for clay-loamy soil, which may result in a reduction of the transport function of soil. During observed period the changes of maximum capillary water capacity wasn't significant. Application of soil protective technologies for heavy soils as integrated system, in long-time horizon doesn't have to mean deterioration of basic soil physical parameters.

Keywords: heavy soils, soil tillage, physical soil properties, long-term treatments, trend analyse

1 Introduction

For the East Slovak Lowland high presence of heavy soil with high content of clay elements are characteristics. Soil types and soil textures alternate on short distances. Heavy Gleyic Fluvisols, Mollic Gleysols, Planosols and Gleysols are situated till on 65% of arable land acreage of the East Slovak Lowland. Different sustainable systems of husbandry on soil with various soil protective technologies are frequently studied. Economic pressures on decreasing of inputs to production process and also requirements on keeping soil fertility have very strong effect on surface expansion of these technologies. In spite of the fact, that for Slovak Republic conventional tillage with ploughing is typical, each time frequently soil protective technologies are used in plant production.

According to Lal et al. (2007) the no-tillage system can be effective in reducing erosion, maintaining soil surface by plant residues, and lowering energy need. Reduced working time and lower costs are additional reasons for adopting no-till (Soane et al., 2012).

For heavy soils of the East Slovak Lowland at no-tillage systems in comparison with conventional tillage higher values of bulk density were found out in works by Kotorová (2007), Mati and Kotorová (2007), Kotorová and Mati (2008), Kotorová et al. (2010) and Kotorová and Šoltysová (2011). By Tóth et al. (2012) the soil tillage has effect also on the content of water in soil. Effect of the soil tillage technology in relation to soil physical properties will become clear in the longer time period by its using in the concrete locality.

The best time-series are longer than five years. The trend component of the time-series is used for modelling of some of the soil parameters. The trend component is used to indicate the direction of the development of the evaluated indicator over time. Büchi et al. (2017) found that the bulk density was lower in the top layer in the reduced tillage treatments than in the conventional

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plough treatment, whereas it was similar in the other layers. This is in contradiction with many studies showing an increase in bulk density with the abandonment of plough (Alvarez and Steinbach 2009; Palm et al., 2014; Soane et al., 2012). However, this increase has also been shown to be only due to a transient compaction, which should disappear with time (Vogeler et al., 2009) and the minimum tillage is adequate to have overcome this initial compaction.

According Šútor et al. (2007), the best time-series are longer than five years and according to Chajdiak (2005), the trend component of the time-series is used for modelling of some of the soil parameters. The trend component is used to indicate the direction of the development of the evaluated indicator over time.

The aim of this work was to compare the development of basic soil physical parameters of heavy soils under different tillage technologies in longer time-series.

2 Material and methods

The study of selected physical soil properties under different tillage and long-time trend of its development was realized between 2006 and 2015 in Milhostov on the experimental workplace of NPPC – Agroecology Research Institute Michalovce. This workplace is located in central part of the East Slovak Lowland near of the city Trebišov (latitude 48° 40′ N, longitude 21° 44′ E, altitude 101 m).

The long-term mean yearly precipitation shows 567 mm, during vegetation season 374 mm, the mean annual air temperature is 9.4 °C, during vegetation season 16.6 °C. From point of view of weather conditions evaluation, the experimental locality belong in climatic region T3, which is warm, very dry, lowland, continental (Linkeš et al., 1996).

The field experiments with different soil tillage were carried out on Gleyic Fluvisol. Gleyic Fluvisol was formed on heavy alluvial sediments by long-time impact of groundwater and surface water. The topsoil has lump aggregate structure with high binding ability and in whole profile it is heavy permeable. In depth 0.7–0.8 m of soil profile coherent layer of dark grey till yellow grey clay is found. Gleyic Fluvisol on experimental site is characterized as heavy, clayey-loamy soil with content of clay particles (I. category <0.01 mm) 51.43%.

In field experiment the effect of three soil tillage technologies – conventional tillage (CT), reduce tillage (RT) and direct sowing (NT) – were studied. The conventional tillage system consisted of current agro-technical operations: stubble ploughing, mean ploughing, smoothing, harrowing and sowing. The reduce tillage system consisted of these agro-technical operations: stubble ploughing by skive cultivator, soil preparation by skive cultivator before sowing and sowing by sowing machine Pneusej Accord. At no-tillage system direct sowing without ploughing by sowing machine Great Plains was used.

The study of soil tillage technologies was realized in field stationary treatment with right crop rotation. Order of field crops in individual experimental years was as follows: 2006 – spring barley (BA), 2007 – soybean (SO), 2008 – winter wheat (WW), 2009 – grain maize (GM), 2010 – BA, 2011 – SO, 2012 – WW, 2013 – GM, 2014 – BA, 2015 – SO.

Physical soil properties were determined from undisturbed soil samples taken once a year in spring (14-day after sowing of spring crops). Topsoil was sampled in cylinders of 100 cm^3 in depth 0.0–0.3 m with four replications. Soil bulk density (BD, kg m^{-3}), total porosity (TP, %) and maximum capillary water capacity (MCWC, %) were determined according to methods described by Hrivňáková et al. (2011).

For modelling of the development of soil parameters the trend analysis was used. The development of the trend component was expressed by equation $y = a + bx$ (Chajdiak, 2005). The trend lines can be assumed as the major trend of the development of selected soil parameters.

Obtained data were tested by statistical methods, from which analysis of variance was used.

3 Results and discussion

Soil tillage changes the conditions of environment for agricultural crops and it is also reason of changes of soil properties. Various soil tillage technologies are used in different combinations in dependence on soil conditions, meteorological factors, level of agronomical practices and agricultural mechanization. The tillage of soil has significant effect not only on physical and hydrophysical properties (Šimanský et al., 2008; Šimanský, 2017).

The bulk density is a basic physical property of soil and soil tillage has influence on its values. In observed experimental period years 2006–2015 the conventional tillage values of bulk density (Table 1.) were in range from 1,379 kg m^{-3} (in year 2012) to 1,546 kg m^{-3} (in year 2010). At reduce tillage values of this parameter were determined in the interval from 1,331 kg m^{-3} (in year 2014) to 1,545 kg m^{-3} (in year 2010). At no-tillage variant bulk density reached 1,392 kg m^{-3} (in year 2008) – 1,623 kg m^{-3} (in year 2011).

Similar results of bulk density for heavy soils on the East Slovak Lowland published Mati and Kotorová (2007), Kotorová and Mati (2008), Kotorová et al. (2010), Kotorová

Table 1 Bulk density [kg m^{-3}] of topsoil in Milhostov

Year	CT	RT	NT	$\bar{x}$ Y
2006	1,491,	1,459	1,41,6	1,455
2007	1,529	1,491,	1,521,	1,51,4
2008	1,471,	1,41,1,	1,392	1,425
2009	1,51,5	1,544	1,541,	1,533
2010	1,546	1,545	1,538	1,543
2011	1,41,2	1,51,8	1,623	1,51,8
2012	1,379	1,451,	1,521,	1,450
2013	1,531,	1,425	1,537	1,498
2014	1,437	1,331,	1,41,4	1,394
2015	1,420	1,481,	1,469	1,457
$\bar{x}$ T	1,473	1,466	1,497	1,479

CT – conventional tillage, RT – reduce tillage, NT – no-tillage, $\bar{x}$ T – average of tillage, $\bar{x}$ Y – average of experimental year

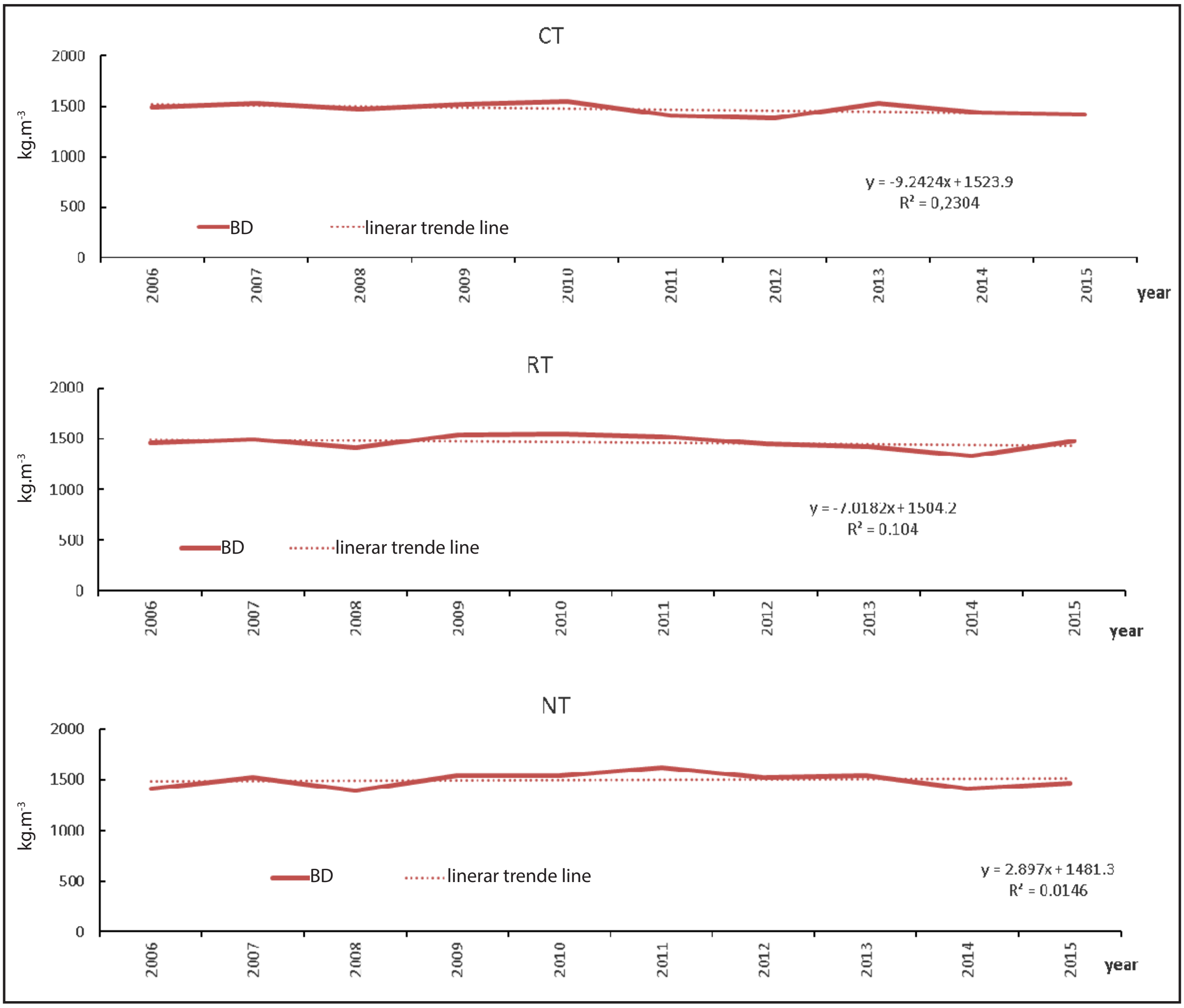

Figure 1 Linear trend of bulk density development for Gleyic Fluvisol

and Šoltysová (2011, 2015). In average, from point of view of soil tillage arrangement, bulk density increased in order of RT (1,466 kg m^{-3}) < CT (1,473 kg m^{-3}) < NT (1,497 kg m^{-3}). The lowest average bulk density (1,394 kg m^{-3}) was determined in year 2014 and the highest (1,543 kg m^{-3}) it was in year 2010. The effect not only tillage technology, but also the weather conditions is probable. The similar results also published Alvarez and Steinbach (2009) who found out that soil bulk density was significantly higher at no-till system in comparison with conventional tillage, but changes of this soil parameter were not determined between conventional and reduced tillage.

During the 10-years period, values of bulk density (Figure 1) were decreased at conventional tillage by 92.42 kg m^{-3} and reduce tillage by 70.18 kg m^{-3}. At no-tillage technology it however was increasing by 28.97 kg m^{-3}. The time course of bulk density in long-term series shows linear trend its development under all observed tillage technologies. The increasing of bulk density under no-tillage may be related to deterioration of soil properties a soil compaction. Presented development of bulk density correspond with results, which presented Ledvina et al. (2004), Dam et al. (2006), Głab and Kulig (2008) and also Elder and Lal (2008). The trend of bulk density for no-tillage variant (Figure 1) indicate the possibility of compaction of topsoil.

Total porosity is function of bulk density and the values of porosity correspond with bulk density values, when higher bulk density the values of porosity are lower (Table 2).

Total porosity corresponded with bulk density. The values of total porosity in range from 41.06 in year 2010 to 47.43% in year 2012 were determined under conventional tillage. The most favourable values of total porosity were determined under reduce tillage variant (41.10–49.26%). The lowest pore volume was ascertained under no-tillage variant (38.12–46.93%). Even though our results showed increasing of bulk density and decreasing of total porosity, according to Moreira et al. (2016) the soil physical properties evaluated suggest that under long-term NT the soil remained physically functional.

Total porosity by valued time-series was decreased at conventional tillage 1.49% and at non-tillage variant by 0.76% (Figure 2). This decreasing wasn't statistically significant.

The course of total porosity in 10-year time-series was opposite to course of bulk density. At conventional and reduce tillage the porosity increased (CT: by +3.52%; RT: by +2.67%), but under no-tillage porosity decreased by 1.11%. However, these changes weren't statistically significant.

Maximum capillary water capacity is important hydro-physical indicator and characterizes amount of water for definite locality that is available for field crops (Šútor et al., 2007; Šimanský et al., 2016). It is depended on the sum of precipitation, the content of clay particles and the soil water storage. The large interval of this parameter is typical for heavy soils. In our experiment, the values of this soil indicator were found in range 31.65–42.03% (Table 3.). From point of view of soil tillage technologies, in average maximum capillary water capacity increased as follows: NT < CT < RT.

In Figure 3 the course of maximum capillary water capacity in 10-years studied time-series is shown. For conventional tillage and no-tillage variant decreasing of this indicator was determined (CT: by -3.87%; NT: by -2.50%), but for reduce tillage variant was determined its

Table 2 The total porosity (%) of topsoil in Milhostov

Year	CT	RT	NT	$\bar{x}$ *Y*
2006	43.16	44.38	46.02	44.52
2007	41.71	43.16	42.01	42.29
2008	43.92	46.21	46.93	45.69
2009	42.24	41.14	41.25	41.54
2010	41.06	41.10	41.36	41.17
2011	46.17	42.13	38.12	42.14
2012	47.43	44.68	42.01	44.71
2013	41.63	45.67	41.40	42.90
2014	45.22	49.26	46.09	46.86
2015	45.86	43.54	44.00	44.47
$\bar{x}$ *T*	43.84	44.13	42.92	43.63

CT – conventional tillage, RT – reduce tillage, NT – no-tillage, $\bar{x}$ *T* – average of tillage, $\bar{x}$ Y – average of experimental year

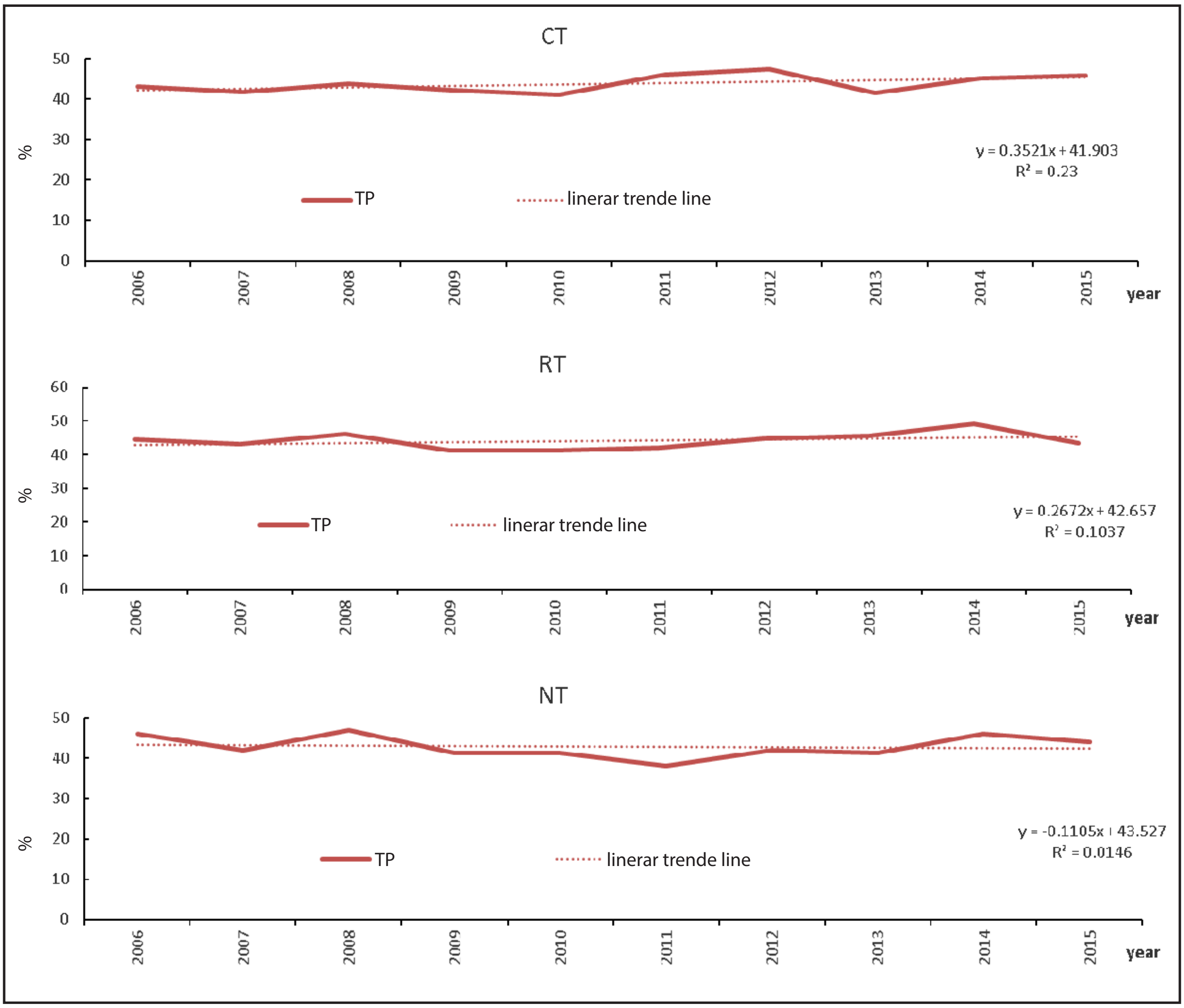

Figure 2 Linear trend of total porosity development for Gleyic Fluvisol

Table 3 The maximum capillary water capacity [%] of topsoil in Milhostov

Year	CT	RT	NT	$\bar{x}$ Y
2006	40.20	40.43	41.25	40.63
2007	35.38	36.45	35.65	35.83
2008	38.05	37.68	35.96	37.23
2009	39.24	39.73	38.58	39.18
2010	38.28	39.34	37.90	38.51
2011	40.64	39.78	36.52	38.98
2012	38.37	38.15	37.09	37.87
2013	37.58	38.73	32.90	36.40
2014	37.62	42.03	37.76	39.14
2015	31.65	37.54	37.37	35.52
$\bar{x}$ T	37.70	38.99	37.10	37.93

CT – conventional tillage, RT – reduce tillage, NT – no-tillage, $\bar{x}$ T – average of tillage, $\bar{x}$ Y – average of experimental year

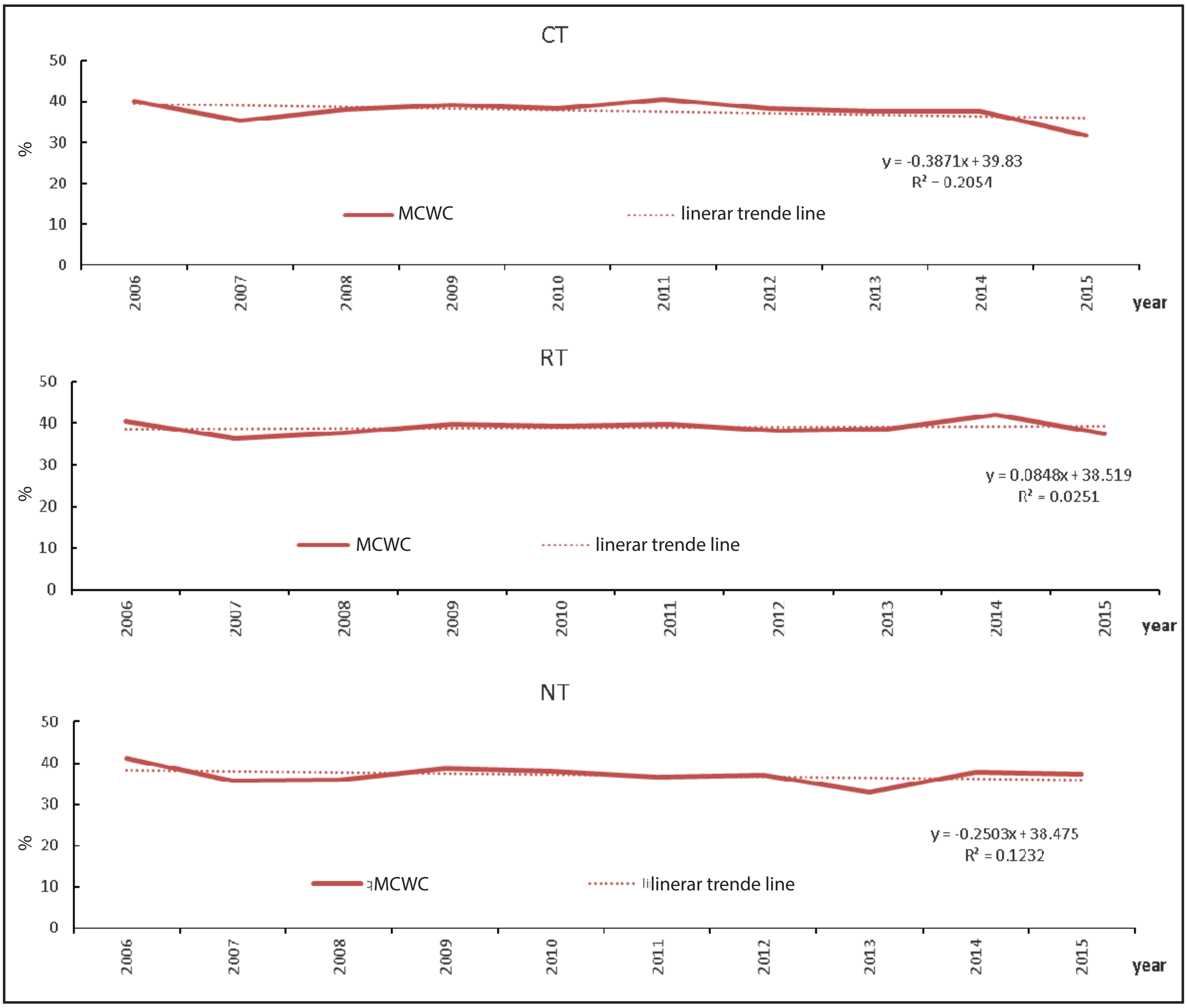

Figure 3 Linear trend of maximum capillary water capacity development for Gleyic Fluvisol

increasing by +0.85%. However, these changes, like for total porosity, weren't statistically significant.

The presented time-series with linear trend confirmed, that application of extreme tillage technologies, as are no-tillage systems without ploughing, is prospective also on heavy soils with higher content of clay particles. The physical and hydro-physical properties of these soil textures aren't significantly deterioration.

In accordance with Moreira et al. (2016) can be concluded that the physical properties indicated that the soil under long-term NT may have reached a physical equilibrium condition, which can be modified by short-term events

Table 4 Analysis of variance for observed soil water storage parameters

Source of variability	Degree of freedom	BD		P_t		θ_{MCWC}	
		F	*P*	*F*	*P*	*F*	*P*
Tillage	2	6.64	++	5.67	++	18.99	++
Year	9	15.28	++	15.29	++	16.88	++
Residual	105						
Total	119						

++P < 0.01; +P <0.05
BD – soil bulk density, P_t – total porosity, θ_{MCWC} – maximum capillary water capacity, *F* – observed value, *P* – probability

Table 5 Statistical evaluation of observed soil physical parameters values ($\alpha = 0.05$)

Source of variability	Factor	Observed parameter		
		BD (kg m^{-3})	TP (%)	θ_{MCWC} (%)
Soil tillage	CT	1473.1 a	43.84 b	37.701 a
	RT	1465.6 a	44.127 b	38.986 b
	NT	1497.2 b	42.919 a	37.098 a
Year	2006	1455.33 b	44.52 c	40.6267 f
	2007	1513.67 cd	42.2933 ab	35.8267 a
	2008	1424.67 ab	45.6867 cd	37.23 bc
	2009	1533.33 d	41.5433 ab	39.1833 e
	2010	1543.0 d	41.1733 a	38.5067 de
	2011	1517.67 cd	42.14 ab	38.98 de
	2012	1450.33 b	44.7067 c	37.87 cd
	2013	1497.67 c	42.9 b	36.4033 ab
	2014	1394.0 a	46.8567 d	39.1367 e
	2015	1456.67 b	44.4667 c	35.52 a

BD – soil bulk density, TP – total porosity, θ_{MCWC} – maximum capillary water capacity, CT – conventional tillage, RT – reduce tillage, NT – no-tillage, ascenders (a, b, c, d, e, f) between factors suggestive of statistically significant references ($\alpha = 0.05$) – LSD test

such as excessive machinery traffic, weather conditions variability and changes in crops grown in the crop rotation system. The modification of the soil properties suggested that soil quality was improved in the reduced tillage treatments (Büchi et al., 2017). Our results, also from point of view of long-term observation, confirmed the suitability of reduce tillage for heavy soils.

From Table 4 and Table 5 it becomes clear statistically significant effect of tillage technology and year on bulk density, total porosity and maximum capillary water capacity of clay-loamy soil in Milhostov.

The highest impact of tillage technologies and experimental year was determined for maximum capillary water capacity. The effect of experimental year on other observed parameters was lower, but similar as for maximum capillary water capacity.

4 Conclusions

Bulk density of Gleyic Fluvisol in Milhostov reached 1,331–1,623 kg m^{-3} and the lowest values (in average 1,466 kg m^{-3}) were found for reduce tillage variant. Values of total porosity were in range from 38.12 to 49.26%, whereby lower values were determined under no-tillage technology. Maximum capillary water capacity values from 31.65% to 42.03% reached level of values typical for soils on the East Slovak Lowland.

The trend analysis for years 2006–2015 show the decreasing of the bulk density and the increasing of the total porosity under conventional and reduce tillage. The course of these soil indicators under no-tillage variant was the opposite. The development trend of maximum capillary capacity during observed period wasn't significant.

From point of view of tillage technology, for clay-loamy soil the reduce tillage is better than conventional tillage or no-tillage. Effect of used technology will be shown after their longer application.

The soil protective technologies are one method for keeping and conservation of the soil fertility. For their successful is needful application as whole the farming system and the continuity of this system is very important. Using of the protective technologies may also contribute to keeping of stability of ecologically sensitive the heavy soils.

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References

ALVAREZ, R. and STEINBACH, H. S. (2009) A review of the effects of tillage systems on some physical properties, water content, nitrate availability and crops yield in the Argentine Pampas. *Soil Tillage Res.*, vol. 104, pp. 1–15. doi: https://doi.org/10.1016/j.still.2009.02.005

BÜCHI, L. et al. (2017) Long and short term changes in crop yield and soil properties induced by the reduction of soil tillage in a long experiment in Switzerland. *Soil Tillage Res.*, vol. 174, pp. 120–129. doi: https://doi.org/10.1016/j.still.2017.07.002

DAM, R. F. et al. (2006) Soil bulk density and crop yield under eleven consecutive years of corn with different tillage and residue practices in a sandy loam soil in central Canada. *Soil Tillage Res.,* vol. 84, no. 1, pp. 41–53. doi: https://doi.org/10.1016/j.still.2004.08.006

ELDER, J. W. and LAL, R. (2008) Tillage effect on physical properties of agricultural organic soils of north central Ohio. *Soil Tillage Res.,* vol. 98, no. 2, pp. 208–210. doi: https://doi.org/10.1016/j.still.2007.12.002

GŁĄB, T. and KULIG, B. (2008) Effect of mulch and tillage system on soil porosity under wheat (*Triticum aestivum*). *Soil Tillage Res.,* vol. 99, pp. 169–178. doi: https://doi.org/10.1016/j.still.2008.02.004

HRIVŇÁKOVÁ, K. et al. (2011) *Uniform methods of soil analysis.* Bratislava: VÚPOP (in Slovak).

CHAJDIAK, J. (2005) *Statistical examples for solving in Excel.* Bratislava: Statis (in Slovak).

KOTOROVÁ, D. (2007) Changes in clay-loam soil properties in different tillaage. *Agriculture (Poľnohospodárstvo),* vol. 53, no. 4, pp. 183–190 (in Slovak).

KOTOROVÁ, D., MATI, R. 2008. Properties and moisture regime of heavy soils in relation to their cultivation. *Cereal Research Communications,* vol. 36, Suppl., pp. 1751–1754.

KOTOROVÁ, D. and ŠOLTYSOVÁ, B. (2011) *Physical and chemical properties of heavy soils.* Piešťany: CVRV – Výskumný ústav agroekológie Michalovce (in Slovak).

KOTOROVÁ, D. and ŠOLTYSOVÁ, B. (2015) *Effects of soil auxiliaries on physical and chemical properties of soils.* Lužianky: NPPC – Výskumný ústav agroekológie Michalovce (in Slovak).

KOTOROVÁ, D., ŠOLTYSOVÁ, B. and MATI, R. (2010) *Properties of fluvisoils in the East Slovak Lowlands under different tillage systems.* Michalovce: CVRV – Výskumný ústav agroekológie (in Slovak).

LAL, R., REICOSKY, D. C. and HANSON, J. D. (2007) Evolution of the plow over 10.000 years and the rationale for no-till farming. *Soil Tillage Res*., vol. 93, pp. 1–12. doi: https://doi.org/10.1016/j.still.2006.11.004

LEDVINA, R. et al. (2004) Soil conservation technologies in field crops production. *Collection of Scientific Papers. Series for Crop Sciences,* vol. 21, no. 2, pp. 61–66 (in Czech).

LINKEŠ, V., PESTÚN, V. and DŽATKO, M. (1996) *Handbook on the use of bonitated soil-ecological units*. 3rd ed. Bratislava: VÚPÚ (in Slovak).

MATI R. and KOTOROVÁ D. (2007) The effect of soil tillage system on soil bulk density and other physical and hydrophysical characteristics of Gleyic Fluvisol. *Journal of Hydrology and Hydromechanics,* vol. 55, no. 4. pp. 246–252.

MOREIRA, W. H. et al. (2016) Seasonal changes in soil physical properties under no-tillage. *Soil Tillage Res.,* no. 160, pp. 53–64. doi: https://doi.org/10.1016/j.still.2016.02.007

PALM, C. et al. (2014) Conservation agriculture and ecosystem services. Overview. *Agric. Ecosyst. Environ.,* no. 187, pp. 87–105. doi: https://doi.org/10.1016/j.agee.2013.10.010

SOANE, B. D. et al. (2012) No-till in northern, western and south-western Europe: a review of problems and opportunities for crop production and the environment. *Soil Tillage Res.,* vol. 118, pp. 66–87. doi: https://doi.org/10.1016/j.still.2011.10.015

ŠIMANSKÝ, V., TOBIAŠOVÁ, E. and CHLPÍK, J. (2008) Soil tillage and fertilization of Orthic Luvisol and their influence on chemical properties, soil structure stability and carbon distribution in water-stable macro-aggregates. *Soil & Tillage Research,* vol. 100, no. 1–2, pp. 125–132. doi: https://doi.org/10.1016/j.still.2008.05.008

ŠIMANSKÝ, V., POLLÁKOVÁ, N. and JONCZAK, J. (2016) Is better minimum than standard mouldboard ploughing tillage from viewpoint of the pore-size distribution and soil water retention characteristic changes? *Cercetari Agronomice in Moldova,* vol. 3, no. 167, pp. 17–26. doi: https://doi.org/10.1515/cerce-2016-0022

ŠIMANSKÝ, V. (2017) Is the period of 18 years sufficient for an evaluation of changes in soil organic carbon under a variety of different soil management practices? *Communications in Soil Science and Plant Analysis,* vol. 48, no. 1, pp. 37–42. doi: https://doi.org/10.1080/00103624.2016.1253717

ŠÚTOR, J. et al. (2007) *Water in the aeration zone of the East Slovak lowlands.* Bratislava: ÚH SAV, Michalovce : SCPV – ÚAe (in Slovak).

TÓTH, Z., DUNAI, A. and JOLÁNKAI, P. (2012) Effect of soil tillage on soil water content. *Növénytermelés,* vol. 61, no. 3, pp. 235–238.

VOGELER, I. (2009) Effect of tillage system and P-fertilization on soil physical and chemical properties: crop yield and nutrient uptake. *Soil Tillage Res.,* vol. 103, pp. 137–143. doi: https://doi.org/10.1016/j.still.2008.10.004

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Original Paper

Preliminary study of insect pests of cucumber (*Cucumis sativus* L.) in Ogbomoso Agricultural Zone of Nigeria

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A field experiment was conducted in 2014 to determine insect pests associated with cucumber in Ogbomoso (Southern Guinea Savanna), Oyo-state Nigeria. Market More and Pointset cucumber varieties were used as treatments. Data were collected at three different phonological growth stages. Data collections commenced at 2 weeks after planting (WAP) and were on weekly basis for six weeks. Four major insect pests were observed namely *Phyllotreta cruciferae* Fabricius, *Diabrotical undecimpunctata* Howardi Barber, *Epilachna vigintiopunctata* Fabricius and *Monolepta* spp Coquilletta on the two varieties. Except *Epilachna vigintiopunctata*,which belong to the family Coccinellidae others are from the family Chrymesolidae. Also, all the insect pests recorded the highest population at seedling and the population reduces at flowering to fruiting stage while *Epilachna* recorded the highest population at fruiting stage. The same trend was also observed for distribution across the age of the plant.

Keywords: Cucumber, insect pest, *Epilachna vigintiopunctata*, population species and Market more

1 Introduction

Vegetables are important in the human diet for the provision of carbohydrates, proteins, vitamins and trace elements they contain (Bakre et al., 2004).In addition to dietary benefits, thereare important supplementary sources of food and nutrition and also serve as one of the major sources of income for small scale farmers to highly commercial farmers. (Selleck and Opena, 1985). Vegetables constitute the fourth largest group of commodities produced in Africa (FAO, 2000). Cucumber is a fruit vegetable which belongs to the Cucurbitaceae family that has been cultivated by man for over 3,000 years (Adetula and Denton, 2003; Okonmah, 2011). Today, Cucumber (*Cucumis sativus* L.) and water melon (*Citrullus lanatus* L.) was ranked best among the 20 most important vegetable crops worldwide (FAOSTAT, 2008). Cucumber is resident to Africa and Asia continent (Sebastian et al., 2010). The crop is cultivated in most parts of northern and eastern Nigeria by peasant farmers (Ekwu, 2007).

Insect pests aremajor constraints to cucumber production in Nigeria. They cause defoliations on leaves, flowers abortion and fruits damage. Thus, causing reduction in quality and quantity of the crop (Gballab, 2011). Apart from causing direct damagemany insect pests also act as vectors for several viral diseases (Kuhar and Speese, 2002). Birch et al. (2011) has reported that insect pests worldwide consume crops sufficient to feed an additional one billion people, hence ability to identify them prior to infestation can lead to higher productivity.Information on range and relative importance of different pests on cucumber in Southern guinea savannah are scanty. Information on species and population are required to determine the insect pests associated with cucumber especially in Southern guinea savannah area of Nigeria and the most critical phenological stage at whichthe insect pests do attack cucumber. Moreover, determining the importance of an insect in any agro-ecosystems, contributes to the description of its status. Such information is necessary for the formulation of a good pest management strategy. The objective of this study therefore, is to determine the insects pests associated with cucumber at different phonological stage in southern guinea savannah of Nigeria.

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2 Material and methods

2.1 Study Area

Field experiment was conducted in the cropping seasons of 2014, at Ladoke Akintola University of Technology (LAUTECH) Teaching and Research Farm, Ogbomoso, Nigeria. Ogbomoso Southern Guinea Savannah of Nigeria is on Latitude 10º 05′ N, Longitude 04º, 30′ E, 34.1 m). The region's climate is known to be hot humid tropical falls in with mean temperature of 27 ^{0}C, annual rainfall of 1,400 mm and marked with wet and dry season

2.2 Collection of cucumber seeds

Seeds of cucumber (*Cucumis sativus*) var. Point-set and Market more, used for this study were obtained from Agro Allied shop in Ogbomoso, Nigeria.

2.3 Agronomy practices

Land was cleared manually, and the thrash were removed. Each plot was divided into beds having 3 × 3 m dimension with a planting distance of 1 × 1 m between and within plant rows, respectively. Randomized Complete Block Design (RCBD) was used to arrange the treatments and was replicated three times. Each plot had 4 rows with 4 plants per row which amounted to 16 plants per plot. Two plant rows from the middle were tagged for data collection. Cucumber seeds were planted in early season of May, 2014 at the rate of three to four seeds per stand. Thinning was done two weeks after planting (WAP) to achieve one plant per stand. Weeding was done manually to reduce competition with the crop.

2.4 Data collection and Data Analysis

Insect pests' species were counted visually from middle plant rows tagged plant stands in the middle row of the experimental plot. The collected insect pests were taken to the Insect Collection Museum of the Department of Crop and Environmental Biology, University of Ibadan for identification. Data were collected on insect species and population at three different developmental stages of cucumber.

1. At seedling (0–4 weeks after planting).
2. At flowering (5–6 weeks after planting).
3. At fruiting (6–8 weeks after planting).

According to BBCH scale, germination and sprouting (0), leaf development (1), formation of lateral shoots (2), stem elongation (3), inflorescence emergence (5), flowering (6), development of fruit (Mishchenko, 2017).

Data Analysis

The number of insect pests encountered on the field was square root transformed before analysis. Data collected were pooled and later subjected to analysis of variance (ANOVA) using SAS software package (SAS Package 2002). Significant means were compared using least Duncan Multiple Range Test (DMRT) at 5% probability level.

3 Results and discussion

It was observed from the field that four major insect pests of cucumber were common in the area of study. Observed insect pests were flea beetle (*Phyllotreta cruciferae*) spotted cucumber beetle (*Diabrotica undecimpunctata*), leaf beetle (*Monolepta* species) and Hadda beetle (*Epilachna vigintioctopunctata*). These insects do cause damage in different phenological stages of cucumber as presented in Table 1. These insects were found at seedling, flowering and fruiting stages of cucumber. They were found defoliating the leaves and damaging fruits. This findings corroborate the work of Shama et al. (2016). *P. cruciferae* was considered as the most destructive among the insect pests observed because it had direct effect on the crop by feeding on the leaves. *P. cruciferae* adult feed on the leaves of young plant leaving shot-hole appearance. This agrees with the report of Indra and Kamini (2003) that occasionally seedlings may be completely destroyed as a result of their infestation. Also it was reported by same author that the larvae live in the soil and feed upon the roots of the host plants, although this was not observed throughout the period of the study.

P. cruciferae recorded the highest number 40, 20 and 16 at seedling, flowering, and fruiting stage respectively on the crop at different phenological stages (growth stages) when compared with other insect pests of cucumber (Table 1). The population of *P. cruciferae* was highest at seedling stage. This has been reported by Alao et al. 2017 that *P. cruciferae* has the highest insect population at seedling stage thus corroborated the report of Root (1973) that flea beetle, *P. cruciferae* is a quick colonizer of cruciferous hosts growing in dense or nearly pure stands and will remain on these plants, depending on the vigor and quality of the hosts plants (Kereiva, 1982). This is as a result of defoliation of the leaves which will eventually reduce the photosynthetic ability of the plant. Moreover, it has been reported that flea beetle adult feeding on young seedlings results in reduced crop stands and plant growth, delayed maturity and lower yield (Mayoori, 2009).

On the other hand, the time of planting of cucumber which was the month of May favors the increase in *P. cruciferae* population. This is in consonance with Burgess and Spur (1984) that warm and sunny conditions favor its large population. Distribution of *P. cruciferae* across the age of the plant showed that *P. cruciferae* was observed at two weeks after planting with higher population of (3.33). At 3, 4 and 5 WAP, the population of *P. cruciferae*

Table 1 Species population of insect pests on two varieties of cucumber planted in an unsprayed plot in 2014 in Ogbomoso (southern guinea savannah) Nigeria

Insects	Order/ Family	Growth stages			Observed damage on cucumber plant parts
		seedli stage	flowering stage	fruiting stage	
Market more					
P. cruciferae	Coleoptera/ Chrysomelidae	40	20	16	feeds on leaves, flowers and young fruits
D. undecimpunctata	Coleoptera/ Chrysomelidae	28	12	11	defoliates the leaves, flowers and feeds on young fruits or leaves
Monolepta spp	Coleoptera/ Chrysomelidae	35	10	0	defoliates the young leaves
E. vigintioctopunctata	Coleoptera/ Coccinellidae	0	0	20	feed on leaves and young fruits
Point-set					
P. cruciferae	Coleoptera/ Chrysomelidae	39	20	15	feeds on leaves, flowers and young fruits
D. undecimpunctata	Coleoptera/ Chrysomelidae	30	12	12	defoliates the leaves, flowers and feeds on young fruits or leaves
Monolepta spp	Coleoptera/ Chrysomelidae	34	11	0	defoliates the young leaves
E. vigintioctopunctata	Coleoptera/ Coccinellidae	0	0	21	feed on leaves and young fruits

Pooled data on insect abundance at different cucumber phenology

Table 2 Distribution of insect pests associated with cucumber across the age of the plant

Phenology	Weeks after planting	*P. cruciferae*	*Monoleptaspp*	*D. undecimpunctata*	*E. vigintioctopunctata*
Seedling	2	3.33^{a}	2.91^{a}	2.79^{a}	0.70^{c}
	3	2.76^{b}	2.90^{a}	2.91^{a}	0.70^{c}
Flowering	4	2.72^{b}	2.95^{a}	2.67^{ab}	0.70^{c}
	5	2.48^{b}	2.41^{ab}	2.41^{ab}	0.70^{c}
Fruiting	6	1.77^{c}	2.03^{b}	2.03^{c}	2.67^{b}
	7	1.65^{c}	1.87^{b}	1.95^{c}	2.85^{a}

Means with the same alphabet(s) along the column are not significantly different using DMRT at 5% probability

had reduced but were not significantly different from one another (2.76, 2.72 and 2.28). Infestation of *P. cruciferae* at 6 and 7 WAP were not statistically different (1.77, 1.65) from each other (Table 2).

Monolepta spp population was high at seedling; it reduced at flowering stage and were not noticed at fruiting stage (35, 10, 0 respectively). Infestation by *Monolepta* spp was the second most abundant at seedling and flowering stage of plant growth. However at fruiting, there were no infestations by *Monolepta* beetles. *Monolepta* spp which comprises *Monolepta australis*, *M. apicalis* and others were the second most abundant at seedling stage among the observed insects. They are polyphagous insect like *P. cruciferae* and are usually referred to as leaf beetles. However, the infestation of *Monolepta* spp accross the age of the plant commenced at 2 WAP while infestation at 2, 3 and 4 weeks were not statistically different from one another with population of (2.91, 2.90 and 2.95, respectively). Meanwhile at 5 WAP the population of *Monolepta* spp was significantly lower (2.41) and at 6 and 7 WAP the infestation were not significantly different from each other with a reduced population respectively (2.03, 1.87) (Table 2).

The activities of Haddabeetle (*E. vigintioctopunctata*) was not noticed at seedling (late May) and flowering stage (June) but seven weeks after planting of cucumber, the insect was noticed which was the month of July. This is in agreement with the report of Khan et al. (2000) who reported that the peak activity of infestation of this species has been noticed from July to August where both the imago and the larvae energetically feed on the epidermal tissues of the host plants.

Also, the number of *D. undecimpunctata* was higher at seedling stage but the population reduced as it developed into flowering stage and fruiting stage, respectively. The population of *D. undecimpunctata* was high at seedling stage but gradually reduced at flowering and fruiting stage Table 1. Moreover, infestation of *D. undecimpunctata* across the age of the plant was high at 2 and 3 WAP (2.79, 2.91) the infestation reduced at 4 WAP (2.67). At 5 WAP the infestation was significantly lower than the previous week i.e 2 and 3 WAP (2.41). However, at 6 and 7 WAP, there were no significant difference between them (Table 2). This observation is in line with Kuhar and Speese (2002) who reported that *D. undecimpunctata* damage to all cucurbits at seedling stage and they feed on the leaves which can lead to the death of the plant.

E. vigintioctopunctata was observed at fruiting stage, feeding on the leaves and fruits of cucumber on the two varieties. It was not noticed at seedling and flowering stage but at the onset of fruiting, it manifested. Its population was higher than other insect pests at fruiting stage. Generally, *P. cruciferae* had the highest population at seedling and fruiting stage, while *E. vigintioctopunctata* had the highest population at harvest (Table 1). Also, *E. vigintioctopunctata* infestation was observed to be higher at 7 WAP (2.85) (Table 2). The population of *P. cruciferae*, *Monolepta* spp and *D. undecimpunctata* were higher at seedling and flowering stage while the infestation by these insects reduced at maturity. Reverse was the case for *E. vigintioctopunctata*a with higher population than other insect pests at maturity stage.

Generally it was observed that, insect infestation throughout the period of this study revealed that the infestation starts at 2 weeks after planting (WAP) except for *E. vigintioctopunctata* and the insect population reduces as number of week after planting increased. More insects were found on the leaves than any other part of the plant and this is in consistent with the work of Bidein et al. (2016) who reported that most parts of plant attacked by cucumber insect pests are leaves. Insect population at flowering was low when compared with seedling stage. According to Parachnowitsch et al. (2012); flowering phenology and late flowering genotypes often escape insect pests. Conclusively, this research on insect pests infestation will greatly assists in the management of insect pests of cucumber.

4 Conclusions

Four major insect pests were observed infesting cucumber plants at different phonological stages. They were Flea beetle (*Phyllotreta cruciferae*), Leaf beetle (*Monolepta* spp), Spotted cucumber beetle (*Diabrotica undecimpunctata*) and Hadda beetle (*Epilachna vigintioctopunctata*). Among the insect pests, *P. cruciferae* has the highest population at seedling stage while its population decreases as the age of the plant increases. This showed that it could cause a major infestation at seedling stage. *Monolepta* spp and *Diabrotica undecimpunctata* were observed at vegetative stage but with lower population. *E. vigintioctopunctata* was observed at fruiting stage which was the economic part of the plant. Conclusively, this assessment of insect pests will greatly assists in the management of insect pests of cucumber.

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References

ADETULA O., DENTON L. (2003) Performance of vegetative and yield accessions of cucumber (*Cucumis sativa* L.). In *Horticultural Society of Nigeria (HORTSON) Proceedings of 21st Annual Conference.* doi: https://doi.org/10.5897/JABSD2015.0239

BAKRE, S. et al. (2004) Cadmium, lead and mercury in fresh and boiled leafy vegetables grown in Lagos, Nigeria. *Environmental Technology,* vol. 25, no. 12, pp. 1367–1370. doi: https://doi.org/10.1080/09593332508618465

BIDEIN T. et al. (2016). Efficacy of combining varietal resistance with organic fertilizer application in reducing infestation of cucumber (*Cucumis sativus* L.) by Insect Pests in the Niger Delta. *American Eurasian Journal of Agriculture & Environmental. Science*, vol. 16, no. 3, pp. 532–542. doi: https://doi.org/10.5829/idosi.aejaes.2016.16.3.12868

BURGESS, L. and SPURR, D.T. (1984) Distribution and abundance of overwintering flea beetles (Coleoptera: Chrysomelidae) in a grove of trees. *Environmental Entomology,* vol. 13, pp. 941–944. doi: https://doi.org/10.1093/ee/13.4.941

EKWU, L. G. et al. (2007) Vegetative growth and yield response of cucumber (L) to nitrogen and phosphorus fertilizer. In *Proceedings of the 20 Annual Conference of Horticultural Society of Nigeria (HORTSON) May 14th–17th*, pp.117–200.

FAOSTAT (2008) *Statistical database of Food and Agriculture Organization of the United Nations.*

GHALLAB, M M. et al. (2011) Sensitivity of four cucumber cultivars to some piercing sap sucking pests infestation and their impact on yield. *Plant Protection Research Institute*, vol. 89, no. 4, 1363.

GRZYWACZ, D. et al. (2014) The use of indigenous ecological resources for pest control in Africa. *Food security*, vol. 6, pp. 71–86.

KAREIVA, P. (1982) Exclusion experiments and the competitive release of insects feeding on collards. *Ecology*, vol. 62, pp. 696–704.

KHAN, M.W. et al. (1991) Toxicity of crude neem extracts (N-4) and (N-9) against the late 2nd instar larvae of *Musca domestica* (PCSIR strain). *Pak. J. Pharm. Sci.,* vol. 4, no. 1, pp. 77–86.

KUHAR, T. P. and SPEESE, J. (2002) *Cucumber Beetle Management in Melons.* Vegetable, Virginia Small Fruit and Specialty Crops. Virginia State University in Virginia.

INDRA, P.S. and KAMINI, V. (2003) Control of flea beetle, *Phyllotreta nemorum* L. (Coleoptera: Chrysomelidae) using locally available natural resources. *Himalayas Journal of Science,* no. 2, pp. 111–114.

MAYOORI, K. and MIKUNTHAN, G. (2009) Damage pattern of cabbage flea beetle *Phyllotreta cruciferae* (Goeze) (Coleoptera: Chrysomelidae), and its associated hosts of crops and weeds. *American-Eurasian Journal of Agriculture and Environmental Sciences,* vol. 6, no. 3, pp. 303–307.

MISHCHENKO, S. et al. (2017) Phenological growth stages of hemp (*Cannabis sativa* L.): codification and description according to the BBCH scale. *Žemės Ūkio Mokslai,* vol. 24, no. 2, pp. 31–36.

PARACHNOWITSCH, A. L. et al. (2012) Phenotypic selection to increase floral scent emission, but not flower size or colour in bee-pollinated *Penstemon digitalis*. *New Phytol.,* vol. 195, pp. 667–675.

ROOT, R. B. (1973) Organization of a plant-arthropod association in simple and diverse habitats: The fauna of collards (*Brassica oleracea*). *Ecological Monographs*, vol. 43, pp. 95–124.

SELLECK, G.W. and OPENA, R.T. (1985) National Programs: the need for increased emphasis on the development of vegetables and Legumes in: Non-Womdim. *An overview of major virus diseases of vegetable crops in Africa,* pp. 213–231.

SEBASTIAN P. et al. (2010) Cucumber (*Cucumis sativus*) and melon (*C. melo*) have numerous wild relatives in Asia and Australia. *Proceedings National Academic Science U.S.A,* vol. 107, pp. 14269–14273. doi: https://doi.org/10.1073/pnas.1005338107

YAMAGUCHI, M. (1993) *World Vegetables.* Department of Vegetable Crop. University of California.

Original Paper

Genetic diversity of Barbary lion based on genealogic analysis

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The aim of this study was to evaluate the state of genetic diversity in population of Barbary lion based on the genealogical analysis. Currently, this lion subspecies does not occur in the wild, and its population is considered to be critically endangered. The pedigree file consisted of 545 animals, while the reference population included 445 individuals. Alongside pedigree completeness, the parameters derived from common ancestor were used to analyse the state of genetic diversity in target population. The completeness of pedigree data had significantly decreasing tendency with increasing generations. The pedigree completeness index was the highest in the first generation (68%). The average value of the inbreeding coefficient was very similar in the reference population and the pedigree file (F = 0.05). Across generations, the trend of inbreeding increase was positive mainly due to the long-term use of specific lines and families for mating. The relative high average relatedness among individuals (AR = 0.06) only reflected the individual increase in inbreeding (3.18%). As expected the higher level of individual increase in inbreeding was found in the pedigree file (3.41%). The effective population size at level 26.66 confirmed that the Barbary lion is critically endangered by the loss of diversity. Because of this, the future continuous monitoring of genetic diversity of this subspecies is necessary, especially for long-term conservation purposes.

Keywords: Barbary lion, diversity, endangered species, pedigree analysis

1 Introduction

Conservation of biodiversity has become one of the most important objectives, since diminishing diversity is considered to be a global problem addressed by many international programs, organizations, and strategies (Kadlečík et al., 2016).

The lion (*Panthera leo*) belongs to mammals, from the taxonomic point of view to species from the genus Panthera and family *Felidae* (Linnaeus, 1758). It is quite different from other species belonging to this family. The lion is characterized by short, close-fitting leather and at the end of the tail with the long hairs. The Lions have a characteristic sexual dimorphism; the male is distinguished by a massive body structure, and the mane that extends from head to chest which sometimes covers a part of the chest (Alden et al., 1998; IUCN, 2005).

Nowadays, lions are found in fragmented populations inhabiting the geographical area of Sub-Saharan Africa and Western India (Riggio et al., 2013). From a historical point of view, the population of the Barbary lion represented a relatively large population. But, since 1990, its population size declined by 43% over the past 21 years (1993–2014). Subpopulations lions approximately totalled an estimated 7,500 Lions in 2014 and comprise a substantial portion of the total species population in applying observed trends to the species as a whole as well as on a regional basis (IUCN, 2010). The North African-Asian population of lions is only represented by today's Asiatic lion (350 wild individuals and 100 zoo captives), so the potential significance of captive Moroccan Royal lions (90 individuals) is not trivial (Black et al., 2013). Although the cause of such rapid decline is not fully understood, the loss of habitats and conflicts with humans are the biggest causes (Riggio et al., 2013). As shown in many studies of wild as well as domestic species, the decrease of population size is mostly accompanied by the significant loss of genetic diversity. That is important for ensuring the adaptive potential of species and preventing the occurrence of inbreeding depression over a long time period (Kadlečík et al., 2016).

This study is focused on the populations of Barbary lion (*Panthera leo leo*) living in captivity. Barbary lions have been considered extinct in the wild since the mid-1960's

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(Black et al., 2013). One of the most important features of the Barbary lion is a very dark and long-haired mane that passes over a shoulder to belly (Hemmer, 1974). The last known wild Barbary lion was shot in the Moroccan part of the Atlas Mountains in 1942 (Black et al., 2013). Barbary lions were offered to royal families and were known as "royal" lions. There are several lions in European zoos that are considered to be partial descendants of Barbary lions, but not purebred Barbary lions because of crossbreeding with other species of lions. Over the last three decades, many observations have been made about of origin purebred Barbary lions, but none of them has been genetically proven (Black, 2009).

The term biodiversity or biological diversity refers to the diversity of all life forms, evolutionary outcomes occurring in nature (Wilson, 1992). Genetic diversity can be defined as the variety of genotypes and alleles present in populations of individuals, which may subsequently manifest themselves in morphological, physiological and behavioural differences among individuals within a given population of the species (Frankham et al., 2002). Individuals of a particular species differ in their genotypic and phenotypic properties. As a result of genetic diversity, the gene pool of a given species is improved, species are being developed and individuals are able to adapt to changing environment conditions. Today's biodiversity status of a given species is a result of its long-term evolution especially adaption to specific environments (Kadlečík et al., 2016).

In the biodiversity assessment, two approaches can be generally observed; the use of diversity indices and a description of population diversity using models. The main difference between models and indices of diversity is based on the fact that the indices try to summarize the diversity of the population in one numerical value, in contrary the models, which try to avoid such information and focus on describing the overall shape of the population curve. It is more logical to use the maximum information contained in the data, however, in some cases, it is more practical and advantageous to use the generally index of diversity combining all the parameters in one value (Jarkovsky et al., 2012).

The ongoing development molecular and statistical methods are providing the scientific community with a wealth of tools for revealing the demographic history of a population. In particular, by bottlenecks, population expansions or declines, as well as effective population (N_e) sizes can now, by a variety of methods, be estimated for natural populations (Spong et al., 2000).

The effective population size represents the number of individuals in populations that vary depending on the inbreeding increase, or the increase in gene frequency changes in the population (Gutiérrez et al., 2009b; Cervantes et al., 2008). The effective population size is generally accepted as one of the most important parameters reflecting the loss of genetic diversity. According to N_e values the population can be regarded as critically endangered (N_e ≤50), threatened (50 > N_e <200), monitored (200> N_e <1,000) and non-endangered population (N_e >1,000) (Oravcová et al., 2006).

The aim of this study was to analyse the state of genetic diversity in populations of Barbary lion as one of the critically endangered wild life species by using genealogical analysis. In the evaluated database, we also measured the values of the relative inbreeding intensity (*F*), the coefficient of average relatedness (*AR*), the individual increase in inbreeding (Δ*F*).

2 Material and methods

2.1 Analysed population

The pedigree file consisted of 545 individuals that were registered in studbooks from 2011 to 2017 and monitored by Adrian Harland (Director of the Port Lympne Reserve for Animals). The genealogical information was obtained mainly from the Moroccan studbooks of a Barbary lion and then supplemented by information in cooperation with various European zoos. The reference population covering living animals in captivity consisted of 455 individuals.

2.2 Analysis of genetic diversity

One of the main factors that affect the reliability of genetic diversity indices is the completeness of pedigree. The completeness of the genealogical information was evaluated based on the pedigree completeness index (*PEC*) according to the following formula (MacCluer et al., 1983):

$$PEC = \frac{2C_pC_m}{C_p + C_m}$$

where:

C_p and C_m – are contributions from the paternal and maternal line but individually:

$$C = \frac{1}{d}\sum_{i=1}^{d} a_i$$

where:

a_i – the share of known ancestors in generations *i*

d – represent the number of generations which was counted

To assess the state of genetic diversity the parameters derived from a common ancestor (effective population size N_e, inbreeding coefficient of an animal *F*, individual increase in inbreeding ΔF_i, average relatedness *AR*) were calculated by using ENDOG v4.8 (Gutiérrez and Goyache, 2005). The inbreeding coefficient of an animal (*F*) is defined as the likelihood that an individual has two identical alleles from one common ancestor Provided that the analysed individuals and their common ancestors did not arise from the mating of relatives, *F* is calculated according to the equation of Wright (1922):

$$F_x = \sum 0.5^{n_1+n_2+1}$$

where:

n_1 – the number of generations from the individual *X* to the common ancestor on the father's side

n2 – the number of generations from individual *Y* to the common ancestor on the mother's side

Inbreeding is considered to be the main genetic factor that threatens the life of the population in the short period. Estimation of the inbreeding coefficient depends on the depth and availability of information in the pedigree, whereas the increase in inbreeding depends on the relative increase from one generation to the next (Toro et al., 2011). Gutiérrez et al. (2008) defined the individual increase in inbreeding (Δ*F*) between two discrete generations as:

$$\Delta F = \frac{F_t - F_{t-1}}{1 - F_{t-1}}$$

where:

F_t and F_{t-1} – the averages at *t* and *t* – 1 generations.

The average relatedness coefficient (*AR*) of each individual is defined as the probability that an allele randomly was chosen from the whole population in the pedigree belongs to a given animal. *AR* is an alternative or complement to *F* and can be used to predict the long-term inbreeding of a population because it takes into account the percentage of the complete pedigree originating from a founder at the population level (Kadlečík a Kasarda, 2007; Gutiérrez et al.; 2009a).

Individual increase in inbreeding (Δ*F*) is often expressed as the effective population size (N_e), which is defined by Hill and Zhang (2004) as the size of an idealised population with the same increment in drift or inbreeding per in observed generations. The rate of loss of genetic diversity within a species or population increases dramatically when N_e <100, while a population with N_e <50 is considered to be at high risk of the detrimental effects of inbreeding (Lewis et al., 2015). Gutiérrez et al. (2008) mention N_e as a key indicator for the conservation of genetic resources as it has a direct relationship to the level of inbreeding, the fitness of animals, and the degree of loss of genetic variability due to random genetic drift.

According to Simon and Buchenauer (1993), the effective population size is calculated as:

$$N_e = \frac{4(N_m \times N_f)}{(N_m + N_f)}$$

where:

f – the number of active pure-bred females enrolled in the studbook

m – the number of active pure-bred males used in pure-bred breeding

3 Results and discussion

Pedigree is a record that contains the most important information about the individual and its ancestors, usually in the 3–5th generations, with the parents of a certain offspring being considered as the first generation. It illustrates cognitive relationships between individuals. Pedigrees provide information on the origin and development of zootechnical taxonomic units that are an important part of breeding works, especially in case of individuals with known ancestors listed in the pedigree have a higher breeding value.

Pedigree analyses have to begin with the founders of the population, so individuals with unknown or estimated ancestors, from which come the known members of the population (Lacy, 1989). This analysis found evidence about maximum 7 generations of ancestors. In our opinion when comparing our result to livestock species, this is a relatively high number of generations traced. When evaluating the results of the analysis of pedigree completeness we also observed the percentage of known ancestors by generation. Since observed values are same we cannot talk about a significant improvement. Figure 1 clearly indicates that with the increasing number of generations the proportion of known ancestors significantly decreases. Within both pedigree file and

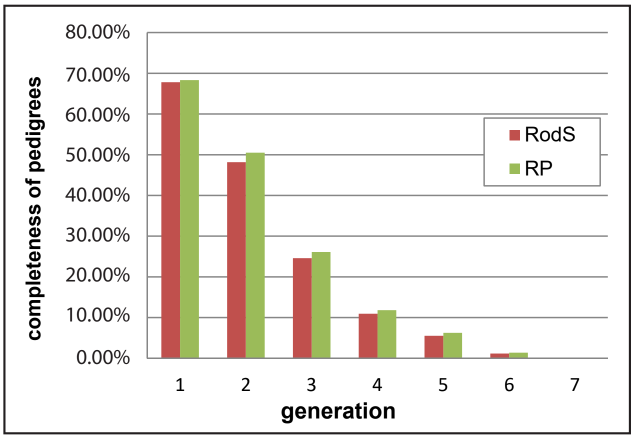

Figure 1 Pedigree completeness index by generations according to MacCluer et al. (1983)
RodS – Pedigree file, RP – Reference population

reference population the highest proportion of known ancestors was observed in the 1st generation (in average 68%), while the lowest values were in the 7th generation (Figure 1).

The effective population size is required to predict the rate of inbreeding and loss of genetic variation in the specific population. Based on this, analysed population of Barbary lion can be labelled as critically endangered population (Oravcová et al., 2006), since the calculated effective population size is less than 50 (26.66). The low effective population size is related to the high relatedness of animals and consequently to the inbreeding coefficient. A similar conclusion was reached by used to estimate N_e for the 2 remaining populations of the endangered ocelot (*Leopardus pardalis albescens*) occurring in the United States. Janečka et al. (2008) used several methods on calculated N_e (Oravcová et al., 2006), resulting in estimates ranging from N_e = 8.0 to 13.9 for the population located at the Laguna Atascosa Wildlife Refuge in Cameron County, Texas. The ocelot population in Willacy County, Texas, had N_e estimates of 2.9 and 3.1, respectively. When comparing with our result, it must be pointed out that we used the pedigree information for calculation of effective population size. In our study, the effective population size was estimated based on individual increase in inbreeding and through regression on equivalent generations for a given subpopulation according to Gutiérrez et al. (2008). However, the calculation in the ocelot population used genetic data from microsatellite loci. Estimates of N_e provide important information on the status of endangered populations and serve as indicators of genetic viability. Therefore, in line with this idea of endangered populations, it can be concluded that threatened populations are vulnerable to the effects of genetic drift and inbreeding, particularly when gene flow is low and the effective population size is low.

From the point of view of the interpretation of indicators derived from the common ancestor represent a set of indicators enabling the evaluation of genetic diversity. Overview of these indicators can be seen in the Tab.1 The obtained value of the average relatedness among animals (*AR* = 0.58%) is higher than the coefficient of the intensity of the inbreeding (F = 0.5%). We can assume that the genetic diversity will continue to diminish in the future and inbreeding will increase. With regard of the risk of inbreeding increase in future generations, it is necessary to improve attention when mating animals with F value of more than 1.01%. In the results, the average inbreeding intensity coefficient in the reference population was 4.2%; the average *F* = 4.5% in the whole pedigree file. The highest recorded inbreeding coefficient was 9.4% (Figure 2). When we comparing our result with the result in the study Zanin et al. (2016) overall, our method was the one that obtained the most higher values F. Should be noted Zanit et al. (2016) worked with, the molecular genetic structure of the Puma (Puma concolor) and Jaguar (Panthera onca) in Mexico. Values F (for subpopulations) were at a level, for certain areas for Puma -0.22 to 0.12 and Jaguar -0.13 to -0.6. Values *AR* were at a level, for certain areas for Puma 1.67 to 4, and Jaguar 2.79 to 3.24. Of the results show Pumas exhibited higher variation in genetic diversity than a Jaguar, for both expected and observed heterozygosities. The genetic variation revealed that, in their study area, there is not a uniform and panmictic population for either species. The gradual transition across all sampled locations suggests an isolation-by-distance pattern of genetic variation.

Our results demonstrate two things. First values of average relatedness coefficient of the reference population was 15.6%. Second, a value of the averaged relatedness coefficient in the pedigree file was 15%. It is important to point out that inbreeding is often associated with a decrease in offspring negative fitness (inbreeding depression). These negative effects are most profound in indicators closely linked to reproductive success, including seminal quality and fecundity. In Barbary lion´s population, the effect of inbreeding depression has been manifested in offspring. Total inbreeding had an impact on the survival of the young and their evolution. The records of the studbook have seen trouble cases of milk production in dams or the offspring has problems with the locomotive apparatus.

As shown in Figure 2, we can observe a rising inbreeding trend in populations considered, as the result of fact that each subsequent generation comes from a small number of females. These inbreeding values significantly complicate the possibilities when composing mating plans.

From the results, it can be said that there is a high percentage of inbreeding in the Barbary lion population

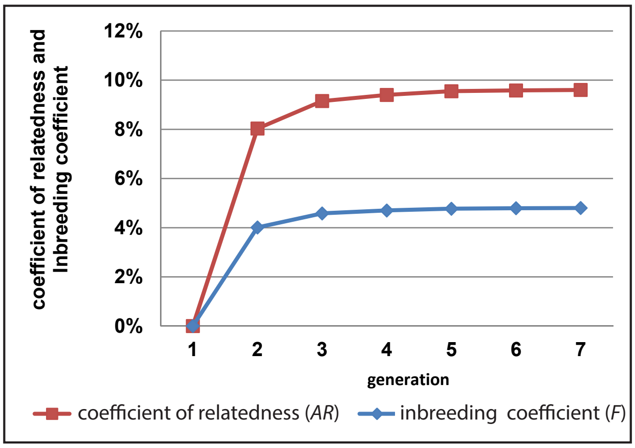

Figure 2 Graphic representation of *F* and *AR* values in the individual recalculated generations

because genetic purity is not entirely certain and the ancestors who consider themselves to be the founders do not have precisely defined relationships between the other ancestors. It can't be denied that the founders already had a certain percentage of inbreeding which they later transferred to their offspring. From these results the average relatedness coefficient of animals for both files, it has a high value, which is higher than the average value of the inbreeding intensity coefficient. In view of the small number of living individuals in the world, an increase in inbreeding intensity may be expected in the future because there will be mating more and more cognate individuals.

In livestock, especially in cattle, such analysis is often given increased attention to the preparation of rescue plans to save the population. Nomura (1999) suggested a suitable alternative so-called ″compensatory mating“ which is defined as a system when family members/individuals, in which are selected most of the individuals, and those are mating with individuals of families from which at least individuals are selected. The author also introduced the concept of the mating score, defined as the number of selected complete siblings of the individual (including the individual himself). It can be said, therefore, that compensatory mating is formulated as the negative selective mating of individuals, based on a mating score. Due to the fact that the males (sires) are sorted downwards and females (dams) that are ranked ascending according to mating scores are individuals with the same position in a row and mating with each other.

In our work we evaluated the representation of individuals in classes according to the intensity of inbreeding, the groups were divided into three groups, with the highest proportion in both files evaluated individuals reaching *F* = 0–0.39 (Table 1). The most inbreed animals had *F* values in the range of 12.5–37.5 in the reference population, representing 16.85% of inbreed individuals. In the pedigree file, it was 15.78% inbreeding of individuals (Table 1). In view of the risk of inbreeding growth in future generations, it is necessary to increase attention when mating animals with an *F* value of more than 0.39%. In the pedigree file, lower values can be seen, since it is made up of ancestors, who have no known parents, and we consider them in our database as basic ancestors. Introduction males (sires) appeared in the reference population, i.e. that they were actively engaged/involved in reproduction. We d not have to forget that individuals who were included in the first class with the lowest inbreeding values, not one hundred per cent pure individuals as their basic ancestors are not known. And we cannot even confirm or refute whether these individuals originated in a related mating and to what extent.

Table 1 Indicators of diversity derived from common ancestors in the pedigree file and in the reference population

Indicators		RP	RodS
Inbreeding coefficient (*F*)		4.16%	4.80%
Coefficient of average relatedness (*AR*)		5.73%	5.50%
F by sex			0.072 (0)
		4.613 ♂	0.0402 ♂
		0.042 ♀	0.047 ♀
AR by sex			0.076 (0)
		0.063 ♂	0.052 ♂
		0.057 ♀	0.051 ♀
Representation of individuals in classes *F*	*F* ≤0	342	420
	F = 0.39–12.5	28	39
	F ≥ 12.5–37.5	75	86
Individual increase in inbreeding (Δ*F*)		2.95%	3.41%

4 Conclusions

To evaluate the state of genetic diversity in the population of Barbary lion the indiacators derived from the common ancestor were used. One of the main factors that affect the reliability of genetic diversity indices is the completeness of pedigree. The pedigree completeness index was the highest in the first generation, with the following generations decreasing. The average value of the inbreeding coefficient was the same in the reference population and the pedigree file (*F* = 4.79%). In individual generations, the development of the coefficient was positive and, in particular, due to the long-term use of mothers and the relatedness of a mating of individuals, because low numbers of people cannot be expected in low numbers. The average relatedness coefficient at 0.06 pointing out to a relatively high degree of affinity among rated individuals. In the population, there is an increase in inbreeding, and the population becomes less demographically stable. Size of the population and inbreeding are related and lead to the loss of genetic diversity. It can be said that the loss of the population is actually the result of the interaction between inbreeding, the impact of human activity, demographic instability and the loss of genetic diversity. It would be appropriate to introduce a system of regular (annual) monitoring of the genetic diversity of lions kept in zoo gardens in the Czech Republic and Slovakia as a joint project in relation to the international database. The results of this work can be taken as an initial assessment.

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References

ALDEN, P. R. et al. (1998) *National Audubon Society Field Guide to African Wildlife.* New York: Alfred A. Knopf, Inc.

BLACK, S. A. (2009) Return of the royal Barbary lion. *BBC NEWS* [Online]. Retrieved 2017-10-12 from http://news.bbc.co.uk/earth/hi/earth_news/newsid_8109000/8109945.stm

BLACK, S. A. et al. (2013) Examining the Extinction of the Barbary Lion and Its Implications for Felid Conservation. *PLoS ONE*, vol. 8, no. 4, e60174. doi: https://doi.org/10.1371/journal.pone.0060174

CERVANTES, I. et al. (2008). Population history and genetic variability in the Spanish Arab Horse assessed via pedigree analysis. *Livestock science,* vol. 113, no. 1, pp. 24–33.

CREEL, S. and ROSENBLATT, E. (2013) Using pedigree reconstruction to estimate population size: genotypes are more than individually unique marks. *Ecology and Evolution,* vol. 3, no. 5, pp.1294–1304. doi: https://doi.org/10.1002/ece3.538

FRANKHAM, R., BALLOU, J. D. and BRISCOE, D. A. (2002) *Introduction to conversation genetics.* Cambridge: Cambridge University Press.

GUTIÉREZZ, J. P. and GOYACHE, F. (2005) A note on ENDOG: a computer program for Analysis pedigree information. *Journal of Animal Breeding and genetics,* no. 122, pp. 172–176.

GUTIÉREZZ, J. P. et al. (2008) Individual increase in inbreeding allows estimating effective sizes from pedigrees. *Genetics Selection Evolution,* vol. 40, no. 4, pp. 359–378.

GUTIÉREZZ, J. P., GOYACHE, F. and CERVANTES, I. (2009a) Endog v 4.6. A Computer Program for Monitoring Genetic Variability of Populations Using Pedigree Information. *User´s Guide.*

GUTIÉREZZ, J. P., GOYACHE, F. and CERVANTES, I. (2009b) Improving the estimation of realized effective population sizes in farm animals. *Journal of Animal Breeding and Genetics,* vol. 126, no. 4, pp. 327–332.

HEMMER, H. (1974) Untersuchungen zur Stammesgeschichte der Pantherkatzen (Pantherinae) Teil 3. Zur Artgeschichte des Löwen Panthera (Panthera) leo (Linnaeus, 1758). *Veröffentlichungen der Zoologischen Staatssammlung,* no. 17, pp. 167–280.

HILL, W.G. and ZHANG, X. S. (2004) Genetic variation within and among animal populations. In: SIMM, G. et al. (eds.) *Farm animal genetic resources.* Nottingham: Nottingham University Press, pp. 67–84.

IUCN. (2005) IUCN. *Red List of Threatened Species. Cat Specialist Group.* [Online]. Retrieved 2017-12-20 from http://www.catsg.org

IUCN. (2010) IUCN. *Red List of Threatened Species (ver. 2010.1).* [Online]. Retrieved 2017-12-20 from http://www.iucnredlist.org/details/15951/3

JANEČKA, J. E. et al. (2008) Small effective population sizes of two remnant ocelot populations (*Leopardus pardalis albescens*) in the United States. *Conservation Genetics.* doi: https://doi.org/10.1007/s10592-007-9412-1

JARKOVSKÝ, J., LITTNEROVÁ, S. and DUŠEK, L. (2012) *Statistical evaluation of biodiversity.* Brno: Akademické nakladatelství CERM.

KADLEČÍK, O. and KASARDA, R. (2007) *Animal Science.* Nitra: SUA (in Slovak).

KADLEČÍK, O. et al. (2016) *Genetic diversity Slovak Spotted and Holstein cattle.* Nitra: SUA (in Slovak).

KARESH, W. B., SMITH, F. and FRAZIER-TAYLOR, H. (1987) A remote method for obtaining skin biopsy samples. *Conserv. Biol.,* no.1, pp. 261–262.

LACY, R.C. (1989) Analysis of founders' representation in pedigrees: founder equivalents and founder genome equivalentsequivalence. *Zoo Biology,* vol. 8, pp.111–124.

LEWIS, T. W. et al. (2015) Trends in genetic diversity for all Kennel Club registered pedigree dog breeds. *Canine Genetics and Epidemiology,* vol. 2, no 13. doi: http://doi.org/10.1186/s40575-015-0027-4

LINNAEUS, C. (1758) *Systema naturae per regna tria naturae sccundum classis, ordines, genera, sepecies cum characteribus, differentiis, synonymis, locis. 10th edition, vol. 1. 1. Holmiae* (*Laurentii salvii*). Stockholm.

MACCLUER, J. W. et al. (1983) Inbreeding and pedigree structure in Standardbred horses. *J. Hered.,* vol. 74, pp. 394–399.

NOMURA, T. (1999) A mating system to reduce Inbreeding in Selection Programmes. Theoretical Basis and Modification of Compensatory Mating. *Journal of Animal Breeding and Genetics,* vol. 116, pp. 351–356.

ORAVCOVÁ, M. et al. (2006) Analysis of livestock breeds in terms of the effective size of their population. *Acta fytotechnica et zootechnica,* vol. 9, pp. 156–159.

RIGGIO, J. et al. (2013) The size of savannah Africa: a lion's (*Panthera leo*). *Biodiversity and Conservation.* doi: https://doi.org/10.1007/s10531-012-0381-4

SIMON, D. L. and BUCHENAUER, D. (1993) *Genetic diversity of European livestock breeds.* Wageningen: WUP.

SPONG, G., JOHANSSON, M. and BJÖRKLUND, M. (2000) High genetic variation in leopards indicates large and long-term stable effective population size. *Molecular Ecology,* vol. 9, pp. 1773–1782. doi: https://doi.org/10.1046/j.1365-294x.2000.01067.x

TORO, M. A. et al. (2011) Assessing the genetic diversity in small farm animal populations. *Animal,* no. 5, pp. 1669–1683.

YAMAGUCHI, N. – HADDANE, B. (2002) The North African Barbary Lion and the Atlas Lion Project (PDF). *International Zoo News,* vol. 49, no. 8, pp. 465–481.

WILSON, O. (1992) *The Diversity of Life.* Cambridge: Harvard University Press.

WRIGHT, S. (1922) Coefficients of inbreeding and relationship. *American naturalist,* no. 56, pp. 330–333.

ZANIN, M. et al. (2016) Gene flow and genetic structure of the puma and jaguar in Mexico. *European Journal of Wildlife Research,* vol. 62, no. 4, pp. 461–469. doi: https://doi.org/10.1007/s10344-016-1019-8

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Original Paper

The analysis of factors affecting the calving difficulty in Slovak Spotted cattle

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The aim of this study was to analyse several genetic and non-genetic factors that can affect the calving difficulty of Slovak Spotted cattle and to find out their statistical significance. A total of 417030 calving difficulty records from 174795 dams were collected during the calving parity from 2001 to 2017. The impact of factors affecting the calving difficulty was analysed by using procGLM implemented in SAS 9.3 on the basis of multifactor analysis of variance. The effects of the herd, a year of calving, the sex of a calf, a breed type, a month of calving, the parity and the sire were tested. The sex of born calf was the most significant factor (R^2 = 25.5%). The calving difficulty was significantly affected also by the herd, a year of calving, a month of calving, the parity and sire. Each of these effects showed high level of significance (P <0.001). The lowest level of statistical significance was found for effect of breed type. Based on obtained results we recommend continuing to use the recording of calving difficulty for the purposes of evaluation of effect of sire on inheritance.

Keywords: cattle, calving difficulty, non-genetic factors, reproduction

1 Introduction

Reproduction makes the greatest contribution to genetic gain in cattle measured in economic units. Reproduction can be as much as four times more economically important than end-product trait. In Slovak Spotted cattle, the calving ease can be regarded as one of the most important reproduction traits from the point of view of its breeding objective Slovak Simmental Breeders Association, 2018).

The calving difficulty can be affected by various genetic and non-genetic factors. Non-genetic factors include the sex of calf, the age of dam, the parity, and the season of calving, nutrition condition of dam before calving, and environmental conditions. On the other hand, the length of gestation, breed type and maternal dimensions of the dam are considered as genetic factors (Záhradková, 2009).

An indicator that greatly affects animal welfare, the livestock economy and the amount of farm work is the calving difficulty. The calving difficulty is influenced by direct and maternal genetic components. Animal selection and breeding strategies can optimize the accuracy of genetic evaluations and correctly highlight the calving difficulty in the multi-tagged indexes that provide estimates of genetic parameters (Strapák et al., 2011).

Slovak Spotted is autochthonous breed which belongs to the Simmental group of cattle. The Simmental is among the oldest and most widely distributed across of all breeds in the world. The Slovak spotted cattle as an important dual-purpose breed with a long tradition of breeding in Slovakia has excellent dairy as well as beef production. Slovak spotted was created by the crossbreeding of several breed (grey-brown Carpathian cattle, red Carpathian cattle and grey Steppe cattle) and it is recognized as one of autochthonous officially accepted as breed in 1958. This breed is typical of a good balance between milk and meat production and is characterized by a larger body frame, symmetrical body stature, good sex expression and good musculature. They are known for their gentle nature, impressive stature and excellent dairy qualities. (Kadlečík et al., 2013, Strapák et al., 2013, Shevhuzhev and Belik, 2017, Bogdányi et al., 1996).

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The aim of this study was to analyse several genetic and non-genetic factors that can affect the calving difficulty in Slovak Spotted cattle and to observe their statistical significance.

2 Material and methods

A total of 417030 calving difficulty records from 174795 dams were used in this study. The calving difficulty records were collected from the first to the sixth lactation during the parturition course from 2001 to 2017. All of records were provided by the Breeding Services of the Slovak Republic, s. e. Any additional information including pedigree data were obtained in cooperation with the Slovak Simmental Breeders Association. The impact of factors affecting the calving difficulty was analysed by using General Linear Models (GLM) procedure implemented in SAS 9.3 (SAS Institute Inc., 2011). The effects of the herd, year of calving, the sex of a calf, breed type, month of calving, parity and sire were tested. To prevent inaccuracy, the effect of year, month and herd were analysed separately and not as combined "contemporary groups". The impact of the individual factor was analysed based on multifactor analysis of variance using following linear model:

$$Y_{ijklmno} = HERD_i + YEAR_j + MONTH_k + SL_l + SEX_m + \\ + BREED_n + SIRE_o + e_{ijklmno}$$

where:
$Yijklmn_o$ – a calving difficulty
$HERD_i$ – fixed effect of the herd ($i = 802$)
$YEAR_j$ – fixed effect of a year of calving ($j = 17$)
$MONTH_k$ – fixed effect of a month of calving ($k = 12$)
SL_l – fixed effect of the parity ($l = 6$)
SEX_m – fixed effect the sex of calf ($m = 4$)
$BREED_n$ – fixed effect of the breed type ($n = 3$)
$SIRE_o$ – fixed effect of the sire ($o = 1852$)
$e_{ijklmno}$ – represents random effect of the residual

Evaluation of calving difficulty (4 – point scale)

For evaluation of the calving difficulty was used 4 – point scale: 1 – spontaneous calving (no assistance required); 2 – easy calving (assistance of 1 – 2 person); 3 – difficult calving (assistance of 3 or more persons or a veterinarian); 4 – caesarean section.

State code of the sex of calf

For identification of sex in the data were used specific codes from animal recording used in Slovak republic: code 1 (bulls); code 2 (heifers); code 16 (live – born but calf died); code 61 (stillbirth).

3 Results and discussion

Analysis of a calving difficulty by years of calving

In this study overall 417030 calving difficulty records of Slovak Spotted cattle, collected during the season from 2001 to 2017, were evaluated. All of collected records for 174795 dams were complete. A total of 87% parturitions occurred easy, while only 0.03% required medical intervention. The value of determinant coefficient for the evaluated effect is $R^2 = 3.5\%$. Table 1 shows the number of observations within each evaluated class of calving score.

Table 1 Calving difficulty in the analysed population

Calving difficulty	Count	%
1 spontaneous	360,997	86.56
2 easy	51,380	12.32
3 difficult	4,511	1.08
4 caesarean section	142	0.03

Compared to our results, Eaglen and Bijma (2009) reported for Holstein cows only 42.07% calving occurred spontaneous, easy calving 50.17%, difficult calving 7.46% and caesarean section 0.29%. Overall our findings are in accordance with findings reported by Strapák et al. (2011), he reported lower frequencies of easy calving of Slovak spotted cattle in 66.48% for heifers and cows had 75.46% of spontaneous calving, the frequencies of easy calving for heifers 20.1% and for cows 12.83% of Slovak spotted cattle. Ryba (2010) demonstrated similar values for all breeds of cattle within the range from 13.94% to 20.05%. Reached conclusion by Kotásek (2012) was the frequencies of easy calving for Holstein breed within the range from 15.62 to 17.34%, the frequencies of difficult calving for all breeds of cattle is little bit higher within the range from 2.05 to 3.36%, the frequencies of calving difficulty for Holstein breed within the range from 1.57 to 2.51%, and Hinrichs and Taller (2011) observed the frequencies of calving difficulty 8.96% for the Holstein breed. Kotásek (2012) demonstrated result for the frequencies calving where which it was necessary caesarean section 0.03 to 0.04% for Holstein breed and Hinrichs and Taller (2011) observed frequencies calving with caesarean section for the Holstein breed was 0.02%. Silvestre et al. (2018) reported for Portuguese dairy cattle per three generations from 320 953 records only 35.55% calving occurred spontaneous, easy calving 63.16%, difficult calving 1.21%, caesarean section 0.08%, in compared with our results we have more proportion of spontaneous calving. Inoue et al. (2017) describes the calving difficulty for Japanese black cattle in five-point scale from 1,850 records: 1. No problem or unobserved

76.1%; 2. Slight problem 13.8%; 3. Cow needed assistance 9%; 4. Considerable force used to deliver 1%; 5. Extremely difficult calving 0.2%. Reached conclusion by Cortes-Lacruz et al. (2017) for Parda de Montana beef breed from 5739 records was for spontaneous calving by 70.3%, easy calving 24.9%, difficult calving 3.1% and caesarean section 0.9%. In compared with our dual-purpose breed has a beef cattle higher proportion of difficult calving and caesarean section.

Analysis of calving difficulty by the month of calving

Within the evaluation of calving difficulty, we found the highest occurrence for the spontaneous calving during months March and April (97.60%). The lowest occurrence was found for calving requiring the caesarean section during month May and June (0.06%). The value of determinant coefficient for the evaluated effect is R^2 = 0.03%. Table 2 shows the number of observations within each evaluated class of calving score by the month of calving.

By comparing the results from Soltner (1978) for Charolais cows occurred the calving ease during months March and April with value 76.06%. Vavrišínová (2007) observed for Charolais cows highest occurrence of difficult calving during months January, February, and from September to December. Results from Johanson and Berger (2003) suggest that calf born during winter has higher weight and then has higher possibility of occurrence difficult calving of up to 15%.

Analysis of calving difficulty by the breed type

The results demonstrated in this section match state of calving difficulty for three breed types. Minimal value of Slovak spotted cattle within group S0 is 87.5% in genotype, breed type S1 has proportion of Slovak spotted cattle 75–87.5% and breed type S2 has proportion of Slovak spotted cattle 50–75%.

From in total of 417030 records, 225832 came from group of S0 cows, 73709 from the group of S1 cows and 117483 records was from the group of S2 cows. Compared to other factors tested in this study, the analysis proved that the breed type is significant effect on calving difficulty. Each of analysed groups showed approximately the same level of calving difficulty. Differences between breed types were negligible, therefore the effect of breed type was not considered in the model equation. The value of determinant coefficient for the evaluated effect was R^2 = 0.002%. Table 3 shows the number of observations

Table 2 Frequencies of calving difficulty by the month of calving

Month of calving	1 spontaneous		2 easy		3 difficult		4 caesarean section	
	count	%	count	%	count	%	count	%
January	31,807	86.32	4,632	12.57	396	1.07	12	0.03
February	30,273	86.58	4,298	12.29	384	1.10	9	0.03
March	38,048	87.60	4,918	11.32	451	1.04	16	0.04
April	32,027	87.60	4,177	11.42	350	0.96	7	0.02
May	29,756	86.62	4,150	12.08	424	1.23	21	0.06
June	28,751	86.66	4,047	12.20	370	1.12	10	0.03
July	30,965	86.68	4,355	12.19	383	1.07	20	0.06
August	28,431	86.38	4,140	12.58	337	1.02	6	0.02
September	25,983	85.98	3,881	12.84	341	1.13	14	0.05
October	25,359	86.53	3,609	12.31	327	1.12	11	0.04
November	29,540	85.89	4,496	13.07	349	1.01	6	0.02
December	30,057	85.53	4,677	13.31	399	1.14	10	0.03

Table 3 Frequencies of calving difficulty by the breed type

Breed type	1 spontaneous		2 easy		3 difficult		4 caesarean section	
	count	%	count	%	count	%	count	%
S0	195319	86.49	27782	12.30	2641	1.17	90	0.04
S1	63918	86.72	8962	12.16	806	1.09	23	0.03
S2	101760	86.61	14636	12.46	1064	0.91	29	0.02

within each evaluated class of calving score by the breed type. Due to assignation to the breed type is specific within each Herd book there is no direct comparison of the results. Breed type has usually low proportion on total variance, but significant as proved by our results.

Analysis of calving difficulty by the sex of calf

During the calving of cows and heifers was recorded almost the same frequency between the calving difficulty of live-born bulls 46.4% and live-born heifers 46.2%. The proportion of live- born calf but calf died was 2.2% and the proportion of stillbirth was 5.2%. The value of determinant coefficient for the evaluated effect is R^2 = 6.11%. Detailed results are presented in Table 4.

The results from Vavrišínová et al. (2007) reported the frequency of stillbirth for Charolais breed as follows: spontaneous calving 0.9%, easy calving 1.5%, and difficult calving 26.8% and for caesarean section 37.7%. Olson (2009) observed in his study the frequency of difficult calving for Holstein breed 19.98% and for Jersey breed 5.73%. Authors dealing with evaluation of calving difficulty (Vavrišínová et al., 2007; Olson, 2009) confirmed the highest frequency of difficult calving for sex with code 61 (stillbirth) and confirmed the easiest calving for sex with code 2 (heifers).

Analysis of calving difficulty by the parity

The multiparous cows were observed the highest occurrence of spontaneous calving. More frequent occurrence of dystocia has heifers. This is mainly because of their incomplete physical development and the reduced space of the pelvic.

The analysis proved that the most calving difficulty was occurred in the heifers. In the second lactation calving difficulty was noticeably reduced compared to the first lactation. The value of determinant coefficient for the evaluated effect is R^2 = 1.04%. Maternal effect was not part of the analysis. Detailed results presented in Table 5 shows the number of observations within each evaluated class of calving score by the sequence of lactation.

Results of Gaafar et al. (2010) showed the frequency of the difficult calving 7.7% stating that the age has an impact to the calving difficulty. Juozaitiene et al. (2017) observed for Lithuanian black and white dairy cows from 559,304 records that 48.75% of calving were evaluated as easy, 13.43% had slight problems, 34.71% of cows needed assistance, 2.87% needed considerable and 0.24% of cows had a difficult parturition, the majority difficult calvings were recorded in heifers or in cows between 6 and 8 lactations. Græsbøll et al. (2015) in his study monitored the influence of selected factors on milk production. One of the factors was the calving difficulty, where they observed that spontaneous calving has the consequence on the higher milk production and observed a significant impact of the difficulty of the first calving. Schaeffer (2003) studied the application of random regression models and one of the examined factors was the application to fertility in dairy cattle and proposed a model with parity, and he reported that the

Table 4 Frequencies of calving difficulty by the sex of calf

Sex of calf	1 spontaneous		2 easy		3 difficult		4 caesarean section	
	count	%	count	%	count	%	count	%
Bulls	169,886	87.81	22,157	11.45	1,380	0.71	54	0.03
Live- born but calf died	6,771	72.12	2,263	24.11	340	3.62	14	0.15
Heifers	172,109	89.40	19,575	10.17	803	0.42	30	0.02
Stillbirth	12,231	56.50	7,385	34.11	1,988	9.18	44	0.20

Table 5 Frequencies of calving difficulty by the parity

Parity	1 spontaneous		2 easy		3 difficult		4 caesarean section	
	count	%	count	%	count	%	count	%
1.	101,794	81.15	21,599	17.22	1,984	1.58	63	0.05
2.	90,844	88.30	11,093	10.78	916	0.89	25	0.02
3.	68,398	88.87	7,888	10.25	655	0.85	27	0.04
4.	48,327	89.14	5,404	9.97	468	0.86	16	0.03
5.	32,131	89.48	3,446	9.60	325	0.91	8	0.02
6.	19,503	90.21	1,950	9.02	163	0.75	3	0.01

result of such an analysis would be a different genetic value for each animal for each parity.

Analysis of calving difficulty by the sire

The sire affects the length of gestation, calving weight and proportions of calf. Effect of sire is one of the possible sources of calving difficulty. Each sire is unique and can affect calving difficulty in different way.

In the dataset of Slovak spotted cattle were in total 1803 sires used in breeding. For the evaluation were used only 14 most important sires, which influenced the results. In the population of Slovak spotted cattle were the most used sire with the state register code HAT001 (Name: Xirno, line: Haxist) and the highest occurrence of difficult calving was observed by sire DIK005 (Name: GS Dionis, line: Dirteck). The value of determinant coefficient for the evaluated effect is R^2 = 5%. Table 6 shows the number of observations within each evaluated class of calving score by the sire.

Analysis of the all factors involved in calving difficulty

The influence of the selected factors was verified based on General Linear Models (GLM) under ANOVA. From the short review above, key finding emerges: the overall explanatory effect of all factors on the variability of the calving difficulty was highly statistically significant and reached the value of the determinant coefficient (R^2 = 25.5%). The determinant coefficient (*R*-square) of 0.254796 means that 25.5% variability of calving difficulty is explained by the effects examined, and the remaining 74.5% variability of calving difficulty can be explained by other reasons than the linearity between the variables. Cumulative value of determinant coefficient of all factors observed by one-way analysis was 30.282%. This leads us to conclusion that other interactions between factors should be considered in future analysis.

Table 7 Statistical significance of the factors involved in calving difficulty

Factors	*R*-square (%)	*Pr > F*	*S*
Total	30.282	<0.0001	++
Herd	14.6	<0.0001	++
Year of calving	3.5	<0.0001	++
Month of calving	0.03	0.0009	++
Parity	1.04	<0.0001	++
Sex of calf	6.11	<0.0001	++
Breed type	0.002	0.0227	+
Sire	5	<0.0001	++

++ highly statistically significant (*P* <0.0001), + statistically significant (*P* <0.05)

4 Conclusions

Based on the results of the analysis we recommend continuing to use the recording of calving difficulty for the purposes of evaluation of effect of sire on inheritance. The results confirm the statistical proficiency between calving difficulty and selected factors. For the Slovak spotted cattle were the most significant and highly statistically significant factors: the sex of calf (R^2 =

Table 6 Frequencies of calving difficulty by the sires

Sire	1 spontaneous		2 easy		3 difficult		4 caesarean section	
	count	%	count	%	count	%	count	%
RAO012	14,131	84.34	2,420	14.44	190	1.13	13	0.08
EGE003	12,251	82.53	2,314	15.59	272	1.83	7	0.05
STG001	11,481	82.37	2,272	16.30	176	1.26	10	0.07
DSO001	10,082	91.74	883	8.03	24	0.22	1	0.01
PKN004	6,762	88.07	873	11.37	43	0.56	0	0.00
RSS001	5,412	78.19	1,349	19.49	155	2.24	6	0.09
MOL003	5,925	88.64	738	11.04	21	0.31	0	0.00
RNN001	5,309	93.12	380	6.67	12	0.21	0	0.00
PLI004	4,888	90.50	477	8.83	31	0.57	5	0.09
BNR001	4,129	79.25	1,000	19.19	78	1.50	3	0.06
HAT001	4,671	97.90	96	2.01	4	0.08	0	0.00
RDD001	3,766	79.59	894	18.89	69	1.46	3	0.06
HLG007	3,788	82.56	735	16.02	64	1.42	0	0.00
DIK005	3,218	74.10	1,012	23.30	110	2.53	3	0.07

6.11%), the parity (R^2 = 1.04%) and the year of the calving (R^2 = 3.5%). By the monitoring selected factors for the influence of calving we can influence selection of animals that have the premise of easy calving. Easy calving is a manifestation of the good reproduction and good reproduction means profitable economy of breeding.

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References

SLOVAK SIMMENTAL BREEDERS ASSOCIATION (2018) *The history of the breed.* [Online]. Retrieved 2017-06-10 from http://www.simmental.sk/o-plemene/historia-vzniku-plemena.html

BOGDÁNYI I. et al. (1996) *Breeding target and breed standard of Slovak spotted cattle.* Trebišov: Slovak Simmental Breeders Association.

CORTES-LACRUZ, X. et al. (2017) Genetic evaluation of calving ease in Parda de Montana beef breed based on linear and threshold models. *Web of Science,* vol. 113, no. 2, pp. 158–175. doi: https://doi.org/10.12706/itea.2017.010

EAGLEN, S. A. E. and BIJMA, P. (2009) Genetic parameters of direct and maternal effects for calving ease in Dutch Holstein-Friesian cattle. *Journal of Dairy Science,* vol. 92, no. 5, pp. 2229–2237. doi: https://doi.org/10.3168/jds.2008-1654

GAAFAR, H. M. A. et al. (2011) Dystocia in Friesian cows and its effects on postpartum reproductive performance and milk production. *Tropical animal health and production*, vol. 43, no. 1, pp. 229–234. doi: https://dx.doi.org/10.1007/s11250-010-9682-3

GRÆSBŒLL, K. et al. (2015) Danish Holsteins favor bull offspring: biased milk production as a function of fetal sex, and calving difficulty. *Plos One.* doi: https://doi.org/10.1371/journal.pone.0124051

HINRICHS, D. and THALLER, G. (2011) Pedigree analysis and inbreeding effects on calving traits in large dairy herds in Germany. *Journal of Animal Science*, vol. 94, no. 9, pp. 4726–4733. doi: https://doi.org/10.3168/jds.2010-4100

INOUE, K. et al. (2017) Inferring causal structures and comparing the causal effects among calving difficulty, gestation length and calf size in Japanese Black cattle. *Animal*, vol. 11, no. 12, pp. 2120–2128. doi: https://doi.org/10.1017/S1751731117000957

JOHANSON, J. M. and BERGER, P. J. (2003) Birth weight as a predictor of calving ease and perinatal mortality in Holstein cattle. *Journal of Dairy Science,* vol. 86, no. 11, pp. 3745–3755. doi: https://doi.org/10.3168/jds.S0022-0302(03)73981-2

JUOZAITIENE, V. et al. (2017) Relationship between dystocia and the lactation number, stillbirth and mastitis prevalence in dairy cows. *Acta Veterinaria Brno,* vol. 86, no. 4, pp. 345–352. doi: https://doi.org/10.2754/avb20178604034

KADLEČÍK, O. et al. (2013) Diversity of cattle breeds in Slovakia. *Slovak Journal of Animal Science,* vol. 46, no. 4, pp. 145–150.

KOTÁSEK, M. S. (2012) *Evaluation calving difficulty of heifers and cows in the Slovak Republic:* Ph.D. Thesis. Nitra: SUA (in Slovak).

OLSON, K.M. et al. (2009) Dystocia, stillbirth, gestation length, and birth weight in Holstein, Jersey, and reciprocal crosses from a planned experiment. *Journal of Dairy Science,* vol. 92, no. 12, pp. 6167–6175. doi: https://doi.org/10.3168/jds.2009-2260

RYBA, Š. (2010) *Evaluation calving difficulty cows of individual breeds in the Slovak Republic:* Ph.D. Thesis. Nitra: Slovak university of agriculture (in Slovak).

SAS Institute Inc. (2011) *SAS 9.3 Statements: Reference*. Cary, NC: SAS Institute Inc.

SCHAEFFER, L. R. (2003) Application of random regression models in animal breeding. *Livestock production Science,* vol. 86, no. 1–3, pp. 35–45. doi: https://doi.org/10.1016/S0301-6226(03)00151-9

SHAVHUZHEV, A. and BELIK N. (2017) Milk productivity of Simmental cows Austrian selection. In: *16th International Scientific Conference Engineering for Rural Development: Proceedings, 24–26. 5. 2017 Jelgava, Latvia,* pp. 1354–1358. doi: http://dx.doi.org/10.22616/ERDev2017.16.N304

SILVESTRE, A. Et al. (2018) Genetic parameters of calving ease in dairy cattle using threshold and linear models. *Italian Journal of Animal Science*. doi: https://doi.org/10.1080/1828051X.2018.1482801

SOLTNER, D. (1978) *La production de viande bovine.* 2nd ed. H. Siraudeau et cie Angers.

STRAPÁK, P. et al. (2011) *Evaluation calving difficulty in the Slovak Republic.* Nitra: SUA (in Slovak).

STRAPÁK P. et al. (2013) *Breeding cattle.* Nitra: SUA (in Slovak).

VAVRIŠÍNOVÁ, K. et al. (2007) Calving analysis in cows of Charolais breed at selected farm. *Journal of Central European Agriculture,* vol. 8, no. 2, pp. 183–190.

ZAHRÁDKOVÁ, R. (2009) *Beef cattle: from A to Z.* Praha: The Czech Beef Breeders Association (in Czech).

Original Paper

The effect of Stockosorb® 500 Micro on the growth-production process of *Festuca arundinacea* Schreb.

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The aim of this paper was to determine the effect of different doses of Stockosorb® 500 Micro on the growth-production process of *Festuca arundinacea* Schreb. cv. Koreta. The pot experiment was realized in laboratory conditions in year 2010. There were used pots with volume 2 dm^3 and area on top 0.014 m^2 and 3 levels of the amount of Stockosorb® 500 Micro in experiment: 0 $g.m^{-2}$, 50 $g.m^{-2}$ and 100 $g.m^{-2}$. Quantity of seeds was 1.18 g per pot (i. e. 40,000 seeds per m^2). Each treatment had 4 replications. Irrigating of pots was with 150 ml water per pot 2 times a week. Results of observations showed a statistically significant effect of Stockosorb® 500 Micro on daily intensity of growth to the height ($p = 0.040$), the total harvest of aboveground phytomass ($P = 0.000$) and non-significant effect on the intensity of the production of aboveground phytomass ($P = 0.084$). Stimulatory effect on indicators of the growth-production process of *Festuca arundinacea* Schreb. cv. Koreta had only Stockosorb® 500 Micro at dose 50 $g.m^2$. Application of 100 $g.m^2$ of Stockosorb® 500 Micro inhibited growth and production of that grass species, but with lower variability of average daily gain of height (*ADGh*), average daily gain of weight (*ADGw*) and thickening lawn index (*TLI*) values. Lower daily intensity of growth and phytomass production and higher turf density (expressed as thickening lawn index) is positively evaluated from the viewpoint of lawn management.

Keywords: average daily gain of weight, average daily gain of height, thickening lawn index, *Festuca arundinacea*, lawn

1 Introduction

In an urban country with high concentration of population, excessive industrialization and low levels of natural and semi-natural ecosystems, ecosystem services are overused. The ecological footprint is consequently greatly increases and deepens its ecological deficit. To mitigate the negative impacts of a high ecological footprint it is possible to use planting of green areas – lawns. These areas successfully supplement the missing natural ecosystems, contribute to the sustainable development of the city, strengthen the territorial system of ecological stability and significantly increase the biodiversity of the residential and industrial landscape (Tomaškin and Tomaškinová, 2012). However, in the current period of global climate changes we have to be deal with the problem of moisture deficit. It has negative effect on the resulting turf quality and functionality. Several authors (Černoch, 2003; Hatfield, 2017) reported the appropriate selection of drought-resistant grass species (for example *Festuca arundinacea* Schreb.), or use of warm-season grasses in turf, enrichment of turf mixtures about small-leaved *Trifolium repens* L. varieties as a way to eliminate the adverse impact of climatic changes on lawn growth. Another option is to use soil conditioners known as hydroabsorbents. They improve the physical properties of soil and substrates used in turf establishment. Due to its ability to bind more than 100-fold amount of water increase water capacity of the soil and thus contribute to reducing the cost of irrigation and improve the exploitability of nutrients from fertilisers (Hrabě et al., 2009). Hydroabsorbents support the growth of the root system, which creates conditions for better recovery and overall appearance of lawns at lower inputs. The function of the hydroabsorbents is also creating a larger and more stable soil aggregates on the basis of agglutinative effects (Salaš and Sloup, 2007). They have application in grassing of extreme habitats (Straka and Straková, 2003), improving the physical properties of degraded or problematic soils (dry sand) (Yang et al., 2014; Schmid et al., 2017), where their effect manifests itself clearly positive. Some authors (Waddington et al., 1974; Gregorová and Ďurková, 2006; Baker et al., 2010) reported positive effect of

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hydroabsorbent on aboveground and underground (root) phytomass production, number of tillers and plant height of selected turfgrass species. Similarly positive effect of hydroabsorbent found out Al-Humaid (2005) on the plant formation, robustness and depth of lawn root system. Chen et al. (2016) states that hydroabsorbents, which are widely used to maintain soil moisture in agriculture, can cause damage to plants. However, their mechanism of action is not well understood yet.

The aim of this scientific and research work was to evaluate the effect of Stockosorb® 500 Micro on selected growth-production characteristics of *Festuca arundinacea* Schreb. cv. Koreta.

2 Material and methods

Pot experiment was realized in laboratory conditions (temperature 20 °C, *rh* = 60–70%) at the Department of grassland ecosystems and forage crops, FAFR – SUA Nitra, Slovakia from April to October 2010. Turf was grown on 7 April 2010 in the containers with volume 2 dm^3 and area on top 0.014 m^2, in 4 replicates. There were 3 variants in this experiment:

- variant 1 (Control): without Stockosorb® 500 Micro (in next text as Stockosorb);
- variant 2 (S50): Stockosorb in a dose of 50 $g.m^{-2}$ (0.72 $g.container^{-1}$);
- variant 3 (S100): Stockosorb in a dose of 100 $g.m^{-2}$ (1.44 $g.container^{-1}$).

Used hydroabsorbent (Stockosorb® 500 Micro) is a polymer of natural substances with effect up to several years. It has the ability to retain water in an amount of more than 100-times its volume, improves soil structure and prevents it from overwetting (Gregorová, 2009; Hrabě et al., 2009).

In the experiment was used *Festuca arundinacea* Schreb. cv. Koreta with sowing quantities approximately 40,000 seeds per m^2 (i.e. 1.18 g of seed per pot). Amount of Stockosorb was mixed with the fluvisoil (its chemical properties are shown in Table 1) before sowing according to variants. At the same time in all variants was applied Duslofert lawn fertiliser (NPK: 15 – 15 – 15) at a dose of 0.43 g per pot (45 $kg.ha^{-1}$ N). In the next period turfs were not fertilised. Based on the general recommendations (Hrabě et al., 2007; Sulvis and Root, 2017) we chose to irrigate with the dose 150 ml water per pot 2 times a week (Tuesday and Friday).

Lawn was cut with scissors at a mean height of 100 mm at 50 mm. Before each cutting was determined height of turf as an average of 10 measurements in each replication. The average daily gain of height (mm per day) was calculated as:

$$ADGh = (\textit{mean height of turf at cutting in mm} - 50\ \text{mm})/\Delta t$$

where:

ADGh – average daily gain of height
Δt – days of growth

Cut aboveground phytomass was drying at 105 °C to constant weight and then was weighted to determine the production. Total aboveground phytomass harvest ($g.m^{-2}$) was determined as the sum of weights of phytomass from individual collections. The average daily gain of phytomass weight ($g.day^{-1}.m^{-2}$) was calculated as:

$$ADGw = \textit{mean production of phytomass at collection}\ \text{in g.m}^{-2} / \Delta t$$

where:
ADGw – average daily gain of weight
Δt – days of growth

Thickening lawn index (*TLI*) ($g.m^{-2}.mm^{-1}$) was determined as the ratio of *ADGw* and *ADGh*.

Data were statistically evaluated by Statistica 7.1 Complete CZ (Statsoft, Inc. 2005) using one-way analysis of variance (ANOVA). To assess the differences between variants was used Fisher`s LSD test at $P \leq 0.05$. On the graphical evaluation of the results was used MS Excel.

3 Results and discussion

The values of the *ADGh* show that the applicated Stockosorb had statistically significant (P = 0.040) influence on the rate of *Festuca arundinacea* Schreb. cv. Koreta growth (Figure 1). High growth intensity (7.71 mm per day) was noted on the variant S50. Higher dose of Stockosorb (100 $g.m^{-2}$) had inhibitory effect, which led to a reduction in the daily growth rate on average for the evaluated period (5.52 mm per day).

According to the classifier for the *Poaceae* family (Ševčíková et al., 2002), we can assess turfs in variants classify as “intense” to “very intense” growing. From

Table 1 Agrochemical composition of the soil used in the experiment

N_t	P	K	Mg	Ca	Na	C_{ox}	pH
$mg.kg^{-1}$						$g.kg^{-1}$	–
2,282.00	54.00	350.00	680.00	4,900.00	40.00	20.82	7.09

viewpoint of turf mowing management is request to uniform growth of grass (Turgeon, 2002; Harper, 2007). Therefore, it can be a higher dose of Stockosorb (S100) considered for more appropriate. In this variant was recorded the lowest variability of the average daily gain of height expressed by the standard deviation (*SD* = 3.04) compared to the other variants (*SD* = 3.62; *SD* = 3.65).

Average daily gain of weight of dry aboveground phytomass (Figure 2) had the same tendency as the intensity of growth in height, with a non-significant effect ($p = 0.084$). Stimulative effect had only lower dose of Stockosorb (S50), which increased the daily production of the phytomass by 0.36 g.day^{-1}.m^{-2}, and 1.01 g.day^{-1}.m^{-2} compared to control and the variant with dose of Stockosorb 100 g.m^{-2}, respectively. However, in terms of turfgrass management, where one of the objectives is the lowest intensity of phytomass production while maintaining the required quality of lawn (Ševčíková, 2002; Harper, 2007; Hrabě et al., 2009), consider as positive effect of higher dose of Stockosorb (S100).The daily production of phytomass was

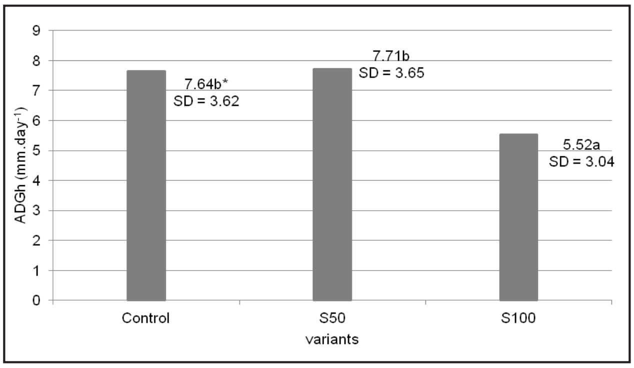

Figure 1 Average daily gain of height (*ADGh*) (mm.day^{-1}) in individual variants
Control – without hydroabsorbent; S50 – hydroabsorbent 50 g.m^{-2}; S100 – hydroabsorbent 100 g.m^{-2}; *SD* – standard deviation
*The different letters at an average values mean statistically significant difference (Fisher`s LSD test, $P \leq 0.05$)

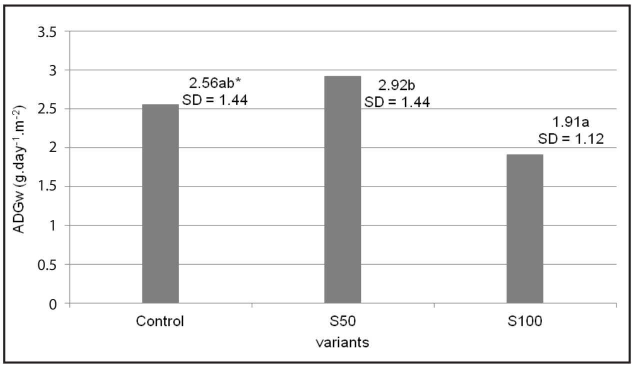

Figure 2 Average daily gain of weight (*ADGw*) of dry aboveground phytomass (g.day^{-1}.m^{-2}) in individual variants
Abbreviations see Figure 1

in this variant evenly, which is documented by the lowest value of the standard deviation (*SD* = 1.12) compared with the other variants (*SD* = 1.44).

Density is an important qualitative indicator of all the lawns. In ornamental lawns it interacts their aesthetic appearance, in the soil-protective lawns is important from anti-erosion viewpoint, in sports turf contributes to the formation of a strong and flexible sod etc. (Hrabě et al., 2009). Therefore, for the evaluation of turfs quality can also use mutual ratio of the *ADGw* and *ADGh*. It is so called thickening lawn index (*TLI*), which is in positive correlation with the density of turf (i.e. the number of tillers per unit area). Higher values of *TLI* mean more phytomass per unit area in conversion on the unit of plant height – turf is denser (Kovár et al., 2012). The values of this indicator presented in Figure 3 show non-significant differences ($p = 0.600$) between variants. However, it can be said that better effectiveness had lower dose of Stockosorb (S50). It resulted in an increase in turf density by 0.06 g.m^{-2}.mm^{-1} and 0.05 g.m^{-2}.mm^{-1} compared to control and variant with dose of Stockosorb 100 g.m^{-2}, respectively. Also the experiment results of Gregorová et al. (2007) and Vozár and Kovár (2010) showed stimulatory effect of Stockosorb on the turf density.

A qualitative indicator of lawn can also be the total harvest of aboveground phytomass per growing season. For lawn establishment is better use the species (eventually varieties) having a total low phytomass production (Murphy, 1996; Turgeon, 2002), thus eliminating the problem of what to do with mown material (aboveground phytomass). From the values of the total harvest of aboveground phytomass resulted that used Stockosorb had statistically significant ($P = 0.000$) effect on the total harvest of dry aboveground phytomass (Figure 4). It was more than 40 g.m^{-2} of phytomass after application of Stockosorb at a dose of 50 g.m^{-2} in comparison with the control (without hydroabsorbent). According to the classifier for the *Poaceae* family (Ševčíková et al., 2002) it

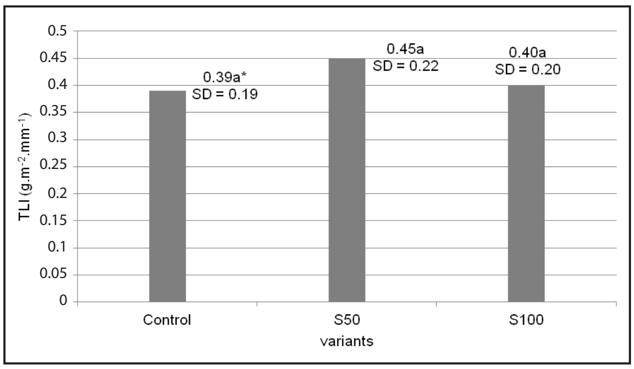

Figure 3 Thickening lawn index (*TLI*) (g.m^{-2}.mm^{-1}) in individual variants
Abbreviations see Figure 1

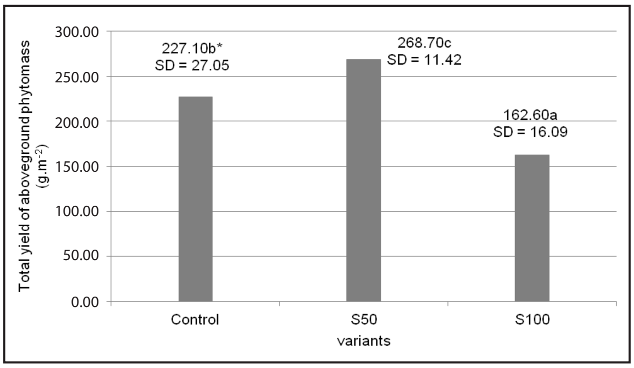

Figure 4 Total yield of dry above-ground phytomass (g.m^{-2}) in individual variants
Abbreviations see Figure 1

is "very low – low" production. Higher dose of Stockosorb (S100) was inhibitory and the total phytomass production of this variant was about 64.5 g.m^{-2} lower compared to the control ("very low" production).

4 Conclusions

Based on the results from this pot experiment we can noted that the daily intensity of growth and the total harvest of above-ground phytomass were statistically significant and intensity of phytomass production was non-significantly influenced by various doses of Stockosorb. Stimulatory effect on evaluated features showed only a dose of 50 g.m^{-2}. Application of 100 g.m^{-2} Stockosorb inhibited the growth-production process of *Festuca arundinacea* Schreb. cv. Koreta, but with lower variability values of some parameters (*ADGh*, *ADGw*, *TLI*). To future, the effects of application of hydroabsorbents should be investigated on the quality of turfs growed in natural conditions in context to global climatic changes.

References

AL-HUMAID, A.I. (2005) Effects of Hydrophilic Polymer on the Survival of Bottonwood (*Conocarpus erectus*) Seedlings Grown under Drought Stress. *European Journal of Horticultural Science,* vol. 70, no. 6, pp. 283–288.

BAKER, S.W. et al. (2010) Water retention and amendment materials for sand-dominated sports turf rootzones: a European perspective. In: *Proceedings of 1st European Turfgrass Soc. Conf.,* Pisa (Italy), 19–20 May 2008, pp. 238–244.

ČERNOCH, V. (2003) The use of white clover for lawns in the conditions of the Czech Republic. In *Trávníky 2003.* Hrdějovice: Agentura BONUS 2003, pp. 43–46 (in Czech).

GREGOROVÁ, H. (2009) *Special turfgrass management.* Nitra: SUA (in Slovak).

GREGOROVÁ, H. and Ďurková, E. (2006) Results with using Stockosorb on lawns. In: *Podtatranské pažite (Proceedings of the Symposium and Scientific Conference with International Participation, issued on the occasion of the 2nd International Festival of Cutting and the 65th Anniversary of the Establishment of the Levočské Lúky Breeding Station a.s., Pribylina – Levoča 30. 6.– 4. 7. 2006).* Nitra: SUA, pp. 187–191 (in Slovak).

GREGOROVÁ, H. et al. (2007) The effect of Stockosorb® 500 Micro on the growth and production characteristics of selected grass species. In *The present and perspectives in the forage crops research and education in multifunctional using of the land: proceedings, September 20, 2007 Nitra – Slovakia.* Nitra: SUA, pp. 285–288 (in Slovak).

HARPER, J.C. (2007) Mowing turfgrasses. *Turfgrass Management – Special Circular,* vol. 147, no. 12, pp. 120–124.

HATFIELD, J. (2017) Turfgrass and climate change. *Agronomy Journal,* vol. 109, pp. 1–11.

HRABĚ, F. et al. (2007) *Green Education – Study Materials.* Hluboká: Český svaz greenkeeperů (in Czech).

HRABĚ, F. et al. (2009) *Turfs for garden, landscape and sport.* Praha: Vydavatelství Ing. Petr Baštan (in Czech).

CHEN, X. et al. (2016) Characteristics and mechanisms of acrylate polymer damage to maize seedlings. *Ecotoxicology and Environmental Safety,* vol. 129, pp. 228–234.

KOVÁR, P. et al. (2012) The turfs quality of selected Slovak varieties of the genus *Festuca under* the conditions without irrigation. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* vol. 40, no. 6, pp. 181–188.

MURPHY, J.A. (1996) *Fine Fescues: Low Maintenance Species for Turf.* [Online]. Retrieved 2018-02-02 from http://njaes.rutgers.edu/pubs/publication.asp?pid=fs688

SALAŠ, P. and Sloup, J. (2007) Use of water retaining substances in soil, for nursery production. *Acta Horticulturae et Regiotecturae,* vol. 10, no. 1, pp. 12–16 (in Czech).

SCHMID, C.J. ET al. (2017) Effect of tillage and compost amendment on turfgrass establishment on a compacted sandy loam. *Journal of Soil and Water Conservation,* vol. 72, pp. 55–64.

STATSOFT, Inc. (2005) STATISTICA Cz [Softwarový system na analýzu dat], verze 7.1. www.StatSoft.cz

STRAKA, J. and Straková, M. (2003) Experience with soil conditioners for grading slopes in extreme habitats. In *Trávníky 2003.* Hrdějovice: Agentura BONUS 2003, pp. 16–21 (in Czech).

SULVIS, F.D. and ROOT, T.L. (2017) The rain-watered lawn: Informing effective lawn watering behaviour. *Journal of Environmental Management*, vol. 199, pp. 109–115.

ŠEVČÍKOVÁ, M. (2002) Growth of above-ground biomass of intensive lawns. In *Trávníky 2002.* Hrdějovice: Agentura BONUS 2002, pp. 47–50 (in Czech).

ŠEVČÍKOVÁ, M. et al. (2002) *Descriptor – grasses.* Zubří: OSEVA PRO.

TOMAŠKIN, J. and Tomaškinová, J. (2012) *Ecological, environmental and social functions of public green in the urban landscape.* Banská Bystrica: UMB FPV (in Slovak).

TURGEON, J.A. (2002) *Turfgrass Management.* 6th edition, New Jersey: Prentice Hall Upper Saddle River.

VOZÁR, Ľ. and Kovár, P. (2010) Impact of improving materials on the density of the lawn. In *Proceedings of lectures VIII. Congress SPpPLPaVv by SAV Nitra 16. June 2010.* Nitra : SUA. pp. 119–122 (in Slovak).

WADDINGTON, D.V. et al. (1974) Soil modification for turfgrass areas. *Pennsylvania State Univ. Agric. Exp. Sta. Progress Report 337.*

YANG, L. et al. (2014) Influence of super absorbent polymer on soil water retention, seed germination and plant survivals for rocky slopes eco-engineering. *Ecological Engineering,* vol. 62, pp. 27–32.

Original Paper

Nutritional value and fermentation characteristics of silage made from hybrid *Rumex patientia* L. × *Rumex tianschanicus* A.Los (Rumex OK 2) in different months during the year

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The aim of this study was to determine the nutritive value and fermentation parameters of silage made from hybrid *Rumex patientia* L. × *Rumex tianschanicus* A.Los (Rumex OK 2). Silages were made in months September, October and November of the year 2017 and next in April and May of the year 2018. In each month two variants were analysed, one without additives and second with an addition of 1% of dried molasses to wilted Rumex OK 2 plants. After 5 weeks fermentation in hermetic sealed plastic bags at temperature 20 °C the concentration of nutrients and parameters of fermentation were analysed in average samples. The content of dry matter in all silages were low and ranged from 7.1 to 18.8%. Content of crude protein was highest in autumn months, when was from 289 to 339 $g.kg^{-1}$ DM, which is much more compared to alfalfa silages. Crude fiber was in spring months from 295 to 422 $g.kg^{-1}$ DM and in autumn months from 126 to 166 $g.kg^{-1}$ DM. Development of fiber components was similar to development of crude fiber content. The concentration of crude protein and neutral detergent fiber in Rumex OK 2 silages from autumn months meet the criteria for first class legume silage. Only silages from October and November had the content of lactic acid more than 10 $g.kg^{-1}$ of original matter. Addition of dried molasses increased (P <0.05) concentration of lactic acid and decreased (P >0.05) concentration of acetic acid in silages from September, October, April and May. All Rumex OK 2 silages did not contain butyric acid. Silage pH value appertain to its dry matter concentration was relative high, which make impossible the good overall assessment. However, according to concentration of crude protein, neutral detergent fiber and proteolysis can be Rumex OK 2 silages from autumn months considered as a nutritional valuable feed. On the other hand Rumex OK 2 silage from September contains high concentration of oxalic acid, which can be potentially hazardous for animals.

Keywords: Rumex OK 2, silage, dried molasses, nutrients, fiber complex, fermentation process

1 Introduction

Production of conserved feeds is very important both for yearlong producing of feed rations and for creating of sufficient amount of substrate reserves for biogas stations for whole year (Juráček et al., 2010; Bíro et al., 2014). Advantages of feed conservation are mainly in option of crop harvesting in time of ideal nutritional value and in possibilities of long-term storage of nutrients and energy. Some members of *Rumex* L. family were and in nowadays still are consider as aggressive plants which force cultural grasses and legumes out from their surroundings and cause problems at herbage conservation due to their low dry matter concentration (Klimeš, 1993). At M. M. Gryshko National Botanical Garden of Ukraine (Kyiv) was from the 1980s hybridized new crop with name Rumex K-1, which contains relative high amount of crude protein, bud had not stabile production (Rakhmetov, 2018). Hybridization continues and in year 2001 was in Ukraine registered hybrid Rumex OK 2 (*Rumex patientia* L. × *Rumex tianschanicus* A.Los), which contains high amount of crude protein similar as Rumex K-1 and its production was stabilized. Rumex OK 2 can be used as a feed crop, vegetables, health plant and also as a technical plant (Usťak, 2007). Bazhay-Zhezherun and Rakhmetov (2014) published that hybrid Rumex OK 2 can be used also as a food or as a medical plant. The

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relative high concentration of crude protein in Rumex OK 2, mainly in young plants, was determined previously in experiment of Hejduk and Doležal (2004). Content of crude protein of Rumex OK 2 plant in months March and April was determined on values 261 and 245 $g.kg^{-1}$ DM respectively and after harvesting in June the crude protein concentration of Rumex OK 2 second crop was on values from 302 to 314 $g.kg^{-1}$ DM. The disadvantage was the very low concentration of dry matter in March and September and the very low production of biomass during this months – only in form of leaves. Very low concentration of dry matter was determined also by Derrick et al. (1993); Bockholt and Kannewurf (2001); Hejduk and Doležal (2004 and 2008). Despite the low concentration of dry matter, the chance of silage production with such high concentration of crude protein need to be verify. For effective utilisation of conserved feed either for animals or in bioenergy industry is necessary to know the concentration of nutrients, eventually other parameters such as the parameters of fermentative process of silages. Therefore the aim of this study was to determine the nutritional value and fermentative process parameters of silages made from hybrid Rumex OK 2 produced in different months without or with an addition of dried molasses.

2 Material and methods

This experiment was realized with silage made from hybrid *Rumex patientia* L. × *Rumex tianschanicus* A.Los (Rumex OK 2). Sample of Rumex OK 2 for silage production were collected in September, October and November of the year 2017 and in April and May of the year 2018. Rumex OK 2 from autumn months of the year 2017 which was used for silage samples preparation was grown after first harvesting of dried Rumex OK 2 plants in July 2017. Samples collecting was realised always around the 20th day of the month. After collecting, whole plants were wilted for three days in indoor condition, by open windows and without external heating. After wilting, Rumex OK 2 plants were cut to the theoretical length of cut 1.5 cm and ensiled (hermetic sealed in plastic bags). Average weight of silage samples was 1,347 ±151 g. In each month, a two variants were ensiled and analysed. First variant was silage from wilted Rumex OK 2 without addition of any additives, this variant was marked as control (C). Second variant was silage of wilted Rumex OK 2 with an addition of 1.0% of dried molasses, this variant was marked with abbreviation (M). During fermentation process, which last for five weeks, plastic bags with silage samples were stored in room without light and at 20 °C. For measuring of the content of basic nutrients and fermentative process parameters a three samples of each variant were analysed. After five weeks, silage samples were prepared for basic nutrients and fermentation process parameters determination. After predrying and homogenisation of samples the concentration of basic nutrients were detected according to Regulation no. 2145/2004-100. Concentration of dry matter (DM) was determined by the gravimetric method, crude protein (CP) by the Kjeldahl's method, crude fat (CFa): extraction by light petroleum, crude fiber (CFi): gravimetrically as the residue remaining after extraction in acid and alkali reagent, acid detergent fiber (ADF): gravimetrically as the residue remaining after extraction in acid detergent solution, neutral detergent fiber (NDF): gravimetrically as the residue remaining after extraction in neutral detergent solution, acid detergent lignin (ADL): gravimetrically as the residue remaining upon ignition after 72% H_2SO_4 treatment, ash: ashing with the use of a muffle furnace by 550 °C and starch by polarimetry. Cellulose (CEL) and hemicellulose (HE) were calculated, CEL = ADF - ADL; HE = NDF - ADF. Content of nitrogen free extract (NFE) and organic matter (OM) were also calculated NFE = dry matter - crude protein - crude fiber - crude fat - ash; OM = dry matter - ash (Juráček et al., 2011). The content of fermentative organic acids (lactic acid, acetic acid, formic acid and butyric acid) and oxalic acid was determined by analyser EA 100 (Villa Labeco, SVK) using the method of ionic electrophoresis. The content of alcohols was determined by Conway microdiffusion method, the content of water extract acidity (AWE) was determined by alkalimetric titration to pH 8.5 and active acidity (pH) was determined by the electrometric method. Proteolysis was calculated as a percent of $N\text{-}NH_3$ out of total N. Results were statistical analyzed in statistic program IBM SPSS v. 20.0. Descriptive statistic and the effect of sampling time on nutrient content was calculated using ANOVA. Differences of nutrient mean values between silage variant in that month were tested by independent *t*-test. $P < 0.05$ was considered as significant.

3 Results and discussion

It is general known that herbage plant of *Rumex* L. family contains at the start of growth very low concentrations of dry matter (Derrick et al., 1993; Bockholt and Kannewurf, 2001; Hejduk and Doležal, 2004 and 2008). Hejduk and Doležal (2008) determined slower decrease of water content also during wilting of *Rumex obtusifolius*. This statement was confirmed with results of this study (Table 1). The Rumex OK 2 silage, mainly from young plants in autumn months, contains high concentration of crude protein. The decrease of crude protein, crude fat, starch and ash concentration in Rumex OK 2 silage was detected from September to November as well as from April to May. The aging effect of plant causes the increase of crude fiber and its components (except hemicellulose) in Rumex OK 2 silage from April to May (Table 1 and 2). Interesting was the decrease of crude fiber and its

Table 1 Nutritional characteristic of silage from Rumex OK 2 made in different months

	Sep 2017		Oct 2017		Nov 2017		April 2018		May 2018		SEM	P
	C	M	C	M	C	M	C	M	C	M		
DM (%)	7.1*	7.4	18.2	17.2	18.0	18.5	12.1*	13.2	18.3	18.8	0.71	***
CP ($g.kg^{-1}$ DM)	339*	319	304*	292	305*	289	175*	162	102	110	14.0	***
CFa ($g.kg^{-1}$ DM)	32.4*	28.4	22.5*	19.1	17.4	16.9	11.8*	9.4	8.4	8.6	1.28	***
CFi ($g.kg^{-1}$ DM)	160	164	158*	166	126*	138	299	295	422	406	17.2	***
NFE ($g.kg^{-1}$ DM)	309*	337	369	372	420*	426	462	486	398	415	9.41	***
S ($g.kg^{-1}$ DM)	35.0*	25.5	29.8	28.0	14.9	4.7	53.7*	41.7	27.7	21.8	2.85	***
OM ($g.kg^{-1}$ DM)	841	848	854	850	868	869	908	903	930*	940	5.57	***
Ash ($g.kg^{-1}$ DM)	159	152	146	150	132	131	92.2	96.9	70.1*	59.1	5.57	***

C – control (silage without additives); M – molasses (silage with addition of 1% of dried molasses); DM% – concentration of dry matter in%; CP – crude protein; CFa – crude fat; CFi – crude fiber; NFE – nitrogen free extract; S – starch; OM – organic matter; SEM – standard error of the mean; * – means between C and M silage in that month were significantly different at *P* <0.05; *** – effect of sampling time on nutrient content was significant at *P* <0.001

Table 2 Fiber characteristic of silage from Rumex OK 2 made in different months

	Sep 2017		Oct 2017		Nov 2017		April 2018		May 2018		SEM	P
	C	M	C	M	C	M	C	M	C	M		
ADF ($g.kg^{-1}$ DM)	174	191	212	209	158	161	350	353	504	506	20.9	***
NDF ($g.kg^{-1}$ DM)	222*	247	229*	243	172*	187	416	420	566	565	23.1	***
ADL ($g.kg^{-1}$ DM)	22.4	21.5	47.7*	38.4	26.8	27.0	61.4	57.9	127*	136	6.40	***
CEL ($g.kg^{-1}$ DM)	151*	169	164	171	131	142	288	295	377	371	14.8	***
HE ($g.kg^{-1}$ DM)	48.7	56.6	29.4	33.8	14.3*	26.0	66.0	67.6	61.1	58.7	3.07	***

C – control (silage without additives); M – molasses (silage with addition of 1% of dried molasses); ADF – acid detergent fiber; NDF – neutral detergent fiber; ADL – acid detergent lignin; CEL – cellulose; HE – hemicellulose; DM – dry matter; SEM – standard error of the mean; * - means between C and M silage in that month were significantly different at *P* <0.05; *** – effect of sampling time on nutrient content was significant at *P* <0.001

components concentration between months October to November. This decrease can be caused by higher count of leaves and lower count of caulicles in silage from November compared to silage from October. Bockholt and Kannewurf (2001) determined concentration of fiber in *Rumex obtusifolius* leaves on value from 120 to 150 $g.kg^{-1}$ DM and concentration of fiber in caulicles on value of 130 to 380 $g.kg^{-1}$ DM. First class legume silage contains at once more than 225 $g.kg^{-1}$ DM of crude protein and less than 375 $g.kg^{-1}$ DM of neutral detergent fiber (Mitrík, 2014). According the concentration of crude protein and neutral detergent fiber, all Rumex OK 2 silages from autumn months meet the criteria for first class legume silages.

Because of low dry matter concentration after wilting, dissatisfy results of fermentation process were expected. Due to concentration of crude protein and nitrogen free extract in silages of Rumex OK 2, the fermentation process quality of this silages were evaluated according to criteria for legume silages. Škultéty (2014) published that legume silage classified in first or in second qualitative class have to have concentration of lactic acid on value at least 10 $g.kg^{-1}$ original matter or more. This criteria met only Rumex OK 2 silages from October and November, silages from other months had concentration of lactic acid lower than 10 $g.kg^{-1}$ original matter. Concentration of acetic acid of Rumex OK 2 silages in November, April and May met according to Mitrík (2014) the requirement for first qualitative class of legume silage. Dry matter concentration and its appertain pH value in Rumex OK 2 silages was in September and May inadequate and in other months was high. Weissbach (1998) declared for cell contents of fresh *Rumex obtusifolius* plants the pH value from 4.5 to 4.8. In general the pH value of all Rumex OK 2 silages was compared to required criteria on high value, which has negative effect on classification of this silages. On the other hand, the value of proteolysis was in all Rumex OK 2 silages adequate for first class legume silage (Mitrík, 2014). Also Weissbach (1998) determined for silage of *Rumex obtusifolius* low value of proteolysis. There is rule, that maize or alfalfa silages with low

Table 3 Results of fermentation process of silage from Rumex OK 2 made in different months

	Sep 2017		Oct 2017		Nov 2017		April 2018		May 2018		SEM	P
	C	M	C	M	C	M	C	M	C	M		
LA (g.kg^{-1} DM)	32.6*	53.4	99.1*	133	58.2	70.1	28.5*	38.4	6.3*	13.2	6.65	***
AA (g.kg^{-1} DM)	49.9	39.8	36.7	32.6	n.d.	15.4	7.0	4.9	8.0	6.1	3.00	***
FA (g.kg^{-1} DM)	15.4	15.0	11.8*	12.9	n.d.	n.d.	n.d.	n.d.	2.7	n.d.	0.92	***
OA (g.kg^{-1} DM)	137*	121	52.1	54.4	50.5	48.6	48.3	42.9	30.8	30.3	0.58	***
Alco. (g.kg^{-1} DM)	32.0*	44.9	13.6	11.5	15.2	10.9	36.9*	16.5	15.1*	24.2	2.09	***
pH	4.9	4.7	5.0	4.7	4.5	4.5	4.3	4.5	4.9	4.9	0.05	***
AWE	500*	573	1009*	1152	878	934	469	431	285	330	47.1	***
DP (%)	4.2	4.0	3.7	3.8	2.1	2.3	10.1	10.6	7.4*	6.3	0.51	***

C – control (silage without additives); M – molasses (silage with addition of 1% of dried molasses); LA – lactic acid; AA – acetic acid; FA – formic acid; OA – oxalic acid; Alco. – alcohols; AWE – water extract acidity (mg KOH pre 100 g of silage); DP – degree of proteolysis in% (N-NH_3 out of total N); n.d. – not detected; * – means between C and M silage in that month were significantly different at *P* <0.05; SEM – standard error of the mean; *** – effect of sampling time on fermentation process parameter was significant at *P* <0.001

concentration of dry matter contains butyric acid. Rumex OK 2 silages did not contain any butyric acid. This fact was also determined previously by Hejduk and Doležal (2008).

Rumex L. family is characteristic with content of oxalic acid, which concentration more than 100 g.kg^{-1} DM can be considered as potentially hazardous as published Kalač and Míka (1997). Higher intake of oxalate by cattle can causes hypocalcaemia, tetanic contraction or death (Tůmová et al., 2010). In this experiment the concentration of oxalic acid in Rumex OK 2 silages in months October, November April, and May was in interval from 30.3 to 54.4 g.kg^{-1} DM, whereas in September it was in interval from 121 to 137 g.kg^{-1} DM. Upon the concentration of oxalic acid in Rumex OK 2 silage from September, it is impossible to feed this silage as single feed to animals. In general, detected concentration of oxalic acid in Rumex OK 2 silage samples (except Rumex OK 2 silage from September) is similar to that in *Rumex* L. herbage published by Hejduk and Doležal (2004). According to Hatcher et al. (1997) concentration of anti-nutritional substances, mainly oxalates and nitrates in dock plants was increased by the fungus Uromyces rumicis (Schum.) Wint. and by fertilisation. On the other hand, fertilisation is important factor of plant production (Hric et al. 2018; Kovár et al. 2017). In disagreement with statement of Hatcher et al. (1997), that young leaves of dock plant contains the lowest content of oxalates, result of this study was, that concentration of oxalic acid was highest in silage from younger plants (April and September) and decreased with the time (Table 3). Derrick et al. (1993) published, that the content of anti-quality substances in the dock leaves is a natural protection of the plant against the herbivores.

Additionally the significance of difference of mean values between control (C) Rumex OK 2 silage without additives and (M) Rumex OK 2 silage with addition of 1% of dried molasses was calculated. Addition of dried molasses significantly (*P* <0.05) decreased concentration of crude protein in Rumex OK 2 silage in September, October, November and April (Table 1). Rumex OK 2 silage with addition of molasses in September, October, April and May (*P* <0.05) and in November (*P* >0.05) had higher concentration of lactic acid. Except silage of November in all Rumex OK 2 silages was after addition of dried molasses lower concentration of acetic acid (*P* >0.05) (Table 3). In silage used for feeding of ruminants is increase of lactic acid and low concentration of acetic acid desirable. All significant differences between C and M variants in particular months are marked in tables with asterisk (Table 1, 2 and 3). Significant effect (*P* <0.001) of sampling time on nutrient concentration was detected for all determined nutrients and fermentation parameters (Table 1; 2 and 3).

Comparison of the average nutrient content from all analysed Rumex OK 2 silage samples without regard to variant to *Rumex obtusifolius* silage published by Hejduk and Doležal (2008) and to average of alfalfa silage published by Juráček et al. (2016) is shown in Table 4. According to concentration of crude protein and crude fiber can be silage from Rumex OK 2 considered as a nutritional valuable feed. By common value feeds exists correlation of crude protein and fiber concentration with NEL. However this statement is not consistent by all plants, mainly by herbs. According to Scehovic (2002), herb rich on crude protein and with low crude fiber concentration could have low degree of digestibility, which is connected with NEL concentration and additional this plant can be worse consumed by animals. The consumption rate of

Table 4 Average nutritional value of silage from Rumex OK 2 compared to *Rumex obtusifolius* L. silage and to alfalfa silage

	Rumex OK 2 silage*	*Rumex obtusifolius* L. silage**	Alfalfa silage***
DM (%)	14.9	17.3	37.3
CP ($g.kg^{-1}$ DM)	240	197	174
CFa ($g.kg^{-1}$ DM)	17.5	u.	28.2
CFi ($g.kg^{-1}$ DM)	233	214	292
NFE ($g.kg^{-1}$ DM)	399	429	393
Ash ($g.kg^{-1}$ DM)	119	127	117
ADF ($g.kg^{-1}$ DM)	282	u.	364
NDF ($g.kg^{-1}$ DM)	327	u.	418
LA ($g.kg^{-1}$ DM)	53.3	12.92	82.0
AA ($g.kg^{-1}$ DM)	22.3	3.6	29.8
BA ($g.kg^{-1}$ DM)	+	+	8.4
Alcohols. ($g.kg^{-1}$ DM)	22.1	2.5	u.
pH	4.7	4.3	4.7
DP (%)	5.4	8.7	13.5

* average of analyse of all Rumex OK 2 silage samples without regard to variant; ** results published by Hejduk and Doležal (2008); *** results published by Juráček et al. (2016); DM% – concentration of dry matter in%; CP – crude protein; CFa – crude fat; CFi – crude fiber; NFE – nitrogen free extract; ADF – acid detergent fiber; NDF – neutral detergent fiber; LA – lactic acid; AA – acetic acid; BA – butyric acid; DP – degree of proteolysis in% ($N\text{-}NH_3$ out of total N); + silage from *Rumex* L. is characteristic with absence of butyric acid; u. – unlisted

Rumex OK 2 silage by animals need to be determined in further experiments.

4 Conclusions

The nutrient content and quality of fermentation process are important factors that determine the quality of fermented feeds. Analysed silages from hybrid Rumex OK 2 (*Rumex patientia* L. × *Rumex tianschanicus* A.Los) mainly in autumn months had high concentration of crude protein from 289 to 339 $g.kg^{-1}$ DM, which is higher than in alfalfa silages. Concentration of nitrogen free extract and crude fibre in Rumex OK 2 silage was comparable to that of alfalfa silage. Despite the low content of dry matter in wilted Rumex OK 2 plants in silages the butyric acid was not detected. Addition of dried molasses before ensiling increased content of lactic acid and decreased content of acetic acid in silages. Only Rumex OK 2 silages from October and November reached the minimal required content of lactic acid (10 $g.kg^{-1}$ of original matter). Because high concentration of oxalic acid is Rumex OK 2 silage from September not usable for feeding as single feed. According to concentration of nutrients in analysed samples the autumn Rumex OK 2 silages had better nutritional value than silages made in spring months. Problematic appears the low concentration of dry matter by all silage samples and by samples from September also the high concentration of oxalic acid. Increase of dry matter together with decrease of oxalic acid can be realized by addition of grassland herbage which has higher content of dry matter and does not contain oxalic acid. Further research about nutritional quality of silage made from Rumex OK 2 together with grassland herbage ant its intake by animals is needed.

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References

BAZHAY-ZHEZHERUN, S. and RAKHMETOV, D. (2014) Nutritional value of shchavnat. *Food Industry*, no. 16, pp. 15–19 (in Ukrainian).

BÍRO, D. et al. (2014) *Conservation and adjustment of feeds.* 1st ed. Nitra: SUA (in Slovak).

BOCKHOLT, R. and KANNEWURF, B. (2001) *Rumex obtusifolius* in peatbog at Mecklenburg-Vorpommern (widening, forage quality, ensilability, force out by extensiveness). In: *45. Jahrestagung AGF, 23.–25. 8. 2001, Gumpenstein,* pp. 49–51 (in German).

DERRICK, R.W. et al. (1993) Intake, by sheep, and digestibility of chickweed, dandelion, dock, ribwort and spurrey, compared with perennial ryegrass. *The Journal of Agricultural Science,* vol. 120, no. 1, pp. 51–61. doi: https://doi.org/10.1017/S0021859600073585

HATCHER, P.E. et al. (1997) The effect of nitrogen fertilisation and rust fungus infection, singly and combined, on the leaf chemical composition of *Rumex obtusifolius*. *Functional Ecology,* vol. 11, no. 5, pp. 545–553. doi: https://doi.org/10.1046/j.1365-2435.1997.00123.x

HEJDUK, S. and DOLEŽAL, P. (2004) Nutritive value of broad-leaved dock (*Rumex obtusifolius* L.) and its effect on the quality of grass silages. *Czech Journal of Animal Science,* vol. 49, no. 4, pp. 144–450.

HEJDUK, S. and DOLEŽAL, P. (2008) Effect of broad-leaved dock (*Rumex obtusifolius* L.) on grass silage quality. *Acta universitatis agriculturae et silviculturae mendelianea brunensis,* vol. 56, no. 5, pp. 75–80. doi: https://doi.org/10.11118/actaun200856050075

HRIC, P. et al. (2018) The changes of the assimilation pigments content of turf *Festuca* spp. leaves after application of different nutrition forms. *Acta fytotechnica et zootechnica,* vol 21, no. 1, pp. 6–10. doi: https://doi.org/10.15414/afz.2018.21.01.06-10

JURÁČEK, M. et al. (2010) Silage energy value for bioenergy utilization. *Acta fytotechnica et zootechnica,* vol. 13, no. 3, pp. 76–78 (in Slovak).

JURÁČEK, M. et al. (2011) Laboratory protocols. In GÁLIK et al. (2011) *Biotechnology and animal food quality – Part II. Animal food quality.* Nitra: Slovak University of Agriculture in Nitra, pp.122–133.

JURÁČEK, M. et al. (2016) The quality of farm-scale alfalfa silages. *Acta fytotechnica et zootechnica,* vol. 19, no. 2, pp. 54–58. doi: http://dx.doi.org/10.15414/afz.2016.19.02.54-58

KALAČ, P. and MÍKA, V. (1997) *Natural harmful substances in plant feeds.* Praha: ÚZPI (in Czech).

KLIMEŠ, L. (1993) Morphometry of leaves of *Rumex crispus,* R. obtusifolius and its hybrid (*R. × pratensis*). *Preslia,* vol. 65, pp. 219–224.

KOVÁR, P. et al. (2017) The influence of various dose of nitrogen on botanical composition of turfs on the basis of drought-tolerant fescues cultivated under conditions without irrigation. *Journal of Central European Agriculture,* vol. 18, no. 2, pp. 494–514. doi: https://doi.org/10.5513/JCEA01/18.2.1922

MITRÍK, T. (2014) Evaluation system of fermentation parameters of legume and grass silages. In BÍRO, D. et al. (2014) *Conservation and adjustment of feeds,* 1st ed. Nitra: Slovak University of Agriculture in Nitra (in Slovak).

RAKHMETOV, D. (2018) *Non-traditional plant species for bioenergetics.* Nitra: Slovak University of Agriculture in Nitra. doi: https://doi.org/10.15414/2018.fe-9788055218557 (in Russian).

REGULATION of the Ministry of Agriculture of the Slovak republic no. 2145/2004-100 about sampling of feeds, laboratory testing and evaluation of feeds (in Slovak).

SCEHOVIC, J. (2002) Main results of scientific projects researching the feed quality of permanent grasslands and meadows. *Ekológia trávneho porastu VI.* Banská Bystrica: VÚTPHP, pp. 326–335.

ŠKULTÉTY, M. (2014) Quality evaluation of silages. In BÍRO, D. et al. (2014) *Conservation and adjustment of feeds,* 1st ed. Nitra: Slovak University of Agriculture in Nitra (in Slovak).

TŮMOVÁ, E. et al. (2010) Natural anti-nutritional and toxic substances in feeds for animals. In OPLETAL, L. and SKŘIVANOVÁ, E. eds. (2010) *Natural substances and its biological activity.* Praha: Charles University, pp. 417–465.

USŤAK, S. (2007) *Cultivation and use of fodder sorrel in condition of Czech Republic.* Prague: Crop Research Institute (in Czech).

WEISSBACH, F. (1998) Research of different herbs from extensive meadows of influence of fermentation process by the silage preparation. *FAL agricultural research,* Special issue, p. 185 (in German).