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CONTENTS

UUDSE KOMBINEERITUD FIKSAATORI KASUTAMINE PIKKADE TORULUUDE MURDUDE RAVIS

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ABSTRACT. *In orthopaedic surgery for the treatment of fractures of long bones of small animals mostly operative methods are used. Precise reposition of fragments, stable fixation of the fracture and mobilisation of the affected limb as early as possible are important factors for the fast consolidation of the bone fracture. At the same time the operation for installation of fixator has to cause minimal traumatization of surrounding soft tissues and maintain as much as possible bone trophic and blood supply. Also, the fixator has to be compact but give maximal strength. Because of these high demands for fixators in veterinary practice there is continious search for new more efficient devices.*

In our experimental study for the treatment of long bone fractures effect of a new fixator combining extramedullary and intramedullary elements of osteosynthesis was evaluated. This rod-through-plate fixator has relatively simple construction and its installation causes minimal traumatization of soft tissue during the operation. The experiments were performed on 4 male Estonian Blackhead sheep. Experimantal bone fractures were performed as transverse osteotomies in the central third of the diaphysis of the femur. Radiographic images showed that the fractures had well repaired and all elements of the fixator staid in the initial position throughout the duration of the whole experiment (10 weeks). Histological study revealed that all parts of the callus had a typical structure during the experimant.

In conclusion, the application of a new combined fixator expands the treatment possibilities for diaphyseal fractures of long bones of small animals as it has a simple construction, is inexpensive and its use does not require special training for the surgeon.

Keywords: *experimental study, rod-through-plate fixator, long bone, sheep, histology.*

Sissejuhatus

Luukoe olulisim ülesanne on tugifunktsioon, seega on tegemist ühe tugevama koega organismis. Luukude on sidekoeliik, mille rakkudevahelised komponendid on mineraliseerunud. Luumurru ravile lähenemine on teistest kirurgilistest manipulatsioonidest mõnevõrra erinev, sest luukude erineb teistest kudedest nii füüsikaliselt kui morfoloogiliselt ehituselt.

Loomadel esineb väga erinevaid luumurru tüüpe ja on täiesti loomulik, et ortopeedil on vajalik leida kõige optimaalsemad fikseerimismeetodid. Nõudeid murdunud luude fikseerimisele on mitmeid: luumurru fikseerimine peab olema minimaalselt ümbritsevaid kudesid traumeeriv; säilitama maksimaalselt luude troofikat ja verevarustust, kuid samas vigastatud piirkonda kindlalt fikseeriv (Brinker *et al*., 1991; Tralman *et al*., 2008). Siit tulenevalt on loomulik vajadus uute fiksaatorite järele (Andrianov, 1999), mis võimaldavad kiirendada jäseme funktsiooni taastumist ja vähendada tüsistuste teket. Väikeloomade puhul on eriti oluline piisavalt tugev ja mugav fiksatsioon, mis võimaldaks loomal võimalikult kiiresti jäsemele toetuda, kuna loomade puhul on välistatud jäseme täielik immobilisatsioon.

Luu vigastuste tekkel omab luukude märkimisväärset paranemisvõimet ning erinevalt pehmetest kudedest, kus paranemine toimub armkoe moodustamisega, paraneb luu uue luukoe tekkimisega. Luumurru paranemine algab kalluse, mis ümbritseb murru piirkonda, moodustumisega ja paranemise kiirus sõltub sellest, kui hästi moodustuvad murru piirkonnas uued kapillaarid ning taastub medullaarne tsirkulatsioon (Sevitt, 1971).

Materjal ja metoodika

Uudne kombineeritud fiksaator. Uudne kombineeritud fiksaator on leiutatud Tartus [autorid prof V. Andrianov (EMÜ), dots A. Lenzner (TÜ), prof T. Haviko (TÜ)] ning leiutis on patenteeritud 2007. aastal (European Patent N-1682008). Valminud fiksaatoril on ka eelkäija (Andrianov *et al*., 2003), mille konstruktsiooni täiendamisel ongi valminud uudne kombineeritud fiksaator, kus on edukalt ühendatud ekstra- ja intramedullaarse osteosünteesi elemendid. Fiksaator on konstrueeritud mehhaanika ja materjalide vastupidavuse põhiprintsiipide alusel, arvestades jõudusid ja pingeid, mis tekivad luu ja metalli vahelistel tugialadel. Vastava tugevusvaruga kinnituselemendid (nn ankursüsteemid) paigaldatakse kindlale kaugusele murru piirkonnast, kus nad moodustavad luuüdiõõnes kolmnurkse kujuga jäiga tugiprofiili. Selline tehniline lahendus pikendab fiksaatori õlga, mis omakorda vähendab füüsilist koormust murru piirkonnas ja seeläbi väldib luuotste nihkumise ja rotatsiooni riski (Andrianov *et al.,* 2003). Uudne kombineeritud fiksaator on valmistatud roostevabast meditsiinilisest terasest ja koosneb tugiplaadist, kahest kaarja kujuga vardast, kahest kortikaalsest luukruvist ja kahest blokkvindist (Andrianov *et al.,* 2007). Tugiplaat on 2 mm paksune ja kumera läbilõikeprofiiliga, selle pikkus peab olema orienteeruvalt 2/5 või 3/5 traumeeritud luu pikkusest ja laius 2/3 luu läbimõõdust. Plaadil on kaks avaust luukruvide ja kaks kanalit kaarja kujuga varraste jaoks. 5.5 mm diameetriga kanalid asuvad 30 mm kaugusel plaadi otstest ning neisse on freesitud 45-kraadise nurga all avaused, milliste läbimõõt peab olema vastavuses varraste läbimõõduga. Vardad pikkusega 40−50 mm, laiusega 5 mm ja paksusega 4 mm on

ristlõikes ovaalse kujuga ja minimaalse koonilisusega 1.5−2 mm perifeeria suunas. Selline varraste ehitus kergendab nende eemaldamist pärast luumurru paranemist. Kanali laius plaadis ja varraste diameeter on standardsed, mis võimaldab ortopeedil teha valik eri suuruses plaatide ja varraste vahel. Varraste tugiplaadi peal paiknev ots on lapiku kujuga ja sama kumerusega nagu tugiplaat, varda sabaotsas on kaks avaust. Üks nendest on 4.5 mm diameetriga kortikaalkruvi jaoks ning teine 3 mm diameetriga blokkvindi jaoks. Mõlemad avad peavad olema vastavuses tugiplaadi peal puuritud avaustega. Avaused on samasuguste läbimõõtudega ja paiknevad 20 mm kaugusel plaadi keskpaigast. Nende eesmärk on kruvide abil kinnitada vardad ja tugiplaat korraga luu külge ja topeltblokeerida varras tugiplaadi külge. Kasutatakse kortikaalset tüüpi kruve läbimõõduga 4.5 mm, mis peavad ulatuma läbi mõlematest luu korteksitest. Blokkvint (diameeter 3 mm, pikkus 5 mm) ei tohi ulatuda luukorteksini. Ülalnimetatud fiksaatori mõõdud on väljaarvutatud keskmise suurusega (massiga kuni 30 ± 5 kg) lamba jaoks. Vajadusel saab fiksaatori mõõte korrigeerida vastavalt looma suurusele, võttes aluseks looma röntgenogrammi.

Katseloomad. Katseloomadeks oli neli Eesti tumedapealist lammast. Lambad olid ostetud Karula vallas (Valga maakond, Eesti) asuvast lambafarmist ning loomade orienteeruv vanus oli neli kuud. Loomade keskmine kaal oli 35 ± 5 kg. Eksperimendi läbiviimisel arvestati Euroopa Liidu direktiiviga 24. novembrist 1986 (86/609/EEC) ja eksperimendiks on andnud loa Põllumajandusministeeriumi loomkatse läbiviimise loakomisjon (19.04.2006).

Anesteesia. Anesteesiaks süstiti i/v medetomidiinvesinikkloriidi 1 mg/ml (Dorbene®, Laboratorios Syva, Hispaania) 0.5 ml, millele järgnes looma intubeerimine. Komesaroff inhalatsiooni aparaadis (Medical Developements, Melbourne, Austraalia) kasutati anesteesiagaasina 2% isofuraani (*isofuranum*) (Forane®, Abbott Laboratories Ltd, Inglismaa). Operatsioonivälja puhastamiseks kasutati *Chemisept-G* (Chemi-Pharm, Tallinn, Eesti) ning operatsiooniväli kaeti steriilselt.

Operatsioon. Operatsioon algas naha sisselõikega, seejärel toimus *m. ext. digiti IV pedis proprius'e, m. digitalis pedis longus'e, m. gastrochnemius'e* ja *m. flexor hallucis longus*'e vahelt juurdepääsutee loomine luuni. Järgnes fiksaatori esialgne sobitamine ning eksperimentaalse murrupiirkonna valimine. Fiksaator kinnitati ajutiselt toruluule ning seejärel lõigati luu läbi *gigly* saega. Pärast murru tekitamist toimus juba fiksaatori lõplik kinnitamine, mille käigus modifitseeriti lamellide nurka ning valiti sobivad kruvid.

Lihaste õmblemiseks kasutati VICRYL® 1 ja nahaõmblusteks VICRYL® 1, CP-1 ja *Safi l ® green l* (Safil®1, Braun, Saksamaa). Õmmeldud haavale lasti *Alamycin* aerosooli ning antibakteriaalseks raviks süstiti prokaiinpenitsilliini 300 mg/ml (Norcilliin®, Norbrook Laboratories Ltd., Põhja Iirimaa) 5 ml i/m. Valuvaigistav ravi tehti vastavalt vajadusele, kasutades s.c. *Carprofen* 50 mg/ml (Rimadyl®, Vericore Ltd., Dundee, Šotimaa) 2 mg/kg lähtudes katselooma kaalust. Pärast operatsiooni tehti röntgenülesvõtted *Medlink URS Veterinary Portable X-ray SP-VET-4.0* (SEDECAL, Hispaania) röntgenaparaadiga.

Röntgenoloogia. Röntgenoloogilised ülesvõtted loomade jäsemetest tehti kahes projektsioonis (otse- ja külgprojektsioon, 1 m kauguselt) röntgenaparaadiga *Medlink URS Veterinary Portable X-ray SP-VET-4.0* (SEDECAL, Hispaania) enne ja pärast operatsiooni kahenädalase intervalliga. Kassetina kasutati *AGFA CR MD 4.0 General Plate* digitaalset röntgenplaati, millelt kujutised laeti *AGFA ADC Solo Digitizer* digitaatori abil arvutisse ning salvestati.

Histoloogia. Morfoloogilisteks uuringuteks võetud uurimismaterjal dekaltsineeriti seadmes „SAKURA TDE™ 30 Decalcifier System". Seejärel fikseeriti koeproovid 4-protsendilises formaliinilahuses ja sisestati parafiini standardse metoodika järgi. Parafiinblokkidest lõigati 7 µm paksused lõigud ja preparaate värviti hematoksüliin-eosiiniga ning van Giesoni järgi. Preparaate uuriti ja pildistati Olympus BX-50 mikroskoobiga.

Eutanaasia. Eutanaasia esimene faas saavutati i/v 20 mg/ml ksülasiinvesinikkloriidi (Xsylapan®, Vetoquinol AG, Bern, Schweiz) manustamisega, arvestusega 0.08−0.75 ml/100 kg. Teises faasis manustati i/v T61® (200 mg embutramiidi + 50 mg mebesooniumjodiidi + 5 mg tetrakaiinvesinikkloriidi; Intervet S.A., EU) doosis 5 ml/50 kg.

Tulemused

Kliinilise seisundi hindamine ja röntgenoloogiline uuring

Pikkade toruluude luumurrud olid eksperimentaalselt modelleeritud lammaste parema sääreluu diafüüsi keskmises kolmandikus. Lambad toetusid fikseeritud jäsemele alates esimesest postoperatiivsest päevast, mis näitab, et fiksaator oli murru kindlalt ära fikseerinud ning jäseme liikuvus oli hea. Loomade üldseisund, söögiisu ja üldine aktiivsus olid head. Postoperatiivselt tehtud röntgenogrammidel on kõikidel loomadel selgelt nähtav toruluu murrujoon (joonis 1).

Kaks nädalat pärast operatsiooni ei täheldatud kliinilisel hindamisel ühelgi loomal jäseme funktsioonihäireid. Röntgenoloogilisel uuringul oli fragmentidevaheline pilu hästi jälgitav (joonis 1). Samuti oli kõikidel röntgenogrammidel eristatav vähene moodustuva periostaalse kalluse hulk. Kõik fiksaatori elemendid olid oma kohtadel.

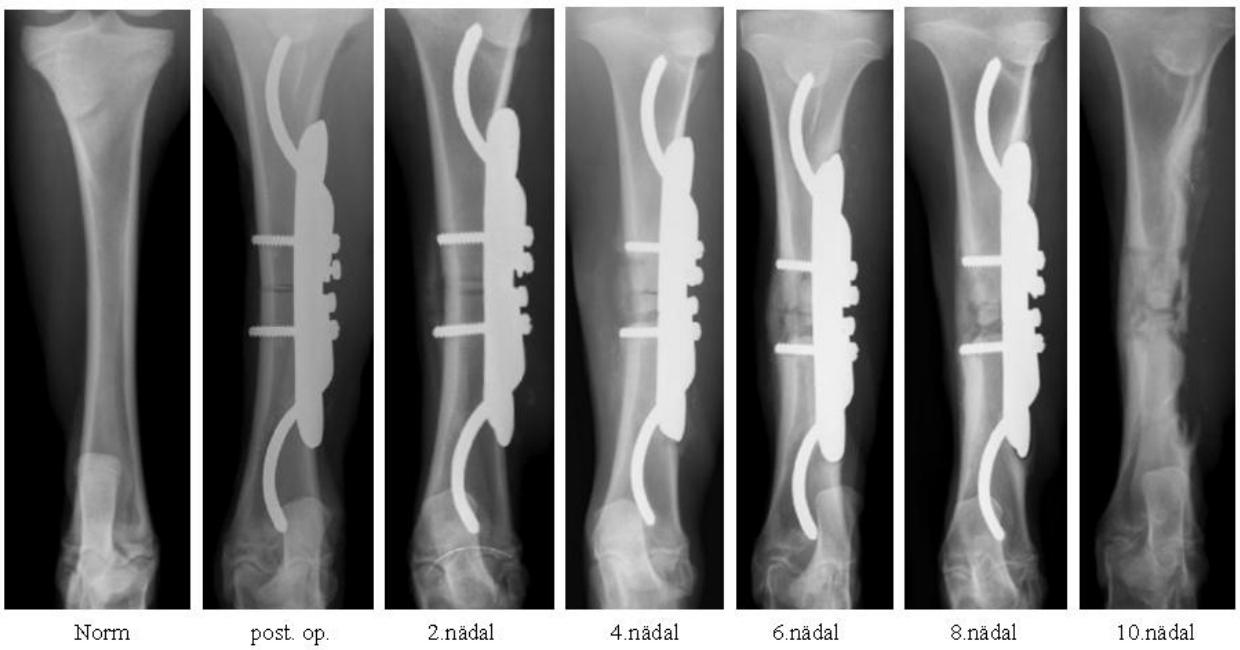
Neli nädalat pärast operatsiooni olid loomade üldseisund ja söögiisu head. Röntgenoloogilisel uuringul oli jälgitav fragmentidevaheline pilu, kuid selle mõõtmed olid seoses moodustuva endostaalse kallusega vähenenud (joonis 1). Samuti oli kõikide loomade röntgenogrammidel nähtav murrutsoonis moodustuv periostaalne kallus. Periostaalne kallus ulatus proksimaalselt ülemise kinnituskruvini ja distaalselt kuni tugiplaadi alumise servani.

Kuus nädalat pärast operatsiooni tehtud röntgenogrammidel (joonis 1) oli toruluu murrujoon ainult aimatav, samas oli nähtav rohkearvuline periostaalne kallus. Periostaalne kallus ümber murrutsooni ja tugiplaadi proksimaalse osa oli oluliselt suurem kui eksperimendi

neljandal nädalal ja ulatus nii distaalselt kui ka proksimaalselt tugiplaadi otsteni. Röntgenogrammidel oli näha, et kõik fiksaatori elemendid olid oma kohtadel.

Katse kaheksandal nädalal ei olnud murrujoon röntgenogrammidel enam jälgitav (joonis 1). Periostaalse kalluse hulk oli võrreldes varasemate uuringutega vähenenud ja murrupiirkonnas toimus intensiivne luukoe moodustumine.

Eksperimendi kümnendal nädalal oli toruluu murrupiirkond täielikult paranenud (joonis 1). Lammaste hea paranemine näitab seda, et antud fiksaator on toruluu murru hästi stabiliseerinud ja ei tekita ümbritsevatele kudedele suurt traumat. Uudse fiksaatori röntgenoloogilised uuringud näitasid, et kõik fiksaatori elemendid olid katse jooksul oma kohtadel, millest järeldub, et fiksaator on väga stabiilne ja sobib koduloomade pikkade toruluude murdude raviks.



Joonis 1. Röntgenoloogia
Figure 1. *Radiographic images*

Histoloogiline uuring

Morfoloogilisel uuringul tuvastati, et toruluu fragmentides olid osteotsüüdid tavapärase ehitusega. Luukanalid olid normist laiemad, selline kanalite avardumine fragmentide otste lähedal on loomulikuks reaktsiooniks traumale. Periostaalne kallus oli loomadel reeglina väga mahukas ja sisaldas palju noort, rakurikast sidekude. Sidekoelises periostaalses kalluses esines väiksemaid luupõrkasid, nende ümber paiknes korrapärane osteoblastide ahel. Luulise kalluse osas paiknes põrkade vahel kohev sidekude, osteoklaste ei olnud. Luukoe põrkadesse olid moodustunud sidekude ja veresooni sisaldavad kanalid ning põrkades paiknesid erinevates arenguastmetes osteotsüüdid. Vahemises ja endostaalses kalluses oli hulgaliselt sidekude, luupõrgad olid selgelt väljendunud, kuid üksikud osteoblastid paiknesid nende ümber ebakorrapäraselt.

Arutelu

Käesolevas eksperimentaalses töös uurisime luukoe regeneratsiooni intensiivsust pikkade toruluude murdude korral, kasutades fikseerimiseks uudset kombineeritud fiksaatorit. Luumurdude paranemist mõjutab murdunud otste stabiilne fiksatsioon, mida rõhutavad ka teised uurijad (Taljanovic *et al*., 2003; Field, 1997). Uudse kombineeritud fiksaatori paigaldamisel ei ole vaja tekitada ulatuslikku kirurgilist juurdepääsu luule, mistõttu on operatsioonile kuluv aeg lühike ja kudede trauma tagasihoidlik. Kombineeritud fiksaatori rakendamisel on põhieesmärgiks maksimaalselt vähendada pehmete kudede traumeerimist operatsioonil ja kindlustada loomale maksimaalselt vastupidav luufragmentide fikseerimine. Luumurdude stabiilne fiksatsioon on aga oluline, tagamaks efektiivset luukoe reparatiivset regeneratsiooni (Taljanovic *et al*., 2003). Kombineeritud fiksaatori korral on luule paigaldatav tugiplaat lühike, samal ajal intramedullaarsed vardad pikendasid fiksaatori õlga proksimaalselt ja distaalselt praktiliselt metafüüsideni. Tänu väiksemale traumale kombineeritud fiksaatori paigaldamisel ja stabiilsele fiksatsioonile suudavad loomad juba esimesel operatsioonijärgsel päeval kanda vigastatud jäsemel keharaskust, mis omakorda mõjub paranemisprotsessile soodsalt, sest mida kiiremini toimub vigastatud jäseme mobiliseerimine, seda kiirem on luumurru regeneratsioon. Kombineeritud fiksaatori stabiilsust kinnitavad ka röntgenoloogilised uuringud, millistel on võimalik jälgida fiksaatori elementide paigutust katse jooksul.

Röntgenoloogilisel uuringul oli nähtav intensiivne kalluse moodustumine alates neljandast nädalast. Sellise

kalluse mahu suurenemise põhjustab ilmselt kombineeritud fiksaatori konstruktsiooniprintsiip, täpsemalt fiksaatori kinnitumise meetod luukorteksile. Nimelt tekib kruvide kinnitamisel tugiplaadi ja kaarjate lamellide vahel nn näpitsate efekt, mis surub luukorteksi lamellide ja plaadi vahele. See tagab fiksatsiooni suure mehaanilise kindluse ja stabiilsuse. Seejuures annab kombineeritud fiksaator dünaamilise fiksatsiooni tänu kumeratele lamellidele luuüdikanalis, kus lamellid toetuvad kolmes punktis endostile, tagades ulatusliku ja stabiilse kontakti luuga. Samas ei tekita need liiga jäika fiksatsiooni, mis võiks põhjustada osteoporoosi ja pärast implantaadi eemaldamist ka uusi luumurde (Field, 1997). Samas ei ole fragmentide fiksatsioon kombineeritud fiksaatori korral täiesti regiidne, vaid tänu varraste amortisatsioonile tekib murrupiirkonnas jäsemete kasutamisel mikroliikumine, mis stimuleerib kalluse moodustamist (Goodship, Kenwright 1985). Kui luuparanemise algperioodil mikroliikumine soodustab kalluse teket, siis hilisperioodis kaltsifitseeruvas kalluses peab liikumine olema minimaalne, kuid vajalik jäikus saavutatakse loomuliku kalluse luustumise pärast (Andrianov *et al*., 2007).

Järeldused

1. Uudse kombineeritud fiksaatori kasutamine võimaldab tänu luu osteosünteesile suurendada fiksaatori õlga, mille tulemusel väheneb koormus luumurru piirkonnas.
2. Uus metoodika kindlustab loomale maksimaalselt vastupidava luufragmentide fikseerimise.

Tänuavaldused

Käesolev eksperimentaalne töö on tehtud ETF grant 7301 ja sihtfinantseeritava teema SF0180012s11 toetusel. Täname üliõpilasi R.T. Kiburit, P. Männikut, D. Uksovit ja K. Nõupuud abi eest eksperimendi läbiviimisel.

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Novel combined fixator use in long-bone fracture treatment

V. Andrianov, A. Arend, M. Aunapuu

Summary

In orthopaedic surgery of small animals mostly operational methods are used to fix long-bone fractures. For proper and rapid healing it is crucial to repose the bone fragments accurately, to fixate the fracture to make it stable, and to mobilize the limb as soon as possible. However, the fixator should produce minimal damage to surrounding soft tissue and it must maintain the blood flow and bone trophic as much as possible. The fixator must be compact and also its construction must be very strong. There is a continuous search to develop newer and more effective fixators. In our research we investigated novel fixator combination to treat long-bone fractures. Our novel fixator combines the intra-and extramedullar fixation elements.

Its design is simple and its placing does not cause significant injury to the surrounding soft tissue. We used four Estonian Blackhead sheep as experimental animals. Experimental fractures were simulated in the sheep right middle third of tibial shaft. During the experiment we found that the fractures were well improved (X-ray examination) and all the elements of fixators were in their right places during the test period (10 week). Histological studies showed that the callus of all parts had a typical structure the entire experimental period. Summary, we can say that using a novel combined fixator extends treatment options of a long-bone fractures treatment in small animal medicine, because the fixator is simple and relatively inexpensive. It is also not difficult to place the fixator and does not require special orthopedic training.

FUNGICIDE AS GROWTH REGULATOR APPLICATION EFFECT ON WINTER OILSEED RAPE (*BRASSCIA NAPUS* L.) AUTUMN GROWTH

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ABSTRACT. *Plant growth regulation during autumn is one of the instruments for oilseed rape growers to improve plant readiness for winter. Influence on plant biometrical parameters by fungicide as growth regulator application allows affect one of the significant risk factors for successful growing of winter oilseed rape – winterhardiness. The aim of our research, started in autumn 2007 and continued up to autumn 2010 in Research and Study farm 'Vecauce' of Latvia University of Agriculture, was to investigate the influence of fungicide (Juventus 90 s.c. – metconazole, 90 g L^{-1}; dose: 0.5 L ha^{-1}) as growth regulator application depending on sowing date (five dates) and sowing rate (four rates) in autumn on two type winter rape cultivars' (line 'Californium' and hybrid 'Excalibur') autumn plant development. Results showed that fungicide application affected oilseed rape plant biometric parameters during autumn, but effect depended on conditions in research year, as well as used cultivar. Sowing time also had influence on increase or decrease of some plant biometrical parameters. Parameters affected significantly ($P < 0.05$) on average by fungicide application were: total plant mass significantly increased in year 2009 for 'Californium', decreased in years 2007 and 2010 for 'Excalibur'; height of growth point decreased for 'Californium' in year 2007 and 2010, but increased in 2008, but that of 'Excalibur' decreased in years 2007, 2009 and 2010; root neck diameter decreased only in years 2007 and 2010 for 'Excalibur'; number of leaves increased in all trial years except year 2010 for both varieties; root length increased in years 2008 and 2009 for 'Excalibur'. Root mass changes in result of fungicide application were insignificant in all trial years. Fungicide application effect depended also on sowing date, but in majority cases were not related to sowing rate.*

Keywords: *winter oilseed rape, sowing date and rate, growth regulator, plant biometric indices.*

Introduction

Wintering of oilseed rape depends on the plant development stage at the end of vegetation period, but plant development could be affected by the growing manner including used cultivar, application of growth regulators and agro-climatic factors. Before the winter period, rapeseed plant should create reasonable plant mass and has to develop definite plant parameters for root-neck diameter, height of growth point above the soil level, and number of leaves. Overgrowing risk exists because of very early sowings and warm autumns. Growth regulation is one of the possibilities to control plant growth during autumn.

Cell division and cell elongation of shoots are usually controlled by the application of growth regulators resulting altered yield structure and reduced plant height, as well as reduced leaf area and increased root/shoot ratio (Bruns *et al.*, 1990; Fisahn, Hofner, 1995). Some researchers from Lithuania in other conditions reported (Gaveliene *et al*., 2002; Miliuviene *et al*., 2004) that application of growth regulator increases number of leaves per plant and root-neck diameter, and decreases height of growth-point of winter rape, thus favouring winterhardiness of the crop. Moreover, growth regulators are used to improve plant survival during winter, to limit development of oilseed rape plants especially with high N-regimes and early sowing date, as well as to increase cold tolerance due to reduction in stem length. Growth regulator application is often combined with use of fungicides application. Moreover, side effects of fungicides are used to regulate plant growth. During shooting application of growth regulators decreases plant height and improves plant stability to prevent lodging and influences yield structure where effectiveness depends on cultivar (Rao *et al*., 1991; Gans *et al*., 2000).

The aim of our research, started in autumn 2007 and continued up to autumn 2010 in Research and Study farm 'Vecauce' of Latvia University of Agriculture, was to investigate the influence of fungicide (Juventus 90 s.c. – metconazole, 90 g L^{-1}; dose: 0.5 L ha^{-1}) as growth regulator application depending on sowing date (five dates) and sowing rate (four rates) in autumn on two type winter rape varieties' (line 'Californium' and hybrid 'Excalibur') autumn plant development.

Materials and methods

The experiments were carried out on winter oilseed rape (*Brassica napus* ssp. oleifera) plants. Four year (starting from 2007/2008 to 2010/2011) investigations were carried out in the Research and Study farm 'Vecauce' (latitude: N 56º 28´, longitude: E 22º 53´) of Latvia University of Agriculture. Three-factor field trial using two type winter rape varieties (line 'Californium' and hybrid 'Excalibur', both bred by Monsanto Crop Science) was carried out; the paper is focused on fungicide as growth regulator application effect on plant autumn growth results for all four seasons (2007, 2008, 2009, 2010). The following factors were investigated:

Factor A − sowing date: starting on 1st August with ten day interval to 10th September (five sowing dates in total). Sowing was done close (with one or two days deviation) to established dates in some occasion because of inappropriate (mainly too moist) soil conditions for sowing. Data of three first sowing dates are represented

in this paper because it was without agronomical rationale to apply growth regulator for small plants sown on 1st and 10th September.

Factor B – fungicide application (B1 – control, without fungicide; B2 – fungicide applied as growth regulator). Fungicide application scheme: 0.5 L ha^{-1} dose of fungicide Juventus 90 s.c. (metconazole, 90 g L^{-1}) was applied at the 4-6 leaves stage:

- on rape sown on 1st August – 30th August 2007, 8th September 2008 and 2009, 9th September 2010;
- on rape sown on10th August – 12th September 2007, 13th September 2008, 22th September 2009, 24th September 2010;
- on rape sown on 20th August – 27th September 2007, 8th October 2008, 30th September 2009, 7th October 2010.

Factor C – sowing rate (C1-120, C2-100, C3-80, C4-60 germinating seeds per m^2 – 'Californium'; C1-80, C2-60, C3-40, C4-20 germinate able seeds per m^2 – 'Excalibur').

Soil at the trials' site was strongly altered by cultivation (ANt) in 2007 and 2010 and sod-gleyic (GLg) (Taxonomy…, 2009) in 2008 and 2009 loam with pH KCl = 6.7 to 7.4; content of available for plants K was 103 to 194 mg kg^{-1} and P – 100 to 136 mg kg^{-1}; organic matter content – 25 to 38 g kg^{-1}. Pre-crop was cereal mixture for silage in all years.

Traditional soil tillage with mould-board ploughing was used, rototilling was used before sowing. The crop was fertilized with a complex mineral fertilizer at the rate of N 12 to 28 kg ha^{-1}, P 18 to 30 kg ha^{-1}, and K 79 to 103 kg ha^{-1} before sowing depending on little different soil conditions in the trial year. Sowing was done according to the previously described design. Weeds were controlled using herbicide Butisan Star s.c. (metasachlor, 333 g L^{-1} + kvinmerac, 83 g L^{-1}), 2.5 L ha^{-1} in 2007–2009 and 3.0 L ha^{-1} in autumn 2010. Herbicide was applied when the oilseed rape was fully germinated in plots of first three sowing dates in 2007 and 2008, and directly after sowing in 2009 and 2010.

At the end of autumn vegetation 10-plant samples were taken randomly for each plot for biometrical analysis.

Number of leaves per plant (No), leave, plant, root weight (g), root length (cm), diameter of root neck (mm), and height of growth-point (mm) were measured in laboratory. ANOVA two-factor with replications (within each sowing date), and three-factor (factors A, B and C – mentioned above) analysis of variance were used for processing the experimental data of each separate variety. Effect of variety on plant growth characterising parameters is not mathematically evaluated.

Meteorological data were collected from automatically working meteorological station approximately 1 km from trial site. Meteorological conditions were considerably different in each trial year and that caused differences between plant biometrical indices through all trial years. October 2009 and 2010 characterizes with very low mean air temperatures. August 2009 and September 2008 was relatively dry, but August 2010 was extremely wet (Fig. 1). The heat accumulated by oilseed rape plants over autumns in trial years was also sufficiently different depending on year; growing degree days (GDD) (Bonhomme, 2000) for characterization of warmth conditions were calculated using formula (1):

$$GDD = \frac{(T_{\max} + T_{\min})}{2} - T_{base} \quad (1)$$

where T_{max}- average daily maximum temperature; T_{min} – average daily minimum temperature; T_{base} –base temperature (5^0C).

Growing Degree Days (GDD), from first sowing date − 1st August up to the end of vegetative growth was as follows: 567 GDD in 2007, 440 GDD in 2008, 428 GDD in 2009 and 478 GDD in year 2010. First decade of August was critical for amount of precipitation in all four trial years (see Figure 1); in year 2008 and 2009 lack of precipitation was observed even in ten day period before 1st sowing date that explains slow seed germination and later plant development (Figure1).

Vegetative period (mean temperature below 5^0C for at least 3 days) ended on 4th November in 2007 and 2008 and did renew for eight to five days period up to 4th December; at 1st November in 2009; at 7th November in 2010.

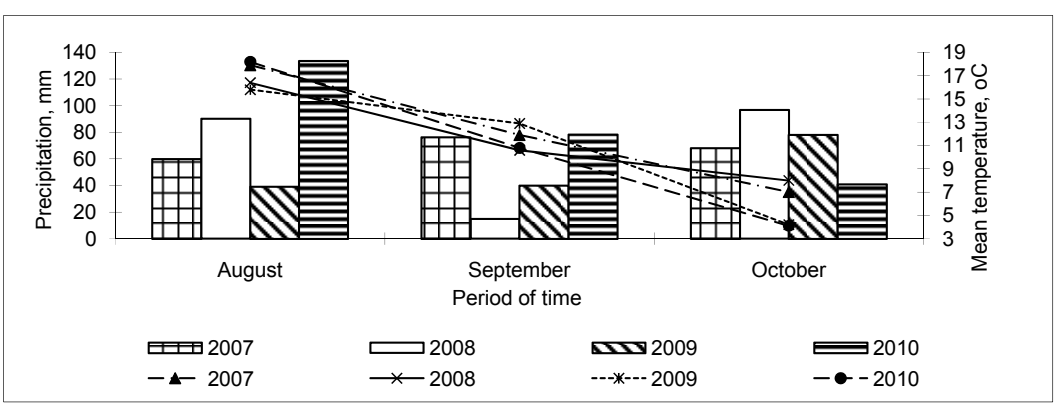

Figure 1. Mean air temperature and precipitation in RSF 'Vecauce' in autumn 2007 to 2010.

Results and discussion

Fungicide application effect depending on sowing date

Fungicide Juventus 90 (as growth regulator) was applied only for plots sown on first three sowing dates when rape plants achieved 4–6 true leaf stage. Rape sown on fourth (1 September) and fifth (10 September) sowing dates did not achieve necessary stage for fungicide application at the first ten-day period of October in all trial years. From the four-year trial results (2007− 2010) we can conclude that winter oilseed rape biometrical parameters were influenced by fungicide application in autumn period and fungicide application effect depended also on sowing date.

First sowing date – 1st August is declared as early sowing date for winter oilseed rape in Latvia conditions because of overgrowth possibility that causes risk for overwintering (Gaveliene *et al*., 1998). Plant growth regulation is expected to give more effect on plant biometrical parameters in such early sowings. At the same time, plant mass depended on used cultivar and conditions of trial year: 'Excalibur' (hybrid F1) formed bigger plants if compared to 'Californium' (line) (Table 1). Average (per all sowing dates and treatments) plant mass was the 18.3−32.9 g for 'Californium' depending on the year, and 39.9−67.6 g for 'Excalibur'; the smallest plants were formed in autumn 2010, when conditions were cooler if compared to long-term average data (long-term date is obtained from regional Hydro Meteorological Station 'Dobele'). Plant mass was affected by fungicide treatment in all trial years (Table 1) and we mainly obtained the expected result: plant mass decreased, but on average per all sowing dates significant ($P < 0.05$) this decrease was only for cultivar 'Excalibur' in autumns 2007 and 2010. Still fungicide application timing for oilseed rape plants is preventive because of different autumn meteorological conditions (including GDD amount). We find also one exception from the tendency to decrease plant mass – on average per all sowing dates plant mass in result of fungicide treatment increased for 'Californium' in 2009. Although leaves caused the bigger proportion of total plant mass in all trial years, root mass of 'Californium' influenced by fungicide application increased significantly ($P < 0.05$) in 2009 and as a result – total plant mass increased. If we look on separate sowing dates, then significant ($P < 0.05$) plant mass increase was observed also for 'Californium' sown on the 1st sowing date of 2009 and 2010 (Table 1). Plants of 'Californium' (see Table 1) were small in both years (2009 and 2010; biggest plants did not exceed 44. 9 g in 2009) and did not look overgrown.

Other important biometrical indices for plant autumn growth are height of growth point (should be less than 30 mm) and root neck diameter (should reach 8 to 10 mm). Height of growth point was highest in plots sown on 1st August in all trial years (Table 2).

Table 1. Fungicide effect on average plant mass (g) depending on sowing date in years 2007−2010

Variety	Sowing date	2007		2008		2009		2010	
		B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	1st August	39.2	31.9	40.8	39.9	30.9	44.9*	20.4	23.9*
	10th August	40.2	37.0	42.3	37.7	24.1	26.9	29.3	23.6
	20th August	21.0	18.6	18.8	17.9	23.6	20.7	7.6	4.7
Excalibur	1st August	90.4	67.0*	55.8	58.9	56.3	61.8	61.8	46.4
	10th August	82.0	72.9	55.8	47.9	54.4	58.4	55.8	49.6*
	20th August	56.1	37.0*	25.5	28.6	53.4	46.2	14.9	10.9

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same sowing date in specific year.

Table 2. Fungicide effect on height (mm) of growth point above soil depending on sowing date in years 2007−2010

Variety	Sowing date	2007		2008		2009		2010	
		B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	1st August	43.0	31.2*	13.9	13.1	19.0	16.5*	26.4	25.3
	10th August	21.6	19.1	12.4	13.3	15.6	13.1*	12.3	10.2*
	20th August	12.2	9.5	9.2	11.1*	11.8	14.6	6.0	5.3
Excalibur	1st August	66.4	38.9*	20.1	20.2	32.7	23.7*	45.8	35.1*
	10th August	35.5	24.4*	14.3	13.3	26.7	27.1	20.5	17.2*
	20th August	19.5	15.0*	11.2	11.2	20.6	15.9*	9.4	8.2

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same sowing date in specific year.

Table 3. Average per all sowing dates and rates root neck diameter (mm) of varieties 'Californium' and 'Excalibur' depending on fungicide as growth regulator application in years 2007−2010

Variety	2007		2008		2009		2010	
	B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
Californium	6.95	6.92	6.96	7.32	6.26	6.00	5.38	5.14
Excalibur	9.85	8.90*	8.44	8.44	8.75	8.71	7.35	6.99*

B1†− control; B2‡ − fungicide treated plants; *$P < 0.05$, when B1 and B2 are compared within the same specific year.

Cultivar 'Excalibur' formed higher average height of growth point if compared to 'Californium' and accordingly risky value for height of growth point (above 30 mm) more frequently was observed for 'Excalibur' (plants sown on 1st August 2007, 2009, 2010, and on 10th August 2007). For 'Californium' growth point above 30 mm was noted only for plants sown on 1st August 2007. Application of fungicide decreased height of growth point in all mentioned cases substantially ($P < 0.05$). Totallly, decrease of growth point was observed in 18 cases from 24 per trial period (Table 2); again some exceptions with increase of growth point in result of fungicide application were observed (Table 2). Mainly our results are similar to those obtained by V. Gaveliene *et al.* (2002) and L. Miliuviene *et al.* (2004) who reported that application of growth regulators decreases height of growth point. We obtained similar results also in our previous investigations with only one sowing time (20th August), but using more varieties and different fungicides (Bankina *et al.*, 2010). Relatively high proportion (η%) of fungicide application influence on height of growth point was noted from three investigated factors (sowing time, sowing rate, fungicide application) (Table 3).

Root neck diameter below 10 mm is considered as acceptable for oilseed rape growing in conditions with milder winters, example – Central Europe (Becka *et al*., 2004). Other researchers found that application of growth regulators can increase root neck diameter (Miliuviene *et al.,* 2004), but our results did not show such a preferable result. Effect of growth regulation on average root neck diameter of 'Californium' was unsubstantial in all trial years; effect of growth regulation on root neck diameter of 'Excalibur' F1 on average was also unsubstantial in 2008 and 2009, but mathematically substantial decrease of average rot neck diameter (in opposite to desirable effect) was observed in 2007 and 2010 (Table 3). Decrease of 'Excalibur's' root neck diameter in 2010 (by 0.36 mm) from agronomical point of view is immaterial. More and significant effect on root neck diameter was shown by sowing time and used cultivar (hybrid formed bigger root neck diameter if compared with line, Table 3). This is in accordance with our previous research (Bankina *et al*., 2010). Differences from results of other researchers can be caused by used growth regulator, varieties and conditions of trial.

Number of leaves per plant increased in result of fungicide application in all trial years on all three sowing dates and for both cultivars. This is in accordance with results of other researchers and our previous investigations (Miliuviene *et al*., 2004; Gaveliene *et al*., 2005; Balodis *et al*., 2007a, 2007b, Bankina *et al*., 2010) and such result is in accordance with expected. Substantial ($P < 0.05$) increase was observed for both cultivars in 2007, 2008, 2009, but only tendency of leaves' increase as result of fungicide application was noted in 2010.

For good overwintering well-developed root is necessary for oilseed rape plants. Other researchers (Gaveliene *et al*., 2002; Miliuviene *et al*., 2004) reported that application of growth regulators can increase fresh root mass. Our previous results also showed such tendency (Balodis *et al*., 2007a; Bankina *et al*., 2010). Opposite results were obtained from pot experiments, when significant influence on root biomass was not obtained by any of the plant growth regulators (Bruns *et al*, 1990). Cases with non-significant effect of fungicide Juventus 90 on fresh root mass prevailed per four trial years for both cultivars and three sowing dates in our experiments, but tendency of fresh root mass increase was noted in 15 cases from 24. Root length changes of 'Californium' in result of fungicide application also was non-significant, but tendency of root length increase was observed in 8 cases from 12. Substantial ($P < 0.05$) average root length increase of 'Excalibur' was noted in 2008 and 2009, but changes in 2007 and 2010 were also mainly non-significant.

Fungicide application effect depending on sowing rate

As different sowing rates were used for both varieties, we have analysed also fungicide effect depending on sowing rate. Sowing rate is the first cause of different plant densities (Balodis, Gaile, 2010), but depending on plant density different values of rape plant biometric indices can be formed. D. Becka et al. (2004) reported that more leaves, less height of growth point and greater diameter of root neck are the result of lower crop density.

Fungicide application effect on fresh plant mass was similar for all sowing rates – when tendency was observed to decrease plant mass – it was similar at all sowing rates: 2007, 2008, and 2010. Plant mass increased at all sowing rates of 'Californium' in 2009, but that of 'Excalibur' in 2009 decreased at lower rates (20 and 40 germinate able seeds per 1 m^2), but increased at higher rates (60 and 80 germinate able seeds per 1 m^2). Effect of fungicide application on fresh plant mass depending on sowing rate in majority cases was insignificant.

Average height of growth point with some exceptions decreased at each sowing rate for both varieties. Significant ($P < 0.05$) decrease was observed for 'Californium' in year 2007 at each sowing rate and in 2009 at sowing rates 100, 80 and 60 germinate able seeds per 1 m^2 (Table 4). The tendency to decrease height of growth point was observed also for 'Excalibur' at all sowing rates in all trial years, but decrease was significant ($P < 0.05$) in years 2007 and 2010, but in 2009 – at sowing rates 80 and 20 germinate able seeds per 1 m^2.

Our results showed that fungicide application had no significant ($P > 0.05$) effect on average root neck diameter for 'Californium' in all trial years at all sowing rates. Though interesting was observation that in years 2007 and 2008 tendency of root neck diameter increase was observed at seven from eight cases, but the opposite situation was observed in years 2009 and 2010 when root neck diameter slightly and insignificantly decreased. Tendency to decrease root neck diameter in result of fungicide application was observed for 'Excalibur' in 13 cases from 16.

The tendency of leaves' number increase in result of fungicide application was observed in majority cases in

trial years, when different sowing rates were used, but significant increase was observed at 14 cases from 32. Relationship with specifically used sowing rate was not noted: significant increase of rape leaves per plant in result of fungicide as growth regulator application was observed at least for one time at each sowing rate. Only a tendency was observed that at lower sowing rates more leaves increased at the result of growth regulation if compared to higher sowing rates for variety 'Californium' in all trial years (example for 'Californium' in 2009: B1C1 (without fungicide, sowing rate 120 germinating seeds per 1 m^2) – 5.4 leaves; B2C1 (fungicide was applied, sowing rate 120 germinating seeds per 1 m^2) – 6.4 leaves; B1C4 (without fungicide, sowing rate 60 germinating seeds per 1 m^2) – 6.7 leaves; B2C4 (fungicide was applied, sowing rate 60 germinating seeds per 1 m^2) – 8.1 leaves). Such tendency was not noted for 'Excalibur'.

Table 4. Fungicide application effect on average per all sowing dates height of growth point (mm) depending on sowing rate of variety 'Californium' in autumn 2007−2010

	2007		2008		2009		2010	
Sowing rate (C)	B1†	B2‡	B1†	B2‡	B1†	B2‡	B1†	B2‡
C1 120	25.4	21.0*	11.5	12.1	14.4	15.0	14.4	13.5
C2 100	26.6	20.6*	12.8	12.2	15.7	12.2*	15.2	13.4
C3 80	25.0	20.1*	11.3	12.3	16.0	17.9*	14.9	12.8
C4 60	25.4	18.1*	11.7	13.4*	15.7	13.7*	15.0	14.8
$LSD_{0.05BC}$	3.63		1.28		1.74		2.36	

B1†− control; B2‡ − fungicide treated plants *$P < 0.05$, when B1 and B2 are compared within the same sowing rate in specific year.

Effect of fungicide application on root length at different sowing rates in majority cases was insignificant, but a tendency was observed that root length increased (in 21 cases from 32). Fungicide as growth regulator also had insignificant effect on root mass at different sowing rates. Only two exceptions were observed: significantly root mass increased for 'Californium' in the result of fungicide application when sown at the rates of 120 and 80 germinate able seeds per 1 m^2 in 2009.

Judging from obtained results, one can say that sowing rate as initial reason of plant density did not cause particular effect of fungicide application. Increase or decrease of values of plant biometric indices in the result of fungicide application was caused rather by used cultivar, sowing date, meteorological conditions at particular sowing date and in specific year or other factors. May be more relationship between exact plant density and direction (increase or decrease of plant parameter) of fungicide application effect can be detected, but it can be clarified in next investigations.

Conclusions

1. Fungicide as growth regulator (Juventus 90 s.c. – metconazole, 90 g L^{-1}) application affected rape plant biometric parameters during autumn, but influence was not equipollent and not always conform to results obtained in other investigations.
2. More marked fungicide effect on values of plant biometric parameters was observed when they were analysed at three different sowing dates. Tendency was observed that plant mass and height of growth point decreased in fungicide treated plots, but result depended from conditions in trial year and variety. Number of leaves in result of fungicide application increased significantly ($P < 0.05$) in 2007, 2008 and 2009, but only tendency of leaves' increase was observed in 2010. Results of root length and mass, and root neck diameter changes at three different sowing times depending on fungicide as growth regulation application were controversial.
3. Sowing rate as initial reason of plant density did not cause particular effect of fungicide application influence on plant biometric parameters. Fungicide application effect on rape plants' sown at different sowing rates in majority cases was insignificant ($P > 0.05$).

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INFLUENCE OF NITROGEN FERTILIZATION RATES ON *FESTULOLIUM* AND *LOLIUM X BOUCHEANUM* FORAGE AND SEED YIELD AND QUALITY

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ABSTRACT. *The objective of this research was to study the influence of fertilization rate on dry matter yield structure and sward persistency of Festulolium and Lolium x boucheanum varieties under agro-ecological conditions of Latvia. Field trials were established on the sod-podzolic soil and fertilized with N 120 $_{(60+60)}$, N180 $_{(60+60+60)}$, P 78 and K 90 kg ha^{-1}. Forages were harvested three times during the growing season. Festulolium hybrids are among the most persistent and productive genotypes of the grasses used in many Europe countries, especially in adverse environments. The productivity of grasslands mostly depends on cultivated grass cultivars. The results of the experiments in the years 2003−2007 highlight the significant DM yield dependence on used variety and the N fertilizer dose increase. On the average the N fertilizer dose increase from 120 to 180 kg ha^{-1} contributed to DM yield increase by 1.6 t ha^{-1} or 17 percent. In the first year of yielding the positive effect of increased nitrogen rates was better expressed on loloid Festulolium cultivars DM yield, and was less expressed on festucoid Festulolium cultivars. On second and third year of the yielding difference in increased nitrogen rates positive effect between loloid and festucoid Festulolium cultivars were not observed. Increasing amount of nitrogen fertiliser provided significant increase in seed yields for all trial varieties. The influence of nitrogen fertiliser rates on seed yield formative elements was different in trial years.*

Keywords: *Festulolium, Lolium x boucheanum*, *nitrogen fertilization, grassland productivity.*

Introduction

Nitrogen fertilization is a management factor that greatly influences the perennial grass yield. *Lolium* species requires high nitrogen fertilisation when it is grown for high dry matter yield. The requirement to reduce N losses to the environment has changed the fertilization practice. Under more sustainable agricultural practices, the N fertilizer rate has to be reduced to an ecological optimum in the order of 150−200 kg ha^{-1} per year (Lantinga, 2002).

A higher herbage production rate from newly established grass swards is one of the expectations in temporary grasslands. Under cutting conditions the yield is often reported to decrease over successive years, with the highest yield in the first harvest year (Lemeziene, 2004). The fertilization level has an effect on the persistence and affects the yield progress during the grass development phase. Tolerance to adverse weather conditions and winter resistance may enhance markedly when plants are provided with abundant N (Aavola, 2005). On the other hand lower N rates can have positive effect on persistance (Soegaard *et al.,* 2007). Introduction of biotic and abiotic stress tolerance from *Festuca* spp. into *Lolium* spp. is offering unique opportunities for the production of versatile hybrid varieties with new combinations of useful characters suited to modern grassland farming (Humphreys et al. 2006). *Festulolium* hybrids are promising species to be used as fodder grasses. Due to its competitive productivity *Festulolium* may be equally ranked with the main forage grasses timothy and meadow fescue grown in climatic zone of Latvia (Gutmane, Adamovics, 2006).

Materials and methods

Field trials were conducted at the Research and Study Farm 'Vecauce' of the Latvia University of Agriculture (LLU) over the period from 2002 to 2007 in different parts of one trial field on a calcareous sod-gleysolic soil (*Luvic Epigleyic Phaeozem (Calcaric) – WRB 2006*), fine sandy loam (medium cultivated, medium deep to deep arable layer, medium high humus content). Soil pH_{KCl} – 7.2, plant available phosphorus (P_2O_5) – 579 mg kg^{-1}, potassium (K_2O) – 238 mg kg^{-1}, humus content 31 g kg^{-1}.

Sowing in trial plots was performed in three years: in May of 2002, 2003 and 2004 in complete block design with four replications, recorded area of a plot – 8 m^2. Grasses were row-seeded using an experimental seeder 'Hege 80', row spacing – 11 cm. For each sowing year (cycle) trial was established in two parts – swards used for herbage production and swards used for seed production, in each separate trial part seven varieties of grasses were tested in two nitrogen fertiliser backgrounds. Perennial ryegrass, hybrid ryegrass and festulolium varieties in the breeding of which parental species represent different species were used in trials.

Developed in Latvia, variety 'Saikava' in EU catalogue has been registered as hybrid ryegrass *(Lolium* × *boucheanum* Kunth*)*, however in trials it is estimated as festulolium *(× Festulolium),* because its parental species used in crossing represent two genera – fescue *(Festuca)* and ryegrass *(Lolium)*.

The sowing rate of grasses was 1,000 germinating seeds per m^2. In the year of sowing, nitrogen (N) – 108 kg ha^{-1}, phosphorus (P_2O_5) – 78 kg ha^{-1} and potassium (K_2O) – 90 kg ha^{-1} were applied as preplant fertiliser. In the production year of grass sward, 78 kg ha^{-1}

P_2O_5 and 90 kg ha^{-1} K_2O were applied as preplant fertiliser in both fertiliser backgrounds prior to the commencement of vegetation. In the first fertiliser background the nitrogen fertiliser rate was N $120_{(40+40+40)}$, in the second fertiliser background it was N $180_{(60+60+60)}$. The nitrogen fertiliser was split into three applications – for the first time prior to the commencement of vegetation, for a second time after the first cut and for the third time after the second cut.

Herbage yield in the vegetation period was recorded by direct method when the grass was harvested from a plot and weighted. In three production years herbage yield was obtained from each grass sward of each sowing year (cycle):

- Sward sown in 2002 was cut respectively in 2003, 2004 and 2005;
- Sward sown in 2003 was cut respectively in 2004, 2005 and 2006;
- Sward sown in 2004 was cut respectively in 2005, 2006 and 2007.

Winter hardiness for trial varieties was assessed visually (in accordance with the regulation No. 6 of the Ministry of Agriculture of the Latvia Republic of 20/06/2003), using a scale 1–9, where 9 is very good winter hardiness, plants have fully survived and 1, where plants are completely winterkilled. Yields of herbage mass were recorded for three cuts in vegetation season, dry matter yields were determined according to 'Value for Cultivation and Use Testing of Plant Varieties (VCU)' (regulation No. 6 of the Ministry of Agriculture of the Latvia Republic of 20/06/2003).

By the LLU Analytical Laboratory for Agronomy Research, the first cut herbage dry matter yield was analysed for the following quality indices: total N, crude protein content in herbage dry matter was calculated as total N x coefficient 6.25 (ISO 5983-2: 2005), neutral detergent fibre NDF (LVS EN ISO 16472: 2006); acid detergent fibre ADF (LVS EN ISO 13906: 2008); the dry matter digestibility *in vitro* (cellular method); net energy of lactation NEL MJ kg^{-1}:

$$NEL = (0.0245 \times TDN\ \%\ DM - 0.12) \times 4.184;$$

Total digestible nutrients DM (TDN), %:

$$TDN = 88.9 - (ADF\ \% \times 0.779)$$

Spreading of snow mould infection in grass swards was detected in spring 2005. Severity of the disease was assessed using a scale 1–9, assuming that 1 – disease symptoms are not evident, all plants are healthy; 9 – all plants are diseased.

For data processing, analysis of variance, simple and multiple linear regression analyses were employed. Data probability level was estimated using Fisher's criteria.

Meteorological information was provided by automatic meteostations 'Hardi Metpole' and Dacom Metapole' located at LLU Research and Study Farm 'Vecauce' and by the nearest weather station in Dobele. Weather conditions in 2002 were favourable for the growth and development of grasses contributing to better establishment and strengthening of stand. Meteorological situation in 2003 was satisfactory for the growth and development of grasses and very good for seed production. All the growing season of 2004 was exceedingly good for vegetative growth of grasses, but excess of moisture had a negative impact on seed yield. The year 2005 was satisfactory both for the growth and development of grasses and seed production. Due to drought, the season of 2006 was unfavourable for vegetative growth. All season long, the year 2007 was favourable for vegetative growth.

Results and Discussion

Winter hardiness. Wintering conditions differed among trial years and that is why results characterising winter hardiness were different. In the first production year all trial varieties showed good mean values of winter hardiness. 'Punia' (developed in Lithuania) was most winter hardy but perennial ryegrass 'Spīdola' and festucoid (F) type festulolium 'Hykor' were somewhat less hardy than 'Punia'. Good winter survival of 'Punia' and 'Spīdola' may be related to their origin, because in breeding new varieties under Baltic climatic conditions more emphasis has been placed on winter hardiness.

Winter survival was the lowest for loloid (L) type festulolium 'Lofa' and late hybrid ryegrass 'Tapirus', however 6.8 points is also a good result for Latvian conditions. Also in the second and third production year Lithuanian variety 'Punia' and F type festulolium 'Hykor' were superior in winter hardiness. Hybrid ryegrass 'Tapirus' and L type festulolium 'Lofa' showed the lowest winter hardiness.

In three production years of swards, consecutive reduction in parameters of winter hardiness was stated for all trial varieties. Reduction was more rapid for L type festulolium varieties than for F type festulolium varieties. The most rapid reduction in parameters of winter hardiness was stated for variety 'Lofa'. The results of three-factor analysis of variance show that variety used and specific production year of sward had significant influence on results of winter hardiness, but the influence of N fertiliser rate, in its turn, was non-significant.

Winter hardiness in 2004/2005 was lower for all trial varieties due to snow mould infection. It was caused by a cover of snow on unfrozen soil in winter. Significant ($p < 0.05$) correlation between the level of infection and winter hardiness of varieties was established.

In swards used for seed production, mean values of winter hardiness were higher for F type festulolium varieties 'Felina' and 'Hykor' (respectively 7.8 and 7.7 points). 'Punia' (developed in Lithuania) with 7.5 points and 'Saikava' (developed in Latvia) with 7.3 points were somewhat behind the above-mentiond varieties. The lowest mean value of winter hardiness (6.6 points) was detected for L type festulolium 'Lofa' and late hybrid ryegrass 'Tapirus'. Poor survival in the severe winter 2002/2003 was the cause why early hybrid ryegrass 'Ligunda' (winter hardiness 2.5 points) was excluded from trials in subseqent sowing years and

instead of it variety 'Felina' was included in seed production trials.

Dry matter yield. Cutting regime consisted of three cuts, which is the average number of cuttings appropriate for cultivated grassland swards in Latvia. Most of the dry matter yields were produced by the first cut. Average dry matter yield of the first cut in three years of production was 4.89 t ha^{-1} or 49% of the annual yield. Higher dry matter yields of the first cut grass were produced by the varieties that characterised with higher total dry matter yields. The influence of winter hardiness on dry matter yields of the first cut grass was different among different production years of sward. The influence of winter hardiness increases with the increase of sward age, and it was higher in the third production year. In the first production year, the influence of winter hardiness on dry matter yield of the first cut grass was low (coefficient of linear regression $b_{yx} = 0.54$) and non-significant ($p > 0.05$), in the second production year in turn it was higher ($b_{yx} = 0.61$) and significant ($p < 0.01$). In the third production year, the influence of winter hardiness was significant ($p < 0.01$), and it was the highest ($b_{yx} = 1.03$), as it is suggested by coefficients of linear regression.

All trial varieties produced low dry matter yields in the second cut under the influence of meteorological conditions – warm and dry weather in mid-summer during several trial years. Average dry matter yield of the second cut in three years of production was 2.09 t ha^{-1} or 21% of the annual yield.

In the first production year, significant differences in mean dry matter yields were found for festulolium, hybrid ryegrass and perennial ryegrass varieties. F type festulolium variety 'Felina' was the most high-yielding, however it should be considered that these are only one sowing year results. Analysis of variance in all production years was employed for varieties with three sowing cycle trial results (n = 24). Comparison among varieties with three sowing cycle trial results showed, that the highest mean values of herbage dry matter yields in the first production year were obtained with another F type festulolium variety 'Hykor' and L type festulolium varieties 'Punia' and 'Perun' (Table 1).

Table 1. Dry matter yield in the first, second and third years of sward use, t ha^{-1} (average for three sowing cycles)

Year of sward use	Variety							
	Spīdola	Tapirus	Perun	Punia	Lofa	Hykor	Felina[1]	Saikava[2]
	Three sowing cycles trial results[3]							
First	9.16 ^{a}	12.32 ^{b}	14.42 ^{c}	14.58 ^{c}	12.67 ^{b}	14.40 ^{c}	16.41	10.91
$S_{\bar{x}}$	0.56	0.67	0.72	0.7	0.68	0.74	0.39	0.86
Second	6.13 ^{a}	7.92 ^{b}	9.27 ^{c}	9.14 ^{c}	8.25 ^{b}	11.94 ^{d}	13.76	6.78
$S_{\bar{x}}$	0.5	0.72	0.66	0.7	0.69	0.78	0.46	0.21
Third	5.34 ^{a}	6.83 ^{b}	8.21 ^{c}	7.36 ^{d}	7.30 ^{d}	10.81 ^{e}	9.26	6.77
$S_{\bar{x}}$	0.27	0.37	0.43	0.27	0.34	0.3	0.34	0.37

[1] *one sowing cycle trial results* (n = 8);
[2] *two sowing cycles trial results* (n = 16);
[3] *for varieties with three sowing cycles trial results (n = 24), mean values in each year of sward use with different letters on superscript are significantly different at the p<0.05 level*.

In the second production year, mean values of the dry matter yields for festulolium, hybrid ryegrass and perennial ryegrass varieties were significantly lower than in the first production year. For perennial ryegrass, the dry matter yields in the second production year decreased by 3.03 t ha^{-1} or 33%. Similar yield decrease – by 36% was observed for hybrid ryegrass and L type festulolium varieties, which accounted for 4.40 and 4.78 t ha^{-1}, respectively. Considerably lower drops in productivity, by 2.46 t ha^{-1} or 17% between the first and second production year was found for F type festulolium 'Hykor', however it was also significant. For another F type festulolium variety 'Felina' (one sowing cycle trial results) this drop in productivity was also 17%.

In the third production year, the average dry matter yield of herbage was significantly lower than in the second production year, however decline in productivity was not so rapid as it was observed between the first and second production year. For perennial ryegrass, reduction in total dry matter yield between the first and third production year was 42% and accounted for 3.82 t ha^{-1}. Similar yield reduction was observed for hybrid ryegrass and L type festulolium varieties (respectively 45% and 44%), which accounted for 5.49 and 5.73 t ha^{-1} respectively. F type festulolium varieties were more stable in productivity with less reduction in yielding ability –35% .

The dry matter yield differences among varieties in sowing cycles formed similarly. Varieties that characterised with higher mean dry matter yields were also higher-yielding in all years of sowing cycles, respectively lower-yielding varieties produced lower yields of dry matter also in each of the trial year. The same relationships were also observed among three production years of sward. It allows conclusion that varieties included in this trial, regardless of their genetic differences, show similar response to ageing of sward and to influence of climatic factors.

In three production years, higher mean annual dry matter yields were produced with F type festulolium 'Hykor' (12.38 t ha^{-1}). Also other variety 'Felina', according to one sowing cycle trial results, had high mean dry matter yields (13.14 t ha^{-1}). 'Perun' (10.63 t ha^{-1}) and 'Punia' (10.36 t ha^{-1}) excelled with yielding ability among festulolium varieties of L type.

Nitrogen fertiliser rate increase from 120 to 180 kg ha^{-1} provided significant increase of mean dry matter yields for all festulolium, hybrid ryegrass and perennial ryegrass varieties in all production years.

In the first production year, the influence of rised rates of nitrogen fertiliser on the increase of dry matter yield was different for festulolium varieties of both L and F type. For L type festulolium varieties 'Perun', 'Punia', 'Lofa' and 'Saikava', increase of N fertiliser rate from 120 to 180 kg ha^{-1} resulted average dry matter yield increase of 2.46 t ha^{-1} or 21%. In turn for F type festulolium varieties 'Hykor' and 'Felina', the positive effect of the increased nitrogen fertiliser rates on crop yield increase was less expressed. For these varieties, the average increase of dry matter yield was only 1.18 t ha^{-1} or 8% (Figure 1).

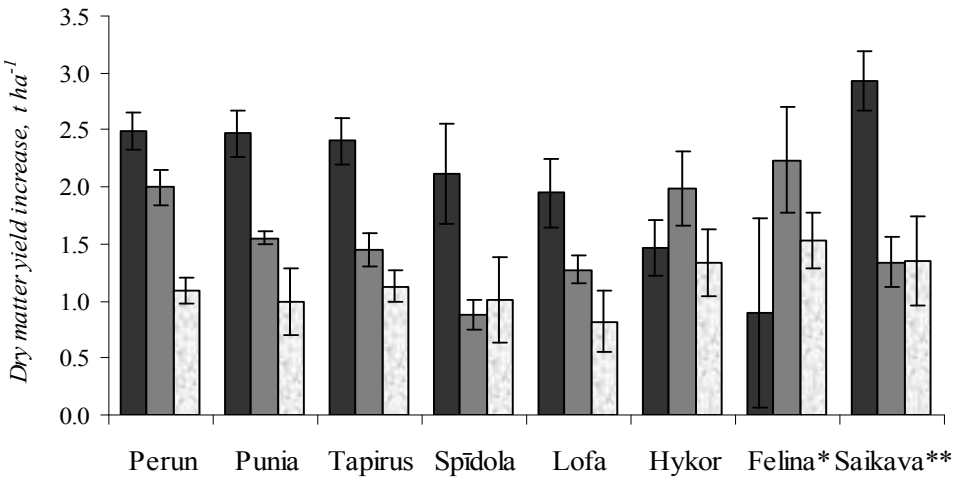

Figure 1. Dry matter yield increase from applied fertiliser rate N 120 rise to N180 kg ha^{-1}.
■ *1st year of sward use*; ■ *2nd year of sward use*; □ *3rd year of sward use*;
** one sowing cycle trial results*; *** two sowing cycles trial results.*

In the second and third production year, differences in dry matter yield increase among festulolium varieties of L type and F type are not found.

The value of the determinant factors influence on dry matter yield formation indicate, that cutting as a factor provides the greatest differences between the herbage dry matter yields in the first and third production year (Table 2). The high influence of cutting factor may be explained not only with the changes in regrowth rate, but also with differences in meteorological conditions during growing season.

Table 2. Variety, nitrogen fertilisation and cut factors influence on average dry matter yield for 3 sowing cycles trial results

Factors	Year of sward use		
	First	Second	Third
Variety (A)	11.8*	39.1*	15.5*
N fertiliser rate (B)	3.8*	7.4*	1.6*
Cut (C)	78.6*	32.3*	76.1*
Interaction (A x B)	0.1	0.5*	0.0
Interaction (A x C)	4.3*	14.9*	3.8*
Interaction (B x C)	0.1*	0.5*	0.8*
Interaction (A x B x C)	0.1	1.1*	0.4*

* *Influence of factor significant at the 95% probability level* ($F_{fakt} > F_{0.05}$).

Variety used was an important factor in the formation of yield differences in all production years of sward. The value of the influence of the variety factor was the highest in the second production year. Though the increase of nitrogen fertiliser rates provided significant increase in the mean dry matter yields, nevertheless the influence of this factor was the lowest. The low influence of the nitrogen fertiliser factor may be possibly explained with optimised nitrogen fertiliser rates applied in the trial when unfertilised control treatment was not used. Regrowth of grass after cutting is influenced not only by meteorological conditions but also by regrowth ability of specific grass species. It is indicated by the significant influence of variety and cutting factors interaction effect on the yield of dry matter in all production years of sward. Climatic and meteorological conditions in particular influence the productivity of perennial grasses to a great extent. The influence of meteorological factors was estimated comparing different trial years as a total of meteorological factors in specific trial year.

Results showed significant differences in the dry matter yields between production years of sward. In both nitrogen fertiliser treatments, production year of sward provided the greatest variation in data for the first cut yield, but meteorological conditions as a factor were also significant (Table 3).

The great influence of sward production year and meteorological conditions interaction effect on the dry matter yield should also be noted. Though the second-cut yields in several trial years were exceedingly low due to dry and warm weather, nevertheless the influence of meteorological conditions was not determinant one. The greatest variation in data of the second-cut and third-cut yield was provided just by interaction between production year and meteorological conditions. The

influence of interaction effect was higher than the influence of separate factors. It suggests that with ageing of sward herbage plants respond to adverse weather conditions more sharply.

Table 3. Variety, year of sward use and meteorological factors influence on dry matter yield formation

Faktors	*N rate*	*Cut*		
		First	*Second*	*Third*
Variety (A)	N 120	9.4*	7.5*	26.4*
	N 180	9.7*	7.3*	21.5*
Year of sward use (B)	N 120	36.1*	16.2*	8.6*
	N 180	33.0*	20.3*	17.2*
Meteorological conditions (C)	N 120	18.9*	6.4*	12.0*
	N 180	14.5*	10.5*	10.9*
Interaction (A x B)	N 120	1.9*	2.0*	3.1*
	N 180	1.2*	1.5*	3.3*
Interaction (A x C)	N 120	0.8*	0.6*	3.7*
	N 180	1.1*	0.7*	0.5
Interaction (B x C)	N 120	28.1*	59.8*	32.4*
	N 180	36.1*	54.9*	37.3*
Interaction (A x B x C)	N 120	0.9*	4.3*	9.4*
	N 180	1.3*	2.8*	3.4*

**Influence of factor significant at the 95% probability level*($F_{fakt} > F_{0.05}$).

In vegetation season the value of the influence of variety on yield differences formation in yield increases, and the influence of variety factor is higher in the third cut. In turn the influence of a specific production year decreases, and it was lower in the third cut than in the first and second cut.

Determinant factors of seed yield and its formative elements. Resistance to lodging and plant length, as agronomically important traits, may have direct or indirect impact on seed yield formation. In all trial years, the influence of variety on lodging resistance was significant ($p < 0.001$). The influence of variety (η, % = 91.8) was considerably higher than the influence of nitrogen fertiliser and factors interaction effect. Analysing the influence of the nitrogen fertiliser rate on lodging resistance, differences in results were detected in trial years. In two years (2003 and 2004), the influence of the nitrogen fertiliser was not significant ($p > 0.05$). Only in 2005 it was significant at the 95% probability level. It could be explained with high level of lodging observed in swards of all L type varieties in both fertiliser backgrounds. Severe lodging of L type festulolium and hybrid ryegrass varieties requires careful consideration whether the increased nitrogen fertiliser rates are useful at the existing agricultural background and sowing rate of seeds.

The generative tiller number per m^2 is is an important indicator in grass swards used for seed production. On the average for three trial years, the generative tiller number was greater for L type festulolium varieties 'Lofa' and 'Saikava'. These varieties also produced the highest yields of seeds. Variety and nitrogen fertiliser rate had different influence on the generative tiller number in trial years. The influence of non-studied factors was high (η, % = 45.1). Such results, possibly, are due to great differences within varieties which made it difficult to find out significance of the influence of studied factors − variety and N fertiliser rate − on generative tiller number.

1,000 seed weight (TSW) in research literature is most frequently characterised as a trait of quality and not determinant indice of seed yield, because grass seeds are very small in size. Higher mean values of TSW were found for L type festulolium 'Perun' and hybrid ryegrass 'Tapirus'. The lowest values of TSW were stated for 'Felina' and 'Hykor'. In all the three years of trials, the influence of variety on TSW was significant ($p < 0.001$). The influence of variety on TSW (η, % = 95.9) was considerably higher than the influence of nitrogen fertiliser and factors interaction effect.

As breeding effect following the cross and parental species vary considerably, festuloliums are morphologically different. Crossings between tall fescue and Italian ryegrass have resulted in varieties sharply different in morphology. Three varieties – 'Felina', 'Hykor' and 'Lofa' – out of all varieties included in trials, is a result of crossing between Italian ryegrass and tall fescue *(L. multiflorum × F. arundinacea)*, but flower head – panicle is observed only for 'Felina' and 'Hykor', while 'Lofa' is characterised with flower head – ear.

Length of a flower head**,** corresponding to type of a flower head – panicle, was shorter for 'Hykor' and 'Felina' than for other varieties that characterise with flower head – ear. In all trial years, the influence of variety on the length of a flower head was significant ($p < 0.001$). The high influence of non-studied factors (η, % = 36.7) on the length of a flower head was stated. It could be explained with a wide range of differences in the length of a flower head within variety.

Weight of a flower head among L type festulolium varieties, was higher for 'Perun' and 'Lofa'. For 'Ligunda' this parameter was the lowest after poor winter survival. The influence of variety on the weight of a flower head was significant ($p < 0.001$), and the influence of variety (η, % = 69.2) was higher than that of nitrogen fertiliser and factors interaction effect.

Number of spikelets per flower head**,** corresponding to type of a flower head – panicle, was considerably higher for 'Hykor' and 'Felina' than for other varieties. For L type festulolium varieties, it was greater for 'Lofa' and 'Saikava'. The influence of variety on spikelet number per flower head was significant ($p < 0.001$), and the influence of variety as a factor was considerably higher (η, % = 97.8) than N fertiliser and factors interaction effect.

The influence of nitrogen fertiliser rates on seed yield formative elements and seed morphological traits, such as plant length, the generative tiller number, TSW, length of a flower head, weight of a flower head and the spikelet number per flower head was different in trial years. Such fluctuations in results may be explained with considerable differences in parameters of previously mentioned seed yield formative elements within variety. The differences within variety at equal fertiliser rates were higher than the mean differences of parameters in two fertiliser backgrounds.

More extended analysis of seed yield formative elements was performed for varieties representing L type

and having ear as a flower head, such as 'Ligunda', Tapirus', 'Saikava', 'Perun', 'Punia', 'Lofa'.

Analysing relationships between seed yields and evaluated quality traits for L type varieties, significant correlation, at least in one of trial years, was established for the tiller number per m^2, ear length and the spikelet number per ear (Figure 2).

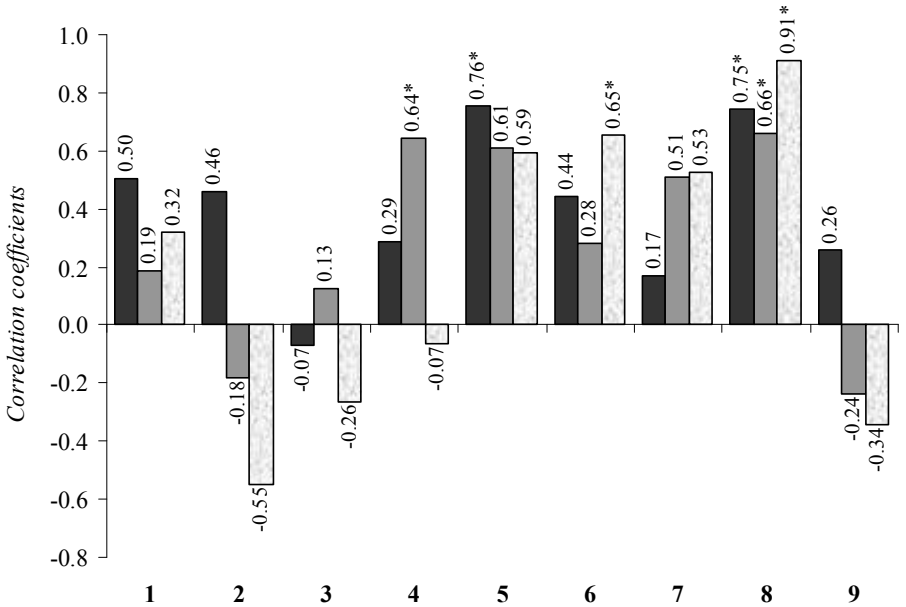

Figure 2. Correlation among seed yield and its formative indices for loloid type varieties.
Year ■ 2003 ■ 2004 □ 2005
1 – *overground biomass*; 2 – *winter hardiness*; 3 – *lodging resistance*; 4 – *plant length*; 5 – *number of generative tillers*; 6 – *ear length*; 7 – *ear weight*; 8 – *number of spikelets per ear*; 9 – *TSW*

The generative tiller number had a positive effect on seed yields of festulolium and hybrid ryegrass varieties in all the three years of trials. Significant linear relationship ($p < 0.05$) between the generative tiller number and seed yield was established in 2003, but in two remaining trial years the probability level was lower ($p < 0.1$).

The generative tiller number had a positive effect on seed yields of festulolium and hybrid ryegrass varieties in all the three years of trials. Significant linear relationship ($p < 0.05$) between the generative tiller number and seed yield was established in 2003, but in two remaining trial years the probability level was lower ($p < 0.1$).

The spikelet number per ear had a positive effect on the yield of seeds produced by L type varieties. Significant linear relationships ($p < 0.05$) between the spikelet number and seed yield were established in all the three years of trials. It suggests that just the spikelet number per ear could be one of determinant factors of seed yield formation for hybrid ryegrass and L type festulolium varieties.

Significant positive correlation in all trial years is stated between the length of ear and weight of ear ($r_{2003} = 0.88 > r_{(0.05;\ 12)} = 0.58$; $r_{2004} = 0.68$ and $r_{2005} = 0.76 > r_{(0.05;\ 10)} = 0.63$). For the major trait that influences seed yield – spikelet number per ear – significant linear relationships ($p < 0.05$) are established with the length of ear in two years of trials. Relationship between the spikelet number per ear and the length of ear was not significant ($p = 0.18 > 0.05$) in 2004. With the increase of the spikelet number per ear the weight of ear increases. Significant linear relationship ($p < 0.05$) is stated in years 2004 and 2005, but in 2003 the probability level ($p = 0.54 < 0.1$) was lower.

Varieties characterised with greater productive tiller number showed the tendency of forming greater spikelet number per ear in all the three years of trials as indicated by positive coefficients of correlation. Significant linear relationship ($p < 0.05$) between the productive tiller number and the spikelet number per ear is stated in 2003, but in two subsequent trial years the probability level was lower ($p < 0.1$). Mutual correlative relationships between thousand seed weight and seed yield as well as between other traits studied were inconsistent between years.

Dry matter quality indices. Crude protein (CP) content is the main determinant of forage quality. The first cut crude protein yield was significantly influenced by variety ($p < 0.01$) in all production years of grass sward. Total crude protein yields in each production year were higher (on average from 321 to 1,177 kg ha^{-1}) with F type festulolium varieties 'Felina' and 'Hykor'. For these varieties, the highest total crude protein yields were provided not only by good yielding ability, but also by higher crude protein content in herbage dry matter as compared to other varieties. Among L type festulolium varieties, 'Punia' produced higher total yields of crude protein in each production year (on average from 241 to 616 kg ha^{-1}). Crude protein content

in herbage dry matter, as well as its yield obtained with the first-cut grass were significantly ($p < 0.01$) influenced by the increase of N rate from 120 to 180 kg ha^{-1} in all production years of sward. In the first production year, the average increase in crude protein yield was 88 kg ha^{-1} or 20%. In the second production year it was 75 kg ha^{-1} or 42%, but in the third production year 131 kg ha^{-1} or 56% (Table 4).

Table 4. First cut crude protein yield for three years of sward use, kg ha^{-1} (average for three sowing cycles)

Variety	Crude protein yield at N120, kg ha^{-1}			Increase of crude protein yield at N180, kg ha^{-1}		
	Year of sward use			Year of sward use		
	First	Second	Third	First	Second	Third
Spīdola	385	173	169	111*	52*	140*
Tapirus	394	131	208	126*	102*	122*
Perun	493	157	241	125*	97*	106*
Punia	559	192	220	113*	99*	151*
Lofa	458	164	205	66	60*	134*
Hykor	639	278	320	80	85*	98*
Felina[1]	1170	330	330	15	35	246
Saikava[2]	310	192	178	67	69	48
Mean	551	202	234	88	75	131
$S_{\bar{x}}$	96	24	21	14	9	20

[1] *one sowing cycle trial results*; [2] *two sowing cycles trial results*;
* *yield increase significant at the 95% probability level for varieties with three sowing cycles trial results*.

The highest increase in crude protein yield in three production years was stated for hybrid ryegrass 'Tapirus' and L type festulolium 'Punia' (respectively 350 kg ha^{-1} or 48% and 363 kg ha^{-1} or 37%).

Acid and neutral detergent fiber (ADF and NDF) content in herbage, on average for three production years, was the lowest for perennial ryegrass 'Spīdola' (respectively 24% and 43%). For the rest of L type varieties NDF was in the range of 46% to 50%, but ADF content ranged from 27% to 30%. Both festulolium varieties of F type 'Hykor' and 'Felina' showed higher mean values for NDF (respectively 56% and 58%) and ADF (respectively 33% and 33%).

The dry matter digestibility is one of the major determinant factors of grass forage quality. On the average for three production years, perennial ryegrass 'Spīdola' was of higher dry matter digestibility (76%). For the rest of L type varieties digestibility was in the range from 69% to 73%. On the average for three production years, F type festulolium varieties 'Felina' and 'Hykor' were of lower dry matter digestibility (respectively 61% and 65%). For the three production years, significant negative correlation is established between the dry matter digestibility and fiber characteristics NDF ($p < 0.001$) and ADF ($p < 0.001$).

Net energy of lactation (NEL), a parameter of forage quality, is closely related with ADF content in herbage dry matter. On the average for three production years, NEL was the highest for perennial ryegrass 'Spīdola' (6.7 MJ kg^{-1} DM). For the rest of L type varieties NEL ranged from 6.2 to 6.5 MJ kg^{-1} DM. For both F type festulolium varieties 'Felina' and 'Hykor' NEL was lower (6.0 MJ kg^{-1} DM), on average in three production years.

The increase in parameters of both fiber fractions, as well as decline in the dry matter digestibility and net energy parameters in the third production year of sward suggest, that the quality of grass forage is influenced by the age of sward.

In all production years of sward, NDF and ADF content in herbage dry matter, the dry matter digestibility and indices of NEL were significantly influenced by grass variety ($p < 0.01$). Significant influence of N fertiliser on NDF and ADF content in herbage dry matter, the dry matter digestibility and NEL was not stated ($p > 0.05$).

Conclusions

Trial varieties of festulolium and late maturity hybrid ryegrass are suitable for seed production and establishment of long-term grassland swards used for forage production under Latvian agro-climatic conditions. Early hybrid ryegrass variety, due to low winter hardiness, is not suitable for production under Latvian conditions.

Yields of dry matter and forage quality formation for festulolium and hybrid ryegrass were significantly influenced by several factors: variety, a seasonal pattern of meteorological factors in specific year, production year of sward, nitrogen fertiliser, regrowth period.

Dry matter yields obtained with perennial ryegrass, hybrid ryegrass and festulolium varieties were equal in production years of sward. Higher-yielding varieties characterised with higher mean dry matter yields in all trial years. All species studied, regardless of genetic differences, equally responded to ageing of sward and impact of meteorological factors.

The influence of winter hardiness on the first-cut yield of festulolium and hybrid ryegrass increases with the increase of sward age. Consecutive reduction in parameters of winter hardiness across production years of sward is stated.

Festucoid type festulolium characterised with higher crude protein content in herbage dry matter, and interaction with higher dry matter yield provided higher first cut crude protein yield.

The dry matter digestibility, neutral detergent fiber (NDF) and acid detergent fiber (ADF) in grass dry matter, as well as net energy of lactation (NEL MJ kg^{-1}) were higher for loloid type festulolium than for festucoid type festulolium.

Festulolium varieties tested are characteristic of two sharply different genotypes – loloid (L) and festucoid (F). These genotypes differ by the structure of a flower head, length of a plant and resistance to lodging.

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A REVIEW ABOUT RESEARCHES ON SOIL SCIENCE

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ABSTRACT. *In review the most important scientific researches conducted during 2001−2010 at the Department of Soil Science and Agrochemistry of Estonian University of Life Sciences are analyzed. The review enfolds researches on Estonian soils' properties, functioning, status, protection and sustainable management. The list of concerned to treated topics references enables to become more profoundly acquainted with presented research problems.*

Keywords: *carbon sequestration, humus forms, soil degradation, management and protection.*

Introduction

A short review includes the most important scientific researches conducted at the Department of Soil Science and Agrochemistry of Estonian University of Life Sciences during the last (2001−2010) decade. The review was prepared in connection with 18th Biennial of Baltic Agronomy Forum, which was held in Tartu in June 30th and July 1st, 2011. As a rule the review enfolds the researches on Estonian soil resources, its characterization and sustainable management, which concluding results are published in scientific journals and collections. Therefore every reader may find the source, where the problem is treated more profoundly. The main task of this work is to introduce to colleagues from other countries our research themes and to find partners for collaboration in the future.

Soils' humus status: pedoecological regularities of organic carbon sequestration

During the last decade several generalizations on Estonian soils' humus status (or functioning of soil in relation to soil organic matter (SOM) stocks and cycling) were conducted (Kõlli, Ellermäe, 2003; Kõlli *et al.,* 2004a, 2007, 2009b, 2010a, 2010b, 2010d). The basic characteristics of soil humus status are the thickness and fabric of epipedon and soil cover, stocks and concentrations of SOM and SOC (soil organic carbon) in different soil horizons and layers, and humus quality – determined by humus forms. As result of these researches the pedoecological regularities of SOC retention in soil, the influence of land use change on SOC retention in soil cover, and the share of different mineral and organic soil types in various (arable, forests and grasslands) land use conditions in total Estonian SOC storage were identified. Every soil type has a specific SOC flow throughout the soil cover depending on pedo-ecological conditions. Land use change influence primarily the properties and fabric of the topsoil, but the humus status of subsoil remains practically unchangeable. The mean soil cover area weighted SOC stock of automorphic mineral soils is 78.9 Mg ha^{-1} and that of the hydromorphic soils 127.5 Mg ha^{-1}. The aggregate of SOC retained in the mineral soils of Estonia amounts to 323 ± 46 Tg (~42% in stabilized humus, 40% – instable raw-humous material and 18% forest floor and shallow peat layers).

Annual cycling of soil organic carbon

Annual cycling of SOC is the main driving force in the formation and functioning of soil cover. The systematized parameters of SOC mean annual cycling were analyzed by mineral soils' types (Kõlli, 2001b, 2002; Kõlli, Tamm, 2009). The annual SOC inputs and outputs in natural soils (0.2–3.6 Mg ha^{-1} yr^{-1}) were calculated on the basis of annual productivity. In researches the influence of land management peculiarities on the annual cycling and balance of SOC and the agrotechnological possibilities for regulation of SOC sequestration and cycling intensity were treated. The weighted mean humus status indices of soil types may be used as benchmarks in the arrangement of sustainable land use and ecologically sound protection of soils. The hereditary soil humus status and fertility of natural soils persists after their cultivation only in low input management conditions. The attainment of SOC cycling equilibration with soil capability is the main goal of sustainable SOC management.

Distribution and organic carbon sequestration capacity of Histosols

The distribution of peat soils was established by main peat soil groups, peat thickness and peat decomposition degree. From the digital soil map (1:10,000) database with 859,701 polygons the soil mapping unit code, formula of soil texture (including peat) and formula of epipedon fabric were compiled (Kõlli *et al.,* 2009a). Peat soils form altogether 10,038 km^2 or 23.5% of the total Estonian soil cover. From the peat soils the fen soils form 59.0%, bog soils 21.7% and transitional bog soils 14.7%. 45% of peat soils are well, 26% moderately and 29% slightly decomposed; by the peat thickness 13% are very shallow, 21% shallow and 66% thick. The dominant natural ecosystems formed on peatlands are: (1) mixed birch, alder, spruce and pine forests on thin (< 100 cm) *sapric* fen soils, and (2) a sparse pine forests and hummock-ridge-hollow raised bogs wooded sparsely by pine on thick (> 100 cm) *fibric* bog soils. The accumulation of organic carbon in peatlands soil cover (0–50 cm) totals 269.4 ± 12.7 Tg and in epipedon layer (0–30 cm) 129.9 ± 5.8 Tg. The SOC sequestered into peatlands soil cover forms 45.4% of total Estonian soil cover SOC. The properties and functioning of peat soil cover and especially its epipedon layer differ in great extent by soil varieties and in comparison with peats located in deeper layers.

Chemical composition and formation of histic epipedons

The chemical properties of the superficial layers of fens and transitional bogs, together with slightly acid *peaty mull*, strongly acid *peaty moder* and very strongly acid *peaty mor* layers were studied (Kõlli *et al.,* 2010b, 2010c). Thus, it spans organic soils *(Histosols)* together with *Histic Gleysols* and *Histic Podzols*, which are intermediate between organic and mineral soils. Moderately acid eutrophic and very strongly acid mesotrophic peats of *Histosols* were uniformly characterised up to 40 cm depth, whereas histic soils were examined their full thickness extent (10–30 cm). The results show that Al, K and heavy metal contents are significantly higher and organic carbon content is lower in histic soils than in *Histosols*. The amounts of Ca, Mg, Mn and Fe are significantly higher and C:N ratio, exchangeable acidity and content of free H^+ lower in less acidic than in more acidic soil types. The total concentration of elements (excluding heavy metals) extracted by *aqua regia* is considerably higher in less acidic soils, at 28–45 g kg^{-1} *versus* 10–12 g kg^{-1}. The mean contents of elements decrease in the order Ca > Fe > S ≥ Al > Mg ≥ P > K > Mn > Na. The most abundant heavy metals are Pb (12–33 mg kg^{-1}), Zn (7–41), Cu (3–12), Cr (2–23) and Ni (2–8). Cd and Hg contents are very low, ranging from 0.2 to 0.5 mg kg^{-1}. In the forming of epipedon from forest floor, (1) the content of *aqua regia* extractable Fe, Cr, Al, Pb and Ni are increased to a great, but S, Na and Hg – to medium extent; (2) the contents of Zn, K and Mn have decreased to great, but Mg and P – to medium extent; (3) the contents of Ca, Cu and Cd remain at the same level. The comparison of *Histosols*' subsoil and substratum peats with *Histosols'* epipedon demonstrates the considerable accumulation of Mn, Pb, Cd, Zn, Hg and Na into mires thin (20 cm) superficial peat layer.

Humus forms and their classification

The humus forms are the base for the interpreting SOM role within ecological framework (Kõlli, 1992, 2010; Kõlli *et al.,* 2008b, 2009; Zanella *et al.,* 2010). In European Reference Base for humus forms the main accent is given (1) to the general structure and principles of classification and (2) to the characterization of terrestrial (formed on automorphic soils) and semiterrestrial (semi- and hydromorphic soils) humus forms. The adequate explanations and comparative analysis are given for zoogenically and non-zoogenically formed organic horizons of humus forms taking into account the structure of organo-mineral horizons and the dominant species of soil animals. Our comparative research into European and Estonian humus forms classifications revealed inclination of the first one toward Mediterranean pedo-ecological conditions.

Soil protection: a pedocentric and ecosystem approach

The constraints of soil are features or circumstances (deficiency, shortcoming, disability) which hinder (limit, prevent) the optimal functioning of soil and prevent to reach the productivity level characteristic to the bioclimatic region. The main constraints are waterlogging, scarcity of organic carbon in topsoil, extremely coarse soil texture, water erosion, flooding, drought hazards, be the presence of lithic, strongly podzolized and compacted soil layers. Soils' degradation features and their causes are widely variegated (Reintam *et al.*, 2001). Soil degradation is deterioration of soil quality, i.e. the partial or entire loss of one or more potential functions of the soil (Kõlli, 2001a; Kõlli *et al.,* 2006, 2008a; Kõlli, Kanal, 2010). More complicated is to identify ecological (soil type-specific) degradation: destruction of soil functioning, degeneration of biological activity, depletion from nutrition elements, worsening of humus status, and presence of deficiency or excess in trace elements. The measures to prevent soil degradation are as numerous and various as the factors which cause the problem: starting from the public awareness, introduction of sound measures for the sustainable use, protection and systematic monitoring of soils to state-supported programs for liming of arable soils, restoration of contaminated soils, reconstruction of drained areas and others. Very important is the enforcement of legislation for protecting fertile soils.

Environment protection ability of soils

The environmental protection ability (EPA) of soils is an integrated capability of the soil cover to stabilize the functioning of the soil's ecosystem in the discharging of environmentally harmful fluxes of substances into the soil. The influence of soil cover on the environmental conditions of an area depends greatly on soil type peculiarities (Kõlli *et al.,* 2004a, 2004b, 2008d, 2009c). Soils with a low EPA are highly vulnerable to degradation, but those with high EPA are more resistant to negative influences and may be used more intensively for agricultural purposes. For evaluation of soils' EPA the soil humus status, texture, specific surface area, cation exchange capacity, calcareousness, thickness, biological activity and fabric of epipedon were used. If the EPA of the epipedon is determined first by the content and quality of SOM, then the EPA of the metric soil layer can be calculated mainly by soil particle size composition and the presence of coarse soil material. The soil management strategies, which lead to higher soil productivity, also enhance the soil's ability to protect the environment. Soil cover is a medium through which the environmental status of an area can be improved.

Contamination of soils

Organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) were analyzed in selected Estonian soils (Sajwan *et al.,* 2008; Kumar *et al.,* 2009). The predominant contaminants were PCBs, followed by OCPs and PBDEs. The PBDEs in Estonian soils were reported for the first time. Based on the data on PCBs, OCPs, and PBDEs, the contamination level of these persistent organic pollutants is relatively low. The results also confirm that Estonia is one of the cleanest eastern European countries.

Changes in agriculture, soil nutrient balances and status of Estonian arable soils

The decrease in agricultural land use and production was very large-scale in the transition to a free market economy and continued until EU CAP was implemented in Estonia (Astover *et al.,* 2006a). The regional differences in land use changes in the 1990s were determined mainly by local bio-physical disadvantages such as soil quality. The efficiency and expediency of natural and economic resources use from the aspects of different soil management, manner of production and market situation were analysed (Vasiliev *et al.,* 2006; Vasiliev *et al.,* 2008; Astover *et al.,* 2008). Plant nutrient (N P K) balances in Estonian arable soils ascertain since 1990s potential degradation of their agrochemical status, which was caused by low investments into arable land (Astover *et al.,* 2006a; Tamm *et al.,* 2009). In collaboration with colleagues from Latvia, Lithuania and other Eastern Europe countries the results of national agro-chemical survey on P status and balances in arable soils were summarized (Csatho *et al.,* 2007; Kõlli *et al.,* 2008c). In Estonia only 40–50% of the yield potential of cereals is realised in actual farming conditions and low realisation of potential is partly due to the insufficient use of fertilisers (Roostalu *et al.,* 2001; Vasiliev *et al.,* 2006).

Soil compaction and its monitoring: the effect of agricultural activity on soil deformation and plants productivity

The soil compaction and fertilization influence: (1) on soil physical properties – bulk density, penetration resistance, water content, porosity, water and air permeability, shear strength and others, (2) on content of plant available P, K, Ca, Mg, total N and SOC, (3) on pH, and (4) on cultural plants and weeds production, development of their shoots and roots, changes in plant community and others were studied (Kuht *et al.,* 2003; Kuht, Reintam, 2004; Reintam, 2011; Reintam, Kuht, 2003; Reintam *et al.*, 2005, 2006, 2008, 2009a, 2009b; Trükman *et al.,* 2006, 2008). The roots resistance to loads, assimilation of nutrients from the compacted soil and roots affect on soil properties were investigated on intensively managed grasslands. The grassland cultures with their extensive root system reduce (due their regeneration ability) the harmful effect of soil compaction and improve soil properties.

Development of spatial agro-economic decision support system

The application of soil information systems, digital soil maps and pedo-ecological models for land use planning were under the research (Astover *et al.,* 2006b). In order to stabilise agricultural production the optimal land use and agricultural production models for diferent regions were elaborated. Optimization of land use and agricultural production in Estonia proceeding from pedoclimatic, environmental protection related and economic conditions were studied. Systematically generalized soil cover data, know-how about functioning peculiarities of different soil types and digitized soil maps have been a ground for GIS based exploitation of land (soil) resources and creating of internet based advisory services for farmers. On the base of each agricultural massive (field) soils analysis the efficacy, expediency and related with production processes risks in exploitation of natural and economical resources in dependence of land use peculiarities, specificity of management (production) and market situation were explained. Pedotransfer functions (compatible with the large-scale soil map of Estonia) for soil bulk density prediction were provided (Suuster *et al.,* 2011). The compilation of digital databases for elaboration optimal land use and agricultural production models for different Estonian regions are under way.

Researches conducted in long-term field experiment

IOSDV (Internationale Organische Stickstoff Dauerdüngungs Versuche) long-term field experiment in Tartu was established in 1989. Effect of mineral and various organic fertilisers on crops yields and its quality, soil properties (Teesalu *et al.,* 2003; 2006; 2008; 2009; Raave *et al.,* 2004; Szajdak *et al.,* 2006; Leedu *et al.,* 2008; Toomsoo *et al.,* 2009) and biota (Kautz *et al.,* 2002), energy efficiency (Astover *et al.,* 2009) etc was studied. The nutrient cycles in system plant-soil, plant nutrition, nutrients efficiency of fertilization and balanced fertilization were studied on the base of long term field rotation: application of different soil nitrogen forms in depending from crop, fertilizing load, soil management and weather conditions; using of cereals straw and soil improvement material (1:1 − bog peat : oil shale cock) as soil organic fertilizers (Teesalu *et al.,* 2006). Soil improvement material is not suitable for spreading directly to the field as organic manure. For fertilizing agricultural crops it recommended to mix (to compost) with town wastewater sludge or solid fraction of pig slurry. These composts improve soil agrochemical parameters in same amount like farmyard manure (Raave *et al.,* 2004). On the base of field trial the effect of organic and mineral fertilizers on soil humus status, on available K, P, and soluble S content in soil as well the actual and residual effect of manure on grain yield and chemical elements ratio in hay were studied. The highest yields were received with the coeffect of organic and mineral fertilizers (increase 58–70%).

The influence of produced from semi-coke recultivation substance and composts on soil characteristics, yield of field crops and environment was studied (Raave et al., 2004). The recultivation substance (oil shale semi-coke with acid bog peat) is (thanks to high Ca and Mg content) suitable for neutralizing acid soils, but its effect on humus pools is not significant. Recultivation substance should be enriched with some nutrient rich organic matter, for which sediment mud from water treatment plants and pig manure prove highly suitable. The environmental hazard of recultivation substance weathered for six months is low.

Complex characterization of Estonian soils: properties, functions, productivity, ecology

Soils properties, functioning and ecology were systematized on three soil matrixes (postlithogenic and synlitho-

genic mineral soils, and organic soils). On the background of these matrixes the generalized data by soil types and pedoecological regularities are presented (Kõlli *et al.,* 2003, 2008b, 2009a; Kõlli, Teras, 2007). Our researches give a systematic characterization of arable and forest soils properties on soil species level, elucidate soil ecology in dependence of land use peculiarities and form a base for soil use in harmony with local conditions. The comparative analysis of arable and natural soil properties and functioning helped to detect wrong perceptions, which have been rooted into everyday land (soil) management. The composition (bio-ecological quality) of SOM (as indicator of soil ecosystem functioning activity) was investigated in concordance with local ecological conditions on the background of generalized SOM quantitative characterization (Szajdak *et al.,* 2005, 2006; Kõlli *et al.,* 2009c). The *Histosols'* peats decomposition and transformation mechanisms and kinetics in natural and cultivated conditions with an aim to create the model of peat transformation kinetics for cultivated exhausted peatlands are investigated.

Soil phosphorus status and its sustainable management

In collaboration with colleagues from Latvia and Lithuania the results of national agro-chemical survey on P status in arable soils over last five decades were summarized (Csatho *et al.,* 2007; Kõlli *et al.,* 2008c). Changes in plant available soil P supply was researched in context of agronomic and environmental aspects. P surplus in arable soils of Baltic countries rests in average under 10%, but P deficiency varies in limits from 27 to 38%. On these areas the mitigation of soil scarcity and optimization of soil P status are needed.

Open cast oil shale quarries and waste dumps: soil formation and agricultural reclamation.

Researches of primary pedogenesis on skeletal quarry detritus of open-cast oil-shale mines show that the humus-accumulative process together with argillisation in situ and development of exchangeable complex are more intensive in cultivated detritus (Reintam, 2004, 2010). On long-term experimental areas situated on antropogenically influenced materials the physical properties, chemical content, recultivation technology and development of microflora were studied (Leedu, 2010a, 2010b; Leedu *et al.,* 2010). In the same region the impact of surface deformation (following to underground oil shale mining) and application of recultivation substance to crop yields were as well studied.

Conservation agriculture: ecologically sound and sustainable use of soil resources

In management of arable soils the tools of conservation agriculture should be used (Kõlli, 2001a; Lahmar *et al.,* 2006). The soil cover is protected (or sustainable land use is attained) in circumstances when soil fertility and functioning is maintained according to the soil type capability (Kõlli et al., 2008a). With the decisive importance in the arrangement of sustainable land use is the matching of soil cover with suitable plant cover on natural areas, and with crops on arable lands (Kõlli, Kanal, 2010).

Biomass potential from agricultural land for bio-energy

Agricultural land resource (including abandoned land) potential for bio-energy production was studied in several regions of Estonia (Suuster *et al.,* 2008; Kukk *et al.,* 2010a; Kask *et al.,* 2011). Soils of abandoned areas are generally of low quality and with limited suitability for crop production; as a result soil-crop suitability analyses could form the basis of knowledge-based bio-energy planning. Agronomic and socio-economic criteria affecting the efficiency of energy crop production were analysed (Astover *et al.,* 2009; Kukk *et al.,* 2010b).

Besides named above researches was as well conducted many episodic researches. For exemple: taxonomy of Estonian soils and its harmonization with international systems (Reintam, Köster, 2006; Reintam, 2007; Kõlli, 2010), biochemically active organic compounds in soils (Szajdak *et al.,* 2005, 2006), peats decomposition ecology and kinetics in Histosols (Tõnutare, 2011) and others, which short characterization was not presented above.

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ÜLEVAADE MULLATEADUSE-ALASTEST UURIMUSTEST

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EMÜ mullateaduse ja agrokeemia osakond

Kokkuvõte

Ülevaade käsitleb EMÜ mullateaduse ja agrokeemia osakonna mullateaduse-alaseid uurimisi aastatel 2001−2010 teemade lõikes. Ülevaade koostati seoses Balti agronoomide foorumi 18. biennaaliga, mis toimus Tartus 2011. aastal 30. juunist kuni 1. juulini. Töö käsitleb peamiselt Eesti muldkatte kui loodusressursi omaduste ja kestliku majandamisega seotud probleeme, eesmärgiga tutvustada neid Balti kolleegidele ja leida võimalikke temaatikaid edaspidisteks ühisuurimusteks. Esitatud on ennekõike need uurimused, mille kohta on publitseeritud kokkuvõtvad artiklid (vt kirjanduse loetelu). Loodetavasti annab taoline esitluslaad põhjalikuma ülevaate meie kompetentsist erinevate probleemide lahendamisel.

Ülevaates käsitletud uurimisprobleemid on: mulla orgaanilise süsiniku akumuleerumise ökoloogilised seaduspärasused ja aastakäive; orgaanilise süsiniku akumuleerumine turvasmuldades ja turvastunud epipedonite keemiline koostis; huumusvormid (ehk huumuskatted) ja nende klassifitseerimine; muldade keskkonnahoiuvõime hindamine lähtuvalt ökosüsteemi tasemelt; muldade saastumine; põllumuldade toiteelementide bilanss ja seisund; muldade tihenemine ja selle seire; põllumajandusliku tegevuse mõju muldade deformatsioonile ja taimkatte produktiivsusele; muldade kasutamise ruumilise agro-ökonoomilise nõuandesüsteemi arendamine; pikaaegsete põldkatsetepõhised uurimused; Eesti muldade kompleksne iseloomustus – omadused, talitlemine, produktiivsus, ökoloogia; muldade fosforiseisund ja selle kestlik majandamine; mullateke põlevkivikarjääridel ja jäätmekuhjatistel ning nende rekultiveerimine põllumajanduslikuks kasutamiseks; muldkatet säästev (keskkonnahoidlik) maakasutus; põllumajandusliku maa potentsiaal bioenergia otstarbelise taimse massi tootmisel.

EFFECT OF DIFFERENCES IN UNREGULATED FACTORS ON YIELD OF WINTER OIL SEED RAPE AND WINTER WHEAT

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ABSTRACT. *The objective of this study: to determine the basis for the view that developing of cartograms for differentiation of growing technologies for winter oil seed rape and winter wheat needs also analyses from subsoil layer. Field characterized with wavy land form morainic hill. Growing of winter oil seed rape in season 2008/2009 followed by winter wheat in 2009/2010. 48 observation points were set to determine following parameters in both soil arable and subsoil layers: organic matter content, soil texture classes, yield of winter oil seed rape and of winter wheat. Obtained data of organic matter content and soil texture classes were used to calculate index of soil density. Crop roots mass and the length of the main root were determined in autumn after crop germination and in spring after renewal of vegetation. Found that root length and total root mass in a spring of winter oil seed rape and winter wheat is the most significant parameter what determines formation of yield. Positive effect of soil density index in both soil arable layer and in subsoil layer on winter wheat yield was explicit with a very high probability. Soil density index in subsoil layer has significant positive effect on the mass of oil seed rape roots in a spring. Significant negative effect of soil moisture in subsoil layer in hill lower slope point was established for oil seed rape and winter wheat yield.*

Keywords: *winter oilseed rape, winter wheat, precision agriculture.*

Introduction

Number of farms what implements precision farming technologies with GPS and GIS applications gradually increases in Latvia. Typically results from soil arable layer is used for differentiation of technologies and for explanation of differences in yield, as well as characteristics of photosynthetic mass is used for description of development of processes in field. Already in previous researches carried out at the Research and Study farm 'Vecauce' of Latvia University of Agriculture was determined high importance of soil agrochemical properties for differentiation of technologies (Vilde, Lapins *et al*., 2007, Dinaburga, Lapins, Kopmanis 2010). Researches on differentiation of field management technologies were carried out also in EU and USA (Moore 1997, Bourennane, Nicoullaud, *et al*., 2003). However researches with cereals and winter oil seed rape shows that crops in favourable growing conditions have very deep root system thus hypothesis can be drawn that soil subsoil layer has important role to growth and development of crops as well.

The objectives of this study: to determine the basis for the view that developing of cartograms for differentiation of growing technologies for winter wheat and winter oil seed rape needs also analyses from subsoil layer; to determine significance of root system development for precision field management technologies.

Materials and methods

Field trials were carried out at the Research and Study farm 'Vecauce' of Latvia University of Agriculture during the years 2008 to 2010 in a drained field 'Lielermani'. Field characterized with wavy mesorelief with relative height above the sea level between 88.5 and 98.6 m. Growing of winter oil seed rape cv. 'Catalina' in season 2008/2009 followed by winter wheat cv. 'Tarso' in 2009/2010. 48 observation points in a grid of 25x25 m were determined. The coordinates of observation points were defined by GPS receiver Garmin IQ 3600 using AGROCOM software AgroMAP Professional. Altitude of stationary observation points was determined by using Trimble GeoXT. On top and as well as on slopes of morainic hills in trial area eroded sod-calcareous and eroded sod-podzolic soils can be found, but sod-gley soils were found on the foot of the hills. All observation points can be divided into four groups according to their location:

- points at the toe of the slope (hereafter TS) with expressed water confluence;
- points at the slope (SL) with water runoff to the toe of the slope;
- points at the head of the hill (HH);
- points at the foot of the slope (FS) with water flow to open drainage system.

Soil analysis was done in a certified laboratory 'Valsts SIA Agroķīmisko pētījumu centrs' using nationally approved standard methods. All data are determined in two soil layers – in soil arable layer at the depth of 0−0.2m and in subsoil layer at the depth of 0.2−0.4 m. Organic matter content in trial field in soil arable layer was on average 28 g kg^{-1}, soil reaction pH_{KCl} on average 6.5, available for plants content of potassium on average 418 mg kg^{-1}, available for plants content of phosphorus on average 306 mg kg^{-1}. Soil granulometric composition was determined by using field method and described as content of physical clay (Guidelines for soil ..., 2007, 2008). Obtained data of organic matter content and granulometric composition were used to calculate index of soil density. Calculations are based on coherences between soil bulk density, organic matter content and soil texture classes (Guidelines for soil ....., 2007).

Yield of winter oil seed rape was harvested with harvester Claas Lexion 420 to create yield map using AGROCOM software, but yield of winter wheat was

determined by taking 3 plant samples in each observation point from 0.1 m^2 area. Determination of winter wheat yield formatting elements was done in the same time.

Crop roots mass and the length of the main root were determined in autumn after crop germination and in spring after renewal of vegetation. 3 oil seed rape plants and 10 winter wheat plants were taken in autumn at growth stage BBCH 11−13 and in spring at BBCH 21−22 for oil seed rape and at BBCH 25−29 for wheat. At the same time soil moisture was determined in three soil layers (0.00−0.05 m, 0.20−0.25 m, and 0.40−0.45 m) and soil penetrometric resistance in five soil layers (0.00−0.10 m, 0.10−0.20 m, 0.20−0.30 m, 0.30−0.40 m and 0.40−0.50 m).

Meteorological conditions in trial years were characterized with increase amount of precipitation in both summers of 2009 and 2010 but temperatures especially in July 2010 was highly above the long term observed (Table 1).

Table 1. The average day and night temperature and precipitation during growing season in 2009−2010 and in comparison with long term average

Month	Long-term average temperature	Temperature, ^{0}C		Long-term average precipitation	Precipitation, mm	
		2009	2010		2009	2010
May	11.2	11.0	11.9	43	18.0	72.6
June	15.1	13.7	14.6	51	95.0	37.8
July	16.6	17.1	20.8	75	136.0	131.8
August	16.0	15.8	18.2	75	38.8	133.4
September	11.5	12.9	10.8	59	39.8	78

Data analysis was performed using mathematical descriptive statistics and correlation analysis.

Results

Differences in relative height in wavy mesorelief conditions effected content of organic matter and thickness of humus horizon. Significantly increased content of organic matter was detected at the foot of slopes (Figure 1). Significant differences in content of organic matter between topsoil and subsoil layers were detected only at the top of the hills.

Thickness of humus horizon on the top of the hills (0.29 m) was significantly ($P < 0.05$) lower if compare with foot of the slopes (0.48 m). While head of the hill characterized with significantly increased content of physical clay. Differences in content of physical clay between topsoil layer and subsoil layer were not detected in any part of morainic hill area.

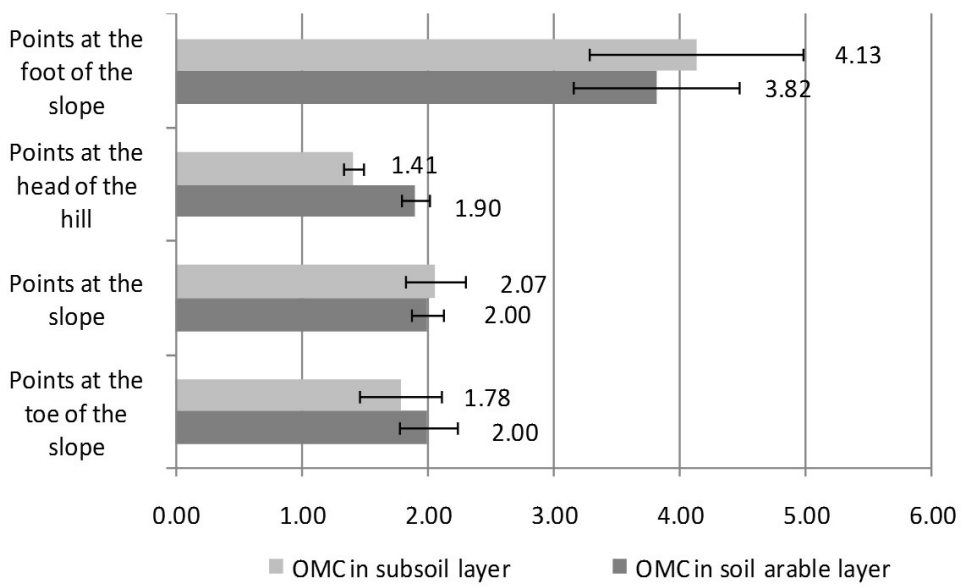

Figure 1. Organic matter content (OMC) in different groups of observations points, g kg^{-1}

Found that root mass of winter oil seed rape in spring is the most significant parameter ($r_{yx} = 0.4521$, $P < 0.001$) what determine formation of oil seed rape yield (Table 2). Also the length of main root and root mass in autumn showed significant positive effect to the winter oil seed rape yield. Positive effect to oil seed rape yield showed also biomass of oil seed rape plants in both autumn and spring time. Significant negative

effect to winter oil seed rape yield showed increase soil moisture content in spring in subsoil layer at the depth of 0.20− 0.25 m and 0.40−0.45 m. None of such unregulated factors as content of organic matter in soil arable layer and subsoil layer, thickness of humus horizon and granulometric composition showed significant effect to winter oil seed rape yield.

Table 2. Factors effected yield of winter oil seed rape, t ha $^{-1}$

Factors, x	r_{yx}
Root mass in spring, 12.05.2009 ***	0.4521
Oil seed rape biomass in spring, 12.05.2009 **	0.3932
Oil seed rape biomass in autumn, 07.10.2008 **	0.3602
Root mass in autumn, 07.10.2008 *	0.3130
The length of main root in autumn, 07.10.2008 *	0.2864
Soil moisture at 0.40−0.45 m, 27.05.2009 *	−0.3138
Soil moisture at 0.20−0.25 m, 27.05.2009 *	−0.3083

Significance: * $P < 0.05$; ** $P < 0.01$; ***$P < 0.001$.

Results showed that root mass of oil seed rape plants in spring time has positive correlation with oil seed rape biomass in spring, root mass in autumn and soil penetrometric resistance in autumn at the soil layer of 0.00−0.10 m (Table 3). Positive correlation found also between index of soil density in topsoil layer and subsoil layer as well and root mass of oil seed rape in spring. That can be explained with soil ploughing what was used for before drilling. Significant negative effect to development of root system of oil seed rape plants showed increased soil moisture in spring at the depth of 0.20 to 0.45 m.

Table 3. Factors effecting root mass of winter oil seed rape in spring

Factors, x	r_{yx}
Oil seed rape biomass in spring, 12.05.2009 ***	0.8975
Root mass in autumn, 07.10.2008 **	0.4038
Soil pemetrometric resistance in autumn before drilling at depth 0.00−0.10 m, 10.08.2008. **	0.3560
Soil density index in subsoil layer *	0.3263
Oil seed rape biomass in autumn, 07.10.2008 *	0.3247
Soil penetrometric resistance in autumn before drilling at depth 0.30−0.40 m, 10.08.2008. *	0.2690
Soil density index in topsoil layer *	0.2669
Soil penetrometric resistance in autumn before drilling at depth 0.20−0.30 m, 10.08.2008. *	0.2611
Soil penetrometric resistance in autumn before drilling at depth 0.10−0.20 m, 10.08.2008. *	0.2604
Soil moisture in autumn before drilling at depth 0.20−0.25 m, 10.08.2008 *	−0.2655
Soil moisture in spring at depth 0.20−0.25 m, 27.05.2009 *	−0.2689
Organic matter content in subsoil layer *	−0.2946
Soil moisture in spring at depth 0.40−0.45 m, 27.05.2009 *	−0.2953
Soil moisture in autumn at depth 0.40−0.45 m, 07.10.2008 *	−0.2972

Significance: * $P < 0.05$; ** $P < 0.01$; $P < 0.001$.

Significance of growth and development effecting factors differed for winter wheat when growing it after winter oil seed rape. Factors with increased positive significance ($P < 0.001$) to winter wheat grain yield were soil density index in topsoil and subsoil layers and relative height above the sea level (Table 4). Significant positive effect on the winter wheat grain yield showed also the length of the main root in the autumn, total root mass and biomass of winter wheat in a spring. Significant negative ($P < 0.01$) relationship found between winter wheat grain yield and increased soil moisture and soil penetrometric resistance in subsoil layer.

Table 4. Factors effected yield of winter wheat grain yield, t ha $^{-1}$

Factors , x	r_{yx}
Soil density index in topsoil layer ***	0.7598
Soil density index in subsoil layer ***	0.7431
Relative height above the sea level ***	0.6121
Soil penetrometric resistance in spring at depth 0.00−0.10 m, 11.05.2010. ***	0.4798
Root mass in spring, 11.05.2010. **	0.3740
Biomass of one wheat plant in spring, 11.05.2010. **	0.3449
The length of main root in spring, 11.05.2010. **	0.3389
Root mass in autumn, 26.11.2009. *	0.3094
Soil penetrometric resistance in spring at depth 0.10−0.20 m, 11.05.2010. *	0.3043
Soil penetrometric resistance in autumn at depth 0.10−0.20 m, 19.08.2009 *	0.2710
Biomass of one wheat plant in autumn, 26.11.2009 *	0.2708
Soil penetrometric resistance in autumn at depth 0.00−0.10 m, 19.08.2009 *	0.2434
Soil moisture in spring at depth 0.00−0.05 m, 11.05.2010 *	−0.2579
Soil moisture in spring at depth 0.40−0.45 m, 11.05.2010 *	−0.2613
Soil penetrometric resistance in autumn at depth 0.40−0.50 m, 19.08.2009 *	−0.2890
Soil moisture in spring at depth 0.20−0.25 m, 11.05.2010 **	−0.4169
Soil penetrometric resistance in sprig at depth 0.30−0.40 m, 11.05.2010. **	−0.4833
Soi penetrometric resistance in spring at depth 0.40−0.50 m, 11.05.2010. ***	−0.6109
Organic mater content in topsoil layer ***	−0.6498
Organic matter content in subsoil layer ***	−0.6603

Significance: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

High ($P < 0.001$) and significant negative linear correlation between increased content of organic matter and winter wheat grain yield can be explained by multicorrelative coherence. Increased content of organic matter was observed in lower parts of morainic hill slopes what characterized with increased soil moisture. Negative significant relationship decreases when using partial correlation analyses between organic matter content in topsoil and subsoil layers and winter wheat grain yield if adding soil moisture and soil penetrometric resistance as controlling variables (Table 5).

Positive effect to root mass of winter wheat in spring showed soil density index in both soil arable layer and in subsoil layer what shows importance of this factor to ensure development of high crop yields (Table 6).

Table 5. Analyses of coherence between winter wheat grain yield, t ha^{-1}, and organic matter content

Factor , *x*	r_{yx}, without controlling variables	r_{yx}, if using soil moisture data in spring at depth 0.20−0.25 and 0.40−0.45 m as controlling variables	r_{yx}, if adding soil penetrometric resistance data in spring at depth 0.3−0.4 and 0.4−0.5 m as controlling variables
Organic matter content in topsoil layer	−0.6498 ***	−0.6039 **	−0.5100 **
Organic matter content in subsoil layer	−0.6603 ***	−0.6078 **	−0.5459 **

Significance: ** $P < 0.01$; *** $P < 0.001$.

Table 6. Factors effecting root mass of winter wheat in spring

Factors, *x*	r_{yx}
Biomass of one wheat plant in spring, 11.05.2010. ***	0.8975
Soil density index in subsoil layer *	0.3263
Biomass of one wheat plant in autumn, 26.11.2009. *	0.3247
Soil density index in topsoil layer *	0.2669
Soil penetrometric resistance in spring at depth 0.2−0.3 m, 11.05.2010. *	0.2611
Organic matter content in subsoil layer *	−0.2946
Soil moisture in spring at depth 0.20−0.25 m , 11.05.2010 *	−0.2957

Significance: * $P < 0.05$; ** $P < 0.01$; $P < 0.001$.

Evaluating effect of wavy mesorelief on yield of winter oil seed rape and winter wheat it have to be taken into consideration that trial area has good drainage system and field is well cultivated. Crop did not suffered from accumulation of precipitation on soil surface and crop drowning in springs and autumns. In such conditions winter oil seed rape cv. 'Catalina' showed more stable yield level compare to winter wheat cv.'Tarso' (Figure 2). Yield decrease of winter wheat was significant in field areas with lowest relative height above the sea level and with runoff to open drainage system.

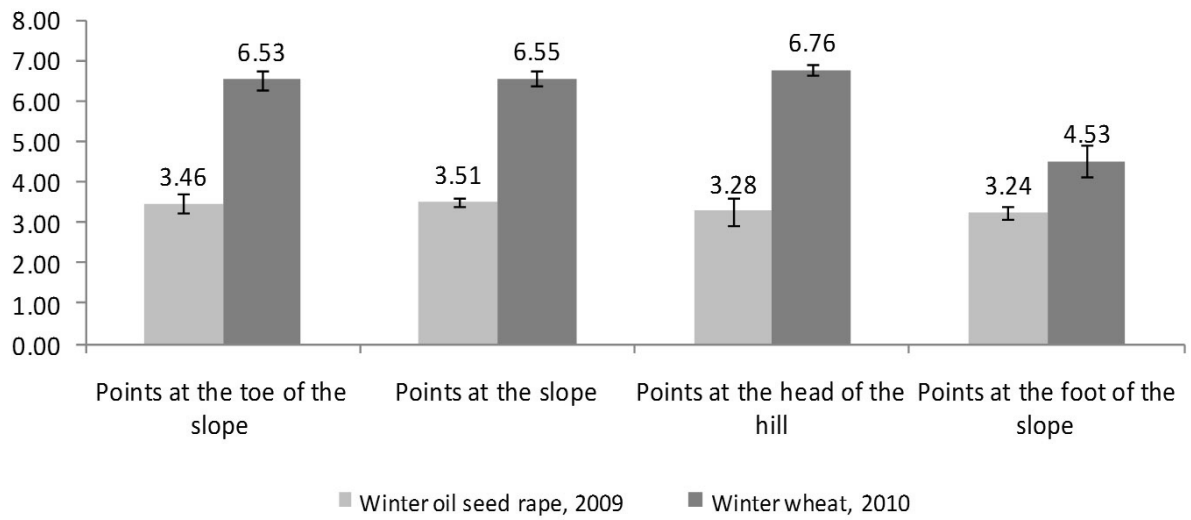

Figure 2. Effect of relief to yield of winter oil seed rape and winter wheat, t ha^{-1}

Discussion

Trial results shows that the view that agrochemical and agrophysical analyses from subsoil layer is important as well for developing of cartograms for differentiation of growing technologies for winter wheat and winter oil seed rape. It is partly proved also in authors previous researches (Vilde, Lapins *et al*., 2007, Dinaburga, Lapins, Kopmanis 2010). Researches on differentiation of field management technologies taking into account specific relief forms and characteristics of subsoil layer were carried out also in EU and USA (Moore 1997, Bourennane, Nicoullaud, *et al*., 2003; Si, Farrell 2004; Shepdt, Nikitina 2009; Kadžiene 2009; Ferrara, Trevisiol *et al*., 2009). Soil density index can be easily and successfully used for evaluation of potential possibilities for growing winter oil seed rape and winter wheat (Guidelines for soil ..., 2007, 2008). Organic matter content is determined during inspection for soil agrochemical properties, but soil texture class to determine clay content can be managed by farm's agronomist himself. Significance of crop root system for yield formation shows further possibilities to investigate and use this factor for precision farming, although some researches has been made in this direction as well (Wallace, Mielke *et al*., 1982; Barracloung 1989; Barzegar, Mossavi *et al*., 2004). However root system is determined by genotype and it have to be specified for each individual cultivar.

Conclusions

Differences in relative height in wavy mesorelief conditions effected content of organic matter and thickness of humus horizon although differences in content of organic matter between topsoil and subsoil layers were detected only at the top of the hills.

Thickness of humus horizon on the top of the hills was significantly lower if compare with foot of the slopes while head of the hill characterized with significantly increased content of physical clay.

Root mass of winter oil seed rape in spring is the most significant parameter what determine formation of oil seed rape yield. Also the length of main root and root mass in autumn showed significant positive effect to the winter oil seed rape yield, but significant negative effect to winter oil seed rape yield showed increase soil moisture content in spring in subsoil layer at the depth of 0.20−0.25 m and 0.40−0.45 m.

Root mass of oil seed rape plants in spring time had positive correlation with oil seed rape biomass in spring, root mass in autumn and soil penetrometric resistance in autumn at the soil layer of 0.00−0.10 m.

Factors with positive significance to winter wheat grain yield were soil density index in topsoil and subsoil layers, relative height above the sea level, the length of the main root in the autumn, total root mass and biomass of winter wheat in a spring. Significant negative relationship found between winter wheat grain yield and increased soil moisture and soil penetrometric resistance in subsoil layer.

Positive effect to root mass of winter wheat in spring showed soil density index in both soil arable layer and in subsoil layer.

In wavy mesorelief area with good drainage system and in well cultivated fields winter oil seed rape cv. 'Catalina' showed more stable yield level compare to winter wheat cv.'Tarso'.

Yield decrease of winter wheat was significant in field areas with lowest relative height above the sea level and with runoff to open drainage system.

Acknowledgements

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KVALITATIIV- JA KVANTITATIIVMEETODIL VALMISTATUD KÜTTESEGU HINDAMINE MOOTORMEETODIL

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ABSTRACT. *In the article the research results concerning the possible uses of alternative fuels and their feeding methods in diesel engines are presented. The alternative fuel-air mixture under study comprises diesel fuel, liquid fuel made of lignocellulose raw materials, and fuel additive improving the cetane number of the mixture. The quantitative correlation of fuel components and their methods of use in a diesel engine are determined by optimizing different fuel-mixing methods. In order to evaluate the composition of the fuel-air mixture, qualitative and quantitative mixing methods are used. In the research paper different mixing methods of fuel components and the influence of created fuel-mixtures on the combustion process are analyzed. The possible methods of use of the fuel-mixture under study in a diesel engine are analyzed. The composition of a local alternative fuel-air mixture is developed and motor method is used to test its methods of use. The physical-chemical properties of the alternative fuel-air mixture are evaluated by measuring the indicator factors and output parameters of the engine. In the article a recommended practice is presented as for how to create an alternative fuel-air mixture and how to use it in diesel engines. The author also evaluates the perspective of developing this kind of an alternative air-fuel mixture.*

Keywords: *qualitative and quantitative fuel mixing methods, indicator index of combustion process, adjustment characteristic of the injection pumps and diesel engines.*

Sissejuhatus

Impordil põhinev vedelkütuseturg ja selle kujundatav mootorikütuse hind muutub tarbijale üha kallimaks. Energiakandjate kõrged hinnad mõjutavad otseselt pakutavate toodete ja teenuste konkurentsivõimet ja tarbijaskonna ostuvõimet. Üks olukorra leevendamise tee on alternatiivsete mootorikütuste, näiteks etanoolkütus, kasutuselevõtt. Eestis on olemas ajaloolised traditsioonid etanooli tootmiseks, kuid puuduvad kogemused selle kasutamisega mootorikütusena. Etanoolil on mitmeid puudusi, miks seda ei saa kasutada mootoris põhikütusena, näiteks: diislikütusest madalam eripõlemissoojus, põlemisprotsessi endotermiline iseloom, halb segunemine teiste kütustega, väikesed määrimisomadused, halvad käivitusomadused ja puhta etanooli tootmise kõrge hind.

Artiklis esitatakse uurimistulemused kohalikust lignotselluloossest toormaterjalist valmistatud etanooli kasutamiseks diiselmootori lisandkütusena. Analüüsitakse uuritavate kütusesegude võimalikke kasutusmeetodeid ja nende mõju diiselmootori põlemisprotsessile. Küttesegu koostise hindamisel kasutatakse kvalitatiivseid ja kvantitatiivseid segumoodustusviise. Kütusekomponentide vahekord küttesegus ja nende kasutusmeetodid määratakse kindlaks erinevate segumoodustusviiside optimeerimise teel. Töötatakse välja minimaalse kontsentratsiooniga etanoolkütus, mille füüsikalis-keemilisi omadusi ja kvaliteeti hinnatakse mootori põlemisprotsessi indikaatornäitarvude ning mootori väljundparameetrite mõõtmisega stendikatsetustel. Artiklis esitatakse tehniline lahendus alternatiivkütuse kasutamiseks diiselmootoris. Samas antakse hinnang väljavalitud alternatiivkütuse kasutamise perspektiivsuse kohta vabariigis. Artikli autorite pakutava lahenduse uudsus seisneb selles, et mootoril kasutatakse kahte toitesüsteemi: põhi- ja abitoitesüsteem, millega tagatakse vastavalt baaskütuse juhtpritse ja lisandküttesegude manustamine etteantud koormusrežiimile. Selline lahendus kindlustab mootori hea käivitumise ja selle töötamise laias töörežiimide vahemikus. Lisandkütus suunatakse tööprotsessi sisselaskekollektori kaudu.

Uurimustöö eesmärk on leida minimaalne etanoolsegu kontsentratsioon, millega mootor on võimeline töötama testplaani ülekoormuspiirkonnas rahuldavalt. Stendikatsetustel kasutati etanoolkütuseid kontsentratsiooniga 90%; 80%; 70% ja 60%. Mootoris toimuva põlemisprotsessi analüüs näitas, et kvalitatiivsel ja kvantitatiivsel teel erinevate kütuste suunamine põlemisprotsessi on tehniliselt lubatav. Seda tõestasid mootori D-120 stendikatsetused. Katsetustel selgus, et 60% etanoolkütus töötab hästi mootori lisandkütusena ja ei tekita mootorile tehnilisi tõrkeid. Pärast keskpikka katsetuste tsüklit etanoolkütustega ei halvenenud katsemootori indikaatornäitarvud ega surveprotsessi lõpprõhk. Baaskütuse pilootpritse vähenemisest tingitud võimsuskao saab kompenseerida etanoolkütuse lisamisega. Etanoolkütuse tootmistehnoloogia on suhteliselt lihtne ja odav. Kuni 70-protsendilise etanooli tootmisega saab tänapäeval hakkama iga farmer. Mootori kohandamiseks etanoolkütusele piisab täiendavast karbureerimisseadmest. Etanooli kasutamine mootorikütusena suurendab energiajulgeolekut, vähendab oluliselt ettevõtjate maksukoormust, toodangu omahinda ja keskkonna saastet.

Metoodika

Etanooli kasutamist mootorikütusena on uuritud põhjalikult juba XX sajandil. Mitmetes riikides, nagu Brasiilia, USA, Boliivia, Uruguai, Saksa LV ja Rootsi, kasutatakse täna etanooli mootori põhikütusena. Välja on töötatud mootorikütuste tehnoloogiad ka etanooli ja

mootoribensiini ning etanooli ja diiselkütuse segude kasutamiseks. Olulisemad sellealased uurimustööd on toodud mitmetes patentides, näiteks WO 2009106647, ning artiklites (Demirbas, 2006; Bialkowski, 2009). Vaatamata läbiviidud uuringutele ja olemasolevatele tehnoloogiatele on Euroopa Liidus täna mitmeid riike, kus alternatiivkütuseid veel ei kasutata. Järelikult on olemas mitmeid objektiivseid faktoreid ja seadusandlikke puudusi, mis takistavad seda tegemast. Nimetatud faktorite väljaselgitamine peaks olema tänaste uurimistööde prioriteet. Osa faktoreid käsitletakse ka käesolevas uurimustöös.

Eesti geograafiline asukoht, vaba tootmismaa olemasolu, elanikkonna kõrge haridustase ja selle traditsiooniline side põllumajanduslikku tootmisega loovad head võimalused kaasaegsete, kohalikust lignotselluloossest toormaterjalist valmistatud vedelkütuste väljatöötamiseks, tootmiseks ja kasutamiseks. Merekliima ja geograafiline laiuskraad mõjutavad Eesti riigi kütuste tootmis- ja kasutustehnoloogiate spetsiifikat. Olulisemaid faktoriteid on õhutemperatuuri ja -niiskuse muutumine aasta lõikes laiades piirides ja eri kombinatsioonides. Eesti Vabariigis kasutatav mootorikütus peab võimaldama mootoril töötada temperatuurivahemikus + 40…– 40^0C. Täiendav geograafiline mõjufaktor on Venemaa turu lähedus. Üldteada on fakt, et Venemaa on maailmas üks suurimaid ahju- ja mootorikütuste tootjaid. Venemaa ei ole tootnud alternatiivkütuseid ega kavatse seda ka lähitulevikus teha. Endiste liiduvabariikide kütusevajadused kaeti fossiilsete kütustega. Ka täna tuuakse Eestisse olulisel määral Euroopa Liidu standarditele mittevastavat kütust. Viitamata ei saa jätta ka faktile, et Venemaa masinaehitusturu lähedus mõjutab meie kütuseturgu. Venemaa põllundustehnika suhteline odavus soosib Eesti farmereid hankima ja kasutama Venemaal toodetud masinaid. Eestis on hetkel kasutuses olevatest traktoritest *ca* 82% toodetud SRÜ-s. Samas on nende traktorite valmistuskvaliteet väga kõikuv.

Uurimistöö eesmärgiks püstitati võimalikult madala kontsentratsiooniga etanoolisegu väljatöötamine ja selle kasutamine mootori lisandkütusena. Ajendiks oli innustada farmereid tootma kohalikke alternatiivkütuseid ilma rektifitseerimis- ja segamisprotsesse kasutamata. Täiendavalt uuriti võimalusi, kuidas minimaalsete kulutustega kohandada enamlevinud põllumajanduslik traktor ümber etanoolkütuste kasutamiseks. Uurimise alla võeti etanoolisegud kontsentratsioonidega 90%, 80%, 70% ja 60%.

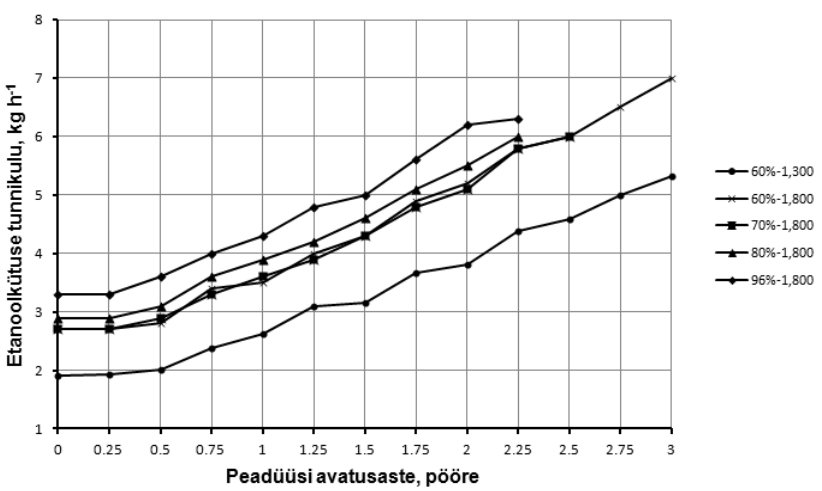
Etanoolkütuse manustamiseks kasutati karburatsiooni tekitavat lisaseadet, mis ühendati mootori sisselaskekollektoriga. Antud meetodil saab kütust manustada sisselaskeklapi avatusperioodil. Mootori põlemisprotsessi toimumiseks vajalikku tsüklietteande kogust (pilootpritse) muudeti standardse toiteaparatuuri abil. Viimase ülesanne on käivitada mootor ja tagada pritsemomendi ajastatus sõltuvalt mootori töörežiimist. Edasise mootori töörežiimide juhtimise tagab operaator etanoolsegu lisamisega. Katsemootori küttesegu koosnes summaarselt järgmistest komponentidest: diiselkütus, etanool, õhk ja vesi.

Tulemused ja arutelu

Diiselmootori etanoolkütuse valik

Uurimuse eesmärgil viidi läbi seeria katsetusi 60%, 70%, 80% ja 90%-se kontsentratsiooniga etanoolkütusega. Katsete käigus mõõdeti põhilised mootori väljundparameetrid, vastavad indikaatordiagrammid ja heitgaaside koostised. Katsetingimused olid: väntvõlli pöörlemissagedus vastas nimipöörlemissagedusele ($n_{e.nom}$); pritsemoment vastas nimimomendile ($\alpha_{i.nom}$); mootori pöördemoment (T_e) oli konstantne; regulaatorihoova ja hammaslati asendid varieerusid. Katse käigus muudeti etanoolkütuse pealeandmise kogust. Katsetulemused on esitatud joonistel 1…3.

Jooniselt 1 nähtub, et karburatsiooni tekitava seadme peadüüsi tootlikkus sõltub etanoolkütuse kontsentratsioonist ja mootori väntvõlli pöörlemissagedusest. Etanoolkütuse tunnikulu ja peadüüsi avatusastme vaheline funktsionaalne seos on ligikaudu lineaarse sõltuvusega.

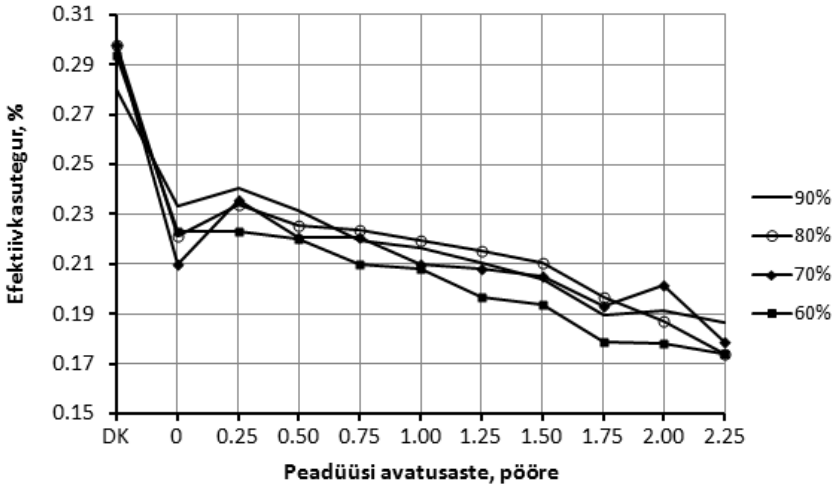


Joonis 1. Etanoolkütuste tunnikulu sõltuvus peadüüsi avatusastmest, valmistamise kontsentratsioonist ja väntvõlli pöörlemissagedusest (n_e = 1,300…1,800 min^{-1})

Figure 1. *Fuel consumption depending on main metering jet opening ratio by different ethanol fuel concentration (60…96%) and crankshaft rotational speed (n_e = 1,300…1,800* rpm*)*

Mootori väljundparameetrite analüüsi põhjal saab teha järgmised järeldused (joonis 2, 3):

1) mootori efektiivkasutegur sõltub etanoolkütuse kontsentratsioonist;
2) mootori kasutegur väheneb etanoolkütuse kasutamisel võrreldes diislikütusega kuni 30%;
3) 90% etanoolkütus suurendab mootoritöö efektiivsust võrreldes 60% etanoolkütusega 6…8%.



Joonis 2. Mootori efektiivkasuteguri sõltuvus etanoolkütuse kontsentratsioonist ja peadüüsi avatusastmest nimikoormusel (DK – diislikütus)

Figure 2. *Effect between the actual efficiency and opening ratio of main metering jet by different ethanol fuel concentration on the mode of nominal rotational speed (DK – diesel fuel)*

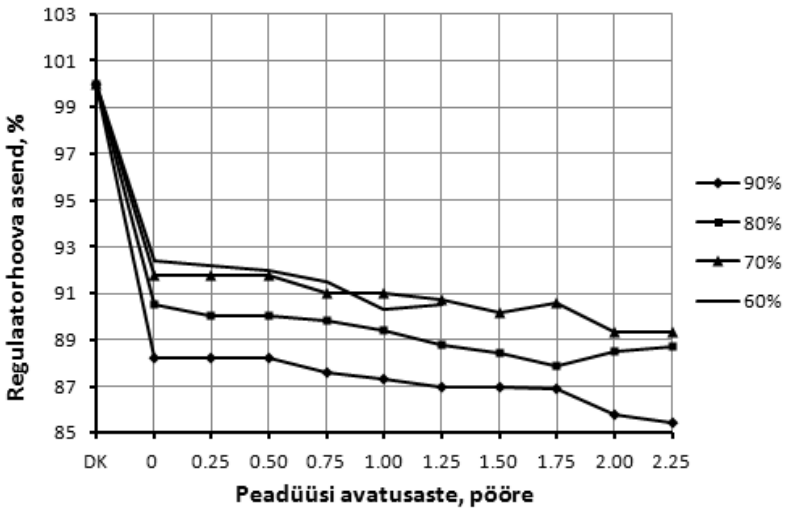
60% etanoolkütuse kasutamise analüüsi põhjal saab teha järeldused:

1) 60% -list etanoolkütust võib diislikütusele lisada kuni 3…4 kg h^{-1};
2) lühiajalise ülekoormuse korral võib vastavat kütust lisada kuni 5 kg h^{-1};
3) etanoolkütuse lisamisel 5.5 kg h^{-1} ja rohkem langeb mootoritöö efektiivsus järsult: põlemisprotsess muutub hilisemaks 14…16 väntvõlli pöördenurga kraadi ja põlemisprotsessi lõpprõhk väiksemaks 10…12 bar.

Ülejäänud, s.o 70%, 80% ja 90% kontsentratsiooniga etanoolkütuste kasutamise kohta saab teha järgmised järeldused:

1) kõikide eespool nimetatud etanoolkütuste pealeandmine kuni 2.5 kg h^{-1} lisaks põhikütusele ei muuda praktiliselt mootori D-120 põlemisprotsessi algparameetreid ($p_{z..max}$ = 50 bar ja $\alpha_{pz.max}$ = 10°);
2) mida suurem on etanoolkütuse kontsentratsioon, seda suurem on selle tunnikulu;
3) 80% ja 90%-lise kontsentratsiooniga etanoolkütuste kasutamisel on indikaatorrõhu muutuse kiirus $\Delta p \Delta \alpha^{-1}$ suurem ja põlemisprotsessi II faas püsivam kui 60% ja 70% etanoolkütuste kasutamisel;
4) seevastu on madalama kontsentratsiooniga etanoolkütuse põlemisprotsessi rõhutõus laugjam, mis lubab vastava kütuse suuremakoguselist kasutamist, ilma et mootoritöö oluliselt halveneks (joonis 3);
5) samas 90%-lise etanoolkütuse lisamisel koguses 5.5 kg h^{-1} ja rohkem põlemisprotsessi lõpprõhk väheneb 13 bar ning põlemisprotsess muutub hilisemaks kuni 10 kraadi.

Etanoolkütuste kasutamisel on vaja teada toiteaparatuuri väljastatud pilootpritse kogust, mida mootor saab konkreetsel koormusrežiimil. Selleks kasutati kõrgrõhupumba reguleerimiskarakteristiku andmeid, mis on esitatud tabelis 1. Katsemootori maksimaalne koormusrežiim on n_e = 1,300 min^{-1}, mis vastab kõrgrõhupumba kiirus-režiimile n_{fp} = 650 min^{-1}.



Joonis 3. Regulaatorhoova asendi sõltuvus seadme peadüüsi avatusastmest erinevate etanoolkütuste kasutamisel ja väntvõlli nimipöörlemissagedusel
Figure 3. *The effect between opening ratio of the covernor level and opening ratio of main metering jet by different ethanol fuel concentration on the mode of nominal rotational speed*

Tabel 1. Kõrgrõhupumba tsüklietteande sõltuvus hammaslati asendist ja pumba nukkvõlli pöörlemissagedusest
Table 1. *The effect of camshaft rotational speed and position of control rack to pump fuel delivery*

Nukkvõlli pöörlemis-sagedus (min^{-1})	Hammaslati asend (mm) ja sellele vastav tsüklietteanne (mm^3 tsükkel^{-1})								
	0	1	2	3	4	5	6	7	8
400	0	6.3	17.5	25.0	37.5	50.0	65.0	85.0	105.0
500	0	6.0	18.0	31.0	40.0	54.0	67.0	84.0	101.0
600	0	8.0	19.7	34.1	44.3	57.0	72.1	86	102.7
650	0	9.0	20.6	35.6	46.5	58.5	74.6	87	103.5
700	0	10.0	21.4	37.1	48.6	60.0	77.1	87.9	104.3
800	0	12.2	23.9	37.5	49.0	60.9	76.4	88.4	105
900	0	14.4	23.3	37.8	49.4	61.7	75.6	88.9	105.6
970	1.6	12.9	23.2	38.1	50.5	60.8	73.2	88.7	106.2

Heitgaaside analüüsitulemused

Segukoostistegur

Diiselmootorites toimub kvalitatiivne segumoodustus. Segukoostistegur (λ_a) väljendab ühe kilogrammi kütuse põlemisest tegelikult osavõtva õhukoguse ($V_{O2.teg}$) ja teoreetiliselt selleks vajamineva õhukoguse ($V_{O2.teor}$) suhet.

$$\lambda_a = \frac{V_{O2.teg}}{V_{O2.teor}} = \frac{B_{a.teg}}{\left(B_{a.teor} \cdot B_f\right)} = \frac{B_{a.teg}}{\left(14.5 \cdot B_f\right)}.$$

Õhu kogus, mis võtab osa ühe kilogrammi kütuse põlemisest mootori silindris, on tegelik õhukogus ($B_{a.teg}$). Mootori töötamisel võivad tegelik ja teoreetiliselt vajalik õhukogus ($B_{a.teor}$) olla järgmistes vahekordades:

$$B_{a.teg} \le B_{a.teor}\text{, siis } \lambda_a \le 1;$$
$$B_{a.teg} = B_{a.teor}\text{, siis } \lambda_a = 1;$$
$$B_{a.teg} \ge B_{a.teor}\text{, siis } \lambda_a \ge 1.$$

Koormuskarakteristiku korral, kus mootori pöörlemissagedus on püsiv muutub tarvitatav õhukogus vähe ja võimsuse reguleerimine toimub B_f muutmise teel. Seega muutub λ_a laias diapasoonis. Värske küttesegu (M_{vk}) kogus moolides määratakse järgmise valemiga:

$$M_{vk} = \lambda_a \cdot V_{02.teor} + \frac{1}{\mu_k},$$

kus μ_k – kütuse aurude molekulaarmass ($\mu_{k.diiselküte}$ = 180…200 kg kmol^{-1}). Arvestades suhtarvu 1 μ_k^{-1} väiksust, võime värske küttesegu hulga määrata seosega:

$$M_{vk} = \lambda_a \cdot V_{02.teor}.$$

Kütuse-õhusegu põlemisproduktide koostis ja maht kilomoolides (M_r) on võrdne:

$$M_r = M_{CO} + M_{CO2} + M_{HC} + M_{N2} + M_{H2} + M_{O2}.$$

Kiirekäigulise diiselmootori nimirežiimil on segukoostisteguri väärtused piirides 1.3…2.3 (Merker *et al.*, 2004). Väiksemad segukoostisteguri väärtused vastavad forsseeritud diiselmootoritele, mis eristuvad teistest mootoritest väiksema õhuerikuluga. Samas väiksemad λ_a väärtused saavutatakse suurematel koormusrežiimidel, kus esineb kütuse keemiliselt mittetäielik

põlemine. Sellega kaasneb CO, põlemisgaaside temperatuuri tõus ja vaatamata vähese hapniku hulgale küttesegus ka NO_x hulga suurenemine. Lubatud λ_a piirväärtus regulaatorkarakteristiku alusel nimipöörlemissagedusel on $\lambda_{a.nom} = 2.78$.

Segukoostisteguri mõõtmistulemused 60% etanoolkütuse korral: koormusrežiimi kasvades segukoostistegur väheneb kuni kaks korda. Peadüüsi ristlõikeava suurenedes ($B_{f.et}$ kasvab) segukoostistegur väheneb kuni 25%. Katseandmetest nähtub, et λ_a parameeter ei sea piire etanoolikoguse kasutamise hulgale. Pigem on tendents segukoostisteguri väärtuse kahanemisele etanoolihulga kasvades küttesegus. Katseandmete alusel saab teha segukoostisteguri mõjust heitgaaside koostise kohta järgmised järeldused:

a) CO on kõige väiksem piirkonnas, kus $\lambda_a = 1.4…2.0$;
b) λ_a muutumisel CO kasvab kiiresti;
c) NO_x ja CO_2 väärtused on maksimaalsed piirkonnas, kus $\lambda_a = 1.4…2.0$;
d) λ_a vähenedes HC väheneb monotoonselt;
e) soovitav mootori töörežiim on nimirežiim, seal eraldub vähem CO ja HC;
f) heitgaaside koostist mõjutavad kõige rohkem mootori tühikäigu-, ülekoormus- ja kiirendusrežiimid.

Vingugaas

Vingugaas (CO) on värvitu, lõhnatu ja maitsetu gaas ning sissehingamisel mürgine. Kopsudes ühineb verega ja takistab hapniku absorbeerumist. Kõrge vingugaasisisaldus õhus põhjustab teadvuse kaotuse ning surma. Vingugaas põleb hästi, tema tihedus on õhuga võrreldes 0.97. Vingugaasi maht põlemisprotsessi keskstaadiumis moodustab 1…6% põlemiskambri mahust. Väljalaskeprotsessi alguseks muutub vingugaasi põhimass süsinikoksiidiks. Vingugaasi täielikku oksüdeerimist silindris takistab hapniku puudujääk ja põlemiskiiruse langus. Sõltuvalt mootori konstruktsioonist, selle tehnilisest seisukorrast ja mootori töörežiimist võib CO kontsentratsioon heitgaasides muutuda piirides 0.001…1%. Tootmishoonetes on CO lubatud piirkontsentratsioon 0.02 mg l^{-1} või 0.0016%.

Järgmised katsetulemused on esitatud 60% etanoolkütuse kasutamise kohta. Koormusrežiimi kasvamisel kõikide peadüüsi avatusastmete korral CO hulk heitgaasides väheneb. Ilmekas seos kehtib etanooli tunnikulu $B_{f.et} = 3.0$ kg h^{-1} ja rohkem korral, kus CO sisaldus heitgaasides erinevatel režiimidel erineb kuni 41%. Samas konkreetsel koormusrežiimil etanooli tunnikulu suurenedes kasvab CO kogus heitgaasides monotoonselt. Koormusrežiimil, kus $V_f = 35.6$ mm^3 tsüklis^{-1} oli CO koguse erinevus peadüüsi alg- ja lõppavatuse korral heitgaasides 0.059 mahu% (24%).

Süsinikdioksiid

Süsinikdioksiid (CO_2) on värvitu nõrgalt kirbe lõhnaga ja mitte mürgine gaas. Õhu ja kütuse põlemisel tekkiv CO_2 tõuseb atmosfääri ja moodustab ümber maakera süsinikdioksiidi kihi. Maakeralt peegelduv soojus ei suuda läbida atmosfääris olevat süsinikdioksiidivööd, mistõttu koos päikesekiirgusega liituv soojushulk tõstab maakera keskmist temperatuuri. Teatud kriitilise CO_2 mahu korral atmosfääris võib tekkida maakeral kasvuhoone efekt. Seetõttu on oluline, et mootorite poolt õhku paisatav CO_2 ei omaks kasvutendentsi.

Järgmised katsetulemused on esitatud 60% etanoolkütuse kasutamise kohta. Koormusrežiimide kasvamisel ($V_f = 20.6$; 35.6 ja 46.5 mm^3 tsüklis^{-1}) ja erinevate peadüüsi avatusastmete korral CO_2 hulk heitgaasides kasvab. Ilmekas seos kehtib etanooli tunnikulu $B_{f.et} = 3.0$ kg h^{-1} korral, kus vastav erinevus ulatub kuni 4.16 mahu% (57%). Konkreetsel koormusrežiimil etanoolkütuse tunnikulu suurenedes kasvab ka CO_2 kogus heitgaasides. Koormusrežiimil, kus $V_f = 46.5$ mm^3 tsüklis^{-1} oli CO_2 koguse erinevus peadüüsi alg- ja lõppavatuse korral heitgaasides kuni 2.65 mahu% (28%).

Süsivesinikud

Heitgaasid sisaldavad eri liike süsivesinikuühendeid (HC), mis on üldjuhul tervisele ohutud ja mille organism ära tarvitab. Samas esineb süsivesinike hulgas ühendeid, mis on mürgised, vähkitekitavad, silma-kurgu limaskesta ärritavad. Suur kogus süsivesinikke õhus põhjustab happevihmu ja fotokeemilist sudu. Mootori heitgaasides olevate HC-de hulk on normeeritud.

Katsetulemused 60% etanoolkütusega näitavad, et väikestel koormustel, kus pilootpritse kogus on väike, esineb küttesegu mittetäielik põlemine ja HC hulk heitgaasides kasvab. Kõrgematel koormusrežiimidel, kus pilootpritse kogus on suurem, väheneb HC hulk heitgaasides monotoonselt, sõltumata etanoolkütuse tunnikulu kasvamisest.

Hapnik

Hapnik (O_2) on värvuseta, lõhnata ja maitseta õhust raskem gaas, mis vees lahustub halvasti. Hapnik on tugev oksüdeerija, oksüdeerides lihtaineid ja ühendite koostisesse kuuluvaid elemente oksiidideks. Lihtainena leidub hapnikku õhus, kus teda sisaldub mahu järgi 21% (1/5) ja massi järgi 23%. Diislikütuses hapnik praktiliselt puudub. Etanoolkütuses ja õhus olev hapnik liituvad diislikütusega silindris küttesegu moodustamisel.

Lämmastikoksiidid

Põlemisprotsessi kõrgete temperatuuride juures tekib lämmastikdioksiid (NO_2). Nimetatud gaas on redisepruuni värviga, mürgise lõhnaga ja vees raskesti lahustuv. Sissehingamisel võib kahjustada kopsukudesid. NO_2 tihedus õhuga võrreldes on 1.58. NO_2 hulk diiselmootori heitgaasides muutub piirides 0.001…0.2%. Lubatud NO_2 hulk õhus, arvutades ümber N_2O_5 kujul, ja selle kontsentratsioon võib olla kuni 0.005 mg liitri^{-1} kohta ehk 0.0001%. Lämmastikoksiidid veega ühinedes tekitavad happevihmasid, mis on aga lahjendatud lämmastikhape ning põhiliselt kahjutu loodusele. Teatud kontsentratsiooni, kõrguse, niiskuse ja päikesekiirguse juures lämmastikoksiidid ja süsivesinikud moodustavad sudu. Lahja küttesegu ja kõrge temperatuuri juures töötavate mootoritega võib õhku paisata piisavalt suure koguse lämmastikoksiide, mis võivad atmosfääris esile kutsuda happevihmasid.

Katsetulemused 60% etanoolkütusega näitavad, et väikestel koormusrežiimidel töötaval mootoril NO_x sisal-

dus heitgaasides on stabiilne ja kuni 10 korda väiksem lubatud piiridest. Suurtel koormustel lämmastikoksiidi hulk heitgaasides kasvab kuni 650 mahu ppm-ni, kuid ei ületa heitgaasides ettenähtud piirväärtusi.

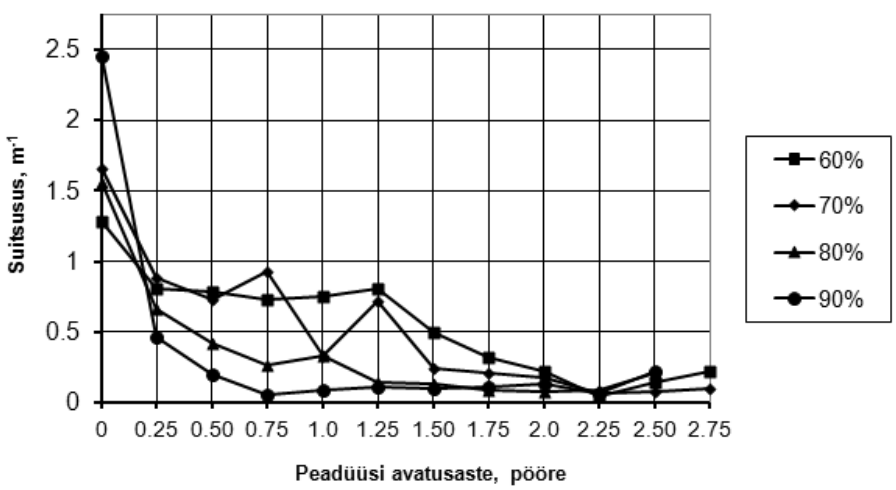
Diiselmootori suitsusus

Suitsusus on tingitud heitgaasides olevate üliväikeste tahke süsiniku (tahm = nõgi) osakeste kaalutud olekus, mis tekivad diiselkütuse pürolüüsil põlemisprotsessis. Põlemisprotsessis toimuvad paralleelselt tahma tekkimine ja selle väljapõletamine. Hästi ettevalmistatud küttesegu kiirel põlemisel algab kohe pärast selle süttimist intensiivne tahma moodustamine. See protsess toimub kiiremini kui väljapõlemine. Järgnevas põlemisprotsessi arengus hakkab tahma väljapõlemine domineerima selle tekkeprotsessi üle. Viimase kütuseportsjoni põlemisprotsessis tahma tekkimine lõpeb ja selle väljapõlemine jätkub kuni vahetult väljalaskeklapi avamiseni. Silindris väljalaskeprotsessi algul tahma tekkeprotsessi suurust saab hinnata diiselmootori heitgaaside suitsuse taseme järgi. Küttesegu turbulatsiooni intensiivistamisega on võimalik lisada põlemiskolletesse hapnikku. Selle tulemusena väheneb tahma tekkimise protsess ja suureneb ajalises mõõtmes tahma väljapõlemisprotsess. Põlemisprotsessis tekkiv leegi maksimaalne temperatuur ületab olulisel määral heitgaaside maksimaalset temperatuuri (Pulkrabek, 2009). Leegi temperatuur saavutab maksimaalse väärtuse *ca* 14…16 kraadi peale ÜSSi. Järgneva 50 väntvõlli pöördenurga kraadi jooksul leegi temperatuur praktiliselt ei muutu.

Faktorid, mis mõjutavad heitgaaside koostist ja suitsust diiselmootori tööprotsessis, võib jaotada kolme rühma: a) konstruktiivsed faktorid (seotud mootori ehitusega ja ekspluatatsioonis muuta ei saa); b) ekspluatatsioonilised faktorid ja reguleeringud; c) mootori ekspluateerimise kvaliteet (kütus, õlid, tehnohoolde järjepidevus, töörežiimide jälgimine, jms). Heitgaaside koostist mõjutavad oluliselt:

a) mootori SKG kulumine ja dehermeetilisuse kasv;
b) õhufiltri mustumine ja sellest tingitud alarõhu muutumine sisselaskeprotsessis;
c) nõgi ja tagi ladestumine silindri-kolvigruppi detailidele;
d) gaasijaotusfaaside muutumine;
e) toiteaparatuuri reguleeringu muutumine;
g) õhulaengu tihedus;
h) väljalaskesüsteemi takistuse muutus;
i) sisseimetava õhu koostis ja eeljahutus.

Mootorite laboris läbiviidud katsetulemused, kus küttesegu moodustus diisli- ja etanoolkütusest, on esitatud joonisel 4.



Joonis 4. Etanoolkütuse tunnikulu mõju mootori heitgaaside suitsusele sõltuvalt selle kontsentratsioonist
Figure 4. *Impact of the ethanol fuel consumption on the opacities of exhaust gases depending on its concentration*

Jooniselt 4 selgub, et heitgaaside suitsusus sõltub etanoolkütuse kontsentratsioonist ja selle pealeandmise kogusest. Mida kõrgem on etanoolkütuse kontsentratsioon, seda väiksem on heitgaaside suitsusus. Selline seaduspärasus kehtib etanoolkütuse pealeandmise koguse juures kuni $\alpha_j = 2.25$ pööret, mis vastab etanoolkütuse tunnikulule $B_{f.et} = 2.5$ kg h^{-1}.

Järeldused

Uurimistöö eesmärk oli välja töötada minimaalse kontsentratsiooniga etanoolkütus, millega diiselmootor töötab rahuldavalt ja selle diagnostilised parameetrid ei välju valmistajatehase kehtestatud piirnormidest.
Läbiviidud uurimistöö tulemused on alljärgnevad.

1. Etanoolkütuse kasutamisel tuleb säilitada standardne toiteaparatuur, millega tagatakse pilootpritse manustamine ja ajastus.
2. Etanoolkütuse pealeandmiseks tuleb kasutada karburatsiooni tekitavat seadet.
3. Diiselmootor D-120 töötab laboratoorsetes tingimustes rahuldavalt 60% etanoolkütusega.
4. Mootori efektiivkasutegur sõltub etanoolkütuse kontsentratsioonist.
5. 60% etanoolkütust võib kasutada lisaks standardsele diislikütusele kuni 4 kg h^{-1}.
6. 70%, 80% ja 90% kontsentratsiooniga etanoolkütuste pealeandmine kuni 2.5 kg h^{-1} lisaks põhikütusele ei muuda praktiliselt mootori D-120 põlemisprotsessi algparameetreid.
7. Heitgaaside suitsusus sõltub etanoolkütuse kontsentratsioonist ja selle pealeandmise kogusest. Mida kõrgem on etanoolkütuse kontsentratsioon, seda väiksem on heitgaaside suitsusus.

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Motor method evaluation of fuel-air mixtures created by using qualitative and quantitative methods

Jüri Olt, Villu Mikita, Risto Ilves, Arne Küüt

Summary

The purpose of this study was to find minimum concentration of bioethanol mixture, which allows satisfactory engine operation in the overload area of test plan. Ethanol fuels EF 90; EF 80; EF 70 and EF 60 were used for performing by engine testing. The analysis of combustion process in the engine indicates that introduction of different fuels in combustion process by qualitative and quantitative method is acceptable in technical terms. This was also proved by the engine testing performed with test engine D-120. After medium long test cycle with addition of bioethanol to the fuel the engine indicators or cylinder pressure did not deteriorate. The tests revealed that ethanol fuel EF 60% works well as additional fuel and it does not cause significant deterioration of the values of engine output parameters. Production of ethanol as local biofuel is relatively inexpensive and the technology used for production is quite simple. In technological terms, nowadays any farmer can manage producing up to 70% ethanol. Elementary carburettor is all that is necessary for adjusting the engine for ethanol fuel. Ethanol fuel consumption was changed by the extent of opening ratio of main metering jet. In the framework of follow-up research on this subject field tests shall be carried out with diesel engine D-120 in summer, in the course of which common control system for both delivery systems shall be developed. Using ethanol motor fuel enhances energy security and reduces environmental pollution. The concentration of exhaust gas components such as CO, CO_2, NO_X as well as the value of smoke in exhaust gas were significantly reduced when using ethanol fuel. The proportion of hydrocarbons, however, was increased. This may be due to reduced efficiency of combustion process. This issue shall be subject to follow-up research. As far as the selection of ethanol fuel is concerned, 60% fuel does not cause significant deterioration of engine operation or increase the amount of other hazardous compounds in exhaust gases. It is recommended to use a 60% ethanol fuel as minimum concentration in addition to regular diesel fuel so that the ethanol fuel would comprise up to 60% of the entire fuel amount used by medium load of engine.

MINERAL FERTILIZER USE EFFICIENCY IN SPRING BARLEY SOWINGS

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ABSTRACT. *Optimum rates of the nitrogen (N) fertilizer in spring barley Tocada sowings were studied in field trials established at the Research and Study Farm „Pēterlauki" of the Latvia University of Agriculture (LLU) over the period 2008–2010. Field trials were conducted on a silt loam brown lessive soil (sod calcareous) with medium high phosphorus (P) and potassium (K) sufficiency levels. Fertilizer treatments: $N_0P_0K_0$ – control (unfertilized); PK fertilizer was equal in all N treatments: N_0, N_{30}, N_{60}, N_{90}, N_{120}, N_{150}, N_{180}, N_{210}.*

Plant nutrient removal with yield is dependent on crop yield level and nutrient content in basic products (grain) and by-products (straw). Nitrogen removal is associated with yield increase as affected by N fertilizer and with the increase of N content in grain and straw. N removal with yield within treatments studied increased from 80 to 145 kg ha^{-1}. The increase in P_2O_5 removal with yield between minimum and maximum value was only 15 kg ha^{-1} and was associated almost only with the increase in grain yield. Difference between minimum and maximum value of K_2O removed was more than two times greater – from 45.5 to 98.1 kg ha^{-1}.

Utilization coefficients of plant nutrients are, to a great extent, dependent on meteorological situation in the growing season. On the average for three years, mineral N utilization coefficient was the highest with nitrogen fertilizer rate N_{60} – 0.44, retaining constant relationship that utilization coefficient gradually decreases with each succeeding N fertilizer rate.

Utilization indices of P_2O_5, averaged over 3 years, are comparatively small however the increase in N fertilizer rate resulted in the increase of P_2O_5 removal. Similar tendencies were observed when analyzing potassium utilization coefficients.

Calculating optimum fertilizer rates, predicted crop yield level and peculiarities of meteorological situation in specific year should be taken into account when quantifying additional fertilizer rates.

Keywords: *spring barley, N uptake, Nitrogen use efficiency.*

Introduction

The crop yield level and quality in today's production agriculture are greatly dependent on utilization and application of mineral fertilizers. Mineral nitrogen combined with appropriate supply of other plant nutrients is one of the most important and effective fertilizers for high yield production. In the whole world about a 100 million ton of mineral nitrogen is used yearly however, unfortunately, not all amounts are utilized by plants for yield formation. A great part of it is migrating into ground waters, rivers, or otherwise and is a hazard to environmental pollution (Glass, 2003).

In compliance with EU Council Directive 91/676/ EEC of 12 December 1991 with regard to water protection against pollution caused by residual nitrate of agricultural origin, excessive fertilizer use endangers environment and therefore measures are needed to limit incorporation of all N-containing fertilizers into soil.

With regard to the Opinion of the European Commission on Nitrate Directive implementation in Latvia in the period 2004–2008, maximum mineral fertilizer rates applied for different crops and limitations in mineral fertilizer use shall be laid down based on research results and conclusions.

Based on 'Latvian Rural Development Program 2007−2015', a document developed for agricultural policy making and on the aims defined there, maximum permissible rates for mineral fertilizer application, and those for mineral N in particular, are to be determined and observed.

In recent years, the increase in crop yield level in farms is reached through more intensive field crop varieties considerably higher in yield potential compare to those used in the 1980's or even 90's. For crop varieties of such a type, utilization of their genetic yielding potential without strict observation of all other cultural operations requires also comparatively high nutrient supply. Under production concentration and specialization, mineral fertilizer is the main source of plant nutrient supply in most of farms now. Wherewith, amounts of applied mineral fertilizers, and mainly mineral N amount applied per unit area, like in other countries, continue to increase particularly in economically strong large-scale farms (Angas *et al*., 2006; Ruza *et al*., 2010).

Indices for particular plant nutrient utilization in Latvia were determined in the second half of the last century under different production conditions. Researches on mineral fertilizer utilization and mineral N in particular have not been conducted under new conditions of production. Recent plant nutrient investigations were associated more with crop yield increase and quality improvement in particular.

Nitrogen is a most dynamic plant nutrient which uncontrolled application at the current cost level may considerably raise the price of end-product, and what is more important – increased rates of N insufficiently utilized by plants may result in environmental pollution (Moreno *et al*., 2003; Macdonald A. J. *et al*., 2009). The topic of the day is what maximum N fertilizer rates are profitable under Latvian soil and agro climatic conditions and what is allowable level to which increase amount of applied nitrogen fertilizer preventing harm to the environment.

Materials and methods

Optimum rates of the nitrogen (N) fertilizer in spring barley Tocada sowings were studied in field trials established at the Research and Study Farm „Pēterlauki" of the Latvia University of Agriculture (LLU) over the period 2008-2010. Field trials were conducted in four replications on a silt loam brown lessive soil (sod calcareous) with medium high phosphorus (P) and potassium (K) sufficiency levels. Fertilizer treatments: $N_0P_0K_0$ – control (unfertilized); N_0PK – PK fertilizer was determined at nutrient removal up to 6 t ha^{-1} grain and in succeeding N treatments: N_0, N_{30}, N_{60}, N_{90}, N_{120}, N_{150}, N_{180}, N_{210} PK fertilizer was equal. P_2O_5, K_2O and the first mineral N fertilizer rate till norm N90 was preplant incorporated during pre-sowing tillage. During growing season all the necessary plant protection measures were performed.

Up-take of N, K_2O and P_2O_5 were noted and coefficient of mineral fertilisation utilization was calculated. Standard deviation and coefficient of determination (R^2) were calculated by Excel MS tools.

The growing season in 2008 after barley sowing in the third decade of April was dry. Dry conditions almost without rainfall prevailed all the month of May – in the second decade 8.2 mm rainfall received in several days was only poor dew on the arid soil. Dry weather continued all the first decade of June. Barley plants tillered poor, and further growth of plants was non-uniform. Precipitation in the second and third decades in June noticeably improved general status of barley plants, sowing became uniform by plant height and formed comparatively productive spikes. In general, the long-lasting period of dryness in spring significantly influenced growth and development of plants and yield formation process.

Spring in 2009 was comparatively warm, windy and dry – in the second and third decades of April rainfall was not observed at all. In May as well only 35% long-term rainfall sum was recorded. Such weather conditions resulted in non-uniform seed germination and non-uniform initial growth. However the first half of June was somewhat cooler with adequate rainfall providing good conditions for plant growth and development. Successive period of time was also favourable for spring barley yield formation.

In 2010 spring barley germinated very uniformly and favourable meteorological conditions in the first half of the growing season contributed to growth and development. However the following period of time was hot and non-characteristic to Latvia. In July and early August, the average air temperatures in decades were $3-6^0$C higher than the long-term averages and they were exceedingly rich in rainfall − twice as much as the long-term averages. Abundant rainfall combined with strong wind resulted in completely lodged barley stands causing difficulties at harvest.

Results and Discussion

Grain yields obtained in 2008 indicate that trial soils without fertilizer application and meteorological situation in this specific year provided comparatively high mean grain yield – 4.17 t ha^{-1}. Application of phosphorus and potassium fertilizer did not give yield increase – deviation is stated within error. In this case nitrogen was, obviously, the limiting factor. Incorporation of N30 per hectare gave 26.7 % yield increase. Yield level remained equal also with fertilizer N60. The increase in nitrogen fertilizer rate up to N90 still gave grain yield 10% more or 35.4% against initial indice. Further increase in N rate practically did not influence the yield level of barley grain, fluctuations were within error. Under the influence of N fertilizer the ratio of grain to straw did not change and was within 1:1.0–1.1.

In comparatively dry spring in 2009, the obtained grain yield in N-free treatments was only 1.84 t ha^{-1}. However already nitrogen fertilizer rate N30 resulted in grain yield increase 1.30 t ha^{-1}. Each succeeding nitrogen fertilizer step up to N90 resulted in significant yield increase. Further increase in N fertilizer rates resulted in somewhat higher grain yield reaching the highest value 4.92 t ha^{-1} in treatment N210.

In general, in 2010 grain yields of spring barley were comparatively good. Such meteorological conditions intensified nitrification process in soil and nitrogen practically did not influence the yield of grain – irrespective of fertilizer rate, grain yields with small fluctuations were equal in all treatments with a tendency to decrease at higher N rates (N90 + 60 and N90 + 90). The ratio of grain to straw, assuming that grain weight is 1, was 1: 0.76 on average. As the nitrogen fertilizer did not contribute to significant yield increase, wherwith incorporated nitrogen utilization indices under conditions of that year were exceedingly low – within 10–25%. Also phosphorus and potassium utilization from the incorporated fertilizer were comparatively very low.

The three-year averages were significantly influenced by non-characteristic meteorological conditions in 2010 when grain yields up to 6.75 t ha^{-1} were obtained in N-free fertilizer treatments on P_2O_5 and K_2O backgrounds. However the three-year averages (Figure 1) suggest that the increase in barley grain yield under Latvian conditions is comparativily stable with applied nitrogen fertilizer rate up to N90. Results of research conducted in other countries show that, depending on climatic zone and soil peculiarities, the highest spring barley yields are obtained with fertilizer rates N 60–120 kg ha^{-1} (Delogu *et al*., 1998; Kaš *et al*., 2010). Research results obtained both by our researchers and those in other countries indicate that further influence of nitrogen fertilizer rate on yield level is more dependent on the character of the growing season (Moreno *et al*., 2003). Wherwith, application of the first mineral N fertilizer rate not exceeding N90 kg ha^{-1} is useful. Further necessity for nitrogen must be determined depending on the character of the growing season and plant status.

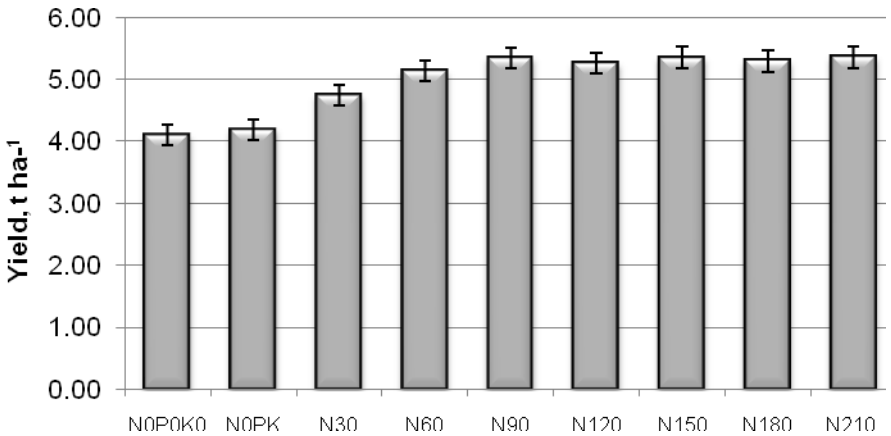

Figure 1. Grain yield, on the three-year average, t ha^{-1}

Nitrogen use efficiency or amount of grain obtained per unit of utilized nitrogen fertilizer is one of the most important indices (Brauer, Barry, 2010). Information summarized in Figure 2 suggest that the highest return from the nitrogen fertilizer − 18.2 kg grain per 1 kg N applied – was obtained with the lowest nitrogen fertilizer rate – N30. Each succeeding nitrogen fertilizer rate applied resulted in gradual decline in N use efficiency reaching 70% between the lowest and the highest nitrogen fertilizer rate. Similar results have been reported in Italy (Delogu, 1998), Spain (Angas, 2006), and in the Czech Republic (Kaš, 2010), that the increase in N ferilizer rate results in the decrease of its use efficiency. The highest reduction in obtained amount of grain per 1 unit N applied was stated for nitrogen fertilizer rates between N90 and N120. Results of data processing also suggest that the nitrogen use efficiency is exactly dependent on the nitrogen fertilizer rate – R^2 = 0.9826.

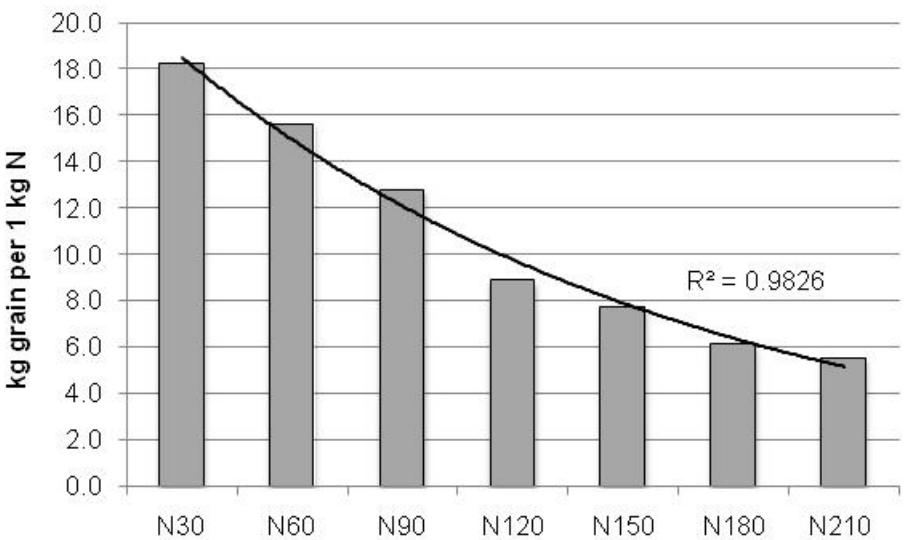

Figure 2. Grain amount obtained per 1 kg N applied

Amount of grain obtained per 1 unit N applied taken as a basis, it is simply to calculate the fertilizer rate at which further increase is unprofitable.

Macronutrient content in grain and straw also changed considerably depending on N fertilizer rate applied. The three-year averages indicate that the increase in N fertilizer rate resulted in gradual increase in grain nitrogen content from 1.52% in N-free treatment to 2.03% with fertilizer rate N180 (Table). Nitrogen content in straw at the same time increased almost twice in these treatments – from 0.44% to 0.85%. P_2O_5 content in grain was not practically influenced by the increased N rates, in straw as well the increase in P_2O_5 content was insignificant – only 0.05%. K_2O content in grain was not influenced by the increase in N fertilizer rates. However K_2O content in straw with the increase in N fertilizer rate increased constantly (more than twice) – from 0.65% in control treatment to 1.57–1.45% in treatments N150, N180.

Table 1. N, P_2O_5 and K_2O content in grain and straw, on the three-year average, %

Treatment	N		P_2O_5		K_2O	
	grain	straw	grain	straw	grain	gtraw
$N_0P_0K_0$	1.52	0.44	0.61	0.19	0.51	0.65
N_0PK	1.56	0.51	0.64	0.22	0.50	0.99
N_{30}	1.70	0.53	0.63	0.21	0.53	0.92
N_{60}	1.85	0.60	0.68	0.20	0.52	1.12
N_{90}	1.84	0.66	0.65	0.22	0.53	1.20
N_{120}	1.99	0.76	0.66	0.22	0.52	1.21
N_{150}	1.90	0.85	0.66	0.24	0.52	1.57
N_{180}	2.03	0.85	0.69	0.23	0.52	1.45
N_{210}	2.00	0.83	0.67	0.24	0.50	1.25

Plant nutrient removal with yield is dependent on crop yield level and nutrient content in basic products (grain) and by-products (straw). Nitrogen removal is associated with yield increase under the influence of N fertilizer and with the increase of N content in grain and straw. However exceeding fertilizer rates N 90−120 kg ha^{-1}, the increase in nitrogen removal is due to increase of N content in grain and straw. Wherewith, nitrogen removal with yield within investigated treatments increased from 80 to 145 kg ha^{-1} (Figure 3). The increase in P_2O_5 removal with yield between minimum and maximum value was only 15 kg ha^{-1} and was associated almost only with the increase in grain yield. At the same time K_2O removal with yield was two times greater as it was indicated by difference in minimum and maximum value – from 45.5 to 98.1 kg ha^{-1} or about 60% utilized nitrogen amount. Literature findings give evidence that total amount of K_2O taken up by plants is exceeding that of total nitrogen but it was not evident in our studies. Adequate amount of potassium also increases the nitrogen use efficiency (Johnston, 2009).

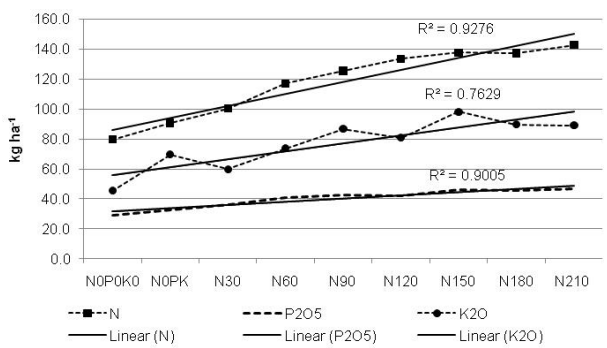

Figure 3. N, P_2O_5, K_2O removal with yield, on the three-year average, kg ha^{-1}

Plant nutrient utilization coefficients or agronomic efficiency was greatly dependent on meteorological situation in the growing season and therefore greatly differed between years. In these studies considerable dissonance was caused by uncharacteristic meteorological situation in 2010 when extremely abundant rainfall and increased air temperatures intensively favoured soil biological processes and nitrification in particular.

Mineral nitrogen utilization coefficients were the highest in 2009 – from 0.66 to 0.35 with definite coherence that the increase in nitrogen fertilizer rate resulted in the decrease of its agronomic efficiency. Similar coherence, but only with somewhat lower indices, was stated also in 2008 – coefficients from 0.61 to 0.28. However in 2010, the nitrogen utilization coefficients were comparatively very low without definite coherence that influenced the three-year averages significantly (Figure 4). On the average for the three trial years, the highest mineral N utilization coefficient was stated for the nitrogen fertilizer rate N60 – 0.44, retaining coherence that with each successive N fertilizer rate the value of utilization coefficient decreases.

P_2O_5 utilization coefficient with the increase in N fertilizer rate in 2008 and 2009 persistently increased. However the highest values were stated in 2009, reaching 0.52 in treatments N180-210. Similar coherence was stated also in 2008 but only with somewhat lower values. However in 2010, like with N fertilizer, P_2O_5 utilization coefficients were exceedingly low and without definite coherence. Wherewith, the three-year average P_2O_5 utilization coefficients were comparatively low however retained coherence that with the increse in N fertilizer rates P_2O_5 utilization coefficient increased.

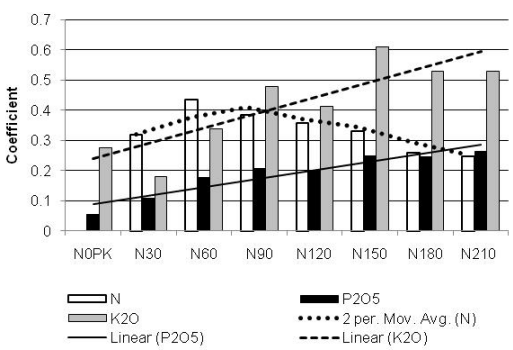

Figure 4. N, P_2O_5, K_2O utilization coefficients

The increase in N fertilizer rate in 2008 and 2009 considerably increased K_2O utilization coefficient – from 0.18 to 0.78 in 2008, but in 2009 from 0.24 to 0.69. In 2010, also potassium utilization coefficient from the mineral fertilizer, like that of N and P_2O_5, was very inconstant between particular treatments without definite coherence that significantly influenced the three-year averages. Wherewith, K_2O utilization coefficients between separate treatments considerably decreased, however like P_2O_5 utilization, general coherence retained that with the increase in N fertilizer rate K_2O utilization coefficient from mineral fertilizer also increased on yield increase and, particularly, on the increase in straw potassium content. Other authors have also reported that potassium utilization efficiency increases with the increase in nitrogen rate. Excess of optimun potassium and nitrogen rates did not give further yield increase. Rate, timing and form of nitrogen application influence potassium fixation, N uptake and transporting in plants. K application could reduce N leaching because increases its uptake (Zhang *et. al*., 2010).

Conclusions

Plant nutrient removal with yield is dependent on yield level and nutrient status in basic product (grain) and by-product (straw). Nitrogen removal is associated with yield increase under the influence of nitrogen fertilizer and with the increase in nitrogen content in grain and straw. Nitrogen removal with yield within investigated treatments increased from 80 to 145 kg ha^{-1}. The increase in P_2O_5 removal with yield between minimum and maximum value is only 15 kg ha^{-1} and is associated almost only with grain yield increase. The difference between minimum and maximum value in K_2O removal is more than twice greater – from 45.5 to 98.1 kg ha^{-1} or about 60% from the nitrogen removed.

Agronomic efficiency of plant nutrients is greatly dependent on meteorological situation in the growing season. On the average for three years, the highest mineral nitrogen utilization coefficient is stated for the nitrogen fertilizer rate N60 – 0.44, retaining coherence that with each successive nitrogen fertilizer rate utilization coefficient gradually decreases.

Increasing nitrogen fertilizer rate P_2O_5 removal increases. Similar coherence is stated also for potassium utilization indices.

Calculating fertilizer rates, P_2O_5 and K_2O amounts are determined according to predicted yield level considering their utilization coefficient at the corresponding yield level. Nitrogen fertilizer rate up to N90 must be pre-plant incorporated, the need for top-dressing must be considered taking into account peculiarities of meteorological situation in specific year.

Acknowledgement

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SIGALATE SISEKLIIMA JA LOOMAPIDAMISTEHNOLOOGIATE HINNANG TÖÖKESKKONNA TEGURITE ALUSEL

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ABSTRACT. *This is an overview paper about thesis for applying for the degree of Doctor of Philosophy in Agricultural Machinery; defended on 2010 in Estonian University of Life Sciences.*

In the eighties the number of pigs reared in Estonia reached one million. The number of pigs began to decrease rapidly in 1989 (Lember et al., 1999) and according to the Estonian Animal Recording Centre the number of pigs in performance testing is 14,475 (as of 31.12.2008), but the total number of pigs is around 369,700 (ETL 2006). Such decrease was mainly due to economic reasons. In order to maintain our position on European market, we have to find cheaper ways to produce meat. One of the opportunities is to enlarge farms and introduce rational animal keeping technologies.

There is a tendency towards building bigger pig farms, both those with deep-litter and those without litter, i.e. pigsties with liquid manure removal. Enlargement of pigsties is accompanied by problems regarding achievement of required indoor climate of the working environment.

In order to ensure efficient production of quality pork in a safe working environment that ensures competitiveness on the European market, it is crucial to develop optimal meat production technologies to be applied in Estonia.

Today it is obvious that such evaluation of technologies cannot be perfect, as it does not take into account the impact of animal-keeping technologies on the indoor climate of the production premises and the level of physical effort for work. Therefore this study focused on the technologies used in pigsties not only in view of the determination of the amount of working time, but also in consideration of their impact on the indoor climate of the working environment and human work load.

Keywords: *Working environment, keeping technology, pig tender, working time expense, degree of difficulty of work, indoor climate.*

Sissejuhatus

Kaheksakümnendatel ulatus sigade arv Eestis miljonini. 1989. a hakkas see kiiresti vähenema (Lember *et al.,* 1999) ning praeguseks on jõudluskontrollis JKK andmetel 14,475 siga (31.12.2008 seisuga), sigade koguarv on aga 369,700 juures (ETL, 2006). Selline langus oli tingitud eelkõige majanduslikest põhjustest. Euroopas oma koha kindlustamiseks otsitakse liha tootmiseks odavamaid teid. Üks võimalus on farmide suurendamine ja loomade ratsionaalsete pidamistehnoloogiate juurutamine.

Üha enam ehitatakse suuri sigalaid, kus loomi peetakse sügavallapanul või allapanuta, kasutades vedelsõnnikusüsteeme. Sigalate suurenemisega tekivad probleemid töökeskkonna normikohase sisekliima saavutamisega (talvel õhuniiskuse, süsinikdioksiidi- ja ammoniaagisisalduse suurenemine, suvel ruumide ülekuumenemine jne) ning Euroopas leviva toodangu eetilise kvaliteedi ja ümbruskonna õhu vastuvõetava lõhna tagamisega (Council of Europe, 1976).

Sigalate sisekliimast sõltub inimese töö- ja sigade elukeskkonna kvaliteet. Vaja on teada inimeste ja loomade, kasutatavate tehnoloogiate, töövahendite ja hoonete vastupidavust sisekliima tingimustele. Loomapidamishoonete sisekliimat mõjutavad mitmed tegurid: kasutamisel olev loomapidamisviis, söötmis-, jootmis-, allapanulaotus- ja sõnnikueemaldamistehnoloogia ning väliskliima (Mothes, 1976; MWPS-33, 1989; Kender *et al.,* 1998).

Uurimustöö eesmärk on sigalate töökeskkonna mitmeparameetrilise uurimise kaudu täiendada andmeid, mis võimaldavad hinnata ja valida sisekliima, tööajakulu ja töö raskusastme tegurite kaudu otstarbekamaid loomapidamisviise ja -tehnoloogiaid.

Uurimustöö uudsuseks on loomade erinevate pidamisviiside ja pidamistehnoloogiatega töökeskkonna pikaajalised kompleksuuringud, mida tehti erinevatel aastaaegadel ning mis sisaldasid sigalate sisekliima mitmeparameetrilisi üheaegseid mõõtmisi, samuti loomapidamisega seotud tööajakulu ja töö raskusastme määramist.

Materjal ja metoodika

Tehnoloogiate valik. Aastatel 1998−2008 tehti erineval aastaajal, erineva loomapidamisviisiga ja tehnoloogiaga seafarmides (860...6,200 siga) uuring, hinnates sise- ja väliskliima parameetreid ja seatalitajate tööd, määrates ühel ajal nii tööajakulu kui raskusastet. Sigalad olid ehitatud silikaatkivi- ja raudbetoonkonstruktsioonina. Loomi peeti sügavallapanul, allapanuta või vähesel allapanul. Söötmine toimus käsitsi või automaatliiniga kuivsööda automaatsöötjatest. Sõnnik eemaldati kas skreeperseadmega, kettkraapkonveieriga, kopp-laaduriga või isevalgumise teel. Loomade jootmine toimus sigalates künast või luttjooturitega. Õhuvahetus oli korraldatud sundventilatsiooniga automaatse õhureguleerimise kaudu.

Erinevusi söötmise, sõnnikueemaldamise, allapanu laotamise ja loomade jootmise tehnoloogiatel uuriti erineva suurusega farmides, kus peeti erineva suurusega searühmades kesikuid, nuumikuid, tiineid ja koos põrsastega emiseid (Reppo, Sada, 2000).

Sisekliima. Uurimistöö aluseks võeti Eesti Vabariigi tervisekaitseseadus (Nõuded sigade pidamisele…, 2002; Tervisekaitse normid... 25048) ja Soome soovitused (Karhunen, 1992), ASHRAE nõuded ja soovitused (ASHRAE, 1997; 1999; 2001), millest selgub, et töökeskkonna sisekliima parameetrite arvväärtused on määratavad sigalas kõrgusel 1.0 m loomadele ja inimesele töökohal 1.5 meetri kõrgusel (Simakov, 1991).

Sisekliimat uuriti sügavallapanuga, vedelsõnniku süsteemiga ja vähese allapanuga nuumikute, kesikute, põrsastega emiste ning põhikarjaga sigalates.

Mitmes riigis, sh Eestis, on ammoniaagi lubatud keskmine piirkontsentratsioon töötsooni sissehingatavas õhus 20 ppm ehk 14 mg/m^3 (EVS 2003; EVS 2004; Töökeskkonna keemiliste…, 2001). Maksimaalseks kontsentratsiooniks ehk piirnormiks peetakse 50 ppm ehk 35 mg/m^3. Loomade elukeskkonnale soovitatakse paljude maade andmetel ammoniaagi piirkontsentratsiooniks 20 ppm ja Soomes MMM andmetel 10 ppm (CIGR 1984, CIGR 2003, Teye 2008).

Sead eritavad gaasi olenevalt kehamassist: kesikud 16, nuumikud kehamassiga 80 kg 37, emised ja kuldid 36...79 liitrit tunnis (Mothes 1976; CIGR 1984; Liiske 2002). Ruumi õhu kõrge süsinikdioksiidisisaldus viitab vähesele õhustatusele ja loomade aktiivsusele (CIGR 2003). Eesti projekteerimise normide (EPN 18.3.1, 12.2) ja Soome ventilatsiooninormide kogu D2 alusel loetakse heaks süsinikdioksiidisisalduseks 0.1% õhu mahu kohta (Neste Air 1990; Sisekliima 1997). Euroopa riikide teadlaste tööde põhjal soovitatakse (CIGR 1984) loomadele lubatava süsinikdioksiidisisalduse ülemmääraks 3,000 ppm. Töökaitse-eeskirja järgi loetakse sisalduse piirnormiks õhus 9,000 mg/m^3 ehk 5,000 ppm (Töökeskkonna keemiliste… 2001).

Eesmärgil uurida sigala sisekliima parameetrite arvväärtuste muutust sõltuvalt tehnoloogiliste protsesside läbiviimisest, talitaja tegevusest, loomade käitumisharjumustest, kella- ja aastaajast, mõõdeti suvel ja talvel õhutemperatuuri, suhtelist niiskust, liikumiskiirust ning hapniku-, süsinikdioksiidi- ja ammoniaagisisaldust ööpäevaringselt mõõtmisintervalliga 1.0 minutit sigalate keskosas 1.5 m kõrgusel põrandapinnast ja mõõtmisintervalliga 15 sekundit söödakäigus, seasulus ja sõnnikurenni kohal 0.1, 0.5, 1.5 ja 2 meetri kõrgusel.

Mõõtekoha valikul lähtuti loomade pidamistihedusest ning mõõteaparatuuri piisavast kaugusest ustest, akendest ja ventilatsiooniavadest. Uurimispäevadel mõõdeti samaaegset ka välisõhu temperatuuri ja suhtelist niiskust kõrgusel 1.5 meetrit maapinnast ning vähemalt 10 meetri kaugusel sigalast.

Temperatuuri ja suhtelise niiskuse samaaegset mõju sigala õhu ammoniaagisisaldusele uuriti suvel ööpäevaringselt sügavallapanul ja vedelsõnnikusüsteemiga sigalas 1.5 meetri kõrgusel põrandast sigala keskosas. Selleks, et vältida sigalas tehtavate tööde mõju sisekliimale, kasutati õhutemperatuuri ja suhtelise niiskuse mõju ammoniaagisisalduse määramiseks kliima parameetrite arvväärtusi mõõdetuna ajal, kui sigalas loomad ei olnud häiritud ehk n-ö puhkasid (kell 6−18).

Sisekliima uurimiseks kasutati ALMEMO Data Loggeri 8990-8 komplekti koos anduritega temperatuuri, suhtelise niiskuse, liikumiskiiruse ning hapniku-, süsinikdioksiidi- ja ammoniaagikontsentratsiooni mõõtmiseks ööpäeva kestel kõrgusel 1.5 meetrit ja päevasel ajal sigala erineval kõrgusel (0.1, 0.5, 1.5 ja 2.0 meetrit põrandast), hoone ristlõikes ja diagonaalis. Ammoniaagisisaldust õhus määrati ka Gas Monitor Pac III firmalt Dräger Safety AG & Co KGaA seadmega. Välisõhu temperatuuri ja suhtelist niiskust mõõdeti firma Rotronic seadmega HygroLog koos anduriga HygroClip S. Mõõtmistulemusi analüüsiti arvutiprogrammiga AMR WinControl, Pac III Software 3.nn, HW3, Excel, SAS. Uurimusandmeid tutvustatakse graafikute ja statistilise töötlemisega saadud diagrammide ning tabelitega.

Seatalitaja tööajakulu määrati seatalitaja sekundilise täpsusega töö kronometreerimisega. Töötaja ööpäevane tegelik tööaeg võeti arvesse struktuurskeemi (Maatalouden työnormit, 1988) järgi, kus tööaeg koosneb püsivast abiajast (10 minutit vahetuses riietumisele, pesemisele jne) ja tootmisülesande täitmise ajast. Viimane sisaldab põhitööaega ja ettevalmistus-lõpetusaega. Tööpäeva pildistamine toimus tööaja igaks tööoperatsiooniks, pausiks jne kulutatud aja määramisega, selle kirjeldamisega ning kronoloogilises järjekorras vaatluspäevikusse kandmisega.

Ööpäevane eritööajakulu määrati kümne kesiku, nuumiku ja tiine emise ning ühe põrsastega emise kohta.

Seatalitaja põhitöökestus koosnes kuivsööda (jõusööt, jahu) söödajaotisse (kärusse) laadimise, veo ja jaotamise ajast, sulgude ja talituskäikude puhastamise, allapanu kärusse laadimise, veo ja laotamise, sigade jootmise ning mõne seadmega töötamiseks vajalikust ajast. Inimtööajakulusse ei arvestatud seadmete masinaega.

Kronometreerimisega saadud ööpäevase tööajakulu alusel arvutati tööajaerikulu T_e (inimminutit kümne sea kohta), kasutades Saksamaa ja Soome metoodikat. Selgus, et levinud on talitustööde ajakulu esitamine vastavalt tööde tehnoloogiatele ja karja suurusele kümne sea kohta. Tööajakulud on KTBL normtabelites antud 50, 100, 200, 300, 500, 1,000 seakohaga karja kohta ja TMRM puhul 60, 120, 250, 500 seaga karja kohta (Maatalouden työnormit 1988; KTBL 1994/95; KTBL 2000/2001). Soome tööajanormid toovad andmeid väiksemate karjade kohta (Maatalouden työnormit 1988). See tuleneb Soomes olevatest väiksematest seafarmidest.

Võib öelda, et talitustööde tööajaerikulu ühe sea kohta väheneb sigade arvu kasvades. Vahepealsete seakohtade arvu korral on tööajakulu leidmiseks võimalik arvutada vastavate regressioonivõrrandite abil (Sada, 1998; Vettik, 2000).

Seatalitaja töö raskusastet uuriti 1998−2005 aastal enam-vähem ühesuguse söödaratsiooniga, kuid erinevatel talitustehnoloogiatel. Raskusastme määramiseks kasutati firma POLAR Elektro OY pulsitestrit Polar 610i Sport Tester (Reppo, 1997). Talitaja tööoperatsioonide aegade mõõtmiseks kasutati stopperit Elektroonika RI-01, mõõtetäpsusega 0.1 sekundit. Pulsisageduse mõõtmiseks kasutatud Polar Sporttester koosnes saatjast (andurist) ja vastuvõtjast. Saatja kinnitati töötajale kummivöö abil ümber rindkere ning vastuvõtja käerandmele. Vastuvõtja salvestas pulsi-

sageduse kohta tuleva info 5-sekundilise intervalliga, milleks oli testril 2.5-tunnine mälumaht. Mõõdetud pulsisagedused salvestati testrist Polar Interface abil arvutisse andmete edasiseks analüüsiks. Kasutades arvuti andmetöötlusprogrammi Polar, saadi töötajate pulsisageduste statistilised read ja diagrammid ning pulsisageduse minimaal-, maksimaal- ja keskväärtused.

Töö raskusaste määrati talitajatel erinevatel töödel mõõdetud keskmise ja suurema pulsisageduse järgi, kasutades WHO soovitatud liigitust (Andersen *et al.*, 1978; Hettinger *et al.*, 1983; Tuure, 1991).

Samaaegselt talitaja pulsisageduse mõõtmisega n-ö pildistati ajaliselt ka nende iga tööoperatsioon kronoloogilises järjekorras. Hiljem sai saadud andmeid omavahel kõrvutades teada pulsisageduse väärtuse igal tööoperatsioonil ehk selgitada välja need töövõtted ja asendid, mis nõuavad talitamisel eriti suurt energiakulu.

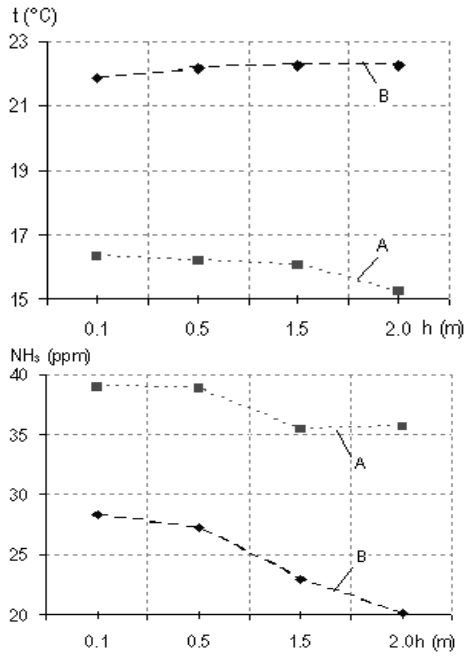
Tulemused ja arutelu

Sügavallapanuga ja allapanuta sigalates näitas talvine ööpäevane uurimine, et sisekliima parameetrite arvväärtusi mõjutavad väliskliima, loomade pidamisviis ja talitustööd. Talvel sigalates mõõdetud õhu ööpäeva keskmised temperatuurid olid vastavalt 12.38^{0}C (standardhälve s.d. 0.466) ja 25.08^{0}C (s.d. 0.485) välisõhu temperatuuri 0.91 (s.d. 0.871) ja 0.28^{0}C (s.d. 0.289) puhul, mis on loomadele normatiividega lubatud piires. Madalam õhutemperatuur oli sügavallapanuga sigalas, kus hoone oli vähem soojustatud ja õhuvahetus suurem (0.15 m·s^{-1}). Suhteline õhuniiskus 82.63% (s.d. 3.145) ja 88.42% (s.d. 4.817), oli üle soovitatu.

Süsinikdioksiidisisaldus sigalate õhus oli ööpäevas keskmiselt 0.11 ja 0.19%, kuid suurenes sigalas talitustööde ajal 0.29%-ni. Keskmine ammoniaagisisaldus oli sigalates 8.89 ja 18.07 ppm, kuid suurenes vedelsõnniku süsteemiga sigalas puhastus ja koristustööde järel kuni 32 ppm-ni. Seasulgudes ja talituskäikudes erineval kõrgusel saadud mõõtmistulemused näitasid, et need erinevad sigala ööpäeva keskmistest ning õhu suhtelise niiskuse ja ammoniaagisisalduse puhul ületasid soovitatavaid väärtusi. See tähendab, et talvel on vajadus tõhustada sigalate õhu niiskusrežiimi ja gaasikoostist, parandada õhuvahetust.

Talvel loomade kõrgusel olevas õhutsoonis mõõdetud temperatuur oli nuumikute ja kesikute sigalas 16.2–16.4^{0}C ja 21.9–22.2^{0}C (joonis 1).

Suvel sügavallapanuga ja vedelsõnnikusüsteemiga sigalas uurimine näitas, et sigalate sisekliima peamised mõjufaktorid on väliskliima ja loomade talitustööd. Sügavallapanuga ja ka allapanuta sigala siseõhu ööpäeva keskmised temperatuurid (vastavalt 17.04 ja 17.60^{0}C, välisõhu temperatuuride puhul 18.15 ja 8.75^{0}C) ning suhtelised niiskused (vastavalt 68.11 ja 78.6%, välisõhu suhtelise niiskuse puhul 71.88 ja 84.19%) olid loomadele soovitavates piirides. Kesikute sigalas tuli hommikul siseõhu optimaalse temperatuuri ja suhtelise niiskuse tagamiseks kasutada osalist põrandakütet. Tänu sigalate heale õhuvahetusele olid ööpäeva keskmised süsinikdioksiidi- (0.06 ja 0.07%) ning ammoniaagisisaldused (20.9 ja 8.7 ppm) normatiivselt lubatud piirides. Talitustööde ajal ületas ammoniaagisisaldus sigalate õhus normatiivselt lubatut, olles sügavallapanuga sigalas 43 ppm ja vedelsõnnikusüsteemiga sigalas 27 ppm (joonis 2).



Joonis 1. Sügavallapanuga (A) ja vedelsõnnikusüsteemiga (B) sigala sisekliima parameetrite keskmised arvväärtused, mõõdetuna erineval kõrgusel sulus

Figure 1. *Average numeric values of indoor climate parameters in deep-litter pigsty A and pigsty B with liquid manure system, measured in the pig-pen at different heights*

Uurimistulemusena määrati suvel ammoniaagikontsentratsiooni graafilised ja empiirilised sõltuvused siseõhu temperatuurist sügavallapanuga sigalas A ($R^2_1 = 0.946$, n = 6,000) (joonis 3) ja vedelsõnnikusüsteemiga sigalas B ($R^2_2 = 0.795$, n = 9,000):

$$P_A(NH_3)_t = 0.6387 \cdot t^2 - 17.815 \cdot t + 136.39 \quad (1)$$

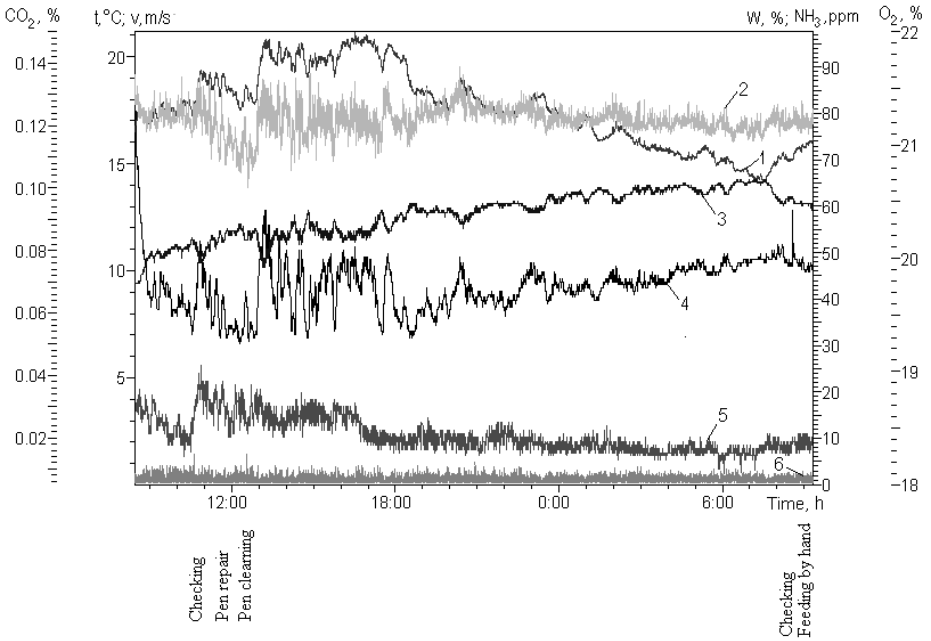
$$P_B(NH_3)_t = 0.2563 \cdot t^2 - 7.2362 \cdot t + 55.2 \quad (2)$$

kui ka temperatuuri ja suhtelise niiskuse koosmõjust (joonis 4) funktsioonidega (n = 12,000, $R^2_3 = 0.966$; n = 18,000, $R^2_4 = 0.7949$):

$$P_A\,(NH_3)_{tW} = 0.837 \cdot t^2 - 0.357 \cdot t \cdot W + 5.649 \cdot W - 195.318 \quad (3)$$

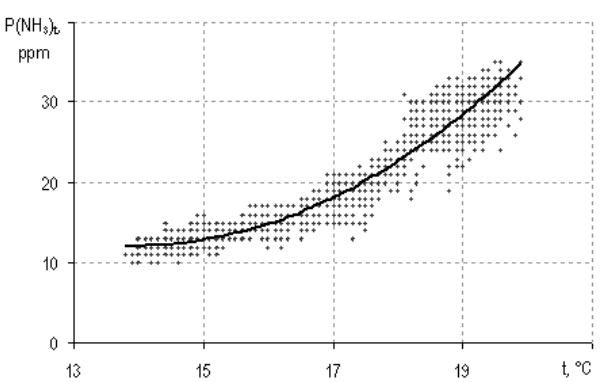
$$P_B\,(NH_3)_{tW} = 0.250 \cdot t^2 - 0.090 \cdot t \cdot W + 1.569 \cdot W - 69.41 \quad (4)$$

Vähesel allapanul sigalates talvel mõõdetud õhu ööpäeva keskmised temperatuurid olid 15.37–21.98^{0}C.

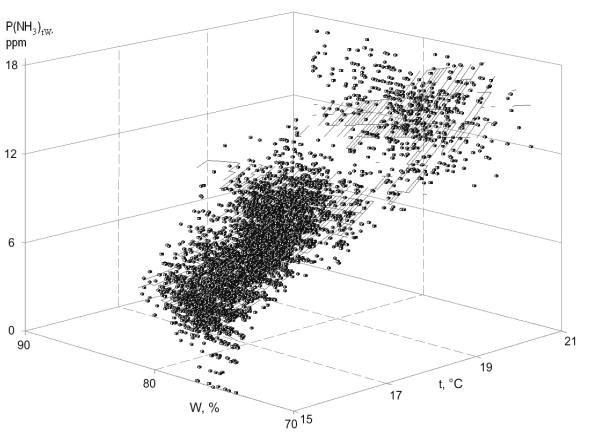


Joonis 2. Ööpäevane sisekliima parameetrite muutus vedelsõnniku süsteemiga sigalas suvel. 1 – temperatuur, 2 – suhteline niiskus, 3 – hapnik, 4 – süsinikdioksiid, 5 – ammoniaak, 6 – õhu liikumiskiirus
Figure 2. *Daily change of numeric values of indoor climate parameters in Pigsty with liquid manure system in summer: 1 – temperature, 2 – relative humidity, 3 – oxygen, 4 – carbon dioxide, 5 – ammonia, 6 – air velocity*

Seasulus loomade puhkealal sisekliima parameetrite uurimine näitas, et temperatuur oli sigalas sügavallapanu pinnal sigade õhutsoonis kõrgem (+16.4^{0}C) kui 2.0 meetri kõrgusel (+15.2^{0}C). Sigalas, kus kesikuid peeti vesiküttega betoonpõrandal, muutus õhutemperatuur kõrgustsoonides vähe. Süsinikdioksiidi kontsentratsioon (0.13 ja 0.19%) oli mõlemas sigalas sigade lamamiskõrgusel praktiliselt võrdne, kuid kuna allapanuta sigala sulu puhkeala põrand on niiske, siis süsinikdioksiid koos veeauruga kerkib üles, tõrjudes ruumi ülemistest õhukihtidest hapniku.



Joonis 3. Ammoniaagi sõltuvus õhutemperatuurist sügavallapanuga sigalas suvel
Figure 3. *Ammonia content correlation in air temperature in the deep-litter Pigsties in summer*



Joonis 4. Ammoniaagisisalduse sõltuvus õhutemperatuurist ja suhtelisest niiskusest vedelsõnnikusüsteemiga sigalas
Figure 4. *Ammonia content correlation in air temperature and relative humidity in the liquid manure pigsty*

Talvel vähese allapanuga sigalate sisekliima parameetrite arvväärtusi (7.67−21.98^{0}C) mõjutavad loomade söötmine ja sõnniku eemaldamine. Väliskliima mõjutab sisekliimat rohkem sigalas, kus ruumid on puudulikult soojustatud. Keskmine õhutemperatuur oli vähese allapanuga sigalas (7,67^{0}C) madalam kui vedelsõnnikuga sigalas, kuna hoone oli vähe soojustatud ja madala välisõhu temperatuuriga (−20^{0}C) oli suhteline niiskus kõrge (99.3%). Õhu ammoniaagisisaldus oli sigalates ööpäeva kestel keskmiselt 10.26−22.47 ppm, kuid see suurenes näiteks õhtuste talitustööde ajal skreeperseadmega sigalas kriitiliselt kuni 48.7 ppm ja 27.49 ppm-ni ja erineval kõrgusel ning kohas 12.6−31.9 ppm.

Suvel oli vähese allapanuga sigalate temperatuur 17.0−24.5^{0}C, olles lubatud piirides, ja suhteline õhuniiskus 68.1−78.6%, ületades välisõhu suurest niiskussisaldusest ja ka seasulgude pesust tingitud soovitatavat piir. Ammoniaagi ööpäevane sisaldus oli 9−21 ppm, kuid suurenes nuumikute sigalas söödajaotusseadmete hooldamisel 34 ppm-ni, mis kutsus esile sigade liikumise, ja sügavallapanuga sigalas sõnniku koristamise ajal (43 ppm) söödaplatsilt.

Nuumikute sigalas, kus kasutati skreeperseadmega laiemat sõnnikurenni, tõusis ammoniaagisisaldus 24 tunni jooksul 44.54, vähese allapanuga 1,000 nuumikuga sigalas puhastus- ja koristus tööde ajal 51.73 ppm.

Uurimistulemused kinnitavad, et ammoniaagi emissioon sõltub ruumi õhutemperatuurist, suhtelisest niiskusest, mille suurenemisega ammoniaagisisaldus õhus suureneb. Märgitakse (Einberg, 2001), et ammoniaagi emissioon võib sõnnikuga määrdunud ja eriti vedelsõnniku pinna lähedal olla üsna kõrge. Väidetakse (Karhunen, 1992), et suurem ammoniaagisisaldus õhus on lauda lae all. Käesolevad uurimistulemused kinnitavad, et ammoniaagisisaldus on õhu madalamates kihtides suurem, põhjuseks on tekkekoha lähedus.

Sigalas sulu madalamates õhukihtides mõõdeti suur ammoniaagisisaldus, ulatudes kõrgusel 0.1 meetrit keskmiselt 39.0 ppm. Puhkealale söödakünast osaliselt sattuva joogivee ja puuduliku põhu põhjusel suurenes õhu suhteline niiskus ja ammoniaagi emissioon õhku. Kuna ammoniaak oma tihedusega (0.7714 kg/m^3) on kergem õhust (1.2928 kg/m^3), tõuseb see üles. Ammoniaak lahustub hästi veeaurus, omandades neutraalse reaktsiooni, ning väheneb ülemistes õhukihtides (Mothes 1976).

Ööpäevane tööajakulu määrati seatalitaja töö kronometreerimisega sekundilise täpsusega. Töötaja ööpäevane tööaeg võeti arvesse struktuurskeemi järgi, kus tööaeg koosneb püsivast abiajast (10 minutit vahetuses riietumisele, pesemisele jne) ja tootmisülesannete täitmise ajast. Tööpäeva pildistamine toimus tööaja igaks tööoperatsiooniks, pausiks vms kulutatud aja määramisega, selle kirjeldamisega ning kronoloogilises järjekorras vaatluspäevikusse kandmisega. Ööpäevane eritööajakulu määrati kümne kesiku, nuumiku ja tiine emise ning ühe põrsastega emise kohta.

Uurimisel selgus, et väiksemad tööajaerikulud (0.24; 0.35 ja 0.56 minutit 10 nuumiku kohta ööpäevas) olid 500, 700 (730) ja 1,000 nuumikuga sigalates, kus vedel- ja kuivsööta jaotati söödakünasse vastavalt automaatliiniga Pellon, Roxell või akukäruga. Automaatliiniga söötmisel inimtööaeg praktiliselt puudub.

Leiti, et käsitsi söötmisel olid väiksemad tööajakulud 1,000 nuumikule sööda jaotamisel söödakärust söödaautomaati Groba ning 650 kesiku puhul künasse vastavalt 0.64 ja 0.58 minutit 10 sea kohta.

Sulgude puhastamisel suurim tööajaerikulu (1.76 min 10 sea kohta ööpäevas) oli 300-pealise nuumikukarja puhul. Sõnniku mehhaniseeritud eemaldamisel olid väiksemad tööajaerikulud (praktiliselt masinajad) suuremates farmides ja sigalates, kus kasutati tiibskreeperit.

Seatalitaja töö raskusastet uuriti tööpäeva vältel ja ka eraldi loomade söötmisel (tabel 1) ning sõnniku eemaldamisel ja allapanu laotamisel (tabel 2). Talitajatel erinevatel töödel mõõdetud keskmise ja suurema pulsisageduste järgi määrati töö raskusaste, kasutades Rahvusvahelise Tervishoiuorganisatsiooni (WHO) soovitatud raskusastme liigitust. Pulsisagedust mõõdeti pulsitestriga Polar 610i Sport Tester.

Leiti, et talitajate tööraskusaste sigade söötmisel (tabel 1) on üldiselt keskmiselt raske. Kergem on see sigade söötmisel söödaautomaatidest, kui võetakse sööta punkrist, jäävad ära lisatööd (nt sööda käsitsi laadimine kärusse). Söötmisel künast on koormus suurem, kuna toimub ka käsitsi sööda jaotamine piki küna. Sööda jaotamine poegivatele emistele oli seatalitaja töö kerge. Sigalates, kus toimus loomade söötmine kord päevas, koormas töökeskkond talitajaid rohkem kui söötmisel kaks korda päevas. Mõlemal juhul laaditi sööt käsitsi kärusse ning kärust künasse. Töö raskusastmeks oli raske töö, mille kergendamiseks tuleks loomi sööta kaks korda päevas või võtta kasutusele käru täitmine söödaga söödapunkrist.

Sügavallapanuga sigalas osutus seatalitajatele keskmiselt raskeks ja raskeks põhu laotamine ning vähese allapanuga sigalates loomade sulgude koristamine (tabel 2).

Tabel 1. Seatalitaja töö raskusaste sigade söötmisel
Table 1. *Tender's Level of Physical Effort for Work During Feeding*

Sigade arv ja liik / *Number of pigsand species*	Loomade pidamisviis / *Way of keeping*	Söödajaotus / *Feeding technology*[1]	Talitaja/*Tender*		Keskmine pulsisagedus, lööki minutis / *Average pulse* rate, *beats/min*	Töö raskusaste / *Work intensity*[3]
			Sugu/*Sex*[2]	Vanus, aastat / Age, *years*		
48 emist / 220 põrsast *sows/piglets*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	49	82	K/*L*
1,000 / 1,000 nuumikut / *fattening*	vähesel allapanul / *low-litter*	kä-aut/ak-kü/ *bar-aut/batbar-tro*	N/*W*	50	125 118	KR/*M* KR/*M*
313 nuumikut, kesikut/ 75 emist / *fattening, yong pig / sows*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	41	127	R/*H*
640 kesikut / *young pig*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	59	104	KR/*M*
36 emist / 160 põrsast *sows/piglets*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	43	120	KR/*M*
250 kesikut / *young pig*	vähesel allapanul/ *low-litter*	kä-kü/*bar-tro*	N/*W*	36	139	R/*H*

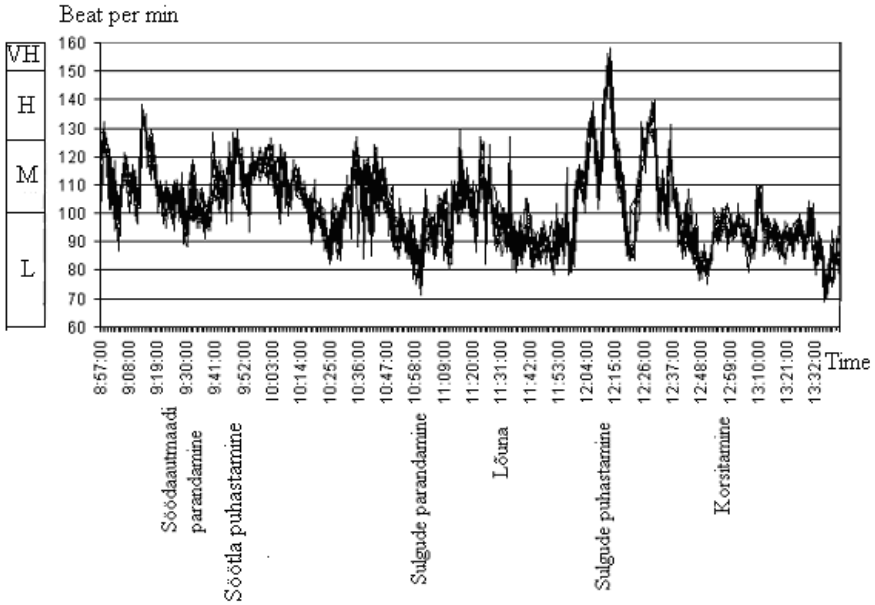
Sigade arv ja liik / *Number of pigsand species*	Loomade pidamisviis / *Way of keeping*	Söödajaotus / *Feeding technology*[1]	Talitaja/*Tender*		Keskmine pulsisagedus, lööki minutis / *Average pulse* rate, *beats/min*	Töö raskusaste / *Work intensity*[3]
			Sugu/*Sex*[2]	Vanus, aastat / Age, *years*		
100 emist / 450 põrsast *sows/piglets*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	43	78	K/*L*
290 nuumik/*fattening*	vähesel allapanul / *low-litter*	kä-aut/*bar-aut*	N/*W*	66	108	KR/*M*
850 nuumikut / 100 emist / *fattening/sows*	vähesel allapanul / *low-litter*	kä-kü/kä-aut/ *bar-tr /batbar-tro*	M	35	147 138	R/*H* R/*H*
25/188/226 vabad ja tiined emised / *free and gestation*	vähesel allapanul / *low-litter*	kä-kü/*bar-tro*	N/*W*	54	121	KR/*M*
200 kesikut/600 nuumikut / *young pig/fattening*	sügavallapanul/*deeplitter*	aut	N/*W*	57	-	-
1270 nuumikut/*fattening*	sügavallapanul/*deeplitter*	aut	M	43	80	K/*L*
500 nuumikut / *fattening*	vedelsõnnik / *liquid manure*	aut	N/*W*	27	-	-
100 emist / 560 põrsast *sows/piglets*	vedelsõnnik/allapanuta / *liquid maure / without litter*	aut/kä-aut/ *aut/bar-aut*	N/*W*	48	76	K/*L*

[1] kä-kü − käsitsi söötmine kärust künasse / *bar-tro − manual feeding from barrow to trough*;
kä-aut − käsitsi söötmine kärust söödaautomaati / *bar-aut − manual feeding from barrow to self-acting automatic fodder*;
kä-aut/ak-kü − talitaja kasutab mitut tehnoloogiat, söötmine käsikärust automaati ja elektrikärust künasse / *bar aut/batbar-tro – tender use several technology, manual feeding from barrow to self-acting automatic fodder and from battery barrow to trough*
aut-söötmine automaatsöödaliiniga / *aut − self-acting automatic fodder.*
[2] M − mees; N − naine / *M −male*; *W –women.*
[3] K − kerge, KR − keskmiselt raske, R – raske / *Work intensity: L – light; M – moderate; H – heavy.*

Tabel 2. Seatalitaja töö raskusaste sõnniku eemaldamisel ja allapanu laotamisel
Table 2. *Tender's Level of Physical Effort for Work During Manure Removal and Litter Spreading*

Sigade arv ja liik / *Number of pigsand species*	Loomade pidamisviis / *Way of keeping*	Sõnnikueemaldustehnoloogia / *Manure disposal technology*	Talitaja/*Tender*		Keskmine pulsisagedus, lööki minutis / *Average pulse rate, beats/min*	Töö raskusaste / *Work intensity*[2]
			Sugu/*Sex*[1]	Vanus, aastat / Age, *years*		
48 emist / 220 põrsast / *sows/piglets*	vähesel allapanul / *low-litter*	skreeper/*scraper*	N/*W*	49	75	K/*L*
1,000 / 1,000 nuumikut / *fattening*	vähesel allapanul / *low-litter*	skreeper/*scraper*	N/*W*	50	132 132	R/*H* R/*H*
313 nuumikut, kesikut / 75 emist/ *fattening, yong pig / sows*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	41	112	KR/*M*
640 kesikut / *young pig*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	59	112	KR/*M*
36 emist / 160 põrsast / *sows/piglets*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	43	128	R/*H*
250 kesikut / *young pig*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	36	122	KR/*M*
100 emist / 450 põrsast / *sows/piglets*	vähesel allapanul / *Low-litter*	skreeper/*scraper*	N/*W*	43	90	K/*L*
290 nuumik / *fattening*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	66	96	K/*L*
850 nuumikut / 100 emist / *fattening/sows*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	M	35	133 130	R/*H* R/*H*
25/188/226 vabad ja tiined emised / *free and gestation*	vähesel allapanul / *low-litter*	kettkraapkonveier / *chain conveyer*	N/*W*	54	118	KR/*M*
200 kesikut / 600 nuumikut / *young pig / fattening*	sügavallapanul/ *deeplitter*	traktor / *with tractor*	N/W	57	125	R/H
1,270 nuumikut/ *fattening*	sügavallapanul/ *deeplitter*	traktor / *with tractor*	M	43	102	KR/M
500 nuumikut/ *fattening*	allapanuta / *without litter*	vedelsõnnik / *liquid manure*	N/W	27	91	K/L
100 emist / 560 põrsast/ *sows/piglets*	allapanuta / *without litter*	vedelsõnnik / *liquid manure*	N/W	48	83	K/L

[1] M – mees; N – naine / *M – male; W – women.*
[2] Töö raskusaste: K − kerge, KR − keskmiselt raske, R – raske / *Work intensity: L – light; M – moderate; H – heavy.*



Joonis 1. Talitaja pulsisagedus ja töö raskusaste sügavallapanuga sigalas 1,270 sea talitamisel: L − kerge, M − keskmiselt raske, H − raske, VH − väga raske

Figure 1. *With deep litter 1,270 pigsties tender pulse rate and degree of work difficulty: L − light, M − moderate, H − heavy, VH − very heavy. Self-acting correcting, Feeding area clearning, Pens repearing, Pens cleaning, Disposal*

Kokkuvõte

Võrreldes erinevaid loomapidamisviise ja -tehnoloogiaid ning hinnates neid saadud sisekliima, seatalitaja tööajakulu ja töö raskusastme alusel võib järeldada järgmist.

- Sügavallapanuga ja vähese allapanuga sigalate sisekliimat mõjutavad rohkem väliskliima ja tehtavad tööd ning seda kahjustab, eriti talvel, ruumi suur suhteline õhuniiskus ja ammoniaagisisaldus, mis tihti ületasid soovitatavuse piiri. Sigalates kasutusel olnud õhutussüsteemid vajavad täiustamist või väljavahetamist. Sisekliima näitajad olid paremad allapanuta sigalates, kus oli kasutusel põrandaküte ja kus õhuvahetus toimis hästi, mis tagas ööpäeva vältel sobiva ja ühtlase temperatuuri.
- Selgus, et vähese allapanuga sigalates suurendavad ammoniaagi emissiooni laiemad skreeperseadmetega sõnnikurennid. Olukorda parandaks tehnoloogia, kus kasutatakse kitsas sõnnikurennis kett- või lattkraapkonveierit. Sobib ka loomade allapanuta pidamine ehk vedelsõnniku eemaldamine, kuid sel juhul hästi ventileeritavate kanalisüsteemidega. Ka sulgude puhastamisel on tööajakulu ja talitaja energeetiline koormus (töö raskusaste) väiksem.
- Leiti, et talitaja tööajakulu ja energeetilise koormuse seisukohalt on sobivad söötmistehnoloogiad:
  - suurematele sigalatele (üle 500 sea) täielikult mehhaniseeritud tehnoloogia, kus kasutatakse ajaliselt programmeeritud sisselülitamisega kuiv- või vedelsööda jaotussüsteeme;
  - väiksematele sigalatele tehnoloogiad *söödapunker-liikuv söödajaoti-söödaküna* või *söödapunker-käru-söödaautomaat* (nt Groba-tüüpi).

Sigalate töökeskkonna mitmeparameetrilise uurimise tulemused võimaldavad täiendada andmeid, mille alusel võib hinnata ja valida otstarbekaid loomapidamisviise ja -tehnoloogiaid.

Sigade pidamisviiside otstarbekuse väljaselgitamiseks on vaja jätkata uurimist majanduslike (näiteks ehituse- ja tehnika maksumus ning kasutuskulud) ja ökoloogiliste näitajate määramiseks.

Tänuavaldused

Käesolev töö on valminud Eesti Maaülikooli tehnikainstituudi, farmitehnika ja ergonoomika osakonna ning farmerite koostöös. Uurimistööd on finantseerinud Eesti Teadusfond (grant nr 2612 ja grant nr 4103) ja Eesti Maaülikool (baasfinantseerimise projekt nr 51-44-11/157).

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Indoor climate and animal keeping Technologies valuation by factors of working environment of pigsties

Oliver Sada

Summary

Research was performed in summer and in winter in deep-litter, without litter and low-litter pigsties with various keeping technologies, by assessing the indoor and outdoor climate parameters.

Data Logger set with sensors was used for studying air temperature, relative humidity, air velocity and contents of oxygen, carbon dioxide and ammonia during a day at different heights, in terms of cross-section and diagonal of the premises, depending on tending works. Research results are presented in the form of graphs, diagrams and tables prepared on the basis of statistical processing.

The graphical and empirical impact of the interaction of air temperature and relative humidity in summer was determined on the concentration of ammonia in deep-litter pigsties and pigsties without litter.

In the course of the study daily amount of working time and tender's level of physical effort for work were determined in pigsties with different animal-keeping technologies.

The results of multi-parametric study of the working environment of pigsties allow supplementation of data that provide basis for evaluation and selection of ecologically, economically and ergonomically purposeful animal-keeping methods and technologies.

FOOD PRICES ANALYSIS FOR THE BALTIC STATES ON THE BACKGROUND OF AGMEMOD 2020 MODELLING FRAMEWORK

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Estonian University of Life Sciences, Institute of Economics and Social Sciences

ABSTRACT. *Article examines the price dispersion in the Baltic States before and after accession. The Law of One Price (LOOP) states that, regardless of the location, at a given moment of time prices of the same products should be equal when converted to a common currency.*

Using the AGMEMOD model which allows analysing the economic impact of prices by providing for the generation of both no policy change (baseline) and scenario analyses, will be of more general applicability and relevance to policy makers. Prices projections are provided over a medium term time horizon, so that by the time of the project's completion it will be possible to make forecasts up to the year 2020. The modelling results analysis based on the high prices model version elaborated at the second half of 2008.

Keywords*: Law of One Price, Common Agricultural Policy, Baltic States, AGMEMOD 2020 model, price dispersion, price convergence, price divergence.*

Introduction

The agrarian sector has become less important in terms of its economic weight and share in GDP during the last ten years in New Member States (NMS) in EU. Farm gate prices (producer prices) most of the NMS cannot reached the levels of Old Member State (OMS) yet. Investigation of this topic based on the Law of One Price theory which says that in an efficient market, competition should ensure the prices of commodities converge on one another. The Law of One Price is the economic rule that, in the absence of trade barriers or transport costs, competition will ensure that a particular good will sell at the same price in all countries.

Estonia, Latvia and Lithuania are the three Baltic States located on the coast of the Baltic Sea on the Nord part of EU. All before mentioned countries are typical with high investments, financial, business and monetary freedom.

This favourable investment situation (good monetary conditions, strong financial position of companies and EU funds) together with attractive incentives for foreign investors has attracted investments from Western, Central Europe and, eventually, Russia. Each of the three countries has entered the Exchange Rate Mechanism and is aiming for Euro zone that now has been postponed probably up to 2011 due to the overall economic stagnation in 2009 caused by unfavourable international economic developments (decreasing of purchasing power, increasing unemployment, diminishing of trade etc.). Producers of tradable goods are facing difficulties due to tight labour market conditions, which have lead to rapidly increasing unit labour costs and constraints on output.

The EU accession agreement on free trade in agricultural products is perceived as a logical continuation to the gradual economic integration for the Baltic States. In May 2004 such an agreement was signed. The main goals of the EU Common Agricultural Policy for ten new EU Member States (including the Baltic States) were

- to create of a free trade zone for agricultural, food and fish products;
- to guarantee the environment and food safety requirements of the CAP;
- the liberalization of agricultural policy;
- to create a fair competition environment among the Old and New Member States of EU.

Due to the previously mentioned goals the investigation of different food prices convergence processes in common economic space is extremely important for agro food trade development in future. On other hand it's absolutely clear that costs and prices for food products, taking into account the requirements of food safety and maintaining environment in good conditions must to increase.

The focus of this paper is on how the food prices dispersion varied related to EU 27 prices in Baltic countries.

The main objective of research is to analyse the market integration opportunities on the base of prices convergence for main agricultural and food products in Baltic States. Therefore the main investigated issues in this article are:

- To use AGMEMOD 2020 model and the methodology to evaluate the price dispersions for the main food commodities of Baltic States;
- To compare and evaluate the Baltic States agricultural producer and food prices on the background of EU prices;

The article compiled on the bases of two research projects. First, which is supported by the Estonian Ministry of Agriculture 'Unification of Prices in European Union and the Expected Impact to the Estonian Food Sector' (2006…2008). And second is the EU 6 Framework Programme project 'Agricultural Member States Modelling for the EU and Eastern European Countries' (2006… 2008).

First section of article devoted to the theoretical overviews and different explanations of price dispersion subject, how AGMEMOD model is built up and what kind of scenarios used for the forecasts.

Second section describes the price data which are used for analyses. The third section presents the empirical evaluation of time series using accounted Price

Dispersion Coefficients (PDC) and visualization of prices forecasts, based on the AGMEMOD model results 2010…2020.

Theories and methods

Theoretical background of the price dispersion analysis based on the Law of One Price (LOOP) conception for investigation the prices of food products before and after accession to European Union. The Law of One Price is the economic rule that, in the absence of trade barriers or transport costs, competition will ensure that a particular good will sell at the same price in all countries. Last years a large body of literature has been dedicated to analysing the empirical evidence for the LOOP as well as for Purchasing Power Parity (Brissimis, S. N., Sideris, D., & Voumvaki, F. K. (2005). What does Purchasing Power Parity (PPP) mean? An economic theory that estimates the amount of adjustment needed on the exchange rate between countries in order for the exchange to be equivalent to each currency's purchasing power. The relative version of PPP is calculated as (1):

$$S = p_1 / p_2 \quad (1)$$

Where:
'S 'represents exchange rate of currency 1 to currency 2;
'P_1' represents the price of good 'x' in currency 1;
'P_2' represents the price of good 'x' in currency 2.

In other words, the exchange rate adjusts so that an identical good in two different countries has the same price when expressed in the same currency.

Due to the lack of appropriate econometric techniques and insufficient or unsuitable data, early empirical studies were mostly unable to find evidence for either of the two hypotheses (Gouveia, P., & Rodrigues, P. (2004). Later studies which extend the data set by including more observations on cross country data are generally able to find support in favour of price convergence. Analysis contributes to the empirical literature on the LOOP in an intra-regional framework by analysing the development of relative prices on a disaggregated level for the entire European Union (EU) over the past 10 years (Jenkins, M. A. (2004). The data used for the empirical assessment of the LOOP consist of harmonized consumer price indices for 90 different product groups from 25 EU countries. In addition to analysing the validity of the LOOP for the entire EU, broad data set also allows to investigate differences between the 15 old EU countries and the 10 countries of Central and Eastern Europe and the Mediterranean that joined the European Union in 2004 (Chilac M., Thomas H. (2004) (Wolszczak-Derlacz J. (2006). The second main approach on the field of LOOP is the investigation of price dispersion problems (Bergin P. R., Glick R. (2006). Indeed, numerous papers have studied the degree of international price dispersion, focusing on various issues. Crucini, Telmer, and Zachariades (2005) demonstrated the effect on price dispersion of basic gravity factors such as tradability and distance, usually interpreted to represent trade costs. Parsley and Wei (2002) examine the impact of currency arrangements, finding that country pairs with currency unions or other exchange rate stabilization have lower price dispersion.

The comparison of price level differences across food commodities in different countries are implemented by measuring declining of price dispersion in certain time path. More specifically, let $p^k_{i,t}$ be the price of food commodity k in country i at time t and $p^k_{j,t}$ is price for same commodity in country j at time t. Then price dispersion $q^k_{ij,t}$ be expressed (2)

$$q^k_{ij,t} = p^k_{i,t} - p^k_{j,t} \quad (2)$$

This approach is almost closer to the present research methodology.

The AGMEMOD 2020 model is an econometric, dynamic, multi-product partial equilibrium model that allows us to make projections and simulations in order to evaluate measures, programmes and policies in agriculture at the European Union (EU) level as well as on the Member States level. Research implemented through the two types of models. First, all the EU Member States compiled the stand-alone country model and after that on the bases of these country models the overall EU model was synthesised.

Country alone model. For each Member State and for all of the commodity markets covered by the model, an operational dynamic multi-market partial equilibrium model has been developed. In particular the AGMEMOD model covers a detailed set of agricultural policy instruments in each country (Figure 1). The model is closed on a residual element of the supply and use identity in general the exports is the closure variable.

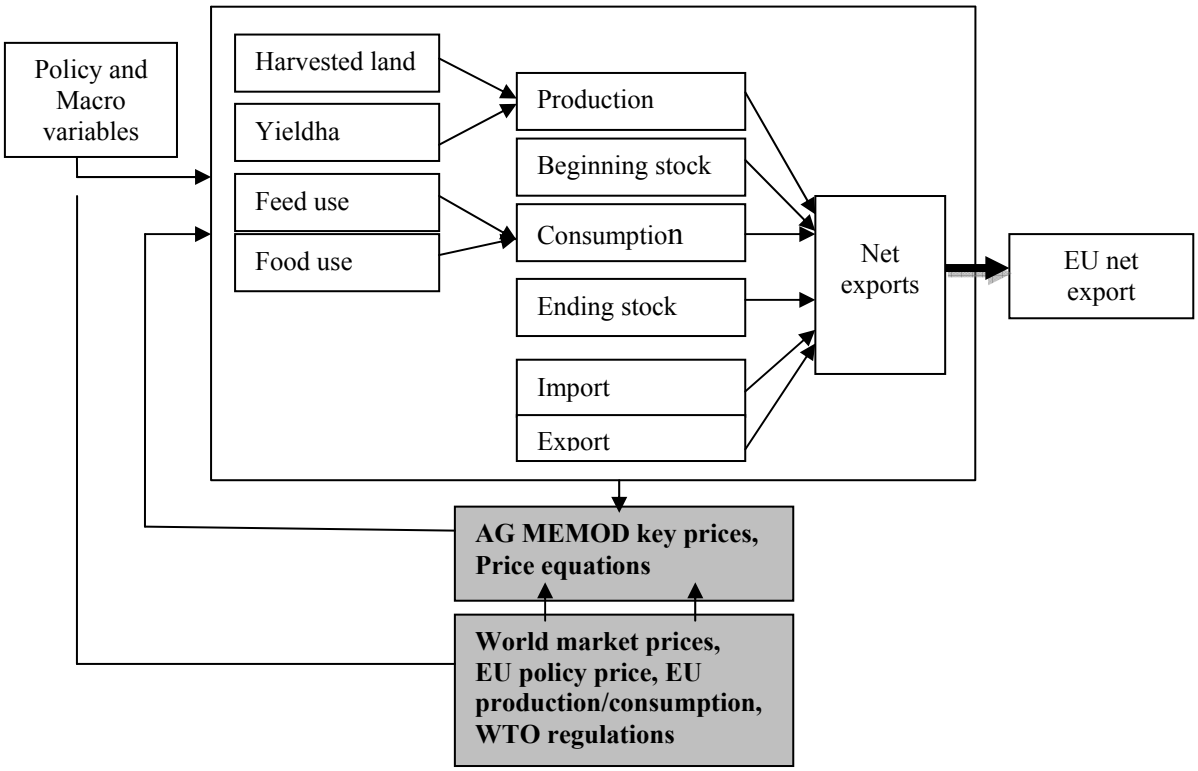

Figure 1. Country model structure of AGMEMOD
Source: Leeuwen M., Tabeau A., Dol W., Bouma F. (2008) 'Technical Report on the combined model' Deliverable reference number: AGMEMOD WP6 P16 D8; Agricultural Economics Research Institute (LEI); p 47.

As a country model mostly does not represent a closed economy, the concept of key markets and key prices has been introduced in order to take into account the influence of other member states on a given country market.

Hence, when the national level market is not considered as the key market in the EU, the internal price is determined as a function of the chosen key price for the EU and the self-sufficiency rate for this market and the self-sufficiency rate for the key market. Thus, these modelling tools allow to generate projection and scenario simulation results for each country and for the EU in aggregate, assuming that variables relative to other countries are exogenous.

EU model. AGMEMOD 2020 is an econometric, dynamic, multi-product partial equilibrium model wherein a bottom-up approach has been used. Based on a common country model template, country level models with country specific characteristics has been developed to reflect the specific situation of their agriculture and to be subsequently combined in a composite EU AGMEMOD model. This approach captures the inherent heterogeneity of the agricultural systems existing across the EU while still maintaining analytical consistency across the country models via as close as possible adherence to template. The maintenance of analytical consistency across the country models is essential for the aggregation and also facilitates the comparison of the impact of a policy across different member states. One of the aims of this study is to integrate all member state models into an EU combined model (Figure 2).

The EU AGMEMOD model developed in this study is based on a methodology similar to that implemented at the country level. To combine these country models, some exogenous variables are internalised in the EU model, and become endogenous variables (self-sufficiency rates and prices of key markets). When solving the EU AGMEMOD model, a closure variable has been chosen to ensure that the supply and use identity holds for all EU markets. AGMEMOD does not consider the distinction between intra EU and extra EU trade at the member state level. Thus intra EU trade disappears at the EU level when summing supply and use identities across countries. This implies that the EU net export variable is used as the closure variable at the EU level. As the combined model does not represent a closed economy, key price linkage equations are used to take into account the impact of the Rest of the World on EU agricultural sectors. The key price equation for a given commodity market is also a function of the EU self-sufficiency rate and thus reflects the endogenous development of the EU internal balance for the commodity concerned. For example, the EU soft wheat key price is modelled as a function of the world wheat price, the EU soft wheat intervention price, relevant trade policy variables and the self-sufficiency rate for wheat in the EU. Hence, the final dynamic, multi-market, multi-country composite model developed allows to generate baseline projections and alternative

scenario simulations for both the EU in aggregate and its member states individually, under the assumption of exogenous world prices. In its current form the composite EU AGMEMOD model also allows us to analyse agricultural policy changes for a given subset of the countries modelled, while considering the rest of the EU as exogenous.

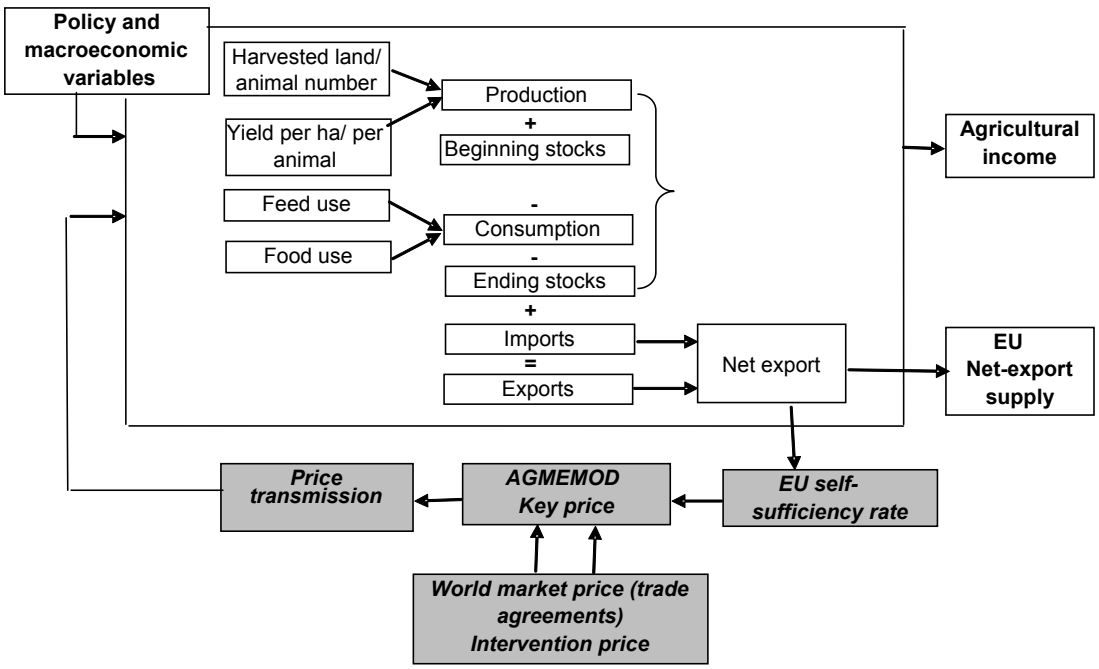

Figure 2. EU combined model structure of AGMEMOD
Source: Leeuwen M., Tabeau A., Dol W., Bouma F. (2008) 'Technical Report on the combined model' Deliverable reference number: AGMEMOD WP6 P16 D8; Agricultural Economics Research Institute
(LEI); p 47.

To better represent the increasing economic integration among Old Member States (OMS) and New Member States (NMS) within the AGMEMOD 2020 model, some variations are admitted for NMS with respect to the general country model template. In particular, all yield equations and all price transmission equations are adjusted to 'impose' technological and price convergence toward the EU avg., as shown in figure 3.

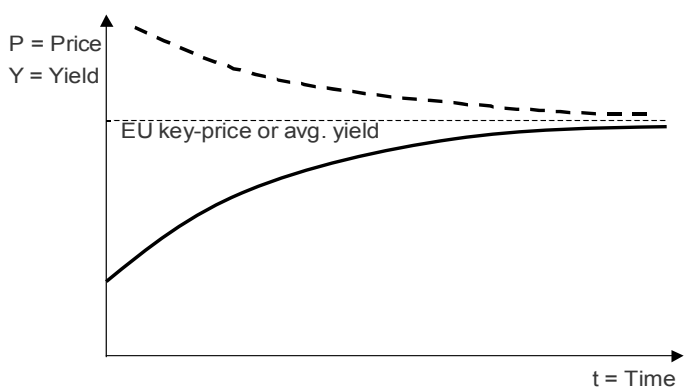

Figure 3. Graphical interpretation of price convergence estimation in AG MEMOD model.

This implies, which these equations have to include additional explanatory variables as follow:

$$y_{i,t} = \alpha + \boldsymbol{\beta}\,\mathbf{X}_{i,t} + D_t\left\{ y_{i,t-1} + \gamma\left[\exp\left(\frac{y_{iEUavg.,t-1} - y_{it-1}}{y_{it-1}} \right) - 1 \right] \right\} \tag{3}$$

Where $y_{i,t}$ indicates price or yield at time t for the i-th commodity in the given country; X indicates the vector of the other explanatory variables (normally included in the equation also in the OMS) and β the respective parameters. D is a dummy assuming value = 0 for OMS and = 1 for NMS. The term within brackets expresses the convergence process, γ being the parameter indicating the convergence speed (expected to be positive) and $y_{iEUavg.,t}$ the EU average yield or the EU key-price. To impose convergence, the exponential form is preferred to the more frequently used logarithmic one, according to the general indication of avoiding logarithmic specifications.

Price dispersion analysis

Special computer programme in Excel environment for automatic price dispersion analyse system (PDAS) was elaborated in Institute of Economics and Social Sciences of Estonian University of Life Sciences. In principal we have opportunity to use the Excel model to compare the prices for every EU country which are presented in database. But our interest at the moment is to analyse the prices of Baltic States with acknowledged key prices (states).

Competitiveness of Estonian, Latvian and Lithuanian agricultural products on the EU common market depends how fast are the price convergence or divergence between the New and Old Member States is. One possible formula for evaluation of price dispersion is (4):

$$\mathbf{PDC_i = (P_{t0,Ri} - P_{t0,Xi})/(P_{t,Ri} - P_{t,Xi})} \qquad \mathbf{(4)}$$

Where:

$\mathbf{PDC_i}$ Price Dispersion Coefficient for commodity i;
$\mathbf{P_{t,Xi}}$ ending price for commodity i in country X;
$\mathbf{P_{t0,Xi}}$ starting price for commodity i in country X;
$\mathbf{P_{t,Ri}}$ ending key price for commodity i in key country R;
$\mathbf{P_{t0,Ri}}$ starting key price for commodity I in key country R.

For the evaluation:

- if PDC > 1 is indication to the price convergence;
- if PDC < 1 is indication to price divergence;
- if PDC < 0 [−] is exceptional case when in the first occur the price convergence and after the equilibrium, usually followed the price divergence or vs.

In case of high price version of AGMEMOD 2020 model solution the highest prices increase for soft wheat, barley, oilseed, milk, cheese, pig meat and eggs are in Lithuania (Table 1). For butter, skim milk powder and beef meat in Latvia.

Data. The database section describes the EU27 historical data and projections for the period to 2020, which are generated by the current AGMEMOD model (AGMEMOD combined model 3.1, December 2008). The macroeconomic projections, key prices for agricultural commodities and agricultural policy assumptions underlying the Baseline are presented in model database. These data are also used in the generation of projections under the alternate policy scenarios. On the national level the database reflected the main indicators (prices, production, consumption, export, import, balances, etc) collected mainly through the EUROSTAT or national statistics agencies.

For any commodity, the market price is endogenously determined. It means that any commodity model includes one equation (*price formation equation*) where price is the dependent variable and the independent variables explain how price is formed within the market. Nonetheless, the endogenous determination of market prices does not mean that they are market-clearing prices. In other words, these prices are not computed to make the market close; as mentioned, market closure is achieved imposing the supply-use identity, given the market price, through one market-closing variable.

There can be two kinds of price formation equations in the commodity models. In the first case, which is the most frequent, we have a *price transmission equation*, where the price is driven by an external price. Generally, this external price is the EU key-price; if there is no EU key-price (for instance in oilseeds' model) price transmission is directly driven by the world price or by other world market indicators. A second case occurs when, for the commodity under consideration, the given country is the most important market within the EU. In this case, the country model presents a *key-price formation equation*. This equation drives price transmission in all the other country models and also 'captures' all exogenous variables affecting price formation and the dynamic structure of the model at the EU combined level. World market price, price policies (intervention prices, for instance), trade agreements, etc., may be included in the key-price (*Source: AGMEMOD 2020; WP2 D2 10/1182)*

In addition, key-price formation may include as explanatory variable the lagged EU self-sufficiency rate, thus making the key-price dynamically respond to previous year's outcome and, consequently, inducing all the other price transmission equations to adjust accordingly.

Historical price data. Historical price data represented the actual prices of different food commodities in certain time path (for Baltic States for example 1995…2006). All historical prices are accounted in Euro's per 100 kg of production (Table 1).

All endogenous data, including the actual prices used in the AGMEMOD model and stored in special file named *HistoryData-EU27.xls* (based on EUROSTAT prices database) − which contains individual country sheets with common set of time series.

Table 1. Price dynamics of main food commodities before and after accession to EU in Baltic States

	1998−2000 €/100 kg	2001−2003 €/100 kg	2004−2006 €/100 kg	PDC	Price dispersion speed and direction
Soft wheat					
Estonia	10.0	9.7	10.6	1.9	Fast convergence
Latvia	10.1	10.2	10.0	1.0	Zero dispersion
Lithuania	11.3	11.1	10.0	0.1	Fast divergence
Key price (FR)	11.4	11.2	11.4	x	x
Rapeseed					
Estonia	20.5	24.1	23.6	0.3	Fast divergence
Latvia	19.1	21.4	20.4	0.9	Slow divergence
Lithuania	17.9	20.8	20.6	4.0	Fast convergence
Key price (DE)	19.6	27.6	21.0	x	x
Raw milk					
Estonia	14.8	18.5	23.1	3.5	Fast convergence
Latvia	14.1	16.1	21.6	2.7	Fast convergence
Lithuania	12.8	14.1	17.0	1.6	Fast convergence
Key price (NL)	29.5	29.8	27.2	x	x
Cheese					
Estonia	231.8	290.1	290.3	1.6	Fast convergence
Latvia	243.8	252.1	275.6	1.4	Fast convergence
Lithuania	226.1	259.7	287.2	1.6	Fast convergence
Key (FR)	463.4	469.3	438.0	x	x
Pig meat					
Estonia	145.0	158.0	159.4	0.8	Moderate divergence
Latvia	135.5	169.8	148.5	0.7	Moderate divergence
Lithuania	157.3	151.6	144.5	4.2	Fast convergence
Key price (DE)	127.4	146.8	137.3	x	x

Source: AGMEMOD combined model 3.1 (2008)

Derived prices (projections). Data for exogenous variables are determined outside the model and these reflect information on agricultural and trade policy, the macro economy and key prices. All exogenous data including the key prices for the EU combine model up to 2020 are stored in the *AssumptionsInput.xls* file which is one module of AGMEMOD combine model 3.1.

Each country model is based on the aligned database with annual time series for agricultural commodity supply and use market balance sheets and price data related to the respective commodities modelled. The current sample covers the price projections for Baltic States from 2004 to 2020 (Table 2).

Table 2. Price dispersion projections of main food commodities related to key prices in Baltic States

	2004−2006 €/100 kg	2018−2020 €/100 kg	PDC	Dispersion speed and direction
Soft wheat				
Estonia	10.6	18.5	−0.4	Convergence to divergence
Latvia	10.0	16.1	2.2	Fast convergence
Lithuania	10.0	17.8	−1.3	Convergence to divergence.
Key price (FR)	11.4	16.7	x	x
Rapeseed				
Estonia	23.6	27.5	1.7	Fast convergence
Latvia	20.4	34.2	−0.1	Convergence to divergence
Lithuania	20.6	37.4	0.0	Fast divergence
Key price (DE)	21.0	25.9	x	x
Raw milk				
Estonia	23.1	28.9	4.2	Fast convergence
Latvia	21.6	24.7	1.1	Slow convergence
Lithuania	17.0	26.0	2.6	Fast convergence
Key price (NL)	27.2	29.9	x	x
Cheese				
Estonia	290.3	306.8	0.8	Slow divergence
Latvia	275.6	322.3	1.0	Zero dispersion
Lithuania	287.2	452.2	4.0	Fast convergence
Key price (FR)	438.0	489.8	x	x
Pig meat				
Estonia	159.4	177.8	1.1	Slow convergence
Latvia	148.5	151.9	−1.7	Convergence to divergence
Lithuania	144.5	187.4	0.2	Fast divergence
Key price(DE)	137.3	158.4	x	x

Source: AGMEMOD combined model 3.1 (2008)

World market prices. Generation of prices for baseline and scenario projections mainly depends on exogenous world market prices. The world market prices projections have, in general, been taken from FAPRI World Outlook (2008). The world livestock and grain prices are market prices from the US Dairy commodity prices and oilseed are generally Northern European prices. In particular, the world market prices are introduced in the key price equation to capture the effect of global supply and demand on the EU market.

Results

Concerning the Baltic States the significant increase of production is expected in oilseeds sector where the yield of rapeseeds increasing more than three time. Production of soft wheat should be increase in all Baltic States. Total milk production in small scale increasing in Estonia and Lithuania.

Fast price convergence in all Baltic States is occurring on the field of milk production where the Price Dispersion Coefficient (PDC) varied between 1.8 and 2.7 which indicate to fast price convergence during the projection period (Table 3). Due to the low price of raw milk the producer prices for cheese and butter significantly under the EU 27 average price in 2005−2020.

High price divergence on the field of pig meat production forecasted during the projected period in Latvia and Lithuania.

Table 3. Prices Dispersion Coefficient (PDC) and forecasts for Baltic Countries (2005…2020)

	2005 €/100 kg	2020 €/100 kg	2020/2005 (%)	Average per year (%)	PDC*
Soft wheat					
Estonia	9.8	18.5	189	5.5	−0.7
Latvia	8.8	16	182	5.1	1.8
Lithuania	8.4	17.7	211	6.9	−1.8
EU 27	10	17.3	173	4.6	x
Oilseeds					
Estonia	21.2	27.5	130	1.9	0.4
Latvia	17.9	34.4	192	5.8	2.5
Lithuania	18.1	37.4	207	6.7	−9.9
EU 27	23.5	37.5	160	3.7	x
Raw milk					
Estonia	22.9	28.7	125	1.6	1.8
Latvia	22	28.2	128	1.8	1.8
Lithuania	17.6	28.2	160	3.8	2.7
EU 27	27.5	31.3	114	0.9	x
Cheese					
Estonia	290.3	315	109	0.5	0.8
Latvia	285.6	332.7	116	1.0	0.9
Lithuania	287.2	467.2	163	3.9	2.6
EU 27	438.8	519.2	118	1.1	x
Butter					
Estonia	252.7	310.5	123	1.4	1.5
Latvia	223	311.6	140	2.5	2
Lithuania	242.6	321.8	133	2.0	2
EU 27	344.6	366.9	106	0.4	x
Pig meat					
Estonia	162.3	178.5	110	0.6	5.8
Latvia	134	151.5	113	0.8	0.3
Lithuania	144.1	188.5	131	1.9	0.3
EU 27	141.1	180.9	128	1.8	x

*Time series 2005−2020
Source: AGMEMOD combined model 3.1 (2008)

Following three subchapters devoted for examples of price dispersion analysis using the automatic price dispersion analyse system (PDAS) which is covered the three main most important agricultural commodities in Baltic States − rapeseed, milk and pig meat.

Price dispersion analysis of rapeseed

Concerning the rapeseeds the main engine of price change is external and internal market demand for rape oil. Rapeseeds prices after the accession (2005) were slightly below the EU 27 average price and close to German (DE) key price in Latvia (LV) and Lithuania (Table 2 and 3).

The price convergence trends for rapeseed are forecasted in Baltic States up to 2020 (Figure 4). High price convergence speed predicted for Estonia where the value of price dispersion coefficient (PDC EE 2.4) is rather notable. For all Baltic countries the rapeseed price projections are higher compared with German key price and below compared with EU 27 average price.

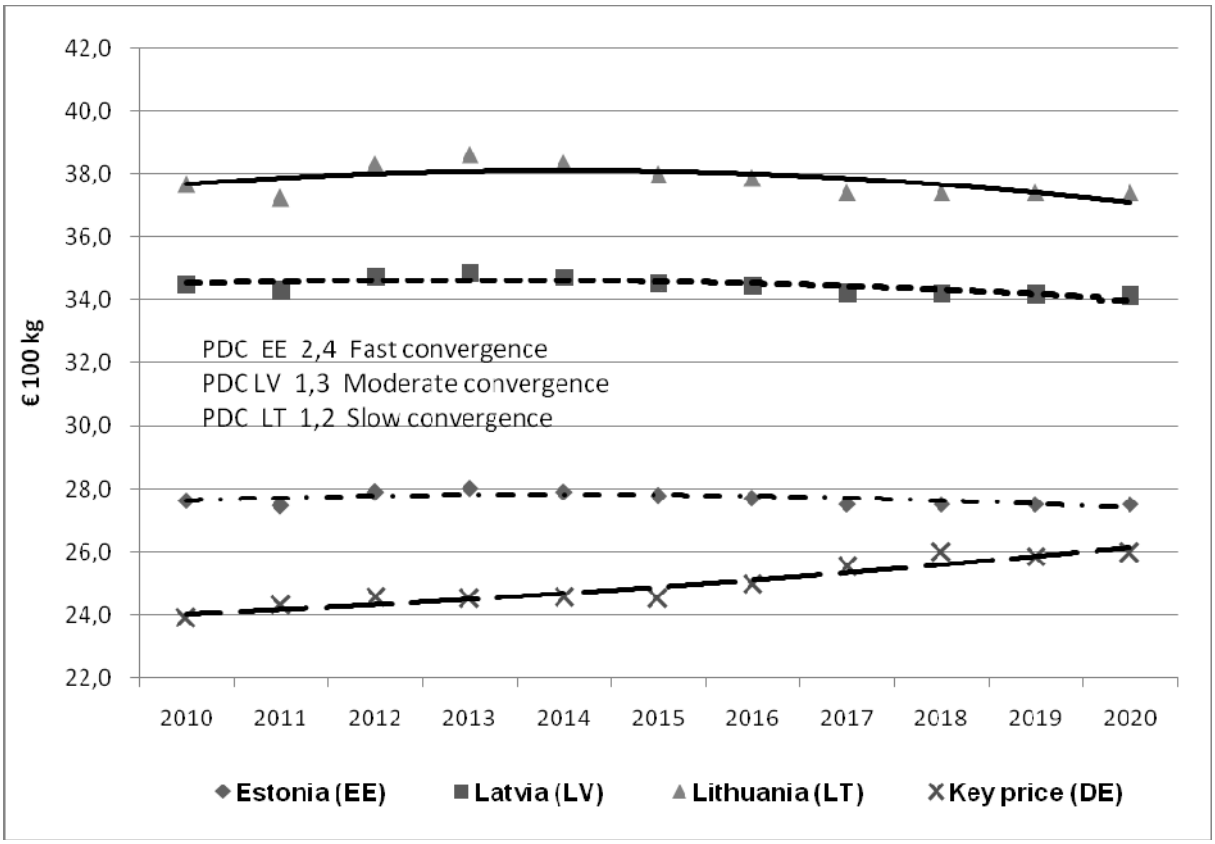

Figure 4. Price projection trends for rapeseed in Baltic States up to 2020.
Source: AGMEMOD combined model 3.1 Baseline (2008)

Significant price changes for rapeseed are predicted in Latvia and Lithuania Prices for rapeseeds is quite stable in Estonia. Growth per year (2005−2020) 0.4 % − is significantly under the predicted general inflation (3%) rate. Moderate and slow price convergence for rapeseed is in Latvia and Lithuania.

Rapeseed strongly competed with cereals. Therefore the grains area are decreasing and rapeseed area harvesting are increasing. Due to the increasing demand for oilseed the EU and World markets the net-exports of rapeseeds during the simulation period are significantly increasing in all Baltic States.

The value of Price Dispersion Coefficient (PDC = 0.4) indicated to the moderate price divergence in future between Estonian and EU 27 average prices.

Rapeseed price was significantly below the EU 27 average price in 2005 and expected to increase close to the reference price level up to 2020 in Lithuania (Table 3).

Rapeseed harvested area and production shows increase in both directions. Yield increase due to the EU and national support, which capacitates to use more fertilisers and pesticides and conditions improvement of technology. Same time path the harvested area of rapeseed expected to increase 2.5 times. Rapeseed domestic consumption increases 15.2 times, taking in to account increasing plants capacities.

The value of Price Dispersion Coefficient (PDC = −9.9) indicated up to 2020 quite fast price convergence and after that divergence between Lithuanian and EU 27 price.

Rapeseed price is under the key price level in 2005 and there are quite fast price convergence observes in simulated period in Latvia (Table 3). Rapeseed yield is growing in line with grain yields. Rape oil is expected to continue to be the fastest growing market for Latvian agricultural products and to be a net-exporter of this commodity. High demand, variety of use and land areas available for crop rotation are contributing to further increase of rapeseed production and export amounts.

The value of Price Dispersion Coefficient (PDC = 2.5) indicated to the fast rapeseed price convergence between Latvian and EU key prices up to 2020 (Table 3).

Price dispersion analysis of milk

Baltic States located in one of the world's most important milk production region. Share of milk production in gross agricultural production varied from 21 up to 28 % in 2007. Some negative trends in the dairy sector have been observed since the beginning of 1990 in all NMS countries. Political and economical changes resulted in a reduction in state support for milk producers and consumers, rapid price growth for production equipment, a change in the land ownership and purchasing power of the population. Milk producers in the Baltic States were reacted to the changes by reducing their milk production.

After the accession to EU (2004) the milk production due to the fast market price increase and introduction of EU support schemes are stabilized in Baltic States. If an average milk prices in 1998−2000 were significantly under the Netherland key price, then first years (2004− 2006) after the accession the fast milk price convergence took place (Table 1).

By model projection producer prices for milk in all Baltic countries will stay under the key prices up to 2020 (Figure 5).

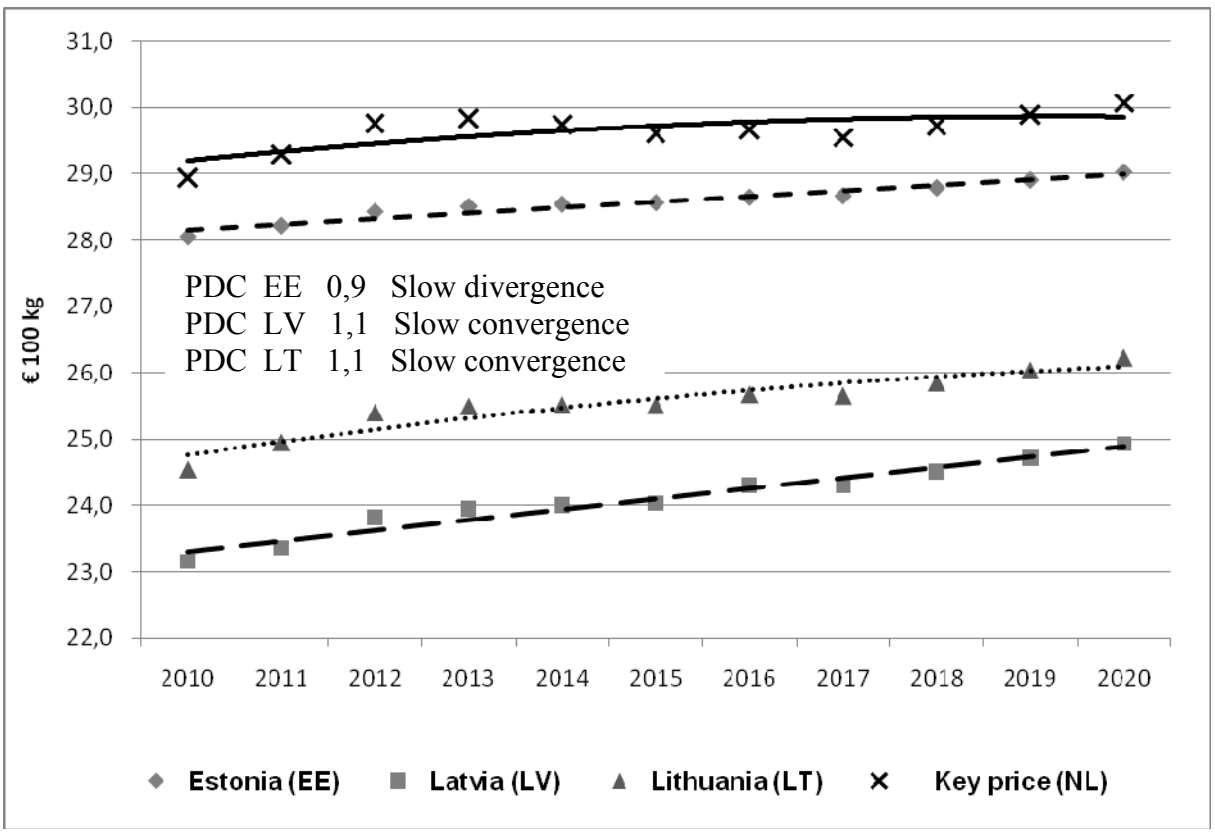

Figure 5. Price projection trends for raw milk in Baltic States up to 2020.
Source: AGMEMOD combined model Baseline 3.1 (2008)

Slow price divergence projected for milk in Estonia and slow convergence for Latvia and Lithuania. The low milk producer price is a grant to obtain some competitive advantages for production of cheese, butter, skim and whole milk powder.

Price dispersion analysis of pig meat

Pig meat is the main meat production branch in Baltic States. The share in gross agricultural production was in Estonia 11%, in Latvia 7.4% and in Lithuania 6.5% in 2008. The self sufficiency of pig meat in same time is slightly under the 100 % in Estonia (89%) and Lithuania (85%), but significantly under 100 % in Latvia (52%).

Historically the pig meat producer prices in Baltic States are higher compared with German key prices and close to average EU 27 in Latvia and Lithuania up to 2006 (Table 1 & 3). By the AGMEMOD 2020 model projections the pig meat producer prices are increasing in all Baltic States and as well in key country (Figure 6).

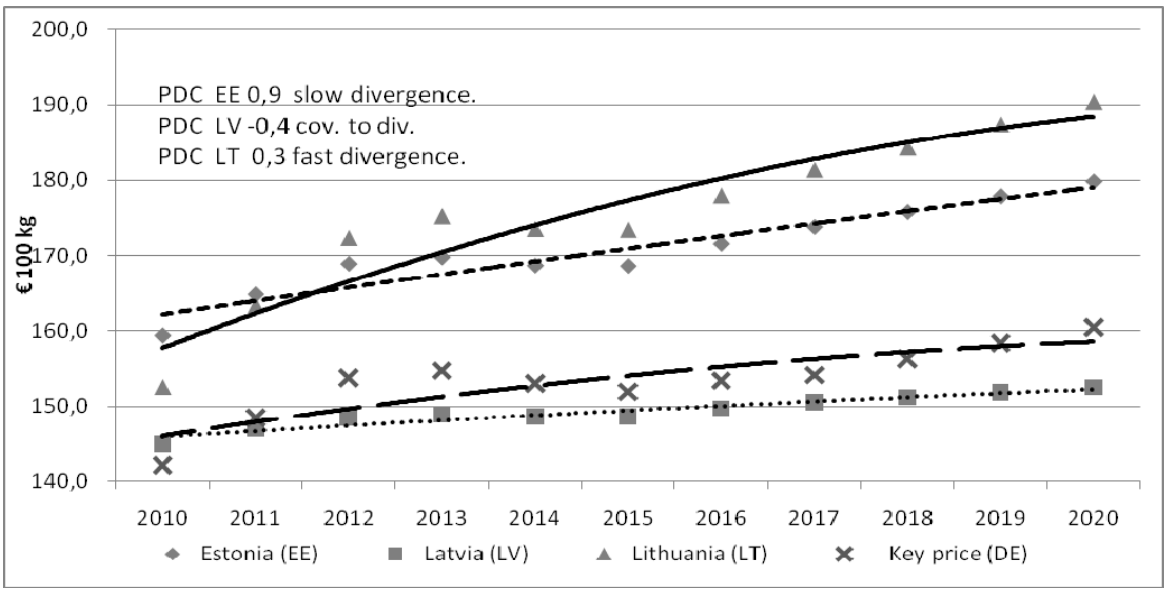

Figure 6. Price projection trends for pig meat in Baltic States up to 2020.
Source: AGMEMOD combined model 3.1 Baseline (2008)

Fast increase of pig meat producer prices up to 2020 are projected for Estonia and Lithuania and these ones are significantly higher compared with German key price. Same indicator remains slightly under the German key price in Latvia.

Discussion and conclusions

The main comparative advantages of the Baltic countries, which determine their specialization in the world market after regaining their independence and during the whole transition period, have been related to their geographical location, highly qualified labour and relatively low wages. After the accession to EU Baltic States with some exceptions were accepted the common market rules.

Over the last few years agricultural prices in all Baltic States as well as in EU internal market have been very floating. After the long term steady decline was broken by a big increase during 2007 which reached exceptional levels by early 2008. Increases in EU market prices in February 2008 against the same month in 2007 were of the following order of magnitude: 84% for wheat, 63% for rapeseed oil, 30% for milk and 35% for cheese.

However food prices have sharply declined since April 2008 and have come back to levels similar to or even below those before the price spikes. Moreover, the global economic uncertainty raises concerns about possible renewed price volatility. The effect of some of the short-term drivers which amplified the increase in agricultural prices in the second half of last year has diminished due to more favourable weather conditions, declining energy prices, lifting of export restrictions. Global supply has responded swiftly and strongly to higher prices, supported by a relaxation of production constraints in the CAP, notably the suspension of mandatory set-aside of arable land and the increased milk quotas from 2008 onwards.

The basic discussion point for the future AGME MOD model solutions is to determine the reliable key prices. Previous model results in large scale affected by extremely high crop prices in 2007 as exceptional case. In 2008 and probably in 2009 also the crop prices significantly decreasing.

Concerning the choice of scenarios these ones are quite similar to each other, without any extreme offers. Therefore the widening of certain extreme model variations allows testing and improving the equations flexibility of the AGMEMOD model.

The general assumption is that the law of one price can be applied in EU internal food markets. Unlike in international trade, where it takes time and effort to move goods physically from one place to another and secondly there are some significant barriers in global food market. But this law does not always hold in practice in food market in EU also. The reason is mostly concern lower transaction and input costs in NMS.

The integration of the NMS into the EU is certainly a good actual experiment to test the LOOP and several price dispersion issues. On the other hand, NMS, as relatively low-price countries undergoing price convergence towards the EU average, would experience a rise in their inflation rates and would have problems in fulfilling the nominal convergence criteria. New Member States (NMS) are afraid that their prices will increase due to integration, while Old Member States (OMS) are afraid that they will have to drop prices if they want to be competitive.

AGMEMOD 2020 model assumed only the price convergence trends. Unfortunately, based on Law of One Price among of some commodity prices related to the EU key prices the price divergence trends are occurred.

This study is quite unique the purpose of analyzing price convergence after the European enlargement in 2004. The main results of the research through the different topics are following:

- Analyses of technical efficiency (yield convergence) indicated to the significant increase of crops yield and livestock productivity in Baltic States after the accession to the European Union compared with forecasted basic indicators before 2004. Therefore, taking into account the quite stable demand of agricultural products on the food market some structural changes were occurred on the field of cereals and oilseed sector. In dairy sector the diminishing of animal compensated the milk production through the rising productivity of dairy cows.
- Concerning the price dispersion the general trend in Baltic States between the national and EU 27 prices are the prices convergence, of course with some exceptions (pig meat).
- By the Baseline results of AGMEMOD 2020 model the self sufficiency rate (SSR) compared with 2005 will increase in grain sector for all Baltic States. Decreases are forecasted for cheese production (except Lithuania).
- Taking into account quite stable demand of food products on the market, purchasing power of national currency and the low share of agriculture in macroeconomic indicators (GDP, GDP deflator, population etc) of the AGMEMOD 2020 high key and world market prices significantly affected the baseline and scenarios results.
- By the results of AGMEMOD 2020 model solutions the best alternative scenario for Baltic States and for all New Member States is the EU wide flat rate scenario with implementation of SPS payment model (2B).

The next steps to improve the model forecasts are to generate two additional AGMEMOD 2020 model versions. First is with moderate increase and the second in condition of low EU key prices.

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Toiduhindade analüüsid Balti riikides AGMEMOD 2020 mudeli raamistikus

Mati Sepp

Kokkuvõte

Hindade konvergents (ühtlustumine) ühises majandusruumis, kus toimib tööjõu ja kaupade vaba liikumine, on objektiivne protsess, millega peavad arvestama kõik sellesse ühendusse kuuluvad riigid. Hindade ühtlustumine põhineb ühel universaalsemal majandusseadusel, mida tuntakse ühe hinna seaduse nime all. Samas, sõltuvalt turumoonutuste ulatusest võib hindade konvergents olla erinevate riikide vahel kiirem või aeglasem. Liigsed turumoonutused aeglustavad hindade ühtlustumist ning vaba konkurentsi soodustamine, vastupidi, kiirendab protsessi. Seepärast, terve majanduse aluseks on olnud, on ja jäävad eelkõige terved hinnad. Põllumajandustootjale pole midagi tähtsamat, kui nende poolt progressiivselt rakendatud töö ja kapitali koostöö tulemusena genereeritud tulem (toode, teenus) ning selle tulemi eest saadav hüvitis (hind).

Toiduhindade ühtlustumise või eristumise hindamiseks täiustas Eesti Põllumajanduse Ministeeriumi 2007. aastal riikliku programmi 'Põllumajanduse rakendusuuringud ja arendustegevus aastatel 2004−2008' raamistikus tellitud uuringus 'Hindade konvergents Euroopa Liidus ning selle mõju Eesti toidusektorile' väljatöötatud hinna konvergentsi koefitsienti (PCC). Arvestades, et alati ei ole tegemist üksnes hindade ühtlustumise trendiga, −2006) ja prognoose (2007−2020).

Kirjutis analüüsib, millises ulatuses muutusid põhiliste toiduainete tootjahinnad Balti riikides esimese kolme Euroopa Liidu liikmesoleku aasta jooksul (2004−2006) võrreldes aastatega 1996−1998 ning üleminekuperioodiga 2001–2003. Teiseks, tuginedes mudeli AGMEMOD 2020 prognoosi tulemustele analüüsiti toiduhindade võimalikke muutusi aastatel 2007−2020.

CHANGES OF SOIL ORGANIC CARBON AND MOBILE HUMIC ACIDS IN RESPONSE TO DIFFERENT AGRICULTURAL MANAGEMENT

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ABSTRACT. *Field and laboratory investigations were done at the Lithuanian Institute of Agriculture (LIA) and Joniskelis Research Station of LIA, Lithuania. The aim of the study was to compare the soil organic carbon (SOC) as well as carbon of mobile humic acids (MHA) contents in the differently used agricultural soils. The data of SOC and MHA investigated in four different field experiments are discussed in this article. In the Experiment 1 the study investigated two soil tillage systems: conventional and sustainable (factor A) and crop rotations with different structure of winter crops (0−100%) (factor B) on a Endocalcari-Endohypogleyic Cambisol at the Joniskelis Research Station of LIA. The field Experiment 2 compared the influence of long-term legume swards on SOC and MHA in an Epicalcari-Endohypogleic Cambisol. In the Experiment 3 the treatments of factor A involved 7 different swards and the treatments of factor B of this experiment involved frequent and less frequent grazing. Five pasture fertilisation treatments* P_0K_0; $P_{60}K_0$; $P_{60}K_{30}$; $P_{60}K_{60}$; $P_{60}K_{90}$ *were investigated in the Experiment 4 in an Epicalcari-Endohypogleic Cambisol in a long term field experiment. SOC content was determined by Tyurin method. MHA was determined according to the Ponomariova–Plotnikova method. Different agricultural management affected changes in SOC and MHA. MHA fraction in Cambisol can be considered as one of the sensitive indicators of SOM changes in the agricultural environment.*

Keywords: *soil organic carbon, mobile humic acids, agriculture, management, sustainable tillage, grassland, pasture, Cambisol, fertilization.*

Introduction

Soil, which is a complex and continuously developing part of many ecosystems, including grassland, plays an especially important role in the protection of natural environment and use of its resources. One of the major sources of soil organic carbon (SOC) is plant residues, the highest content of which is left in the soil by perennial grasses, especially legumes. Soil C and N sequestration potential can be enhanced by utilization of management practices such as conservation tillage and intensive cropping systems. Impacts of tillage on soil organic matter (SOM) in surface soils have been well documented, but results vary due to soil type, cropping systems, residue management, and climate (Paustian *et al.*, 1997).

Some experimental findings suggest that in grazed swards the build up of (SOC) is higher than that in cut swards and that, in general, the accumulation of carbon is higher at higher mineral nitrogen fertilisation. Using legume/grass swards and improving the use of grazed swards one can also expect satisfactory productivity of swards and C accumulation in the soil. The data on organic carbon accumulation in the soil at different management of legume/grass swards are scarce. The floristic diversity and productivity of long-term Lithuanian pasture ecosystem is closely related to management practices and environmental factors. Annual inputs of organic matter are greater in grasslands than in other agricultural soils. Grass leys supply two to three times more organic matter to soil than annual crops such as cereals (Lægreid *et al.*, 1999). In pasture ecosystem the organic matter and livestock excreta accumulate in the topsoil and take part in the processes of mineralization and humification there (Gutauskas, Slepetienė, 2000).

Agricultural policies in the EU are enhancing the increase of biodiversity in all ecosystems including the pastures. The higher biodiversity at the organic pastures was a result of the extensive farming situation, in terms of low farm mineral inputs (Baars, 2002). Proper well-replicated networks of grassland biodiversity management experiments are urgently needed at the national and European levels. Using the scientific knowledge on evolution and ecology of grassland biodiversity, effective grassland farming and biodiversity conservation can be integrated (Pärtel, 2005).

SOM and humic substances are important indicators of soil fertility as they are involved in the stabilization of soil aggregates and binding of metals and anthropogenic organic chemicals (Donisa *et al.*, 2003). Their stability and turnover rates are important factors in interpreting the effects of agricultural and land use changes on soil system dynamics and carbon cycling (Spaccini *et al.*, 2006). Sometimes changes in SOC due to management practices are difficult to investigate while these changes occur slowly, are relatively small compared to the vast SOC pool size, and vary both spatially and temporally (Russell *et al*., 2004; Purakayastha *et al*., 2008). In various research works it is documented that some of the soil C fractions are more sensitive to management practices than the total SOC (Campbell *et al*., 1997). There is not so much evidence on the changes in mobile humic acids (MHA), which being influenced by the management practices, can be considered as indicarors of the changes occurring in the soil. These soil C fractions may serve as indicators of

future changes in total SOC that are presently undetectable. There is a lack of data on SOC changes obtained in precision field experiments, and especially the long-term experiments. This gap should be filled.

The purpose of our study was to determine the contents of SOC and MHA accumulated in the differently used agricultural soil: to compare soil properties using conventional and sustainable tillage, the performance of long-term grass/white clover/forbs swards under grazing management; to evaluate the effect of different PK fertilisation rates on accumulation of SOC and MHA in long-time scale; to study soil properties of ecologically grown mono- and multi-component long-term legume swards.

Materials and methods

A field Experiment 1 was established on a glacio-lacustrine clay loam on silty clay *Endocalcari-Endohypogleyic Cambisol* at the Joniskelis Research Station of the Lithuanian Institute of Agriculture (LIA) situated in the northern part of the Central Lithuania's lowland. The study investigated two soil tillage systems: conventional and sustainable and crop rotations with different structures: 0, 25, 50, 75 and 100% of winter crops in a crop rotation. The parent material is glacio-lacustrine clay. Clay particles (< 0.002 mm) in the A_a horizon (0−30^{0}cm) constitute 27.0%, in the B_1 horizon (52−76 cm) 51.6%, in the C_1 horizon (77−105 cm) 10.7%, and in the C_2 horizon (106−135 cm) 11.0%. Before the experiment, soil pH (KCl 1M, w/v 1:2.5) was 6.6-6.8; available phosphorus (P_2O_5) 154 mg kg^{-1} and available potassium (K_2O) determined by the Egner-Riem-Domingo (A-L) method 304 mg kg^{-1}. Soil samples were collected from 0−15 and 15−25 cm depths.

The field Experiment 2 compared the influence of long-term legume swards on soil humic substances in an *Epicalcari-Endohypogleic Cambisol* with clay content of 11.9%, silt 34.2% and sand 53.9% in Akademija, near Kedainiai. Before the experiment, plough-layer's pH (KCl 1M, w/v 1:2.5) was 7.0; available phosphorus (P_2O_5) determined by Egner-Riem-Domingo (A-L) method: 128 mg kg^{-1}; and available potassium (K_2O) 211 mg kg^{-1}. Soil samples were collected from 0−10, 10−20 and 20−30 cm depths with 6−8 boreholes per replicated plot. In both Experiments 1 and 2, the soil of three field replicates was investigated in the laboratory. Experiment 2 explored the effects of seven swards grown for 5 years under ecological management on the accumulation of humic substances in different soil layers. No fertilizers or pesticides were used. The following long-lived swards and their mixtures were investigated: *Galega orientalis; Medicago sativa; Onobrychis viciifolia; galega/Medicago/Festulolium; Galega/ Onobrychis/Festulolium; Galega/Medicago/T. Pratense/ Festuloilium; Galega/T. Repens/Onobrychis/ Festulolium.* The experiment was laid out as a randomized complete block with four replications.

A bi-factorial field trial was established in 1998 on an *Epicalcari-Endohipogleic Cambisol* in Akademija, central part of Lithuania (Experiment 3). The treatments of factor A involved 7 different swards consisting of *Trifolium repens* L., *Medicago varia* Mart., *Lolium perenne* L., *Poa pratensis* L., *Festulolium*. The treatments of factor B involved frequent (F) and less frequent (LF) grazing (with 6 or 5 grazing per season respectively). The content of SOC and MHA was determined in the soil of pasture swards in the third year of use at the 0−25 cm layer.

In the Experiment 4 long-term trials were conducted at the LIA over the period 1993−2002. The experiments have been carried out since 1961. Five fertilisation treatments were investigated: P_0K_0; $P_{60}K_0$; $P_{60}K_{30}$; $P_{60}K_{60}$; $P_{60}K_{90}$. The experimental soil is *Epicalcari-Endohypogleic Cambisol*. Each treatment of the field trial had four replicates. Experimental pastures were grazed 3−4 times per season on a rotational basis with a herd of dairy cows. Before each grazing cycle, the plots in the pasture were cut to a grazing height.

Analytical methods. SOC content was determined by Tyurin method modified by Nikitin (1999). Mobile humic acids (MHA) are free or weakly bound with clay minerals fraction. According to the Ponomariova–Plotnikova method mobile humic substances were extracted by 0.1M NaOH solution (room temperature) at a soil–solution ratio of 1:20 and separated into humic and fulvic acid fractions by acidifying the extract to pH 1.3–1.5 using 0.5M H_2SO_4 at 68–70^{0}C and after following MHA's were separated by filtering (Ponomareva, Plotnikova, 1980). Carbon of mobile humic acids (MHA) was determined spectrophotometrically using Carry 50.

Results

Data on the SOC and MHA investigations of differently used agricultural soils are presented in this work. Our findings suggest that sustainable soil tillage system affected organic carbon accumulation in the soil (Table 1). Sustainable soil tillage significantly increased SOC content both in the topsoil and subsoil compared with conventional tillage. In the conventional tillage system the content of SOC accumulated in the topsoil (0−15 cm) was from 11.5−11.9 g kg^{-1} in the crop rotation with 0−50% of winter crops to 12.2 g kg^{-1} in the crop rotation with 75−100% of winter crops. In the sustainable soil tillage system, SOC content was significantly higher in the topsoil (0−15 cm) from 13.1−13.2 g kg^{-1} (0−50% of winter crops in the crop rotation) to 13.7 g kg^{-1} (100% of winter crops in the crop rotation). The highest SOC content was in the sustainable soil tillage system, having increased the share of cereals in the crop rotation structure to 100%. Similar regularities were identified in the 15−25 cm layer. These results demonstrate also the role of wintering crops in SOM and SOC conservation.

Table 1. The influence of soil tillage systems and proportion of winter crops in the crop rotation on the content of SOC (g kg^{-1}). Mean data from 2004−2006

Proportion of winter crops, % (A)	Depth (cm)	Soil tillage system (B)	
		Conventional	Sustainable
0	0–15	11.9	13.2
	15–25	11.0	11.8
25	0–15	11.5	13.1
	15–25	11.5	12.8
50	0–15	11.8	13.1
	15–25	11.5	12.5
75	0– 15	12.2	13.1
	15–25	12.2	12.0
100	0–15	12.2	13.7
	15–25	12.2	13.2
Mean across tillage (B)	0–15	11.9	13.2
	15–25	11.7	12.5
LSD_{05}		0–15 cm	15–25 cm
A		0.42	1.0
B		0.21	0.50
AB		0.63	1.5

The data presented in Figure 1 and Figure 2 show the variation of humified carbon representing by mobile humic acids (MHA) in 0−15 cm and 15−25 cm soil layers. It was found that increasing the area of longer vegetation wintering crops and applying sustainable tillage in the heavy soil had a positive influence on the MHA. The data show a significant increase in these MHA in the crop rotation with winter crops in both soil layers similar to trends in the SOC content. Compared with conventional tillage (CT), sustainable tillage (ST) significantly increased MHA content in topsoil (0−15 cm) from 0.68 to 0.85 g kg^{-1}. An increase in the share of winter crops in the crop rotation to 100% strengthened this effect and the highest content of MHA was identified here.

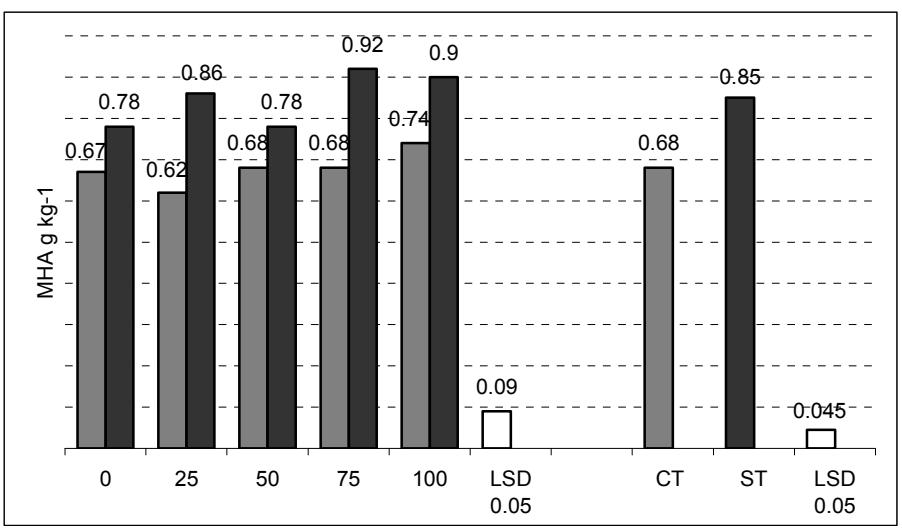

Figure 1. Effect of soil tillage systems and proportion of winter crops in the crop rotation on the MHA in 0−15 cm soil layer. CT-conventional tillage; ST-sustainable tillage.

Statistically significant topsoil increases in MHA were obtained in the crop rotation with 100% winter crops, compared with the rotation composed solely of spring crops. MHA was 3.0−6.0% of SOC using the conventional tillage, and 2.0 to 4.0% using sustainable tillage. While in the sustainable tillage MHA content (% in the soil) increased compared to conventional tillage, but in the sustainable tillage it seems that SOC content increased due to an accumulation of more stable SOC fractions.

Pastures, meadows and leys in Lithuania cover about 1 million hectares and account for over one third of the total agricultural land. Besides forest ecosystems, grassland ecosystems make up one of the largest areas in Lithuania, like in many European countries. Therefore these ecosystems are also extremely important from the environmental viewpoint and it is vital to know them. Nonetheless there are few researchers involved in this area, and particularly in the research into carbon accumulation and transformation processes. The data show, that the soil under long-lived swards after 5 years of cultivation was rich in SOC: in all soil layers 0−10, 10−20, 20−30 cm the SOC content had mean values of 15.1, 14.1 and 11.7 g kg^{-1}, respectively. Multi-component swards (throughout the 0−30 cm layer) tended to increase SOCs content more than mono-component swards (Table 2).

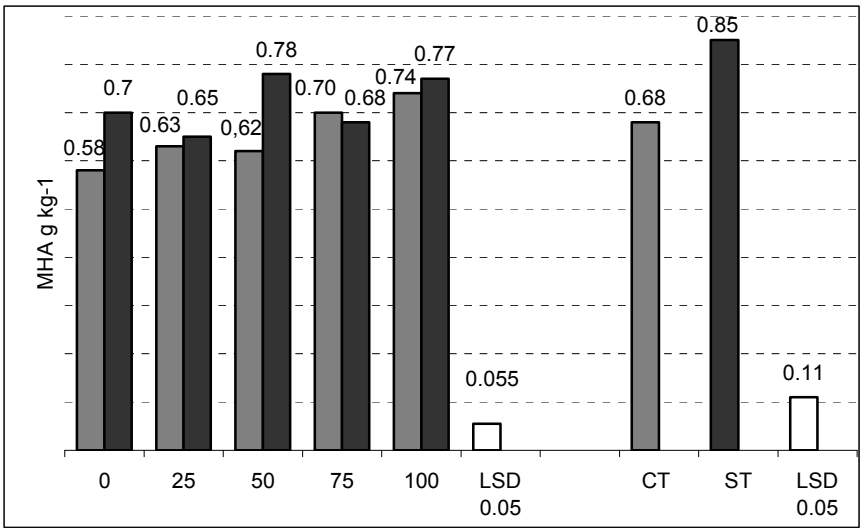

Figure 2. Effect of soil tillage systems and proportion of winter crops in the crop rotation on the MHA in 15−25cm soil layer. CT-conventional tillage; ST-sustainable tillage.

Table 2. The influence of grass species on the content of SOC (g kg^{-1}) in soil. Mean data from five year sward

Grass (factor A)	Soil depth (factor B) (cm)			Mean across all depths
	0−10	10−20	20−30	
Galega orientalis	14.4	14.2	11.5	13.4
Medicago sativa	15.1	13.8	12.1	13.7
Onobrychis viciifolia	15.3	13.9	12.1	13.8
Galega/Medicago/Festulolium	15.2	14.8	12.3	14.1
Galega/Onobrychis/Festulolium	15.0	14.5	11.3	13.6
Galega/Medicago/T. pratense /Festulolium	15.5	13.9	11.3	13.6
Galega/T. repens /Onobrychis/Festulolium	15.5	13.9	11.5	13.6
Mean across grasses	15.1	14.1	11.7	

LSD_{05}	
A	0.63
B	0.37
AB	1.16

Notes: Galega orientalis 100%; 2. *Medicago sativa* 100%; 3.*Onobrychis viciifolia* 100%; 4. *Galega orientalis* 40%, *Medicago sativa* 40%, *Festulolium* 20%; 5. *Galega orientalis* 40%, *Onobrychis viciifolia* 40%, *Festulolium* 20%; 6. *Galega orientalis* 40%, *Medicago sativa* 20%, *Trifolium pratense* 20%, *Festulolium* 20%; 7. *Galega orientalis* 40%, *Trifolium repens* 20%, *Onobrychis viciifolia* 20%, *Festulolium* 20%.

MHA accumulation in the soil depended on swards and their mixtures' biological characteristics. The highest amount of MHA accumulated in the soil under four-component sward (Figure 3). The use of mono- and multi-component swards during the 5 year experimental period determined significant increases in MHA. Compared with the 2001 data, the content of MHA increased more than two-fold. In the four-component sward (*Galega/T. repens/Onobrychis/Festulolium)* the 0−30 cm soil layer had more MHA, compared with mono-sward (*Galega orientalis)*. MHA content in the 0−10 cm and 10−20 cm soil layer was 2.0 to 3.0% of the SOC, and the deeper layer (20−30 cm) only 2.0%. This reflects more intensive humification and SOM transformation processes occurring in the top layer of grassland soil.

At the Experiment 3 a trend was observed that a higher content of organic carbon was accumulated in the soil under frequently grazing of swards (Table 3).

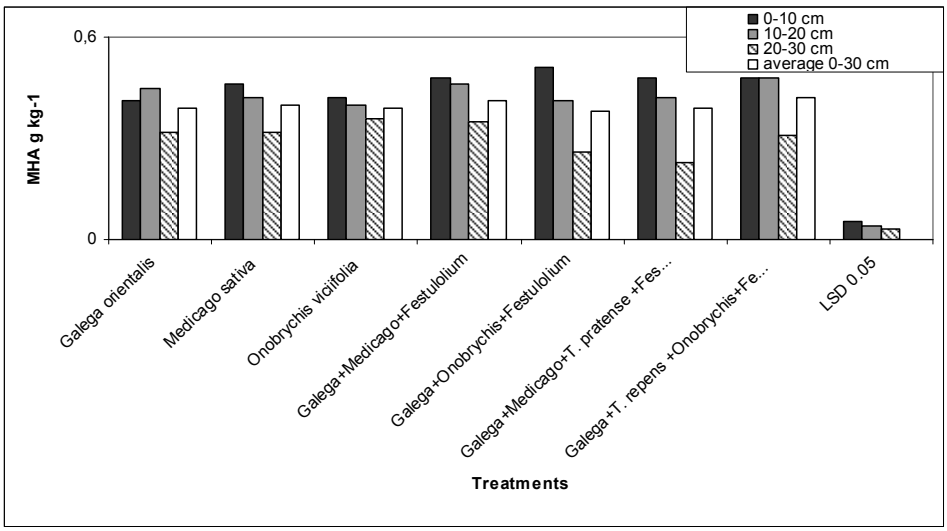

Figure 3. The effect of grass species on the MHA in different soil layers. Mean data from five year sward
1. Galega orientalis 100%; 2. *Medicago sativa* 100%; 3.*Onobrychis viciifolia* 100%; 4. *Galega orientalis* 40%, *Medicago sativa* 40%, *Festulolium* 20%; 5. *Galega orientalis* 40%, *Onobrychis viciifolia* 40%, *Festulolium* 20%; 6. *Galega orientalis* 40%, *Medicago sativa* 20%, *Trifolium pratense* 20%, *Festulolium* 20%; 7. *Galega orientalis* 40%, *Trifolium repens* 20%, *Onobrychis viciifolia* 20%, *Festulolium* 20%.

Table 3. Organic carbon accumulation in the soil under grazed swards, Akademija, 2002

Treatment	SOC g kg^{-1}	
	F	LF
Trifolium repens/Lolium perenne	19.8	17.7
Trifolium repens/Poa pratensis/Lolium perenne/	17.1	17.7
Medicago sativa/Poa pratensis/Lolium perenne/	18.0	17.8
Medicago sativa/ Trifolium repens/ Lolium perenne	19.1	18.5
Lolium perenne N_0	18.4	17.7
Lolium perenne N_{240}	17.4	17.0
Trifolium repens//Lolium perenne/Festuliolium	17.9	17.3

N_0 − without mineral fertilisers; N_{240} – fertilisation rate 240 kg ha^{-1}; F − grasses grazed frequently; LF − less frequently

Figure 4 shows that the highest MHA content in the soil accumulated under sward a mixture consisting of legume *Trifolium repens* and grasses grazed frequently (1.38− 1.47 g kg^{-1}) and in other investigated sward mixtures the opposite trends were determined. MHA content in the 0–25 cm soil layer was 6.0 to 8.0% of the SOC. This shows intensive humification and SOM transformation processes occurring in the top layer of soil under different F or LF grazed pasture swards.

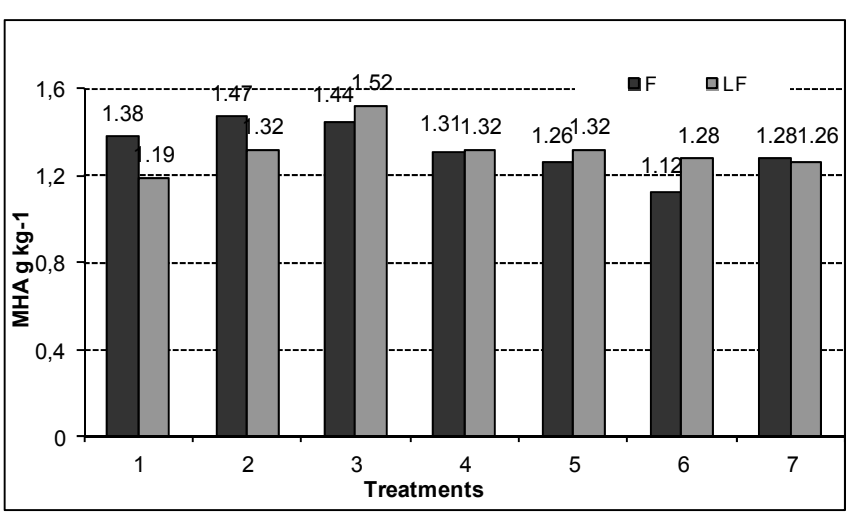

Figure 4. MHA accumulation in the 0−25 cm layer of different swards. F-frequent, LF-less frequent grazing.
1. Trifolium repens/Lolium perenne; 2. Trifolium repens/Poa pratensis/Lolium perenne; 3. Medicago sativa/Poa pratensis/Lolium perenne; 4. Medicago sativa/Trifolium repens/Lolium perenne; 5. Lolium perenne N_0; 6. Lolium perenne N_{240}; 7. Trifolium repens/Lolium perenne/festulolium

At the Experiment 4 long-term (40 years) grazing management of multi-component grass/legume/forbs swards maintained natural soil fertility and in the long run improved its quality parameters. The application of the inorganic PK fertiliser on the background of grazing had a strong and stable effect on the processes SOC and MHA accumulation in the soil (Table 4).

SOC content in the 0−10 cm layer was 3 times as high as that in the 20−30 cm layer. Yet, in the deep 30−50 cm layer relatively high contents of SOC were established and they were markedly higher than those in similarly managed soils under crop rotations. The MHA content in the soil (0−30 cm layer) applied with PK fertilisers increased by 8 % to twice (Figure 5). This reflects very intensive SOM transformation processes occurring in the long term pasture soil fertilized by inorganic PK.

Table 4. Distribution of SOC content in different layers of soil of the 40 year-old pasture

Treatment	Soil layer (cm)			
	0−10	10−20	20−30	30−50
	SOC g kg^{-1}			
P_0 K_0	28.8	15.4	9.74	3.49
P_{60} K_0	32.9	16.5	9.16	3.56
P_{60} K_{30}	34.3	17.7	10.2	3.91
P_{60} K_{60}	34.7	18.4	11.5	4.09
P_{60} K_{90}	35.7	19.3	12.4	4.28
LSD_{05}	2.70	1.98	2.72	1.33

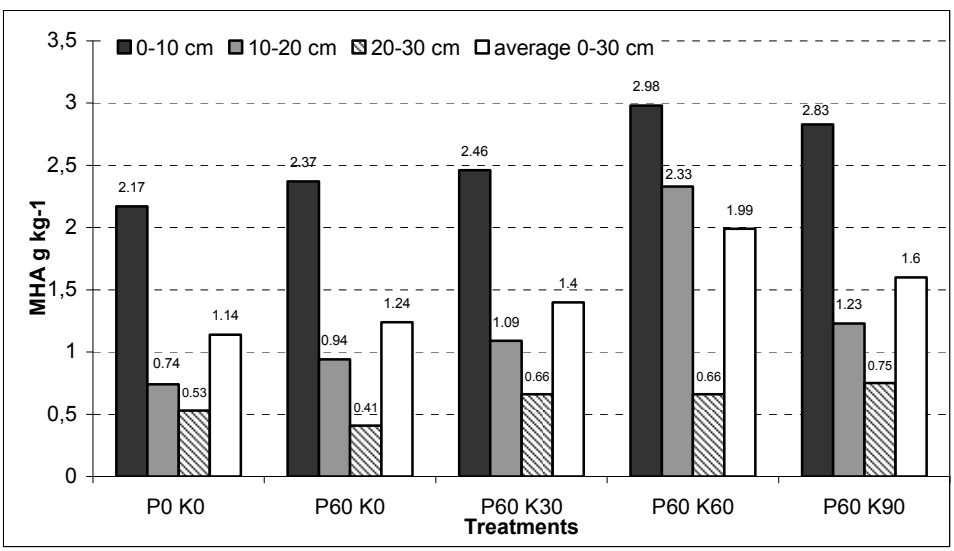

Figure 5. MHA content in different layers (0−10, 10−20, 20−30 cm) of soil in a long term (40 years) pasture

Discussion

Research results help to look slightly differently at the impact of sustainable soil management methods (grasses and sustainable tillage) on the accumulation of SOC and MHA. One of the major sources of SOC is plant residues, the highest content of which is left in the soil by perennial grasses, especially legumes (Paustian *et al*., 1997). It was reported earlier, that a large amounts of pasture plant residues and roots were continually contributed to the soil, as well as the near to neutral soil reaction resulted in prevalent humification processes (Gutauskas, Slepetiene, 2000). The newly obtained data of our research show that the content of MHA in a long-term pasture soil depended on PK fertilisation level and increased most in the fertilisation treatment $P_{60}K_{60}$. The data show that the highest amount of SOC and MHA accumulated in the soil that had not been tilled for a long time, compared with arable soils. Although arable soils contain less SOC and MHA, the sustainable tillage applied on them promoted SOC and MHA accumulation. According to SOC and MHA content, the long-term (40 years) pasture soil stratified in different layers (0−10, 10−20 and 20−30 cm). When fertilised with PK up to $P_{60}K_{60}$, SOC content in the 0-10 cm layer was 1.8−2 times higher than in the 10−20 cm layer, and as many as 2.9−3.6 times as high as that in the 20−30 cm layer. MHA content in different soil layers differentiated even more: in the 0−10 cm layer it was up to 2.9 times higher than in the 10−20 cm, and as many as up to 4 times as high as that in the 20−30 cm layer. This shows that MHA more sensitively responds to soil use as pasture when fertilised with PK and eventually forms very active SOC and MHA-rich 0−10 cm top soil layer. MHA accumulation depended also on soil texture. The trial done on a heavy-textured clay loam soil showed the least MHA share compared with lighter-textured soils. MHA makes up a different part in SOC depending also on soil management practices. On the other hand, organic matter transformation processes are influenced by soil specific properties and its texture. Thus, higher content of clay particles in the soil increases MHA sorption and due to the interaction with the soil mineral part, SOM mobility declines which results in lower MHA

relative share. Conversely, an increase of the share of fractions of mobile humic acids in the total organic carbon demonstrates a high SOM activity. Our findings on MHA supplement the data obtained by other researchers about the role of certain parts of SOC such as dissolved organic carbon, microbial biomass carbon, particulate organic carbon and others as indicators of changes in SOM pool. We found that MHA fraction in *Cambisol* can also be considered as one of the sensitive indicators of SOM changes in the agricultural environment.

Conclusions

Positive effect of grasses on the accumulation of SOC and MHA was determined. The highest SOC and MHA contents accumulated in the soil that had not been tilled for a long time, compared with arable soils. In grassland soil the SOC and MHA tented to accumulate in the topsoil. The long-term use (40 years) of swards as pastures increased SOC content in the 0−10 cm soil layer by as many as 2−2.5 times. The swards with legumes were found to promote SOC and MHA accumulation whose values depended on the composition of swards. In the four-component sward (*Galega/ Trifolium Repens/ Onobrychis/Festulolium)* the 0−30 cm soil layer had more MHS, compared with monosward (*Galega orientalis)*. A trend was observed that a higher content of organic carbon is accumulated in the soil under less frequent grazing of swards. The content of MHA depended on PK fertilisation level and increased most in the fertilisation treatment $P_{60}K_{60}$. MHA made up a different share in SOC depending on soil agricultural management as well as on the soil itself.

Acknowledgements

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EESTI VUTITÕU MUNAJÕUDLUSNÄITAJATE DÜNAAMIKA AASTATEL 1987–2010

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ABSTRACT. *Estonian Quail as a breed was recognized in 1987 and since this time wellknown as hardy, suitable for factory farming and disease free quail's population. The dynamics of egg performance traits of Estonian Quails kept in two largest Estonian quail farms – Järveotsa and Äksi – during over than twenty years are presented and discussed. In 2000 a new breeding programme to improve the main egg performance traits of quails was initiated and during the 16 generations two different quail families were formed: egg-type and meat-type. In 2009 an average 322 and 318.5 eggs a year were produced per egg-type and meat-type quails, respectively. An average egg weight of egg-type quails was 14.2 g and eggs of meat-type quails were a little lighter – 13.7 g. It was concluded from the trials that keeping female quails in pairs with males did not reduce the number of eggs laid during a year. Live weight of quails considerably increased during the laying period, at the end of laying period egg-type quails weighed 254 g and meat-type quails' weight was an average 260 g, which was about 30% bigger in comparison with initial weight at the first egg onset. The correlation between eggs laid in the first laying month and 6 months was high ($r = 0.78$, $P < 0.001$), which gives opportunity to predict the egg production of quails in early stages of laying period.*

Keywords: *Estonian Quail, quail egg production, quail egg weight, quail live weight.*

Sissejuhatus

Esimesed farmivutid Eestis koorusid 1967. a EPA eriloomakasvatuse kateedris Üleliidulise Linnukasvatuse Teadusliku Uurimise ja Tehnoloogia Instituudi katsefarmist toodud haudemunadest. EPA teadlased hakkasid uurima põldvuttide kasvu ja arengut, lindude munemisbioloogiat, munade ja vutiliha keemilist koostist (Ruus *et al.*, 1967). Et aga ENSV Põllumajandusministeerium polnud vutikasvatusest huvitatud, ei saanud linnukasvatusteadlased oma uut uurimisobjekti praktikale piisavalt tutvustada ja ettevõtmine jäi tollal paraku soiku.

Tõsisemalt hakati vutikasvatusega tegelema 10 aastat hiljem, kui 1976. aastal rekonstrueeriti Kaarepere Metsakatsejaamas F. Nõmmsalu ja K. Ilmeti initsiatiivil tühjalt seisnud partla ja Venemaalt toodi sisse 1,000 vaarao tüüpi vutti (Naaber, Ilmet, 1986). Juba järgmisel aastal algas Harald Tiku juhtimisel sihikindel aretustöö sissetoodud vutipopulatsiooni jõudlusnäitajate parandamiseks ning eesmärgiks seati Eestisse sobiva, heade jõudlusnäitajatega oma vutitõu loomine.

Eesti vutitõug aretati Kaarepere Metsakatsejaama Kaiavere vutifarmis 1977…1987. a mitmete Eestisse sissetoodud vutipopulatsioonide baasil (V. Tikk, 2003). Aretustöö esimesel etapil ristati suurema kehamassiga lihatüübilisi vaarao emasvutte märksa kergemate munatüübiliste jaapani isasvuttidega. Esimese sisestava ristamisega paranesid mitmed vuttide produktiivsusnäitajad, kuid emasvuttide munemisintensiivsus ja noorlindude säilivus polnud veel soovitud tasemel. Teine sisestav ristamine tehti inglise valgete munatüübiliste vuttidega (toodi 1979. a Poolast), kes olid vaaraovuttidest küll 40–60 g kergemad, kuid munesid viimastest 35–45 muna aastas rohkem. Pärast teise põlvkonna ristandite saamist keskenduti perekondaretusele, loodi 76 munatüübiliste ja 52 lihatüübiliste vuttide perekonda. 1984. a alustas Kaiaveres tööd aretuslindla, kus oli võimalik registreerida individuaalpuurides 369 emasvuti munajõudlusnäitajad. Järgnevalt rakendati ka kaasaegne andmetöötlus (Teinberg, 1986) ning parandati vuttide söötmispidamistingimusi. Kümneaastase töö tulemusena kinnitati 1988. aastal Üleliidulise Agrotööstuskomitee käskkirjaga eesti muna-lihavutid vutitõuna (Приказ..., 1988) ja anti välja autoritunnistus.

Eesti vuttide produktiivsusnäitajad olid tõu tunnustamisel järgmised: mune keskmise vuti kohta aastas (365 munemispäeva) 304 tk; täiskasvanud vuttide kehamass 32-nädalaselt ♀♀ 195 g, ♂♂ 170 g; muna keskmine mass 12.0 g; 28-päevaste noorvuttide kehamass ♀♀ 128, ♂♂ 117 g; söödakulu 1 kg munamassile 2.62 kg (H. Tikk, V. Tikk, 2007). Tõu tunnustamise eelsel 10-aastasel aretusperioodil olid 20 põlvkonna jooksul lähtematerjali produktiivsusomadused suurenenud järgmiselt: munatoodang 88.4%; 4-nädalaste noorvuttide kehamass ♀♀ 33.3%, ♂♂ 34.5%; täiskasvanud vuttide kehamass ♀♀ 27.5%, ♂♂ 23.2%; täiskasvanud vuttide säilivus 16% (Акт..., 1987).

Eesti vutitõu tunnustamise eel uuriti ka selle tõu erinevate produktiivsusomaduste vahelisi seoseid. Statistiliselt tõenäosteks osutusid neist järgmised (H. Tikk, *et al*., 1988): mida vanemalt hakkas emasvutt munema, seda suurem oli munatoodang ($r = 0.25$, $P < 0.05$); mida kergem oli emasvutt 40-päevaselt, seda suurem oli munatoodang ($r = –0.40$, $P < 0.001$); muna keskmine mass ei olnud usutavalt seotud teiste munemisbioloogiliste näitajatega; esimese kuu munatoodang ei olnud statistiliselt usutavas seoses 13 kuu munatoodanguga; 2. ja 3. munemiskuu munatoodang oli tugevas seoses 13 kuu munatoodanguga, vastavalt $r = 0.33$, $P < 0.01$ ja $r = 0.41$, $P < 0.001$. Eesti vuti aretustöö käigus on uuritud erinevate vutipopulatsioonide ristamistulemusi (H. Tikk *et al.,* 2009) ja eesti vuttide võimet muneda ka kaks muna päevas (H. Tikk, *et al.*, 2003), samuti vutimunade toiteväärtust ning kvaliteeti (H. Tikk *et al.*, 2010).

Käesolevasse artiklisse on koondatud mitme aasta katsete tulemused, kus uuriti eesti vuttide munajõudlusnäitajaid – munatoodangut, munemahakkamise iga, vuttide kehamassi ja munamassi dünaamikat munemisperioodil. Viimase 10 aasta tootmis- ja katseandmete põhjal analüüsitakse kahe kaasaegse eesti vuti aretusperekonna (perekond 4, munatüübiline ja perekond 8, lihatüübiline) munajõudlusnäitajaid. Kasutatud on vuttide individuaalse jõudluskontrolli andmeid.

Materjal ja metoodika

Eesti vuttide aretustöö ja nende jõudlusega seotud uurimised on aja jooksul toimunud mitmetes vutifarmides. Käesolevaks ajaks on vutikasvatusalaste uurimiste keskusteks kujunenud Järveotsa ja Äksi vutifarmid. Järveotsa vutifarmis, mis on Eesti suurim, ulatub suguvuttide koguarv mitmekümne tuhandeni ja kus lisaks eesti vuttidele on olemas ka suhteliselt suur Prantsuse päritolu lihavuttide populatsioon. Äksis peetakse ainult eesti tõugu vutte ja nende koguarv ulatub paari tuhandeni.

Vaatlusalusel perioodil peeti vutte rühmapuurides, neid söödeti vastavalt kasvujärgule ja jõudlusele täisratsiooniliste segajõusöötadega, mille retseptid baseeruvad toitefaktorite soovitatavatel kontsentratsioonimääradel (H. Tikk, Piirsalu, 1997). Vuttide jõudluskontrolli teostati individuaalsetes katsepuurides, mis võimaldas täpselt registreerida kõik uurimustööks vajalikud jõudlusnäitajad.

Uurimustulemuste statistilises analüüsis kasutati erinevuste olulisuse hindamiseks *t*-testi ja dispersioonanalüüsi. Tunnustevahelised erinevused loeti tõenäoseks, kui $P < 0.05$.

Tulemused ja arutelu

Kaasaegseid eesti vuttide muna- ja lihatüübilisi perekondi on välja kujundatud 16 põlvkonna jooksul. Perekondaretusega alustati 2000. aastal. Eesmärk oli luua kaks erinevat jõudlustüüpi: veidi kergem ja suurema munevusega ning raskem, kuid piisavalt hästi munevate vuttide perekond. Eesti vuttide munaproduktiivsus munemiskuude lõikes aastatel 2006–2009 on toodud tabelites 1 (munatüübilised) ja 2 (lihatüübilised). Traditsiooniliselt arvestatakse kanadel ja vuttidel munemiskuu pikkuseks 28 päeva. Eesti vutid saavutasid juba teisel munemiskuul üle 90%-lise munemisintensiivsuse (munevuse) ja see püsis nii muna- kui ka lihatüübilistel vuttidel kõrge kuni munemisperioodi lõpuni.

Tabel 1. Munatüübiliste vuttide munajõudlus (mune keskmise vuti kohta, tk) erinevatel kontrollaastatel (n = 54)
Table 1. *Egg production of egg-type Estonian Quails (Family 4) (n = 54)*

Munemiskuu / *Laying month*	Individuaalkontrolli aastad / *Years of individual control*				
	2006–2007	2007–2008	2008–2009	2008–2009	2009
I	14.3	15.5	18.5	19.8	20.6
II	25.4	24.9	25.2	24.8	25.7
III	25.8	24.8	25.8	25.9	25.3
IV	25.3	25.2	25.9	25.7	25.5
V	25.8	25.0	24.9	24.5	25.6
VI	25.4	24.7	25.6	24.9	25.5
VII	25.5	25.2	25.4	25.4	24.7
VIII	25.5	25.0	24.4	24.9	24.6
IX	25.4	24.9	24.5	24.1	25.0
X	25.0	23.7	24.7	25.2	23.9
Kokku, tk / *Total egg number*	243.8	238.3	244.9	245.2	246.4
Keskmine munemisintensiivsus, % *Average laying intensity*, %	87.1	84.9	87.5	87.6	88.0

Tabel 2. Lihatüübiliste vuttide munajõudlus (mune keskmise vuti kohta, tk) erinevatel kontrollaastatel (n = 54)
Table 2. *Egg production of meat-type Estonian Quails (Family 8) (n = 54)*

Munemiskuu / *Laying month*	Individuaalkontrolli aastad / *Years of individual control*				
	2006–2007	2007–2008	2008–2009	2008–2009	2009
I	17.4	17.0	18.2	18.7	22.3
II	24.9	25.1	25.1	24.0	26.1
III	24.6	25.7	26.3	25.4	25.7
IV	25.6	26.2	26.1	25.6	25.7
V	25.5	24.9	25.1	23.9	25.6
VI	25.7	24.8	25.4	25.0	25.6
VII	25.5	24.0	25.6	25.7	25.3
VIII	25.4	24.9	24.9	25.3	24.7
IX	25.6	24.3	25.3	25.6	25.1
X	23.1	24.2	24.4	25.0	23.5
Kokku, tk / *Total egg number*	243.3	241.7	246.4	244.2	249.6
Keskmine munemisintensiivsus, % *Average laying intensity*, %	86.9	86.4	88.0	87.2	89.1

Eesti vuttide munajõudlus 2006–2009 kontrollaastatel oli kõrge, olulist erinevust (P > 0.05) kahe perekonna vuttide munatoodangus ei olnud. Viie aasta keskmine 10 kuu munatoodang oli munatüübilistel vuttidel (perekond 4) 243.7 ja lihatüübilistel vuttidel (perekond 8) 245.0 muna. Mõlema perekonna vuttide keskmiseks munemisintensiivsuseks kujunes üle 87%, mis on märkimisväärne tulemus.

Vutid on varavalmivad linnud ja alustavad munemist noores eas. Munemahakkamise vanus sõltub vuttide genotüübist, nende söötmis- ja pidamistingimustest ning on tugevalt seotud kogu vutikasvatuse majanduslike näitajatega (Sreenivasaiah, Joshi, 1988; Okamoto *et al*., 1989; Singh, Panda, 1986; Thomas, Ahuja, 1988).

Lihatüübilised emasvutid olid munemahakkamisel keskmiselt veidi vanemad (1.4–3.5 päeva) kui munatüübilised, veidi kergemad emasvutid (tabel 3). Munatoodang muna- ja lihatüübilise rühma vahel oluliselt ei erinenud (P > 0.05). Mõned uurijad on leidnud, et munemahakkamise vanus on positiivses korrelatsioonis munemisperioodi munatoodanguga ja munamassiga, seega hiljem munema hakkavatel vuttidel kujuneb kogu perioodi munatoodang suuremaks ja munad on raskemad (Camci *et al*., 2002). Mõned uurijad on oma katsetes jõudnud just vastupidisele järeldusele. Kocak *et al.* (1995) uurimuses oli vuttide munemahakkamise vanus negatiivses korrelatsioonis (r = –0.461) munatoodanguga.

Tabel 3. Eesti vuttide munemahakkamise vanus (% vuttide algarvust)
Table 3. *Age of egg laying onset of Estonian Quails (% of total quails)*

Elupäevad / *Age (days)*	Perekond 4 / *Family 4*			Perekond 8 / *Family 8*		
	2008	2009	2010	2008	2009	2010
Enne 45 / *Before 45*	7.4	11.1	33.3	–	7.5	7.4
45	1.9	9.3	1.9	1.9	7.5	7.4
46	5.6	13.0	9.2	–	7.5	7.4
47	5.6	18.4	9.2	5.6	9.4	5.6
48	5.6	9.3	9.2	11.1	13.2	11.4
49	12.9	5.6	5.6	5.6	3.8	7.4
50	9.2	5.6	5.6	20.3	7.5	12.6
51–55	31.4	20.0	20.4	46.2	24.3	26.0
56–60	16.7	7.4	5.6	7.4	17.0	7.5
Pärast 60 / *After 60*	3.7	–	–	1.9	1.9	7.4
Keskmine munemise algus *Average age at egg laying onset*	50.1	47.5	47.2	51.5	50.3	50.7

365-päevase munatoodangu andmed (tabelid 4 ja 5) näitavad, et 4. perekonna emasvuttide munatoodang oli mitte oluliselt (P > 0,05) suurem kui 8. perekonna emasvuttidel. 2009. a munesid munatüübilised üksi puuris peetud emasvutid 322.0 ja lihatüübilised 318.5 muna. Järgmisel, 2010. aastal, peeti katsevutte paaris koos isaslinnuga. Munajõudlus oli veidi suurem munatüübilistel vuttidel, kes munesid keskmiselt 321.5 muna ja lihatüübilistelt vuttidelt saadi keskmiselt 312.9 muna. Vuttide munemisintensiivsus ja aastas saadud munade arv ei olenenud sellest, kas emasvutte peeti koos isasvuttidega või olid emasvutid individuaalpuurides üksikult. Santos *et al*. (2011) uurimusest selgus samuti, et vuttide munatoodang ei sõltunud ühes puuris peetavate lindude arvust.

Tabel 4. Eesti vuttide (munatüübilised, perekond 4) munatoodang ja munemisintensiivsus 2009.–2010. a
Table 4. *Egg production of Estonian Quails(Family 4, egg-type) in 2009–2010*

Munemiskuu *Laying month*	Emasvutt üksi, 2009 (Äksi) *Female alone, 2009*		Emasvutt koos isasega, 2010 (Matjama) *Female with male, 2010*	
	mune keskmise vuti kohta, tk *average number eggs per quail*	munemis-intensiivsus *laying intensity %*	mune keskmise vuti kohta, tk *average number eggs per quail*	munemis-intensiivsus *laying intensity, %*
I	20.3	72.5	22.4	80.0
II	25.9	92.5	25.7	91.2
III	26.2	93.6	25.7	91.2
IV	25.8	92.1	25.2	90.0
V	26.2	93.6	25.4	90.7
VI	26.0	92.9	25.1	89.6
VII	25.2	90.0	25.2	90.0
VIII	25.3	90.3	25.1	89.6
IX	25.0	89.3	25.1	89.6
X	25.1	89.6	25.4	90.7
XI	23.9	85.4	24.1	86.1
XII	22.8	81.4	23.2	82.8
XIII (29 päeva / 29 days)	24.5	84.5	24.4	81.3
I–X	250.8	89.6	249.8	89.2
I–XII	297.5	88.9	297.1	88.4
Kalendriaastal 365 päeva *Total 365 days*	322.0	88.2	321.5	88.0

Tabel 5. Eesti vuttide (lihatüübilised, perekond 8) munatoodang ja munemisintensiivsus 2009.–2010. a
Table 5. *Egg production of Estonian Quails (Family 8, meat-type) in 2009–2010*

Munemiskuu *Laying month*	Emasvutt üksi, 2009 (Äksi) *Female alone, 2009*		Emasvutt koos isasega, 2010 (Matjama) *Female with male, 2010*	
	mune keskmise vuti kohta, tk *number eggs laid*	munemis-intensiivsus, % *laying intensity, %*	mune keskmise vuti kohta, tk *number eggs laid*	munemis-intensiivsus, % *laying intensity, %*
I	19.5	69.6	19.3	68.9
II	25.0	89.3	25.6	91.4
III	25.0	89.3	25.6	91.4
IV	25.4	90.7	26.1	93.2
V	25.5	91.1	25.6	91.4
VI	25.5	91.1	25.0	89.2
VII	25.4	90.7	24.7	88.2
VIII	25.2	90.0	24.7	88.2
IX	24.6	91.4	24.4	87.1
X	24.4	87.1	23.8	85.0
XI	23.4	83.6	23.0	82.1
XII	23.8	85.0	21.8	77.8
XIII (29 päeva / *29 days*)	25.8	88.9	23.3	77.7
I–X	245.5	87.7	244.8	87.5
I–XII	292.7	87.1	289.6	86.2
Kalendriaastal 365 päeva *Total 365 days*	318.5	87.3	312.9	85.7

Viimastel aastatel on eesti vuttide muna keskmine mass võrreldes tõu tunnustamise aegsega tunduvalt suurenenud. Ülevaate eelmise munemisaasta vutimunade keskmistest massidest annab tabel 6. Tabelist selgub, et tõu tunnustamise aegne muna keskmine mass (12.0 g) on tunduvalt suurenenud. Munatüübilistel vuttidel (perekond 4), oli see 14.2 g ja lihatüübilistel (perekond 8) oli keskmine munamass veidi väiksem – 13.7 g. Seega munesid kergemad vutid veidi raskemaid mune ja vastupidi, kuigi, erinevus ei ole suur ega statistiliselt oluline ($P > 0,05$). Munatüübilistel eesti vuttidel oli keskmine muna mass kogu munemisperioodi vältel üle 14 grammi, ainult esimesel kuul munetud munad olid veidi kergemad. Selles rühmas oli ka linde, kes munesid vahel ka alla 10-grammiseid mune. Lihatüübilistel vuttidel oli munade massi varieeruvus väiksem, keskmine munamass jäi alla 14 grammi, kuid alla 10-grammiseid mune ei olnud.

Lindudel, sealhulgas ka vuttidel, on linnu kehamass ja muna mass üldjuhul positiivses korrelatsioonis (Strong *et al.,* 1978; Marks, 1983; Leeson *et al*., 1991; Ipek *et al*., 2004; Murakami, Ariki, 1998; Murakami *et al*., 2008; Kadam *et al*., 2006). Kaasajal võiks sobivaks vutimuna keskmiseks massiks olla 13.5 g. Selline muna sobib tarbijale, kuid vutimuna mass on seotud ka paljude vuttide jõudlust otseselt väljendavate ja majanduslikult oluliste näitajatega: vutimuna mass korreleerub vutitibude väljainkubeerumisega (Altan *et al*., 1995), vastkooruvate vutitibude kehamassiga (Shanawany, 1987), vutitibude suremusega (Skewes *et al*., 1988) ja vutitibude hilisemate jõudlusnäitajatega (Morris *et al*., 1968; Al-Murrani, 1978).

Muna keskmise massi stabiliseerimiseks on individuaalkontrollil olevate eesti vuttide seast pidevalt praekeeritud raskeid ja üliraskeid (15–25 g) mune munevad emasvutid. Vutimunade suhteline mass (muna mass/ kehamass) on niigi poole suurem kui kanamunadel ja väga suurte munade munemine võib põhjustada munajuha ja kloaagi rebendeid, põletikke ja lõppeda emasvuti surmaga. Muna keskmine mass eesti vuttidel muutus individuaalse jõudluskontrolli andmetel munemisperioodi vältel suhteliselt vähe. Kui munakanad hakkavad munemisperioodi lõpul munema suuremaid ja õhema koorega mune, mis on munemisintensiivsuse languse kõrval ka üks nende väljaprakeerimise põhjusi, siis vuttide munad on kogu munemisperioodi vältel suhteliselt stabiilse massiga. Esimesel munemiskuul kujuneb keskmine muna mass tagasihoidlikumaks, esimesed munad on väiksemad, kuigi sel perioodil saadakse neilt tavalisest rohkem ka ülisuuri, kaherebulisi mune.

Emasvuttide kehamassi iseloomustavad tabelis 7 toodud andmed, mis näitavad, et emasvuttide kehamass munemise algul moodustas vaid 69% munemise lõpetanud vuttide kehamassist. Vuttide kehamassi ja nende munatoodangu vaheliste seoste uurimisel ei ole seni jõutud kindlatele seisukohtadele, sest vuttidega läbiviidud katsetes on kasutatud erinevat geneetilist materjali, katselindude söötmis-pidamistingimused on olnud erinevad jne (F. Minvielle, Y. Oguz, 2002). Eesti emasvuttide kehamass oli munemise algul keskmiselt 175–180 g. Munemisaasta jooksul suurenes emasvuttide kehamass tunduvalt, olles 254 ja 260 g vastavalt 4. ja 8. perekonna lindudel. Kehamassi varieeruvus oli suurim lihatüübilistel vuttidel, nende rühmas ulatus munemisperioodi lõpul mõne emasvuti kehamass 362 grammini. Tõu tunnustamise ajal kaalusid 6-kuused emasvutid keskmiselt 191 g.

Tabel 6. Eesti vuttide muna massi dünaamika 2010. kontrollaastal (iga kuu 2 järjestikust päeva), n = 54
Table 6. *Egg weight dynamics of Estonian Quails in 2010 (every month 2 consecutive days)*

Munemiskuu *Laying month*	Perekond 4 / *Family 4*			Perekond 8 / *Family 8*		
	muna keskmine mass, g *average egg weight, g*	väikseim muna, g *the smallest egg, g*	suurim muna, g *the biggest egg, g*	muna keskmine mass, g *average egg weight, g*	väikseim muna, g *the smallest egg, g*	suurim muna, g *the biggest egg, g*
I	13.9	10.9	16.8	13.3	11.4	16.4
II	14.0	11.6	17.1	13.6	10.5	16.6
III	14.3	9.7	17.1	13.7	11.6	16.4
IV	14.2	10.5	16.9	13.7	10.8	20.3
V	14.3	12.5	17.3	13.9	10.9	17.3
VI	14.3	11.4	16.9	13.5	11.6	16.1
VII	14.2	9.0	17.7	13.8	11.8	16.7
VIII	14.1	10.9	17.6	13.7	10.3	17.0
IX	14.3	12.1	17.6	13.8	12.0	17.1
X	14.2	11.9	17.5	13.9	11.9	16.6
Keskmine / *Average*	14.2	–	–	13.7	–	–

Tabel 7. Emasvuttide kehamass 2010. a
Table 7. *Live weight of female Estonian Quails in 2010*

Näitaja / *Item*	Pere 4 / *Family 4*	Pere 8 / *Family 8*
Keskmine kehamass munemise algul, g *Average live weight at the laying onset, g*	178.3	180.4
Kehamassi varieeruvus, g *Variability, g*	156–198	132–208
Keskmine kehamass munemise lõpul, g *Average live weight at the end of laying period, g*	254.0	260.8
Kehamassi varieeruvus, g *Variability, g*	198–310	195–362
Kehamassi muutus munemisperioodi jooksul, g *Live weight change during the laying period, g*	+ 78.7	+ 80.4

Korrelatiivseid seoseid eesti vuttide mõne viimase aasta munemisbioloogiliste näitajate vahel on toodud tabelis 8. Vuttide 1. munemiskuu munatoodang oli tugevas korrelatsioonis nende 3 ja 6 kuu munatoodanguga. Vuttide munemahakkamise vanus oli negatiivses korrelatsioonis nende hilisema munajõudlusega. Kahe perekonna individuaalse jõudluskontrolli andmetel põhinevad seosed omavahel oluliselt ei erinenud. Olulisi erinevusi ei olnud ka viimaste aastate seoste võrdlemisel 1988. a avaldatud (H. Tikk *et al*., 1988) vastavate korrelatsioonide suurusjärkudes. Endiselt esineb ka tugev positiivne korrelatsioon esimese munemiskuu ja kuue munemiskuu munatoodangute vahel, mis võimaldab prognoosida vuti potentsiaalset munatoodangut munemisperioodi varajases faasis.

Tabel 8. Emasvuttide munajõudlusnäitajate vahelised seosed 2010. a
Table 8. *Correlations between egg performance traits of Estonian Quails in 2010*

Produktiivsusnäitajad / *Correlated traits*	Pere 4 (n = 42) *Family 4 (n = 42)*		Pere 8 (n = 40) *Family 8 (n = 40)*	
	r	P	r	P
Kehamass 35-päevaselt – 1. muna munemise vanus päeva *Live weight at 35-days – age at laying onset*	–0.17	> 0.05	–0.08	> 0.05
Kehamass 35-päevaselt – mune I munemiskuul *Live weight at 35-days – No. eggs laid in 1st month*	0.30	< 0.05	0.05	> 0.05
Kehamass 35-päevaselt – mune 3 munemiskuuga *Live weight at 35-days – No. eggs laid in 3 months*	0.29	> 0.05	0.14	> 0.05
Kehamass 35-päevaselt – mune 6 munemiskuuga *Live weight at 35-days – No. eggs laid in 6 months*	0.16	> 0.05	0.16	> 0.05
1. muna munemise vanus – mune I munemiskuul *Age at laying onset – No. eggs laid in 1st month*	–0,84	< 0.001	–0,49	< 0.001
1. muna munemise vanus – mune 3 munemiskuuga Age at *laying onset – No. eggs laid in 3 months*	–0.74	< 0.001	–0.52	< 0.001
1. muna munemise vanus – mune 6 munemiskuuga *Age at laying onset – No. eggs laid in 6 months*	–0.68	< 0.001	–0.52	< 0.001
Mune I munemiskuul – mune 3 munemiskuuga *Number eggs laid in 1st month – No. eggs laid in 3 months*	0.90	< 0.001	0.93	< 0.001
Mune I munemiskuul – mune 6 munemiskuuga *Number eggs laid in 1st month – No. eggs laid in 6 months*	0.78	< 0.001	0.78	< 0.001

Järeldused

Eesti vutitõu tunnustamisjärgse (1987–2010) selektsioonitöö põhilised tulemused on munajõudluse osas järgmised.

1. Kaasajal toimub eesti vuttide selektsioonitöö kahe perekonnaga – perekond 4, munatüübiline, ja perekond 8, lihatüübiline, kelle munajõudlusnäitajad on veidi erinevad.
2. Keskmine munemahakkamise iga eesti vuttidel oli 47...50 päeva, esimesed munad saadi munatüübilistelt vuttidelt varem, lihatüübilised hakkasid munema paar päeva hiljem.
3. Täiskasvanud eesti emasvuttide kehamass munemisperioodi algul moodustas 69% 365 päeva munenud emasvuttide kehamassist. Munemisaasta lõpuks suurenes emasvuttide kehamass tunduvalt, olles munatüübilistel eesti vuttidel keskmiselt 254 g ja lihatüübilistel vuttidel 260 g.
4. Viimase 16 põlvkonna jooksul on eesti vuttide aastane munatoodang suurenenud, 2010. aastal saadi lihatüübilistelt vuttidelt keskmiselt 318.5 muna ja munatüübilistelt 322.0 muna. Tõu tunnustamise ajal (1987. a) munesid eesti vutid keskmiselt 285 muna aastas.
5. Emasvutiga puuris koos peetav isasvutt ei mõjutanud statistiliselt usutavalt ($P > 0.05$) vuti munemisintensiivsust.
6. Vutimunade keskmine mass 2010. aastal oli lihatüübilistel vuttidel 13.7 g ja munatüübilistel 14.2 g, ületades tunduvalt tõu tunnustamise aegset (1987. a) muna keskmist massi (12.0 g).
7. Vuttide munemahakkamise vanus oli negatiivses korrelatsioonis nende nii esimese, kolme kui ka kuue kuu munatoodanguga, munatüübilistel vuttidel oli korrelatsioon tugev ($r = –0.68...–0.84$) ja lihatüübilistel vuttidel keskmine ($r = –0.49...–0.52$).
8. Eesti vuttide munemisbioloogiliste näitajate vahelised seosed olid 1987. a saadud tulemustega samalaadsed. Esimesel munemiskuul munetud munade arv võimaldab küllaldase täpsusega prognoosida kolme ($r = 0.90...0.93$) ja kuue ($r = 0.78$) munemiskuu toodangut.

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Egg performance dynamics of Estonian Quail in 1987–2010

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Summary

Estonian Quails as a national breed was formed during the ten years of breeding and selection of the different quail populations imported to Estonia. Estonian Quails were recognized in 1987 as a new quail breed. Production performance data of Estonian Quails at the beginning of breed formation period were as follows (H. Tikk, V. Tikk, 2007):

- year egg production – 285,
- live weight at the age of 32-weeks – females 195 g; males 170 g,
- average egg weight – 12.0 g,
- live weight at the age of 28-weeks – females 128 g; males 117 g,
- feed conversion rate 2.62 kg/kg.

During ten years (1977–1987) of selection and breeding of quails to establish the criteria for Estonian Quails the main production performance traits were considerably improved:

- year egg production increased by 88.4%,
- live weight at the age of 4-weeks increased by 33.3% and 34.5% for females and males, respectively,
- live weight of adult quails increased by 27.5% and 23.2% for females and males, respectively,
- survival of adult quails improved by 16%.

Correlations between the different production performance data of quails before they have been recognized as the Estonian Quail breed were studied and established (H. Tikk *et al*., 1988):

- age at laying onset and total egg production in year ($r = 0.25$, $P < 0.05$),
- live weight of female quails at 40-days and total egg production in year ($r = –0.40$, $P < 0.001$),
- egg weight was not correlated to other egg performance traits (number eggs laid),
- number of eggs in the first laying month was not correlated to eggs laid during the 13 laying months,
- number of eggs in the 2nd and 3rd laying months were correlated to eggs laid during the 13 laying months ($r = 0.33$, $P < 0.01$ and $r = 0.41$, $P < 0.001$, *resp*.).

Results of crossing of Estonian Quails with different quail populations imported to Estonia are discussed and published (H. Tikk *et al*., 2009). In 2003 the phenomenon of Estonian Quails to lay 2 eggs a day was recorded and investigated (H. Tikk *et al*., 2003), also quail eggs quality and nutritional value were studied (H. Tikk *et al*., 2010).

The egg production performance data of Estonian Quail in recent years are discussed in this paper and compared with the traits at the beginning time of breed formation.

Results and discussion

Family breeding of Estonian Quails was started in the year 2000 and during the 16 generations egg-type and meat-type families were formed. Egg production traits of Estonian Quails in years 2006–2009 are presented in the Table 1 and 2.

It is concluded from the data presented in the Tables 1 and 2 that there were no significant differences in egg production between meat- and egg-type quails as the average number of eggs laid in 10 laying months were 243.7 and 245.0 for egg- and meat-type quails, respectively. Meat-type quails (Family 8) started to lay eggs an average 1.4–3.5 days later than quails of 4th Family (egg-type).

Total egg production a year (365 days) was bigger in egg-type quails (Tables 4 and 5) compared with meat-type quails. An average number of eggs in 2009 from quails Family 4 (egg-type) was 322.0 and meat-type quails laid 318.5 eggs, respectively. All female quails were kept in cages separately from males. In 2010 in the trials female quails were caged with males (in pairs) and total number of eggs laid was not significantly ($P > 0.05$) lower compared with female quails kept separately from males. Opinion, that keeping female quails with males reduces the egg number was not proved in our studies.

An average egg weight of Estonian Quails in recent years was considerably increased. At the time of Estonian Quail breed recognition in 1987 the average egg weight was 12.0 g. In the Table 6 the egg weight dynamics in 2010 during the 10 laying months of egg- and meat-type Estonian Quails are presented.

Egg-type Estonian Quails laid heavier eggs (14.2 g) compared with quails in Family 8 (meat-type), which eggs were 0.5 g lighter (13.7 g). According to our trials

and experience the optimal egg weight for Estonian Quails would be 13.5 g.

In the Table 7 the live weight dynamics of Estonian Quails are presented. At the beginning of laying period the average live weight of females in Family 4 was 178.3 g and in Family 8 only 2.1 g more – 180.4 g. During the laying period the average live weight of female quails considerably increased. At the end of laying period the average live weight of females was 254 and 260 g, in Family 4 and Family 8, respectively.

Live weight of Estonian Quails have increased in comparison with the live weight at the breed formation period, when the average weight of female quails at the age of 6-months was 191 g.

In the Table 8 the correlations between egg performance traits of Estonian Quails are presented.

Data of individual performance control in Family 4 and Family 8 did not differ significantly ($P > 0.05$). These data are similar with our earlier works (H. Tikk *et al*., 1988). Number of eggs laid in the 1st and first 6 laying months are highly correlated ($r = 0.78$), which enables to predict the total egg production of quails at the beginning of laying period.

Conclusions

Main results of selection in 1987–2010 with Estonian Quails are as follows:

1. During the last decade two different strains (families) in Estonian Quail population were formed: Family 4, egg-type and Family 8, meat-type.
2. An average age of laying onset in Estonian Quails in 2010 was 47 days for egg-type and 51 days for meat-type females.
3. Live weight of female quails grew considerably at the end of 365-days lasted laying period. At the beginning of laying period the average live weight of female quails consisted only about 69% of adult quails at the end of laying period.
4. During the 16 generations the average number of eggs per year considerably increased (an average by 37 eggs, in 1987 – 285 eggs and in 2010 – 322 eggs per quail).
5. Keeping female quails in pairs with males had no influence on the total number of eggs laid during the laying period.
6. The average egg weight of Estonian Quails in 2010 was 13.7 g and 14.2 g, for meat- and egg-type families, respectively.
7. An average age of the laying onset in quails was negatively correlated with the egg production in the first, three and six laying months ($r = –0.68…–0.84$ for egg-type and $r = –0.49…–0.52$ for meat-type quails).
8. Number of eggs laid in the 1st with 3 or 6 laying months were highly ($r = 0.78…0.93$) correlated, which gives opportunity to predict the total egg number for the whole laying period at the early stages of laying.

KROONIKA

VORMSI – KULTUURISAAR!

Aimur Joandi

Sellise nime all peeti tänavu 28.−30. juulil Akadeemilise Põllumajanduse Seltsi ja Vormsi vallavalitsuse ühiskonverents. Allpool esitatud ajakava annab tunnistust, et tööpäevad olid pingelised: ettekanded Vormsi seltsimajas vaheldusid väljasõitude ja jalgsirännakutega.

Kuna 29. juulil tähistati saarel olevipäeva, Norra kuninga Olav II Haraldssoni surma-aastapäeva, oli seal palju külalisi, enamik rootslasi. Kirik ja kõrts olid õhtuti rahvast täis.

Neljapäev 28. juuli

- Avamine. *Arvo Leola, APS-i president.*
- Vormsi asustamine rootslaste poolt. *Jorma Friberg, Rannarootsi muuseum, kuraator.*
- Vormsi rootslaste elust enne sõda ja sõja ajal, ema meenutuste põhjal. *Toivo Tomingas, Haapsalu.*
- Rannarootslaste eestvõitleja Hans Pöhl (1876–1930). *Sven Salin*, *Eestirootsi kultuurinõukogu aseesimees.*
- Stendiettekanded:
- Vene õigeusk Vormsi rootslaste seas 1886–1944. *Jaanus Plaat, Eesti Kunstiakadeemia professor.*
- Vormsi pärandkooslused. *Kadri Tali, Eesti Maaülikooli vanemteadur.*
- Matk Rumpo säärel. *Teejuht keskkonnaspetsialist Elle Puurmann.*
- Vormsi talumuuseumi külastus.
- Öökontsert kirikus: J. S. Bach. F. Chopin, S. Kullerkupp.
- Mälestusjumalateenistus ja küünalde asetamine kalmistul.

Reede 29. juuli

- Vormsi elu ja käekäik täna ning väljavaated. *Urmas Pau, Vormsi vallavanem.*
- Mälestushetked Spuhl-Rotalia ja Konstantin Kreegi kalmul Hullos, koolimaja taga männisalus.
- Lihaveiste kasvatamisest. *Aigar Suurmaa, loomakasvatuse eriteadlane lihaveiste alal.*
- Loodusõpe Vormsil ja Vormsi Aabitsad. *Jana Kokk. Vormsi lasteaia õpetaja-juhataja.*
- Vormsi põllumajandus nõukogude perioodil. *Helgi Maurer, kauaaegne Vormsi agronoom.*
- Vormsi loomakasvatus 2010. *Ege Kanarbik, ettevõtja.*
- Vormsi maaelu toetavad keskkonnaprojektid. *Elle Puurmann.*
- *Jaan* Spuhl-Rotalia elust ja tegevusest. *Aimur Joandi, agronoom.*
- Väljasõit saare lääne ja põhjapoolsesse ossa. *Teejuht õpetatud agronoomi haridusega vormsilane Ene Sarapuu.*

Laupäeval 30. juulil

- Vormsi kirik läbi aegade. *Ants Rajando, Vormsi koguduse diakon ja arhitekt.*
- Põllumajandustootmise olukord Vormsil. *Rein Lillak, Eesti Maaviljeluse Instituudi direktor.*
- Arutelu ja läbirääkimised ning konverentsi lõpetamine.

APS-i esindus tegi Vormsi teekonnal mõned sissepõiked ka huvitavatesse paikadesse mandril: Mahtra talurahvamuuseum, Eeru talupojakõrts, Põllumajanduspark Kuusikul, Rannarootsi muuseum, Haapsalu Läänemaa muuseum, Ilmar Jõesoo eraraamatukogu (15,000 köidet), Kehtna park.

Reisigrupp koos vastuvõtjatega Põllumajanduspargis Kuusikul

Loodetavasti õnnestub avaldada Vormsi kogumikuna kõik ühiskonverentsi ettekannete materjalid. Nendest kolm, laiemale lugejaskonnale huvipakkuvamat, on esitatud lühendatud kujul ka käesolevas kroonikas.

Vormsi maakasutusest

Ene Sarapuu

Vormsi saare pindala on ligikaudu 9,300 ha. Mulla tekke protsess on kestnud seal suhteliselt lühikest aega, mõni tuhat aastat. Vormsi kuulub tüüpiliste kamarkarbonaatmuldade (rähkmuldade) ja soostunud muldade valdkonda. Need rähkmullad sisaldavad rohkesti paetükke, kruusa ja munakaid, on kõige koreserikkamad, kivisemad ja kõige madalama viljakusega mullad Eestis.

Suulise rahvapärimuse järgi on Vormsi koosnenud kolmest saarest, mille vahelt oli võimalik paadiga läbi sõita. Saare merest kerkimise protsess kestab väga aeglaselt ka praegu. Vormsilaste arv sajandite jooksul on olnud väga erinev. Sõjad, katkud, väljarändamised ja põgenemised on korduvalt harvendanud Vormsi asustust, uued sisserändajad on toonud rahvale jällegi täiendust. On tuldud Rootsist, Soomest, Hiiumaalt, tulid ka eestlased. Vormsilaste arv 1934. aastal oli 2,547. Rahvastiku tihedus oli tollal 27 elanikku ühe km² kohta, Vormsi oli seega üks tihedamini asustatud paiku Eestis.

Siilupõllundus. Põld, kuigi vaid *ca* 18 % saare üldpinnast, oli vormsilaste peamine toitja. Haritavat maad oli vähe, seetõttu olid Vormsi talud väikesed. Pooled taludest olid 20 ha ja väiksemad. Üks viiendik oli üle 30 ha ja umbes üks kolmandik oli 20–30 ha. Teravilja oli napilt, sest jaanipäevaeelne kuiv tegi tihti suviviljadele kurja. Kasvatati palju hea kvaliteediga kartuleid, mida müüdi Rootsi ja Soome.

Põllul valitses nn nöörimaa süsteem – maa oli jaotatud kitsasteks nöörsirgeteks põldudeks. Põllu pikkus võis ulatuda kilomeetrini, laius oli aga 10–15 meetrit. Jagamisel oli püütud igale talule anda samaväärse viljakusega maad, sellest ka põllu siilutamine. Kogu põld oli piiratud taraga. Et vormsilane omas vähe põldu, tuli seda hästi harida ja hooldada. Umbrohutõrje oli püüdlik ja tõhus. Must kesa oli tõesti must, sest kevadel künti seda adraga ja suvel hariti korduvalt äkkega. Kasutusel oli kolmeväljasüsteem: talivili, kevad- ja suvivili, kartul. Sellest raamist ei võinud ükski peremees end välja murda.

Kuna põld oli jaotatud võrdselt, võis arvata, et kõik talud ühe küla piires olid ühesuurused. Nii see siiski ei olnud. Mõned suurendasid oma põldu sellega, et tegid metsast alet. Selliseid põllulappe kutsuti ‘seve’ ja seal kasvatati kanepit, lina, ube ja hernest. Kapsaid kasvatati küla ühises kapsaaias. See asus tavaliselt külas niiskes kohas ja igal talul olid seal oma kapsapeenrad. Kui oli võimalik, rajati kapsaaed küla keskele.

Vormsi külad uppusid rohelusse: saared ja kased, pihlakad, toomingad, sirelid, palju ka õunapuid. Paljud õunapuudest olid küll vähese väärtusega, kuid siiski oli õunu, mis läksid ekspordiks. Sortide nimed olid aastatega unustunud, kuid teati Rootsi õunasorti ‘Åkerö’. Pirnipuid kasvas Vormsil vähe, kuid kirsse, ploome ja kreeke leidus kõikjal.

Heinamaad olid samuti jagatud tükkideks ja taraga piiratud. Tükk oli tavaliselt kuus niidukaart lai ja kuni kilomeeter pikk. Põldude piirid olid sügavate vagudega ja piirikividega tähistatud, heinamaade piiride leidmine oli raskem. Piiritülisid Vormsil siiski ei esinenud.

Korralikke karjamaid oli Vormsil vähe. Üksikutel küladel olid taraga piiratud maad, kuhu võis loomad sööma lasta. Külatänav, mets, mereäärsed alad ja ühismaad olid karja peamised söögikohad. Lüpsilehmad toodi igal õhtul koju ja neile anti lisasööta. Noorkari ja lambad võisid kogu suve oma tahtmist mööda metsas hulkuda. Hilissügisel võis tihti metsas kohata inimesi, kes otsisid oma mullikaid ja lambaid. Riigimetsas, kus alustati uute kultuuride rajamist, tegi selline karjatamine suurt kahju.

Kui hein tehtud ja ädal kasvama oli hakanud, saadeti lüpsilehmad heinamaale. Sellega lehmade piimaand suurenes ja tekkis isegi piima ülejääk. Seda kasutas ära keegi ettevõtlik mees ja asutas kolmekümnendate keskel meierei. Esimesel aastal olid kõik taludes rõõmsad lisasissetuleku üle, kuid varsti puhkes tüli, kuna perenaised proovisid üha rohkem piima meiereisse viia, et raha teenida. Mehed, kes olid harjunud tarvitama palju piima, eriti suvel, ei leppinud lõssiga. Lõpuks oli meier sunnitud oma ettevõtte sulgema.

Kuigi vormsilane niitis hoolega oma heinamaad, ‘käis vikatiga üle’ nii võsa, teepeenrad kui kraavikaldad, kollitas teda ikkagi heinavähesus. Seetõttu oli Vormsil talu kari väike. Rohkem kui pooltel taludest oli 2–3 lehma. Sigu kasvatati ikka kaks, üks oma tarbeks ja teine müügiks. Liha viidi Haapsallu lihunikele või suitsutati ja müüdi vahemeestele, kes viisid selle Rootsi või Soome. Eksport oli siiski väga väike.

Lambakasvatus oli vormsilaste karjakasvatuses tähtis osa. Leidus ju Vormsil palju kadakasi karjamaid, kus ainult lambad leidsid endale toitu. Lambaheinale tehti lisaks lehiseid. Kodus kedratud villasest lõngast kudusid naised kindaid, sokke ja sukki. Neid pakuti Haapsalu tänavatel müügiks. Okaspuumetsa oli Vormsil piisavalt, kuid saare idaosa oli metsavaene. Mets oli jaotatud nagu põldki ja ühel talul võis olla mitut metsatükki. Kitsad sihid eraldasid neid. Mitmes külas olid saekaatrid, kus valmistati ette puidust ehitusmaterjal. Metsa mandrilt ei toodud. Segametsa esines Vormsis vähe. Okaspuumetsast raiuti kõik lehtpuud välja, heinamaalt aga kõik okaspuud.

Vormsi naine oli peamine põlluharija. Suvi läbi ta kas kündis või äestas. Kuni Esimese maailmasõjani künti härgadega, äestati aga hobustega. Pärast sõda kasutati põllutöödel ainult hobuseid.

Kuni Teise maailmasõjani olid Vormsi elanikud peamiselt rootslased. Idast tulevat ohtu kartes põgenes enamik neist ja talud jäid tühjaks. Tühjaks jäänud küladesse asusid elama peamiselt sõjapõgenikud üle kogu endise Nõukogude Liidu. Kolhoosikord ja hoolimatus võõra vara suhtes muutsid mitmed sõjast puutumata jäänud külad varemeteks.

Kolhoosikorra tulekuga loodi saarel algul palju väikesi kolhoose, igas külas oma. Põldu hariti alguses endistest elanikest jäänud traditsioonide ja korra järgi. See hakkas aga kiiresti muutuma. Kadusid piirikraavid ja -märgid, harima hakati suuremate põllutükkidena. Kolhoosikorra edenedes moodustati saarel lõpuks üks suurem sovhoos ja kalurikolhoos.

Vormsi sovhoos. 1972. aastal likvideeriti kalurikolhoos ja Vormsist sai üks suur Vormsi sovhoos, metsa majandamiseks oli moodustatud Vormsi metskond. Maakasutuseks oli kogu saar jaotatud sovhoosi ja metskonna vahel kaheks. Kuni 1982. aastani tegeles põlluharimise ja karjakasvatusega saarel Vormsi sovhoos. 1981. aastal oli sovhoosi kogu maakasutus 4,929 hektarit. Loomi oli sovhoosil järgmiselt: veiseid kokku 840, neist 274 lüpsilehma, lambaid 429, sigu 14 ja hobuseid 9.

1982. aastal liideti Vormsi sovhoos K/K Lääne Kaluriga. Kuna kolhoos tervikuna oli paremal järjel kui sovhoos, oli võimalik rohkem investeerida ka põllumajanduse arendamisse.

1988. aastal oli kolhoosi maakasutus suurenenud ja moodustas nüüd 5,819 hektarit. Suurenemine oli toimunud, kui metskonnalt saadi sovhoosi liitmisel kolhoosiga metsamaad juurde. Samuti oli tehtud maaparandust ja massiivistatud põldusid. Siiani olid paljud kiviaiad alles olnud, põllud olid tükeldatud ning suurte traktoritega oli maaharimine raske.

Vormsil tehti peamiselt kultuurtehnikat ja lahtist kraavitust, sest drenaaži rajamine ei olnud võimalik.

Kui võrrelda eelnevaid perioode ja kolhoosiaega, siis ei ole maakasutuses Vormsi saarel väga suuri muutusi toimunud. Vahekord põllumaa ja metsamaa vahel on jäänud üpris püsivaks. Kolhooside lagunemise ja uustalude rajamisega toimus ka Vormsi maakasutuses tugev muutus. Tekkis palju põllumaad, mis jäi omanikuta, maa hakkas kasvama võsasse ja lokkas umbrohi.

Järjest rohkem endisi omanikke sai oma maad tagasi, kuid nad ei ela Vormsil ega tegele maaharimisega. Pärast kolhoosikorra lõppu moodustati saarel üks põllumajandusühistu, kus peeti *ca* 100 veist. Lisaks moodustati mõned uustalud, kus loomade arv oli väga väike. Lagunes Vormsi metskond, tänaseks on jäänud RMK-le *ca* 400 hektarit metsa.

Praeguseks on maade tagastamine Vormsi saarel suures osas lõppenud. Valdav osa saarest kuulub endistele omanikele – rannarootslastele. Rahvaarv saarel on kasvanud ja uuesti on ausse tõusnud loomapidamine, sellele aitavad kaasa erinevad toetused. Tänane ja endine kogukond on saavutanud positiivsed kokkulepped maa kasutamiseks.

Loo arvuliste andmete koostamiseks on kasutatud omaaegse Haapsalu rajooni Agrotööstuskoondise arhiivi (Lindström, 1982).

Tere tulemast ussisaarele!

Toivo Tomingas

Raske on arvata, millest tuleneb saare niisugune nimi, kuid rootslaste Ormsö (loe: Urmsö) ja sakslaste Worms vihjavad ometi sellele, et madusid on seal läbi aegade üsna rohkesti elanud.

Kui kirjanik Juhan Paju umbes 30 aastat tagasi saarele Hosby (loe: Huusbi) külla suvekodu krundi sai, lubas ta panna kohale nime selle elusolendi järgi, kes esimesena vastu tuleb. Juhani suvekodu sai nimeks Nastiku. Võimalik, et viikingid lähtusid samast loogikast.

Ettekande teema on periood Vormsi rahva ajaloos XX sajandi I poolel ja kuna minu mälestused algavad sajandi II poolest, siis toetun oma jutus valdavalt sellele, mida olen kuulnud eakalt emalt, põliselt vormsirootslaselt.

Et minu vanemate ja vanavanemate elu oli vormsilastele väga tüüpiline, võib kirjeldust nende eluloost laiendada kogu saarele, misjuures saab sealsest elustolust üsna tõepärase pildi.

Minu vanaisa Hans Öman sündis 1885. a tüüpilise talupere lasterikkasse perekonda, kus isa oli kalur, ema ja lapsed tegid põllutöid ning kasvatasid kariloomi. Sama eelloo saab rääkida ka vanaemast, kelle sünniaeg oli samuti 1885 ja neiupõlvenimeks Notman. Noored leidsid teineteist arvatavasti 1912. a paiku ja asusid oma elu Norby külas sisse seadma, sest seal elas Hansu vanaema, kelle talust pojapojale natuke maad eraldati.

Tsaaririik jagas Hosbys sealse karjamõisa maadest umbes 100 ha Vene-Jaapani sõja veteranidele, moodustades 20 uut talu, esialgsete nimedega Soldatitükid numbritega 1−20.

Soldatitükist number 10 sai Hansase talu. Perre sündis lapsi juurde, hariti maad, põllurammu saamiseks peeti veiseid rohkemgi, kui piima pärast vaja olnuks. Nii tegid kõik teisedki talud. Ka lambakari oli igas talus kohustuslik. Lammas kui tarbeloom kõlbas ju kõigeks – vill lõngaks, nahk kasukaks, rasv küünaldeks, liha patta, pabulad põllule!

Põllurammu pakkus mingil määral ka meri. Selle teema lõpetuseks tooksin siinkohal välja ühe Vormsilt pärit vanasõna: ‘Koera sitt pole sõnnik ja kaasavara pole varandus!’

See pisut jämedakoeline tõdemus tundub esmalt mitte väga õiglane, kuid Vormsi taluperedes oli tihti palju lapsi. Ja kui perest oli mitu tütart mehele panna, siis tõepoolest, mis varandus see kaasavara ikka olla sai.

Elus kala, küttepuud, kartulid, vili ja sealiha – need olidki põhilised kaubad, mida Vormsi eksportis. Eesti Vabariigi ajal oli saarel õige mitu kaljas-purjekat. Tavaliselt rannakülade meeste enda ehitatud ja vahel lausa ühe pere meeskonnaga.

Mida mere tagant vastu toodi? Kahe sõja vahel oli saarel üks suur mood jalgratas. Kahtlemata oli igas majas vikatite-kirveste teritamiseks suur Gotlandi käi. Rootsist oli pärit ka naiste rahvarõivais kohustuslik sinise-valgekirju siniste klaasnööpidega pluus igapäevase riietusesemena. Eks põllutööriistad, tööstuskaubad laiemalt üldse olidki imporditud Läänemere teiselt kaldalt.

Vormsi meestel tekkis aeg-ajalt võõrastes randades ka keelelisi arusaamatusi.

Näiteks on teada juhus, kui laevamees teatas Stockholmis kai serval seisvale prouale, et lastiks on ‘tofflor’. Proua lõi käsi kokku ja küsis, kuhu küll panna terve koorem tuhvleid.

Nõks oli selles, et Vormsi keeles oli ‘tuflar’ kartulid − tuletis saksa *kartoffel*’ist. Rootsi keeles kannab kartul nime *potatis*, sarnaselt inglise keelega.

Huvitava tähelepanekuna peab märkima, et Vormsil kasvatati Rootsi päritolu õuna- ja pirnisorte.

Kuidas olid suhted Eesti Vabariigiga? Head. Kuigi Vormsi on 'meretagune asi', kus kehtiv riigikord ja seadus pole tegelikult kunagi 100% kehtinud, võib tuua mõned head näited.

Vabadussõjast võtsid osa ka paljud Vormsi mehed. Kolm neist langes ja Vormsi kogukond püstitas neile Hullosse kiriku värava vastu mälestusmärgi, mis on oma tagasihoidlikus vormis püsti siiani.

Vormsiski oli riigikeel eesti keel, kuid kogu igapäevane asjaajamine toimus kohalikus murrakus. Muuseas, kui ma kuulan Vikerraadiost kihnu- või mulgikeelseid uudiseid, mõtlen alatasa, et Vormsil kõneldud keel oli kaugelt rohkem omaette keel. Riigirootslane ei saanud sellest niigi palju aru kui keskmine eestlane soomlasest. Vahe neil kahel rootsi keelel on umbes nagu taani keelel riigirootsiga. Edumeelsemad vormsirootslased õppisid eesti keele ära ja ajasid kohtutes, notari juures, igasugustes riigiametites asju iseenda ja teistegi eest. Vajadusel tõlgina. Riik omalt poolt ehitas kolmekümnendail saarele uue koolimaja, meierei, leivatööstuse, haigla, postkontori jne.

Rootsikeelse rahvaülikooli ja kogu rannarootslaste kultuurilise liikumise eesotsas oli Hans Pöhl. Päritolult noarootslane, kujunes temast rahvajuht, kelle koht oma rahva seas on vabalt võrreldav näiteks C. R. Jakobsoniga.

Kui nüüd lõpetuseks küsida, kuhu siis kogu see rahvakild kadus, on vastuseks üks sõna. Sõda. Teine maailmasõda algas rannarootslastele niisama traagiliselt kui poolakaile. Nõukogude Liidu ultimatiivne tegevus võttis rahvalt nende kodud, kuhu rajati kurikuulsad baasid. Siit käis sõjarinne üle nii minnes kui tulles. Ja enamik, kes olid juba korra nõukogude võimu näinud, ei jäänud seda uuesti ootama. Ei saa öelda, et sakslased oleksid lasknud heal meelel rootslastel iidsele kodumaale tagasi asuda, kuid Rootsi armee major Carl Mothander on väga huvitavalt ja detailselt kirjeldanud oma diplomaatilisi pingutusi, et seda saavutada.

Vormsi asustamisest rootslaste poolt

Jorma Friberg, Rannarootsi muuseumi kuraator

Millal ja mis tingimustel rootslased toonase Eesti rannikut ja saari asustama hakkasid, on juba alates 19. sajandi keskelt kuni tänase päevani ajaloolastele ja uurijatele suurt huvi pakkunud. Läbi on uuritud kõik teadaolevad dokumendid ja kirikuarhiivid. Kuna ajaloolisi dokumente nende sündmuste kohta väga palju pole säilinud, on praegu keeruline tõest tervikpilti rekonstrueerida. Dokumentaalse materjali puudusel on aja jooksul palju teooriaid tekkinud, üks markantsemaid on T. E. Karsteni teooria 1939. aastast, kui ta arvab Eestis elavaid rootslasi kuuluvat vana-germaanlaste hõimu, kes suure rahvasterände ajal siia elama on asunud ja kelle soome-ugrilased hiljem rannikule ja saartele tõrjunud on (Karsten, 1939).

Samuti olid levinud tõekspidamised, et asustamine toimus juba varasel viikingiajal. Aja jooksul käidi kordamööda üksteist röövimas, nii skandinaavlased Eestis kui eestlased Skandinaavias. Russwurm arvab, et rootslaste kolonisatsioon sai aset leida kohe pärast eesti paganate, saarlaste Sigtuna hävitamist 1188. aastal. Spuhl väidab aga vastu, et seda ei saanud mitmel põhjusel sündida enne 13. sajandit − kuni selle ajani olid eestlased vaba rahvas ja rannaäärsed sõjakad suguharud, saarlased ja ridalased, pidasid mereröövli ametit. Spuhl välistas sellise sõjaka rahva lähedusse elama asumise kindlalt.

1211. aastast 1227. aastani allutasid eestlasi sakslased ja taanlased. Alles pärast saarlaste alistamist võis rootslastel tekkida võimalus lääne rannikut ja saari asustama hakata.

Suures sõjamöllus aastatel 1210 ja 1211 olid ridalased alati koos teistega võitlemas, seega olid parimad sõjamehed otsa saanud ning kui Rootsi kuninga Johann I (Johan Sverkerson 1219–1222) sõjavägi 1220. aastal ridalaste tähtsama sadama juures Rohukülas maale tuli, polnud neile kedagi vastu hakkamas. Rootslased võisid maanteed mööda rahulikult Lihula alla minna.

Tühjaks jäänud randasid võis tekitada ka asjaolu, et aasta varem, 1219, olid taanlased suure sõjaväega liikvel olnud. Spuhlile meeldib mõte ja oletus, et just siis, Johann I sõjaväe kaitse all, võisid esimesed asukad Rohuküla poole purjetades või sõudes lähedal asuval tühjal Vormsil maabuda.

Pärast saarlaste alistamist 1227 olid suured rannikualad Lääne-Eestis inimestest tühjad, väidetavalt ka Hiiumaa ja Vormsi saar. Pärast Saare-Lääne piiskopkonna loomist, tõenäoliselt 1228. aastal, võisid piiskopkonnal tulla mõtted asustada või kutsuda tühjadele rannaaladele juba varem ristitud rootslasi, kes võisid paganlikest eestlastest usaldusväärsemad olla. Teada on, et esimest korda leiame rootslaste mainimist Haapsalu linnaõiguses 1294, kus neile antakse eestlastega võrreldes mitmed eesõigused. Paul Johansen arvab, et esimene suurem plaaniline rootslaste asustamisaktsioon Vormsile ja Noarootsi sai alguse u 1270-ndatel piiskopi, toomkapiitli, foogti ja rüütelkonna koostöös (Johansen, 1951).

Vormsilaste endi pärimuses liigub jutt, et: 'Rootsi kuningad on neid lubanud elama asuda siia, et ohjeldada eestlastest mereröövleid, ülesanne mis sisaldab suurel määral eluohtlikkust. Sellepärast olla neile ka antud privileegid, ja koormatud neid ainult väikese maamaksuga' (Hupel, Topografische...).

Svante Jakobsson julgeb selles kahelda. Seevastu arvab ta, et Wormsö ja Nuckö (Noarootsi) olid 1328. aastal veel seal aasta läbi elavate inimesteta, piiskopi alamad kasutasid saari kui karjamaid. Kui piiskop soovis saari rahvastada, pöördus ta vaevalt saarlaste ja hiidlaste poole.

Vormsile elama asumise plaanide tõekssaamise periood pidi vältama kindlasti mõned head aastad ja see pidi toimuma 1330. aastate lõpul. Sten Karling on uurinud Vormsi kirikut ehituslikult ja dateerinud selle rajamise 1300. aastate algusesse, usutavasti 1330.−1340. aastad.

Jakobsen usub, et kolonisatsioon pidi tõenäoliselt toimuma aastatel 1337–1346.

Edvin Lagman on Sviby küla nimest järeldanud, et Svealaste by, Svia by tähendab rootslaste küla ja asukad on saabunud otse Rootsist. Rootslaste kolonisatsioon toimus kindlasti mitmes etapis, erinevate arvamuste järgi alates 13. sajandist ja kestis kuni 16. sajandini.

A. W. Hupel on ühe vana müüdi järele arvanud, et saar sai nime mereröövel Ormi järgi.

P. Johansen selgitab nime veel Olavi saagaga, kus Olav Tryggvassonil oli laev nimega Ormen Lange. Olavi vennal Haraldil oli paat Ormen. Ka Lagman toetab seda teooriat vähemalt selles osas, et isikunimi on moodustanud saare nime tüve. Nimi Wormse ilmub kirjalikes allikates aga 1391 piiskop Winrichi kirjas. Ka Hiiurootsi nimevorm on kasutusel olnud, kuid väga lühikest aega. See annab selgelt mõista, kes on olnud esmased püsiasukad.

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ILMAR MÜÜRSEPP − 80

Üheksandal augustil tähistas 80. sünnipäeva veterinaarmeditsiini ja loomakasvatuse instituudi sigimisbioloogia osakonna emeriitprofessor Ilmar Müürsepp. Juubilar on sündinud 1931. aastal Tartumaal Tammistu vallas talupidaja perekonnas. Hugo Treffneri Gümnaasiumi lõpetamise järel astus ta Tartu Riikliku Ülikooli veterinaariateaduskonda, kust viidi 1951. aastal üle vastmoodustatud Eesti Põllumajanduse Akadeemiasse, mille lõpetas 1955. aastal veterinaararstina. Õppimise ajal tegeles Ilmar Müürsepp aktiivselt teadustööga, olles pikka aega teaduskonna Üliõpilaste Teadusliku Ühingu esimees. Peamiselt huvitus ta patoloogilise histoloogia alastest uurimustest, millest valmis mitmeid auhinnatöid.

Pärast EPA lõpetamist töötas Müürsepp mõned aastad Alatskivi sovhoosi veterinaararsti ja Kallaste rajooni peaveterinaararstina, seejärel Eesti Loomakasvatuse ja Veterinaaria Teadusliku Uurimise Instituudi (ELVI) Viljandi Põllumajandusloomade Kunstliku Seemenduse Jaama veterinaararstina. Alates 1961. aastast pühendus Ilmar Müürsepp teadustööle. Võimekast teadlasest sai ELVI sigimispatoloogia labori juhataja (1969−1979) ja edasi sigimisbioloogia osakonna juhataja (1979−1994). ELVI reorganiseerimise järel, aastatel 1994−1997, oli Ilmar Müürsepp Eesti Põllumajandusülikooli sigimisbioloogia korraline professor ja juhtivteadur ning 1996. aasta lõpuni ka sigimisbioloogia osakonna juhataja. Alates 1997. aastast on juubilar EMÜ emeriitprofessor.

Ilmar Müürsepal on veterinaariakandidaadi (1965) ja veterinaariadoktori (1974) teaduskraadid. Doktoridissertatsiooni ‘Emaka limaskesta subkliiniline patoloogia sünnitusjärgsel perioodil ja sigimatuse korral lehmadel’ kaitsmine toimus Leningradi veterinaariainstituudis. Tema teaduslik tegevus on pühendatud veiste sigimise füsioloogia, patoloogia ja ravi uurimisele. Oma teadustööga ning aktiivse organisaatorina on ta andnud panuse veiste kunstliku seemenduse arendamisele vabariigis. Tema väljatöötatud sigimatuse profülaktika- ja ravimeetodid olid efektiivsed ja praktikas laialdaselt kasutusel. Emakapõletike uurimisel kasutas ta endomeetriumi biopsiate võtmist ja nende histoloogilist uurimist − kokku tehti üle 1,000 biopsia. 1982. aastal alustati Ilmar Müürsepa juhendamisel embrüosiirdamisuuringuid, mille tulemusena töötati välja efektiivne farmis kohapeal kasutatav embrüosiirdamistehnoloogia, mille eest uurimisrühm pälvis 1993. a Eesti Vabariigi teaduspreemia.

Ilmar Müürsepp on avaldanud üle 160 teadusliku artikli ja on kaheksa raamatu autor või kaasautor. Ta on kirjutanud suure osa käsiraamatust ‘Veterinaarsünnitusabi ja günekoloogia (Valgus, 1979). Müürsepp on tulemuslikult juhendanud seitset doktori-, kandidaadi- ja teadusmagistriväitekirja. Juubilar on pälvinud teadustulemuste eest mitmeid tunnustusi: Eesti NSV teeneline teadlane (1985), Eesti NSV riikliku preemia laureaat (1985), Üleliidulise Põllumajandusteaduste Akadeemia korrespondentliige (1991), Venemaa Põllumajandusteaduste Akadeemia välisliige (1992), Eesti Vabariigi teaduspreemia laureaat (1993). Ilmar Müürsepp on Eesti Põllumajanduse Akadeemia esimene audoktor (1989).

Ilmar Müürsepp on oma töös olnud nõudlik nii enda kui ka töökaaslaste suhtes. Kindlat põhimõtet − uurimustöös peab alati valitsema akadeemiline korrektsus ja ülim metoodiline täpsus − on juubilar alati järginud ise ja nõudnud seda ka kolleegidelt. Töökus ja sihikindlus, raudne loogika ning teadlase intuitsioon on temas ühinenud parimaks kombinatsiooniks. Ehkki haigus hoiab teda koduseinte vahel, on ta jätkuvalt hea nõuandja, uurimustöö innustaja ja ülikoolielule kaasaelaja.

Soovime heale kolleegile palju tervist ja jõudu!

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VLI teadusdirektor
sigimisbioloogia osakonna juhataja

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NÄIDIS

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ABSTRACT. *Use of…..*
Keywords*:*

Sissejuhatus

Talitritikale laialdasem levik maailmas on pidurdunud tema terade väga sagedase koristuseelse peas kasvamaminemise tõttu., seda eriti niiskema ja jahedama kliimaga piirkondades (Smith, Jones, 1998; Brown, 1999; Adams, 2000).

Lehekülje suurus ja häälestus
Lehekülje suurus A4. Kasutada **Microsoft Word'i, justify, Times New Roman,** suurus **10**. Abstrakti ja Võtmesõnade puhul kasutada *kursiivi.* Lehekülje numbreid mitte kasutada. Ladinakeelsete nimetuste ja statistiliste terminate puhul kasutada *kursiivi* (*t*-test, $n = 193$, $P > 0.05$). Kasutada ülamärkidena '….', mitte jutumärke "……".

Tabelid
Kõik tabelid peavad olema tekstis viidatud (tabel 1; tabel 1, 2). Tabeli pealkirjas kasutada **Ariali** suurusega **9,** inglisekeelne pealkiri ***kursiivis Ariel*** suurusega ***9***. Tekst ja numbrid tabeli sees **Times New Roman** suurus **10.** Kasutada **TAB** ja ainult horisontaaljooni.

Joonised
Kasutada ainult must-valgeid jooniseid. Joonise allkirjad **Ariel** suurusega **9** ja inglisekeelne allkiri ***kursiivis Ariel*** suurusega ***9***. Kõik joonised peavad olema tekstis viidatud (joonis 1; joonis 1, 2; joonised 1-3).

Kasutatud kirjandus

Teksti sees kasutada kahe autori puhul **koma**. Kui autoreid on rohkem kui kaks, siis kasutada esimese autori järel '*et al*':

Smith and Jones (1998); (Smith, Jones, 1998)
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Raamatud
Autori(te) nimi ja initsiaalid, avaldamise aasta, raamatu pealkiri, avaldaja, avaldamise koht, lehekülgede arv.

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Artiklid ajakirjas
Autori(te) nimi ja initsiaalid, ilmumisaasta, artikli pealkiri, sidekriips, ajakirja nimetus (täisnimetus), väljaande number ja leheküljed. Artiklite pealkirjad, mis on avaldatud teistes keeltes kui inglise, saksa, prantsuse, hispaania või portugali keeles, peaks olema tõlgitud inglise keelde koos täiendusega lõpus (vene keeles, ing. k. abstrakt).

Fairey, N. A., Lefkovitch, L. P. 1996a. Crop density and seed production of creeping red fescue (Festuca rubra L. var. rubra). 1. Yield and plant development. – Canadian Journal of Plant Science, 76 (2), p. 291–298.
Danieljan, S.G., Nabaldijan, K.M. 1971. The causal agents of meloids in bees. – Veterinaria, 8, 64–65 (vene keeles).

Artikkel kogumikus
Autori(te) nimi ja initsiaalid, ilmumisaasta, artikli pealkiri, sidekriips, kogumiku nimetus, koostaja nimi sulgudes, avaldaja, ilmumise koht, leheküljed.

Rand, H. 1992. Heintaimede seemnekasvatus. – Rohumaaviljelus talupidajale (koostaja H. Older). AS Rebellis, Saku, 44–74.

Toimetised
Autori(te) nimi ja initsiaalid, ilmumisaasta, artikli pealkiri, sidekriips, *toimetise nimetus kursiivis*, ilmumise koht ja leheküljed.

Tomic, Z., Mladenovic, R. 1995. Perennial grass seed production in some mountain region in Serbia. – *Proceedings of Third International Herbage Seed Conference June 18–23 1995. Halle*, p. 346–350.

Märkused

Kasutada ´. ´ (mitte ´ , ´): 0.6 ± 0.2
Kasutada koma tuhandete märkimiseks – 1,230.4 (üks tuhat kakssada kolmkümmend koma neli)
Ilma vaheta: 5^0C, 5% (mitte 5 ^{0}C, 5 %)
Kasuta ´–´ (mitte ´-´) ja ilma vaheta: pp. 27–36, 1998–2000, 4–6 min, 3–5 kg
Kasuta vahesid: 5 h, 5 kg, 5 m, C : D = 0.6 ± 0.2
Kasuta ´kg ha^{-1} ´ (mitte ´kg/ha´)
Kasuta ´ ^{0} ´: 5^0C (mitte ´5^oC ´)

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Papers must be in English (British spelling). English is revised by a language reviewer, but authors are strongly urged to have the papers reviewed linguistically prior to submitting. Contributions should be sent electronically. Papers are considered by referees before acceptance.

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Structure
Title, Authors (names), Authors' place of work with full address, Abstract (up to 250 words), Keywords (up to7 words), Introduction, Materials and methods, Results, Discussion, Conclusions, Acknowledgements, References.

FOR EXAMPLE

TITLE

Authors

Adresses

ABSTRACT. In laboratory pupal…
Keywords: *triticale…*

Introduction

In many countries rural….

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- Use *italics* for Latin biological names and for statistical terms (*t*-test, $n = 193$, $P > 0.05$)
- Use single ('……') instead of double quotation marks ("……")

Tables
- All tables and figures must be referred to in the text (Table 1; Tables 1, 2)
- For tables use font Times New Roman, regular, 10 points
- Use **TAB** and not space bar between columns
- Do not use vertical lines as dividers, only **horizontal** lines are allowed
- Primary column and row headings should start with an initial capital, secondary headings without initial capital

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- Use only black and white for figures
- Use font **Arial** within the figures
- Legend below the figure must not be in a frame of the figure
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References

Within the text
In case of **two** authors use comma. In case of more than two authors, reduce to first author "*et al*."
Smith and Jones (1996); (Smith, Jones, 1996)
Brown *et al.* (1997); (Brown *et al*., 1997)
Adams (1998); (Adams, 1998)

When referring to more than one publication, arrange them using the following keys: 1. year of publication (ascending), 2. alphabetical order for the same year of publication:
(Smith, Jones, 1996; Brown *et al*., 1997; Adams, 1998; Smith, 1998)

For whole books
Name(s) and initials of the author(s), year of publishing, title of the book publisher, town of publishing, number of pages.
Tritton, D. Y. 1988. Physical Fluid Dynamics. Clarendon Press, Oxford, 350 pp.
Shiyatov, S. G. 1986. Dendrochronology of the Upper Timberline in the Urals. Nauka, Moskva, 350 pp. (in Russian).

For journals articles
Titles of papers published in languages other than English, German, French, Italian, Spanish, and Portuguese should be replaced by an English translation, with an explanatory note at the end, e.g., (in Russian, English abstr.).

Habel, R. E., Budras, K.-D. 1992. Anatomy of the Prepubic Tendon in the Horse, Cow, Sheep, Goat and Dog. – American Journal of Veterinary Research, 53 (11), p. 2183–2195.
Danielyan, S.G., Nabaldiyan, K.M. 1971. The causal agents of meloids in bees. – Veterinariya, 8, p. 64–65 (in Russian).

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Yurtsev, B.A., Tolmachev, A.I., Rebristaya, O.V. 1978. The floristic delimitation and subdivisions of the Arctic. – In Yurtsev, B. A. (ed.): The Arctic Floristic Region. Nauka, Leningrad, p. 9–104 (in Russian).

For conference proceedings:
Name(s) and initials of the author(s), year of publishing, proceedings title, name(s) and initials of the editor(s) (preceded by **In**), proceedings name (***in italic)***, publisher, town of publishing, page numbers:
Ritchie, M.E., Olff, H. 1999. Herbivore diversity and plant dynamics: compensatory and additive effects. – In Olff, H., Brown, V.K., Drent, R.H. (eds): *Herbivores between plants and predators. The 38th Symposium of the British Ecological Society*. Blackwell Science, Oxford, UK, p. 175–204.

Please note

Use '**.**' (not '**,**') : 0.6 ± 0.2
Use a 'comma' for thousands – 1,230.4 (one thousand two hundred and thirty and four tenths)
Without space: 5°C, 5% (not 5 °C, 5 %)
Use '–' (not '-') and without space: pp. 27–36, 1998–2000, 4–6 min, 3–5 kg
Spaces: 5 h, 5 kg, 5 m, C : D = 0.6 ± 0.2
Use 'kg ha^{-1}' (not 'kg/ha')
Use ' ° ' : 5°C (not 5^{o}C)