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EFFECT OF WATER DEFICIT ON THE GROWTH AND YIELD OF DIFFERENT GENOTYPES OF TOMATO IN SEMI-ARID CLIMATE CONDITIONS

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ABSTRACT. In areas where the supply of water for irrigation is limited, tomato production is often subject to drought stress. This study was conducted at the Department of Horticulture and Landscape Gardening, University of Diyala, Baqubah, Iraq in 2021 wherein 22 genotypes ('S.G', 'San II', 'M.O', 'Red Pear', 'F.R', 'Marb', 15 F1 hybrids were obtained from 6×6 half diallel cross and 'Bobcat' control hybrid) were cultivated under full irrigation [covering 100% of crop evapotranspiration demands (ETc)] and water deficit (50% of ETc) conditions. The results showed that cv. 1×6 produced the longest plants (119.01 cm) and the least time to flowering (10.23 days). Most branches (31.98) were produced by cv. 5×6. Both cvs. 1×6 and 5×6 produced the most leaf area (1 991 and 1 977 cm^2 respectively) and most yield per plant (6.75 and 6.84 kg respectively). The 100% ETc irrigation treatment produced the longest plants (91.21 cm), the greatest number of branches (28.12), the most leaf area (1 673 cm^2), and the highest plant yield (4.61 kg). The 50% ETc irrigation treatment produced the least time to flowering (13.7 days). Irrigation level lowering to 50% ETc achieved good results for the water use efficiency (WUE) use with predicted $R^2 = 1.00$. Therefore, the results of this study recommend using the interaction of (both cvs. 1×6 and 5×6 irrigated with the 50% ETc treatment) to save water on irrigation and produce a high yield of tomatoes.

Introduction

Water is the most important component of agricultural output (Du *et al.*, 2015). As a result, lowering water usage for agriculture is a top priority in any country's development of sustainable agriculture (Lu *et al.*, 2021). The utilization of contemporary irrigation systems and plant breeding for water stress resistance are currently required to ensure global food security. As a result, it is critical to address this main challenge (*i.e.* excessive irrigation) to boost agricultural productivity. In this context, increasing crop water use efficiency (WUE) and stress tolerance become a challenge to fulfilling global food demand while consuming the least amount of agricultural water (Liu *et al.*, 2021).

Plants with higher WUE have lower leaf transpiration rates, which leads to higher leaf temperature, which results in decreased photosynthetic rates, plant growth, and yield (Medrano *et al.*, 2015; Fullana-Pericàs *et al.*, 2022). As a result, there is a pressing need to assess the performance of a large number of crop genotypes in the field to identify those that have higher WUE and drought tolerance while still producing and preserving acceptable commercial fruit quality (Mickelbart *et al.*, 2015).

Tomatoes (*Solanum lycopersicum* L.) are one of the most widely grown vegetables in the world, with output nearly doubling in the previous two decades, from 1 000 million to 1 900 million tons (FAOSTAT, 2021). Although, the tomato crop is widely dispersed and suited to a wide variety of conditions (Cuartero, Fernández-Muoz, 1999), it is mostly grown in temperate locations, especially in the Mediterranean basin. Tomatoes are a high-water-demanding crop in the open field, requiring more than 3 L per plant every day at maturity (Wu *et al.*, 2021). Considering the projected climate change scenario, it is critical to investigate tomato genotypic diversity to identify the most stress-resistant genotypes, which may then be used to increase WUE by reducing fruit output and quality under adverse circumstances. Given its global importance and status as the model species for fleshy fruit corps, the tomato crop is a well-known target for development

(Giovannoni, 2006, Klee, Giovannoni, 2011, The Tomato Genome Consortium, 2012). Due to millennia of selection under Mediterranean summer conditions, most drought-resistant genotypes in tomatoes have been identified among local landraces in the Mediterranean basin (Bota *et al.*, 2014; Patanè *et al.*, 2016). Several long shelf-life (LSL) landraces exhibit better drought tolerance than current genotypes, and several of their adaptation processes for increasing WUE have previously been documented (Conesa *et al.*, 2020). The LSL phenotype, which is characterised by extended fruit post-harvest conservation, is found in several West-Mediterranean landraces, including the 'de Ramellet' tomato from the Balearic Islands (Bota *et al.*, 2014, Conesa *et al.*, 2014), the 'de Penjar' tomato from the Eastern Iberian Peninsula (Casals *et al.*, 2012), and some Italian (Sacco extended review of LSL landraces distribution and traits can be found in Conesa *et al.*, 2020).

In this study, the physiologic and agronomic performance of 22 tomato genotypes under well-watered and deficit irrigation conditions was assessed.

Materials and Methods

Plant material

In this study, 22 tomato genotypes were evaluated at the College of Agriculture, University of Diyala, Iraq in 2021. Seeds were germinated under greenhouse conditions in plastic trays filled with peat-based substrate. To ensure seed germination and avoid the spread of fungal and virus diseases, seeds were treated according to the procedure described in Hamdi (2022). The dataset for air temperature, humidity, and solar radiation for the length of the experiment for which it was received from the meteorological station at the University of Diyala is included in Figure 1.

The genotypes were further evaluated in field conditions on the silty loam soils. The soil was classified as silty loam texture. The soil sample was taken from a depth of 3–10 cm and physiochemical properties were done before planting as shown in Table 1. The soil texture was determined according to Day (1965) and the soil content elements were measured according to (Jackson, 1958; Black, 1965).

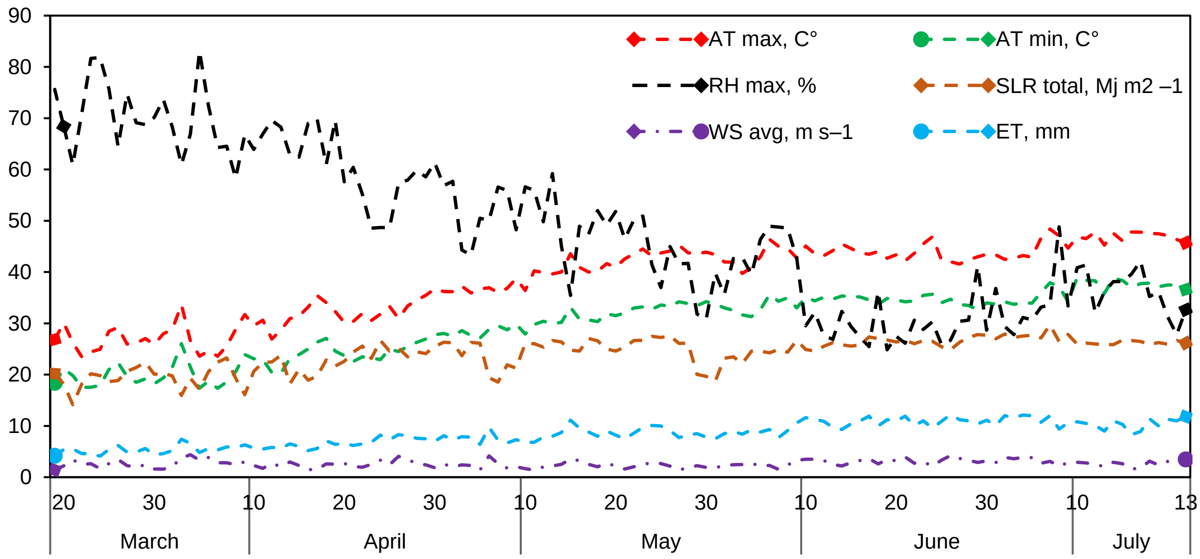

Figure 1. Maximum and minimum daily air temperature (AT), humidity (RH), solar radiation (SLR), wind speed (WS), plus evapotranspiration (ET) at Baqubah city. Monthly precipitation data was sourced from an onsite weather station at the University of Diyala

Table 1. Some chemical and physical soil properties of the field before planting

Parameters		Value	Unit
pH (1:1)		4.07	
Electrical conductivity (1:1)		7.55	dS
Organic matter		6.90	g kg^{-1}
$CaCO_3$		260.10	g kg^{-1}
Available nutrients	N	54.01	mg kg^{-1}
	P	8.04	mg kg^{-1}
	K	81.79	mg kg^{-1}
Soil separates	Sand	301.25	g kg^{-1}
	Silt	493.55	g kg^{-1}
	Clay	205.20	g kg^{-1}
Bulk density		1.35	mg m$^{3-1}$
Field capacity		25	%

Irrigation treatments

Two treatments were established, the first was irrigation at 100% of daily crop evapotranspiration (ETc) (Table 2) and the second, was irrigation at 50% of ETc. Weekly reference evapotranspiration was calculated according to FAO-56 (Allen *et al.*, 2008) using data obtained by two nearby weather stations. ETc was obtained as the product of the reference evapotranspiration (ETo) and the crop coefficient (Kc) at each growth stage (Allen *et al.*, 2008). Six plants were randomly selected from each plot to determine: plant height (cm), number of branches, total leaf area (cm^2), time to 50 flowering (day), and yield per plant (kg). WUE (kg m$^{3-1}$) was calculated as total yield (kg ha^{-1}) obtained per unit volume of seasonal evapotranspiration (m^3 ha^{-1}) (Wang *et al.*, 2007).

Table 2. Growth coefficient (Kc) and daily crop evapotranspiration (ETc) in mm day^{-1}, crop evapotranspiration (ETcd) in mm decade^{-1}.

Month	Decade	Stage	Kc coefficient	ETc mm day^{-1}	ETcd mm dec^{-1}
March	1	Initial	0.60	2.17	2.2
	2		0.60	2.46	24.6
	3		0.60	2.67	29.4
April	1	Develop	0.61	2.90	29.0
	2		0.76	3.87	38.7
	3		0.95	5.65	56.5
May	1	Mid	1.14	7.75	77.5
	2		1.19	9.10	91.0
	3		1.19	9.97	109.6
June	1	Mid	1.19	10.92	109.2
	2	Late	1.17	11.57	115.7
	3		1.01	10.24	102.4
July	1	Late	0.88	9.14	45.7

Statistical analysis

Data were subjected to analysis of variance using SAS JMP 9.1 (SAS Institute, Cary, NC). Means were separated with the Tukey-Kramer HSD test to determine the significant differences between means and the confidence level was 0.05.

Results and Discussion

Genotypes impact some measured traits of tomato

Table 3 shows the effect of genotypes and water deficit on the growth and yield of tomatoes. The cv. 1×6 produced the longest plants (119.01 cm) and the least time to flowering (10.23 days) while the cv. 'M.O' had the shortest plants (68.35 cm) and longest time to flowering (19.37 days). The cv. 5×6 produced the greatest number of branches (31.88) compared with other genotypes. Both cvs.1×6 and 5×6 produced the most leaf area (1 991 and 1 977 cm^2 respectively) and yield plant (6.75 and 6.84 kg respectively) compared with other genotypes. The reason for this can be attributed to genetic differences between genotypes (Al-Mfargy *et al.*, 2015; Abood *et al.*, 2019; Dariva *et al.*, 2021; Fayezizadeh *et al.*, 2021; Zhao *et al.*, 2021). Cultivar genotype may affect a plant's ability to absorb nutrients and/or the efficiency to transport them to the target organs, inducing, as a consequence, the plant growth positive response to irrigation application (Al-Mfargy, 2017; Giuliani *et al.*, 2018; Lu *et al.*, 2019; Aldubai *et al.*, 2022)

Water deficit impact on some measured traits of tomato

Table 3 shows the 100% ETc irrigation treatment produced the longest plants (91.21 cm), the greatest number of branches (28.12) most leaf area (1 673 cm^2) and most plant yield (4.61 kg) compared with other irrigation levels. The 50% ETc irrigation treatment produced and least time to flowering (13.76 days) compared with other irrigation levels. Full irrigation at 100% ETc provided a consistent supply of water to the entire root area of plants thereby water deficit conditions were minimized (Al-Shammari *et al.*, 2018; Giuliani *et al.*, 2019). Most morphological, physiological and biochemical processes associated with plant development might have compromised during water deficit and can result in poor photosynthesis, respiration and nutrient metabolism (Wu *et al.*, 2021). This reduction in the growth and yield of tomatoes might be due to an interruption in the photosynthesis process during the water deficit period (Sallume *et al.*, 2020).

Table 3. Effects of genotypes and irrigation levels on the plant height, number of branches, total leaf area, time to flowering and yield plant of tomato

Factors / Genotypes	Plant height, cm	No. branches per plant	Total leaf area, cm^2	Time to flowering, day	Yield plant, kg
'S.G' (1)	97.59^{D}	22.82^{JK}	1 419^{L}	17.80^{D}	3.58^{GH}
'San II' (2)	73.33^{P}	22.15^{LM}	1 327NO	18.29^{B}	3.18^{I}
'M.O' (3)	68.35^{R}	20.66^{O}	1 269^{P}	19.37^{A}	2.43^{J}
'Red Pear' (4)	74.04^{NO}	21.56^{N}	1 414^{L}	18.29^{B}	3.42^{H}
'F.R' (5)	87.03^{K}	23.73^{HI}	1 471^{JK}	17.89^{D}	3.56^{GH}
'Marb' (6)	92.24^{G}	24.20^{GH}	1 567^{I}	16.57^{EF}	3.94^{F}
1×2	76.54^{M}	22.17^{LM}	1 386^{M}	17.81^{D}	3.50^{GH}
1×3	70.85^{Q}	22.44^{KL}	1 337^{N}	17.89^{D}	3.46^{H}
1×4	81.76^{L}	23.34^{H}	1 482^{J}	16.45^{F}	5.02^{C}
1×5	113.77^{B}	25.48^{EF}	1 816^{D}	14.67^{H}	5.43^{B}
1×6	119.01^{A}	29.15^{B}	1 991^{A}	10.23^{N}	6.75^{A}
2×3	70.11^{Q}	22.18^{LM}	1 310^{O}	18.14^{C}	3.18^{I}
2×4	74.47^{N}	22.90^{JK}	1 469^{JK}	16.63^{E}	3.68^{G}
2×5	89.74^{I}	25.26^{F}	1 568^{I}	14.80^{H}	4.08^{EF}
2×6	96.38^{E}	28.35^{C}	1 783^{E}	12.89^{K}	4.98^{C}
3×4	73.72^{OP}	21.56^{MN}	1 454^{K}	18.05^{C}	3.43^{H}
3×5	91.15^{H}	24.47^{G}	1 610^{H}	13.60^{I}	4.19^{E}
3×6	93.41^{F}	25.87^{DE}	1 836^{C}	12.69^{L}	4.69^{D}
4×5	88.59^{J}	23.26^{IJ}	1 709^{F}	13.19^{J}	4.98^{C}
4×6	91.85^{G}	26.36^{D}	1 935^{B}	12.69^{L}	5.52^{B}
5×6	107.60^{C}	31.88^{A}	1 977^{A}	11.67^{M}	6.84^{A}
'Bobcat'	82.34^{L}	22.45^{KL}	1 685^{G}	15.26^{G}	4.11^{EF}
Irrigation levels ETc					
50	82.78^{B}	20.33^{B}	1 492^{B}	13.76^{B}	3.93^{B}
100	91.21^{A}	28.12^{A}	1 673^{A}	17.58^{A}	4.61^{A}

Data in interaction analyzed with Least Squares Means and means separated with Tukey *post-hoc* test.
Values in groups in columns followed by the different capital letters are significant at the level of $P < 0.05$.

Impact of genotypes and water deficit interaction on some measured traits of tomato

Table 4 shows the genotype and irrigation-level interaction affected some measured traits of tomatoes. The cv. 1×6 irrigated with the 100% ETc treatment produced the tallest plants (123.17 cm), and most leaf area (2 154 cm^2). The same cv. irrigated with the 50% ETc treatment produced the least time to flowering (8.81 days), compared with other treatments. The cv. 5×6 irrigated with the 100% ETc treatment produced the greatest number of branches (36.28) compared with other treatments. Both cvs.1×6 and 5×6 irrigated with the 100% ETc treatment produced the most plant yield (7.02 and 7.18 kg respectively) compared with other treatments.

Table 4. Interaction effect of genotypes and irrigation levels on the plant height, number of branches, total leaf area, time to flowering and yield plant of tomato

Factors		Plant height, cm	No. of branches	Total leaf area, cm^2	Time to flowering, day	Yield plant, kg
Genotypes	Irrigation levels ETc, %					
'S.G' (1)	50	92.79^{L}	18.98^{TU}	1 351^{VW}	15.88^{N}	3.14$^{P–T}$
	100	102.39^{G}	26.66^{JK}	1 487^{P}	19.72^{F}	4.02^{IJK}
'San II' (2)	50	69.17^{X}	18.31^{VW}	1 248^{Y}	16.22^{KL}	2.94^{RST}
	100	77.48^{U}	25.99^{M}	1 407^{RST}	20.37^{B}	3.43^{NOP}
'M.O' (3)	50	63.02^{Z}	16.81^{X}	1 205^{Z}	17.45^{I}	1.86^{U}
	100	73.68^{V}	24.52^{O}	1 334^{W}	21.29^{A}	3.01^{RST}
'Red Pear' (4)	50	69.69^{X}	17.72^{W}	1 372^{UV}	16.39^{K}	3.00^{RST}
	100	87.39^{T}	25.41^{MN}	1 457^{Q}	20.23^{BC}	3.84^{KL}
'F.R' (5)	50	82.67^{Q}	19.39ST	1 397^{STU}	15.97^{MN}	3.11^{QRST}
	100	91.39^{M}	28.08^{GH}	1 545^{MN}	19.81^{EF}	4.01^{IJK}
'Marb' (6)	50	87.80^{O}	19.45ST	1 518NO	14.65^{PQ}	3.68^{LMN}
	100	96.67^{HI}	28.95^{FG}	1 617^{K}	18.49^{H}	4.20^{IJ}
1×2	50	72.90^{W}	18.33^{VW}	1 276^{X}	15.89^{N}	2.99^{RST}
	100	80.17^{R}	26.01^{L}	1 497^{OP}	19.73^{F}	4.02^{IJK}
1×3	50	67.21^{Y}	18.60^{UV}	1 263^{XY}	15.97^{MN}	3.18^{PQR}
	100	74.48^{V}	26.28^{JK}	1 412^{RS}	19.81^{EF}	3.74^{KLM}
1×4	50	78.12^{TU}	19.69^{S}	1 397^{STU}	14.53^{QR}	4.98^{FG}
	100	85.39^{P}	27.99^{H}	1 567^{LM}	18.37^{H}	5.06^{FG}
1×5	50	109.14^{E}	21.64^{Q}	1 695^{I}	13.75^{T}	5.05^{FG}
	100	118.39^{B}	29.32^{E}	1 938^{D}	15.59^{O}	5.81^{C}
1×6	50	114.85^{C}	25.31^{NO}	1 829^{F}	8.81^{Z}	6.48^{B}
	100	123.17^{A}	32.99^{B}	2 154^{A}	11.65^{V}	7.02^{A}
2×3	50	66.38^{Y}	18.34^{VW}	1 194^{Z}	16.21^{KL}	2.84^{T}
	100	73.83^{V}	26.02^{L}	1 427^{R}	20.07^{CD}	3.52^{MNO}
2×4	50	70.25^{X}	19.04^{TU}	1 384^{TU}	14.31^{RS}	3.16$^{P–S}$
	100	78.68ST	26.77^{JK}	1 555^{LM}	18.95^{G}	4.20^{IJ}
2×5	50	84.80^{P}	21.41^{QR}	1 433^{QR}	12.97^{U}	3.90^{JKL}
	100	94.68^{K}	29.11^{EF}	1 704^{HI}	16.63^{J}	4.26^{HI}
2×6	50	92.23^{LM}	24.99^{O}	1 575^{L}	10.97^{X}	4.97^{FG}
	100	92.23^{L}	31.71^{C}	1 992^{C}	14.81^{P}	5.00^{FG}
3×4	50	69.02^{X}	17.87^{W}	1 412^{RS}	16.13^{LM}	2.86ST
	100	78.42^{T}	25.62^{M}	1 497^{OP}	19.97^{DE}	4.00^{IJK}
3×5	50	87.11^{O}	20.62^{R}	1 494^{OP}	11.65^{V}	3.84^{KL}
	100	95.18^{JK}	28.32^{GH}	1 725^{H}	15.52^{O}	4.54^{H}
3×6	50	89.31^{N}	21.97^{PQ}	1 725^{H}	11.27^{W}	4.15^{IJ}
	100	97.50^{H}	29.78^{DE}	1 947^{D}	14.11^{S}	5.22^{EF}
4×5	50	84.67^{P}	19.41ST	1 644^{JK}	11.77^{V}	4.97^{FG}
	100	92.50^{L}	27.11^{IJ}	1 774^{G}	14.61^{PQ}	4.99^{FG}
4×6	50	87.81^{O}	22.52^{P}	1 866^{E}	10.77^{X}	5.50^{DE}
	100	95.88^{IJ}	30.21^{D}	2 003^{C}	14.61^{PQ}	5.54^{CD}
5×6	50	102.85^{F}	27.49^{HI}	1 889^{E}	9.75^{Y}	6.50^{B}
	100	112.36^{D}	36.28^{A}	2 065^{B}	13.59^{T}	7.18^{A}
'Bobcat'	50	79.31^{RS}	19.32ST	1 655^{J}	11.57^{V}	3.33^{OPQ}
	100	85.37^{P}	25.58^{MN}	1 714^{HI}	18.96^{G}	4.89^{G}

Data in interaction analyzed with Least Squares Means and means separated with Tukey *post-hoc* test.
Values in groups in columns followed by the different letters are significant at the level of $P < 0.05$.

Effect of the genotypes and irrigation levels on the WUE of tomato

Both genotypes and irrigation amount influenced WUE significantly as shown in (Fig. 2). Both 1×6 and 5×6 irrigated with the 50% level treatment produced the highest WUE (33.32 and 33.34 kg m^{3-1} respectively) and the lowest amount of WUE (7.74 kg m^{3-1}) was obtained in 'M.O' cv. irrigated with the 100% level treatment.

In WUE (Fig. 3), linear regression indicated a strong relationship with irrigation level lowering. The WUE increased linearly when the 50% irrigation level was lowered. The relationships recorded for WUE show a predicted $R^2 = 1.00$ and a line regression equation ($Y = –0.1668*X + 28.54$) for both irrigation levels. The highest WUE obtained in water-stressed plants could be attributed to a lower volume of water provided (50% of total water volume) in comparison to control plants, as well as a minor yield drop (fully irrigated-unsprayed plants). It is generally understood that, in times of water scarcity or drought, slowing the rate of water loss saves soil water for a longer period, resulting in a better yield and, as a result, higher WUE (Abd Allah, 2019; Liu *et al.*, 2021; Fullana-Pericàs *et al.*, 2022; Wu *et al.*, 2022).

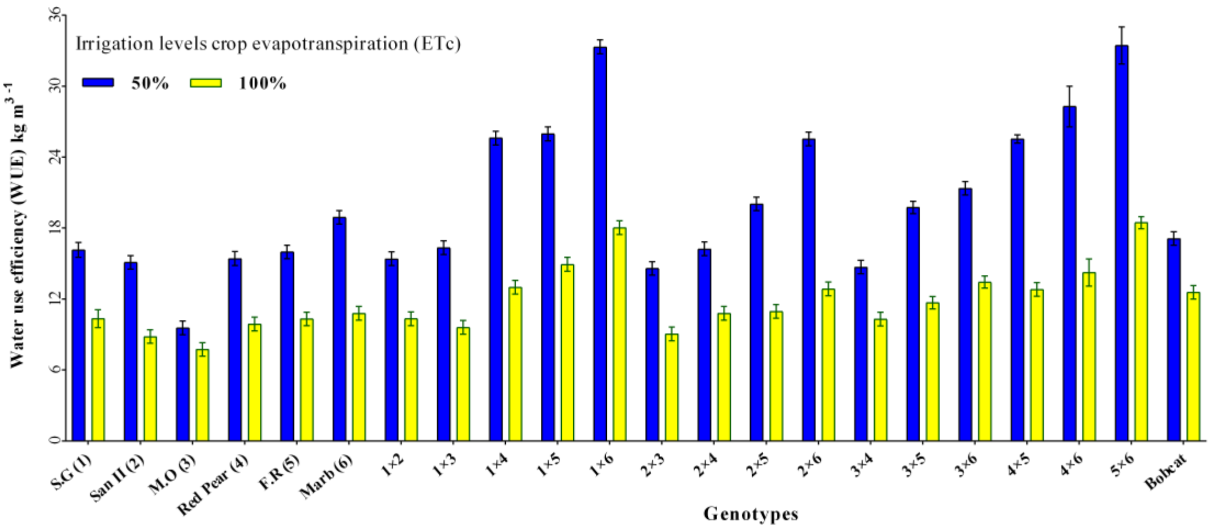

Figure 2. Effect of the genotypes × irrigation levels on water use efficiency of tomato plants yield

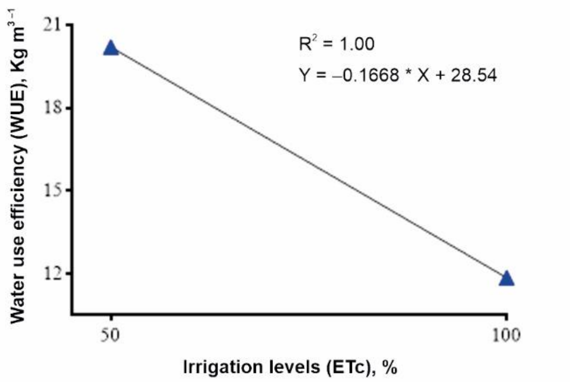

Figure 3. Effect of the irrigation amount analyzed with linear regression on water use efficiency for tomato plants yield.

Conclusion

The wide variation in all the genotypes might be due to their genetic makeup, which indirectly governs the morphology of the plant genetic differences between genotypes played a role in alleviating the negative impact of water deficit and improved vegetative growth and production of tomatoes plus water use efficiency. The plant height, number of branches, total leaf area and yield per plant in 100% ETc treated plants were the highest.

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Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

GJH, AMA – designed the experimental setup;
GJH – analysed the data and results, and wrote the manuscript;
GJH – editing the manuscript.

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IMPACTS OF WATER AVAILABILITY AND PLANT DENSITY ON MORPHO-PHYSIOLOGICAL CHARACTERISTICS OF FENUGREEK (*Trigonella foenum-graecum*)

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ABSTRACT. Plant density and water availability are the most important factors determining the yield of crops and medicinal plants. To investigate the effect of these two factors and their interaction on the yield and morpho-physiological characteristics of fenugreek, an experiment was conducted in the form of split plots based on a randomized complete block design (RCBD) with three replications in 2020. Water availability (favourable conditions, mild stress and severe stress) were placed in main plots and plant densities (22, 44 and 66 plants $m^{2\,-1}$) were placed in sub-plots. The results showed a three-fold increase in plant density under optimal moisture conditions increased grain yield from 998 to 1 380 kg ha^{-1} and biological yield from 2 600 to 3 259 kg ha^{-1}, respectively, while in mild and severe water stress, did not affect grain yield and biological yield. In all three moisture conditions, a 3-fold increase in plant density reduced the number of seeds per pod and a 2-fold increase in plant density reduced the number of pods per plant. Although in some crops, the increase in density under water stress conditions can compensate for the decrease in yield, in fenugreek, the increase in density under water stress conditions was not beneficial for the plant. Increasing the density to medium (44 plants $m^{2\,-1}$) reduces the source strength and applying high density through sink restriction causes a decrease in yield. On the other hand, moisture limitation by reducing the number of pods per plant, the number of seeds per pod and the number of seeds per plant reduced the size of the sink and the mass of 1 000 seeds, which indicates the strength of the source, was not affected.

Introduction

Fenugreek is a plant with the scientific name of *Trigonella foenum-graecum* L. whose leaves are used as a fresh vegetable or in some Iranian dishes. The ground fenugreek seeds are widely used in traditional medicine (Seghatoleslami, Ahmadi Bonakdar, 2010). In addition to grain yield, its biological yield is also important. Plant density is one of the most important factors determining the yield of crops and medicinal plants. (Postma *et al.*, 2021).

Numerous studies on the effect of plant density on fenugreek yield have been conducted mainly in the range of plant densities of 20 to 120 plants $m^{2\,-1}$. Experiments conducted by Khosravi *et al.* (2014) showed that at an initial density of 22 plants $m^{2\,-1}$, grain and biological yield, were 900 and 2 500 kg ha^{-1}, respectively, and increasing plant density had no effect on these two traits. In the experiment of Zandi *et al.* (2013), the highest grain yield was obtained from the density of 60 plants $m^{2\,-1}$ and increasing the density to 80 22 plants $m^{2\,-1}$ resulted in a 7.7% increase in biological yield.

The availability of water in the soil is also one of the most important factors determining the yield of crops and medicinal plants (Ahmed *et al.*, 2018; Pieczynski *et al.*, 2013). According to the report of Dadrasan *et al.* (2015), at full irrigation, the seed yield of fenugreek was 839 kg ha^{-1}, which decreased by 27 and 42%, while the irrigation volume decreased by 25 and 50%, respectively. In their experiment, the reduction of biological yield of fenugreek in 25 and 50% irrigation treatments compared to full irrigation was 40 and 65%, respectively.

Few studies have focused on the interaction of water stress and plant density in fenugreek. In the experiment of Khosravi *et al.* (2014), the effect of irrigation intervals of 5 and 10 days was investigated in different densities. When the irrigation intervals were 5 days, the increase in density led to a 12% increase in grain yield, but when the irrigation intervals were 10 days, the increase in density, did not lead to an increase in grain yield. Research by Rahimi *et al.* (2009) in asparagus showed that in optimal irrigation, medium plant density, compared to low plant density, increased grain yield, but when water stress occurred, no difference in grain yield was observed between the two densities. According to their research, high plant density compared to low plant density also led to a significant reduction in grain yield in all irrigation treatments. Studies by Abdolahi-Mayvan *et al.* (2019) on European borage showed that increasing plant density from low to medium increased biological yield and high densities reduced grain yield at all irrigation treatments. The above researches indicate the ineffectiveness or negative effect of increasing plant density under water stress.

Therefore, the hypothesis of the present study is based on the idea that medicinal plants grow even in their richest natural habitats with much lower plant densities than field planting and even the lowest conventional planting densities are a kind of density increase imposition for the medicinal plant (Lemaire *et al.,* 2001; Ojija *et al.,* 2021; Trinder *et al.,* 2021;), therefore, increasing plant density will have little benefit to compensate for the decrease in the individual plant yield due to water stress (Rahimi *et al.,* 2009) and may even reduce yield (Abdolahi-Mayvan *et al.,* 2019).

Another purpose of this study is to determine the best plant density in different conditions of water availability to achieve acceptable yield with the least amount of water consumption. If the hypothesis of this study that the increase in plant density is not beneficial under water stress is correct. Then saving on seeds and other inputs will be beneficial.

Materials and Methods

The experiment was conducted in the South Khorasan province of Iran (longitude N 58° 83´ and latitude E 34° 1´) and at an altitude of 1 500 meters above sea level. The average long-term annual temperature and precipitation are 14.3 °C and 134 mm, respectively. The Köppen-Geiger climate classification is BWk (desert or arid climate).

The soil was the montmorillonite clay loam (34% clay, 22% sand, 44% silt), low in organic matter (7.112 g kg^{-1}) with a pH of 7.7, EC of 0.99 dS m^{-1}, and bulk density of 1.45 g $cm^{2\,-1}$. The amount of nitrogen and absorbable phosphorus were 38.0 mg kg^{-1} and 13.4 mg kg^{-1} respectively.

This study was performed as split plots in a randomized complete block design with three replications. Water stress (100, 75 and 50% of the required water) in the main plot were considered as optimal conditions, mild stress and severe water stress, respectively. Plots were irrigated through a drip irrigation system. Drippers were placed 50 cm apart, with a flow rate of 1.5 litres per hour. Irrigation frequency was based on total available soil water (TAW) and water soil depletion. Crop water requirement during the growing season was determined based on evapotranspiration (ETP). Reference ETP (ETP0) was measured using a class A evaporation pan. ETP0 was then multiplied by the water stress coefficient (Ks) and the crop coefficient (Kc) to calculate the crop evapotranspiration (ETPc). To create mild and severe water stress, the plots were irrigated after depletion of 25% and 50% of available soil water content (AWC), respectively. Soil water content (SWC) was measured daily by using four granular matrix sensors (Watermark Soil Moisture Sensors, Irrometer Co. Inc., Riverside, CA), installed in the soil at 20 cm intervals, up to 80 cm deep.

Plant densities (66, 44 and 22 plants $m^{2\,-1}$) were assigned to sub-plots. Row space was 30 cm and in-row space was 5, 10 and 15 cm, respectively. Each plot consisted of 4 rows 5 m long.

60 kg of nitrogen (urea), 60 kg of phosphorus (P_2O_5) and 60 kg of potassium (K_2O) per hectare were added to the soil during field preparation based on the field soil test. Irrigation and plant density treatments were applied after plant establishment (about 30 days after emergence).

Nitrogen was applied during the two more stages (the first stage after thinning of plants and the second stage at the beginning of flowering) at a rate of 50 kg urea ha^{-1} in each stage. Seeds were disinfected with Tiram fungicide at a concentration of 2 g L^{-1}. Sowing, in the form of a dry planting method, was done on both sides of the ridges. No specific plant pests and diseases were observed and weeding was done manually

The number of pods per plant, number of seeds per pod and 1 000 seed mass were measured by sampling ten random plants from the middle rows of each plot.

To measure relative leaf water content (RWC), five whole leaves were removed from each plant. First, fresh mass (FM) was measured with the help of a precise digital scale (Atrorios Germany) with an accuracy of 0.0001 g, then to reach the state of turgescence, was placed in the refrigerator for four hours in distilled water. To remove excess moisture, after removing the leaves from distilled water, they were dried between two layers of filter paper and then their turgor mass (TM) was measured. To measure the dry mass (DM), the samples were placed in an oven for 48 hours at a temperature of 70 °C to dry, and their dry mass was measured, and then the relative water content of the leaf was calculated according to the Equation 1 (Maxwell, Johnson, 2000).

$$\mathrm{RWC} = \frac{(\mathrm{FM} - \mathrm{DM})}{(\mathrm{TM} - \mathrm{DM})} \times 100 \qquad (1)$$

The amount of chlorophyll and fluorescence parameters of chlorophyll (F0, Fm, Fv, Fv/Fm), were measured using OS1-FL Chlorophyll Fluorimeter 2 (Opti-Sciences, Inc., Hudson NH, USA). To measure the amount of leaf chlorophyll fluorescence parameters, first, the youngest whole leaf from 5 plants of each plot, was chosen and after about 20 minutes and adapting to the dark, with the use of special receivers for the device, evaluation took, for this purpose, the flash of infrared light connected to the place of the clamp valve and immediately after opening the valve, the data corresponding to minimum fluorescence (F0), maximum fluorescence (Fm) and the ratio of variable fluorescence to maximum fluorescence (Fv/Fm) reading and its fluorescence was recorded. Measurement of chlorophyll fluorescence was done in the early morning and near evening when the intensity of radiation was low.

Irrigation continued for up to 15 days before the pods were fully mature. Harvesting was carried out 180 days after planting when the pods were dry. Biological yield and seed yield were measured from the middle part of each plot and the harvest index was calculated by the ratio of grain yield to biological yield.

SAS 9.4 statistical software was used for the statistical analysis of data. The means were compared using Duncan's multiple range test at the level of 0.05 probability and the figures were drawn using the MS Excel 2019 software.

Results and Discussion

Water stress

Under optimal irrigation conditions, grain yield was 1173 kg ha^{-1}, while in mild and severe water stress, 24.1 and 37.5% reduction in grain yield was observed, respectively, and the difference between all three stress levels was significant in terms of grain yield (Tables 1 and 2). The decrease in biological yield in mild and severe stress compared to the favourable conditions, was 16.1 and 24.1%, respectively (Tables 1 and 2), and there was a significant difference between the water stress levels in terms of biological yield (Table 2). According to the report of Dadrasan *et al.* (2015), 25 and 50% irrigation treatments reduced the yield of fenugreek seeds by 27 and 42%, respectively, and their biological yield by 40 and 65%, respectively, compared to full irrigation. Whereas, contrary to this report, our results showed that the reduction in water availability reduced grain yield more severely than biological yield. Increasing the intensity of water stress led to a significant decrease in harvest index with a similar trend to grain yield (Table 2). The harvest index difference was significant in all three stress levels, similar to grain yield (Table 2). This result shows that the decrease in grain yield due to the increase in water stress has little to do with dry matter production and is more related to how dry matter is distributed. In an experiment by Meena *et al.* (2021), the decrease in grain yield and total biomass of fenugreek due to mild water stress was different and was 9.1 and 12.9%, respectively. However, in severe water stress conditions, it was the same and about 43.5%.

The response of the number of seeds per pod and 1 000 seed mass to water stress also showed that the number of seeds per pod decreased significantly under stress conditions, but 1 000 seed mass did not change contrary to expectations (Table 2). As in the research of Baradaran *et al.* (2013), increasing the irrigation interval from 4 to 12 days caused a significant decrease in the number of seeds per pod and the number of pods per plant and a significant increase in 1 000 seed mass (Table 2).

Table 1. Mean squares for the effect of irrigation regimes, plant density and their interaction on some studied traits in fenugreek

Sources of variation	df	Pod length, cm	Seed per pod	Pods per plant	Stem diameter, mm	Plant height, cm
Block	2	5.4**	8.2**	64.3**	0.04^{NS}	21.6^{NS}
Irrigation (I)	2	1.4^{NS}	7.4**	45.2**	0.11**	322.4**
Error$_a$	4	0.3	2.5	7.0	0.01	6.1
Plant Density (D)	2	1.84*	14.9**	11.4*	0.07*	139.4**
I × D	4	0.2^{NS}	0.83^{NS}	6.3*	0.04^{NS}	81.9*
Error$_b$	1	0.48	4.7	1.5	0.02	20.4
CV%		10.5	8.5	7.9	10.1	17.4
		Chlorophyll florescence	Relative water contents, %	Biological yield, kg ha^{-1}	Grain yield, kg ha^{-1}	1 000 seed mass, g
Block	2	0.42^{NS}	900.4^{NS}	477 284**	264 261**	7.2^{NS}
Irrigation (I)	2	0.97*	1270*	1 111 780**	448 290**	0.5^{NS}
Error$_a$	4	0.02	313.3	30 172	33 815**	1.1
Plant Density (D)	2	0.52*	5218*	258 070**	90 074	0.3^{NS}
I × D	2	0.22**	2352**	15 576*	33 140*	0.01^{NS}
Error$_b$	1	0.05	567.2	39 456	7 898	1.4
CV%		7.6	3.5	8.0	9.5	16,0

^{NS} – non-significant, * – significant at 0.05 level and ** – significant at 0.01 level

Despite the decrease in the number of seeds per pod due to the increase in stress intensity, the pod length was not affected by water stress (Tables 1 and 2), which shows that water stress reduces the availability of photosynthetic material for each seed and thus parts of the pod remains empty and this has also reduced grain yield. Also, increasing the stress decreased the stem reserves so that the stem height and stem diameter decreased with water stress (Table 2), which shows an increase in the remobilization of stem dry matter to the seeds under conditions of reduced photosynthesis. In the experiment of Bazrkar-Khatibani and Fakheri (2018), water stress reduced plant height from 59.1 to 47.5 cm (19.5%), but unlike the present study, their results showed that the amount of leaf area per pod under optimal irrigation and water stress conditions was almost the same. In the experiment of Bazrkar-Khatibani and Fakheri (2018), water stress reduced plant height from 59.1 to 47.5 (19.5%), but unlike the present study, their results showed that the number of pods and the amount of leaf area per pod under optimal irrigation and water stress conditions, was almost the same, indicating that the source strength-sink size relationship did not change in water stress condition.

Overall, the evidence of the present study shows that water stress mainly by reducing the sink size and partitioning efficiency of dry matter to grain (harvest index) has reduced grain yield in fenugreek and has less correlation with biological yield and dry matter production efficiency.

Table 2. Mean comparisons for simple effect of irrigation regimes and plant density on some studied traits in fenugreek

Traits	Plant height, cm	Stem diameter, mm	Pods per plant	Seeds per pod	Pod length, cm	1 000 grains mass, g	Grain yield, kg ha^{-1}	Biological yield, kg ha^{-1}	Harvest index, %	Chloro-phyll flore-scence	Relative water contents, %
Irrigation regimes											
FWC	31.7^{a}	1.5^{a}	17.4^{a}	31.2^{a}	7.2^{a}	9.8^{a}	1173^{a}	2 859^{a}	41.0^{a}	0.88^{a}	85.1^{a}
MWS	26.0^{b}	1.3^{b}	16.4^{a}	12.7^{b}	6.9^{a}	9.7^{a}	890^{b}	2 398^{b}	37.1^{b}	0.84^{ab}	74.3^{b}
SWS	19.8^{c}	1.2^{b}	13.2^{b}	8.90^{b}	6.4^{a}	9.4^{a}	732^{b}	2 170^{c}	33.7^{c}	0.79^{b}	68.2^{b}
Plant density											
D22	29.1^{a}	1.4^{a}	17.2^{a}	22.5^{a}	7.2^{a}	9.8^{a}	837^{b}	2333^{b}	35.8^{b}	0.85^{a}	77.2^{a}
D44	26.9^{a}	1.3^{ab}	16.6^{a}	13.5^{b}	6.9^{ab}	9.6^{a}	922^{b}	2431^{b}	37.9^{ab}	0.84^{a}	74.0^{a}
D66	21.5^{b}	1.2^{b}	13.2^{b}	12.5^{b}	6.3^{b}	9.4^{a}	1037^{a}	2663^{a}	38.9^{a}	0.80^{b}	75.2^{a}

FWC – favourable water conditions; MWS – mild water stress; SWS – severe water stress.
D22, D44 and D66 – 22, 44 and 66 plants per m$^{2\,-1}$, respectively.
Means followed by the different letters in the same column differ statistically by the Tukey test (P <0.05).

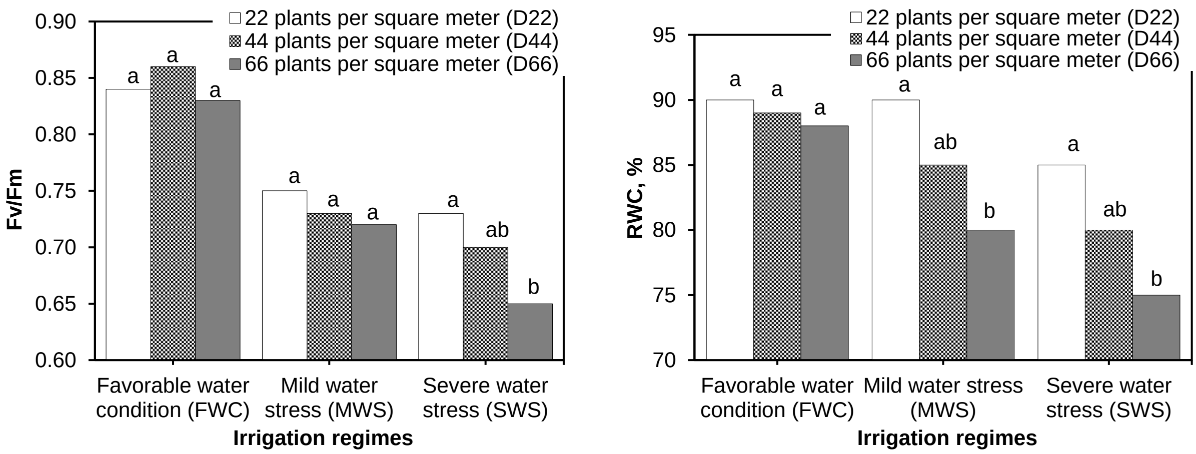

Figure 1. The mean comparisons for the interaction effect of irrigation regimes × plant density for chlorophyll fluoresce and leaf relative water content in fenugreek (Fv/Fm – ratio of variable fluorescence to maximum fluorescence; RWC – relative leaf water content. Means followed by the different letters differ statistically by the Tukey test (P <0.05).)

Plant density

Increasing plant density from 22 to 44 plants m$^{2\,-1}$ only reduced the number of seeds per pod and other traits, especially 1 000 seed mass did not change (Table 2), so it can be concluded that this increase in density by reducing the number of seeds per pod, reduces the yield of an individual plant, but the grain yield per unit area did not change (Table2), which indicates that the yield loss of individuals was compensated by increasing the density, up to 44 plants m$^{2\,-1}$.

This result implies that doubling the plant density from 22 to 44 plants m$^{2\,-1}$ and consequently increasing competition between plants, had no effect on the availability of photosynthetic material at the beginning of flowering, which determines the number of pods per plant as well as, the availability of photosynthetic materials for each grain during grain filling, which determines the mass of a thousand grains. However, in the interval after the beginning of pod formation until the maximum pod length (beginning of seed filling), which almost coincides with the maximum leaf area index, the reduction of photosynthetic material due to shading of leaves on top of each other, causes the loss of several newly-formed seeds and producing pods with fewer seeds or hollow pods. Further increase in plant density from 44 to 66 plants m$^{2\,-1}$ showed a different result so that increasing plant density in this range did not reduce the number of seeds per pod but reducing the number of pods per plant (Table 2), led to a decrease in the yield of individuals. However, by increasing the density in this range, grain yield per unit area increased. These results may suggest that increasing plant density, first by reducing source strength due to shading, and then by further increasing plant density through sink size restriction, leads to reduced individual seed yield. Some experiments performed in Iran on the effect of plant density on fenugreek yield indicated that this factor does not have a significant effect on yield and yield components. Increasing plant density from 10 to 40 (Seghatoleslami, Ahmadi

Bonakdar, 2010) and from 60 to 120 plants m^{-2} (Zandi *et al.,* 2013), had no effect on 1 000 seed mass, number of seeds per pod, number of pods per plant, and grain yield, and only in some cases did it increase total biomass, for example increasing the density from 60 to 80 plants m^{2-1} led to a 7.4 % increase in biomass (Zandi *et al.,* 2013).

Water stress and density interactions

The interaction effects of plant density and water stress on relative leaf water content and chlorophyll fluorescence were significant (Table 1). Under optimal irrigation conditions and mild stress, there was no difference in chlorophyll fluorescence between different densities, while at severe water stress, 66 plants had a significantly lower chlorophyll fluorescence than 22 plants m^{2-1} (Fig. 1). Also, under favourable water conditions, there was no difference in relative leaf water content between different densities, but in mild and severe water stress conditions, the relative leaf water content at a density of 66 plants compared to 22 plants m^{2-1}, was significantly lower (Fig. 1). The interaction effect of plant density with water stress was significant for several pods per plant, plant height, grain yield, biological yield, but for 1 000 seed mass, number of seeds per pod and stem diameter was not significant (Table 1).

As mentioned earlier ,the increase in plant density, probably due to shading and decrease in canopy photosynthesis and, consequently the need to increase the remobilization of photosynthetic material from stem to seeds, has reduced plant height. However, the decrease in plant height due to increasing plant density was observed only in optimal irrigation conditions and mild stress and only after a 3-fold increase in plant density from 22 to 66 plants m^{2-1}, but in severe water stress, plant height did not differ significantly at different densities (Fig. 2). This result confirms that in optimal irrigation conditions or mild water stress where there is no sharp decrease in the number of pods per plant, the size of the sink is large and requires a lot of current photosynthesis. Under these conditions, increasing plant density causes leaf shade and reduces the penetration of light into the canopy and consequently, sufficient photosynthetic material for the seeds does not provide. As a result, stem reserves are transferred to the seed, which reduces the height and diameter of the stem. However, in severe water stress, the number of seeds per pod and the number of pods per plant is drastically reduced (Table 2), and due to the small size of the sink, the current photosynthetic material meets the grain requirements and the stem reserves are not used much. Therefore, in severe water stress, increasing plant density did not affect plant height (Fig. 2).

In the experiment of Ghobadi and Fattahi (2016) on coriander, the interaction effect of plant density with irrigation on plant height and harvest index was insignificant and on all yield components (number of umbels per plant, number of seeds per umbel and seed mass) and grain yield and biological yield were significant. This indicates the small role of stem reserves in the formation of yield and its small impact on plant regeneration efforts. In their experiment, increasing plant density in both optimal irrigation and water stress conditions in the shoot formation stage did not affect yield, but when water stress was in the reproductive stage, increasing the density from 10 to 50 plants m^{2-1} increased yield. However, increasing the density from 50 to 70 plants m^{2-1} reduced the yield.

At all levels of water stress, there was no difference in the number of pods per plant between densities of 22 and 44 plants m^{2-1}, while the density of 66 plants m^{2-1} compared to lower plant densities, significantly reduced the number of pods per plant (Fig. 2).

This decrease in severe, mild stress and optimal conditions was 36%, 20% and 15%, respectively, *i.e.* in severe stress conditions, it decreased more than twice as much as optimal (Fig. 2). Our result shows that in optimal irrigation conditions, due to sufficient photosynthetic material in the fertilization stage of flowers and the initial formation of pods, competition due to increased plant density did not affect the number of pods per plant. Water stress reduced grain yield mainly due to the decrease in the number of pods per plant and the role of the number of seeds per pod was small. Hence, in water stress conditions, also increase in plant density due to an increase in leaf area during the conversion of flowers into pods has reduced the penetration of light into the canopy and reduced current photosynthesis which led to the formation of fewer pods. This result is more pronounced in mild water stress than in severe water stress (Fig. 2).

The reason for this difference may be related to the greater possibility of maintaining and developing leaves and more shading and more severe loss of current photosynthesis in the flower-to-pod conversion stage under mild stress conditions compared to severe stress. As mentioned earlier, the results of Ghobadi and Fattahi (2016) research indicated the usefulness of medium plant densities in water stress conditions compared to low densities for coriander, while the results of Rahimian *et al.* (2019) were different and similar to the results of the present study. In their experiment, increasing plant density increased grain yield of asparagus and psyllium, but under water stress, increasing plant density led to reduced yield.

The interaction of plant density and water stress was significant for the number of grains per pod (Table 1 and 2). In all three levels of stress, increasing the density from 22 to 44 plants m^{2-1}, caused a significant decrease in the number of seeds per pod, adding more plants (density of 66 plants m^{2-1}), in none of the stress levels, did not affect the number of seeds per pod (Fig. 2). As mentioned earlier, increasing plant density first by reducing the number of seeds per pod reduces grain yield and by increasing the density, grain yield decreases by reducing the number of pods per plant, which can be the reason for not reducing the number of seeds per pod from 44 to 66 plants m^{2-1}, at all levels of stress.

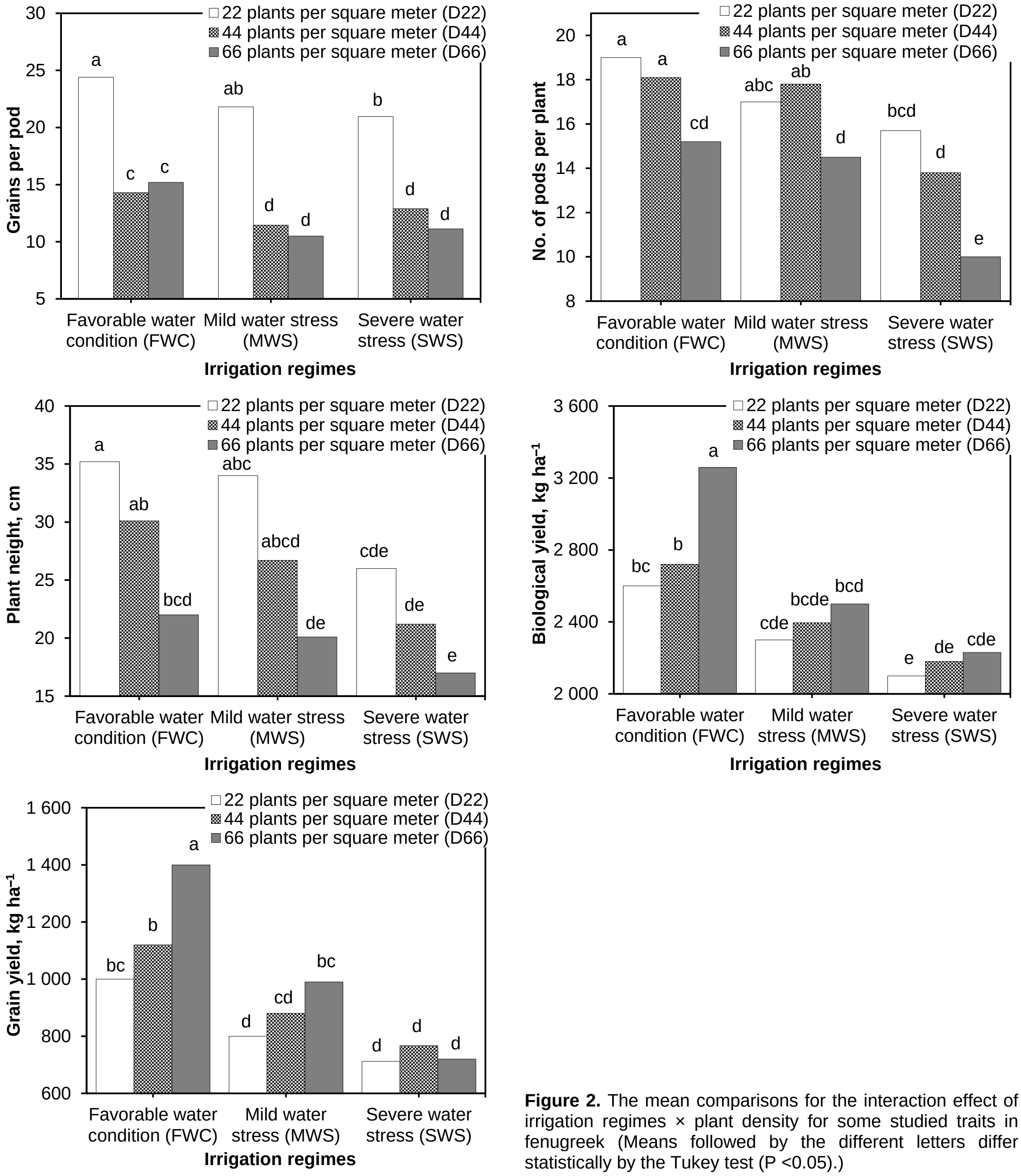

Figure 2. The mean comparisons for the interaction effect of irrigation regimes × plant density for some studied traits in fenugreek (Means followed by the different letters differ statistically by the Tukey test (P <0.05).)

The interaction effects of water stress and density on grain yield and biological yield were significant (Table 1), and the pattern of interactions of these two traits is the same (Fig. 2). At mild and severe stress, no difference was observed between different plant densities in terms of biological yield and grain yield (Fig. 2). While in optimal irrigation conditions ,increasing the density from 22 to 66 plants m^{2-1} caused a significant increase in both grain yield and biological yield (Fig. 2). Therefore, it seems that increasing plant density cannot compensate for the decrease in grain yield or biological yield due to water stress, however, in optimal irrigation conditions, a 3-fold increase in plant density could significantly increase grain yield and biological yield (Fig. 2).

Conclusion

The yield of each plant is the result of the interrelationship between the source and the sink. One of the most important factors affecting the size of the source and sink is plant density. Plant density can affect yield by changing yield components, changing source strength as well as allocation and partitioning of assimilates. The results of this experiment confirm that water stress reduced the size of the sink by reducing the number of pods per plant, number of seeds per pod and number of seeds per plant, while the mass of 1 000 seeds, which is the most indicative of source strength, did not change. On the other hand, increasing the density led to a decrease in single plant yield, but this decrease was compensated by increasing the density so that the yield per unit area did not change. It seems that, at medium densities, single plant yield is reduced by reducing source strength, and at higher densities due to sinking restriction. The reason for this is that at high densities the number of pods per plant decreases. Under optimal water conditions, increasing density limits the current photosynthesis. On the other hand, in the absence of water stress, due to the larger size of the sink and the need for more photosynthetic materials, the remobilization ratio increased. However, in severe water stress due to a reduction in sink size, current photosynthesis met the plant needs and, as a result, remobilization did not change. The research hypothesis was based on the idea that medicinal plants, even in the richest and most suitable natural habitats, grow with a much lower density than the common plantings in agriculture. For this reason, planting the fenugreek medicinal plant in the agricultural system at a density higher than the natural habitat can be a kind of imposition of density on the plant, which is aggravated in the conditions of drought stress and it is necessary to pay more attention to this issue in research.

Conflict of interest

The authors have declared that no competing interest exists.

Author contributions

MHD – guidance and monitoring of experiment, designed the study, wrote the protocol, critical revision on the initial draft and approved of the final manuscript
AM – wrote the first draft of the manuscript, reviewed the experimental design, analyzed the data
AB – Cooperation in farm implementation.
All authors read and approved the final manuscript.

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ECOLOGICAL AND ECONOMIC EFFICIENCY OF GROWING ON DARK GRAY SOILS OF BEAN-CEREAL GRASSES

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ABSTRACT. The efficiency of growing leguminous and cereal agrophytocenoses (*Trifolium pratense* and *Medicago sativa* sown with the addition of *Bromus inermis*, *Lolium multiflorum*, *Festuca rubra*), highlighted their economic and energy advantages over cereal grasses. The article presents the results of the study of the influence of grass mixtures on the main indicators of the efficiency of growing sowing phytocenoses during haymaking in the Carpathians on dark grey soil. Growing agrophytocenoses without mineral fertilizers ensures the maintenance of 370–520 € ha^{-1} of net profit, with the profitability of 151–187%, the cost of 1 ton of feed units – 56.7–66.7 €, bioenergy coefficient – 2.5–2.9, energy efficiency ratio – 5.8–6.5 and energy consumption per 1 ton of feed units – 4.0–4.7 GJ. The cultivation of alfalfa-cereal grasses is ensured on dark-wet soil with three years of use of the best indicators of economic and energy efficiency. It was found that on both experimental bean-cereal grasses the highest efficiency is maintained when $P_{60}K_{60}$ is applied in combination with inoculation of seeds of bean strains of nodule bacteria.

Introduction

By development level, forage production in Ukraine lags far behind member states of the world economic community due to extensive, resource- and nature-intensive and environmentally hazardous management. This fact significantly affects the process of production of quality food raw materials and food products of animal origin and the formation of state food security (Pidpalyi *et al.*, 2013; Konyk, 2016). The largest share of the cost of livestock products is the cost of procurement of feed, so increasing their production at the moment will stop the decline of this industry (Klymenko, 2009; Karpenko *et al.*, 2019; Karbivska *et al.*, 2020). The cheapest food today can be obtained by growing meadow grasslands (Veklenko, 2003;

Scherner *et al.*, 2016; Cordeau *et al.*, 2017; Voloshyn, 2018; Hryhoriv *et al.*, 2022).

Grasslands are a major component of landscapes and are increasingly appreciated for their important role in providing sustainable development of ecosystems and they form a general positive impact on the environment (Hlushchenko, 2008; Capelo *et al.*, 2014; Isselstein, 2014; Paz-Ferreiro, 2016; Litvinov *et al.*, 2020).

The efficiency of growing agrophytocenoses largely depends on the species composition of grasses. According to studies conducted in Turkey, the introduction of *Lotus corniculatus* and *Medicago falcata* in the grass mixture can increase relatively net income by 83 USD compared to cereal grassland (Ates *et al.*, 2017). The main index of meadow agrophytocenoses economic efficiency is the cost of their creation, which is significant and takes the main share of all costs (Pukalo, 2015; Biermacher, 2012). The use of bean-cereal grasses is economically beneficial only with a high proportion of bean grasses, and, as it is known, they grow at a high level for only 2–3 years (Vyhovskyi, 2013; Panakhyd *et al.*, 2020).

One of the most important factors influencing the efficiency of growing meadow grasses is mineral fertilization (Schellberg, 1999). However, there are much data concerning the negative effects of mineral nitrogen on bean grasses. An alternative to it is the use of biological products which reduce agrochemical load and provide high-quality competitive agricultural products and preserve soil and environmental fertility. The use of inoculants is highlighted in the work of Dutch researchers Köhl *et al.* (2015). According to their data, seed inoculation is effective even on poor soils, in particular with a lack of phosphorus. The cost of bio preparations is only 3–5% of the profit (Petrichenko *et al.*, 2012; Patyka *et al.*, 2015).

With the help of energy assessment of agrophytocenoses cultivation, it is possible to compare different technologies of agricultural production with the help of energy costs and determine the structure of energy flows in agrocenoses and identify the main reserves of technical energy savings in agriculture (Konyk, 2016; Kvitko *et al.*, 2021; Mishchenko *et al.*, 2022a,b). Quantitatively determining the energy efficiency of growing meadow phytocenoses can be with the help of spent and received energy (Tatariko *et al.*, 2005; Hetman, 2014; Karbivska *et al.*, 2020).

Our work was based on a working hypothesis, the essence of which was in the complementary influence of cereal and bean grasses with complex fertilization systems, the economic efficiency of which is still insufficiently studied in the conditions of Precarpathians. However, until recently, such issues have not been studied enough, which became the goal of our research.

Materials and Methods

The research was conducted on dark grey drained soil of SE "Victory" (GPS coordinates latitude 48°56'55', longitude – 24°41'35') of Ivano-Frankivsk Institute of AIP, Tysmenytsk district of Ivano-Frankivsk region during 2017–2019. The research was conducted according to methodology of the Institute of Fodders of NAAS (Babych, 1994).

The study was conducted on seven fertilization backgrounds in combination with the use of appropriate strains of nodule bacteria – without fertilizers (control), $N_{30}P_{60}K_{60}$, $N_{30}P_{60}K_{60}$ + strain, $P_{60}K_{60}$, $P_{60}K_{60}$ + strain, $P_{90}K_{120}$, $P_{90}K_{120}$ + strain, and experiments on cereals were conducted on two backgrounds – without fertilizers, $N_{30}P_{60}K_{60}$.

Areas of sown plots – 180 m^2, accounting – 25 m^2. Seeds of bean grasses were treated by strains of nodule bacteria immediately before sowing grass mixtures. Seeds of perennial bean grasses before sowing were inoculated with nodule bacteria *Rhizobium trifolii* (*Trifolium pratense*) and *Rhizobium meliloti* (*Medicago sativa*).

The soil of the experimental area was dark grey podzolic heavy loam with the following agrochemical parameters: humus content in an arable layer – 2.12%, saline soil pH – 4.8, alkaline-hydrolyzed nitrogen – 53, mobile phosphorus – 83, mobile potassium – 69 mg kg^{-1} soil.

Evaluation of weather conditions in the years of research was carried out based on meteorological data obtained at Ivano-Frankivsk Regional Center for Hydrometeorology. They differed from long-term indices, but were favourable for the formation of agrophytocenoses of bean-cereal grasses, 2017 was characterized by unfavourable weather conditions, as a period with dry vegetation season and thermal regime with average monthly air temperature only 0.6 °C above normal 13.6 °C (long–term average for 2008–2019). The annual precipitation amount was 637 mm, and during vegetation season – 429 mm, which was respectively at the level of 67 mm or 14% less than the long-term average index. In April, July, August and September precipitation amount was significantly smaller than the norm (496 mm), by 1.6–2.6 times, in May and June precipitations were within the norm. This, of course, negatively affected the regrowth of grasses in the aftermath, and especially in the 3rd mowing, 2018 was characterized by the best weather conditions for perennial grasses compared to all years, with the highest precipitation amount at relatively moderate temperatures. The average air temperature both for the year and the growing season was higher than the norm (13.6 °C) by 0.9 and 1.0 °C, respectively. The annual precipitation amount was 1 015 mm, and during vegetation season – 778 mm, which is 387 and 282 mm more than the norm (496 mm).

In 2019 were recorded unfavourable weather conditions for the growth and development of perennial grasses, primarily due to lack of moisture, although air temperature during the vegetation period was moderate, with an average temperature of only 0.6°C above normal, and in May, June, July weather conditions were normal. The annual precipitation amount was 490 mm, and during the vegetation period – 386 mm, which is 138 and 110 mm less than the norm.

An economic evaluation of growing technologies for perennial grasses based on the studied elements was performed according to the method of evaluating the effectiveness of research with the help of technological maps with prices of 2020, energy evaluation was made according to the method by Medvedovskyi and Ivanenko (1988).

Statistical processing of yield data was performed by Microsoft Excel 2010.

Results and Discussion

When growing bean grasses at the control the following indices were obtained: net profit (389.7–521.0 € ha^{-1}), profitability level (151–187%) and the cost of 1 ton of fodder units (66.5–98.4 €) and 1 ton of crude protein (268.2–331.5 €) (Table 1).

On cereal grassland net profit and profitability were lower by 1.5–2.0 and 1.1–1.3 times, respectively, and prime cost of 1 ton of fodder units and crude protein – higher by 1.1–1.2 and 1.4–1.8 times. Alfalfa-cereal grasses provided higher indices of economic efficiency in the variants without fertilizers than clover-cereal grasses with a net profit of 1.3 times higher. A similar advantage of alfalfa-cereal grasses was on other studied backgrounds.

Research has proved that the variant with leguminous grasses had the highest level of profitability (145%), and in our study, it was higher than 42% in the variant of alfalfa-cereal grasses, while in cereals this figure was 141% (Konyk, 2016; Kvitko *et al.*, 2021; Mishchenko *et al.*, 2022a,b).

In comparison with the results obtained in similar climatic conditions, the researchers Panakhyd *et al.* (2020) proved that the costs of creating alfalfa-lovage-cereal agrophytocenosis ranged from 158.45 to 469.35 € ha^{-1}, whereas our costs were at the level of 250.25–476.10 € ha^{-1} in clover-alfalfa-cereal grass and depended on the type of fertilizer (Panakhyd *et al.*, 2020). In the background, $N_{30}P_{60}K_{60}$ the indices of economic efficiency of growing bean-cereal grasses compared to the variant without fertilizers decreased. Net profit and profitability decreased by 1.3–1.5 and 2.3–2.6 times, and the prime cost of 1 ton of fodder units and crude protein increased by 1.6 times. This is stipulated by the fact that due to a sufficient supply of soil with essential nutrients the grasses reacted poorly to nitrogen in cereal grassland.

Analysis of the research results showed that among fertilizer variants on both studied bean-cereal grasslands, the best indices of economic efficiency were obtained when applying $P_{60}K_{60}$ in combination with strains of nitrogen-fixing preparations. Net profit and profitability on clover grassland amounted to 359.1 € ha^{-1} and 85% accordingly, with the prime cost of 1 ton of fodder units and crude protein 92.03 and 451.33 €.

On alfalfa-cereal grassland, net profit and profitability were 478.0 € ha^{-1} and 107% respectively, and the prime cost of 1 ton of fodder units and crude protein was lower (80.53 and 375.6 €). However, the addition of only a strain of nitrogen-fixing drug, especially on alfalfa-cereal grassland, both with the application of $N_{30}P_{60}K_{60}$ and $P_{60}K_{60}$, $P_{90}K_{120}$ was generally ineffective. It was found that the most important economic indicators depended on the composition of the legume component of the grass mixture and fertilizer. With the application of mineral fertilizers, energy consumption, and gross and exchange energy output increased proportionally.

Payback of total energy consumption per 1 ha of exchange and gross energy on the background of $P_{60}K_{60}$ was the lowest with indices of 1.8 and 3.8 respectively, which is by 0.2 and 0.4 less compared to the background of $N_{60}P_{60}K_{60}$ and by 0.5 and 1.0 less than in the variant without fertilizers (Table 2).

Table 1. Economic efficiency of growing bean-cereal grasses with different fertilization in combination with strains of nodule bacteria

Grass mixture (species of grass and sowing rates of their seeds, kg ha^{-1})	Fertilization	Gross products, € ha^{-1}	Costs, € ha^{-1}	Net profit, € ha^{-1}	Profitability, %	The prime cost of 1 ton, €	
						fodder units	crude protein
Trifolium pratense, 10 + cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	648.3	258.6	389.7	151	66.5	331.5
	$N_{30}P_{60}K_{60}$	720.0	453.3	266.7	59	104.9	503.6
	$N_{30}P_{60}K_{60}$ + strain	763.3	467.6	295.7	63	102.1	492.2
	$P_{60}K_{60}$	726.7	409.9	316.7	77	94.0	460.6
	$P_{60}K_{60}$ + strain	768.3	424.3	359.1	85	92.0	451.3
	$P_{90}K_{120}$	755.1	452.4	302.6	67	99.9	486.4
	$P_{90}K_{120}$ + strain	791.7	467.4	324.3	69	98.4	476.9
Medicago sativa, 10 + cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	800.0	279.0	521.0	187	58.1	268.2
	$N_{30}P_{60}K_{60}$	868.3	477.0	391.4	82	91.5	422.1
	$N_{30}P_{60}K_{60}$ + strain	903.3	492.0	411.4	84	90.8	411.8
	$P_{60}K_{60}$	890.0	431.6	476.4	110	80.8	375.3
	$P_{60}K_{60}$ + strain	925.0	13409	478.0	107	80.5	375.6
	$P_{90}K_{120}$	903.3	14182	430.6	91	87.2	400.6
	$P_{90}K_{120}$+ strain	921.7	447.0	433.9	89	88.2	406.4
The cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	438.3	181.7	256.7	141	69.1	478.1
	$N_{30}P_{60}K_{60}$	560.0	369.7	190.3	51	110.0	637.4

Table 2. The energy efficiency of growing bean-cereal grasses with different fertilizers in combination with strains

Grass mixture (species of grasses and sowing rates of their seeds, kg ha^{-1})	Fertilization	Energy consumption, GJ ha^{-1}	CEE	BEC	Energy consumptions per 1 ton of fodder units, GJ
Trifolium pratense,10 + cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	15.7	6.5	2.9	4.04
	$N_{30}P_{60}K_{60}$	25.4	4.5	2.0	5.89
	$N_{30}P_{60}K_{60}$ + strain	27.3	4.3	1.9	5.96
	$P_{60}K_{60}$	24.8	4.5	2.0	5.69
	$P_{60}K_{60}$ + strain	25.3	4.7	2.1	5.49
	$P_{90}K_{120}$	27.7	4.3	1.9	6.11
	$P_{90}K_{120}$ + strain	28.6	4.3	1.9	6.02
Medicago sativa, 10 + cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	22.6	5.8	2.5	4.71
	$N_{30}P_{60}K_{60}$	29.5	4.6	2.0	5.66
	$N_{30}P_{60}K_{60}$ + strain	30.3	4.7	2.1	5.59
	$P_{60}K_{60}$	27.7	5.1	2.2	5.19
	$P_{60}K_{60}$ + strain	28.3	5.3	2.3	5.15
	$P_{90}K_{120}$	30.8	4.5	2.0	5.68
	$P_{90}K_{120}$ + strain	31.5	4.5	2.0	5.70
The cereals (*Bromus inermis*, 12 + *Lolium multiflorum*, 12 + *Festuca rubra*, 10)	without fertilizers (control)	14.2	4.6	2.2	5.40
	$N_{30}P_{60}K_{60}$	24.7	3.4	1.6	7.35

The best energy efficiency indices were obtained when growing bean-cereal grasses in the variant without fertilizers. In particular, the total energy consumption both per 1 ha and per 1 ton of fodder units was the lowest and ranged between 15.7–22.6 and 4.04–4.71 GJ respectively, and the payback of energy consumption per exit from 1 ha of exchange and gross energy as bioenergy coefficient (BEC) and energy efficiency ratio (CEE) was the highest (2.0–2.9 and 5.8–6.5).

On cereal grassland energy consumption per 1 ton of fodder units was 1.1–1.4 times higher compared to alfalfa- and clover-cereal grasslands and payback of total energy consumption as BEC and CEE were 1.1–1.3 and 1.3–1.4 times lower respectively. Clover-cereal grassland provided higher energy efficiency in these environmental conditions than alfalfa-cereal grassland, where in particular in the variant without fertilizers energy consumption per 1 ton of fodder units was lower, and BEC and CEE 1.1 times higher. A similar advantage of alfalfa-cereal grassland was recorded in other studied backgrounds.

On the background of $N_{30}P_{60}K_{60}$ indices of energy efficiency of growing both bean-cereal grasses compared to the variant without fertilizer deteriorated. The cost recovery of both BEC and CEE decreased by 1.5–1.6 times, and energy consumption per 1 ha and per 1 ton of fodder units increased by 1.5–1.6 times. Similar deterioration regularity of cultivation energy efficiency from the application of $N_{30}P_{60}K_{60}$ compared to the control was in cereal grassland, but with lower BEC and CEE and higher energy consumption per 1 ton of fodder units.

Among fertilizer variants on both studied bean-cereal types of grass, slightly better energy efficiency indices were obtained during the application of $P_{60}K_{60}$ in combination with the use of nitrogen-fixing strains. In this case, BEC and CEE on clover-cereal grassland were 2.1 and 4.7 respectively, with energy consumption per 1 ton of fodder units of 5.49 MJ. On alfalfa–cereal grassland BEC and CEE compared to clover–cereal grassland, as well as in the variant without fertilizers, were higher with rates of 2.3 and 5.3 respectively, and energy consumption per 1 ton of fodder units less with parameters of 5.00. However, the addition of only strain of nitrogen-fixing drug, both on the background of $N_{30}P_{60}K_{60}$, and on the background of $P_{60}K_{60}$ and even $P_{90}K_{120}$ was not always effective, both by indices of BEC and CEE and energy consumption per 1 ton of fodder units.

With increasing doses of phosphorus and potassium fertilizers, energy efficiency also deteriorated. In particular, when applying $P_{60}K_{60}$ compared to the control on bean-cereal grasslands, BEC and CEE decreased by 0.9 and 1.9–2.0 respectively, the payback of 1 t of fodder units increased by 1.4 times, and with an application of $P_{90}K_{120}$ decreased accordingly by 1.0–1.1 and 2.2–2.5 and increased by 1.5 times. The highest forage productivity with grass was observed for the third year of use, in this period the yield of forage units reached 7.1 t ha^{-1}.

Conclusion

The best indices of economic and energy efficiency are provided by growing alfalfa-cereal grasslands. Among fertilizer variants, the highest indices of economic efficiency are provided with the application of $P_{60}K_{60}$ in combination with the use of drugs of appropriate strains of symbiotic nitrogen fixation with net profit and profitability of 360–477 € ha^{-1} and 85–107% with a cost of 1 ton of fodder units 80–93 €. Application of $P_{60}K_{60}$, $P_{90}K_{90}$ and $N_{30}P_{60}K_{60}$ worsens economic and energy efficiency indicators.

Obtained results will allow agricultural producers to choose optimal measures for the creation and use of bean-cereal grasses taking into account their needs and possibilities. A promising area of research in this context is establishing of economic efficiency of technologies for radical improvement of meadows, which would ensure quality fodder at a minimal cost.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publications of this paper.

Author contributions

UK – study conception and design, drafting of the manuscript;
YB – performed the literature data analysis and discussion of the results;
VN, AH – analysis and interpretation of data and is the corresponding author;
VT, DL – author of the idea, guided the research;
DST, NT – acquisition of data, drafting of the manuscript;
OS, VS – critical revision and approval of the final manuscript.
All authors read and approved the final manuscript.

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TRENDS IN THE TRANSFORMATION OF PLANT ONTOGENESIS UNDER GLOBAL CLIMATE WARMING

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ABSTRACT. Observations of the process of ontogenesis in a group of woody plants and forest grass in the phytocenoses of the Ukrainian Polesie of Sumy region with their division into boreal and nemoral species were done. Found that in the last two decades, nemoral plant species begin vegetation earlier and pass the first phases of the ontogenetic cycle faster than boreal species. Changes in plant ontogenesis, in turn, lead to changes in the population characteristics of plant species: the number of individuals in the population, the size and configuration of the population field and the ontogenetic and vital spectra of populations changed. There has been a tendency to regular changes in the ontogenetic spectra of both nemoral and boreal plant species, but their nature was different. In nemoral plant species, the proportion of juvenile and immature individuals in the ontogenetic spectra increased and populations acquired the character of invasive, reflecting the process of progressive strengthening of their position in phytocenoses. In populations of boreal species, on the contrary, the ageing process accelerated – the proportion of old generative, senile and subsenile individuals increased.

Introduction

Global climate warming in different regions of the planet is manifested to a different extent. On the territory of Ukraine, according to meteorological observations, it is expressed quite clearly. Since 1991, each subsequent decade has been warmer than the previous one: 1991–2000 – by 0.5 °C, 2001–2010 – by 1.2 °C, 2011–2020 – by 1.7 °C. In the north–eastern part of the Sumy region, the average annual temperature in the last decades of the twentieth century was 8.2°C, and in the period 2015–2020, it was steadily maintained at 10 °C.

In recent years, summer maximum temperatures have increased that significantly affecting the vital state of plants. Over the past three years, they have risen in the summer months (Table 1).

Table 1. Maximum summer temperatures (°C) for the last three years

Month	2019	2020	2021
June	33	34	37
July	33	36	35

On the contrary, the number of days with severe frosts in winter has decreased. The duration of the growing season for plants has changed: it has begun to start earlier and ends later.

In the eastern part of the Ukrainian Polesie, the average annual precipitation tended to increase. During the period from 1940 to 2010, it increased on average from 550 to 660 mm, in contrast to the south and centre of Ukraine, where the climate became drier (Kovalenko, 2012; Semenova, Polovyi, 2020; Polevoi *et al.*, 2019). But over the past decade, the tendency to decrease precipitation has also manifested itself in this region (Fig. 1). Sharp fluctuations in the amount of precipitation falling in adjacent years have become characteristic: it varies from 344 to 729 mm per year, which creates tension in the water balance of perennial plants.

Global climate warming in its effect on the habitat of plants is diverse. In recent decades, the concentration of carbon dioxide in the air has increased as a result of warming (Saxe *et al.*, 2001; Sytnik, Bagniuk, 2006; Seidl *et al.*, 2017). There are certain trends in the properties of the soil: the height of the groundwater, the amount of humus and the content of nitrogen, potassium and other biogenic minerals in the soil are noticeably changing.

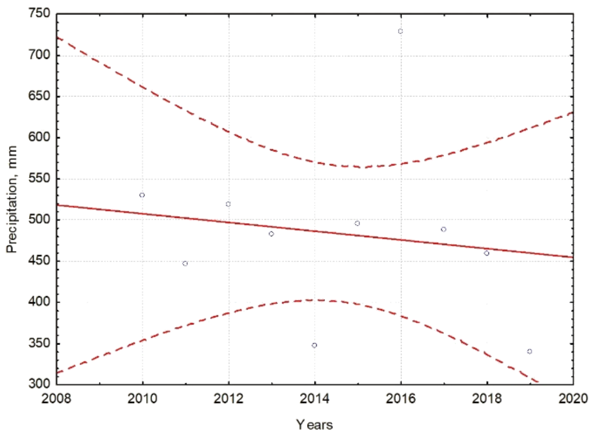

Figure 1. Annual precipitation in Sumy region for the period 2010–2020 (according to Meteo Farm)

In the aggregate final impact, environmental changes caused by global climate warming have a significant effect on photosynthesis and the production process of plants, on metabolism, in general, and ultimately on their size. Changes in the composition of the forest entomofauna of pollinators affect the reproduction of entomophilic forest plants (Pureswaran *et al.*, 2018; Polevoi *et al.*, 2019; Sereda, 2011). All these changes have a multidirectional character. They are favourable for thermophilous plants and not favourable for boreal plants (Kolomyc, 2006).

Global climate warming leads to the transformation of all types of natural ecosystems (Malhi *et al.*, 2020). In Ukraine, the borders of climatic zones are shifting towards the north: steppe, forest-steppe and forest zones.

In the Ukrainian Polesie, there was a tendency to change the species composition of forests with more thermophilous invasive plant species being introduced into them.

Changes in forest vegetation under the influence of global climate warming and its aridization are of a chain character (Fig. 2). They begin with the transformation of the grass-subshrub layer of forest ecosystems. It changes the relationship between the abundance of plant species, new species appear, some fall out completely, which ultimately changes the nature of the regeneration niches for tree species. And changes in the nature of regeneration transform the composition of the tree tier. Thus, the key to understanding the processes which take place in the forests of the Ukrainian Polesie, under the influence of global climate warming processes, is in the grass-subshrub layer of forests of the Ukrainian Polesie.

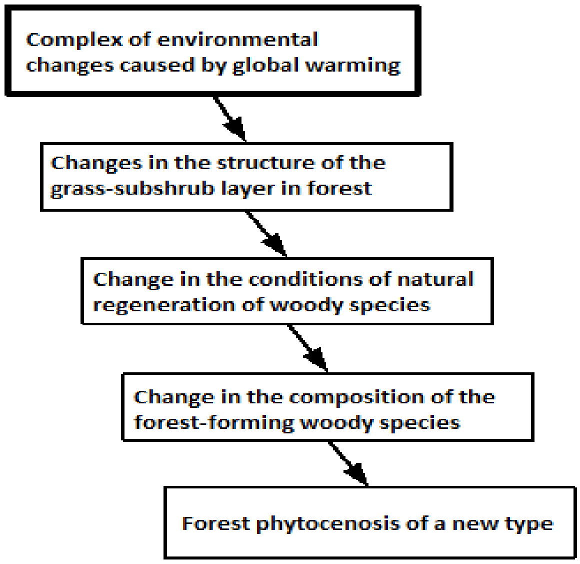

Figure 2. Diagram illustrating the chain nature of the transformation of forest ecosystems under the influence of global warming

In the complex transformations that occur in the living ground cover of forest ecosystems, in turn, one should distinguish primary and secondary processes. The primary ones are changes in the state of plant individuals – their ontogenesis, and the secondary ones are changes in the populations and, at the final stage, the phytocenoses that they are part of (Fig. 3).

Plant individuals act as a primary acceptor of the perception of parameters of the ecological habitat. Changes in their vitality and the ontogenetic spectrum of populations under the influence of unfavourable environmental conditions lead to a change in the number of individuals and a decrease in the size of their population fields. And this, in turn, causes the transformation of forest phytocenoses and forest ecosystems as a whole.

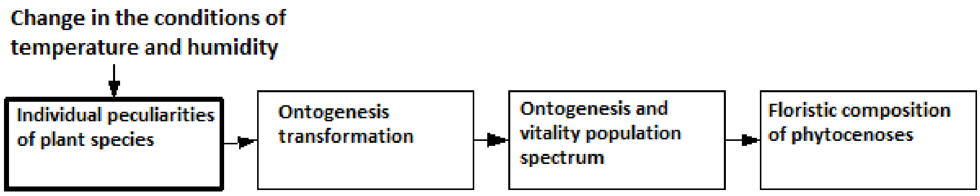

Figure 3. A sequence of processes carried out when the state and viability of plant individuals change, as primary acceptors of the changing ecological environment

Materials and Methods

To identify the stability of forest plants and the transformation of their ontogenesis in the period 2000–2021, we conducted observations of the process of ontogenesis in a group of woody plants and forest grass in the phytocenoses of the Ukrainian Polesie of Sumy region with their division into boreal and nemoral species based on the generally accepted criteria (Zozulin, 1955; Popadiuk *et al.*, 1994).

The group of boreal species included: *Vaccinium myrtillus L., Majanthemum bifolium L., Oxalis acetosella L., Trientalis europaea L., Circaea alpine L., Paris quadifolia L.* The group of immoral forest grasses included *Lathyrus vernus (L.) Bernh., Aegopodium podagraria L., Carex pilosa Scop., Asarum europaeum L., Convallaria majalis L., Viola riviniana Rchb., Stellaria holostea L.*

The two groups of forest–forming tree species were identified similarly. The group of boreal species included: *Pinus sylvestris L., Picea abies (L.) H. Karst., Populus tremula L., Betula pendula Roth., Betula pubescens Ehrh., Alnus incana (L.) Moench., Alnus glutinosa (L.) Gaertn., Salix pentandra L.* The group of nemoral species consisted of: *Quercus robur L., Tilia cordata Mill., Acer negunda L., Acer platanoides L., Pyrus communis L., Fraxinus excelsior L., Ulmus glabra Huds.*

To determine the growth parameters of plants, the method of morphometric analysis was used (Zlobin *et al.*, 2022), with the help of which metric parameters (plant height, phytomass *etc.*) were determined first, and then allometric parameters (absolute growth rate, relative growth rate).

Evaluation of ecological amplitudes of plants of each group was carried out using the ecological scales of Didukh (2011) according to the generally accepted methodology.

Ontogenetic analysis of populations was carried out according to generally accepted methods (Zlobin *et al.*, 2022). In each species, within the population, the number of plants of different ontogenetic states was determined – from seedlings (p) to subsenile (ss) and senile (s) plants. Based on these data, the percentage of plants in each ontogenetic state within the population was determined and the ontogenetic spectra of the populations were determined.

Results

The assessment of the ecological amplitudes of plants of these two groups according to ecological scales (Didukh, 2011) has shown that with species individuality, nemoral species of forest grasses are on average more thermophilic (average amplitude 4.86–12.00 *vs.* 3.83–11.3) and less demanding of the humidification regime (5.71–10.57 *vs.* 6.00–11.34 in boreal species) (Table 2).

Table 2. Ecological amplitudes of boreal and nemoral forest herbaceous plants

Plant species	Thermal regime	Humidity	Soil water regime
Boreal plant species			
Vaccinium myrtillus	2–9	7–12	8–16
Majanthemum bifolium	4–11	7–11	8–16
Oxalis acetosella	4–13	5–11	8–16
Trientalis europaea	3–10	7–12	8–16
Circaea alpina	6–13	5–11	10–17
Paris quadifolia	4–12	5–11	9–15
Average	3.83–11.33	6.00–11.34	8.5–16.0
Optimum	7.58	8.67	12.25
Nemoral plant species			
Lathyrus vernus	4–13	5–10	8–15
Aegopodium podagraria	5–12	5–12	9–17
Carex pillosa	6–11	6–13	8–15
Asarum europaeum	6–12	7–9	9–15
Convallaria majalis	5–12	7–11	8–16
Viola riviniana	4–12	5–11	8–15
Stellaria holostea	4–12	5–11	8–16
Average	4.86–12.00	5.71–10.57	8.29–15.57
Optimum	8.43	8.14	11.93

*values are in Celsius.

A similar analysis carried out for boreal and nemorale species of woody plants (Table. 3) has shown that nemoral species are characterized by the optimal thermal regime, which is 1.6 °C higher than the boreal ones. According to the scales of climate humidity and soil water regime, ecological optima and amplitudes of non-moral species are shifted towards aridity. In general, these types of woody plants are more adapted to changes in the forest-growing conditions resulting from global climate warming. They are better able to tolerate high summer temperatures and summer droughts, which gives them competitive advantages in the conditions of increasing global warming.

The expansion of nemoral plant species to the north is also facilitated by such a feature of their ontogenesis as a high growth rate of phytomass.

Several nemoral tree species have an advantage over boreal ones in terms of growth rate. Thus, according to the classification accepted in dendrology, such a nemoral species as *Acer platanoides* refers to very fast-growing tree species with an annual increase of two or more meters, and *Fraxinus excelsior* and *Ulmus glabra*

– to fast-growing with an average increase of at least 1 meter per year. It differs in the speed of growth and undergrowth of nemoral tree species.

Table 3. Ecological amplitudes of boreal and nemoral forest trees

Plant species	Thermal regime	Humidity	Soil water regime
	Boreal plant species		
Pinus sylvestris	7–12	7–11	8–20
Picea abies	5–10	7–10	10–18
Populus tremula	4–12	6–11	9–19
Betula pendula	4–12	6–11	9–19
Betula pubescens	3–10	7–11	10–20
Alnus incana	3–10	7–10	11–19
Alnus glutinosa	4–11	6–11	11–19
Salix pentandra	4–12	4–11	13–19
Average	4.25–11.13	6.25–10.75	10.13–19.12
Optimum	7.69	8.5	14.63
	Nemoral plant species		
Quercus robur	6–12	6–11	8–17
Tilia cordata	6–12	6–11	9–18
Acer negunda	7–15	6–11	9–15
Acer platanoides	6–11	6–10	9–17
Pyrus communis	6–13	10–15	7–15
Fraxinus excelsior	8–13	10–16	8–17
Ulmus glabra	7–11	9–14	9–17
Average	6.57–12.14	7.57–12.57	8.43–16.57
Optimum	9.36	10.07	12.50

*values are in Celsius.

The study of annual tree rings throughout the boreal zone shows that a decrease in the growth rate of the boreal group of tree species has been observed in many areas of Eurasia since the 1900s and is associated with an increase in the average annual temperature. This is observed in many areas throughout the boreal zone among a wide range of coniferous species studied. A decrease in growth rates is more often observed in warmer areas and indirectly confirms that this is a reaction to warming and aridization of the climate (Olsson, 2011; Gauthier *et al.*, 2015).

Currently, successful natural regeneration of maple, linden, elm and ash is registered in the forests of Left-Bank Ukraine (Rumiantsev *et al.*, 2016). In the future, oak, maple, elm and other broad-leaved species will replace the disappearing conifers.

Pine is a tree species with a fairly wide ecological amplitude, but even its natural renewal under the canopy of forests is best carried out in fresh forests and sub-forests (Sendonin, Bilous, 2013, and climate aridization is unfavourable for the sustainable existence of pine forests.

For the last decades, it is characteristic that poor natural renewal of spruce is recorded along the southern border of the forest zone in birch-aspen-spruce stands. The vitality of spruce undergrowth is deteriorating (Pukinskaia, 2021) and as a result, mixed forests with spruce are replaced by lime-maple forests. The cenotic optimum for small undergrowth of another boreal species *Pinus sylvestris* covers only the conditions of several phytocenoses of *Pineta (sylvestris) hylocomiosa* and *Pineta (sylvestris) franguloso (alni)-vacciniosa (myrtilli)* association group (Skliar, 2015). On the contrary, the undergrowth of the nemoral tree species *Acer platanoides* is characterized by wide habitat versatility and accumulates in large quantities in forest phytocenoses of different types (Skliar, 2012).

Nemoral species of herbaceous plants have an advantage over boreal species of herbs in terms of growth rate and accumulation of phytomass. We have evaluated and compared the absolute growth rate (AGR) and relative growth rate (RGR) in the boreal species such as *Vaccinium myrtillus* in the five associations: I – *Pinetum myrtilloso-hylocomiosum*; II – *Pinetum molinioso-myrtillo-sum*; III – *Querceto-Pinetum myrtillosum*; IV – *Betuletum molinioso-myrtillosum*; V – *Betuleto-Pinetum franguloso-myrtillosum* with corresponding indicators of the nemoral species *Aegopodium podagraria* in the three associations: I – *Quercetum coryloso-aegopodiosum*; II – *Querceto-Pinetum coryloso-aegopo-diosum;* III – *Betuleto-Pinetum coryloso-aegopodiosum* (Table 4).

Table 4. Absolute (AGR) and relative growth rate (RGR) of such boreal species as *Vaccinium myrtillus* and such nemorale species as *Aegopodium podagraria*

Association	AGR, g day^{-1}	RGR, g g^{-1} day^{-1}
	Vaccinium myrtillus	
I	0.013 ± 0.02	0.01 ± 0.003
II	0.06 ± 0.018	0.007 ± 0.002
III	0.021 ± 0.006	0.012 ± 0.005
IV	0.045 ± 0.015	0.013 ± 0.006
V	0.047 ± 0.03	0.009 ± 0.003
	Aegopodium podagraria	
I	0.027 ± 0.01	0.020 ± 0.008
II	0.070 ± 0.03	0.028 ± 0.006
III	0.039 ± 0.01	0.023 ± 0.011

It can be seen that in the boreal species such as *Vaccinium myrtillus*, under the most favourable conditions (association V), the absolute growth rate is 0.047 g day^{-1}, and the relative growth rate is at most 0.013 g day^{-1}. Whereas in such nemoral species as *Aegopodium podagraria*, these indicators in the most favourable ecological and phytocenotic environment (association II) are respectively equal to 0.070 g day^{-1} and 0.028 g g^{-1} day^{-1}, *i.e.* more than two times higher. Such difference in the conditions of climate warming gives nemoral species significant competitive advantages and enables them to displace boreal species from phytocenoses.

Phenological observations have shown that in the last two decades, nemoral plant species begin vegetation earlier and pass the first phases of the ontogenetic cycle faster than boreal species. The germination of seeds and the growth of ramets in nemoral plant species in spring is also carried out more actively and faster.

The competitive advantages of nemoral species in the conditions of earlier spring warming are also determined by the fact that, by their initial biological nature, they belong either to the group of early spring plants (*Asarum europaeum*) or to spring-summer plants (*Aegopodium podagraria*). Boreal species mostly belong to the group of summer or even summer-autumn species (*Oxalis acetosella, Paris quadrifolia*).

Phenological changes in boreal species of flowering plants caused by global warming turn out to be incompatible with the life cycles of pollinating insects, which leads to the loss of both types of organisms from forest ecosystems (Heller, Zavaleta, 2009; Patyka, Patyka, 2014).

In recent decades, in the forest communities of Polesie, there has been a tendency to regular changes in the ontogenetic spectra of both nemoral and boreal plant species (Table 5). But their nature is different. In nemoral plant species, the proportion of juvenile and immature individuals in the ontogenetic spectra increases and populations acquire the character of invasive, reflecting the process of progressive strengthening of their position in phytocenoses. In populations of boreal species, on the contrary, the ageing process accelerates – the proportion of old generative, senile and sub-senile individuals increases in them. The phytocenotic position of this group of species is weakening under the influence of global climate warming in the forests of the north of Sumy region.

Table 5. Changes in the ontogenetic spectra of plants of the grass-subshrub layer during 2000–2020

Plant species and years of observations		Ontogenetic states, %							
		j	im	v	g1	g2	g3	ss	s
Boreal	2000–2005	7	6	15	23	25	18		6
	2015–2020	4	4	14	11	26	27	3	11
Nemoral	2000–2005	1	12	14	25	21	13	11	3
	2015–2020	9	17	20	24	16	10		4

j – juvenile, im – immature, v – virginile, g1 – young generative, g2 – middle aged generative, g3 – old generative, ss – subsenile, s – senile.

Discussion

Thus, the reactions of boreal and nemoral plant species of forest phytocenoses in the north Sumy region to climate change are opposed. Depending on their genetically determined properties, the vital state of individuals changes to one degree or another, which in turn affects the passage of the plant stages of ontogenesis. Its phases may shorten or lengthen, at the stages of germination – juvenile individuals, an increase or decrease in survival is observed.

Changes in plant ontogenesis, in turn, lead to changes in the population characteristics of plant species: the number of individuals in the population, the size and configuration of the population field and the ontogenetic and vital spectra of populations change. Such trends in population processes play a key role in the dynamics of forest ecosystems (Zlobin, 2009).

The variation of the ontogenetic spectra of populations is due to the conditions in which the ontogenesis of individual individuals forming the phytopopulation takes place. Therefore, the ontogenetic spectra of populations carry important information on the course of the processes of renewal and extinction of individuals, about the rate of generational change in populations and, therefore, enable to assess and predict the dynamic processes in phytocenoses that are formed by these populations. The ontogenetic spectra of plant populations have independent significance, they almost do not correlate with the population density and the number of plants in it.

The changes that have begun in the ontogenetic processes of plant individuals give impetus to other transformations of populations of boreal and nemoral plant species. If the complex of environmental impacts for a particular boreal plant species is negative, then the population field is insularized, that is. its dismemberment into separate parts. The process completes with the loss of a plant species from the phytocenosis with the appearance of free ecological niches into which other plant species are introduced. As a result, the phytocenosis is transformed, and its syntaxonomic status changes.

At the same time, the emergence of free ecological niches strengthens the phytocenotic positions of nemoral species and opens the way for the introduction of invasive plant species into the forests of Polesie. Indeed, 126 invasive species have been registered in the Desniansk-Starogut National Nature Park and their share in the flora is 16% (Panchenko, Kutiavin, 2011; Burda *et al.*, 2015). Invasive ephemerophytes such as *Callistephus chinensis (L.) Nees, Nicotiana rustica L., Lupinus luteus L., Aronia melanocarpa (Michx.)* Elliot and xerophytes *Epilobium pseudorubescens* and *Axyris amaranthoides L.* have been identified in the flora of this park.

Climate warming is a global process that manifests itself in many ways and its manifestations have been recorded and noted in various ecosystems of the world for a long time by many researchers. Thus, under the conditions of global climate changes, changes in the floristic and syntaxonomic composition, the course of phenological phenomena, as well as the coenopopulation structure of meadow ecosystems were noted during the population-ontogenetic studies of the dominant species of floodplain meadows of the Sozh River within the Vetkiv district of the Gomel region (Daineko *et al.*, 2022).

According to the results of four-year research Danko (2022) of the cenopopulation of *Cyperus michelianus* (L.) Link., a characteristic representative of pioneer psammophyte communities formed on alluvial sands, changes in the density of individuals within the population, changes in the ontogenetic spectrum, and an increase in the density of generative individuals in drought conditions were found.

Populations of rare plant species, as a critical component of biodiversity, are primarily affected by such a global factor as climate change, which leads to their degradation and extinction. According to Klymenko (2022), who analyzed threats to the sustainable existence of populations of rare plant species in the Sumy region (Ukraine), the process of degradation and extinction occurs as follows: there is a successive decrease in the vitality of individuals and, in particular, indicators of reproduction, a decrease in the number of individuals in the population, fragmentation of the population into separate loci and, finally, its complete extinction.

Dmytrakh (2019) studied the impact of climate change on the population of herbaceous plant species in the modern conditions of the Ukrainian Carpathian highlands, noted the increase in the activity of successional demutation processes. The main reason for the changes in the structure of populations is the inability to compete in the conditions of the invasion of tree-shrub species and to adapt to the changed environmental conditions. It was noted that in some cases, dynamic trends in populations are accompanied by an increase in the number of individuals and the expansion of their borders, while in others the changes are opposite, which is associated with a decrease in the number and their fragmentation.

Specialists of the World Wildlife Fund (WWF) singled out climate change as one of the five groups of main ecological factors that cause the global impoverishment of biodiversity (Ivaniuta *et al.*, 2020). Most researchers believe that the impact of climate change on changes in biodiversity is underestimated.

In general, as a result of climate change, the species composition and population structure of plant communities is undergoing restructuring (Didukh, 2009).

Conclusion

The analysis has shown that the initial manifestation of environmental changes caused by climate warming is recorded primarily at the level of plant individuals and occurs at the pace of the first phases of ontogenesis. Forest ecosystems are characterized by two processes: change in the floral composition of plant species that form the grass-subshrub layer and change in the composition of forest-forming tree species. The first of these processes is primary, the second is completely conditioned by it. As a result of these processes, against the background of the loss of competitive advantages, a trend of general nemoralization of forest phytocenoses of Polesie with changes in their floral composition is formed in the group of boreal species.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publications of this paper.

Author contributions

IK – study conception and design, drafting of the manuscript;
SB – performed the literature data analysis and discussion of the results;
AZ – analysis and interpretation of data and is the corresponding author;
IP – author of the idea, critical revision and approval of the final manuscript, guided the research;
OA – acquisition of data, drafting of the manuscript;
HK – performed the literature data analysis, critical revision and approval of the final manuscript, guided the research.
All authors read and approved the final manuscript.

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LÜHIARTIKKEL: EESTI MULDKATTE HUUMUSSEISUND JA KESKKONNAHOIDLIK MAJANDAMINE

SHORT COMMUNICATION: HUMUS STATUS OF ESTONIAN SOIL COVER AND ITS ENVIRONMENT PROTECTIVE MANAGEMENT

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ABSTRACT. In the framework of the European mission "Soil Deal for Europe" ambitious tasks have been load to the whole European Union and forming its states in the field of carbon management. Departing from pedo-ecological conditions of Estonia, the pros and cons of the European Union's plans about carbon farming are treated. By the principles of pedocentric approach the soil humus status and carbon farming technologies are soil type specifics and should be utilized in the most detailed as possible soil taxonomic unit, for which by Estonian soil classification are soil species and soil varieties. Thanks to gathering during large scale (1:10,000) soil mapping in earlier time data and proceeding later field experiments in Estonia there are relatively good databases on soil humus status for all most dominated soil species and/or varieties by different land use conditions (arable, grass- and forest lands). The main available quantitative characteristics on soil humus status (expressed via carbon) are concentration (g C kg^{-1}) and superficial densities (Mg C ha^{-1}) of organic carbon given by soil species and their genetic horizons in above-named third land use conditions. Besides that, these data have been calculated (1) separately for humus cover (humipedons) and subsoil layers and (2) as well in relation to layers with certain thickness (30, 50 and 100 cm). As a qualitative index of humus status, the humus cover types (humus forms) have been elaborated separately for arable soils and for being in natural state soils. As the carbon concentration in arable soils depends mainly on contents of clay particles, watering conditions and calcareousness, was possible to elaborate for all dominating arable soils three humus (and carbon) concentration levels: scarce, optimal and excess, which are needed for choice of suitable to soil conditions agro technology. There is a declared serious shortage of knowledge on composition of soil organisms' societies by soil types and on syn- and autecology of their functioning.

Muldkatte roll süsinikumajanduses

Seoses Euroopa Liidu (EL) ambitsioonika kliimapoliitikaga on liikmesriikidele pandud suured lootused maastike süsinikuringe reguleerimise osas. Otsitakse otstarbekaid lahendusi eesmärgi – suurendada süsinikuvarusid muldkattes – täitmiseks. Atmosfääri CO_2 süsiniku sidumine lagunemisele vastupidava huumuse koosseisus muldkattesse on oluline samm kliimaneutraalsuse saavutamisel. Lisaks on mulla orgaaniline süsinik (OS) mullatervise indikaator.

Euroopa üldistusena on leitud, et haritavate mineraalmuldade OS koguvaru väheneb aasta keskmisena 0,1–0,4% mulla OS kontsentratsiooni pöördumatu vähenemine tõttu. Orgaanilise süsiniku kadu muldkattest loodetakse leevendada või vältida muldade potentsiaalsest OS sidumis-võimest lähtuva taastava põllumajanduse põhimõtete juurutamisega. Üheks teejuhiks seoses ökosüsteemide muldkatete OS kadudega on missiooni „Euroopa mullakokkuleppe“ raames arendatav süsiniku majanduse programm (EC, 2021a, 2021b). "Euroopa mullakokkuleppe" eesmärk on saavutada mulla hea seisund kooskõlas rohelise kokkuleppega kliima, elurikkuse, nullsaaste ja kestlike toidusüsteemide valdkonnas. Euroopa Komisjoni (EK) järgi on see roheline ärimudel, mis peaks innustama maavaldajaid rakendama muldkatte omadusi parandavaid tehnoloogiaid suurendades OS sidumist biomassi, mortmassi ja mulda ning vähendades CO_2 emissiooni atmosfääri. Peale haritavate maade süsinikuringe korrastamise juhitakse tähelepanu suurtele OS varude kaotustele kuivendatud turbamuldadest ja metsamuldade suuremale süsinikukoguse akumuleerimisvõimele võrreldes põllumuldadega.

Euroopa Komisjoni strateegia järgi on kestlike süsinikuringete reguleerimise võteteks metsastamine ja taasmetsastamine; agrometsandus ja segapõllumajandus; püüde- ja vahekultuuride kasvatamine; mulla OS sisalduse suurendamine; turbaalade ja märgalade taastamine; põllumaa sihipärane muutmine kesaks ning tootmisest kõrvale jäetud maa muutmine püsirohumaaks (EK, 2021a). Kõik mistahes pedo-ökoloogilistele tingimustele sobivad muldade majandamise võtted, peaks lähtuma muldade degradatsiooni vältivatest mullakaitse põhimõtetest.

Euroopa Liidu plaanide kriitilistes analüüsides avaldatakse kahtlusi süsinikumajanduse suhtes, kuna mulla OS sidumine on sageli pöörduv (mittekestev) nähtus (European Commission, Directorate-General …, 2021). Kriitikute sõnul on orgaanilise päritoluga süsiniku stabiilsesse (mullas pikka aega säilivasse) olekusse muutmine raskesti juhitav ja selle mõõtmine keerukas (Appunn, 2022). Seega on komplitseeritud nii sellele protsessile hinnangu andmine kui ka rohepesu võimaluste vältimine. Muldkatte OS sisalduse määramise teeb keerukaks selle suur varieerumine ajas ja ruumis ning võimalikud vead mullaproovide võtmisel (FAO, 2019). Selgusetu on ka erinevate määramismeetodite sobivus muldkatte OS sisendite ja väljundite sertifitseerimisel. Euroopa Komisjoni arvates saab muutumisi adekvaatselt hinnata alles 3–5 aasta möödudes. Vigade ja pettuste vältimine OS muldkattesse sidumise kohta vajab asjakohast seiret, aruandlust ja muutuste tõestamist. Kriitikute arvates tuleks süsiniku põllumajanduse sertifikaatide turu loomise asemel kasutada rohkem alternatiivseid põllumajanduse kliimajälge vähendavaid strateegiaid (liigse väetamise vältimine, veetaseme tõstmine turbamuldades, kariloomade arvukuse optimeerimine jt.). Sobivaks peetakse ka kultuuride mitmekesistamist, liblikõieliste kasvatamist, agro-metsanduse arendamist ja püsirohumaade kasutuse laiendamist.

Paraku tuleb tõdeda, et nii EK kui kriitikute väljapakutud võtted ei ole universaalselt kasutatavad erinevate regioonide muldkatete kohta, kuna need soovitused on tehtud erinevate (sageli vaid domineerivate) tingimuste tasemelt. Tegelikult sõltub EK kohustuste rakendamine süsinikuringe regulatsiooni osas ikkagi konkreetse koha detailsetest pedo-ökoloogilistest tingimustest (EK, 2021b; Rodrigues jt, 2021). Seega on otstarbekas, et liikmesriigid korrigeeriks probleemi lahendamise teid lähtuvalt kohalikest oludest. Keskkonnaseisundile sobivat süsinikuringe regulatsiooni tuleks teha võimalikult detailsel mulla elementaarareaali või taksoni tasemel ning toetudes kohalikele mullastiku-uurimise andmebaasidele, ühiskonna vajadustele ja regioonis omandatud praktilistele kogemustele. Taoline muldkeskne *(pedocentric)* käsitlus on ka kohalike loodusressursside otstarbeka kasutamise ja kaitse alus.

Alles väljatöötamise ja praktikas katsetamise järgus on praegu ka Euroopa mullakokkulepet ja süsinikku siduvat majandamist toetavad tegevused nagu süsinikku siduvate majandamistavade tutvustamine, ühiste hindamisviiside väljatöötamine, süsiniku eemaldamise sertifitseerimine ning rahastamine põhimõtete ("saastaja maksab") arendamine. On tervitatav, et plaanides on kavandatud suur hulk tegevusi ühiskonna teadlikkuse tõstmiseks süsinikumajanduse alal millisteks on korrapärane teabevahetus, konverentsid, maavaldajate teadmiste suurendamine sihipäraste nõustamis-, andme- ja seireteenuste kaudu, laborite võrgustiku ja kliimateadliku põllumajanduse näidisvõrgustiku rajamine jms. Juriidilisest aspektist on kavandatud vastavasisulise ekspertrühma tööle rakendamine, süsiniku eemaldamise sertifitseerimist käsitleva EL-i õigusraamistiku väljatöötamine ning EL-i standardite kasutusele võtmine kasvuhoonegaaside heite ja süsiniku eemaldamise seireks, aruandluseks ja tõendamiseks.

Nähtub, et EL-i plaanid maastike süsinikuringe suunamise osas on ambitsioonikad ja ehk isegi ülemäära optimistlikud. Meie arvates ei saa väljapakutut võtta kui revolutsioonilist muudatust mullaressursside majandamises. Pigem oleks hakatuseks vaja teha regioonipõhine tagasivaade ja siiamaani tehtu kriitiline analüüs süsinikuga seotud küsimustes, et selgitada mitte ainult kitsaskohad vaid tuua esile ka positiivsed suundumused. Uued arendused peaksid lähtuma senini edukalt tehtu raamidesse, võttes arvesse olemasolevad süsinikuga seotud andmebaasid. Ei saa õigeks pidada fokuseerimist vaid süsinikule, kuna ei tohiks tähelepanuta jätta toidu tootmist, kogukonna eluolulist keskkonda ja rahalist tasuvust, kuna ökoloogiliselt õige muldade majandamisega kaasneb ka keskkonnale soodne süsinikuseisund.

Muldade huumusseisundi hindamine muldkattekaudse orgaanilise aine voo alusel

Muldkattekaudne süsiniku ringe väljendub huumusseisundis, mis hõlmab muldkatet läbiva orgaanilise aine (OA) voo kõigi põhiliste lülide seisundi ja talitlemise. Orgaanilise aine (ja selles sisalduva OS) voog saab alguse uue OA sisendist muldkattesse, jätkub selle muundumise ja lagunemisega mullaelustiku toimel ning lõpeb OA mineraliseerumise või stabiilsete huumuse moodustumisega. Iga OA voo lüli talitlus on sellele järgnevate talitluste eeldus. Orgaanilise aine voog ei ole valdavalt lineaarne, vaid enamasti mitmekülgselt hargnev ainevoogude võrgustik. Nii agro- kui metsaökosüsteemides võib OA voog olla oluliselt mõjutatud inimese majanduslikust tegevusest ehk OA voogusid on võimalik inimtegevuse kaudu reguleerida, juhtides neid meile sobivas suunas.

Muldkatet läbivas OA voos eristub kaks teineteisest talitlemise poolest oluliselt erinevat faasi. Esimene faas realiseerub ökoloogiliste või bioloogiliste protsesside läbi, teine aga füüsikalis-keemilist ja mehhaaniliste mõjutuste kaudu. Orgaanilise aine voo esimene ehk bioloogiline faas on eluliselt tähtis auto- ja heterotroofse produktiivsuse aspektist, kuna sellest sõltub nii ökosüsteemi füto-(taimne-)produktiivsus, kui ka OA lagunemise dünaamika muldkattes. Ainevoo teise faasi mulla OA, mis koosneb mullaelustiku ekskrementidest, lagunemisele vastupidavatest taimse ja loomse varise osistest ja stabiilsest huumusest, on taimede ja mullaelustiku talitlemiseks sobivate õhu-, vee-, hapendustaandus- ja soojusrežiimide kujundaja. Ainevoo teisest faasist sõltub mulla neelamismahutavus, puhverdamise võime ja ökosüsteemi talitlemiseks sobiva mullareaktsiooni kujunemine. Mõlemas faasis toimuvat OA voo kulgu on põhimõtteliselt võimalik reguleerida otstarbekohase maakasutustehnoloogia abil. Mulla OA voos võib esineda ka tagasipöördeid. Näiteks võib teatud osa stabiilsest OA-st uuesti lülituda bioloogilistesse protsessidesse.

Omandatud kogemused Eesti muldkatete huumusseisundi majandamise kohta

Eesti andmebaasid muldkatete huumusseisundi kohta näitavad, et muldade OA majandamist tuleks teha muldkeskselt, lähtudes võimalikult detailse taksoni (mullaliigi ja/või mullaerimi) tasemelt. Seoses mullaomaduste olulise erinevusega vajavad eraldi käsitlust haritavad (põllu-), metsa- ja rohumaamullad. Ühte huumusseisundi uurimise valimisse ei ole õige segamini ühendada kontrastsete omadustega muldasid ning ammugi mitte segamini turvas- ja mineraalseid muldi. Küll aga on praktika seisukohalt otstarbekas käsitleda põllu-, rohumaa- ja metsamuldade huumusseisundit geneetiliselt sarnaste mullagruppide lõikes, kuna grupis olevad mullad võivad omadustelt ja talitlemiselt olla üksnes vähesel määral erinevad.

Muldkatte OA sisalduse kontsentratsioonid ja varud võivad olla kalkuleeritud, kas kuiva OA-na või OA-s sisalduva OS või energia alusel. Käesolevas töös käsitletakse huumusseisundit OS kaudu, kuna erinevate mullahorisontide (metsakõdu, huumushorisont, turvas) OS kontsentratsioonid on suurel määral erinevad. Mullaliigi huumusseisundi kvantitatiivseteks põhinäitajateks on huumuskatte erinevate horisontide OS kontsentratsioonid kuiva mullapeenese (Ø <1 mm) kohta (g OS kg^{-1}) ja OS varud pindalaühiku kohta (Mg OS ha^{-1}), antuna teatud kindla mullahorisondi või erinevate tüsedustega mullakihtide lõikes. Orgaanilise süsiniku varud on arvutatud OS kontsentratsiooni ja mahukaalu alusel, millest on lahutatud muldkatte koresega täidetud ruumala (%-des). Täiendavateks huumusseisundit kajastavateks näitajateks on üldlämmastiku (N) hulgad (kontsentratsioon ja varu) ning C:N suhe. Orgaanilise aine voo dünaamikat iseloomustab (1) sisend muldkattesse aastavarise (uue OA) näol (Mg OS ha^{-1} a^{-1}), (2) varise lagunemise/humifitseerumise määr (väljendatuna kas koefitsiendina või graafiliselt) ning (3) väljund CO_2-na või vees lahustunud OA-na (Mg OC ha^{-1} a^{-1}). Erosiooniohtlikel aladel on arvesse võetud ka ümberpaigutunud ja/või algkohalt eemaldatud OS kogused.

Huumusseisundi mõju produktiivsusele näitab ökosüsteemi fütomassi pindtihedus (Mg OS ha^{-1}), antuna võrreldavuse huvides (1) agroökosüsteemides teatud kindla kultuuri (oder) suhtes, (2) looduslikes rohumaa ökosüsteemides mullaomadustele kohandunud taimekooslustes ja (3) eelvalminud või küpsetes metsades, takseerimisnäitajate poolest võimalikult sarnastes puistutes. Agro- ja rohumaaökosüsteemide aastafütoproduktiivsus (AFP) ehk primaarse (taimse) biomassi aastatoodang) Mg OS ha^{-1} a^{-1}) on arvutatud fütomassi pindtiheduse alusel, liites sellele aasta jooksu lagunenud/varisenud fütomassi koguse ning lahutades ületalve säiliva osa, mis puudub üheaastastel kultuuridel. Metsade AFP hindamisel on metsaökosüsteemi kogu AFP-st eristatud pikaks ajaks (60–90 aastaks) puu tüvedesse akumuleerunud fütomass, selle tüvepuidu koguse kasvatamiseks vajatavad võrastiku oksad (keskmise elueaga 10–15 aastat) ning ühe aasta jooksul juurde kasvanud okkad okaspuudel ja lehed lehtpuudel. Samas ei ole võimalik metsa kasvatada ilma juurestikuta, alusmetsata ja alustaimestikuta, mis kõik kaasnevad nii puutüvede fütomassile kui ka selle AFP-le kasvukoha mulla viljakusest (mulla metsakasvatuslikest omadustest) sõltuvates kogustes.

Eesti muldkatte huumusseisund sõltuvalt maakasutuse viisist ja mulla liigist

Eesti muldade klassifikatsioonis on eristatud kokku 67 normaalselt ja 42 anormaalselt arenenud mulla liiki. Nendest sobib vähemalt rahuldaval tasemel põllumaana kasutamiseks vastavalt 24 ja 11 mullaliiki. Eesti piirkondades, kus põlluharimiseks sobivaid muldasid ei ole piisavalt, on kasutusele võetud kuivendatud märjad mullad. Taoliselt oleks võimalik kasutada *ca* 13 mineraal- ja 4 turvasmulla liiki. Aastakümneid kestnud mullaomadusi arvestavas maakasutuses on üldreeglina haritavateks põllumaadeks valitud piirkonna kõrgema viljakusega valdavalt parasniisked mineraalmullad.

Eesti parimateks põllumuldadeks ehk nn ideaalmuldadeks on teralis-tompja struktuuriga neutraalsed või nõrgalt happelised tüseda huumuskattega (28–35 cm) bioloogiliselt aktiivsed huumusrikkad kerge ja keskmise liivsavi lõimisega mullad, milliste alusmuld on ligikaudu meetri ulatuses hea vee ja õhu läbilaskvuse ning mahutavusega vähese koresesisaldusega karbonaatsed liivsavid. Geneetiliselt on taolisteks muldadeks normaalse arenguga leostunud ja leetjad mullad. Praktiliselt samasuguste omadustega on ka nimetatud mullaliikide kuivendatud gleistunud (ehk niisked) variandid. Haritava maana kasutamiseks sobivad võrdlemisi hästi ka väheste puuetega Põhja-Eesti rähksed (puudeks on koreserikkus) ja Lõuna-Eesti kahkjad (puudeks on ülagleistumine ja/või madal pH) mullad. Samas ei ole loetletud puuded ja ka ajutine liigniiskus (mida näitab gleistumine) üldsegi negatiivse mõjuga metsakasvatuse puhul. Näiteks on kahkjad mullad Eesti kõige produktiivsemad metsamullad.

Eesti eri paikade parimad põllumullad on mullatekketingimustest sõltuvalt vähemal või suuremal määral erinevad. Eesti mullastiku uurimise tulemusena eristatud 116 agro-mikrorajooni mullastikud erinevad üksteisest mullaliikide ja -erimite koosseisu ehk mullakoosluste, piirkonna viljakamate mullaerimite ning huumusseisundi poolest (EPP 1974). Mullaliikide(-erimite) lõikes saab eristada suurema või vähema mõjuga nii põllupidamist kui ka metsakasvatust mõjutavaid puudeid, mis pärsivad ühtlasi ka süsinikuringeid. Enamlevinud puueteks haritavatel maadel on tugevasti koreseline või kerge lõimis, ebasobiv veerežiim (liigniiskus ja põuakartlikkus), vähene huumuse sisaldus (kontsentratsioon ja varu), mullaerimite tugev kontrastsus ja erosiooniohtlikkus. Metsakasvatust loetletud puuded eriti ei takista, kuigi võivad vähendada produktiivsust. Ratsionaalse muldkeskse maakasutuse võtmeks on mullaomadustest lähtuv maa-ala kasutus, mille puhul on arvestatud nii sobivust kultuuridele ja puuliikidele, kui ka viimaste nõudlust kasvutingimuste suhtes. Pedoökoloogiliselt otstarbekohane maakasutus tagab ka parima muldade kaitse.

Ökosüsteemide OS ringet muldkatte osas iseloomustab tema sisendite ja väljundite vahekord. Tasakaalustunud ringega looduslikes ökosüsteemides on need kaks suunda ligikaudu võrdsed või vaid vähesel määral nende kahe keskmisest erinevad. Mõnel aastal võib olla OS sisend suurem, teinekord aga väljund suurem, kuid paljuaastate keskmisena on nad ikkagi ligikaudu võrdsed. Samas võivad ökosüsteemide fütomassi pindtihedused (Mg OS ha^{-1}) OS tasakaalustunud sisendi/väljundi (1:1 suhte) korral olla suurtes piirides erinevad. Tasakaalustunud aineringega ökosüsteemides kaasneb suurema aastasisendiga tavaliselt ka suurem väljund. Tasakaalustumatus sisendi/väljundi vahekorras esineb, ühelt poolt, muldkatte talitluse stagnatsiooni korral, kus sisend on suurem väljundist (sisend>väljund). Sellisteks muldadeks on mitte ainult rabamullad, vaid ka happelised turvastunud (turvastunud moor tüüpi huumuskattega) mullad. Seoses intensiivistunud mulla OA lagunemisega on suurem väljundi osakaal (sisend<väljund) omane kuivendatud glei-, turvastunud ja turvasmuldadele.

Looduslikes ökosüsteemides toimib OS sisendvoog praktiliselt ühe kanali kaudu, milleks on atmosfääri CO_2 arvel moodustunud fütomassi maapealsest ja -alusest varisest moodustunud surnud OA (mortmass). Vähesel määral võib mullaelustiku toiteahelatesse lisanduda OA-t ka juureeritiste näol. OS ringe väljund muldkattest võib olla, ühelt poolt, ökosüsteemi sisene, milleks on suhtelisel pikaaegne OS talletamine puurinde fütomassi ja inertse huumusena muldkattesse. Teiselt poolt on tegemist ökosüsteemist välja suunatud OS voogudega, milleks on heterotroofne hingamine varise lagunemise protsessis või lagunemise vaheproduktide leostumine muldkattest. Väljundiks on ka ökosüsteemi taimkatte autotroofne hingamine, eemaldamine kas põllukultuuride saagiga või raietega metsades ja huumuse kadu erosiooni toimel.

Agro-ökosüsteemides võib AFP-st pärinevale varisele ja koristusjäätmetele kui sisenditele lisanduda ka erineva päritoluga orgaanilised väetised. Süsinikuringe põllult eemaldatavateks komponentideks (väljunditeks) võivad teraviljade kasvatamisel olla nii terad kui põhk, kartuli kasvatamisel aga mugulad. Osa OS-st võib talletuda ka muldkattesse, kuid enamjaolt on see protsess tasakaalustunud ökosüsteemides siiski vaid pöörduv nähtus.

Tagasivaade Eesti põllumajandusliku maa muldkatte seisundi kohta

Kahel viimasel aastakümnendil on Eesti põllumajanduslik tegevus järjest enam kaasajastunud, muutunud tehnoloogiliselt professionaalsemaks ja olnud majanduslikult edukas. Seda näitab põllukultuuride ja rohumaade saagikuse kasv, loomakasvatuse kõrged produktiivsuse näitajad, kaasaegse masinapargi olemasolu ning maakasutajate asjakohane teadlikkus. Tänu interneti kaudu kergesti kättesaadavale 1:10000 digitaliseeritud mullastiku kaardile on järjepanu jõutud lähemale optimaalsele muldkesksele maakasutusele (Maa-uuringud, 2009). Maakasutuse korraldamisel on arvestatud nii mullaliikide sobivust erinevatele kultuuridele, kui ka vastupidi, igale kultuurile on leitud võimalikult parim mullastiku sobivust arvestav kasvukoht. Järjest enam on põllumeeste seas täppismaaviljeluse edendajaid.

Põhjust kurtmiseks pole ka maastike hea keskkonnaseisundi hoidmise osas (Lahmar jt, 2006). Erirežiime rakendatakse nitraaditundlikel ja erosiooniohtlikel aladel, turbamuldade kasutus haritava maana on viidud miinimumi, ammendatud karjääride ja rajatistega piirnevatele aladele on rajatud tehismuldasid, endised madala viljakusega põllumullad on suures osas metsastatud ning põllumaade harimise kvaliteet ja rohumaade käitlemise tase on kiitust väärivad. Möödapääsmatult vajalik väetiste ja taimekaitsevahendite kasutamine on viidud kooskõlla kultuuride vajadusega. Väetiste ja kemikaalide hektarikoormused on Euroopa keskmistest tunduvalt madalamad, mida tõestavad ka nende üleriigiliselt tarnitud kogused. Kirjeldatud Eesti põllumajanduse peavoolu rikastavad ühelt poolt rikkalikud mahemaaviljeluse kogemused teiselt poolt aga võistlused suurte saakide nimel.

Mullaomaduste stabiilsuse suhtes eristub kolm muutumise astet (1) mullaliigi(-erimi) iseloomulike tunnuste kompleks on kestlikult püsiv omadus, (2) mullaliigi huumusseisundit iseloomustavad näitajad võivad muutuda perioodiliselt – mõne kuni 7–8 aasta jooksul ja (3) huumuskatte taimetoiteelementide ja humifitseerumata OA varud muutuvad pidevalt ehk igal aastal. Varasemat põllumuldade reepertaset kajastavad mudelprofiilid koos mullaliigile (erimile) iseloomulike tunnuste andmetega, millistest igaüks on koostatud mõnekümne üksikprofiili alusel. Eesti põllumuldade kohta on olemas enamlevinud püsi- ja perioodiliselt muutuvaid omadusi kajastavaid mudelprofiile kokku 50. Metsamuldade kohta on neid 27.

Sõltuvalt mulla lõimisest, veerežiimist ja karbonaatsusest on huumuskatte OS kontsentratsioonid mullaliikide kaupa erinevad (Kõlli, 1987). Lõimiste reas liivsaviliiv-liivsavi-savi ehk l-sl-ls-s suureneb OS sisaldus parasniisketes muldades keskmiselt 2,3–3,5 g kg^{-1} võrra. Niiskete muldade OS sisalduse suurenemised sama lõimiste rea kohta on 2,9–5,2 g kg^{-1}. Orgaanilise süsiniku sisaldus niiskete muldade huumuskatetes on võrreldes parasniisketega 1,9–4,1 g kg^{-1} võrra suurem. Huumuskatte karbonaatsusest ehk mulla reaktsioonist tingitud OS sisaldused parasniisketes muldades erinevad alates kahkjatest ja leetunud muldadest kuni rähksete muldadeni 5,8–6,4 g kg^{-1} võrra. Kuna kõik mulla OS sisaldust mõjutavat faktorit (lõimis, veerežiim, karbonaatsus) on mullaliikide kaupa erinevad, saab huumusseisundi hinnangu ühele või teisele mullale anda mullaliigi alusel. Niiskete ja märgade muldade suurem OS sisaldus on tingitud suuremast humifitseerumata OA sisaldusest, millise lagunemine intensiivistub maade kuivendamisel. Samas viitab humifitseerumata OA suurenenud sisaldus OS ringe peetusele ehk stagnatsioonile.

Mulla OS varu (Mg ha^{-1}) kui olulise mulla huumusseisundit iseloomustava kvantitatiivse näitaja arvutamise aluseks on mullaliikide ja horisontide lõikes erinev OS kontsentratsioon. Orgaanilise süsiniku varu oleneb vastava kihi tüsedusest, mahukaalust ehk lasuvustihedusest ja korese ruumalast. Nii horisontide tüsedused, kui mahukaalud mõõdetakse reeglina tasakaalustunud olekus. Eesti muldasid iseloomustavates andmebaasides on huumusseisundi näitajad (OS kontsentratsioon ja varu) antud valdavalt mulla geneetiliste horisontide (sh huumuskatete) lõikes. Samas on need näitajad arvutatud ka kindla tüsedusega (30, 50 ja 100 cm) mullakihtide kohta, et saada andmeid võrdlemaks teiste Euroopa regiooni muldade huumusseisunditega. Huumuskatte OS varud mullaliikide lõikes erinevad üksteisest sarnaselt nende OS kontsentratsioonidega, peegeldades seega erinevate muldade OS mahutusvõimet. Kuna varude erinevused on tingitud valdavalt mullakihi tüsedustest, on huumuskatte OS varu üheks suurendamise võtteks selle tüseduse kasvatamine mullaharimise ja OA sisendi suurendamise kaudu.

Muldade OS sisaldusele (kontsentratsioon ja varud) pädeva hinnangu andmiseks on kvantiteedi kõrval vaja teada ka selle pedo-ökoloogilist kvaliteeti, mida näitab erineva detailsusega määratud mulla OA (ehk huumuse) fraktsiooniline koostis. Heaks integreeritud huumuskatte kvaliteedi näitajaks, mis võtab arvesse ka huumuse fraktsioonilise koostise, on huumuskatte tüüp (ehk huumusvorm), milliseid on Eesti põllumuldade huumuskatete klassifikatsioonis kümme tüüpi mineraal- ja kolm turvasmuldade kohta.

Eespool toodut arvestades, ei ole Eesti suhtes õigustatud traagilise pildi loomine muldade halvast (ebatervest) seisundist, mida nüüd laialt levinud arvamusena kutsutakse taastama heasse seisu (*sic!*). Tegelikult on aastakümneid kestnud töö tulemusel paranenud põllumuldade huumusseisund, füüsikalis-keemilised omadused ja eriti põlluharimise kvaliteet. Väetamine on reeglina orienteeritud aasta jooksul kulutatud taime toiteelementide taastamisele, kasutades vajaduse korral pealtväetamist ja perioodilist lupjamist hoidmaks huumuskatte happesuse kultuuridele sobivas seisundis. Juurutatud on külvikorrad liblikõieliste rikka põldheinte seguga ning vahe- ja järel-kultuuride kasvatamine. Kasutatakse minimeeritud harimist selleks sobivatel muldadel ja otsekülve kõrrepõldu. Kuna paljudes Eesti regioonides ei jätku (või siis mõnedes regioonides on vaid vähesel määral) põllumajanduslikuks tootmiseks parasniiskeid muldasid, on piirkondliku põllumajanduse normaalseks toimimiseks olnud hädavajalik niiskete (gleistunud) ja märgade (glei- ja turvastunud) muldade kuivendamine. Seega on piirkonniti õigustatud nii kaasaegsete kuivendussüsteemide rajamine kui ka amortiseerunud süsteemide remont.

Euroopa kokkuleppeid arvestav edaspidine muldade majandamine

Euroopa Komisjoni poolt päevakorda võetud muldade hea seisundi tagamine on aga igati tervitatav, sest see on mitte ainult põllumajandusliku tootmise, vaid ka ümbritseva keskkonna hea seisundi tagamise alus (EU, 2022). Euroopa Komisjoni tegevussuunised muldade kohta (antuna Eesti suhtes prioriteetsuse järjekorras) on jägmised: senisest mahukam stabiilse OS konserveerimine muldkattesse; muldkatte saastumise vältimine või vähendamine ning saastunud muldade tervendamine; muldade struktuursuse parandamine ja bioloogilise mitmekesisuse suurendamine; huumuskatte erosiooni vältimine; viljaka mulla rajatiste alla võtmise vähendamine ning rajatiste ja kaevanduste alt vabanenud alade rekultiveerimine; põllumajandusmaa kasvuhoonegaside emissiooni osakaalu vähendamine. Õigustatult on peetud vajalikuks kasvatada ühiskonna teadlikkust muldade ülesehituse, omaduste ja talitlemise alal. Euroopa ulatuses tõsiseks probleemiks olevat maade kõrbestumist ja ka sooldumist Eesti oludes praktiliselt ei esine.

Mistahes mullaliigi OS kontsentratsiooni suurendamise võimaluste hindamisel tuleks lähtuda sellele mullaliigile omasest optimaalsest tasemest. Juhul kui OS sisaldus on alla liigile omase OS optimaalse kontsentratsiooni vahemikku, on kõrgema OS sisalduse saavutamine vähe kulunõudev ja reaalne. Kui aga olemasolev tase on optimaalse taseme ülemise piirini ulatuv või sellest isegi kõrgem on edaspidine OS kontsentratsiooni suurendamine komplitseeritud ja kulukas seoses mulla OS mahutusvõime täitumisega. Eestis on optimaalsed OS sisalduse alumised ja ülemised tasemed kalkuleeritud (kindlaks tehtud) 36 põllumulla erimi kohta.

Lähtudes Eesti pedo-ökoloogilistest tingimustest nähtub, et EK suuniste täitmise otstarbel oleks vaja selgitada ja analüüsida muldade huumusseisundiga seotud probleeme. Eesti põllumajanduslikult kasutatava muldkatte oleva huumusseisundi ehk lähtetaseme selgitamise aluseks on digitaalne mullastiku kaart mõõdus 1:10000, mis võimaldab sedastada mistahes Eesti regiooni mullastiku koosseisu mullaliikide ja/või -erimite tasemel (Maa-uuringud, 2009). Aastakümnete kestel Eestis tehtud muldade uurimised on tõestanud teatud muutuste esinemist muldade huumusseisundis, sõltuvalt kasutatud agro-tehnoloogiast, kuid samas mulla püsiomaduste (lõimis, profiilide ülesehitus jms) püsimist stabiilsetena (EPP, 1978, 1983, 1985a, 1985b). Seega saab väita, et mulla liigid (ja ka erimid) on valdavalt samad alates mullastiku suures mõõtkavas kaardistamise aegadest. Vähese pindalaga muutuste erandid on seotud (1) kuivendamisega (turvastunud ja gleimullad muutuvad sarnasemaks gleistunud muldadega), (2) erosiooniga (suurenenud on erosiooni aste) ja (3) leedemuldade ülesharimisega (kuna nende asemele kujunevad leetunud mullad).

Muldade OA humifitseerumata ja stabiilseks muutunud osiste vahekord muutub seaduspäraselt alates parasniisketest (värsketest) muldadest turvasmuldade suunas, kuna selles suunas väheneb stabiilse huumuse osakaal ning suureneb humifitseerumata fraktsiooni osakaal. Põhiliselt on see tingitud intensiivse elutegevuse lakkamisest vee konserveeriva mõju ja hapniku juurde tuleku halvenemise tõttu mulla veerežiimide reas – parasniisked ehk värsked -> niisked ehk gleistunud -> märjad ehk glei- -> turvasmullad. Viimastes omakorda väheneb huumusainete osakaal alates hästilagunenud turvastest halvasti lagunenud turvasteni. Niiskete ja märgade muldade kuivendamisel so. Õhustuse ja happesuse reguleerimise korral intensiivistub neil muldadel mullaelustiku OA-t lagundav tegevus koos heterotroofse hingamise ja CO_2 emissiooni intensiivistumisega.

Kahetsusväärne, et mulla OS rolli hindamisel on pööratud liialt vähe tähelepanu mulda läbiva OA voo bioloogilisi protsesse käivitavale etapile. Selle etapi OA voo kulgemisest sõltub taimkatte järkjärguline varustamine toiteelementidega, mis vabanevad mulda sattunud värskest varisest mullaelustiku talitlemise toimel. Seega enne mulla stabiilse(inertse) huumuse moodustumist, mõjutab mulla humifitseerumata OA nii saagi kujunemist (produktiivsust), kui ka mullaelustiku talitlemist ning väärib senisest suuremat tähelepanu. Võrratult suurema tähelepanu on pälvinud bioloogilisest töötlusest järele jäänud mulla OA ehk stabiilne huumus, kuna sellest sõltub kestva säilivusega süsiniku akumulatsioon mulda. Loomulikult on ka inertsel huumusel oluline roll taimede ja mullaelustiku eluruumi moodustumisel, kuid ta ei ole otseseks energiaallikaks mullaelustikule ehk ei ole mullaelustiku poolt söödav. Küll aga on huumus tänu suurele neelamismahutavusele justkui taime toiteelemente akumuleeriv sahver. Mullaelustiku liigirikkus sõltub ennekõike sellest osast mulla orgaanilisest ainest, mis on elustikule söödav ehk pole veel muutunud stabiilseks huumuseks. Seega sõltub mullaelustiku arvukus neile kättesaadava toidu olemasolust.

Tuleb tõdeda, et osa soovitatud muldkatte süsinikumajanduse reguleerimise võtetest ei ole sobivad kasutamiseks Eesti tingimustes erinevatel tõestust leidnud põhjustel. Ennekõike tuleks nimetada põllumaa kesaks või püsirohumaaks muutmise soovitust, mis vähendab küll süsihappegaasi emissiooni, kuid viib alla (mustkesa puhul nulli) ka selle sidumise ökosüsteemi. Eesti kui metsarikka maa tingimustes ei oleks ehk õige rakendada agro-metsandust, kus põllukultuuride ja loomakasvatuse süsteemidesse on sissevõetud veel ka puittaimede kasvatamine.

Kokkuvõtteks

Euroopa Innovatsiooninõukogu toetab murranguliste tehnoloogialahenduste ja pöördeliste uuendustega seotud teadusuuringuid, nagu kestliku põllumajanduse laiendamine, kliimamuutustele vastupanuvõime suurendamine, lämmastiku- ja metaaniheidete vähendamine ning süsinikuvaru suurendamine mullas. Süsinikku siduva majandamise juurutamise aluseks on digiandmetehnoloogia kasutamine selleks, et saada täpseid hinnanguid süsinikuheite ja süsinikku siduva majandamise kohta. Kestlike süsinikuringete saavutamiseks pakutakse maavaldajatele heite vähendamise ja süsiniku atmosfäärist eemaldamise suurendamise eest (kas ikka väärilist?) tasu usaldusväärse ärimudeli alusel, mis põhineb süsiniku eemaldamise sertifitseerimise andmetele. Loodetakse, et koos süsinikku siduvate muldade majandamise võtetega suureneb ökosüsteemide elurikkus ning ökosüsteemi poolt pakutavad hüved tasakaalustuvad muldade ülesehituse, omaduste ja talitlemise iseärasustega.

Süsiniku atmosfäärist eemaldamine ja olemasolevate süsinikuvarude kaitsevõtted varieeruvad sõltuvalt bioklimaatilistest ja lokaalsetest (topograafia, mullaliikide kooslus, maakasutuse tavad) tingimustest. Eestis on valdavate mullaliikide kohta olemas võrdlemisi detailne andmestik leviku, morfoloogia, füüsikalis-keemiliste omaduste, kasutussobivuse ja kaitse osas erinevate kasutusviiside (põllud, metsad, rohumaad) lõikes. Puudulik on aga andmestik mullaelustiku koosseisu ning nende aut- ja sünökoloogia kohta. Üksnes mullaelustiku üldistest taksonoomilistest ja arvukuse andmetest ei piisa kaugeltki selleks, et kujundada süvendatud tasemel arusaamist muldade talitlemisest. Hädavajalikud on regionaalsed mullaliigipõhised teadmised domineerivate organismikoosluste talitlemise kohta.

Mullaelustiku koosseis, mitmekesisus ja aktiivsus on otseselt sõltuvad nende energiatarvet rahuldava humifitseerumata OA (eelhuumuse) olemasolust mullas. Liikide poolest rikkalikum ja arvukam mullaelustiku toitumisahelate võrgustik saab eksisteerida vaid piisava energiaallika (toidu) olemasolu korral. Mida arvukam ja suurem talitluse mahu poolest on mullaelustik, seda rohkem vajatakse ka eelhuumuse staadiumis olevat või juureeritiste kaudset orgaanilist ainet. Vajalik oleks saavutada mullaliigi ja kasvatatava kultuuri OS potentsiaalile vastav elustiku optimaalne (mitte maksimaalselt võimalik) arvukus ja liigirikkus. Tähtis on, et kõik mulla OA-ga seotud bioloogilised talitlemised saaksid toimida järjekindlalt ja tõrgeteta. Mullaliigi põhine mullaelustiku mitmekesisus sõltub mitte niivõrd muldkatte kui terviku ülesehitusest, vaid ennekõike huumuskattest. Mullaliikidele omase elustiku mitmekesisus sõltub mullastiku mitmekesisusest, siis mullaliikide mitmekesisus sõltub omakorda maa-ala geoloogilisest mitmekesisusest.

Huvide konflikt / Conflict of interest

Autor kinnitab artikliga seotud huvide konflikti puudumist
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Humus status of Estonian soil cover and its environment protective management

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Summary

In an introductory part of the work the mutual dependencies between humus cover and carbon farming is analysed. In the following introduction part the possibilities for characterization peculiarities of soils' humus status on the base of organic matter flux through the humus cover are treated. In the third part the acquired knowledge upon management of humus status of Estonian soils are acquainted. In the fourth subdivision of the article the dependence of soil covers' humus status from land use ways and soil species are analysed. For understanding the extent of changes in properties of agricultural areas' soil covers the earlier time soil characteristics are used. In the sixth subdivision is analysed the suitability of proposed by European Commission innovative agro-technologies in future land uses of Estonia. For conclusion, the role proposed by European Innovation Council supporting activities, the problems aroused with scarce knowledge upon soil living organisms and the dependence of soil organisms from pedodiversity and availability of energy for their acting is discussed.

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ANNUAL DYNAMICS OF MICROCLIMATE PARAMETERS OF FARROWING ROOM IN PIGSTY USING TWO DIFFERENT VENTILATION SYSTEMS

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ABSTRACT. The study aimed to investigate the valve and geothermal microclimate systems' impact on microclimate indicators in farrowing rooms. In farrowing rooms, where the valve type of ventilation was installed, the temperature in the farrowing room in summer and autumn exceeded the norm by 3.90 and 1.60 °C, respectively. The amplitude of the average values of the annual temperature dynamics at all these measurement points was higher at using valve-type ventilation relative to geothermal, which provided a constant temperature during the year. Humidity during all seasons of the year was optimal with the use of both microclimate systems, but in summer and autumn, it was probably higher during using geothermal ventilation. The content of carbon dioxide reached its highest values in the autumn months with the use of both systems to create a microclimate, but without exceeding the norm. At the same time, its content was probably higher in the summer months in the room for keeping pregnant sows with the geothermal type of ventilation by 400 ppm or 50% ($P < 0.01$). The ammonia content tended to increase in the autumn months in both farrowing rooms, but reached its highest values in the fall, remaining, however, within normal limits. The hydrogen sulfide content did not exceed the optimal values for both farrowing rooms during all seasons without a statistically significant difference between different types of ventilation. In the farrowing rooms where the geothermal ventilation system was used, the highest H_2S content was in the winter months, amounting to 3.59 ppm, which is 0.96 ppm or 26.81% ($P < 0.001$) higher than in spring, 0.83 ppm or 23.29% ($P < 0.001$) higher than in summer and 0.26 ppm or 7.44% ($P < 0.05$) higher than in spring.

Introduction

The increase in average annual temperatures and abnormally hot periods during the year, which has been observed in recent decades, determines a new approach to improving the microclimate of livestock facilities. The effects of heat stress, high humidity or gassiness of pig housing are manifested in the disruption of their physiological processes, reduced immunity, behavioural changes and reduced productivity, so the introduction of cooling and air conditioning is a key factor in mitigating these negative effects (Maskal *et al.*, 2018; Watanabe *et al.*, 2019). Various cooling methods have been implemented in pig farms. The air temperature can be reduced with the help of adiabatic cooling technology, as a system of fogging under high pressure (Parois *et al.*, 2018). In modern pig farms, large evaporating plates can support the tunnel ventilation system. Currently, much attention is also paid to the development of energy and water-saving methods of cooling using, for example, heat exchanger "ground-air" or "ground-water" (Wiegert *et al.,* 2018; Godyn *et al.,* 2020).

A review of pig heat and moisture production described in publications (Linden, 2021) reports that new genetic lines of pigs produce almost 20.0% more heat than their counterparts in the early 1980s. Pigs usually develop heat stress at much lower temperatures when humidity is high. The degree of humidity directly affects the metabolic processes in animals. When the indoor air temperature decreases excessively, the moisture concentration automatically increases, as a result of which condensate settles on the surfaces, which leads to moisture and supercooling, development of fungi and pathogenic microflora (Min *et al.*, 2015). At elevated temperatures, the humidity drops critically and the air becomes dry, causing the pigs to overheat, which also negatively affects their overall condition (Tkachuk, 2010).

Heat stress causes behavioural and physiological responses and therefore negatively affects livestock productivity (Vitali *et al.*, 2021). Among agricultural species, pigs are particularly susceptible to high temperatures. The increase in the frequency of hot periods observed in the last decade determines a new approach to the improvement of livestock facilities (Shi *et al.,* 2006). The effects of heat stress are manifested in disorders of physiological processes, immune disorders, and changes in animal behaviour, so the introduction of cooling technologies is a key factor in eliminating these negative effects (Seibert *et al.*, 2018; Godyn *et al.*, 2020). Pigs feel warm depending on temperature and humidity (Ross *et al.*, 2017). Sows and boars suffer from acute and constant exposure to high temperatures and humidity. As a result, infertility can be a relatively short-term or prolonged illness from which the animal does not recover for a long time (Lucy, Safranski, 2002).

The gas composition of the air of industrial premises affects the metabolism, productivity of animals and their disease resistance.

Technologies such as exhaust fans, curtains and heaters are now being introduced in piggeries to increase the efficiency of creating optimal conditions for pigs. Ventilation has undergone some changes as more and more pig farms have begun to rely on electronic modes and mechanics (Sapkota *et al.*, 2016). Due to the development of ventilation control technologies in piggeries, it has become more difficult, given the fan steps and more accurate air inlets, which may lead to a lack of scientific understanding of how to ventilate the premises for optimal health and comfort of pigs (Olczak *et al.*, 2015; Zangaro, 2021).

Given the important issues of pig welfare, it should be noted that the optimal microclimatic conditions for suckling sows with piglets are a major factor in ensuring not only the comfort and health of the animal but also further productivity and growth rate. Thus, the study of improving the microclimate systems in pig farming facilities is a topical issue in modern pig farming.

The article aims to investigate the influence of different microclimate systems on the microclimate parameters in the farrowing room during the year and to identify their dependence on changes in seasonal factors.

Materials and Methods

The experiment was conducted in the conditions of the industrial pig complex of Globinsky Pig Complex LLC, Globino, Poltava region, Ukraine (49.394005, 33.311125). The influence of the type of microclimate system in the sections of the premises for keeping suckling sows on its parameters was established by the object of research. The data obtained from measurements of microclimate parameters were the material of the study. Measurements of microclimate parameters were carried out in the same rooms for farrowing, which differed in the system of microclimate. The operation of microclimate systems in both farrowing rooms was adjusted so that the microclimate parameters were at the level of values approved in the departmental standards of technological design of pig farms (VNTP-APK-20.05, 2005). But the microclimate systems did not equally cope with the values of the microclimate at the level of approved standards (Table 1).

Table 1. Departmental norms of technological design of pig enterprises

Indicator	Norms
Indoor air temperature, °C	19–24
Air temperature in the area of piglets activity, °C	22–30
The temperature of the piglet's lair, °C	28–35
The temperature of the sow's lair, °C	24–36
Air velocity, m s^{-1}	0.15
Relative air humidity, %	40–70
Indoor air characteristics:	
CO_2, ppm	2 000
NH_3, ppm	28.18
H_2S, ppm	7.04

The farrowing room No. 1 of Globinsky Pig Complex LLC, where the microclimate system was created and maintained by the ventilation equipment of the German company Big Dutchman: with microclimate control module 307pro L15CE6, was taken as a control room. Microclimate control module connected to temperature sensor DOL 12 (measuring range –10…+40 °C), relative humidity sensor DOL 114 (measuring range 17–100% RH), vacuum sensor DOL 18 (measuring range 6.89–68.9 kPa), CO_2 sensor DOL 19 (measuring range 0–10 000 ppm), NH_3 sensor DOL 53 (measuring range 0–100 ppm) and meteorological station. Sows with piglets of the control group were kept in farrowing rooms with an air supply in the farrowing section utilising supply valves CL 1911 F located on both sides of the farrowing section there (Fig. 1). Exhaust air was extracted from the farrowing room through the roof shafts CL 600 equipped with two exhaust fans FF 063-6ET.

The design features of the experimental room for farrowing No. 2 of Globinsky Pig Complex LLC (Fig. 2) were identical to the planning and ventilation equipment of the German company Big Dutchman: with microclimate control module 307pro L15CE6, connected to temperature sensor DOL 12 (measuring range –10…+40 °C), relative humidity sensor DOL 114 (measuring range 17–100% RH), vacuum sensor DOL 18 (measuring range 6.89–68.9 kPa), CO_2 sensor DOL 19 (measuring range 0–10 000 ppm), NH_3 sensor DOL 53 (measuring range 0–100 ppm) and meteorological station. But experimental microclimate system there was fundamentally different in type and technological implementation from the air supply system in the farrowing section. In this farrowing room, external unprepared air enters the farrowing section via two underground air ducts and four perforated under-ceiling air distribution ducts located above the farrowing pens.

In general, both the control and research rooms for farrowing were identical to the configuration of the interior layout and were built of the same building material. The sections of the premises where the piglets were farrowed and kept during the suckling period until weaning were of equal area, had the same number of individual pens, the same watering systems, transport and distribution systems and identical designs of vacuum-self-flowing manure removal systems, but they differed microclimate systems.

The study and the methods used to obtain the result were approved by the committee on ethics and humane treatment of animals of the Sumy National Agrarian University.

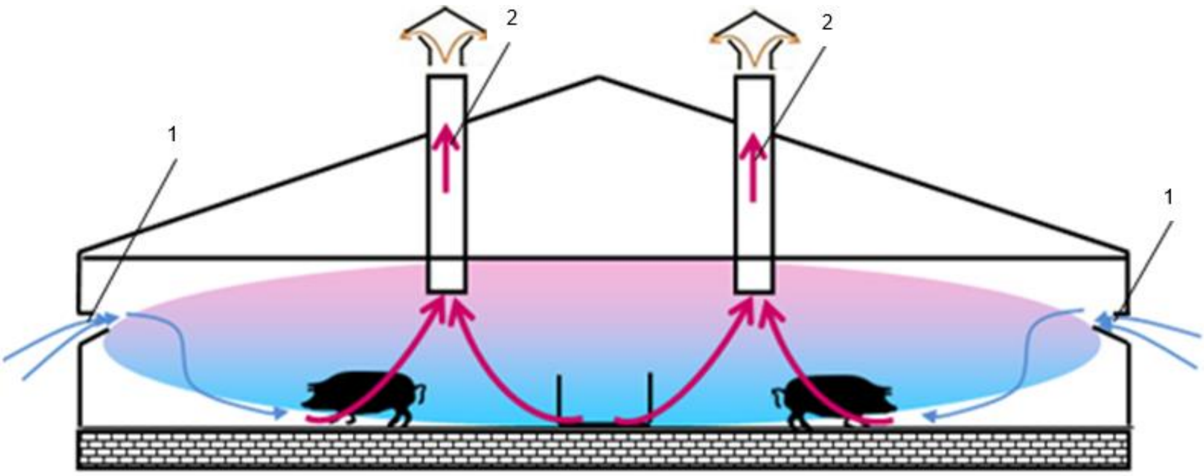

Figure 1. Scheme of air movement in the farrowing room with valve ventilation (I control group) (1 – supply valve; 2 – exhaust shafts)

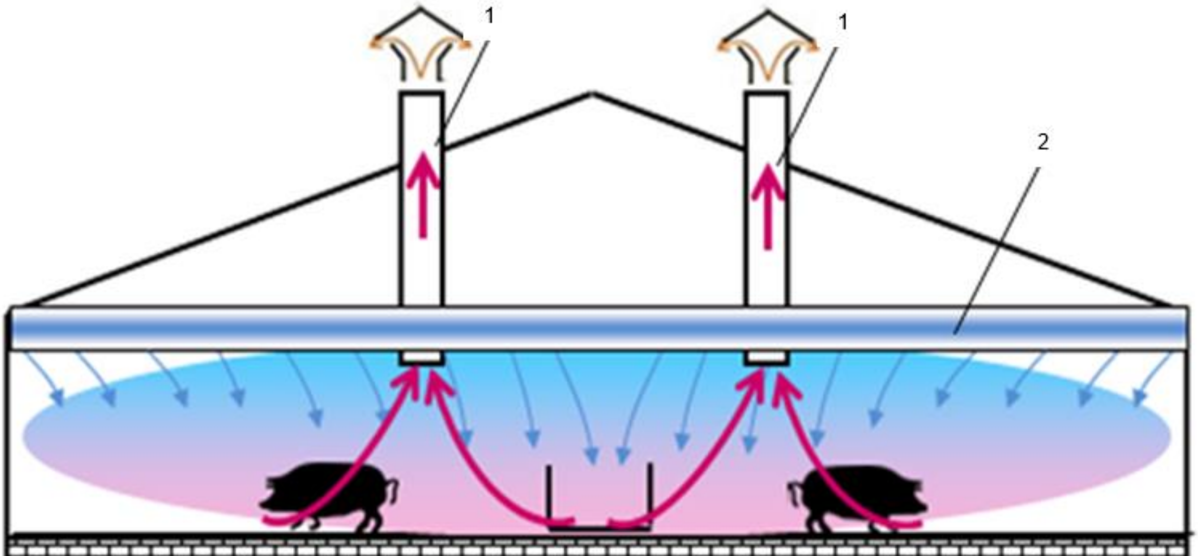

Figure 2. Scheme of air movement in the farrowing room with geothermal ventilation (II research group) (1 – exhaust shafts; 2 – sub-ceiling supply air duct)

Measuring the microclimate parameters

Microclimate parameters were measured three times for each season of the year, once a month. On the day of measurement, microclimate parameters were measured once in the morning and once in the evening at the same time. During the winter season, three measurements were performed: one in December, one in January, and one in February. In the spring season, three measurements were made: one in March, one in April and one in May. During the summer season, three extinctions were carried out: one in June, one in July and one in August. In the autumn season, three measurements were made: one in September, one in October and one in November.

Indoor air temperature and air temperature in the area of piglet activity were measured using pyrometer Testo 805 (Testo AG, Lenzkirch, Germany) with a measuring range –25…+250 °C (±1.0 °C). Measurement areas were chosen in the middle and two opposite corners of the room, departing from the walls up to one meter. Vertically, temperature measurements were carried out in three zones: 0.3 and 0.7 m from the floor and 0.6 m from the ceiling.

The temperature of the piglet's lair, the temperature of the sow's lair and air velocity were measured using a thermo-anemometer Testo 425M (Testo AG, Lenzkirch, Germany) with a measuring range of 0 to 20 m s^{-1} (±0.03 m s^{-1}) and –20…+70 °C (±0.5 °C). The temperature of the piglets' and sows' lairs was measured in each pen. The average values of piglet lair measurements and sow lair temperature were taken into account.

Relative air humidity was measured using thermo-hygrometer Testo 605 (Testo AG, Lenzkirch, Germany) with a measuring range of 5–95% RH (±3.0% RH). Measurements of indicators were made at the level of lying piglets (7.0 cm), their standing (25.0 cm) and the level of the respiratory tract of an adult (160.0 cm).

Content in the air of ammonia (NH_3), hydrogen sulfide (H_2S) and carbon dioxide (CO_2) were measured using the gas analyzer DOZOR-CM4 (NPP ORION, Ukraine) with a measuring range for CO_2 0–10 000 ppm (±2 500 ppm), for NH_3 0–28.18 ppm (±7.05 ppm), for H_2S 0–21.12 ppm (±3.52 ppm).

Data analysis

The obtained results were analyzed using Excel 2010. Results were expressed as mean values, standard deviations, and standard error of the mean in the tables. The dissemblance significance ($P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$) between the microclimate parameters (n = 36) was analyzed by the Student's t-test.

Results

Estimation of microclimate parameters in premises for suckling sows with piglets with different types of microclimate systems in winter allowed us to identify that the air velocity in the farrowing room with the geothermal type of ventilation was lower than in the room equipped with a valve type of ventilation by 0.04 m s^{-1} or 36.36% ($P < 0.05$) (Table 2). This led to a decrease in air exchange in the farrowing section. Thus, in the control farrowing room, the air exchange was 1.93 m^3 s^{-1}, while in the farrowing room with geothermal ventilation it was 0.71 m^3 s^{-1} smaller. A study of microclimate indicators created by different systems of its creation and maintenance in sows in the spring season found a higher velocity of air in the farrowing room using a valve system of microclimate by 0.07 m s^{-1} or 38.89% ($P < 0.05$). This caused an increase in air exchange in it by 1.22 m^3 s^{-1} and, as a result, a lower level of concentration of harmful gases there.

Table 2. Indicator microclimate parameters during the seasons of the year, n = 36

Indicator	Winter	Spring	Summer	Autumn
Group I (valve type ventilation)				
Indoor air temperature, °C	20.1 ± 0.37^{A}	20.3 ± 0.21^{A}	27.9 ± 0.31^{aB}	25.6 ± 0.21^{C}
Air temperature in the area of piglets activity, °C	27.3 ± 0.16^{A}	24.9 ± 0.11^{B}	28.2 ± 0.30^{C}	26.9 ± 0.18^{A}
The temperature of piglet's lair, °C	31.4 ± 0.12^{A}	32.9 ± 0.16^{B}	34.9 ± 0.19^{C}	33.1 ± 0.28^{D}
The temperature of the sow's lair, °C	23.9 ± 0.14^{A}	24.0 ± 0.19^{AC}	25.9 ± 0.19^{B}	24.4 ± 0.14^{C}
Air velocity, m s^{-1}	0.11 ± 0.012^{aA}	0.18 ± 0.018^{aBD}	0.35 ± 0.024^{aC}	0.21 ± 0.022^{D}
Volume speed of air movement, m^3 s^{-1}	1.93	3.15	6.20	3.68
Relative air humidity, %	55.2 ± 0.59^{A}	61.3 ± 0.65^{B}	45.9 ± 0.45^{aC}	64.2 ± 0.73^{aD}
Indoor air characteristics:				
CO_2, ppm	1 200.0 ± 80^{A}	1 200.0 ± 130^{A}	800.0 ± 60^{bB}	2 300.0 ± 190^{C}
NH_3, ppm	6.72± 1.250^{A}	5.93± 0.758^{A}	2.22 ± 0.210^{B}	9.78 ± 0.620^{C}
H_2S, ppm	2.11 ± 0.025^{A}	2.17 ± 0.073^{A}	1.29 ± 0.008^{B}	2.47 ± 0.056^{C}
Group II (geothermal type ventilation)				
Indoor air temperature, °C	23.0 ± 0.21^{AB}	22.4 ± 0.17^{AB}	23.1 ± 0.19^{bAB}	22.7 ± 0.19^{AB}
Air temperature in the area of piglets activity, °C	27.9 ± 0.18^{A}	27.0 ± 0.13^{B}	26.8 ± 0.19^{B}	25.8 ± 0.19^{C}
The temperature of piglet's lair, °C	35.2 ± 0.10^{A}	34.8 ± 0.15^{A}	34.8 ± 0.21^{A}	34.0 ± 0.24^{B}
The temperature of the sow's lair, °C	26.8 ± 0.14^{A}	23.9 ± 0.18^{B}	25.3 ± 0.19^{C}	24.6 ± 0.15^{D}
Air velocity, m s^{-1}	0.07 ± 0.011^{bA}	0.11 ± 0.020^{bA}	0.16 ± 0.036^{bB}	0.15 ± 0.019^{B}
Volume speed of air movement, m^3 s^{-1}	1.22	1.93	2.8	2.63
Relative air humidity, %	52.1 ± 0.55^{A}	62.4 ± 0.48^{B}	52.1 ± 0.54^{bA}	57.1 ± 0.69^{bC}
Indoor air characteristics:				
CO_2, ppm	1 800 ± 100^{A}	1 500 ± 160^{B}	1 200 ± 70^{bC}	2 000 ± 200^{A}
NH_3, ppm	8.46 ± 1.154^{A}	7.13 ± 0.944^{A}	5.28 ± 0.168^{B}	8.21 ± 0.943^{A}
H_2S, ppm	3.59 ± 0.061^{A}	2.63 ± 0.074^{B}	2.76 ± 0.014^{B}	3.33 ± 0.062^{C}

Different lowercase letters (a, b) indicate statistical differences between the ventilation systems at the level of $P < 0.05$. Different capital letters (A, B, C, D) indicate a statistical difference between the seasons at the level of $P < 0.05$.

Analysis of the parameters of microclimate systems in the sections for farrowing during the summer season showed that when valve ventilation was used, the value of indoor air temperature was higher by 4.80 °C or 17.20% ($P < 0.001$), the velocity of indoor air was higher by 0.19 m s^{-1} or 54.29% ($P < 0.001$), which caused a greater air exchange in it by 3.4 m^3 s^{-1} and, as a result, a decrease in relative air humidity by 6.20% RH ($P < 0.001$), CO_2 content by 400 ppm or 50.00% ($P < 0.01$). The study of microclimate indicators in the autumn months in farrowing rooms equipped with different types of ventilation found difference in the relative air humidity, which was higher in the farrowing room with a valve system to create a microclimate by 7.10% RH ($P < 0.001$).

Seasonal dynamics of microclimate indicators in farrowing premises revealed their diverse changes during the study period. Thus, the air temperature in farrowing rooms equipped with valve ventilation for sows and suckling piglets was significantly higher in the summer and autumn months compared to winter by 7.80 °C or 38.81% ($P < 0.001$) and 5.50 °C or 27.36% ($P < 0.001$). In the premises where geothermal ventilation was installed, there was no statistically significant difference between the indicators during all seasons of the year. Evaluation of the annual dynamics of air temperature in the area of piglets activity using a valve ventilation system found that in the spring it was significantly lower than in winter by 2.40 °C or 8.79% ($P < 0.001$) and in the summer it was significantly higher than in winter by 0.90 °C or 3.30% ($P < 0.05$), and there was no significant difference between its autumn and winter values. The temperature in the area of piglets activity kept in the geothermal microclimate system was probably the highest in the winter months, exceeding the spring season by 0.90 °C or 3.23% ($P < 0.01$), summer season by 1.10 °C or 3.94% ($P < 0.01$) and in the autumn season by 1.7 °C or 5.41% ($P < 0.001$).

A study of the temperature of piglets lair in the farrowing room with a valve system of microclimate found that in winter its values were the lowest and inferior to spring by 1.50 °C or 4.78% ($P < 0.001$), summer by 3.50 °C or 11.15% ($P < 0.001$), autumn 1.70 °C 5.41% ($P < 0.001$). In the same study period, the temperature of the piglet's lair in a farrowing room with a geothermal microclimate system in winter, spring and summer did not differ significantly, and in autumn it was lower than in winter by 1.20 °C or 3.41% ($P < 0.001$). The annual dynamics of sow's lair temperature in the control group were marked by the absence of a significant difference between its indicators in winter and spring, but in summer its values prevailed in winter by 2.00 °C or 8.37% ($P < 0.001$), and in autumn the advantage over winter values was 0.50 °C or 2.09% ($P < 0.05$). In the experimental group, the values of sow's lair temperature were the highest in the winter months, exceeding the indicators of the spring season by 2.90 °C or 10.82% ($P < 0.001$), summer season by 1.50 °C or 5.60% $P < 0.001$), the autumn season by 2.20 °C or 8.21% ($P < 0.001$).

A study of the annual dynamics of air velocity in a farrowing room equipped with a valve ventilation system was found to have the lowest values in the winter season, which were significantly inferior to the values of the spring months by 0.07 m s^{-1} or 63.64% ($P < 0.01$), summer months by 0.24 m s^{-1} or 218.18% ($P < 0.001$), autumn months by 0.10 m s^{-1} or 90.91% ($P < 0.01$), which caused a lower level of volume speed of air movement by 1.22, 4.27 and 1.75 m^3 s^{-1} in accordance. The dynamics of the rate of air movement in the farrowing room equipped with a geothermal ventilation system were similar. It was found that in summer the air velocity was higher than in winter by 0.09 m s^{-1} or 125.57% ($P < 0.05$), and in autumn – by 0.08 m s^{-1} or 114.29% ($P < 0.01$). It was established that in the summer the level volume speed of air movement in the farrowing room with geothermal type ventilation was higher than the winter value of this indicator by 1.58 m^3 s^{-1}, than the autumn value of this indicator by 1.58 m^3 s^{-1} and then the spring value of this indicator by 0.71 m^3 s^{-1}. No significant difference in the values of the indicator between spring and winter measurements was found.

Analysis of the annual values of air humidity in the room for keeping pregnant sows with a valve system to create a microclimate revealed that in winter this figure was lower than its spring and autumn values by 6.1% RH ($P < 0.01$) and 9.00% RH, respectively ($P < 0.001$), but higher than in summer by 9.3% RH ($P < 0.001$). In the farrowing room with a geothermal microclimate system, the air humidity in the spring exceeded winter values by 10.30% RH ($P < 0.001$), and in autumn – by 5.00% RH ($P < 0.001$). There were no significant differences between winter and summer air humidity values in the farrowing room.

A study of the gas composition in farrowing rooms where pigs were kept using the valve type of ventilation showed that there was no significant difference between the winter and spring values of CO_2 in the air. However, the content of carbon dioxide in the summer was lower than in winter by 400 ppm or 33.33% ($P < 0.01$), and in autumn, on the contrary, exceeded the winter by 800 ppm or 66.67% ($P < 0.01$). The dynamics of carbon dioxide content in the farrowing room using geothermal ventilation was manifested in the excess of winter values over spring and summer, respectively, by 1 700 ppm or 91.67% ($P < 0.001$) and 600 ppm or 33.33% ($P < 0.001$). In this case, the CO_2 content in the experimental group in the autumn and winter months did not differ significantly.

Assessment of the dynamics of ammonia content in the room for suckling sows with air supply through wall valves revealed no statistically significant difference between the winter, spring and autumn months, and in summer they were lower than in winter by 4.49 ppm or 66.88% ($P < 0.01$). The values of NH_3 content in the farrowing room with a geothermal type of microclimate system in the winter, spring and autumn seasons did not differ statistically significantly. In summer, the ammonia content in the experimental group was significantly lower than in winter by 1.59 ppm or 37.60% ($P < 0.05$).

It was found that using the classical type of ventilation in farrowing rooms, the hydrogen sulfide content did not differ significantly in winter and spring, but in winter it was higher than in summer by 0.82 ppm or 38.87% ($P < 0.001$), but lower than in autumn – by 0.35 ppm or 16.61% ($P < 0.001$). In the farrowing room where the geothermal ventilation system was used, the highest H_2S content was in the winter months, 3.59 ppm, which was 0.96 ppm or 26.81% ($P < 0.001$) higher than in spring, 0.83 ppm or 23.29% ($P < 0.001$) higher than in summer and 0.26 ppm or 7.44% ($P < 0.05$) higher than in autumn.

Discussion

The results of research confirm that in all seasons the supply and exhaust ventilation of uniform pressure provided the optimal temperature regime, but the concentration of carbon dioxide in all periods of the year, except summer, was higher than the maximum allowable (Ladyka *et al.,* 2020). It is known that exposure to carbon dioxide increases the incidence of stillbirths and abortions in pregnant sows (Huynh *et al.,* 2004). Other authors (Dubeňová *et al.*, 2013) have reported that CO_2 levels in the farrowing room ranged from 515.293 to 519.580 ppm. This did not coincide with our results, because with the use of valve ventilation, we had fluctuations in the level of CO_2 in the range of 800–2 300 ppm, and with the use of geothermal ventilation, CO_2 varied in the range of 1 200–2 000 ppm. However, our findings on carbon dioxide levels using geothermal ventilation are similar to results (Ostović *et al.*, 2009) on farrowing room CO_2 levels in spring 1 566.67 ppm and autumn 1 555.56 ppm.

The geothermal ventilation system provides more stable throughout the year indicators of temperature and humidity and the temperature of the lair of piglets and sows, compared with the valve ventilation. At the same time, it creates worse air pollution in the farrowing room (Mykhalko, Povod, 2020). We found like in our previous studies (Mykhalko, Povod, 2020), that geothermal ventilation maintains a more stable microclimate during all seasons of the year compared to valve-type ventilation.

The speed of air movement in the area of life of animals plays an important role in ensuring their comfortable growing conditions. Air mobility as a parameter of the microclimate refers to the factors that have a direct impact on the thermoregulation of piglets and sows and the gas composition of the air in the farrowing room (Demchuk *et al.*, 2009). Exposure to hydrogen sulfide reduces the average daily gain and average daily feed intake and increases the incidence of diarrhoea in piglets. Increasing the hydrogen sulfide content in farrowing rooms may increase the number and diversity of the intestinal microbiota (Cui *et al.*, 2021). Its adverse effects are also well known in humans, including irritation of mucous membranes, especially eyes, olfactory paralysis, sudden but reversible loss of consciousness, pulmonary oedema, death, and genotoxic effects of high doses (Szabo, 2018). Published studies indicate that higher temperatures in the pig housing and lower air velocities have led to a significant increase in H_2S concentration (Ni *et al.*, 2002). Other studies have reported (Demchuk *et al.*, 2009; Jo *et al.,* 2020) that air mobility has a significant effect on the pollution of the farrowing room. This was confirmed by the results of our current experiment, which found that the higher amplitude of fluctuations in air velocity in the farrowing room, the lower the content of harmful gases and vice versa.

Exposure to ammonia can cause pathological changes in many tissues and organs of pigs (Rong, Aarnink, 2019; Xia *et al.*, 2021). Levels of 50 to 100 ppm affect productivity, especially daily gain, which can be reduced by 10% over long periods of exposure. At 50 ppm and above, the clearance of bacteria from the lungs of piglets is also impaired, and therefore animals are more prone to respiratory diseases (Houghton, 2021). Concentrations of ammonia and hydrogen sulfide were higher in piggeries using self-flowing manure removal systems from lattice pits with lattice floors and conventional ventilation than in pig housing with other types of ventilation (Kim *et al.*, 2008; Forcada, Abecia, 2019). Ammonia concentration and ventilation rate showed a weak negative correlation ($r = -0.13$). Ammonia emissions were more affected by ammonia concentration ($r = 0.88$) than ventilation intensity ($r = 0.31$). This suggests that reducing ammonia concentrations by accelerating indoor air movement can effectively reduce ammonia emissions (Jo *et al.*, 2020). The results of our studies on ammonia content in farrowing facilities did not coincide with the findings (Kim *et al.*, 2008; Forcada, Abecia, 2019), which reported higher levels in valves with valvular ventilation. We found the opposite situation when the ammonia content was lower using the valve microclimate system and higher using the geothermal one.

The scientific article results (Saha *et al.*, 2014) showed the concentration of NH_3 in the farrowing room varies seasonally depending on the values of outdoor temperature. Significant correlations were found ($P < 0.001$) of NH_3 concentration with external seasonal climatic fluctuations, including the outdoor temperature, humidity, wind speed and direction, hour of the day and day of the year. We did not establish such relationships, however, we found seasonal fluctuations in the ammonia content and noted a decrease in the summer months and an increase in the winter and autumn months.

Conclusions of experiments (Krommweh *et al.*, 2014; Islam *et al.*, 2016; Mun *et al.*, 2021) showed that a geothermal microclimate system has the potential to reduce emissions of CO_2 and other harmful gases. But our results do not coincide with this opinion and showed that with the use of a geothermal microclimate system in the farrowing room, the content of CO_2 and other harmful gases was higher than during the use of a valve microclimate system all year round, especially in autumn.

Conclusion

Both valve-type ventilation and experimental geothermal ventilation provide microclimate parameters that meet the veterinary standards for keeping pigs in farrowing facilities. However, the use of valve-type ventilation did not ensure the normal temperature in the farrowing room and allowed it to exceed the norms in summer and autumn by 3.90 °C and 1.60 °C, respectively.

Geothermal ventilation provides a more stable air exchange by normalizing the temperature and air movement in the farrowing room and, accordingly, ensures a normal level of humidity during all seasons of the year. The valve ventilation system better removes polluted air from the farrowing room, minimizing the negative impact of harmful gases on the reproductive qualities of sows and the growth rate of piglets.

Conflict of interest

We declare that there is no conflict of interest with financial or other organizations and with any person regarding the material published in this manuscript.

Author contributions

PM – organized an experiment in the enterprise;
MO, MP – processed data, summarized them and interpreted the results;
MO, KO – assessed the current problems of the manuscript;
MO, TV – performed statistical data processing;
SV, OS, KH, OL – performed critical revision and approve the final manuscript.

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MICROBIAL REMEDIATION OF PETROLEUM-POLLUTED SOIL

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ABSTRACT. The issues of land pollution, restoration, and return of land to agricultural cultivation are today. Especially, this is gaining new relevance in modern conditions of military action on the territory of Ukraine and other countries, which causes the reduction of cultivation areas. Therefore, there is a need for maximum cleaning and restoration of polluted soils to ensure environmental and food security. Petroleum hydrocarbons are classified as major environmental pollutants due to their stability and durability in the environment. The influence of petroleum hydrocarbons is caused by direct toxic activity and by the soil environment transformation. The research aimed: to study the effectiveness of probiotics in the technology of soil cleaning and remediation; evaluate the phytotoxic effect of oil-contaminated soil before and after the application of probiotics; to find the optimal concentration of probiotics for the effective cleaning and remediation of soil. The seedling method was used to evaluate the phytotoxic effect of contaminated soil before and after the application of probiotics. Research results showed an ambiguous impact on *Pisum sativum* and *Avéna satíva* at different times after pollution. In the initial phase, polluted soil has no significant influence on *Pisum sativum*. For *Avéna satíva* soil, become toxic right away after pollution. Phytotoxic effect of *Pisum sativum* and *Avéna sativa* decrease by the indexes of seed emergence, roots length, roots weight, underground part length and ground part weight due to probiotics treatment. The high efficiency of biological remediation by probiotics in comparison with soil cleaning in natural conditions is determined in the experiment. Probiotic concentration 1:10 is the most effective of all studied initial concentrations of pollutants. Reducing probiotic concentration leads to a decrease in the efficiency of soil cleaning from petroleum products.

Introduction

The level of environmental pollution increases with industrial growth. Petroleum hydrocarbons are classified as major environmental pollutants due to their stability and durability in the environment. These include alkanes, cycloalkanes, polycyclic aromatic hydrocarbons, and many other organic pollutants (Ambaye *et al.*, 2022). Petroleum hydrocarbons are considered one of the most ecologically dangerous soil pollutants. The source of this pollution is the enterprises of oil refining, petrochemical and chemical industries, transport, waste deposits *etc*. (Fanaei *et al.*, 2020). Soil can absorb many chemical compounds and hold them in the superficial fertile soil layer. Petroleum products change chemical, mechanical, biochemical, and physicochemical soil properties (Hung *et al.*, 2020). These modifications can lead to plant or micro-organism death, which impacts soil self-cleaning (Wang *et al.*, 2017). The influence of petroleum products is caused by the direct toxic effect and by the transformation of the soil environment.

The issues of land pollution, restoration, and return of land to agricultural cultivation are today. Especially, this is gaining new relevance in modern conditions of military action on the territory of Ukraine and other countries, which causes the reduction of cultivation areas. Food shortages could cause a global food crisis. Therefore, there is a need for maximum cleaning and restoration of polluted soils to ensure environmental and food security. Soil petroleum pollution has direct and indirect influences on plants. The direct influence consists of the immediate effect of the pollutant on plants. The effect of oil carbohydrates on the cellular and physiological level is manifested by the alteration of photosynthesis and chloroplast structure. These compounds damage chloroplast, mitochondria and root cell membranes. The plants, which grow in the conditions of petroleum product pollution, can contain much more stress-protecting compounds (Mukome *et al.*, 2020). On the other hand, the indirect impact manifests through the change in morphological, physicochemical and biological properties of the soil (Hung *et al.*, 2020). In addition, petroleum pollution can have negative as well as stimulating action on plants. Hence, the determination of the phytotoxic effect is a relevant method to study petroleum-polluted soil.

The level of oil pollution affects not only plants but also microorganisms. As an important part of soil ecosystems, soil microorganisms are mainly involved in the soil material and energy cycles. There are many kinds of soil microorganisms, which mainly include prokaryotes such as bacteria and actinomycetes and eukaryotes such as fungi, algae and protozoa. Bacteria, as the largest proportion of soil microorganisms, mainly use heterotrophic nutrition. They are distributed in the surface soil and are the most active component of soil microorganisms. Actinomycetes are widely distributed in soils with high contents of alkaline and organic matter. Fungi are aerobic microorganisms that exist in the tillage layer. As opposed to bacteria and actinomycetes, fungi can grow and reproduce in acidic soil. Algae and protozoa are not widely distributed in soils. The growth of algae is greatly affected by light and water, and protozoa mainly feed on organic matter and can consume bacteria and algae (Cabral *et al.*, 2022). Therefore, we should choose optimal and environmentally-friendly remediation methods of petroleum polluted soil.

A wide range of methods and technologies for of remediation polluted soil is mentioned in the scientific literature (Asghar *et al.*, 2016; Wang *et al.*, 2018; Ossai *et al.*, 2020; Haider *et al.*, 2021), the usage of probiotics for soil cleaning is not studied thoroughly. The abandoned usage of probiotics is limited by their insufficient studies, the absence of scientific and research bases, the comparative analysis of probiotics, the determination of required doses as well as the profit to obtain a wanted result *etc*. Hence, there is a necessity to further petroleum product influence research on the vegetation and new methods establishment for polluted soil treatment by microorganisms.

The study aimed: 1) to study the effectiveness of probiotics in the technology of soil cleaning and remediation; 2) to evaluate the phytotoxic effect of oil-contaminated soil before and after the application of probiotics; 3) to find the optimal concentration of probiotics for the effective cleaning and remediation of soil.

Materials and Methods

An assessment of the phytotoxic effect of petroleum-polluted soil was carried out in the Laboratory of Agroecological monitoring of Poltava State Agrarian University, Ukraine. The seedling method was used to evaluate the phytotoxic effect of contaminated soil before and after the application of probiotics (ISO 11269-1:2012; ISO 11269-2:2012). This method is based on the test culture reaction to different contaminants in the soil. It permits to detection of the toxic activity or stimulating action of various compounds. As test cultures, we used plants that are capable or not fixing nitrogen and are typical species for contaminants*:* *Pisum sativum* and *Avéna satíva* (Hrytsaienko, 2003). The experiment was performed in four repetitions.

The experiment to a determination of phytotoxic effect on *Pisum sativum* and *Avéna satíva* included the following factors:

Factor A – the duration of petroleum pollution. Variant 1 – the sowing of test cultures on the 2^{nd} day after petroleum pollution. Variant 2 – the sowing of test cultures on the 30^{th} day after petroleum pollution. Variant 3 – the sowing of test cultures on the 180^{th} day after petroleum pollution.

Factor B – petroleum products concentrations (1 000, 2 000, 5 000, 10 000 and 20 000 mg kg^{-1}). The concentration of petroleum products in control (natural condition for podzolic chernozem) was 40 mg kg^{-1}. The samples were taken on the 14^{th} day after sowing.

Factor C – the application of probiotic Sviteco-Agrobiotic-01 (Chrisal NV, Lommel, Belgium; based on *Bacillus subtillis*) with the aim of soil bioremediation. The probiotic was applicated on the second day after petroleum pollution.

The determination of phytotoxicity was evaluated by the following indexes: the test culture seed emergence, roots length, roots weight, ground part length, and ground part weight.

The phytotoxic effect (*PE*) was determined by the Formula 1 (Pisarenko *et al.*, 2019):

$$PE = \left[\frac{Mo - Mk}{Mo}\right] \times 100\%, \quad (1)$$

where *Mo* – the mass or growth index of control soil; *Mk* – the mass or growth index of soil, treated by tested water (where the probiotic is present).

The determination of petroleum hydrocarbonates in soil was determined by infrared spectroscopy IRAFFINITY-1S (Shimadzu, Japan) after the 30^{th} day of contamination (MVV 31-497058-009-2002).

The phytotoxic effect of more than 20% is considered significant. PE <20% – non-toxic; PE = 20–40% – low toxicity; PE = 40–60% – medium toxicity; PE = 60–80% – dangerously toxicity.

Results

Phytotoxic effect of petroleum polluted soil on *Pisum sativum*

The research results (Table 1) show that in Variant 1 petroleum pollution had no significant toxic effect on the *Pisum sativum* growth because the values of phytotoxic effect were less than 20% and variated in the range from 11.9 to 16.9%. This indicated the stimulation of the plant growth under the influence of the studied factors at all experimental concentrations.

Table 1. Phytotoxic effect of polluted soil on *Pisum sativum* before and after probiotic treatment

Time of petroleum pollution	The concentration of petroleum products, mg kg^{-1}	Phytotoxic effect, %									
		By seed emergence		By roots length		By roots weight		By ground part length		By ground part weight	
		Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]
Variant 1	1 000	2.6	–1.2**	5.0	–2.5**	0.8	–1.1**	6.7	–1.1**	0.0	–1.2**
	2 000	2.6	–1.6**	9.3	–1.0	–0.8	–0.5**	–5.7**	–5.1**	–3.4**	–5.2**
	5 000	–2.6**	–3.2**	14.3	2.4	–0.5	–0.6**	3.7	–2.1**	–5.2**	–4.5**
	10 000	10.4	2.5	11.4	3.6	–9.3	–5.5**	9.8	3.1	–9.3**	–10.2**
	20 000	16.9	3.1	15.0	5.1	–11.9	–5.6**	13.6	4.2	–11,9**	–5.2**
Variant 2	1 000	2.7	–0.6**	–3.9**	–0.5**	2.6	–0.1**	1.7	–1.2**	0.7	–2.1**
	2 000	13.3	–0.4**	1.9	1.2	7.6	1.2	11.3	–3.1**	4.3	1.2
	5 000	9.3	1.2	3.9	1.5	5.7	1.5	**24.8***	1.1	10.1	5.1
	10 000	9.3	3.5	5.8	1.5	9.8	0.2	**22.6***	12.1	13.0	7.8
	20 000	13.3	5.7	8.3	2.2	–3.8	–1.1**	–0.2**	–1.1**	–6.5**	–2.5**
Variant 3	1 000	18.0	2.5	14.0	2.8	**25.0***	5.1	1.8	–2.1**	2.0	–1.1**
	2 000	**28.8***	7.8	**53.7***	10.1	**39.1***	6.1	**21.2***	5.1	12.6	5.3
	5 000	**42.4***	10.2	**57.4***	12.2	**55.1***	6.8	**35.9***	10.1	**28.3***	9.1
	10 000	**67.0***	15.1	**72.8***	15.5	**75.1***	15.1	**65.2***	12.1	**60.3***	14.3
	20 000	**78.3***	18.2	**49.3***	18.1	**78.2***	**21.5**	**51.8***	15.3	**79.8***	**22.0***

*The phytotoxic effect of more than 20% was considered significant.
**Negative values of the phytotoxic effect indicate the stimulation of plant growth and development under the influence of the studied factors.
[1]Phytotoxic effect before probiotic application.
[2]Phytotoxic effect after probiotic application.

The following results were obtained in Variant 2 after the 30th day after petroleum pollution: the length and the weight of roots at all concentrations of pollutant were nearly the same and the phytotoxic effect was in the range of 8.3–9.8%. So, on the 30th day after pollution, the soil was not toxic to the root system of *Pisum sativum*. The length of the ground part of *Pisum sativum* decreased with the petroleum concentration increasing up to 5 000 mg kg^{-1}. At the petroleum concentrations of 5 000 and 10 000 mg kg^{-1}, the phytotoxic effect reached 24.8% and 22.6% respectively, which indicated the soil toxicity concerning the development of the ground part of plants. The values of phytotoxic effect in Variant 1 after the use of probiotics were in the range of –10.2 to 5.1%. The average value of phytotoxic effect after the application of the probiotic was 2.78%, which was two times lower compared to the values before the application of the probiotic. The soil pollution was not toxic at petroleum concentrations of 1 000 and 2 000 mg kg^{-1} after the probiotic application, conversely, observe the stimulation of *Pisum sativum* growth. The insignificant phytotoxic effect (2.4%) was at a petroleum concentration of 5 000 mg kg^{-1}. The phytotoxic effect values increased with increasing the pollution concentration up to 5.6% (at 20 000 mg kg^{-1}), but this was not considered significant.

The increase of petroleum concentration (to 20 000 mg kg^{-1}) in Variant 2 caused an increase in the underground parts of plants. The root's length becomes very close to the values of plants in the control conditions. The weight of the underground part of plants also changed, following a similar tendency. There were no significant differences from control plants at the petroleum concentration from 1 000 to 20 000 mg kg^{-1}. Hence, the research results of Variant 2 showed the considerable toxic effect of petroleum products on the underground part of the *Pisum sativum* at concentrations of 5 000 and 10 000 mg kg^{-1}. An average value of phytotoxic effect in Variant 2 after the application of probiotic was not significant (3.13%). The values were in a range from –3.1 to 12.1%. The research results showed that with the increase of petroleum concentration phytotoxic effect increased in Variant 2.

The growing of *Pisum sativum* in Variant 3 on the 180th day after soil pollution obtained the following results: the root length reduction was observed at a concentration of 2 000 mg kg^{-1}. The minimal value was spotted at 10 000 mg kg^{-1}, but there were no significant differences between pollutant concentrations (2 000, 5 000, 20 000 mg kg^{-1}). By increasing the starting pollutant concentration, the soil toxicity also increased. The maximal phytotoxic effect value (72.8%) was observed at 10 000 mg kg^{-1}. At the studied concentration of petroleum products of 2 000; 5 000 or 20 000 mg kg^{-1} phytotoxic effect corresponded to 53.7, 57.4 and 49.3%, respectively. The root weight decreased along with the petroleum concentration increase. The significant decrease in plant weight and phytotoxic effect (25%) occurred at a concentration of 1 000 mg kg^{-1}. The ground part length of a plant was changing at the same rate as a root length. A considerable decrease in plant height was already observed at the initial pollutant concentration of 2 000 mg kg^{-1}. The concentration of 1 000 mg kg^{-1} did not influence the plant sizes. The biggest phytotoxic effect (65.2%) corresponded to the petroleum concentration of 10 000 mg kg^{-1} and the minimal value (1.8%) – of 1 000 mg kg^{-1}. The underground part weight of a plant started to decrease at the petroleum concentration of 5 000 mg kg^{-1} and continued to decrease with the pollutant concentration increment. The maximum value of the phytotoxic effect (79.8%) was achieved at the petroleum concentration of 20 000 mg kg^{-1}. Consequently, the soil became toxic to *Pisum sativum* at all investigated concentrations on day 180 after contamination. The research results of Variant 3 after the use of probiotics showed the phytotoxic effect decrease of *Pisum sativum*. The soil toxicity was insignificant (–2.2...18.20%) at all studied petroleum concentrations. Except for the indexes of roots weight and underground part weight where the phytotoxic effect of *Pisum sativum* was significant at pollution concentrations of 20 000 mg kg^{-1} – 21.5 and 22.0% respectively.

Therefore, with the increasing duration of pollution and the petroleum concentration of soil, the phytotoxic effect of *Pisum sativum* increased by the indexes of seed emergence, roots length, roots weight, ground part length and weight. *Pisum sativum* soil becomes toxic only on the 30th day after the pollutant application (5 000 and 10 000 mg kg^{-1}) and the toxicity increased over time. The research results showed the decrease of the phytotoxic effect of *Pisum sativum* by the indexes of seed emergence, roots length, roots weight, ground part length, and ground part weight due to the application of probiotics.

Phytotoxic effect of polluted soil on *Avéna satíva*

The research results of *Avéna satíva* growing in Variant 1 showed the phytotoxic effect in the range from 1.4 to 46.0% (Table 2). At all petroleum concentrations, less than 5 000 mg kg^{-1} observed an insignificant phytotoxic effect (less than 20%) by studied indexes (except seed emergence and roots length). Starting at pollutant concentration 5 000 mg kg^{-1} the height of the ground part of a plant decreased relative to control plants. *Avéna satíva* had a significant phytotoxic effect at petroleum concentrations starting from 10 000 mg kg^{-1}. The petroleum concentration up to 20 000 mg kg^{-1} had no visible impact on the root weight. The weight of the ground part changed at the same rate as the root weight at different concentrations. The diminution of weight was only noticeable at 10 000 and 20 000 mg kg^{-1} and the phytotoxic effect was 20.7 and 35.6% respectively. The pollutant concentration of 20 000 mg kg^{-1} shows the maximal soil toxicity in Variant 1 by all studied indexes (34.8–40.9%). The application of probiotics in Variant 1 shows a decrease in soil toxicity. The values of the phytotoxic effect were in the range from –1.2 to 15.1%, which was not significant (less than 20%).

The research results of *Avéna satíva* growing on the 30th day after soil pollution (Variant 2) showed some decrease in phytotoxic effect compared to Variant 1. The values of the phytotoxic effect were in the range of 0.0 to 35.6%. The soil toxicity was not significant (less than 20%) at all studied pollutant concentrations by all studied indexes, except seed emergence and roots length. The *Avéna satíva* showed a significant phytotoxic response for these indicators at a petroleum concentration of 20 000 mg kg^{-1}. Thus, the soil on day 30, after contamination did not induce a toxic response of *Avéna satíva* at any of the concentrations tested. The results of probiotic application in Variant 2 showed the decreasing of phytotoxic effect about three times by all studied indexes and petroleum concentrations. Thus, the phytotoxic effect in Variant 2 after the use of probiotics was insignificant (–0.5...10.3%).

Table 2. Phytotoxic effect of polluted soil on *Avéna satíva* before and after probiotic treatment

Time of petroleum pollution	Concentration of petroleum products, mg kg^{-1}	Phytotoxic effect, %									
		By seed emergence		By roots length		By roots weight		By ground part length		By ground part weight	
		Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]	Before[1]	After[2]
Variant 1	1 000	15.5	1.5	2.3	0.2	3.4	–1.2**	8.7	1.1	1.4	0.5
	2 000	16.9	3.5	12.4	5.1	5.1	0.6	10.7	5.2	9.4	1.1
	5 000	**20.8***	3.5	**22.2***	6.5	5.1	2.2	18.8	3.6	13.8	1.5
	10 000	**23.9***	7.8	**36.0***	10.2	5.9	2.3	**25.5***	8.9	**19.6***	12.2
	20 000	**40.9***	10.5	**40.1***	12.3	**35.6***	4.9	**46.0***	8.9	**34.8***	15.1
Variant 2	1 000	7.5	1.2	3.3	0.2	2.2	–1.2**	–0.4**	–4.2**	2.7	0.2
	2 000	13.0	5.2	7.9	0.8	0.0	–0.5**	2.2	–3.2**	8.0	0.5
	5 000	18.1	7.8	9.5	3.6	9.5	0.9	3.2	0.5	3.6	1.1
	10 000	17.8	8.1	11.5	5.2	16.8	1.5	4.1	0.9	5.3	1.6
	20 000	**35.6***	10.3	19.2	7.1	**20.7***	4.9	9.9	1.1	11.6	3.3
Variant 3	1 000	1.5	–1.2**	–2.1**	–5.1**	1,6	0.5	3.4	–0.9**	1.9	–1.2**
	2 000	–6.2**	–5.2**	9.6	–1.2	4.7	3.5	1.7	1.2	4.6	–0.5**
	5 000	–8.5**	–10.5**	2.1	0.6	7.9	3.9	9.1	3.3	1.0	–0.5**
	10 000	1.5	0.5	6.4	1.2	6.3	2.8	6.8	3.2	3.7	1.2
	20 000	**43.9***	1.2	10.7	3.1	13.4	4.9	4.0	3.5	15.7	7.8

*The phytotoxic effect of more than 20% was considered significant.
**Negative values of the phytotoxic effect indicate the stimulation of plant growth and development under the influence of the studied factors.
[1]Phytotoxic effect before probiotic application.
[2]Phytotoxic effect after probiotic application.

The research results of *Avéna satíva* growing in Variant 3 showed insignificant soil toxicity by all studied indexes. The values were in the range from –8.5 to 43.9%. Only at the petroleum concentration of 20 000 mg kg^{-1} phytotoxic effect by seed emergence was significant – 43.9%. The phytotoxic effect increased by 11–13% at an initial pollutant concentration of 20 000 mg kg^{-1}. The petroleum products at studied concentrations did not influence the ground part and root system of *Avéna satíva*, growing on the 180th day after pollution. In this case, the phytotoxic effect was not higher than 16%. Thus, in Variant 3, polluted soil affects only the seed emergence of *Avéna satíva* starting at 20 000 mg kg^{-1} and had no impact on the biometric indexes of *Avéna satíva* at any studied concentration. The probiotic use in Variant 3 reduced the phytotoxic effect (up to 7.8%) and even had the stimulation effect of *Avéna satíva* growth by seed emergence (–1.2...–10.5%) and ground part weight (–0.5...–1.2%) at petroleum concentrations less than 5 000 mg kg^{-1}.

Therefore, with the increasing time of soil pollution, the phytotoxic effect of *Avéna sativa* decreased by the indexes of roots length, roots weight, ground part length, and ground part weight, except for seed emergence. For *Avéna sativa*, the soil was toxic only on the 2nd day after pollutant application at concentrations 10 000 and 20 000 mg kg^{-1} by all studied indexes. The research results showed a decrease in phytotoxic effect and even in some variants stimulation effect of *Avéna sativa* by the indexes of seed emergence, roots length, roots weight, underground part length, and ground part weight due to the use of probiotics.

Content of petroleum products in the soil and determination of the optimal probiotic concentration

The research on petroleum content in the soil at different probiotic concentrations and natural soil cleaning (Control) is shown in Table 3. The research results showed that the efficiency of soil cleaning from petroleum products in natural conditions was in the range of 18 to 41% depending on the initial pollutant concentration. With increasing initial pollutant concentration, we observed a decrease in the soil cleaning efficiency in natural conditions. Thus, in natural conditions, at an initial pollution concentration of 1 000 mg kg^{-1}, the petroleum content decreased up to 590 mg kg^{-1} (by 41%); at the initial pollution concentration of 2 000 mg kg^{-1} – decreased up to 1 240 mg kg^{-1} (by 38%); at the initial pollution concentration of 5 000 mg kg^{-1} – decreased up to 3 250 mg kg^{-1} (by 35%); at the initial pollution concentration of 10 000 mg kg^{-1} – decreased to 7 300 mg kg^{-1} (by 27%); at the initial pollution concentration of 20 000 mg kg^{-1} – decreased up to 16 400 mg kg^{-1} (by 18%). That was, then lower initial petroleum concentration in the soil, the natural processes of soil cleaning were better, the lower amount of petroleum products keep in the soil.

Table 3. Content of petroleum products (± standard error, mg kg^{-1}) in the soil before and after probiotic treatment

Initial petroleum concentration in the soil, mg kg^{-1}	Content of petroleum products, mg kg^{-1}			
	Control (remediation in natural conditions)	Probiotic use, dilution 1:10	Probiotic use, dilution 1:100	Probiotic use, dilution 1:1 000
1 000	590 ± 0.32	140 ± 0.20	220 ± 0.17	450 ± 0.22
2 000	1 240 ± 0.55	360 ± 0.38	520 ± 0.26	1 040 ± 0.60
5 000	3 250 ± 0.60	1 000 ± 0.27	1 500 ± 0.42	2 950 ± 0.45
10 000	7 300 ± 0.81	2 500 ± 0.35	3 200 ± 0.55	7 000 ± 0.68
20 000	16 400 ± 0.70	6 200 ± 0.54	10 400 ± 0.80	15 600 ± 0.54

The probiotic efficiency for the reduction of phytotoxic effect for the plants was established by the previous stages of our research. The different probiotic concentrations (1:10; 1:100; 1:1 000) were studied for the practical use of probiotics to remediate petroleum-polluted soil. The research results show that the greatest efficiency of soil cleaning from petroleum products observe at the probiotic concentration of 1:10 for all studied initial concentrations of pollutants. At all studied initial concentrations, the content of petroleum products decreased by 69–86%. The efficiency of probiotic use at concentration 1:10 was higher by 45–51% comparative with soil remediation in natural conditions. The results of probiotic use at concentration 1:100 showed a decrease in petroleum product content by 7–21%. The lowest efficiency of probiotic application was at a concentration of 1:1 000, content of petroleum products in the soil at all studied initial concentrations of pollutant decreased by 22–55%.

For all studied probiotic concentrations, results showed a decrease in the efficiency of soil cleaning from petroleum products with the increasing initial concentration of pollutants. Thus, at the initial concentration of pollutant 1 000 mg kg^{-1} content of petroleum products in the soil decreased by 55–86%; at the initial concentration of pollutant 2 000 mg kg^{-1} – by 48–82%; at the initial concentration of pollutant 5 000 mg kg^{-1} – by 41–80%; at the initial concentration of pollutant 10 000 mg kg^{-1} – by 30–75%; at the initial concentration of pollutant 20 000 mg kg^{-1} – by 22–69%.

Experiment showed high-efficiency probiotic use in the soil remediation from petroleum products in comparison with soiled cleaning in natural conditions. The probiotic concentration 1:10 was the most effective at all studied initial concentrations of pollutants. The reduction of probiotic concentration leads to a decrease in the efficiency of the soil cleaning from petroleum products.

Discussion

Our findings correspond to other studies conducted by Steliga and Kluk (2020) and Haider *et al.* (2021). Thus, Haider *et al.* (2021) have shown that petroleum hydrocarbons significantly induce severe phytotoxicity and cause inhibition in seed germination, seedling development, and photosynthesis activity in plants. Research results by Steliga and Kluk (2020) showed reducing in root length of *Lepidium sativum*, *Sinapis alba* and *Sorghum saccharatum* by 65.1, 42.3 and 47.3%, respectively, with increasing petroleum hydrocarbon concentration in the soil by 7791 mg kg^{-1}.

The microbial remediation can completely mineralize organic pollutants into carbon dioxide, water, inorganic compounds and cell proteins, or convert complex organic pollutants into other simpler organics (Das, Chandran, 2011). Microorganisms can utilize petroleum hydrocarbons as their only source of carbon, allowing them to degrade organic pollutants in the soil. Microorganisms can destroy 62–75% of petroleum hydrocarbons in the soil in 150 to 270 days According to previous studies (Cai *et al.*, 2016; Iqbal *et al.*, 2019), most microorganisms and plants are suitable for soil remediation. Studies by Varjani and Upasani (2016), Pi *et al.* (2018) and Yuan *et al.* (2018) have demonstrated that bacteria, including *Rhodococcus sp.*, *Pseudomonas sp.*, and *Scedosporium boydii*, can degrade petroleum contaminants. Hydrocarbons are mostly degraded by bacteria via aerobic pathways. The pollution concentration dropped by 14 and 8%, respectively, after 45 days of degradation by *Pseudomonas aeruginosa* (Zhang *et al.*, 2020). *S. changbaiensis* and *P. stutzeri* may decompose 39.2 ± 1.9% and 47.2 ± 1.2% of TPH in soil, respectively within 30 days (the initial petroleum concentration is 1 026 ± 50 mg kg^{-1}) (Li *et al.*, 2020). *T. versicolor* can degrade 50% of TPH within 280 days (the initial petroleum content of the soil is 1 727 mg kg^{-1}) (Lladó *et al.*, 2012). Research results of Christopher *et al.* (2021) found that 61.80% of total petroleum hydrocarbon removal efficiency in treated soil by surface-modified lipopeptide biosurfactant produced using *Bacillus Malacitensis*. The germination of seeds increased from 60 to 100% and the phytotoxicity of root and shoot was reduced from 89.50 and 88.45% to12.55 and 11.87% respectively.

Our previous studies (Pisarenko *et al.*, 2019; Pysarenko *et al.*, 2021) have shown the possibility of probiotic application for soil cleaning of disposal sites and the use of antibacterial properties of probiotics (based on *Bacillus subtilis*) in agrocenosis. The first report about the utilization of petroleum hydrocarbons by *Bacillus subtilis* strains was made by Lily *et al.* (2009). Maximum degradation of petroleum compounds was approximately 84.66% after 24 hours and continued up to 28 days. These findings inferred that *Bacillus subtilis* strains are a very efficient degrader of petroleum hydrocarbons and it can degrade a wide range of petroleum hydrocarbons including naphthalene, anthracene, and dibenzothiophene. Therefore, *Bacillus subtilis* strains could serve as a better candidate for bioremediation of PAHs contaminated soil. Research results of Tao *et al.* (2016) revealed the promising potential of *Bacillus subtilis* strains for application to the degradation of crude oil. The degradation ratio (85.01%) was superior to the indigenous bacterial consortium (71.32%) after 7 days of incubation when the ratio of inoculation size of indigenous bacterial consortium and *Bacillus subtilis* was 2:1.

Our research confirms results by Cai *et al.* (2016) and Iqbal *et al.* (2019) and shows that the remediation potential of microorganisms is rapidly negatively affected when the concentration of petroleum pollutants in the soil increases. Thus, the efficiency of microbial remediation from petroleum products with an increasing initial concentration of the pollutant (from 1 000 to 20 000 mg kg^{-1}) decreases from 86 to 69%.

Conclusion

1. Petroleum pollution has an ambiguous impact on *Pisum sativum* and *Avéna satíva* at different times after pollution. In the initial phase, the polluted soil has no significant influence on *Pisum sativum*. Only on the 30th day after pollutant introduction does soil become toxic at a concentration of 5 000 and 10 000 mg kg^{-1} for *Pisum sativum*. Soil toxicity grows over time of petroleum pollution in this case. For *Avéna satíva* soil become toxic at once after pollution only and does not increase with time of petroleum pollution.
2. The phytotoxic effect of *Pisum sativum* and *Avéna sativa* decrease by the indexes of seed emergence, roots length, roots weight, the ground part length and ground part weight due to the use of probiotics.
3. Determinate the high efficiency of biological remediation by probiotics in comparison with soil cleaning in natural conditions. Probiotic concentration 1:10 is the most effective of all studied initial concentrations of pollutants. Reducing probiotic concentration leads to a decrease in the efficiency of soil cleaning from petroleum products.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this paper.

Author contributions

PP – the author of the idea, critical revision, and approval of the final manuscript.
MS –performed the data analysis, studied the conception and interpretation of data.
AT – the corresponding author, discussion of the results and drafted the manuscript.
YT –collected data and acquisition of data.
ST – made literature search.
All authors read and approved the final manuscript

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STORAGE STABILITY OF CHICKEN PATTIES AFTER TREATMENT WITH POMEGRANATE, POTATO AND APPLE PEEL EXTRACTS

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ABSTRACT. The goal of this study was to evaluate the comparative effect of alcoholic extracts of pomegranate peel powder (POMPEP), potato peel powder (POTPEP) and apple peel powder (APPPEP) on oxidative and microbial stability of chicken meat patties during frozen storage at −18 °C for 60 days. The formulations of meat products were treated with different freeze-dried alcoholic peel extracts (T1 – control; T2 – 1% POMPEP; T3 – 1% POTPEP and T4 – 1% APPPEP). Peroxide value (PV), thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), pH, total aerobic bacteria (TAB), and psychrophilic bacteria (PSB) counts were determined after 0, 15, 30, 45 and 60 days of storage. The addition of extracts led to a significant decrease in PV (13.62–26.82%), compared with control. Regarding the secondary oxidation products, the TBARS values of different patties decreased in the order of POMPEP > APPPEP > POTPEP > Control. FFA values of the POTPEP treated patties were significantly higher than in other extracts, whereas there were no significant differences in the pH values among studied extracts. TAB and PSB values of the treated patties were less than the maximum allowed value.

Introduction

Chicken meat and its products such as chicken patties occupied an important place in daily human food and have been increasing worldwide because of its excellent nutritional and quality properties, as they have low-fat contents and high polyunsaturated fatty acids (Darwish *et al.*, 2012; Cagdas, Kumcuoglu, 2015, Santos *et al.*, 2019; Chinprahast *et al.*, 2020). Chicken meat patties are susceptible to oxidative changes and microbial growth during frozen storage, and fat autoxidation induced by an aerobic conditions while microbial growth can cause by many factors such as increased level of moisture, protein, polyunsaturated fatty acids, simple nutrients (such as non-protein-nitrogen compounds) and pH (Santana Neto *et al.*, 2021). Both of the deterioration indicators above are the major reasons for reduced shelf life and quality value in chicken meat patties during storage (Jiang, Xiong, 2016; Turgut *et al.*, 2017). Due to using of synthetic antioxidant agents has been found to exhibit toxicological effects, plant-origin phenolics are natural sources of antioxidants and are considered by consumers as better and safer than synthetic agents (Naveena *et al.*, 2008; Devatkal *et al.* 2011). Therefore, peels of fruit are produced as waste during fruit processing industry and contain phenolic compounds with antioxidant and antimicrobial activities can be used to minimize changes in quality attributes of the chicken patties during processing and storage and also, they have acceptance by consumers (Vaithiyanathan *et al.*, 2011; Bazargani-Gilani *et al.*, 2015).

Nowadays, the application of natural-origin antioxidants and antimicrobial extracts in the chicken meat industry is largely increased (Sharma, Yadav, 2020). One of the excellent sources of bioactive compounds is food technology by-products such as pomegranate, apple and potato peels. Furthermore, the peels contain valuable compounds compared with other different parts (Rahnemoon *et al.*, 2021). Tannins, anthocyanins and flavonoids, ellagitannins, proanthocyanidin, gallic acid, punicalagin, ellagic acid, quercetin, p-coumaric acid, caffeic acid, vanillic acid and other phenolic compounds are present in pomegranate, apple, and potato, especially in the peel and are represent bioactive phenolic compounds (Kanatt *et al.*, 2005; Qu *et al.*, 2012; Sabally *et al.*, 2016; Colle *et al.*, 2019; Barkhordari, Bazargani-Gilani 2021; Das *et al.*, 2021).

Recently, antioxidant and antibacterial effects of many plant peel extracts in different chicken meat products had been documented (Kanatt *et al.*, 2010; Mantihal *et al.*, 2021). However, there is little published study available on the incorporation of ethanolic extract of pomegranate, apple, and potato peels in chicken patties during frozen storage, therefore, the present research was undertaken to find out the influence of those extracts as a natural antioxidant and antibacterial on some quality characteristics of chicken patties samples stored in LDPE (low density polyethylene) bags under freezing at −18 °C for 60 days.

Materials and Methods

Sample preparation

Iraqi whole chicken meat (freshly slaughtered and deboned) was purchased from the local chicken market; pomegranate (*Punica granatum L.*), green apple (*Pyrus malus L.*) and potato (*Solanum tuberosum*) were procured from a local market in Mosul city, Ninevah governorate, Republic of Iraq. All chemical materials used in the experiments research were of analytical grade.

Alcoholic extract powder preparation

The preparation of alcoholic extract powder for the peels of pomegranate, apple and potato was carried out according to the procedure described by Wafa *et al.* (2017). The fruits used in this research were washed under running water, cut manually by using a knife and peeled off. The obtained peels were further cut by a sharp knife into small pieces and air-dried at 60 °C till constant weight. Dried pieces were powdered using an electric grinder to a fine powder. The peels were lastly packed in polyethene bags and stored at freezing temperature before extraction. For extraction, each peel extract powder was soaked with 70% ethanol for 48 h in a water bath with shaking. The ratio of mixing was 1:20 w/v. After cooling and filtering the extracts, the supernatant of each alcoholic peel extract was concentrated in a vacuum rotary evaporator (IKA, Germany). The concentrate was freeze drying to obtain alcohol soluble powder which was stored in brown bottles until further use.

Preparation of chicken meat patties

Table 1 shows the different ingredients used in the chicken patties formulation, and they were prepared using chicken thigh and skin. Meat samples were ground twice at 12- and 5-mm plates respectively, by using a pilot mincer, ten kilograms of chicken meat were prepared to make chicken patties. Chicken meat formulation samples were treated as follows (Table 1): T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP). Thoroughly mixing was done between extracts and other components of each formulation of chicken meat patties. The moulding of meat patties (100 g) was made in a patty former. Packaging of each sample of chicken meat patties was conducted in LDPE bags and stored at freezing for 60 days at −18 °C. Each patty was withdrawn at 0, 15, 30, 45 and 60 days and tested for peroxide values (PV), thiobarbituric acid reactive substances (TBARS), free fatty acids (FFA), pH, total aerobic bacteria counts (TAB) and psychrophilic bacteria counts (PSB), with three replicates.

Table 1. Chicken meat patties formulations were used in this research

Ingredient type, %	Treatments			
	T1	T2	T3	T4
Minced chicken thigh	80	80	80	80
Minced chicken skin	10	10	10	10
Water	8.9	7.9	7.9	7.9
Dry mixture of spice	0.1	0.1	0.1	0.1
Salt	1	1	1	1
POMPEP		1		
POTPEP			1	
APLPEP				1

T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP).

Determinations

Peroxide value

The peroxide number of chicken patties samples was performed using the titration method described by AOAC (2010), with some modification and expressed in milliequivalents per kilogram (meq O_2 kg^{-1}) of the sample. A chicken patties 5 g sample was weighed and mixed with 30 ml glacial acetic acid-chloroform solution as a mixture ratio of 2:3 in a 250 ml glass-stoppered flask. The mixture was thoroughly agitated for 3 min. Next, 0.5 ml of saturated potassium iodide (KI) solution was put into the flask. The mixture was left in the dark for 10 minutes, followed by the addition of 30 ml of distilled water and starch solution indicator with a concentration of 1%. The titration of the flask contents with 0.01 N sodium thiosulphate standard solution was conducted till the endpoint was reached (disappearance of colour). The peroxide results were expressed as milliequivalents (meq O_2 kg^{-1}) of a sample using Formula 1.

$$PV\ (meqO_2\, kg-^1) = \frac{T\ x\ N}{W} \times 1000, \tag{1}$$

where
T − ml of the titre used.
N − normality of the titre solution.
W − sample weight.

Thiobarbituric acid reactive substances

This test was estimated by the colourimetric procedure used by Sharma *et al.* (2017b), with suitable modifications. A chicken meat patties sample was blended using a commercial blender and then two grams of the blended meat sample was mixed with

2 ml of a 30% (v/v) trichloroacetic acid solution containing 8 ml of phosphate buffer solution at pH 7. The resulting mixture was homogenized and then filtered into a volumetric flask and made up to 25 ml with distilled water. Then, a 3 ml aliquot of the filtrate was transferred into test tubes containing an equal volume of 2–thiobarbituric acid reagent (0.005 M). Tubes were heated at 80 °C for 35 min, followed by cooling in a cold-water bath (10 °C) for 10 min. The absorbance was determined at 532 nm using UV-VIS spectrophotometer, and TBARS value was calculated according to Formula 2.

$$\text{TBARS, mg MDA kg}^{-1} = (\text{Abs.} \times 5.2), \quad (2)$$

where
Abs. − sample absorbance value.
MDA − malonaldehyde.

Free fatty acid

FFA value was measured according to the procedure suggested by Kalem *et al.* (2018). 25 g of the chicken patty was dissolved in 137 ml of chloroform solvent under stirring in the presence of anhydrous sodium sulphate. The resultant was filtered by Whatman filter paper to obtain the chicken particles' free filtrate. Five drops of ethanolic phenolphthalein indicator (1%) were mixed with filtrate. Before titration, with 1 N potassium hydroxide (KOH) until the pink colour appears. FFA was computed and expressed as seen in Formula 3.

$$\text{FFA, \%} = \frac{(\text{A} \times \text{N} \times 28.2)}{\text{W}}, \quad (3)$$

where
A − ml of titre consumed.
N − normality of titre consumed.
W − weight of the sample.

pH

For pH estimation in the chicken patties, a 5 g sample was homogenized in 20 ml of distilled water using a blender (Waring Commercial Blendor®, USA) for 5 min. A standardized pH meter was used for analysis (Nardoia *et al.*, 2018).

Microbiological analyses

Microbiological analyses were evaluated according to the methodologies described by Harrigan and McCance (1976). For that, a 25 g aliquot of the chicken patties was blended with 225 ml 0.1% peptone water (Oxoid, UK) under sterile conditions, to obtain 1:10 dilution. Serial dilutions were prepared and 0.1 ml from appropriate dilutions were plated in triplicate on the specific media as follows: the total aerobic and psychrophilic bacteria were counted on nutrient agar (Hi Media, Mumbai, India), after incubation at 37 °C for 72 h and at 7 °C for 7 days, respectively. The average number of colonies was computed and multiplied by the reciprocal of dilution; the results were given as the log number of colony-forming units per gram of chicken patty (log10 cfu g^{-1}).

Statistical analysis

The effects of type extract (three different plant peel extracts) and storage time as main experiment factors were analyzed, and data were subjected to analysis of variance (ANOVA) by using SAS (Proc. GLM, SAS program, version 9.3, SAS Institute, 2012). Statistical differences among least-square means were tested with Duncan's multiple comparison *post-hoc* test. Statistically significant differences were considered at P <0.05. All the determinations were conducted in triplicate.

Results and Discussion

Table 2 shows changes in peroxide (PV) values of various chicken patties samples during the frozen storage period. At zero-day storage, the initial value of PV of the control was the same in other treated samples 0.73 meq kg^{-1}. The chicken patty formulations exhibited PV values varying from 0.73 to 6.97 meq kg^{-1}. The greatest value was found to be in control as 6.97 meq kg^{-1}. On storage period 60 days, POMPEP and POTPEP and APPPEP had significantly lower PV values (P <0.05), than the Control. This research shows that the inclusion of plant peel extracts in meat products slows down the oxidation process. There were significant differences (P <0.05) among POMPEP and POTPEP and APPPEP in the last time of storage. Antioxidant effect of POMPEP, POTPEP and APPPEP due to their polyphenolic compounds, which prevent the formation of free radicals, and then delay the onset of the autooxidation in chicken patties (Akarpat *et al.*, 2008). Our findings were in accordance with Turgut *et al.* (2017), Shahamirian *et al.* (2019) and Haque *et al.* (2020).

Table 2. Effect of POMPEP, POTPEP and APPPEP (1%) on peroxide value of chicken patties during storage at −18 °C for 60 days

Type of extract	Peroxide value, meq kg^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.73 ± 0.08^{Ae}	3.09 ± 0.10^{Ad}	4.64 ± 0.12^{Ac}	6.53 ± 0.03^{Ab}	6.97 ± 0.05^{Aa}
T2	0.73 ± 0.04^{Ae}	2.06 ± 0.07^{Cd}	3.06 ± 0.10^{Cc}	4.85 ± 0.05^{Db}	5.10 ± 0.13^{Da}
T3	0.73 ± 0.02^{Ae}	2.62 ± 0.03^{Bd}	3.44 ± 0.04^{Bc}	5.61 ± 0.11^{Bb}	6.02 ± 0.03^{Ba}
T4	0.73 ± 0.03^{Ae}	2.20 ± 0.22^{Cd}	3.17 ± 0.06^{Cc}	5.16 ± 0.09^{Cb}	5.47 ± 0.07^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Changes in TBARS values throughout storage at −18 °C for 60 days are shown in Table 3. The changes in TBARS readings of the remaining formulations except for the control sample followed a similar trend. Extract free chicken patties sample (Control) had the maximum TBARS values 2.738 mg MDA kg^{-1}, whereas POMPEP infused chicken patties had the minimum TBARS value 0.484 mg MDA kg^{-1}.

Table 3. Effect of POMPEP, POTPEP and APPPEP (1%) on TBARS of chicken patties during storage at −18 °C for 60 days

Type of extract	TBARS, mg MDA kg^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.421 ± 0.003^{Ae}	1.045 ± 0.009^{Ad}	1.591 ± 0.003^{Ac}	2.636 ± 0.005^{Ab}	2.738 ± 0.008^{Aa}
T2	0.421 ± 0.005^{Ae}	0.484 ± 0.005^{Dd}	0.679 ± 0.002^{Dc}	1.006 ± 0.007^{Db}	1.201 ± 0.004^{Da}
T3	0.421 ± 0.005^{Ae}	0.733 ± 0.009^{Bd}	1.037 ± 0.006^{Bc}	1.544 ± 0.003^{Bb}	1.739 ± 0.005^{Ba}
T4	0.421 ± 0.004^{Ae}	0.593 ± 0.008^{Cd}	0.741 ± 0.009^{Cc}	1.162 ± 0.016^{Cb}	1.357 ± 0.003^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

The reduction percentage of TBARS on chicken meat samples containing three different extracts was expressed as 56.14% in T2, 36.49% in T3 and 50.44% in T4 at the end of the duration of storage in comparison to T1. Based on these findings, POMPEP were much more effective than the other extracts in reducing the development of TBARS. Similar to our results, significantly lower TBARS during frozen storage of Shirazi thyme, cinnamon, and rosemary incorporated beef burgers were reported by Gahruie *et al.* (2017) and clove extract added beef patties by Zahid *et al.* (2020).

Effects of POMPEP, POTPEP and APPPEP on the free fatty acid values of frozen stored chicken meat patties are shown in Table 4. The results exhibited that the lowest initial FFA value found in the T2 and T4 (0.22%, (P <0.05)), whereas the highest initial FFA value (0.37%), found in the T1 (P <0.05). The FFA values of chicken meat samples gradually increased with extended storage days, with POMPEP-treated meat having the lowest value (P <0.05) at 60 days of frozen storage. This increase could be the result of lipid gradually oxidizing during storage (Baker *et al.*, 2013; Reddy, 2017).

Table 4. Effect of POMPEP, POTPEP and APPPEP (1%) on free fatty acids of chicken patties during storage at −18 °C for 60 days

Type of extract	Free fatty acids, %				
	Frozen storage time, day				
	0	15	30	45	60
T1	0.37 ± 0.113^{Ae}	0.70 ± 0.026^{Ad}	0.93 ± 0.026^{Ac}	1.06 ± 0.072^{Ab}	1.25 ± 0.062^{Aa}
T2	0.22 ± 0.095^{Ab}	0.27 ± 0.062^{Bb}	0.35 ± 0.070^{Cb}	0.49 ± 0.070^{Ca}	0.58 ± 0.036^{Ca}
T3	0.29 ± 0.079^{Ac}	0.39 ± 0.098^{Bc}	0.56 ± 0.056^{Bb}	0.67 ± 0.078^{Bb}	0.82 ± 0.020^{Ba}
T4	0.22 ± 0.046^{Ac}	0.29 ± 0.096^{Bc}	0.40 ± 0.036^{Cb}	0.53 ± 0.036^{Ca}	0.60 ± 0.020^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

pH values of chicken patties formulations are displayed in Table 5. All chicken patties samples had pH values ranging from 6.46 to 6.64 initially before frozen storage. The pH values of chicken patties with different treatments declined slightly within the storage period. The bacterial activity during thawing, which consumes sugar and produces acids, may be responsible for the reduction in pH levels during frozen storage (Gahruie *et al.*, 2017). At any storage time intervals at −18 °C, the pH values of chicken patties samples with POMPEP and APPPEP differed significantly (P <0.05) from control (Table 5). The results agreed with Özer *et al.* (2018) in mechanically deboned chicken patties and Haque *et al.* (2020) in beef muscle.

Table 5. Effect of POMPEP, POTPEP and APPPEP (1%) on pH of chicken patties during storage at −18 °C for 60 days

Type of extract	pH				
	Frozen storage period, day				
	0	15	30	45	60
T1	6.64 ± 0.046^{Aa}	6.62 ± 0.026^{Aa}	6.61 ± 0.053^{Aa}	6.60 ± 0.044^{Aa}	6.58 ± 0.085^{Aa}
T2	6.46 ± 0.070^{Ba}	6.45 ± 0.061^{Ca}	6.45 ± 0.053^{Ba}	6.44 ± 0.036^{Ba}	6.42 ± 0.036^{Ba}
T3	6.55 ± 0.020^{Aba}	6.53 ± 0.017^{Ba}	6.53 ± 0.026^{ABa}	6.52 ± 0.053^{ABa}	6.50 ± 0.017^{ABa}
T4	6.51 ± 0.062^{Ba}	6.50 ± 0.020^{BCa}	6.49 ± 0.075^{Ba}	6.49 ± 0.070^{Ba}	6.46 ± 0.052^{Ba}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Number of total aerobic (TAB) and psychrophilic bacteria (PSB) as $\log_{10}$ cfu g^{-1} in chicken meat patties samples during storage for 60 days at −18 °C conditions are presented in Tables 6 and 7, respectively. TAB and PSB counts were found in freshly made chicken patties before freezing to be 3.52 ± 0.070 and 0 ± 0, respectively. Low initial TAB counts and the absence of PSB in the sample could be due to sanitary processing techniques and the antibacterial roles of plant peel extracts (Sharma *et al.*, 2017a; Shahamirian *et al.*, 2019).

On the 0 day of the frozen storage period, there were no significant differences (P >0.05) in TAB and PSB counts among the chicken patty samples. TAB and PSB increased during storage while POMPEP, POTPEP, and APPPEP antibacterial characteristics were confirmed. In comparison to the control T1, patties that contained extract had the lowest TAB and PSB at the end of the storage period. The presence of polyphenols, which have an antimicrobial effect by reacting with sulfhydryl groups in proteins and rendering them inaccessible to microbes, could explain the antibacterial activity (Wolfe, Liu, 2003; Hayrapetyan *et al.*, 2012; Akyol *et al.*, 2016). In general, the reduction in number of both TAB and PSB with meat patties containing added natural antibacterials throughout frozen storage is mainly due to the presence of polyphenolic compounds in considerable amounts. Antimicrobial activity of those compounds has included many mechanisms such as denaturation of enzymes, chelating with carbohydrates, vitamins, and minerals, changing the structure and function of the bacterial membrane (Hayrapetyan *et al.*, 2012; Baker *et al.*, 2013).

Table 6. Effect of POMPEP, POTPEP and APPPEP (1%) on Total aerobic bacteria count counts of chicken patties during storage at −18 °C for 60 days

Type of extract	Total aerobic bacteria count, log10 cfu g^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	3.52 ± 0.070^{Ae}	3.87 ± 0.036^{Ad}	4.10 ± 0.030^{Ac}	4.60 ± 0.070^{Ab}	4.71 ± 036^{Aa}
T2	3.52 ± 0.070^{Ac}	3.62 ± 0.096^{Bc}	3.80 ± 0.082^{Bb}	3.99 ± 0.017^{Ba}	4.01 ± 0.085^{Ba}
T3	3.52 ± 0.044^{Ad}	3.69 ± 0.095^{Bc}	3.82 ± 0.035^{Bb}	4.07 ± 0.053^{Ba}	4.11 ± 0.026^{Ba}
T4	3.52 ± 0.035^{Ac}	3.66 ± 0.053^{Bbc}	3.82 ± 0.106^{Bab}	4.00 ± 0.234^{Ba}	4.04 ± 0.078^{Ba}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Table 7. Effect of POMPEP, POTPEP and APPPEP (1%) on psychrophilic bacteria count counts of chicken patties during storage at −18 °C for 60 days

Type of extract	Psychrophilic bacteria count, log_{10} cfu g^{-1}				
	Frozen storage time, day				
	0	15	30	45	60
T1	0 ± 0^{Ae}	1.37 ± 0.061^{Ad}	1.62 ± 0.108^{Ac}	2.09 ± 0.079^{Ab}	2.36 ± 0.030^{Aa}
T2	0 ± 0^{Ad}	1.15 ± 0.056^{Bc}	1.24 ± 0.050^{Bc}	1.49 ± 0.072^{Cb}	1.59 ± 0.061^{Da}
T3	0 ± 0^{Ad}	1.27 ± 0.139^{ABc}	1.39 ± 0.104^{Bc}	1.80 ± 0.140^{Bb}	2.00 ± 0.060^{Ba}
T4	0 ± 0^{Ae}	1.20 ± 0.035^{Bd}	1.31 ± 0.026^{Bc}	1.66 ± 0.044^{BCb}	1.81 ± 0.106^{Ca}

Least square means ± standard error (*se*) followed by the different capital letters in the columns and lower-case letters in the rows are significantly different (LSM with Duncan's test; P <0.05).
T1 − no peel extract was added (Control), T2 − 1% of pomegranate peel extract powder (POMPEP), T3 − 1% of potato peel extract powder (POTPEP), T4 − 1% of apple peel extract powder (APPPEP)

Conclusion

Fruit processing operations waste different plant parts such as peel, containing important antioxidant and antibacterial compounds (polyphenols). These compounds can be used for extraction and extract can be used on meat products to improve products storability. The inclusion of alcoholic extracts of pomegranate, potato, and apple peels at a 1% ratio to chicken patties formulations stored under frozen conditions minimized oxidetive changes of lipids as significantly lowered physicochemical parameters (PV, TBARS, FFA, pH). Moreover, those extracts had a significant inhibition effect against bacterial growth.

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Conflict of interest

The authors declare that they have no conflict of interest relating to the publication of this research work.

Author contributions

EAT 50%, OHA-J 50% − study conception and design;
EAT 50%, OHA-J 50% − acquisition of data;
EAT 50%, OHA-J 50% − analysis interpretation, writing, and approval of the final manuscript.

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EPA ZOOTEHNIKATEADUSKONNAST EMÜ VETERINAARMEDITSIINI JA LOOMAKASVATUSE INSTITUUDIKS

1951 – Eesti Põllumajanduse Akadeemia

Zootehnikateaduskond alustas tööd kolme kateedriga: põllumajandusloomade aretus (juhataja kt dots Cerelius Ruus, hiljem dots Aarne Pung), põllumajandusloomade söötmine (juhataja dots August Muuga), eriloomakasvatus (juhataja dots Cerelius Ruus. 1958. aastast toodi zootehnikateaduskonda ka bioloogia ja orgaanilise keemia kateeder (juhataja prof August Siim). Teaduskonna koosseisu kuulus aastatel 1953–1958 ka piimasaaduste tehnoloogia osakond (juhataja dots Jaan Klaar).

1955. aastal loodi võimalus omandada loomakasvatusalane kõrgharidus ka kaugõppes; avati kaugõppeteaduskond nelja osakonnaga; agronoomia-, **zootehnika-,** hüdromelioratsiooni- ja põllumajanduse mehhaniseerimise osakond.

1957. aastal õppis EPAs 1694 üliõpilast sh zootehnika erialal 241, lõpetas 21 õpetatud zootehnikut. 1958. aastast liideti Zootehnikateaduskonnaga ka bioloogia ja orgaanilise keemia kateeder.

Kõikide erialade üliõpilased, kes astusid statsionaarsesse õppesse, saadeti esimesel õppeaastal septembri algul kolhoosidesse/sovhoosidesse terveks kuuks sügis-/põllutöödele. Selline kord kehtis 1980-ndate aastate lõpuni.

Teaduskond	**Erialad**	**Üliõpilaste arv**
Agronoomiateaduskond. Dekaan prof August Marland	Agronoomia	234
	Aiandus	97
Zootehnikateaduskond. Dekaan dots Evald Peebsen	**Zootehnika**	**159**
	Piimasaaduste tehnoloogia	**25**
Veterinaariateaduskond. Dekaan dots Evald Peebsen	Veterinaaria	225
Hüdromelioratsiooni ja maakorralduse teaduskond. Dekaan dots Herbert Muischneek.	Maaparandus	25
	Maakorraldus	50
	Metsamelioratsioon	86
Metsamajanduse teaduskond Dekaan dots Teodor Krigul	Metsamajandus	165
	Metsatööstus	110
Põllumajanduse mehhaniseerimise teaduskond. Dekaan v.-õp Hermann Tamm	Põllumajanduse mehhaniseerimine	75
Kokku üliõpilasi		1251

1957. aasta 4. septembri postitemplit kandev kiri zootehnika eriala I õa üliõpilaselt:

Tere, kodused!

Oleme juba kolhoosis. Meie päralt on kolm tuba ja köök – tühi maja. Magame põrandal õlgedel. Lubati hiljem narid teha, aga ei tea, kas midagi välja tuleb. Täna hommikupoole tööle veel ei aetud ja praegu oleme kõik siruli. Ootame, millal supp valmis saab. Kokad teevad värskekapsasuppi. Meile toodi terve lammas, võid, piima, kurke. Täna hommikul käisime pohli toomas salatiks ja natuke saime seeni ka. Meid on praegu siin 25 inimest. Igaüks on ise kandist. Üks koguni Saaremaalt ja üks on venelane. Ei tea, kuidas see hakkama saab. Õhtupoolikul läheme arvatavasti lina kitkuma. Siin olevat igavene suur linapõld. Küll on kole, kui kogu aeg tuleb ainult lina kitkuda!

Me oleme igaveses kolkas. Valgast tükk maad kaugel ja keskus ka 10 km kaugusel. Meie õppejõud lubas küll kaubelda, et vahel kinno viiakse autoga st veoautoga. Me oleme Läti piiri ääres. Teispool maanteed on suur Läti kolhoos.

Neljapäev.

Oleme praegu lõunal. Kõht on nii täis, et ei jõua liigutadagi. Olid kapsad ja kartulid värske lihaga. Olen isegi piima jooma hakanud. Kogu hommikupoole katkusime lina. Käed on nii valusad. Päevanorm on 500 m^2. Pool on ära ja pool jääb õhtupoolikuks. Kole palju ikka küll. Seda lina on nii palju kah. Ei tea, millal otsa saab…! Ema, kirjuta ka mulle, aga tee seda kaunis kähku, sest ma ei tea, kui kaua kiri siia tuleb. Aadress on: Valga rajoon, Lenini-nimeline kolhoos, Kaagjärve külanõukogu, III brigaad (EPA).

Joonis 1. Üliõpilased ühismajandis kartuleid võtmas 1990. a (A. Tänavots)

1960. aastal moodustati EPAs liha- ja piimasaaduste tehnoloogia osakond ning piimasaaduste tehnoloogia eriala viidi Zootehnikateaduskonnast Veterinaariateaduskonda.

1961. aastal õppis EPAs 2348 üliõpilast sh Zootehnikateaduskonnas 240. Teaduskonnas avati vene osakond, kuhu tulid/võeti õppima soovijad ka väljastpoolt Eestit st NSV Liidu liiduvabariikidest.

Joonis 2. Zootehnikateaduskonna 1962. aasta lõpuaktusel peab kõne lõpetaja ja hilisem EPA 5. rektor Olev Saveli. Tagaplaanil EPA 2. rektor Minna Klement

1960-ndatel aastatel töötasid Zootehnikateaduskonnas õppejõududena põllumajandusloomade aretuse kateedris: prof Aarne Pung (pm-loomade aretus, veisekasvatus, üldloomakasvatus), dots Karl-Robert Kurm (veisekasvatus ja pm-loomade aretus), dots Leida Lepajõe (pm-loomade/lindude aretus), dots Harry Mauring (üldloomakasvatus, hobusekasvatus), dots Rein Teinberg (pm-loomade aretus ja geneetika), ass Ilme Nõmmisto (pm-loomade/lindude aretus).

Joonis 3. EPA põllumajandusloomade aretuse kateedri juhataja prof. Aarne Pung ja tema aspirant Olev Saveli ning vanemteadur Rein Teinberg (1966)

Põllumajandusloomade söötmise kateedris: prof August Muuga, dots Elmar Rätsep, dots Hilda Pruul, v-teadur/assistent Viivi Sikk, ass Hilda Mägi.

Eriloomakasvatuse kateedris: prof Cerelius Ruus (linnu-, sea-, lambakasvatus), prof Elmar Liik (sea-, lamba-, linnukasvatus), dots Edvard Meisner (sea-, lamba-, üldloomakasvatus), v-õp Harald Tikk (eriflooma-, linnu-, küülikukasvatus), v-õp Vilma Raudsepp (lamba-, küülikukasvatus).

Keemia kateedris: prof August Siim, dots August Männik, dots Heiti Jalviste, dots Vladimir Tali, v-õp Mall Reeben, v-õp Kalju Haldma, ass Erna Neufeld, ass Ants Nilson, ass Endel Tigane, Endel Järv (oli Kohtla-Järve Keemiatehnikumi dir asetäitja õppealal).

Alates 1964. aastast oli Zootehnikateaduskonnas õppeaeg 4 aastat ja 5 kuud. Esimesel kursusel õpetati ühiskonnateadusi (NLKP ajalugu, poliitiline ökonoomia, dialektiline ja ajallooline materialism, teadusliku kommunismi alused), üld- ja bioloogilisi aineid (vene keel ja võõrkeel, keemia, botaanika, zooloogia, füüsika, kõrgema matemaatika alused). Teisel kursusel alustati erialaste õppeainete õpetamist. **Zootehnika eriala üliõpilased õppisid järgmisi õppeaineid**: loomade anatoomia, histoloogia, füsioloogia, mikrobioloogia, taimekasvatus, rohumaaviljelus, põllumajandusloomade söötmine, biomeetria, tõuaretuse organiseerimine, põllumajandusloomade aretus, geneetika, veterinaaria alused, zoohügieen, veterinaarsünnitusabi kunstliku seemendusega, histoloogia ja embrüoloogia, veise-, sea-, linnu-, lamba-, hobuse- ja karusloomakasvatus, piimandus, liha- ja tapasaaduste tehnoloogia, mesindus, põllumajanduse ökonoomika, tootmise planeerimine, raamatupidamine ja statistika, loomakasvatushoonete ehitamine, põllumajandusliku tootmise mehhaniseerimine ja elektrifitseerimine, nõukogude riigi ja õiguse alused, teadusliku ateismi alused, kehaline kasvatus, tsiviilkaitse, ohutustehnika.

Teoreetiliste teadmiste kinnitamiseks ja praktiliste kogemuste omandamiseks toimusid erinevad suvepraktikad. I kursuse õppepraktikal/tööpraktikal omandati loomade hooldamise oskus, teadmised botaanikast ja zooloogiast ning sooritati traktoristi – masinisti kvalifikatsioonieksam sh omandati oskus juhtida roomiktraktorit.

II kursusel oli katsetehniline praktika; üliõpilased töötasid loomakasvatusalasel katsetööl õppejõudude juhendamisel. II kursusel sooritati autojuhi kvalifikatsioonieksam. Õppesõidud toimusid peamiselt veoautoga.

III kursusel oli brigadiripraktika; praktika toimus vabariigi parimates majandites ja oli jaotatud kaheks; suviseks ja talviseks.

IV kursusel oli menetluspraktika; üliõpilased töötasid sovhoosides/kolhoosides zootehniku asetäitjana või selektsionäärina. Enne praktikale minemist sooritati masinlüpsi instruktori kvalifikatsiooni eksam, mis sisaldas lüpsiaparaadi lahti võtmist ja töökorda panemist kiiruse peale.

Praktikat oli zootehnika erialal: I ja II kursusel – 10 nädalat, III ja IV kursusel 20 nädalat.

1964. aastal õppis EPAs 1645 üliõpilast sh Zootehnikateaduskonnas 177 üliõpilast, lõpetas 39 õpetatud zootehnikut. 1971. aastal õppis Zootehnikateaduskonnas 234 üliõpilast, lõpetajaid oli 41.

Zootehnikateaduskonna lõpetamine toimus diplomitööga või kompleks-riigieksamitega loomakasvatuses (põllumajandusloomade söötmine, aretus, eriloomakasvatus jne) ning ökonoomilistes ainetes (poliitiline ökonoomia, põllumajandusökonoomika, tootmise organiseerimine, statistika ja raamatupidamine).

Nõudlus õpetatud zootehnikute järele oli väga suur, sest Eesti NSV-s oli üle 700 suurmajandi ja loomakasvatuse spetsialiste vajasid ka tõuaretuse ja teadusliku uurimise asutused. Igal kevadel jäid lõpetajate nö tööle suunamisel paljude majandite ja asutuste soovid täitmata. Lõpetajate tööle suunamine/määramine toimus suunamiskomisjonide kaudu. Lõpetajad määrati tööle nende õppetulemuste paremusjärjestuse alusel st esimesena said nimekirjas olevate majandite/ettevõtete töökohtade hulgast valida endale sobiva töökoha teaduskonna kõige tublimad lõpetajad. Eelis oli ka lastega/lapsega vanematel. Pakutavate töökohtade juures oli kirjas ka palga suurus, ja kui pakuti ka elamispind, siis pakutava korteri suurus/tubade arv. Paljudel juhtudel olid majandite esindajad ja lõpetajad juba varem kohtunud ja suusõnalised kokkulepped sõlminud. Sellistel juhtudel esitasid majandite juhid/esindajad teaduskonna suunamiskomisjonile lõpetajate nimed, keda nad soovisid. Tihti juhtus, et suunamiskomisjon ei arvestanud üliõpilaste ja/või ettevõtete juhtide soovidega; sellisel juhul oli nuttu kui palju…

1966. aasta sügisel võimaldati osale Zootehnikateaduskonna üliõpilastest spetsialiseeruda linnukasvatuse erialale; linnukasvatuse rühma kuuluvad üliõpilased sooritasid praktika alates II kursusest linnukasvatusmajandites/linnuvabrikutes.

Linnukasvatusega tegelevaid majandeid oli palju ja kõik nad vajasid/ootasid spetsialiste.

I lend linnukasvatuse spetsialiste lõpetas EPA Zootehnikateaduskonna 1971. aastal. Linnukasvatuse eriala esimesed lõpetajad olid: Malle Ilves, Vello Ilves, Vaike Jeršova, Ene Kerm, Vello Kiis, Mairold Kõrvel, Urve Laanemets, Valeri Neps, Jüri Nohrin, Matti Piirsalu, Elli Priimägi, Anne Tamson, Matti Tohver. Asta Veere.

II lend linnukasvatuse spetsialiste lõpetas 1992. aastal sh Ardo Lass, Eve Samuli, Ove Tikk, Külli Vikat jt.

1974. aastal oli EPAs 6 teaduskonda: **Zootehnikateaduskond** (dekaan dots Rein Teinberg); Agronoomiateaduskond (dekaan dots Paul Kuldkepp); Veterinaariateaduskond (dekaan dots Paul Saks); Majandusteaduskond (dekaan dots Harri Piho); Metsanduse ja Maaparanduse Teaduskond (dekaan dots Endel Laas); Põllumajanduse Mehhaniseerimise Teaduskond (dekaan dots Heino Möller).

Zootehnikateaduskonnas oli neli kateedrit. Põllumajandusloomade aretuse kateedrit (Mitšurini 30, IV korrus) juhatas akadeemik, prof Aarne Pung. Õppejõududena töötasid: prof Karl-Robert Kurm (veisekasvatus, piimatootmise tehnoloogia), prof kt Leida Lepajõe (põllumajandusloomade aretus, tõuaretuse organiseerimine), dots Rein Teinberg (põllumajandusloomade geneetika), dots Harry Mauring (hobusekasvatus, loomakasvatus). V-teadur Ilme Nõmmisto õpetas loomakasvatust.

Põllumajandusloomade söötmise kateedrit (Mitšurini 30, III korrus) juhatas prof Ülo Oll. Söötmisõpetust õpetasid õppejõud: prof August Muuga, dots Hilda Pruul, dots Elmar Rätsep, dots kt Viivi Sikk. Dots Jaan Klaar õpetas piimatehnoloogiat ja mikrobioloogiat.

Eriloomakasvatuse kateedrit (Leningradi mnt 86, I korrus) juhatas dots Edvard Meisner (seakasvatus), õppejõududena töötasid: dots Vilma Raudsepp (lambakasvatus), dots Harald Tikk (linnu- ja karusloomakasvatus), assistent Ants Uibo (seakasvatus). V-teadur Mart Enneveer õpetas kalakasvatust.

Joonis 4. Zootehnikateaduskonna üliõpilased loengul 1959. aastal (Leningradi mnt 84 auditooriumis). 1. laua taga on Lembit Rebane ja Rein Kuku, nende selja taga Tõnu Toim. Kaks viimast olid koos Tartu Rajooni TSN Täitevkomitee aseesimehed

Keemia kateedrit (Mitšurini 36, II korrus) juhatas dots Endel Järv. Õppejõududena töötasid dotsendid Heiti Jalviste, August Männik, Erna Neufeld, Ants Nilson, Mall Reeben, Vadimir Tali, v-õp-d Kalju Haldma ja Endel Tigane.

1975. aastal tekkis päevakorda Zootehnikateaduskonna nime muutmise küsimus. Arvati, et zooinsener on tähenduselt kõvem kui zootehnik; et kõrgharidustasemega sobib sõna "insener" rohkem kui "tehnik" ning see annab teaduskonnale ja erialale soliidsust juurde.

1976. aastal kinnitati teaduskonna nimeks **Zooinseneriteaduskond** ja uued üliõpilased immatrikuleeriti Zooinseneriteaduskonda. Õppeplaani lisati õppeaine Insenerigraafika, mis kadus õppeplaanist juba nelja aasta pärast, sest õppeaine läbimine kujunes raskemaks kui arvati, ka ei olnud õppejõud üliõpilaste jaoks kuigi kättesaadav, sest oli väljastpoolt EPAt.

1976. aastal lõpetas Zooinseneriteaduskonna 56 õpetatud zootehnikut. Üliõpilastele, kes astusid Zootehnikateaduskonda, anti lõpetamisel diplom õpetatud zootehniku kvalifikatsiooniga. Üliõpilastele, kes astusid Zooinseneriteaduskonda, anti lõpetamisel diplom zooinseneri kvalifikatsiooniga.

1981. aastal õppis Zooinseneriteaduskonnas 249 üliõpilast, lõpetas esimene lend zooinsenere (57 sh 20 kaugõppes).

Õppeaeg Zooinseneriteaduskonnas oli alates 1987. aastast 4 aastat ja 9 kuud (varem 4 aastat ja 7 kuud). Sisseastumiseksameid oli kolm: bioloogia, keemia ja eesti keel (kirjand).

Üliõpilastel oli nüüd võimalus õppida ka kalakasvatust, mesindust ja karjakoerte kasvatust, omandada B kategooria autojuhi, masinlüpsi instruktori ja koerakasvatuse instruktori kvalifikatsioon. Ühiskondlike Erialade Teaduskonnas (ÜET) oli võimalik omandada lektori, kodunduse, ehisaianduse, ratsaspordi jt instruktori eriala.

Üliõpilaste õpiedukust jälgisid hoolega kursusejuhendajad; probleemsed üliõpilased kutsuti kateedrijuhataja jutule ja kui see ka tulemusi ei andnud, siis dekaani jutule.

EPA kõik sh Zooinsneriteaduskonna meesüliõpilased pidid kohustuslikus korra läbima sõjalise õpetuse, millega valmistati ette tagala ohvitsere. Loomakasvatuse eriala üliõpilased said ettevalmistuse toiduainetega varustamise organiseerimise alal. Sõjanduse õpetust kureeris sõjanduse kateeder asukohaga Kreutzwaldi 5; kateedri ülemaks oli polkovnik Ahto Peets.

Sõjaline õpetus oli tunniplaanis 2., 3. ja 4. kursusel; üks kord nädalas (8 tundi) ja kanda tuli mundrit. Enamusele oli see õppeaine vastumeelne ja seal käidi selleks, et EPAst välja ei visataks. Probleem oli ka selles, et sõjaväes juba teeninud üliõpilastelt nõuti ikkagi sõjalises õppes osalemist ja üliõpilased, kes olid läbinud sõjanduse, pidid pärast lõpetamist ikkagi minema sõjaväeteenistusse. Üliõpilaste 1988. aastal korraldatud boikott sõjalise õpetuse vastu, mille organiseerimisel osalesid eriti aktiivselt Zooinseneriteaduskonna meesüliõpilased, kujunes teaduskonna dekaanile ja EPA rektorile parajaks pähkliks.

Õppetöö sõjanduses lõpetati alates 1.09.1990 ja sõjanduse kateedrile ehitatav õppehoone (aadressil Kreutzwaldi 64) anti Zooinseneriteaduskonna valdusesse. Zooinsneriteaduskonna kasutusse see hoone siiski ei jõudnud, kuigi ruumide sh dekanaadile ja kateedritele/õppejõududele mõeldud ruumide jaotus oli tehtud. Otsustati, et majast saab EPMÜ uus peahoone;

juurdeehitusena valmis aula, ja **uude peahoonesse (Kreutzwaldi 64) koliti endisest peahoonest (Riia 12) 1996. aastal.**

Zooinseneriteaduskond otsustati paigutada/mahutada ehitatavasse Veterinaariateaduskonna kompleksi, mis pidi valmima kahes etapis. Veterinaariateaduskonna I õppehoone (Kreutzwaldi 62) valmis 1992. aastal.

1987. aastal lõpetas XXXVI lend õpetatud zootehnikuid/zooinsenere. Kursusejuhendaja dots kt Ilme Nõmmisto saatis nad "lendu" meenutustega ajalehes Eesti Põllumajanduse Akadeemia 26.03.1987 artikliga Neli aastat ja seitse kuud – nagu keegi nad iseendale tegi: "Statistilised andmed räägivad sellest, et 75 vastuvõetud üliõpilasest lõpetab kõrgkooli 51. Küllaltki suur väljalangevus (32%) seletub mitmeti: osa noormehi pidi minema aega teenima, osa ei saanud õppimisega hakkama, mõnel aga tuli lahkuda ebaväärika käitumise tõttu. Kõige raskem oli lõpetada esimest kursust, tunda andis nõrk ettevalmistus, eriti täppisteadustes. Ei osatud üliõpilaste vääriliselt käituda. Paljusid vedas alt oma võimete ülehindamine; arvati, et eksamiks valmistumiseks piisab ainult kolmest eksamieelsest päevast. Nii kujuneski esmakursus komistuskiviks kümnele protsendile sisseastujatest. Võibolla mõjus õppetulemustele ka see, et zooinseneriteaduskonda astusid paljud agronoomiks ja veterinaariks pürgijad, kes viimasel hetkel väikese konkursi tõttu zooinseneriteaduskonnas otsustasid siia üle tulla. Kuid suurem enamus ületas raskused ning neile algasid tõesti Elu Parimad Aastad EPAs. Teisel ja kolmandal kursusel oli hoogu isetegevuseks, kursuseõhtute korraldamiseks ja huvitava nääriõhtu tarvis. Esimest korda teaduskonna ajaloos söödi kursuse nääriõhtul verivorste. Teine ja kolmas kursus olid teineteise leidmise ja perekonna rajamise aeg. Praegustest lõpetajatest on oma kursuselt elukaaslase leidnud kolm. Lapsi on kursuse üliõpilastel kümme. Kursusevanem ja ametlik esindaja oli Priit Rander. Kuna noormehi oli kursusel ainult seitse, oli tegelik tegutseja ja otsustaja naispool. Kohusetundlikud rühmavanemad olid Anneli Tragel, Maire Pütsepp ja Katrin Sard. Rahvamaleva rasket rege vedas Alo Teder ja vedas hästi. Üliõpilaste Teadusliku Ühingu tööst hakati agaralt osa võtma juba teisel kursusel. ÜTÜ konverentsil on esinetud 26 ettekandega, millest 16 olid neljandal kursusel. Paljude eelnev uurimus kasvas diplomitööks. Fotomehena tegutses kursuse pikim noormees Andu Rämmer. Hea esinemise eest isetegevusülevaatusel on dekaani korraldustega kiita saanud paljud teist. Tubli pillimees oli Priit Rander. Kursuse ööbikud olid Asti Teder ja Tiiu Mölder. Kunstnikukätt on Kaija Einastel, kes kujundas ka eelmise aasta lõpetajate kutsekaardi. Tagasivaates kujunesid need 4 aastat ja 7 kuud just sellisteks, nagu keegi nad iseendale tegi – kes tahtis, võis igal pool kaasa lüüa, kes ei tahtnud, see leppis tudengielu sündmustes ainult pealtvaataja rolliga.

Mida arvab EPA-s oldud ajast kursus ise? Kahjuks ei jõudnud veel puhuma hakata värsked tuuled, mis oleksid tugevdanud demokraatiat ja nõrgendanud autokraatiat. Veider tundus erialapraktikate ületähtsustus. Nii mõnigi kord kujunes see töö tegemise asemel hoopis lõputuks ooteajaks, kuid sealt puudumist võis vabandada ainult surm. Nii mõnegi aine õpetamisest oleks lootnud suuremat elulähedust ja objektiivsemat teadmiste hindamist. Kas õpetama peab ikka nii killustatult? Tunniplaan jagab päeva eri õppeainete vahel, millel omavahel tihti puudub seos. Järgmisel nädalal on eelmisel tunnil räägitu ununenud. Õppeained peaksid järgnema üksteisele blokina ja lõppema kohe eksami või arvestusega. Imelik tundub ka nõue teha kursusetöö valmis enne, kui õppeaine on läbi võetud. Et tulevikku ei ole minevikuta, siis tuleb loota, et uutmine ja demokraatia pääsevad järgmiste lendude puhul võidule".

Zooinseneriteaduskonnas oli 1987. aasta 4 kateedrit. Dekanaat asus aadressil Lai tn. 30. Samas majas olid ka erialakateedrid (aretus, söötmine, eriloomakasvatus), keemia kateeder paiknes kahes kohas; aadressil Lai 36 ja Veski 13.

Põllumajandusloomade aretuse kateedrit juhatas dots Valdeko Kaarupun, õppejõududena töötasid prof Leida Lepajõe, prof Olev Saveli (1/4 kohaga), dotsendi kt-d Anne Lüpsik ja Ilme Nõmmisto, v-õp Eha Türk, ass Heldur Peterson.

Kateedri teadustöö teemad olid seotud veiste, sigade, hobuste ja lindude aretusega. Uuriti ka lindude, nutriate ja kalade valguväärindust ning transferriini tüüpe loomade veres.

Põllumajandusloomade söötmise kateedrit juhatas prof Ülo Oll, õppejõududena töötasid prof Elmar Rätsep, dots Viivi Sikk, dots Hilda Tammsalu, v.-õp Jaak Tölp.

Kateedri teadustöö hõlmas nii söötade koostise üksikasjalikumat (mikroelemendid, aminohapped) uurimist kui ka lehmade, sigade ja lindude (broilerite) söötmist. Seedekatseid korraldati ka lammastega. Kateeder osales aktiivset vabariigi proteiiniprogrammi (1986–2000) väljatöötamisel.

Eriloomakasvatuse kateedrit juhatas prof Harald Tikk, õppejõududena töötasid prof Karl-Robert Kurm, dots Mart Enneveer, dots Edvard Meisner, dots kt Ants Uibo, ass Peep Piirsalu.

Kateedri teadustöö teemad olid seotud veisekasvatuse, lamba-, sea-, linnu- kala- ja karusloomakasvatuse tehnoloogiatega.

Keemia kateedrit juhatas dots Ants Nilson, õppejõududena töötasid dots Endel Järv, dots Mall Reeben, dots Vladimir Tali, v.-õp Katrin Kolk, v.-õp Tõnis Lepiku, v-õp Regina Pällin, ass Leeni Leis, ass Anu Viigi.

Kateeder oli nö üle-EPA-line; keemiat õpetati kõikide teaduskondade üliõpilastele.

1988. aastal toimus Zooinseneriteaduskonnas tähtsündmus; põllumajandusloomade aretuse kateedri juhataja, **prof Olev Saveli valiti** EPA Õpetatud Nõukogu 20.05.1988 laiendatud istungil **EPA uueks rektoriks**. O. Saveli alustas rektorina tööd 01.09.1988. Teaduskonda juhtis jätkuvalt dekaanina dots Valdeko Kaarupun.

Joonis 5. Auditoorium Laia tänava õppehoones (I. Nutt)

Joonis 6. Üliõpilased väljumas Laia tänava õppehoonest (paremalt Elmo Mõlder, Alo Tänavots, Pille Peedor (Vare) ja Varpo Vare (A. Tänavots)

EPA Õpetatud Nõukogu 31.08.1989. aasta istungil kinnitati Zooinseneriteaduskonna üliõpilaste poolt loodud üliõpilasseltsi TAURUS põhikiri.

Joonis 7. Tauruse ruumid asusid aadressil Lai 30 (Urmas Võro, Riina Högren ja Õilme Kuivjõgi). Taamal Tauruse sümboliks olnud sarvedega kolju (P. Ilves)

TAURUSe tegevuse eesmärgiks oli edendada ja populariseerida loomakasvatust, ühendada põllumehe vaimsus, eriti aga loomakasvatuse vastu huvi tundvaid üliõpilasi kõikidest kõrgkoolidest, vilistlasi ja õppejõude, kelle tegevus või huviala on seotud loomakasvatusega või sellega piirnevate teadusharude ja huvialadega. TAURUSe asupaigaks sai Lai 30 õppehoone keldrikorrusel olev ruum, mille üliõpilased ise oma jõududega korda tegid sh baarileti ehitasid. Üliõpilasseltsi TAURUS esimeseks presidendiks sai prof Olev Saveli.

EPA lõpetajate sh õpetatud zootehnikute/zooinseneride riiklik tööle suunamine lõpetati 1990. aastal. Kuni selle ajani toimus lõpetajate tööle määramine nö suunamiskomisjonide kaudu.

1990. aastal valiti Zooinseneriteaduskonna dekaaniks dots Anne Lüpsik.

Dekaanidena on teaduskonda varem juhtinud: dots Evald Peebsen (1951–1952); prof Johannes Kaarde (1952); prof Elfriede Ridala (1952–1958); prof Aarne Pung (1958–1961); dots Karl-Robert Kurm (1961–1965); dots Leida Lepajõe (1965–1968); dots Edvard Meisner (1968–1971); prof Karl-Robert Kurm (1971–1974); prof Rein Teinberg (1974–1979); prof Ülo Oll (11.08.1979–1986); dots Valdeko Kaarupun (1986–1990).

Zooinseneriteaduskonna Nõukogu otsusega (5.11.1990) loodi kolm prodekaani kohta ja määrati tööülesanded: v-õp Peep Piirsalu – prodekaan õppetöö alal (õppeplaanid, õppepraktika välismaal); dots Jaak Tölp – prodekaan teadustöö alal; dots Mart Enneveer – prodekaan halduse alal.

1. jaanuarist 1991 nimetati Zooinseneriteaduskond Loomakasvatusteaduskonnaks.

1991. aastal oli EPAs 7 teaduskonda: **Loomakasvatusteaduskond** (dekaan dots Anne Lüpsik); Agronoomiateaduskond (dekaan dots Juhan Jõudu); Veterinaariateaduskond (dekaan dots Aadu Kolk); Majandusteaduskond (dekaan dots Harri Piho); Metsandusteaduskond (dekaan prof Ivar Etverk); Maainseneriteaduskond (dekaan dots Väino Tamm); Põllumajanduse mehhaniseerimise teaduskond (dekaan dots Tõnis Peets).

Alates 26. septembrist 1991 muudeti Eesti Põllumajanduse Akadeemia Eesti Põllumajandusülikooliks. EPMÜ oli Eesti Vabariigi riiklik ülikool ja õppetöö toimus ülikoolis koostatud õppekavade/õppeplaanide alusel.

1991. aasta 1. septembrist reorganiseeriti EPA olemasolevad teaduskonnad ja moodustati 5 teaduskonda: põllumajandusteaduskond, mille koosseisus oli 4 instituuti (agronoomia-, **loomakasvatus-**, majandus- ja liha-piimainstituut), veterinaariateaduskond, inseneriteaduskond, mille koosseisus oli 2 instituuti (tehnika- ja maainseneriinstituut), metsandusteaduskond, humanitaarteaduskond. Teaduskondade eesotsas oli dekaan, keda abistas dekanaadi sekretär. Instituute juhtis direktor, keda abistas kantselei juhataja (endine "dekanaadi sekretär").

Eraldiseisva loomakasvatusteaduskonna asemel oli nüüd loomakasvatusinstituut, mis kuulus põllumajandusteaduskonna koosseisu.

	Erialad	Üliõpilaste arv
Põllumajandusteaduskond (dekaan dots Armand Sukamägi) sh		1062
1. Agronoomiainstituut. Viljandi mnt Eerika. Direktor dots Juhan Jõudu	Agronoomia	352
	Aiandus	45

	Erialad	Üliõpilaste arv
2. **Loomakasvatusinstituut.** Lai tn 30 Direktor dots Anne Lüpsik	**Loomakasvatus**	**297**
3. Majandusinstituut. Riia mnt 12 Direktor dots Harri Piho	Põllumajanduse ökonoomika ja organiseerimine	64
	Põllumajandusraamatupidamine ja -analüüs	24
4. Liha-piimainstituut. Narva mnt 84 Direktor dots Meili Rei	Liha- ja piimatehnoloogia	137

Põllumajandusteaduskonna dekaani kohuseid hakkas täitma dots Armand Sukamägi. Loomakasvatusinstituudi direktoriks valiti senini dekaanina töötanud dots Anne Lüpsik.

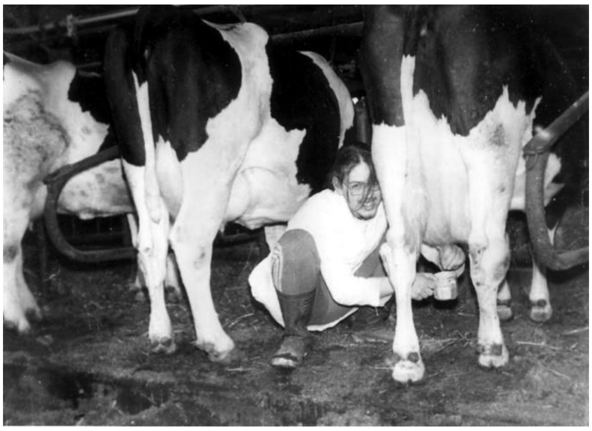
Loomakasvatusinstituudis oli 297 üliõpilast; EPMÜ-s oli üliõpilasi kokku 3957 sh kaugõppes 1302, erialasid oli 17.

1991. aastal võeti loomakasvatuse erialale kandideerijad põllumajandusteaduskonda ühise konkursi alusel, 1992. aastal instituutide/erialade kaupa. 1992. aastal immatrikuleeriti EPMÜ loomakasvatusinstituudi esimese kursuse üliõpilaseks 20 uut sisseastujat, teise kursuse üliõpilaseks 30 Türi KPK-st tulnud üliõpilast.

Rakendus uus õppekorraldus st ainekeskne õppesüsteem. Õppetöö hakkas toimuma neljas tsüklis ja igale tsüklile järgnes eksamite sooritamise nädal. Sügissemester koosnes kahest 7-nädalasest tsüklist, kevadsemester kahest 9-nädalasest tsüklist. Õppetöö mahtu hakati arvestama ainepunkti-süsteemis; üks nädal õppetööd (35 tundi auditoorset tööd) andis 1 ainepunkti (AP). Iga õppeaasta lõpuks pidi kogutud ainepunktide summa kasvama vähemalt 40 AP võrra. Õppekava koosnes baasainetest, humanitaarainetest, võõrkeelest ja valikainetest. Baasained olid kohustuslikud õppeained, humanitaaraineid oli vaja 4 aasta jooksul valida ja õppida 10 AP-d.

Loomakasvatuse eriala üliõpilased, kes immatrikuleeriti 1990/1991. õppeaastal, saadet II poolaastaks (st III ja IV tsüklis) praktilisi teadmisi ja kogemusi omandama **Türi sovhoostehnikumi** (hilisem Türi Kõrgem Põllumajanduskool). 1991/1992. ja 1992/1993. õppeaastal õppisid loomakasvatuse eriala esmakursuslased (va need, kes olid lõpetanud tehnikumi) Türil terve aasta, seejärel jätkasid õpinguid Tartus. 1993/1994. õppeaastal immatrikuleeritud loomakasvatuse eriala üliõpilased (25) olid sügissemestril Türil ja kevadsemestril Tartus. Alates 1994/1995. õppeaastast (EPMÜ rektor prof Mait Klaassen) toimus õppetöö Tartus.

Loomakasvatuse eriala esmakursuslased, kes õppisid Türi Kõrgemas Põllumajanduskoolis terve aasta, õppisid seal järgmisi õppeaineid: autoõpetus B-kat. lubade saamiseks (200 tundi), traktoriõpetus (90), põllutöömasinad (80), arvutiõpetus (80), agronoomia alused (120), loomakasvatuse alused (120), farmide mehhaniseerimine ja elektrifitseerimine koos lüpsimeistri kursusega (120), töö- ja olmeohutus (40), võõrkeel (110), kehaline kasvatus (160), humanitaarained (100), õppepraktika 10 nädalat.



Joonis 8. Ole Müürisepp Türi sovhoostehnikumis praktilisi teadmisi omandamas 1991. a (A. Tänavots)

Need esmakursuslased, kes olid lõpetanud erialatehnikumi, jäid Tartusse (ei pidanud minema Türile) ja õppisid siin baasaineid: üldkeemia (96 tundi), põllumajanduskeemia (96), matemaatika (71), füüsika (60), arvutiõpetus (72), eesti keel (60), vene keel (50), võõrkeel (120), kehaline kasvatus (160), ning humanitaaraineid. Teist õppeaastat alustati koos Türi KPK-st tulijatega.

Ülikooli nõukogu 30.04.1992. a otsusega likvideeriti põllumajandusteaduskond ja inseneriteaduskond, kinnitati EPMÜ uus struktuur ja õppetoolide nimekiri. Moodustati 10 instituuti ja üks teaduskond: agronoomiainstituut, **loomakasvatusinstituut**, majandusinstituut, liha- ja piimainstituut, tehnikainstituut, maainseneriinstituut, keskkonnainstituut, metsandusinstituut, humanitaarinstituut, taimekaitseinstituut ja **veterinaariateaduskond.**

Joonis 9. Üliõpilaste õppeekskursioon dots Heldur Petersoni juhendamisel Tori hobusekasvandusse 1993. a (A. Tänavots)

Loomakasvatusinstituudis oli kolm õppetooli ja üks lektoraat: aretusõpetuse ja veisekasvatuse õppetool (õppetooli juht prof Olev Saveli), söötmisõpetuse ja toitumisfüsioloogia õppetool (prof Olav Kärt), väikelooma- ja linnukasvatuse õppetool (prof Harald Tikk), keemia lektoraat (dots Ants Nilson).

1.11.1992 seisuga töötasid aretusõpetuse ja veisekasvatuse õppetoolis (juh. prof Olev Saveli) õppejõududena: dotsendid Valdeko Kaarupun, Ilme Nõmmisto, Anne Lüpsik, assistendid Eha Türk, Heldur Peterson, Tiit Helm. Õppetoolis olid veel: emeriitprofessor Leida

Lepajõe, prof Arnold Rüütel, doktorandid Avo Karus, Einar Orgmets, magistrandid Käde Kalamees, Heikki Paltser, Ando Põldaru, Ave Velt, abipersonal Larissa Belova, Helgi Tennisson, Toomas Toim.

Söötmisõpetuse ja toitumisfüsioloogia õppetoolis (juh. prof Olav Kärt) töötasid õppejõududena: abiprof Ülo Oll, dotsendid Viivi Sikk, Jaak Tölp, assistendid Silvi Tölp, Jaan Loite. Õppetoolis olid veel: v-teadur Andres Hellenurme, doktorant Allan Kaasik, magistrandid Ülle Jõenurm, Katrin Rannik, Piret Siimpoeg, Aneli Šmigelskite, abipersonal Antoniina Kiis, Anne Krips, Kaja Kruuk, Üllar Oll.

Väikelooma ja linnukasvatuse õpetoolis (juh. prof Harald Tikk) töötasid õppejõududena: dotsendid Peep Piirsalu, Aleksander Lember, assistendid Ants Uibo, Jaanus Hämmal, Renaldo Mändmets. Õppetoolis olid veel: doktorandid Eve Samuli, Toomas Murulo, magistrandid Paul Jalas, Anželika Kazakova, Ardo Lass, Meeli Saveli, Külliki Vikat, v-zootehnik Viive Tikk ja v-laborant Riina Tisler.

Keemia lektoraadis (juh dots Ants Nilson) töötasid õppejõududena: lektorid Regina Pällin, Katrin Kolk, õpetajad Avo Karus, Virge Karus, Leeni Leis, Tõnis Lepiku, abipersonal Ene Enno, Emmeline Männik, Urve Ojaperv, Salme Vene.

1993. aastal võeti EPMÜ-sse vastu 275 üliõpilast sh loomakasvatuse erialale 25, EPMÜ-s oli kokku 286 õppejõudu sh Loomakasvatusinstituudis 20.

Instituut osales aastatel 1993–1995 Euroopa Liidu kõrgharidusprogrammis TEMPUS. Projekti eesmärgiks oli loomakasvatusalase kõrghariduse arendamine Eestis. Projekti koordinaatoriks oli Suurbritannia Walesi ülikool Bangoris, projekti partneriks oli Kieli Ülikool Saksamaal ning Kuopio Ülikool Soomes. Projekti raames said paljud LKI üliõpilased ja õppejõud võimaluse külastada partnerülikoole; osaleda erinevatel koolitustel ja seminaridel, külastada farme/põllumajandusettevõtteid ja sooritada praktikat, töötada raamatukogus vm.

1994. aasta 1. juunil ühendati Eesti Põllumajandusülikooli (EPMÜ) Loomakasvatusinstituut (direktor dots Anne Lüpsik) ja Eesti Loomakasvatuse ja Veterinaaria Teadusliku Uurimise Instituudi (ELVI) (direktori kt Toomas Vain) loomakasvatusalase uurimistemaatikaga seotud osakonnad. Reorganiseeritud asutuse nimeks sai **Eesti Põllumajandusülikooli Loomakasvatusinstituut** (EPMÜ LKI). Moodustunud EPMÜ Loomakasvatusinstituudil olid teaduskonna õigused. LKI põhikiri kinnitati EPMÜ Nõukogus 8.09.1994.

Instituudi direktoriks sai prof Olav Kärt, asedirektoriks Toomas Vain ja asedirektoriks õppe alal dots Anne Lüpsik.

Moodustunud EPMÜ Loomakasvatusinstituut oli ainus akadeemilist loomakasvatusalast kõrgharidust andev asutus Eestis, olles samaaegselt juhtiv institutsioon loomakasvatusteaduse alal. Kõrvuti õppe- (sh magistri- ja doktoriõpe) ning teadustööga arendati ka nõustamistegevust. Instituudis oli 145 töötajat sh 70 õppejõudu/teadustöötajat, 103 üliõpilast sh 18 magistranti ja 8 doktoranti. I kursusele võeti 17 uut üliõpilast (kohti oli 25).

EPMÜ Loomakasvatusinstituudi administratsioon paiknes Kreutzwaldi 1 peahoones, dekanaat ja õppetoolid/osakonnad toodi Laia 30 õppehoonest Kreutzwaldi 1 mõisamajja. Dekanaadi metoodikuks sai Hilja Pärnaste.

Instituudi struktuurilise terviku moodustasid osakonnad koos professuuriga (4), teenindavad allüksused ja katsebaasid/-jaamad (6).

Aretusosakonna aretusõpetuse ja geneetika professuuris (osakonna ja professuuri juhataja prof Olev Saveli) töötas 6 õppejõudu ja õpetati järgmisi õppeaineid: zooloogia, bioloogaia (dots Ilme Nõmmisto, dots Eha Türk), geneetika (dots Anne Lüpsik), aretusõpetus (prof Olev Saveli, dots Eha Türk), hobusekasvatus (dots Heldur Peterson), veisekasvatus (prof Olev Saveli, dots Valdeko Kaarupun), üldloomakasvatus (dots Eha Türk), aretus ja geneetika (dots Valdeko Kaarupun, dots Anne Lüpsik), mesindus (dots Ilme Nõmmisto), talu planeerimine (dots Heldur Peterson).

Aretusosakonnas uuriti eesti veisetõugude aretusväärtust ja jõudlusvõime suurendamist uute aretusvõtete ning sugulastõugude kasutamise teel, uuriti võimalusi loomade kehaehituse parandamiseks, tegeleti veiste hindamise uute meetodite väljatöötamise ning rakendamisega, katsetati piimatõugu veiste lihajõudluse parandamist tarberistamisega lihatõugudega. Geneetika laboris (juh. Tiiu Õkva, hiljem Haldja Viinalass) uuriti populatsioonide geneetilise struktuuri muutusi verefaktorite, vereseerumi ja piimavalkude pärilike tüüpide abil, kontrolliti loomade põlvnemisandmete õigsust.

Aretusosakonna teadustöös kasutati Vabariigi Jõudluskontrolli Keskusest saadud jõudluskontrolli andmeid vabariigi majandite ja üksikute ettevõtete kohta, katseid viidi läbi erinevates majandites/ettevõtetes. Teadustöö tulemusi rakendati praktikasse Jõudluskontrolli Keskuse kaudu ning läbi Eesti Tõuloomakasvatuse Liidu, mille keskus asus aretusosakonnas.

Söötmisosakonna söötmisõpetuse ja toitumisfüsioloogia professuuris (professuuri juhataja prof Olav Kärt, kaasprofessor Ülo Oll, osakonna juhataja v-teadur Helgi Kaldmäe) töötas 4 õppejõudu ja õpetati järgmisi õppeaineid: põllumajandusloomade söötmine ja toitumisfüsioloogia (prof Ülo Oll), söötmisõpetus (prof Olav Kärt, dots Jaak Tölp), loomakasvatusteaduse alused (prof Ülo Oll), sigade söötmise erikursus (prof Ülo Oll), veiste söötmise erikursus (prof Ülo Oll), loomakasvatus (dots Viivi Sikk), maailma loomakasvatus (v-teadur Helgi Kaldmäe).

Söötmisosakonnas uuriti põllumajandusloomade proteiini- ja energiatarbe katmise võimalusi suure toodangu saamiseks, mittetraditsiooniliste söötade ja söödalisandite toimet loomade seedeprotsessile ja ainevahetusele ning piimatoodete kvaliteedile, töötati välja sobivaid ratsioone ja söötmisviise, määrati söötade kvaliteeti sh keemilist koostist, uuriti loomade ainevahetust.

Uurimistöö katsebaasideks olid põhiliselt Piistaoja veisekasvatuse katsejaam, Tartu riigimajand ja Eerika katsetalu, kus asusid fistulloomad. Teadusuuringute läbiviimine toetus osakonna keemialabori (juh Lauri Ploom) tehnilisele baasile, kus määrati söötade kvaliteeti ning anti soovitusi söötade otstarbekaks kasutamiseks, tehti vere, vatsasisu, rooja ja uriini uurimisi.

Väikelooma- ja linnukasvatusosakonna väikelooma- ja linnukasvatuse professuuris (osakonna ja professuuri juhataja prof Harald Tikk) töötas 5 õppejõudu ja õpetati järgmisi õppeaineid: üld- ja eriloomakasvatus (dots Ants Uibo), seakasvatus (dots Aleksander Lember), lambakasvatus (dots Peep Piirsalu), linnukasvatus (prof Harald Tikk), karusloomakasvatus (prof Harald Tikk), kalakasvatus (dots Tiit Paaver), koerakasvatus (dots Al-der Lember), konsulendikursus (prof Harald Tikk, dots Aleksander Lember).

Osakonnas uuriti põllumajanduslindude selektsiooni ja söötmise normeerimist, sigade söötmise ja kunstliku seemenduse probleeme, lammaste produktiivomaduste parandamisvõimalusi ja ensüümpreparaatide kasutusvõimalusi põlumajandusloomade ja lindude söötmisel.

Uurimistöö läbiviimiseks ja suunamiseks olid osakonnal tihedad sidemed Kehtna Lindude Kontrollkatsejaamaga, Kurtna Linnukasvatuse Katsejaamaga, Sakala Tõulinnukasvatuse Ühistuga, Matjama vutifarmiga, Kehtnas asuva LKI seakasvatuse osakonnaga, Aravete põllumajandusühistuga, Eesti Linnukasvatajate Seltsi ja Eesti Lambakasvatajate Seltsiga.

Keemia professuuris (professuuri juhataja prof Ants Nilson) töötas 8 õppejõudu ja õpetati keemiat kõikidele EPMÜ üliõpilastele. Uuriti valkude ja ensüümide polümorfismi põllumajandusloomade kudedes ja vereseerumis, koostöös taimekaitseinstituudiga uuriti uute ökokeemiliste taimekaitsevahendite sünteesi ja omadusi.

Lisaks söötmisosakonnale, aretusosakonnale ja väikelooma- ja linnukasvatuse osakonnale, kus tegeleti õppe- ja teadustööga, oli instituudis veel neli osakonda, kus tegeleti ainult teadustööga.

Seakasvatusosakond (juhataja Kalju Eilart) paiknes Kehtnas ja tegeles sigade hindamismetoodikate ja Eestile sobivaima sigade aretussüsteemi väljatöötamisega, uuriti erinevate toimeainete mõju kasvavate sigade jõudlusele, määrati sealiha kvaliteeti ja selle parandamise võimalusi.

Kalakasvatusosakond (juhataja Tiit Paaver) paiknes Ilmatsalus ja tegeles karpkala geneetika ja parasitoloogia, fikerforelli kasvatamise ning sisevete kalanduse sh kalavarude taastootmise küsimustega.

Loomakasvatustehnoloogia osakond (juhataja Allan Kaasik) paiknes Eerikal ja tegeles veisefarmide tehnoloogiliste (sh lüpsmine, söötmine) võimaluste uurimisega, pidamistehnoloogiate automatiseerimise ja loomade tervise ja toodangu kvaliteedi automaatse kontrolli rakendamise võimalustega farmides.

Piimanduslabor (juhataja Arvi Olkonen) tegeles lüpsi- ja piimainventari pesu- ja desoainete retseptide väljatöötamise ja testimisega, erinevate piimajahutusseadmete katsetamisega eesmärgiga vähendada piima bakteriaalset saastumist.

Loomakasvatusinstituudi koosseisu kuulusid ka järgmised katsejaamad: Kurtna Linnukasvatuse Katsejaam (dir Vello Ilves), Arkna Loomakasvatuse Katsejaam (dir Heino Kukk), Piistaoja Veisekasvatuse Katsejaam (dir Olev Roosileht), Tori Hobusekasvandus (dir Jaak Ehrlich), Kehtna Riigimajand (dir Mart Riisenberg), Tartu Riigimajand (dir Avo Mölder).

EPMÜ Loomakasvatusinstituudi kõrgeim otsustusõigus oli 24-liikmelisel teadusnõukogul.

EPMÜ Loomakasvatusinstituudi lõpetajatele väljastati aastatel 1992 ja 1993 diplom eriala lõpetamise kohta (on lõpetanud loomakasvatusinstituudi loomakasvatuse erialal). Bakalaureuseõppe lõpetajatele, kes astusid ülikooli alates 1994. aastast, anti bakalaureusekraad. Diplomile kirjutati, et on täitnud nt loomakasvatuse bakalaureuseõppe õppekava täies mahus ja talle on antud bakalaureusekraad loomakasvatuse erialal. Esimesed bakalaureusekraadiga diplomid väljastati 1998. aastal.

Enne 1994. aastat EPMÜ-sse astunud üliõpilastele anti diplom/ülikooli kraadita diplom. Diplomile kirjutati, et on täitnud nt loomakasvatuse eriala õppekava täies mahus.

Joonis 10. Enne 1994. aastat EPMÜ-sse astunud üliõpilastele anti diplom/ülikooli kraadita diplom (1994. a lend) (K. Avi)

Alates 1995. aastast rakendus ülikoolis **4+2 õppesüsteem;** 4- aastasele bakalaureuseõppele (õppekava maht 160 AP) järgnes 2- aastane magistriõpe (80 AP) ja 4-aastne doktoriõpe (160 AP). Loomaarstiõppe kestuseks sai 5 aastat (200 AP). 1995. aastal vastuvõetud üliõpilased alustasid õpinguid uute, kõrgharidusstandardile vastavate õppekavade alusel.

Loomakasvatusinstituudis oli üks bakalaureuseõppe õppekava ja üks magistriõppekava. Bakalaureuseõppe õppekava **Loomakasvatus** koosnes järgmistest moodulitest: üldõppemoodul (kuni 30 AP), suunaõppemoodul (20–25 AP), erialaõppemoodul (60–70AP), lisaõppemoodul (19–25 AP), vabaained (14–20 AP), lõpueksam (6 AP).

Magistriõppekava **Loomakasvatus** koosnes järgmistest kohustuslikest üldainetest (11 AP): võõrkeel (5 AP), teadustöö metodoloogia (3 AP), pedagoogika alused (2 AP), praktiline pedagoogiline töö (1 AP) ja erialaõppe õppeainetest (25 AP): loomakasvatussaaduste kvaliteedinõuded ja standardid (7 AP), loomakasvatuse ja loomakasvatusteaduse areng maailmas (3 AP), erialaaine vastavalt magistritöö teemale (15 AP). Valikaineid tuli õppida 2–5 AP mahus, magistritöö maht oli 39–44 AP-d.

4+2 õppesüsteemi bakalaureuseõppe lõpetajatele anti bakalaureusekraad, magistriõppe lõpetajatele magistri teaduskraad (põllumajandusmagistri teaduskraad loomakasvatuse erialal), doktoriõppe lõpetajatele – doktorikraad (põllumajandusdoktor; *Doctor of Agriculture* (*Dr (Agr)*) loomakasvatuse erialal, filosoofiadoktor (*PhD*) loomakasvatuse erialal).

1995. aastal õppis Loomakasvatusinstituudis 132 üliõpilast sh 55 kaugõppes, lõpetas 31 üliõpilast.

1997. aastal lõpetas loomakasvatuse eriala 47. lend. **Esimesed bakalaureusekraadiga loomakasvatuse eriala lõpetajad** said diplomi 1998. aastal ja võisid alustada õpinguid magistriõppes.

Alates 1.09.1997 alustas tööd EPMÜ Loomakasvatusinstituudi asedirektorina õppe alal dots Einar Orgmets; senini sellel kohal töötanud dots Anne Lüpsik läks EPMÜ õppe- ja teadusosakonna juhatajaks.

Alates 2002/2003. õppeaastast rakendus 3+2 õppesüsteem. Uued üliõpilased immatrikuleeriti bakalaureuseõppekavale (õppe kestus 3 aastat) **Loomakasvatussaaduste tootmine** (kood 396). Õppekava osadeks olid: valdkonnaõpe (25 AP), suunaõpe (23,5 AP), erialaõpe (37,5 AP), spetsialiseerumised ja lisaõppemoodul (5 AP). Bakalaureuseõpe lõppes bakalaureuseeksamiga.

Valdkonna- ja suunaõppe õppeained olid samad, mis 4+2 õppesüsteemi bakalaureuseõppekava **Loomakasvatus** üldõppe- ja suunaõppemoodulis.

Erialaõppe õppeained olid: maailma loomakasvatus, loomade heaolu ja käitumine, aretusõpetus, söötmisõpetuse põhikursus, veisekasvatus, seakasvatus, tapa- ja lihasaaduste tehnoloogia väiketootmises, toiduohutus, piimatoodete tehnoloogia, linnukasvatus, hobusekasvatus, lamba- ja kitsekasvatus, õppepraktika (1 AP), erialapraktika (3 AP).

Spetsialiseeruda oli võimalik ühele järgmistest erialadest: **loomakasvatus** (14 AP), **kalakasvatus** (14 AP), **liha- ja piimatehnoloogia** (26 AP), **agroökoloogia** (20 AP). Agroökoloogia eriala õppeained olid: mullateaduse alused, maaviljeluse põhikursus, agrokeemia, rohumaaviljelus, rohumaade tehnoloogia, taimekasvatuse üldkursus.

Loomakasvatusinstituudis oli 4 magistriõppekava; tulenevalt bakalaureuseõppe õppekavas olevatest spetsialiseerumistest. Magistriõppekavad olid: **Loomakasvatus** (kood 449), **Kalakasvatus** (462), **Agroökoloogia** (447), **Liha- ja piimatehnoloogia** (455).

3+2 õppesüsteemi bakalaureuseõppe lõpetajatele anti bakalaureusekraad (bakalaureusekraad loomakasvatuse erialal), magistriõppe lõpetajatele magistrikraad (magistrikraad loomakasvatuse erialal), mis ei ole teaduskraad. Doktoriõppe lõpetajatele anti teaduskraad (Filosoofiadoktor).

2002. ja 2003. aastal võeti üliõpilasi vastu uue (3+2) õppesüsteemi bakalaureuseõppekavale ning vana (4+2) õppesüsteemi magistriõppesse. 2004. aastal asus bakalaureuseõppekavale Loomakasvatussaaduste tootmine õppima 85 uut üliõpilast. Bakalaureuseõppes õppis loomakasvatust 2004. aastal 243 üliõpilast.

2004. aastal juhtis Loomakasvatusinstituuti direktorina prof Olav Kärt. Asedirektor õppe alal oli Einar Orgmets, teadusdirektor oli Katri Ling.

Instituudi koosseisu kuulusid osakonnad ja laboratooriumid.

Loomakasvatusinstituudi aretusosakonnas töötasid: prof Olev Saveli (juhataja), dotsendid Ilme Nõmmisto, Einar Orgmets, Eha Türk, Heldur Peterson, Anne Lüpsik (kohakaaslus), vanemteadur Elli Pärna, teadurid Peeter Järv ja Aare Kureoja, statistik Tanel Kaart, vanemlaborandid Heli Pärtma, Priit Pihlik, Larissa Saltõkova, Helgi Tennisson, Alo Tänavots, Meeli Voore. Aretusosakonna juurde kuulus geneetika laboratoorium (juhataja Haldja Viinalass). Aretusosakond asus aadressil Kreutzwaldi 1 (mõisamaja) II korrusel.

Joonis 11. EPMÜ Loomakasvatusinstituudi (LKI) aretusosakonna kollektiiv (1997). Esimene rida (vasakult): L. Saltõkova, A. Tänavots, V. Veinberg, osakonna juhataja prof O. Saveli, H. Viinalass, A. Lüpsik. Teine rida (vasakult): P. Järv, E. Türk, H. Tennisson, I. Nõmmisto, H. Pärtma, V. Karus, I. Tomba. Kolmas rida (vasakult): A. Suurmaa, A. Kureoja, M. Kilk, H. Peterson, S. Värv, A. Orasson. Pildilt puuduvad: T. Kaart, V. Kaarupun, T. Liibusk, E. Orgmets, T. Piirimäe, E. Pärna, T. Õkva

Joonis 12. LKI aretusosakonna geneetika labori kollektiiv (1997). Esimene rida (vasakult): S. Värv, I. Tomba, H. Viinalass, M. Kilk, V. Karus. Teine rida (vasakult): T. Õkva (juh), T. Liibusk, A. Orasson

Söötmisosakonnas töötasid: Helgi Kaldmäe (juhataja), prof Olav Kärt, dots Silvi Tölp, vanemteadurid Katri Ling ja Meeli Vadi, teadurid Hanno Jaakson, Andres Olt, Meelis Ots ja Eve Rihma, vanemspetsialistid Virve Karis ja Viivi Sikk, peaspetsialist Jaak Samarütel, katsetehnikud Irina Vikman, Ljudmilla Grigorjeva, Ülle Laurits ja Inge Lippasaar. Söötmisosakonna juurde kuulus keemia laboratoorium (juhataja Tõnu Virma). Söötmisosakond asus aadressil Kreutzwaldi 46 ja Kreutzwaldi 1.

Joonis 13. LKI söötmisosakonna kollektiiv (1997). Esimene rida (vasakult): V. Sikk, V. Karis, L. Ploom, osakonna juhataja H. Kaldmäe, prof. O. Kärt, A. Kiis, E. Pedak. Teine rida (vasakult): T. Tamm, H.-M. Raidväli, M. Vadi, Ü. Vares, Ü. Lätt, A. Krips, I. Vikman, J. Tölp. Kolmas rida (vasakult): V. Reial, K. Kruuk, E. Hellenurme, P. Margus, K. Ling, V. Ploom, S. Tölp, Ü. Peda. Pildilt puuduvad: R. Kirsel, A. Leesmäe, M. Metsaalt, M. Mäesalu, Üllar Oll, T. Virma

Väikelooma- ja linnukasvatuse osakonnas töötasid: prof Aleksander Lember (juhataja), dots Peep Piirsalu, lektorid Jaanus Hämmal ja Ragnar Leming, vanemlaborant Irje Leontjeva. Osakonna juurde kuulusid: kalakasvatuse osakond (juhataja v-teadur Tiit Paaver), loomakasvatustehnoloogia osakond (juhataja v-teadur Allan Kaasik), piimanduslaboratoorium (juhataja teadur Merike Henno). Väikelooma- ja linnukasvatuse osakond asus aadressil Kreutzwaldi 1 (mõisamaja) II korrusel.

Joonis 14. LKI väikelooma- ja linnukasvatusosakonna kollektiiv (1997). Esimene rida (vasakult): A. Lember, R. Tisler, osakonna juhataja prof. H. Tikk, V. Tikk. Teine rida (vasakult): A. Uibo, J. Hämmal, P. Piirsalu

Joonis 15. LKI kalakasvatusosakonna kollektiiv (1997). Esimene rida (vasakult): A. Laius, T. Tohvert, M. Aid. Teine rida (vasakult): R. Gross, osakonna juhataja T. Paaver, A. Vasemägi, J. Kasesalu. Pildilt puudub: K. Lotman

Joonis 16. LKI loomakasvatustehnoloogia osakonna kollektiiv (1997). Esimene rida (vasakult): H. Kiiman, H. Kask, osakonna juhataja A. Kaasik, M. Miil, I. Veermäe. Teine rida (vasakult): A. Nõmmeots, L. Ainsaar, O. Põldmaa, V. Poikalainen. Pildilt puuduvad: K. Ader, E. Müller, J. Praks

Keemia osakonnas töötasid: prof Avo Karus (juhataja), dotsendid Katrin Kolk, Tõnis Lepiku, Leeni Leis, lektor Virge Karus, vanemlaborandid Liivia Oraste, Salme Vene ja Tiiu Lepiku. Osakonna juurde kuulus ökokeemia laboratoorium (juhataja Enno Mõttus). Keemia osakond asus aadressil Veski 13.

Joonis 17. LKI keemia osakonna kollektiiv (1997). Esimene rida (vasakult): L. Leis, A. Viigi, R. Pällin, R. Leis. Teine rida (vasakult): osakonna juhataja prof. A. Nilson, S. Vene, V. Nõmm, K. Kolk. Kolmas rida (vasakult): T. Lepiku, A. Karus, U. Ojaperv, S. Kuusik, E Mõttus. Pildilt puuduvad: M. Eimre, I. Liblikas

Loomakasvatusinstituudi koosseisu kuulus veel kirjastusgrupp (juhataja Ene Hellenurme) ja majandusosakond (juhataja Aarne Puusepp).

EPMÜ nõukogu 4.05.2004 otsusega muudeti ülikooli akadeemilist struktuuri **alates 1.01.2005.** Moodustati viis instituuti: Põllumajandus- ja keskkonnainstituut (PKI) (direktor Illar Lemetti, õppedirektor Are Selge), **Veterinaarmeditsiini ja loomakasvatuse instituut** (VLI) (direktor Toomas Tiirats, õppedirektor Einar Orgmets, Majandus- ja sotsiaalinstituut (MSI) (direktor Rando Värnik, õppedirektor Tiiu Ohvril), Metsandus- ja maaehitusinstituut (MMI) (direktor Paavo Kaimre, õppedirektor Toomas Timmusk), Tehnikainstituut (TI) (direktor Margus Araks, õppedirektor Arvo Leola).

Veterinaarmeditsiini ja loomakasvatuse instituut (VLI) (inglise keeles *Institute of Veterinary Medicine and Animal Sciences of Estonian University of Life Sciences*) **moodustati senise EPMÜ Loomakasvatusinstituudi (dir prof Olav Kärt), loomaarstiteaduskonna (dekaan prof Toivo Suuroja) ja Agrobiokeskuse (dir Jüri Kumar) ühinemise** teel.

2005. aastal õppis veterinaarmeditsiini ja loomakasvatuse instituudis 706 üliõpilast. Instituudi hallata oli bakalaureuseõppekava Loomakasvatussaaduste tootmine (spetsialiseerumised: loomakasvatus, kalakasvatus, liha- ja piimatehnoloogia), loomaarstiõppekava Veterinaarmeditsiin, 3+2 õppesüsteemi magistriõppekavad Loomakasvatus, Kalakasvatus, Liha- ja piimatehnoloogia, Agroökoloogia, 4+2 magistriõppekavad Toiduhügieen ja veterinaarkontroll ning Loomakasvatus, doktoriõppekava Veterinaarmeditsiin ja toiduteadus.

Alates 27. novembrist 2005 on ülikooli nimeks **Eesti Maaülikool (EMÜ**).

2007. aastal õppis Veterinaarmeditsiini ja loomakasvatuse instituudis 601 üliõpilast sh bakalaureuseõppes 164, loomaarstiõppes 308, magistriõppes 91, doktoriõppes 38. Instituudi hallata oli üks bakalaureuseõppekava (Loomakasvatussaaduste tootmine), üks loomaarstiõppekava (Veterinaarmeditsiin), kolm magistriõppekava (Loomakasvatus, Toiduainete tehnoloogia, Kalakasvatus) ja üks doktoriõppekava (Veterinaarmeditsiin ja toiduteadus).

2010. aastal oli Veterinaarmeditsiini ja loomakasvatuse instituudi hallata juba kaks bakalaureuseõppekava: Loomakasvatussaaduste tootmine (kood 396) ja Toiduainete tehnoloogia (kood 100984), üks loomaarstiõppekava Veterinaarmeditsiin (398), kolm magistriõppekava: Loomakasvatus (kood 449), Toiduainete tehnoloogia (455), Kalakasvatus (462) ning üks doktoriõppekava.

2014. aastal muutus bakalaureuseõppekava Loomakasvatussaaduste tootmine (kood 396) nimetus; õppekava nimeks sai Loomakasvatus ja kalakasvatus (396). 2016. aastal lahutati õppekavas loomakasvatuse ja kalakasvatuse õpe; õppekava nimetuseks sai Loomakasvatus (396); avati uus bakalaureuseõppekava Kalandus ja vesiviljelus (143997), mida hakkas haldama PKI. 2013. aastal avati inglise õppekeelega loomaarstiõppekava Veterinaarmeditsiin (118977).

Veterinaarmeditsiini ja loomakasvatuse instituudis õppivate üliõpilaste arv on olnud stabiilne; alates 2016. aastas on stabiliseerunud ka bakalaureuseõppes loomakasvatust õppivate üliõpilaste arv:

Aasta	Üliõpilaste arv VL-s			
	Instituudis kokku	sh loomakasvatuse erialal (bak)	sh toiduainete tehnoloogia erialal (bak	sh veterinaarmeditsiini erialal
2008	620	171	-	321
2009	676	206	-	337
2010	702	185	44	341
2011	689	170	70	330
2012	686	135	94	327
2013	656	117	92	317 sh 24 ingliskeelsel õppekaval
2014	618	99	77	326 sh 55 ingl
2015	569	82	71	325 sh 83 ingl
2016	538	52	62	338 sh 113 ingl
2017	497	40	50	328 sh 143 ingl
2018	513	43	59	334 sh 174 ingl
2019	519	44	55	331 sh 186 ingl
2020	576	64	61	352 sh 200 ingl
2021	574	58	63	365 sh 204 ingl

Veterinaarmeditsiini ja loomakasvatuse instituuti juhib Toomas Tiirats, kes valiti instituudi direktoriks alates 1.01.2022 kuni 31.12.2026. Direktori asetäitja teaduse alal on prof Riho Gross.

Instituudi õppetegevust juhib direktori asetäitja õppe alal Einar Orgmets, õpet korraldavad Piret Aus ja Külli Kõrgesaar.

Eesti Maaülikooli veterinaarmeditsiini ja loomakasvatuse instituudis on 7 õppetooli:

Õppetool	Õppetooli juht
Kliiniline veterinaarmeditsiin	Prof Toomas Orro
Söötmisteadus	Prof Meelis Ots
Toiduhügieen ja rahvatervis	Prof Mati Roasto
Toiduteadus ja toiduainete tehnoloogia	Dots Ivi Jõudu
Tõuaretus ja biotehnoloogia	Prof Haldja Viinalass
Vesiviljelus	Prof Riho Gross
Veterinaarne bio- ja populatsioonimeditsiin	Prof Arvo Viltrop

Endisest Loomakasvatusinstituudi aretusosakonnast (6 õppejõudu, 2 teadurit) on välja kasvanud **Veterinaarmeditsiini ja loomakasvatuse instituudi (VLI) tõuaretuse ja biotehnoloogia õppetool.** Õppetoolis on 7 õppejõudu ja 6 teadurit. Õppejõududena töötavad prof Haldja Viinalass (õppetooli juht), prof Ülle Jaakma (ülikooli teadusprorektor), prof Tanel Kaart, prof Andres Valdmann, dots Heli Kiiman, vanemlektor Alo Tänavots, lektor Einar Orgmets. Õppetooli juurde kuulub geneetika labor. Õppetool asub aadressil Kreutzwaldi 46 ja Kreutzwaldi 62.

Loomakasvatusinstituudi söötmisosakonnast (3 õppejõudu, 6 teadurit) ning väikelooma- ja linnukasvatuse osakonnast (4 õppejõudu) on välja kasvanud **VLI söötmisteaduse õppetool.** Õppetoolis on 8 õppejõudu ja 3 teadurit. Õppejõududena töötavad: prof Meelis Ots (õppetooli juht), prof David Arney, dots Allan Kaasik, dots

Marko Kass, dots Ragnar Leming, lektor Peep Piirsalu, õpetajad Tiia Ariko ja Priit Karis. Õppetooli juurde kuulub sööda ja ainevahetuse labor (juh. Andres Olt) ja piima kvaliteedi uurimise labor (juh. Merike Henno). Õppetool asub aadressil Kreutzwaldi 46 ja Kreutzwaldi 62.

Loomakasvatusinstituudi keemia osakonnast (5 õppejõudu) **on saanud VLI toiduteaduse ja toiduainete tehnoloogia õppetooli** juurde kuuluv **keemia üksus**, kus töötab 5 õppejõudu.

Eesti Põllumajanduse Akadeemia Zootehnikateaduskonnast on saanud Eesti Maaülikooli Veterinaarmeditsiini ja loomakasvatuse instituut: **EPA Zootehnikateaduskond (ZT)(1951) ->** EPA Zooinseneriteaduskond (ZI)(1976) -> EPMÜ Loomakasvatusteaduskond (LK) (1.01.1991) -> EPMÜ Põllumajandusteaduskonna Loomakasvatusinstituut (LKI) (1.09.1991) -> EPMÜ Loomakasvatusinstituut (LKI)(1.09.1992) -> EPMÜ Loomakasvatusinstituut (LKI + ELVI) (1.06.1994) **-> Veterinaarmeditsiini ja loomakasvatuse instituut (VLI) (1.01.2005).**

Veterinaarmeditsiini ja loomakasvatuse instituut (VLI) (*Institute of Veterinary Medicine and Animal Sciences of Estonian University of Life Sciences*) moodustati senise Loomakasvatusinstituudi (dir prof Olav Kärt), Loomaarstiteaduskonna (dekaan prof Toivo Suuroja) ja Agrobiokeskuse (dir Jüri Kumar) ühinemise teel.

EPA Zootehnikateaduskonna Zootehnika erialast (1951) kasvas välja EMÜ VLI bakalaureuseõppe õppekava Loomakasvatus (Zootehnika (1951) -> Zooinsener (1976) -> Loomakasvatus (1991) -> Loomakasvatussaaduste tootmine (2002) -> Loomakasvatus ja kalakasvatus (2014) -> **Loomakasvatus**) ning **magistriõppe õppekava Loomakasvatus.**

EPA Zootehnikateaduskonna piimasaaduste tehnoloogia erialast (1951) kasvas välja EMÜ VLI bakalaureuseõppe õppekava Toiduainete tehnoloogia ja **magistriõppe õppekava Toiduainete tehnoloogia.**

Bakalaureuseõppe õppekava Loomakasvatus (kestusega 3 aastat, 180 EAP) koosneb järgmistest moodulitest: üldmoodul (23 EAP), erialamoodul (127 EAP), eriala valikainete moodul (12 EAP), vabaained (8 EAP), bakalaureusetöö või –eksam (10 EAP).

Üldmooduli õppeained on: sissejuhatus loomakasvatuse õpingutesse; teadustöö alused; inglise erialakeel; riskianalüüs ja töökeskkonna ohutus; üldkeemia; keskkonnakaitse ja -korraldus; biomajanduse alused.

Erialamooduli õppeained on grupeeritud alammooduliteks:

Loomade kehaehitus ja talitus (14 EAP): koduloomade morfoloogia; biokeemia ja molekulaarbioloogia alused; loomafüsioloogia alused.

Tõuaretus (15 AP): loomageneetika; aretusõpetus; informaatika ja biomeetria.

Söödatootmise ja söötmisteadus (16 EAP): põllumajandustaimed; agronoomia alused ja söödatootmine; söötmisõpetus.

Loomade heaolu, tervis ja sigimine (15 EAP): loomade käitumine, heaolu ja kaitse; mikrobioloogia ja immunoloogia; loomatervishoid ja veterinaaria alused; sigimisõpetus.

Loomakasvatussaaduste tootmine (55 EAP): üldloomakasvatus; loomapidamise mehhaniseerimise alused; veisekasvatus; seakasvatus; linnukasvatus; lamba- ja kitsekasvatus: hobusekasvatus; küülikukasvatus; maheloomakasvatus; loomakasvatuse õppepraktika (2 EAP); loomakasvatusettevõtte praktika (8 EAP); lihatehnoloogia alused; piimatehnoloogia alused.

Maaettevõtlus (12 EAP): maaettevõtluse alused; põllumajandusökonoomika; ideest äriplaanini.

Magistriõppe õppekava Loomakasvatus (kestusega 2 aastat, 80 EAP) koosneb järgmistest moodulitest: erialamoodul (79 EAP), eriala valikainete moodul (6 EAP), vabaained (5 EAP), magistritöö (30 A). Erialamooduli õppeained on grupeeritud alammooduliteks:

Teadustöö metodoloogia loomakasvatuses (15 EAP): uurimistöö metoodika ja katsete planeerimine loomakasvatuses; akadeemiline kirjutamine; statistiline andmetöötlus; loomakasvatuse kursusetöö. Loomade heaolu ja pidamine (8 EAP): loomade heaolu hindamine; loomakasvatus ja keskkond; loomakasvatushooned ja nende tehnoloogiline sisustus.

Tõuaretus ja söötmisteadus (39 EAP): loomageneetilised analüüsimeetodid; lineaarsed mudelid loomade aretusväärtuse hindamisel; söötade ja loomse materjali analüüsimeetodid; toitumisfüsioloogia ja metabolism; piimaveisekasvatuse erikursus; lihaveisekasvatuse erikursus; seakasvatuse erikursus; lamba- ja kitsekasvatuse erikursus.

Tootmise planeerimine ja juhtimine loomakasvatuses (17 EAP): nõuandeteenistus ja –süsteemid; põllumajandusettevõtte majandusliku tegevuse analüüs; äristrateegiad; loomakasvatusettevõtte juhtimise praktika (6 EAP).

Bakalaureuseõppe õppekava Toiduainete tehnoloogia (100984) (kestusega 3 aastat, 180 EAP) koosneb järgmistest moodulitest: üldmoodul (35 EAP), erialamoodul (115 EAP), eriala valikainete moodul (12 EAP), vabaained (8 EAP), bakalaureusetöö või -eksam (10 EAP).

Üldmooduli õppeained on: kõrgema matemaatika alused; üldkeemia; inglise erialakeel; riskianalüüs ja töökeskkonna ohutus; keskkonnakaitse ja –korraldus; biomajanduse alused; maaettevõtluse alused; ideest äriplaanini.

Erialamooduli õppeained on grupeeritud alammooduliteks:

Toiduteaduse alused (20 EAP): sissejuhatus toiduainete tehnoloogiasse; uurimistöö alused toiduainete tehnoloogias; biokeemia ja molekulaarbioloogia alused; füüsikaline ja kolloidkeemia; üldmikrobioloogia.

Toidutoore (9 EAP): toiduainete taimne toore; toiduainete loomne toore.

Toidutöötlemise protsessid ja seadmed (18 EAP): füüsika ja elektrotehnika alused; insenerigraafika I; toiduainetööstuse protsessid ja üldseadmed; toiduainetööstuse tehnoloogiliste liinide projekteerimise alused.

Toiduainete tehnoloogia (54 EAP): tööstuslikuid mikroobid ja juuretised; piimatoodete tehnoloogia alused; tapa- ja lihasaaduste tehnoloogia alused; taimsete toiduainete tehnoloogia alused; pagari- ja kondiitritoodete tehnoloogia alused; jookide tehnoloogia aluse; kalatoodete tehnoloogia alused; toiduainete tehnoloogia erialapraktika.

Toiduainete kvaliteet ja ohutus (14 EAP): toiduainete sensoorse hindamise alused; toiduainete säilitamise ja konserveerimise alused; toiduainete pakendamine; toiduohutuse juhtimissüsteem toiduainete töötlemisel.

Magistriõppe õppekava Toiduainete tehnoloogia (kestusega 2 aastat, 80 EAP) koosneb järgmistest moodulitest: eriala ühismoodul (50 EAP), lihatehnoloogia eriala spetsialiseerumismoodul (35 EAP), piimatehnoloogia eriala spetsialiseerumismoodul (35 EAP), taimsete toiduainete tehnoloogia eriala spetsialiseerumismoodul (35 EAP), vabaained (5 EAP), magistritöö (30 AP).

Eriala ühismooduli õppeained on grupeeritud alammooduliteks:

Toiduainete keemia ja biotehnoloogia (13 EAP): toiduainete füüsikalised ja keemilised analüüsimeetodid; toiduainete mikrobioloogia; toidu lisaainete keemia ja funktsionaalsus, toiduainete biotehnoloogia.

Toiduainetööstuse juhtimine ja planeerimine (13 EAP): toidu seadusandluse alused; toidu tootmishügieen ja järelevalve; kvaliteediõpetus; äristrateegiad. Toiduteadus (24 EAP): toiduainetööstuse tehnoloogiliste protsesside teoreetilised ja tehnoökonoomilised alused; uurimistöö metoodika toiduainete tehnoloogias; toiduainete töötlemisel tekkivate kõrvalsaaduste väärindamine; statistiline andmetöötlus; toiduainetööstuse tootearendus.

Lihatehnoloogia eriala spetsialiseerumismooduli (35 EAP) õppeained: lihatehnoloogia füüsikalis-keemilised ja biokeemilised alused; tapasaaduste tehnoloogia; lihatööstuse eriseadmed; lihasaaduste tehnoloogia; kursuseprojekt lihatehnoloogias; lihatehnoloogia ettevõttepraktika.

Piimatehnoloogia eriala spetsialiseerumismooduli (35 EAP) õppeained: piimatehnoloogia füüsikalis-keemilised ja biokeemilised alused; piimatoodete tehnoloogia; piimatööstuse eriseadmed; kursuseprojekt piimatehnoloogias; piimatehnoloogia ettevõttepraktika.

Taimsete toiduainete tehnoloogia eriala spetsialiseerumismooduli (35 EAP) õppeained:

jookide tehnoloogia; taimsete toiduainete tehnoloogia; pagaritoodete tehnoloogia; kondiitritoodete tehnoloogia; kursuseprojekt taimsete toiduainete tehnoloogias; taimsete toiduainete tehnoloogia ettevõttepraktika.

2022. aastal on Veterinaarmeditsiini ja loomakasvatuse instituudi hallata kaks bakalaureuseõppekava, kaks loomaarstiõppekava, kaks magistriõppekava ja üks doktoriõppekava; doktoriõppekava Põllumajandus haldamine toimub koostöös teiste instituutidega.

VLI üliõpilasi õpib nendel õppekavadel kokku 547 sh 218 välisüliõpilast:

Õppeaste	Õppekava	Üliõpilaste arv seisuga 01.05.2022
Bakalaureuseõpe	Loomakasvatus (kood 396)	51
	Toiduainete tehnoloogia (100984)	54
Bakalaureuse- ja magistriõppe integreeritud õpe (Loomaarstiõpe)	Veterinaarmeditsiin (398)	156
	Veterinaarmeditsiin (118977) inglise õppekeel	202
Magistriõpe	Loomakasvatus (449)	13
	Toiduainete tehnoloogia (455)	21
Doktoriõpe	Põllumajandus (80132)	13 sh 4 välisüliõpilast
	Veterinaarmeditsiin ja toiduteadus (80134)	37 sh 11 välisüliõpilast
Üliõpilasi kokku		547

Instituudis töötab 287 inimest, nendest akadeemilistel ametikohtadel 116. Akadeemilistel ametikohtadel töötjatest 75 on õppejõud, 41 on teadurid. Instituudi õppejõududest (75) on kõige enam lektoreid (36 sh vanemlektoreid 7), professoreid on 17 sh 1 nooremprofessor ja 3 kaasprofessorit, dotsente on 9, assistente 6, õpetajaid 5, külalisõppejõude on 2. Teaduritest (41) 9 on vanemteadurid.

Seisuga 21.04.2022 töötavad Veterinaarmeditsiini ja loomakasvatuse instituudis professorina, dotsendina, vanemteadurina:

Professor	David Richard Arney
	Rajeev Bhat
	Fazeli Alireza
	Riho Gross
	Tanel Kaart
	Katrin Kaldre
	Sulev Kõks
	Toomas Orro
	Tõnu Püssa
	Mati Roasto
	Andres Valdmann
	Haldja Viinalass
	Arvo Viltrop
Nooremprofessor	Helena Andreson
Kaasprofessor	Piret Hussar
	Kadrin Meremäe
	Meelis Ots
Dotsent	Terje Elias
	Sergei Jurtšenko
	Ivi Jõudu
	Allan Kaasik
	Piret Kalmus
	Avo Karus
	Kalle Kask
	Ragnar Leming
	Kerli Mõtus
Vanemteadur	Merike Henno
	Ülle Jaakma
	Katri Ling
	Toonika Rinken
	Hanno Jaakson
	Marko Kass
	Tõnu Püssa
	Anti Vasemägi
	Septimiu Radu Ionescu

Audoktoriks on valitud järgmised EPA-s töötanud **doktorid**: Ilmar Müürsepp (ELVI sigimisbioloogia osakonna juhataja), Arnold Rüütel (LKI aretusõpetuse ja veisekasvatuse õppetooli professor), Voldemar Tilga (ELVI mikrobioloogia labori juhataja).

Veterinaarmeditsiini ja loomakasvatuse instituudi (sh endise Loomakasvatusinstituudi ja Loomaarstiteaduskonna) õppejõududest on emeriitprofessoriks valitud 19 ja emeriitdotsendiks 22 endist õppejõudu.

Emeriitprofessoriks on valitud järgmised **Loomakasvatusinstituudi (sh ELVI)** professorid: Arnold Rüütel (1993), Elmar-Ants Valdmann (1994), Ants Ilus (1994), Ants Nilson (1994), Harald Tikk (1997), Olev Saveli (2004).

Emeriitprofessoriks on valitud järgmised **Loomaarstiteaduskonna** professorid: Kaljo Reidla (1993), Nikolai Koslov (1995), Kaarel Kadarik (1995), Hanno Kübar (1995), Karl Peterson (1995), Ilmar Müürsepp (1996), Ants Nummert (1999), Jaan Praks (2003).

Emeriitprofessoriks on valitud järgmised **Veterinaarmeditsiini ja loomakasvatuse instituudi** professorid: Toivo Suuroja (2005), Meili Rei (2008), Olav Kärt (2011), Toivo Järvis (2014), Tiit Paaver (2016).

Emeriitdotsendiks on valitud järgmised **Veterinaarmeditsiini ja loomakasvatuse instituudi** õppejõud: Huno Eller (2007), Alida Kiis (2007), Elbi Lepp (2007), Ilme Nõmmisto (2007), Vilma Raudsepp (2007), Evald Reintam (2007), Viivi Sikk (2007), Juhan Simovart (2007), Edvard Meisner (2007), Paul Saks (2007), Aadu Kolk (2007), Jaagup Alaots (2007), Mall Reeben (2009), Madis Aidnik (2009), Anne Lüpsik (2009), Priit Elias (2015), Mihkel Jalakas (2017), Enn Ernits (2017), Vladimir Andrianov (2018), Silvi Tölp (2019), Tiiu Saar (2020), Aleksander Lember 2020).

Anne Lüpsik
emeriitdotsent

HANS KÜÜTS – *IN MEMORIAM*

20.12.1932–†06.10.2022

6. oktoobril lahkus meie seast Eesti Teaduste Akadeemia akadeemik, Jõgeva Sordiaretusjaama (instituudi) kauaaegne direktor Hans Küüts.

Hans Küüts sündis (20.12.1932) Põlva maakonnas Suuremetsa külas. Oli Rasina põhikooli (lõpetanud 1947), Tartu I Keskkooli (1951) ja Eesti Põllumajanduse Akadeemia (1956. a *cum laude*) vilistlane, kes tegi oma väärika elutöö Jõgeval: algul teaduri-sordiaretajana (1958-1964), siis aretusosakonna juhatajana (1964-1973) ja kauaaegse direktorina (1973-1998). Aastatel 1998-2015 töötas veel osalise tööajaga vanemteadur-konsultandina aidates kaasa asutuse juhtimisel üldküsimustes ja odra sordiaretuse rühma töös.

Teraviljakultuuride sordiaretajaks õppis Hans Küüts Rootsis Svalöfi Aretusinstituudis (1969-70). Sealnähtu ja õpitu ning kolleegide juures kogetu võttis kokku raamatutes *Odra sordiaretuse uuemad meetodid Rootsis* (Tln., 1971, 152 lk) ja *Kaera ja odra sordiaretus ning seemnekasvatus Soomes* (Tln., 1974, 48 lk). Praktilises sordiaretuses tehtule tagasi mõeldes meenuvad odrasordid 'Toomas', 'Miina', 'Esme', 'Liisa', 'Elo', 'Teele' 'Anni' 'Viire', 'Leeni' ja 'Maali'. Odra agrotehnika alal kaitses ta (1968) ka teaduste kandidaadi kraadi. Lisaks odra aretamisele on Hans Küüts andnud kaaluka panuse ka kaera ja suvinisu sordiaretuses. Ta on 6 kaerasordi ja 2 suvinisusordi kaasautor.

Tartus keeltekoolis omandatud hea inglise keele oskus võimaldas tal omal ajal osaleda rahvusvahelises suhtluses. Ta oli esimene eestlane, kes võeti Euroopa Sordiaretajate Ühenduse (EUCARPIA) liikmeks (1974), on olnud seal aastatel 1981-2000 odra ja 1989-1994 kaera geneetika ning sordiaretuse rahvusvaheliste sümpoosionide organiseerimiskomitee liige, korduvalt juhatanud rahvusvahelisi sordiaretusalaseid sümpoosione ja esinenud ettekannetega. Oli rahvusvaheliselt tuntud, mis võimaldas luua head suhted aretustööks nii vajalikke katsemasinaid ja laboratooriumi aparatuuri tootvate firmadega ja nende omanikega. Teiselt poolt vene keele valdamine, hea suhtlemisoskus ning rakendatud diplomaatiavõtted kindlustasid omal ajal vajalikud ostud ka Moskvapoolse valuutarahaga. Direktoritöö lõpetamisel oli Hans Küütsi juhitud Jõgeva Sordiaretuse Instituut üks paremini katsetehnikaga varustatud uurimisasutus mitte ainult Eestis vaid ka kogu Nõukogude Liidus.

Jõgeva Sordiaretusjaama (aastast 1992 instituudi) direktorina kulutas Hans Küüts palju energiat asutuse väljaehitamisele. Praegune Eesti Taimekasvatuse Instituut Jõgeval töötabki põhiliselt neis hoonetes, mis valmisid Hans Küütsi direktorina töötamise ajal. Oli ehitaja ja ehituse kvaliteedi suhtes nõudlik. Selleaegsete ehitusmaterjalide kehvale kvaliteedile vaatamata saavutati tase, mis jäi kõigile suurelt kodumaalt Jõgevat külastama tulnud kolleegidele silma.

Tähelepanuvääriv oli Hans Küütsi omaaegne oskus leida andekaid ja töökaid kõrgkoolilõpetajaid sordiaretustöö jätkajaks. See lõi eelduse, et asutus jäi suurte muutuste keerises üldse ellu ja teenib Eesti põllumeest tänaseni. Ka enda aretustöö jätkaja kasvas tal välja omast perekonnast. Tütar Ülle on tänaseks odra sordiaretuse alal edukalt kaitsnud doktori kraadi ja on juba mitme uue sordi autor.

Akadeemik Hans Küütsi tulemuslik töö sordiaretaja ja asutuse juhina ei ole jäänud märkamata ega tunnustuseta. Juba 42-aastasena omistati talle teenelise teadlase aunimetus (1974). Ta on pälvinud (kollektiivi liikmena) kahel korral, mõlema riigikorra ajal (1987, 1999), riikliku teaduspreemia, vabariigi president on tunnustanud tema elutööd V klassi Riigivapi ordeniga (1997) ja Jõgevamaa oma vapimärgiga (2006). Rahvusvaheline teadusüldsus on annetanud talle N. I. Vavilovi mälestusmedali (1987). Ta oli pikka aega Rootsi Svalövi Sordiaretuse Instituudi teadusnõukogu välisliikmeks. Hans Küüts on valitud Eesti Teaduste Akadeemia akadeemikuks (1994), Eesti Põllumajandusülikooli geneetika ja sordiaretuse õppetooli professoriks (aastast 1995 emeriitprofessor), Eesti Agronoomide Seltsi presidendiks (juhtinud seltsi aastatel 1991-1997), Eesti Rukki Selts seltsi aupresidendiks. Akadeemiline Põllumajanduse Selts on valinud ta auliikmeks (2000), ja määranud elutööpreemia (2002), Jõgeva vald on valinud Hans Küütsi valla aukodanikuks (1998) ja määranud talle elutöö preemia (2002). Siintoodud tunnustuste loetelu ei pretendeeri kaugeltki täiuslikkusele.

Vaatamata kogunenud aastatele jäi Hans Küüts kuni viimase ajani hingelt ikka erksaks, täpseks ja osavõtlikuks kolleegiks, kes suhtles inimestega endiselt talle omasel energilisel, sütitaval ja sõbralikul kombel. Hinnaline, kuid harva esinev omadus inimesel, kes on veerand sajandit juhtinud edukat teadusasutust ja pälvinud samas ridamisi suuri tunnustusi.

Hans Küüts on meile hea näide sellest, kuidas anne ja töökus võimaldavad ka üsna tavalisel talus sündinud ja maakoolis kooliteed alustanud poisil suureks isiksuseks sirguda. Imetlusväärne kunst on aga seejuures lihtsaks maal elavaks inimeseks jääda. Just seda kunsti valdas Hans Küüts, akadeemik, suurepäraselt. Paremini, kui keegi meist.

Mälestus Hans Küütsist kui andekast teadlasest, edukast sordiaretajast, võimekast instituudi juhist, kolleegist ja alati abivalmis sõbrast jääb kõigile, kellel temaga eluteel kokkupuutumisi oli, alatiseks püsima.

Ants Bender

DOKTORIKRAADI KAITSJAD EESTI MAAÜLIKOOLIS 2022. AASTAL
THESIS DEFENDERS ESTONIAN UNIVERSITY OF LIFE SCIENCES IN 2022

LIINA SOONVALD
VÄETAMISE, PÕLLUKULTUURI NING SORDI MÕJU TAIMEJUURTE SEENTE KOOSLUSTELE
RESPONSE OF ROOT FUNGAL COMMUNITIES TO FERTILISATION, CROP SPECIES AND CULTIVAR
Juhendajad: professor Marika Mänd, professor Alar Astover, professor Leho Tedersoo (TÜ)
4. veebruar 2022

HELI KIRIK
PISTESÄÄSKLASTE (DIPTERA: CULICIDAE) MITMEKESISUS EESTI LINNAKESKKONNAS JA LOODUSES
MOSQUITO (DIPTERA: CULICIDAE) DIVERSITY IN THE URBAN ENVIRONMENT AND COUNTRYSIDE OF ESTONIA
Juhendajad: vanemteadur Olavi Kurina, teadur Lea Tummeleht
28. veebruar 2022

VAHUR ROONI
LIGNOTSELLULOOSSETEST JÄÄTMETEST VEDELA BIOKÜTUSE TOOTMISEKS KEMIKAALIVABA EELTÖÖTLUSMEETODI VÄLJATÖÖTAMINE JA OPTIMEERIMINE
DEVELOPMENT AND OPTIMIZATION OF A REAGENT-FREE PRETREATMENT METHOD FOR PRODUCTION OF LIQUID BIOFUELS FROM LIGNOCELLULOSIC WASTE
Juhendaja: professor Timo Kikas
7. aprill 2022

ENELI PÕLDVEER
PUISTU SEISUNDI JA STRUKTUURITUNNUSTE KVANTITATIIVNE HINDAMINE HEMIBOREAALSETES METSAÖKOSÜSTEEMIDES
QUANTITATIVE ASSESSMENT OF STAND STRUCTURAL TRAITS AND HEALTH CONDITION IN HEMIBOREAL FOREST ECOSYSTEMS
Juhendajad: professor Henn Korjus, kaasprofessor Diana Laarmann
27. aprill 2022

CHIKODINAKA NKECHINYERE OKEREKE
KESKKONNASTRESSIDE MÕJU TROOPILISTE KULTUURTAIMEDE LEHTEDE FOTOSÜNTEESILE JA LENDUVATE ORGAANILISTE ÜHENDITE EMISSIOONIDELE
EFFECTS OF ABIOTIC STRESS ON FOLIAGE PHOTOSYNTHETIC CHARACTERISTICS AND VOLATILE ORGANIC COMPOUND EMISSIONS IN TROPICAL AGRICULTURAL SPECIES
Juhendaja: professor Ülo Niinemets
11. mai 2022

KRISTEL PANKSEP
MIKROSKOOPIAST GEENIDENI, KUIDAS OTSIDA TOKSILISI SINIVETIKAID MADALAST EUTROOFSEST JÄRVEST
FROM MICROSCOPY TO GENES - UNMASKING TOXIC CYANOBACTERIA IN A SHALLOW EUTROPHIC LAKE
Juhendajad: professor Veljo Kisand; teadur Helen Agasild; professor Kaarina Sivonen
23. mai 2022

REINE KOPPEL
NISU SAAGI JA KÜPSETUSKVALITEEDI STABIILSUS BALTI REGIOONIS
STABILITY OF YIELD AND BAKING QUALITY OF WHEAT IN BALTIC CONDITIONS
Juhendajad: dotsent Evelin Loit, vanemteadur Mati Koppel
3. juuni 2022

FARIBA BAHRINI
LINNAPARKIDE KASUTUSMUSTRID, RUUMILINE LIGIPÄÄSETAVUS JA KASUTAJAEELISTUSED IRAANI PEALINNAS TEHERANIS
PATTERN OF URBAN PARK USE,SPATIAL ACCESSIBILITY AND PREFERANCES OF URBAN PARK USERS IN TEHRAN, IRAN
Juhendaja: professor Simon Bell
10. juuni 2022

ASSAR LUHA
OCCUPATIONAL NOISE EXPOSURE AND HEARING PROBLEMS AMONG ACTIVE MILITARY SERVICE PERSONNEL IN ESTONIA
MILITAARMÜRA EKSPOSITSIOON JA KUULMISPROBLEEMID EESTI TEGEVVÄELASTEL
Juhendajad: professor Eda Merisalu, kaasprofessor Hans Orru
17. juuni 2022

HENRI JÄRV
THE IMPACT OF PROTECTED AREAS GOVERNANCE AND MANAGEMENT PRACTICES ON HUMAN WELL-BEING AND LOCAL SOCIOECONOMIC CONDITIONS
KAITSEALADE HALDUSSÜSTEEMI JA KAITSEKORRALDUSLIKE MEETMETE MÕJU INIMESTE HEAOLULE NING KOHALIKELE SOTSIAALMAJANDUSLIKELE OLUDELE
Juhendajad: professor Kalev Sepp, lektor Raymond David Ward
21. juuni 2022

KRISTEL PEETSALU
MUUTUSED ÄGEDA FAASI VALKUDE KONTSENTRATSIOONIDES, NENDE SEOSED TERNESPIIMA JA MASSI-IIBEGA VASTSÜNDINUD MÄLETSEJALISTEL
CHANGES IN ACUTE-PHASE PROTEINS' CONCENTRATIONS OF NEONATAL RUMINANTS IN RELATION TO COLOSTRUM AND WEIGHT GAIN
Juhendajad: professor Toomas Orro, teadur Lea Tummeleht
21. juuni 2022

JORDI ESCUER GATIUS
PÕLLUMULLAST ERALDUVA DILÄMMASTIKOKSIIDI VÄHENDAMINE
MITIGATION OF NITROUS OXIDE EMISSIONS FROM ARABLE SOILS
Juhendajad: kaasprofessor Merrit Shanskiy, kaasprofessor Kaido Soosaar, professor Alar Astover
30. juuni 2022

MARTA MARIA ALOS ORTI
LINNAÖKOLOOGIA VÄLJAKUTSED: UUED ÖKOSÜSTEEMID, UUED LAHENDUSED
URBAN ECOLOGY: NOVEL ECOSYSTEMS, NOVEL CHALLENGES
Juhendaja: professor Lauri Laanisto
29. august 2022

KÄTLIN PITMAN
BIOSENSOR ARRAY FOR BOD MEASUREMENTS IN DIFFERENT TYPES OF WASTEWATER
BIOSENSOR-RIVI ERINEVATE REOVETE BIOKEEMILISE HAPNIKUTARBE UURIMISEKS
Juhendajad: kaasprofessor Merlin Raud, kaasprofessor Jaak Nerut, professor Timo Kikas
29. august 2022

GRETE TÕNISALU
PISIIMETAJAD, VÄIKE-KONNAKOTKAS JA SERVAALAD: SAAKLOOMA, KISKJA JA ELUPAIGA SEOSTE UURING PÕLLUMAJANDUSMAASTIKUS
SMALL MAMMALS, THE LESSER SPOTTED EAGLE, AND ECOTONES: A CASE STUDY ON PREDATOR-PREY-HABITAT RELATIONSHIPS IN AGRICULTURAL LANDSCAPE
Juhendaja: vanemteadur Ülo Väli
5. september 2022

FRANCESCA CARNOVALE
LAMMASTE HEAOLU NENDE TRANSPORDIL KUUMAS JA KÜLMAS KLIIMAS
WELFARE OF LIVESTOCK SHEEP TRANSPORT IN HOT AND COLD CLIMATES
Juhendajad: professor David Arney, vanemlektor Andres Aland, professor Fabio Napolitano
3. oktoober 2022

KAI-YUN LI
MEHITAMATA ÕHUSÕIDUKI RAKENDAMINE PÕLLUKULTUURIDE SAAGIKUSE JA MAA HARIMISVIISIDE TUVASTAMISEL
UNMANNED AIRCRAFT SYSTEMS AND IMAGE ANALYSIS IN YIELD ESTIMATION AND AGRICULTURAL MANAGEMENT
Juhendajad: professor Kalev Sepp, professor Niall Burnside, doktor Ants Vain
5. oktoober 2022

OLESJA ESCUER
ILUTAIMEDE KASV JA ARENG SÕLTUVALT ORGAANILISTE LISANDITEGA MUUDETUD MULLATINGIMUSTEST
ORNAMENTAL PLANT GROWTH AND DEVELOPMENT DEPENDING ON SOIL CONDITIONS MODIFIED BY ORGANIC ADDITIVES
Juhendajad: professor Kadri Karp, kaasprofessor Merrit Shanskiy
18. oktoober 2022

INDREK KERES
VILJELUSVIISI JA N-VÄETAMISE MÕJU TALINISU SAAGI JA TAINA KVALITEEDILE
COMBINED EFFECTS OF GROPPING SYSTEM AND N-FERTILIZATION ON WINTER WHEAT YIELD AND BAKING QUALITY
Juhendajad: kaasprofessor Tiina Tosens, professor Ülo Niinemets, dotsent Evelin Loit
27. oktoober 2022

THAISA FERNANDES BERGAMO
KLIIMAMUUTUSE MÕJU HINDAMINE RANNANIIDU TAIMEKOOSLUSELE MESOKOSMI KATSE JA MEHITAMATA ÕHUSÕIDUKIGA KOGUTUD ANDMETE PÕHJAL
COMBINING UNMANNED AERIAL VEHICLES AND A MESOCOSM EXPERIMENT TO UNVEIL PLANT COMMUNITIES SHIFTS UNDER GLOBAL CHANGE CONDITIONS IN COASTAL MEADOWS
Juhendajad: professor Kalev Sepp, dr. Raymond D. Ward ja professor Christopher B. Joyce (University of Brighton)
22. november 2022

NEDA NAJDABBASI
ALTERNATIIVSED BIOTÕRJE STRATEEGIAD KARTULI-LEHEMÄDANIKU INTEGREERITUD TÕRJEKS
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Juhendajad: professor Marika Mänd, professor dr. ir. Geert Haesaert (Ghent University), professor dr. ir. Kris Audenaert (Ghent University)
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