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Evaluation of a different fertilisation in technology of corn for silage, sugar beet and meadow grasses production and their impact on the environment in Poland

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The most significant and irreversible is the overexploitation of the environment, which is constantly exposed to various forms of pollution. Soil pollution is the result of excessive use of fertilizer in a limited area for growing. Total of 30 technologies were analysed, specifying the pollution degree from fertilizers and natural manure. Technologies concerned three crops: corn for silage, sugar beet and meadow grasses. Informations were derived by surveys. During the analysis, it has been noted that some cultivation technologies exceeded the permissible level (170 kg N·ha^{-1}) of nitrogen fertilization. In analysis were noted the nitrogen excess delivered to the fields every year. Probably that was connected with the overproduction in surveyed farms. Overproduction (according to permissible level of nitrogen) averagely reached 98.29 kg·ha^{-1} of delivered nitrogen, giving 6 290 560 m^3 of biogas.

Key words: NPK fertilization, environmental protection, soil fertilization, technologies of agricultural production.

INTRODUCTION

Environmental degradation is a quick and adverse process to the surrounding nature. In case of agricultural land it can lead to disturbances in soil, irreversibly inhibiting the process of soil formation (Code of Good Agricultural Practice, 2004). Deteriorating physical, biological and chemical properties of the soil, effects of limiting production and greatly reduce soil fertility.

The consequences of environmental imbalances may be global, where the only way to preserve the balance is the policy of interdependency, which based on controls and sanctions, that keeps the highest standards (AgriLife, 2009). The European Union (EU) conducts policy, in which farmers must comply with standards and rules to maintain the liquidity of European subsidies. The cross compliance rule is consistent with the environmental standards of Good Agricultural and Environmental Conditions (GAEC) (2014), which are directly relevant to the protection of environment, public health, plant and animal welfare and the maintenance of agricultural land according to the principles of agricultural and environment respect (MRiRW, 2013). These standards are described in the regulation of the signature

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2009/73/EC, established within the EU (Directive 2009/73/EC). Directive regulates the political establishment and obliges all EU members for direct implementation of the provisions.

The rational agricultural land use in the main part lays on the responsibility of all agricultural entrepreneurs. Maintenance of land cultivation in proper condition, leads to the appropriate elemental soil saturation (Stachowicz, 2010), creating the crop yields of high quality (Smagacz et al., 2010). To apply appropriate doses of minerals for selected crops, the optimal mixture of synthetic fertilizers and natural manure should be prepared (Czuba, 2001; Kopiński, 2010; Fotyma et al., 2010; Tujaka, 2010). Fertilizers supply the soil with nitrogen (N), phosphorus and potassium in form of oxides P_2O_5 and K_2O (Konieczna and Roman, 2014). The most common way of selection of the mineral value of soil is the method "on the surface of the field" (Nowak, 2013), which is the procedure to monitor the balance of NPK in the soil. This tool is described in the Regulation of the Minister of Environment, 2002 (Dz.U. z 2003 r. nr 4, poz. 44). According to the regulations of Polish directives, the level of nitrogen supplied to the soil with fertilizers should not exceed 170 kg N/ha (The EU Nitrates Directive, 2010).

The aim of research was to determine the balance of NPK fertilization in technology of corn for silage, sugar beet and meadow grasses production. The following research hypothesis was formulated: Did the physicochemical properties of the soil and controlled growing conditions by optimal selection of technology result in cost reduction of the crop production allowing at the same to rational use of natural resources.

MATERIALS AND METHODS

The NPK balance method was used as described by Code of Good Agricultural Practice (2004), explaining how to determine the needs for individual elements of selected crops. The method relies on the balance between the volume of elements supplied to the soil contained in synthetic fertilizers as well as in the natural manure and the value taken up by the crop during the growing season. Survey data were grouped for each type of crop, for which individual technological cards prepared for each farm. Analysed crops were: corn for silage, sugar beet and meadow grasses. In surveyed farms, plants were cultivated on soil of the average bonitation class (IV-th class of soil), by the conventional crop production systems. The study was conducted on the 30 surveyed farms in Poland, in which the groups of 10 crops of corn for silage, 10 crops of sugar beet and 10 crops of meadow grasses (Table 1) were specified. The balance of the organic substance may be monitored, according to the Formula (1).

$$S = W + P + N_o \cdot W_o + N_g \cdot W_g + N_{gn} \cdot W_{gn} + N_s \cdot W \qquad (1)$$

Where: S – balance of organic matter [$t \cdot ha^{-1}$], W – coefficient of soil reproduction or soil degradation of organic matter for crop [$t \cdot ha^{-1}$], P – coefficient of soil reproduction of organic matter for undersown plants, catch crops and mulch [$t \cdot ha^{-1}$], N_o – farmyard manure fertilization [t], W_o – coefficient of soil reproduction of organic matter for farmyard manure [$1 \cdot h^{-1}$], N_g – liquid manure fertilization [t], W_g – coefficient of soil reproduction of organic matter for liquid manure [$1 \cdot h^{-1}$], N_{gn} – slurry fertilization [t], W_{gn} – coefficient of soil reproduction of organic matter for slurry [$1 \cdot h^{-1}$], N_s – straw fertilization [t], W_s – coefficient of soil reproduction of organic matter for straw [$1 \cdot h^{-1}$],

The coefficient of soil reproduction and soil degradation of organic matter was derived from Code of Good Agricultural Practice (2004). To conduct the balance of fertilization needs in the technology it is necessary to use the Formula (2).

$$S_{NPK} = N_{NPK} - Z_{NPK} \qquad (2)$$

Where:S_{NPK} – balance of NPK demand for crop [$kg \cdot ha^{-1}$], N_{NPK} – NPK applayed by fertilization [$kg \cdot ha^{-1}$], Z_{NPK} – NPK demanded by crop [$kg \cdot ha^{-1}$],

Discharged value of NPK (Z_{NPK}) that were demanded by the each particular crop has been derived from Code of Good Agricultural Practice (2004). The level of NPK values (N_{NPK}) that were supplied by fertilization were gathered from crop technology survey and presented in the Table 1. Fertilizers were applied by agricultural machines, which were located on the farm as a technical equipment. Natural manure were derived from livestock on the farm.

The analysis required the usage of dedicated computer software, which analytical module based on a mathematical algorithm. Algorithm allows to estimate the balance of NPK nutrients, humus content and level of nitrate nitrogen in the soil. The summary of data that was described in Table 1, shows the balance of NPK based on studies which were conducted on the surface of the field (Jończyk and Stalenga., 2006). The study used the "P.W. 3.3" computer program, which was created in the framework of the Multiannual Programme 2011-2015 titled "Standardization and monitoring of environmental projects, agricultural technology and infrastructure solutions for security and sustainable development of agriculture and rural areas" in Activity 3.3 titled: "Monitoring the effectiveness of the installation and agro energy efficiency of use of raw materials". Designed computer program, requires declare to variables for each crop. Input parameters in the analysis were type of soil, yield value and the level of synthetic fertilizers and natural manure. The analysis of particular crop was based on the phased specification of parameters characterizing the agricultural activities, under which the program calculated the balance of NPK, depending on factors specific to the technology.

Builded for the project realization (Multiannual Programme for 2011-2015, Activity 3.3) computer program and database, were created on the base of the principles of the Code of Good Agricultural Practice (2004). The program allows to perform calculations for the technology of the following crops: corn, beets, grains, legumes, meadow grasses and grain mixtures. The computer program database has also declared information concerning the content of chemical compounds (nitrogen, phosphorus oxide and potassium oxide) in particular synthetic fertilizers and natural manure. The contents of natural manures were presented in Table 2.

The computer program also prepares and declares database of synthetic fertilizers and natural manure, which can be modified according to the specific research needs. The coefficients of nutrients in fertilizers allow for calculation of the NPK balance using the data declared as an integral part of the used technology. The values of each chemical fertilizers are summarized in Table 3. The computer application was used as a tool for monitoring changes in the elemental content of the topsoil, influence of agrotechnical activities, which are contributing to the reduction of groundwater quality. Algorithm is also equipped with a module to estimate the value of nitrate nitrogen in the soil (N_{NO3}) depending on the crop. The value of nitrate nitrogen as an indicator of the potential environmental hazard (IUNG-PIB, 2008) was dependent on several weather stations in Poland, by analyzing the annual rainfall for that area.

Table 1. Characteristics of selected crop technology.

Technology	Yield [t·ha^{-1}]	Area [ha]	Nutrients [kg·ha^{-1}]					
			From natural manure			From synthetic fertilizers		
			N	P_2O_5	K_2O	N	P_2O_5	K_2O
SUGAR BEETS								
S1	62	3.24	199.50	157.50	182.00	122.52	0.00	92.59
S2	72	6	137.70	81.60	153.00	174.00	184.00	180.00
S3	57	2	239.40	189.00	218.40	50.20	196.00	30.00
S4	70	2.5	228.00	180.00	208.00	49.50	137.50	137.50
S5	75	2	228.00	180.00	208.00	121.00	49.50	108.00
S6	80	5	171.00	135.00	156.00	163.00	90.00	135.00
S7	55	2.5	228.00	180.00	208.00	55.76	92.00	120.00
S8	50	4	0.00	0.00	0.00	98.00	60.00	60.00
S9	40	6	216.00	128.00	240.00	81.00	60.00	60.00
S10	75	6.4	171.00	135.00	156.00	30.00	60.00	60.00
Corn for silage								
C1	80	13	156.68	61.85	193.78	197.16	92.25	180.38
C2	50	13	189.00	112.00	210.00	181.00	60.00	160.00
C3	80	4.5	84.00	46.00	74.00	148.40	96.00	144.00
C4	60	2	257.10	136.20	261.00	131.40	57.50	67.50
C5	50	2	0.00	0.00	0.00	138.00	60.00	114.00
C6	70	3.5	227.00	136.40	210.00	75.57	0.00	0.00
C7	50	2	216.00	128.00	240.00	115.00	28.00	25.20
C8	72	3.4	311.12	173.09	352.85	173.00	24.00	24.00
C9	65	3.25	122.98	62.35	143.34	114.65	0.00	0.00
C10	55	1	162.00	96.00	180.00	66.90	50.00	60.00
Meadow grasses								
M1	45	14.44	92.11	36.36	113.92	223.21	92.06	120.08
M2	50	3.25	77.54	42.46	68.31	46.03	0.00	0.00
M3	42	19	4.42	2.42	3.89	48.00	96.00	96.00
M4	30	15	126.00	74.67	140.00	84.36	30.00	40.00
M5	29	4	142.50	112.50	130.00	216.00	40.00	60.00
M6	60	7.9	146.20	80.06	128.80	123.04	0.00	0.00
M7	59	2.1	114.00	90.00	104.00	56.70	0.00	0.00
M8	35	10	39.90	31.50	36.40	129.20	0.00	0.00
M9	19	5	120.00	3.00	180.00	255.00	0.00	0.00
M10	53	8.24	77.03	29.99	94.25	96.85	0.00	0.00

S - Sugar beet, C - corn for silage, M - meadow grasses, Source: Own study.

Table 2. Contents of N,P,K in selected natural manure.

Fertilizer	Nitrogen (N) [%]	Phosphorus oxide (P_2O_5) [%]	Potassium oxide (K_2O) [%]
Farmyard manure	0.57	0.45	0.52
Liquid manure	0.42	0.23	0.37
Slurry	0.40	0.01	0.60
Straw	0.60	0.24	1.24

Source: Own study based on Grabowski 2009.

Table 3. Contents of N, P, K in selected synthetic fertilizers.

Name of fertilizer	Nitrogen (N) [%]	Phosphorus oxide (P_2O_5) [%]	Potassium oxide (K_2O) [%]
Can 27%N	27	0	0
Ammonium phosphate POLIDAP	18	46	0
Urea 46%	46	0	0
Polidap	18	46	0
Polifoska 4	4	12	32
Polifoska 6	6	20	30
Polifoska 8	8	24	24
Polifoska PK 20	0	20	18
Ammonium sulphate	27	0	0
Saletrzak	27	0	0
Potassium salt	0	0	60
Triple superphosphate	0	0	60
Dolomitic lime	0	46	0
Wuxal K (dolistny)	9	25	25

Source: Own study based on information published in manufacturer's website.

Table 4. Synthetic fertilizers and natural manure applied in the technology of sugar beet (S), corn for silage (C) and meadow grasses (M).

Technology	Natural manure			Synthetic fertilizers												
	Farm yard manure	Liquid manure	Slurry	Can 27%N	Ammonium phosphate POLIDAP	Urea 46%	Polifoska 4	Polifoska 6	Polifoska 8	Polifoska PK 20	Ammonium sulphate	Saletrzak	Potassium salt	Triple superphosphate	Dolomitic lime	Wuxal K (dolistny)
C1	N	U	N	N	U	U	N	N	N	N	N	N	U	N	N	U
C2	U	N	N	N	N	U	U	N	N	N	N	N	N	N	N	N
C3	N	U	N	N	N	U	N	U	N	N	N	N	N	N	N	N
C4	U	U	N	N	N	U	N	U	N	N	U	N	N	N	N	N
C5	N	N	N	N	N	U	N	N	N	U	N	N	U	N	N	N
C6	U	N	U	N	N	U	N	N	N	N	N	N	N	N	N	N
C7	U	N	N	N	N	U	N	N	N	U	N	N	N	N	N	N
C8	U	U	N	N	N	N	N	N	U	N	U	N	N	N	N	N
C9	U	U	N	N	N	U	N	N	N	N	N	N	N	N	N	N
C10	U	N	N	N	N	U	N	N	N	N	N	N	N	N	N	N
S1	U	N	N	N	N	U	N	N	N	N	U	N	U	N	N	N
S2	U	N	N	N	U	N	N	N	N	N	U	N	U	N	U	N
S3	U	N	N	N	U	U	N	N	N	N	N	U	U	N	N	N

Table 4. Contd.

S4	U	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
S5	U	N	N	N	N	N	N	N	U	N	U	N	N	N	N	N
S6	U	N	N	N	N	N	N	U	N	N	U	N	N	N	N	N
S7	U	N	N	N	N	U	N	N	N	N	N	N	U	U	N	N
S8	N	N	N	N	N	N	N	N	N	N	U	N	N	N	N	N
S9	U	N	N	N	N	N	N	N	N	N	U	N	N	N	N	N
S10	U	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
M1	N	U	N	N	U	N	N	N	N	N	U	N	U	N	N	N
M2	N	U	N	N	N	N	N	N	N	N	U	N	N	N	N	N
M3	N	N	U	N	N	N	N	N	N	N	N	N	N	N	N	N
M4	N	U	N	N	N	N	N	N	N	U	U	N	N	N	N	N
M5	N	U	N	N	N	N	N	U	N	N	U	N	N	N	N	N
M6	N	U	N	U	N	N	N	N	N	N	N	N	N	N	N	N
M7	U	N	N	N	N	N	N	N	N	N	N	U	N	N	N	N
M8	U	N	N	N	N	N	N	N	N	N	U	N	N	N	N	N
M9	N	N	U	N	N	N	N	N	N	N	U	N	N	N	N	N
M10	N	U	N	N	N	N	N	N	N	N	U	U	N	N	N	N

U – used, N – not used. Source: Own study.

All analyzed technologies have individual level of fertilization depending of quality and quantity. Calculations include the value of delivered nutrients from synthetic fertilizers, natural manure and aftercrops during the cultivation.The volume of NPK by which the technology has impoverished the soil, was determined in content of elements in the crop yields. Summary of applied synthetic fertilizers and natural manure in analyzed technology of sugar beet, corn for silage and meadow grasses were presented in Table 4.

RESULTS AND DISCUSSION

Tables 5 to 7 summarizes the results of NPK balance calculation from delivered and received nutrition for each crop. The calculations are characterized by maintaining the balance of nutrients in the soil during the cultivation of individual plants. The EU Nitrates Directive (2010) specifies the maximum value of nitrogen that can be delivered to the soil from the natural manure per year. The diagram (Figure 1) shows that the most of technologies were close to the upper level of allowed nitrogen fertilization value. The average content of nitrogen that was applied with natural manure amounted to 149.5 $kg•ha^{-1}$, and the average nitrogen value applied with the synthetic fertilizers amounted to 118.8 $kg•ha^{-1}$. Presented diagrams characterize the content of nitrogen, phosphorus oxide and potassium oxide in the soil for individual cultivation technologies (Figures 1 to 3). The positive and negative value of balance, were derived from calculation of NPK demand of crop (Formula 2).

The average content of phosphorus oxide that was applied with natural manure amounted to 94.0 $kg•ha^{-1}$, and for synthetic fertilizers amounted 55.2 $kg•ha^{-1}$. With respect to the potassium oxide values were respectively: for natural manure 153.1 $kg•ha^{-1}$, and for synthetic fertilizers 69.1 $kg•ha^{-1}$.

Conclusions

Analysis of the mineral substances balance allowed to state that several owners of surveyed farms exceeded the fertilization rate recommended by Code of Good Agricultural Practice (2010). Presented diagrams, show NPK balance in an extreme point with the value 408 $kg·ha^{-1}$ (technology C8) and negative -492 $kg·ha^{-1}$ (technology M8). Also the maximum volue 170 kg $N·ha^{-1}$, recomended by the Nitrote Directive was exceded in 46.6% of forms in the case of natural

Table 5. Balance of NPK in technology of corn for silage (C).

Symbol of technology	Main crop yield [$t \cdot ha^{-1}$]	N [$kg \cdot ha^{-1}$]	P_2O_5 [$kg \cdot ha^{-1}$]	K_2O [$kg \cdot ha^{-1}$]	NPK [$kg \cdot ha^{-1}$]
C1	80	58	42	6	106
C2	50	53	115	-14	154
C3	80	-64	30	-150	-184
C4	60	174	163	30	368
C5	50	-47	-10	-116	-173
C6	70	-32	38	-112	-106
C7	50	158	138	3	299
C8	72	244	170	-6	408
C9	65	174	131	-27	278
C10	55	26	69	-13	82

Source: Own study.

Table 6. Balance of NPK in technology of sugar beet (S).

Symbol of technology	Main crop [$t \cdot ha^{-1}$]	N [$kg \cdot ha^{-1}$]	P_2O_5 [$kg \cdot ha^{-1}$]	K_2O [$kg \cdot ha^{-1}$]	NPK [$kg \cdot ha^{-1}$]
S1	62	74	59	-128	5
S2	72	24	151	-135	40
S3	57	62	294	-123	233
S4	70	-3	206	-110	94
S5	75	49	110	-172	-13
S6	80	14	97	-229	-118
S7	55	64	184	-30	219
S8	50	-102	-20	-265	-387
S9	40	149	176	8	333
S10	75	-99	75	-293	-317

Source: Own study.

Table 7. Balance of NPK in technology of meadow grasses (M).

Symbol of technology	Main crop [$t \cdot ha^{-1}$]	N [$kg \cdot ha^{-1}$]	P_2O_5 [$kg \cdot ha^{-1}$]	K_2O [$kg \cdot ha^{-1}$]	NPK [$kg \cdot ha^{-1}$]
M1	45	84	97	-56	124
M2	50	-130	-28	-227	-384
M3	42	-161	38	-145	-268
M4	30	57	63	3	123
M5	29	172	57	-20	209
M6	60	-37	-4	-225	-266
M7	59	-129	8	-243	-364
M8	35	-131	-51	-310	-492
M9	19	278	-24	67	321
M10	53	-90	-28	-239	-357

Source: Own study.

manure, and in 83.3% of forms in the case of total fertilisation. High values of nitrogen may have negative impact on the environement. These excessive volues appeared on 90% of forms producing sugar beet (S)

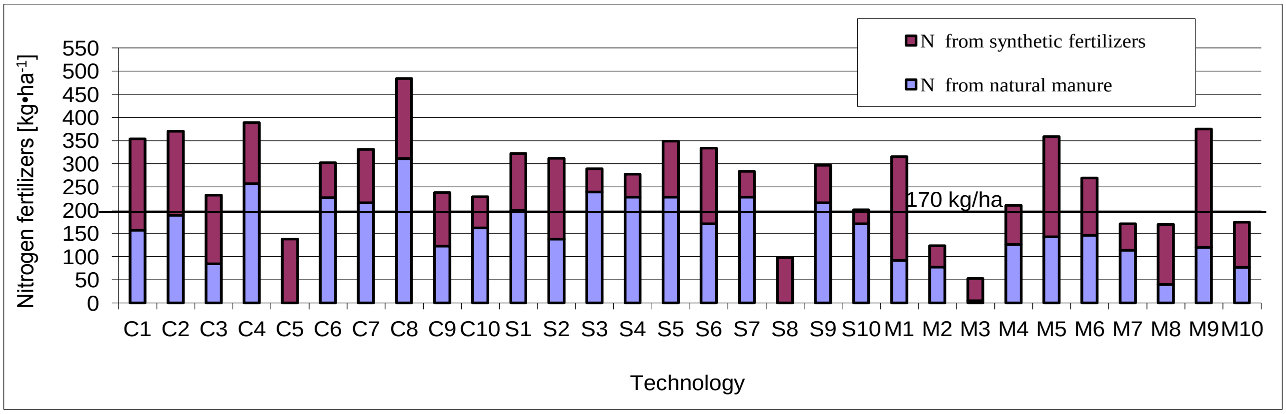

Figure 1. The level of nitrogen fertilization in technologies of corn for silage, sugar beet and meadow grasses. S - Sugar beet, C - corn for silage, M - meadow grasses.

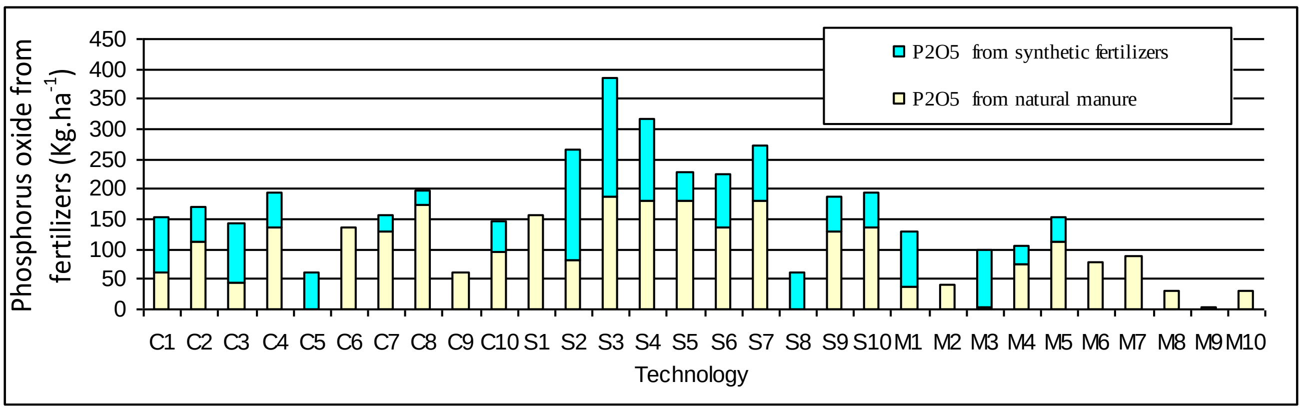

Figure 2. The level of phosphorus oxide fertilization in technologies of corn for silage, sugar beet and meadow grasses. S - Sugar beet, C - corn for silage, M - meadow grasses.

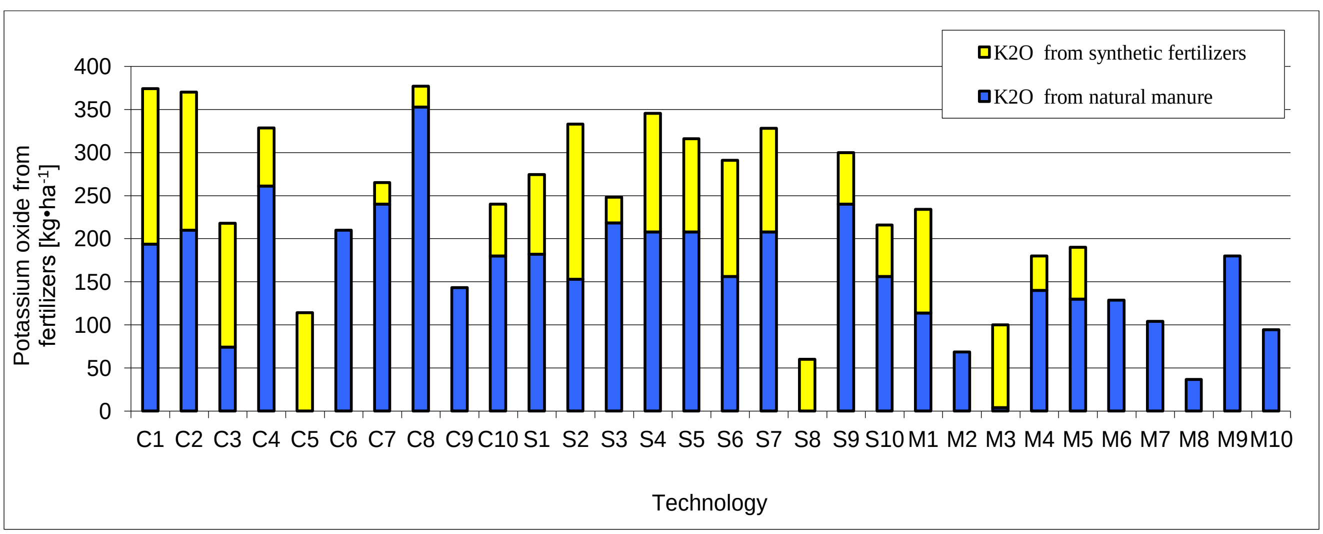

Figure 3. The level of potassium oxide fertilization in technologies of corn for silage, sugar beet and meadow grasses. *S* - Sugar beet, C - corn for silage, M - meadow grasses.

and corn for silage (C) and on 70% of forms cultivating meedow grasses (M). The average volue of this excess amounted to 98.29 $kg \cdot ha^{-1}$ over the recommended 170 kg $N \cdot ha^{-1}$.

In the case of natural fertilization excess may be caused by animal waste overproduction in the survey farms overproduction of natural wastes could be better utilized for biogas production. If the natural manure content 0.5% (Table 2) of nitrogen. According to average excess of nitrogen is 98.29 $kg \cdot ha^{-1}$, it can be calculated that 19 658 $kg \cdot ha^{-1}$ of natural manure is wasting every year on the field. Natural manure consists 60-80% of dry organic matter, that gives the capability of 300 to 700 $m^3 \cdot t^{-1}$ of biogas production (Fugol and Szlachta., 2010). Overproduction of wasted natural manure could generate 6 290 560 m^3 of biogas, that gives 3 774 336 m^3 of pure methane (CH_4) every year.

Disclosure of Conflict of Interest

The authors have not declared any conflict of interest.

Conflict of Interest

The author(s) have not declared any conflict of interests.

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