DOI: 10.17707/AgricultForest.63.3.19

Mykola KHARYTONOV, Oleksandr VELYCHKO [1]

CROPS ADAPTATION MANAGEMENT IN THE CONDITIONS OF STEPPE LANDSCAPE OF UKRAINE

SUMMARY

Preformed study approved for studied crops the dependency between crop nutrient uptake and concentration as well the impact of landscape positions, adaptation potential of species, varieties and hybrids occurrence. Perennial legumes (alfalfa, sainfoin) were more unpretentious. Pea varieties are moderately pretentious appeared to be better than cereal crops - megatrophs (barley, corn) in terms of edification for growing on slopes. The consumption of nutrients for the production of 1 ton of corn grain and relative quantity of by-products was lower for the slope of the southern position than for the flat and the northern hill slope of the landscape position. The uneven appearance of the resource potential factors for eroded lands dictates the need for differentiated use of arable lands.

Keywords: hill slopes, soil erosion, landscape position, crop productivity, nutrients, uptake

INTRODUCTION

The steppe zone of Ukraine is known as a zone with intensified development of erosion processes, around 35 % of all arable lands are affected by erosion each year (Kharytonov et al. 2004). Landscape features is a major factor in erosion process. All washed soils are formed on slopes with surface runoff. The intensity of erosion processes depends on the characteristics of hill slopes including angle slope, shape, length and exposition.Intensive land cultivation, complicated relief, large share of cultivated crops in rotation promote the development of erosion processes (Kharytonov et al. 2016; Nazmi et al. 2011; Mehdizade et al. 2013). Excessive densifying of the upper layers of molisoils and drastic reduction in the maximal intensity of water absorption are the main causes of the progressing erosion (Stone et al. 1985; Thelemann et al. 2010). Hillslope processes are defined by unique site characteristics such as soil physical and chemical properties, water retention and flow patterns, biological processes and topographic influences (Molodovskaya et al. 2011; Marques de Silva and Silva. 2008; Rochette et al. 2011; Kaspar et al. 2003) found that in years with below-average rainfall, corn yield was negatively correlated with relative elevation,

---

[1]Mykola Kharytonov (corresponding author: envteam@ukr.net), Department of Plant Breeding and Seeds Management, Faculty of Agronomy, Dnipropetrovsk State Agrarian and Economic University, Dnipro, UKRAINE.
Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.

slope, and curvature, whereas in years with above-average rainfall, corn yield was positively correlated with relative elevation and slope.

Increasing of the adaptive capacity of crops is based on adaptation mechanisms similar to those for plants, which are representatives of natural flora (Lykholat et al. 2016). The similar data were obtained when crops growth at specific landscape positions is influenced by several interacting hill slope process across a typical soil arena (Schipanski et al. 2010; Snapp and Kravchenko, 2015; Russenes et al. 2016). Influence of landscape position and terrain attributes an annual crop yield has been studied. In particular, corn yield and total plant biomass was greater at foot slopes benefiting from more available soil water at those lower landscape positions (Stone et al. 1985; Marques de Silva and Silva. 2006).

Corn grown yield at the depositional, flat and south-western hill slope positions lower than at all other positions. There were differences in the stover to grain ratio between landscape positions. The flat landscape position had a 6.9:1 ratio of stover to grain, whereas the depositional site had a 9:1 ratio (Thelemann et al. 2010). The same tendency was established in studies showing reduced yield at lower landscapes position with excessive amounts of water tend to collect (Kravchenko and Bullock 2000; Parent et al. 2008).

Means of adaptive macro- and micro-differentiation include the ecological specialization of species and varieties sowing. The cropping plan and crop rotation has been treated using a variety of approaches based on different objectives and handled at very different scales incorporated into agronomic, economic and land-use models (Farquharson and Baldock, 2008; Lazrak et al.. 2010; Ladoni et al. 2016). As follows, the design of agroecosystems based on increasing of species, varieties and hybrid variety is the first rate task. The key element of this approach is the formation of an adaptive species structure for cultivated areas for each particular element of the natural landscape. The choice of crops and their allocation to plots is at the core of the farming system management (Negassa et al.2015; Velychko, 2014). These decisions concentrate all the complexity involved in cropping system design and selection at the farm level because of their many involvements at different stages of the crop production processes (Simic et al. 2016). The large number of possible adaptation options, model-based exploration tools are commonly used to supplement traditional empirical approaches (Schaller et al. 2012; Han et al. 2017) for designing and evaluating innovative agricultural production systems.

Allocation of ecologically similar territories and choosing appropriate crops for those should be considered as the first step. No less important task is the right choice of crops for introduction into the crop rotation for culturing on sloping lands, which characterized by different exposition.

The aim of the research is to provide an assessment of the adaptive potential of crops under the conditions of the steppe agro-landscape of the Ukrainian steppe.

MATERIALS AND METHODS

Experimental areas were divided according to rate of received solar irradiation, moisture supply, organics and mineral nutrient content in the soil (Fig. 1). Crops were planted across the main slope on the experimental field. Determination of the dependence of the plants' reaction of on the flat, northern (N) and southern (S) hill slope landscape position was planned. This approach allows to determine the areas where the same crop, variety or hybrid are grown on maximaly different reliefs, which is considered as major affecting factor. An overland gain of alfalfa, espresso, barley and corn was evaluated in the phase of agricultural maturity.

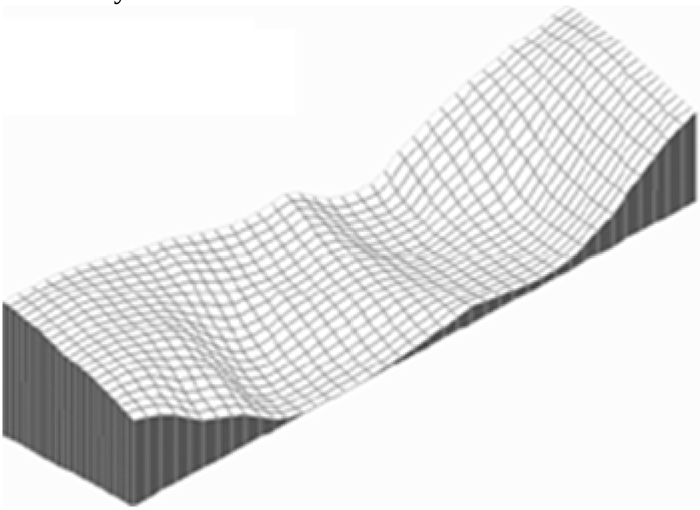

Figure 1. Digital map of the studied arable land

The green mass of peas was sampled in the phase of branching and budding. The nitrogen and phosphorus concentration in plant samples was estimated using Kjeldahl method. Total P concentrations of the applied residues were determined by sulfuric acid digestion (Thomas et al. 1967). Potassium was determined with flame photometry.

The intensity of the nitrogen fixation of the nodules of peas was determined by the Hardy acetylene method (Hardy et al. 1968) on the gas chromatograph Chrom-5 (Czech Republic).

Crop uptake rates for nitrogen, phosphorus and potassium are calculated per yield of dry matter for crops.

RESULTS AND DISCUSSION

Calculation of release and consumption of the main nutrients by alfalfa and saffron harvests are presented in the Tables 1 and 2.

As it can be concluded from the Table 1, the rates of removal of nitrogen with aboveground biomass of alfalfa and sainfoin are higher for the hill slope of northern position.

Similar effect when alfalfa biomass at the western hillslope position was higher than the depositional position (Thelemann et al. 2010).

More favorable environmental conditions also resulted in higher removal rate of phosphorus by leguminous plants on the "shadow" slope of the northern exposition (compared to the flate landscape position).

The lowest level of potassium removal was observed on the slope that was strongly eroded. In the bulk mass of the alfalfa hay, the ratio of N: P: K varied from 1:0.3:0.8 for the sample harvested from the plain land to 1:0.25:0.5 for the samples harvested on the slopes.

Obviously, these difference can be explained by the greater accumulation of nitrogen as a result of symbiosis with rizobacteria.

Table 1. Ratio, yield (ton/ha) and uptake of nitrogen, phosphorus and potassium with alfalfa and sainfoin biomass (three mows in two years) at landscape positions, kg / ha

Landscape position	N: P: K		
	Yield		
	N	P_2O_5	K_2O
	Alfalfa		
Flat	1: 0.3: 0.8		
	8.37		
	159.37	45.8	131.8
Northern hill slope	1: 0.25: 0.5		
	9.89		
	246.06	61.71	119.2
Southern hill slope	1: 0.25: 0.5		
	5.10		
	124.80	31.78	67.9
	Sainfoin		
Flat	1: 0.3: 0.6		
	8.20		
	176.4	47.55	110.0
Northern hill slope	1: 0.3: 0.5		
	10.33		
	214.8	65.3	108.4
Southern hill slope	1 : 0.3 : 0.55		
	6.04		
	111.1	34.8	61.1

The ratio of N: P: K for the sainfoin was virtually unchanged at rate of 1: 0.3: (0.5-0.6).

In our opinion, this can be explained by the famous fact that alfalfa, like most of mesophytes more than the sainfoin (xerophyte) had adapted to the conditions of northern hill slope position.

The data on ratio, yield and total removal of main nutritions with the biomass of two varieties of green pea at different landscape positions are shown in the table 2.

From the two mentioned local varieties of peas, “Ukisniy 9” had a lower dependence on the relief than “Lgovsky – zelenozerny”.

Study of the activity of the nitrogenase complex in the root nodules of plants revealed the difference for the three varieties of peas and dependence on the landscape features (Fig. 2).

In particular, certain peas varieties local selection showed high rate of nitrogen fixation. On the northern slope, which was more humid, higher levels of nitrogen fixation (up to 200 μg of nitrogen per hour per plant) was recorded for “Vusaty” variety.

Table 2. Ratio, yield (ton/ha) and uptake of nitrogen, phosphorus and potassium with the biomass of different varieties of green pea at different landscape positions, kg / ha

Landscape position	N: P: K		
	Yield		
	N	P_2O_5	K_2O
	Pea “ Lgovsky – zelenozerny ”		
Flat	1 : 0.3 : 1.4		
	12.2		
	171.2	54.65	165.1
Northern hill slope	1 : 0.3 : 0.8		
	12.4		
	181.1	76.3	131.8
Southern hill slope	1 : 0.4 : 0.8		
	10.5		
	168.0	50.4	100.8
	Pea “Ukisniy 9”		
Flat	1: 0.25 : 0.5		
	12.1		
	355.7	89.2	176.4
Northern hill slope	1: 0.23 :0.4		
	13.9		
	437.5	98.3	173.6
Southern hill slope	1: 0.17: 0.36		
	11.0		
	287.0	49.0	102.4

The level of nitrogen fixation for peas on the plain land and at the bottom of the valley was lower than on the slopes in 2 - 8 times.

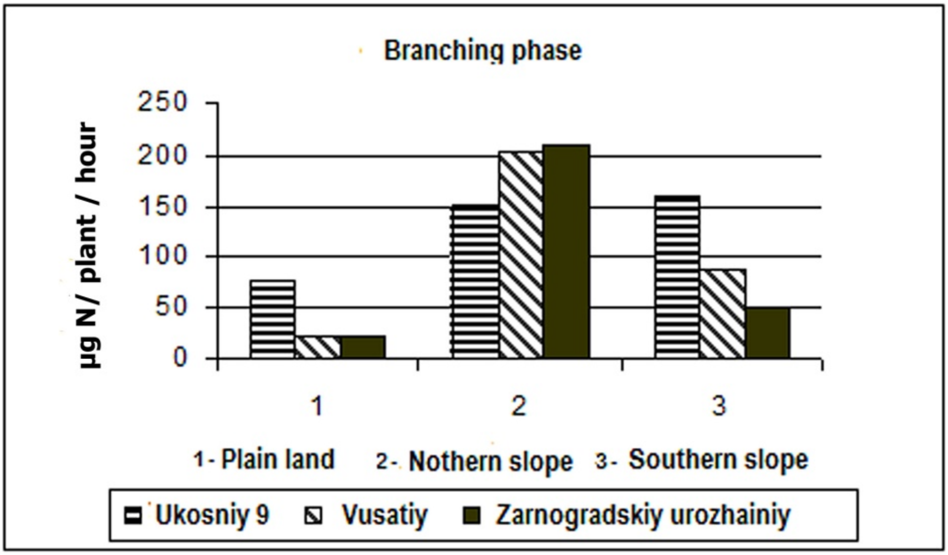

Figure 2. Dynamics of the nitrogenase activity in peas' nodules in branching phase µg N/plant/hour

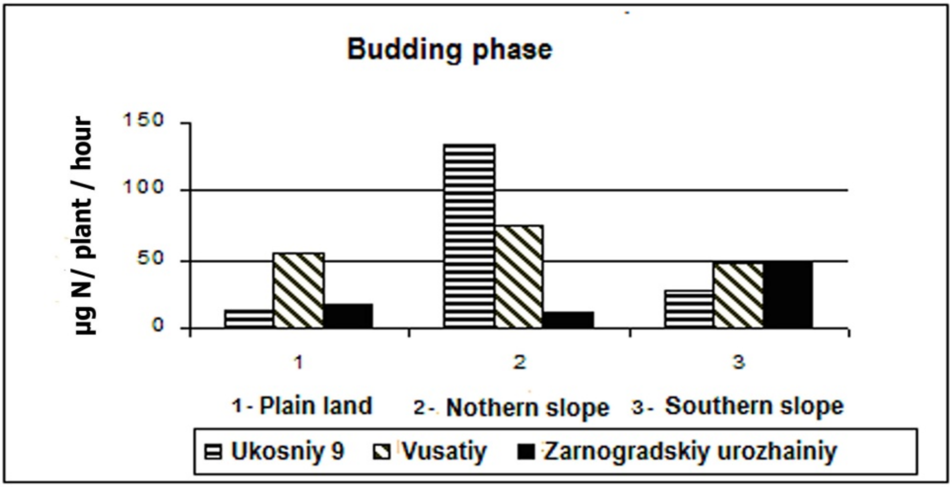

Figure 3. Dynamics of the nitrogenase activity in peas' nodules in budding phase µg N/plant/hour

As it follows from the data presented in the Table 3, barley plants actively responded on the growing conditions of cultivation, which reflected on the harvest and crop nutrient removal.

The uptake of nitrogen, phosphorus and potassium with the barley harvest on the slope of the southern exposition decreased by 48 and 36 % compared to the flat landscape position.

The difference in the macronutrients concentration capacity for the aboveground mass of barley reflected on the ratio of their removal according to the elements of landscape. In particular, the ratio of N:P:K for plant harvested on the plain land was 1: 0.34: 0.74, on the slopes of the northern and southern positions, ratio changed from 1: 0.36: 0.78 to 1: 0.33: 0.76 accordingly.

Table 3. Nutrients uptake rate for aboveground mass of barley and the costs required for production of 1 ton of the grain and relative quantity of leaf and steam mass of barley.

Landscape position	Yield, ton/ ha	Nutrition uptake with main and by products, kg/ha			Demand for production of 1 ton of grain and according amount of stem and leaf mass, kg		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Flat	2.92	101.7	34.7	74.8	34.8	11.9	25.6
Northern hill slope	2.50	80.3	28.8	62. 8	32.1	11.5	25.1
Southern hill slope	1.89	63.0	20.8	48.1	33.3	11.0	25.4

The response of corn hybrids to the culturing conditions was significantly different from these observed for barley. The ratio of N: P: K, in average, for studied hybrids, was within the range of 1: 0.39: (1.01-1.07).

General features of the NPK removal with aboveground mass of corn and cost required form production of 1 ton of grain and relative leaf and stem mass for corn hybrids are presented in the Table 4 and 5.

Table 4. Corn nutrient uptake with harvest and the cost required to produce 1 ton of grain (numerator) and relative leaf and stem mass for corn hybrids (denominator) on the flat

Hybrid	Yield ton / ha	Uptake, kg/ha			Demand for production of 1 ton of grain and according amount of stem and leaf mass, kg		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Dniprovsky-141	4.15 / 9.96	117. 4	54.4	110.8	28.3	13.1	26.7
Pioner 3978	4.53 / 10.87	113. 7	45.0	110.8	25.1	9.9	24.5
Dniprovsky-310	4.84 / 11.62	113. 8	43.4	117.2	23.5	9.0	24.2
Dniprovsky -505	6.07 / 14.57	141. 8	49.7	158.1	23.4	8.2	26.0
Krasnodarsky -303	5.75 / 13.8	136. 6	48.2	142.6	23.8	8.4	24.8
Average	5.07 / 12.16	124.7	48.1	127.9	24.8	9.7	25.2

After analysis of the yield data for the corn hybrids, it should be noted the preference of the slope with the northern exposition, reflected on the bulk crop nutrient removal.

In average, the removal of N, P, K for the slope of the northern exposition was on 5.8; 2.0; 8.0 kg / ha higher than for the plain land and on 23.8; 9.2; 32.0 kg / ha higher than for the slope of the southern exposition. This observation can be explained by biological specialties of studied crop hybrids.

Table 5. Corn hybrids nutrient uptake with and cost required for production of 1 ton of grain (numerator) and the corresponding number of leaf mass (denominator) on the northern and southern hill slopes positions

Variety	Yield, ton / ha	Uptake, kg/ha			Demand for production of 1 ton of grain and according amount of stem and leaf mass, kg		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O
Northern hill slope position							
Dniprovsky-141	4.62 / 11.09	127.2	56.6	123.6	27.5	12.3	26.8
Pioner 3978	5.14 / 12.34	119.4	49.3	127.5	29.2	9.6	24.8
Dniprovsky-310	4.76 / 11.42	103.6	43.5	117.4	21.8	9.1	24.7
Dniprovsky -505	5.92 / 14.21	137.1	47.0	150.6	23.2	7.9	25.4
Krasnodarsky -303	6.40 / 15.36	149.5	53.6	161.8	23.4	8.4	25.3
Average	5.37 / 12.88	127.4	50.0	136.2	23.8	9.5	25.4
Southern hill slope position							
Dniprovsky-141	3.66 / 8.78	101.0	45.1	99.1	27.5	12.3	27.0
Pioner 3978	4.26 / 10.22	109.1	42.8	102.5	25.6	10.0	24.1
Dniprovsky-310	4.07 / 9.77	100.3	39.7	103.3	24.6	9.8	25.4
Dniprovsky -505	4.19 / 10.06	103.1	36.4	109.1	24.6	8.7	26.0
Krasnodarsky -303	4.28 / 10.27	104.4	40.1	106.8	24.4	9.4	25.0
Average	4.09 / 9.82	103.6	40.8	104.2	25.3	10.0	25.5

In all environmental conditions, hybrid Dniprovsky-141 always consumed more nitrogen, phosphorus and potassium than any other studied hybrid.

CONCLUSION

Preformed study approved for studied agricultural crops the dependency between crop nutrient removal and concentration as well the impact of landscape positions, adaptation potential of species, varieties and hybrids occurence. Perennial legumes (alfalfa, sainfoin) were more unpretentious. Pea varieties (Ukisniy 9" "Lgovsky – zelenozerny" and "Vusatiy") are moderately pretentious appeared to be better than cereal crops - megatrophs (barley, corn) in terms of edification for growing on slopes. It can be explained by special adaptation reactions, such as symbiotic nitrogen fixation, better capacity for absorbtion of mobile forms of nutrients from the soil, *etc*.

ACKNOWLEDGMENTS

This study was supported with Ministry of Education and Science of Ukraine.

REFERENCES

Farquharson, R., Baldock, J., (2008) Concepts in modelling N2O emissions from land use. Plant Soil 309:147–167

Han, Z., Walter, M.T., Drinkwater, L.E., (2017) N2O emissions from grain cropping systems: a meta-analysis of the impacts of fertilizer-based and ecologically-based nutrient management strategies. Nutr. Cycl. Agroecosyst: 335–355

Hardy R. W. F., Holsten R. D., Jakson E. K. and Burns R. C. (1968) The acetylene-ethylene assay for N2 fixation: laboratory and field evaluation. PI. Physiol. 43, 1185-1207

Kaspar J.C., Colvin T.S., Jaynes D.B., Karlen D.E.James and Meek D.W. (2003) Relationship between six years of corn yields and terrain attributes. Precis.Agric.4:87-101

Kharytonov, M., Bagorka, M., Gibson, P. (2004) Erosion effects in the central steppe chernozem soils of Ukraine. I.Soil Properties. Agricultura. Published by the University of Maribor, Faculty of Agriculture, Slovenia; Vol.3. № 1:12-18.

Kharytonov, M. M., Pashova, V. T., Mitsik, O. O., Nazarenko, M. M., Bagorka, M. O. (2016) Estimation of winter wheat varieties suitability for difference growth of landscape conditions. Agricultural and mechanical engineering: Materials of Interna-tional Symposium ISB-INMA TECH. Bucharest, 27-29.10., INMA, 401 – 406.

Kravchenko and Bullock, (2000) Corellation of corn and soybean grain yield with topography and soil properties. Agron. J. 92: 75-83.

Ladoni, M., Basir, A., Robertson, P.G., Kravchenko, A.N., (2016) Scaling-up: cover crops differentially influence soil carbon in agricultural fields with diverse topography. Agric. Ecosyst. Environ. 225:93–103

Lazrak E.G, Mari J.F, Benoit M (2010) Landscape regularity modelling for environmental challenges in agriculture. Landscape Ecol 25 (2):1–15

Lykholat Y., Khromyk N., Ivan'ko I., Kovalenko I., Shupranova L., Kharytonov M. (2016) Metabolic responses of steppe forest trees to altitude - associated local environmental changes. Agriculture and Forestry, 62 (2): 163-171.

Marques de Silva, J.R. and Silva L.L.. (2006) Evaluation of maize spatial variability based on field flow density. Biosystems Eng. 95:339–347

Marques de Silva, J.R., and Silva L.L.. (2008) Evaluation of the relationship between maize yield spatial and temporal variability and different topographic attributes. Biosystems engineering 101: 183–190

Mehdizade B., Asadi H., Shabanpour M., and Ghadiri H. (2013) Impact of erosion and tillage on the productivity and quality of selected semiarid soils of Iran. International Agrophysics, 27, 291-297

Molodovskaya, M., Warland, J., Richards, B.K., Öberg, G., Steenhuis, T.S.. (2011) Nitrous oxide from heterogeneous agricultural landscapes: source contribution analysis by eddy covariance and chambers. Soil Sci. Soc. Am. J. 75: 1829–1838.

Nazmi, L., Asadi, H., Manukyan, R.. (2011) Changes in soil properties and productivity as affected by land use and slope position in the northwest of Iran. Int. J. Food Agric. Environ. 9: 864–870

Negassa, W., Price, R.F., Basir, A., Snapp, S.S., Kravchenko, A.. (2015) Cover crop and tillage systems effect on soil CO2 and N2O fluxes in contrasting topographic positions. Soil Tillage Res. 154: 64–74.

Parent A.C., Belanger M.C., Parent L.E., Santerre R., Viau A.I., Anctie I., Bolinder M.A. and Tremblay C. (2008) Soil properties and landscapes factors affecting maize yield wetspring conditions in eastern Canada.Biosystems Eng. 99: 134-144.

Rochette, P., Pennock, D.J., Hénault, C., Cellier, P., Richard, G., (2011) Effect of topography on nitrous oxide emissions from winter wheat fields in Central France. Environ. Pollut. 159:3149–3155.

Russenes, A.L., Korsaeth, A., Bakken, L.R., Dörsch, P.. (2016) Spatial variation in soil pH controls off-season N2O emission in an agricultural soil. Soil Biol. Biochem. 99: 36–46.

Schaller D., Reynaud G., Jacques Bergez J. (2012) Models to support cropping plan and crop rotation decisions. A review. Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 32 (2):.567-580

Schipanski, M., Drinkwater, L., Russelle, M.. (2010) Understanding the variability in soybean nitrogen fixation across agroecosystems. Plant soil 329: 379–397.

Simic M., Dragicevic, V., Kresovic, B., Videnovic, Z., Dumanovic, Z. (2016): Advanced cropping technology of maize (Zea mays L.) in Serbia. Agriculture and Forestry, 62 (1): 227-240. DOI: 10.17707/AgricultForest.62.1.26

Snapp, S.S., Kravchenko, A.. (2015) Cover crop and tillage systems efect on soil CO_2 and N_2O fluxes in contrasting topographic positions. Soil Tillage Res. 154: 64–74.

Stone J.R., Gilliam S.W., Cassel D.K., Robarge W.P. 1985. Effect of erosion and landscape position on the productivity of piedmont soils. Soil Sci. Soc. Am. J. 49: 987-991.

Thelemann R., Johnson S., Sheaffer C., Benerjees S., Cai H., Wyse D. (2010) The effect of landscape position on biomass crop yield. Agronomy journal. Vol.102. 2:.513-522.

Thomas R.L, Sheard R.W., Mayer J.R. (1967) Comparison of conventional and automated procedures for nitrogen, phosphorus and potassium analysis of plant material using a single digestion. Agron. J. 59: 240-243.

Velychko, O. (2014) Development of infrastructural objects of providing logistics in the system of storing plant cultivation produce, Economic Annals-XXI, Vol. 1-2: 110-113