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MINERAL NUTRITION OPTIMIZATION AS A FACTOR AFFECTING BLUE LUPINE CROP PRODUCTIVITY UNDER CONDITIONS OF GLOBAL CLIMATE WARMING

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ABSTRACT

The scientific study presents the results concerning the influence of meteorological conditions on blue lupine crop productivity. The research substantiates the types and combinations of mineral macro- and micro-fertilizers providing for full realization of the biological potential of blue lupine (*Lupineus angustifolius* L.) under the conditions of global climatic changes.

Field studies were conducted during the period of 2016-2019 on sod-mesopodzol sandy-loam soils. The average monthly temperature and the amount of precipitation during the growing season of blue lupine had some deviations from average long-term indices. During the research period the blue lupine plants were being formed under favourable temperatures, but were exposed to the negative effects of low water availability, that resulted in worth conditions for their growth and development as well as in lower grain yields.

During a 3-year period of studies the crop yield was in a range of 0.98-2.54 t/ha depending on fertilization and weather conditions during the growing season. As follows from the results of correlation-regression analysis concerning the dependence of blue lupine grain yield on meteorological characteristics, it has been found that there is a correlation (close linear dependence) between weather conditions and grain yield. Herewith, a negative reaction of a sort Peremozhets to weather conditions deviations from average longstanding indices during the growing season has been registered.

Keywords: meteorological conditions, growing season, air temperature, rainfall, foliar fertilizing, fertilizers.

INTRODUCTION

Sustainable development of agricultural production is one of the topical problems, its successful solving will ensure the food safety of the country. Among the main priorities in agricultural sector development is grain legume crops growing, which are the source of complete vegetable protein and significantly contribute to agroecosystems nitrogen balance (Bhardwaj et al., 2004; Peoples et al., 2009; Faligowska et al., 2020). Supplying people with protein food stuffs is still one of the most complicated and important global problems. The scientific study has confirmed that blue lupine is the most perspective for growing from among a small assortment of grain legume crops (Sujak et al., 2006; Barczak et al., 2014).

There is 31-42% of protein in lupine seeds (Pollard et al., 2002). Lupine grain does not differ from soya bean as to its biological value and nonreplaceable amino acids in albumen. A small quantity of trypsin and chemotrypsin inhibitors promotes to lupine feeds digestibility and absorbency, makes it possible to use lupine grain as a protein-rich additive in a mixed feed industry (Sujak et al., 2006; Degola and Jonkus, 2018).

Lupine grain is characterised by high nutritional value (Bartkiene et al., 2016). Lupine seeds additives are used when making bread and paste goods, as well as meat and dairy products (Xu et al., 2006; Kuznetsova et al., 2015; Villarino et al., 2015). It has been established that lupine seeds have positive effects on human health (Chango et al., 1998; Belski, 2012; Kuznetsova et al., 2015).

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Lupine is irreplaceable for improving soil fertility, especially under organic land husbandry, as it promotes to keeping a positive balance of humus in soil (Sujak et al., 2006; Faligowska et al., 2020). The root system of lupine penetrates deeply into the soil horizons, provides their structuralization and improves their water availability (Trükmann et al., 2008). Thanks to secretions from a root system lupine is able to turn poorly soluble compounds of phosphorus and potassium into available forms for other crops, as well as to accumulate them in soil (Lambers et al., 2006; Richardson et al., 2011; Shen et al., 2011). Lupine has high nitrogen-fixing capacity (Sulas et al., 2016) and under favourable conditions to leave with nutritive deads up to 150 kg/ha of symbiotic nitrogen in soil (Peoples et al., 2009). Unfortunately, some yearly yield deviation in lupine, caused by special aspects of adaptive reactions fromation to stress factors, has been observed (Georgieva et al., 2018).

Blue lupine yield level depends on such elements of growing technology as sort, fertlizing and pre-sowing seeds treatments (Bieniaszewski et al., 2012; Szymańska et al., 2017; Mazur et al., 2019). Application of fertilizers is an important factor of increasing the crop yield as well as of realizing sorts biological potential. There are some contradictions between yield rate and its quality, and plants resistance to unfavourable growing conditions. An important task is to improve the efficiency of mineral fertilizers by the coefficient of nutrutives usage as well as by reducing their losses.

Climatic resources significantly affect the main indicator of an agricultural production - crop yield. The crops growing season is closely connected with the amount of precipitation and air temperature (Mazur et al., 2019). Global climatic changes decrease the chances to a sustainable farming, reduce the opportunity to receive stable crop yields that is caused by negative impacts of extreme weather conditions. Unfavourable, abiotic, stress conditions (drought, salinization, extreme temperatures, heavy metals, excessive moistening, oxygen deficiency) are a threat to a sustainable development of an agricultural sector (Mehla et al., 2017; Hasanuzzaman et al., 2020).

As climate changes cause problems for plants growth and development, only sorts with high adaptivity (tolerance for stress) can realize their biological potential under such conditions. Due to crops adaptation to stress factors, the negative effects of climatic changes can be reduced (Pereira, 2016; Raza et al., 2019).

Optimal conditions under which the biological yield and its economically valuable part are formed can be different (Annicchiarico, 2008; Annicchiarico et al., 2010). An important task of agricultural production is to ramp up blue lupine grain production irrespective of extreme climatic conditions (droughts, dry hotwinds, high temperatures etc.). For these purposes, productivity formation of blue lupine must be studied together with factors which affect the amount of biological yield of a crop. Similar studies of recent sorts of blue lupine are not numerous. One of the ways to enhance the grain yield is to use modern technologies of blue lupine growing. These technologies increase the resistance of plants to stress factors of the environment.

In this connection, the purpose of our research was to study special aspects of blue lupine yield formation depending on applying fertilizers and on foliar fertilizing under different weather conditions during the plants growing season.

MATERIAL AND METHODS

Scientific study on the effects of mineral nutrition on grain yield of blue lupine under global warming conditions was conducted during 2016-2019 under conditions of an experimental field of the Institute of Agriculture of Polissia, Ukraine. The soil type – sod-mesopodzol sandy-loam.

At the beginning of an experiment the test soil was characterized by a low content of easy hydrolysable nitrogen, mobile forms of phosphorus and potassium (Table 1).

Table 1. Chemical characteristics of topsoil of tested soil

Depth of taking samples, sm	pH $_{kCl}$	Humus content, %	Content, mg per 100 g of soil		
			N	P_2O_5	K_2O
0-25	5.7	1.1	62.2	20.5	12.9

Field test scheme included the next factors:

Factor A - applying fertilizers into soil:

1. Control (without fertilizers).
2. Ammonium saltpeter, GR, 50 kg + Ammophos, GR, 115 kg + Potassium chloride, GR, 100 kg/ha ($N_{30}P_{60}K_{60}$) – Variant 1;
3. Ammonium nitrate lime, GR, 70 kg + Ammophos, GR, 100 kg + Vegetable carbon, GR, 200 kg/ha ($N_{30}P_{60}K_{60}$) – Variant 2;
4. Arvy, GR, 300 kg/ha ($N_{30}P_{60}K_{60}$) – Variant 3.

Factor B - foliar fertilizing:

1. Control (without fertilizers);
2. Crystallon $N_3P_{11}K_{38}$ (brown), 3.0 kg/ha;
3. Humifield, GR, 0.04 kg/ha;
4. Magnesium sulfate, GR, 2.5 kg/ha;
5. Crystallon $N_3P_{11}K_{38}$ (brown), 3.0 kg/ha + Humifield, GR, 0.04 kg/ha + Magnesium sulfate, GR, 2.5 kg/ha.

The total area of a plot is 36.0 m^2. The accounting area is 22.5 m^2.

Frequence - triple, variants arrangement - systematic.

Cultivation technology of blue lupine of sort Peremozhets is standard for Polissia zone. Foliar fertilizing of lupine with micro- and macro- elements was topped in the course of budding. Regular phenological observations, records and analysis were conducted according to established procedures during the growing season. Yield record of blue lupine grain was kept by continuous reading by means of harvesting and weighing.

The data were processed statistically by analysis of variance (multi-factor ANOVA).

RESULTS AND DISCUSSION

Weather and climatic conditions alongside with soil fertility level are first-priority and essential factors of crop yield enhancement. The effectiveness level of these agrotechnical measures is determined by these factors. Maximal yield gain can be achieved when farming practice of crop growing takes into account not only biological and sort characteristics but also agrometeorological conditions of a growing area. Thus, the interdependence between weather condition effects and crop yield is important for understanding and for prognostication of the reaction of plants growth and development to climatic changes.

Characterizing weather conditions of blue lupine growth during 2016-2019 it can be concluded that during this period the plants did not lack warmth but suffered from lack of moisture. A limiting factor of lupine grain yield was a regime of water availability, which resulted in reduction in grain yields (Table 2).

Table 2. Meteorological conditions during the growing season of blue lupine during the period of 2016-2019

Specification	Years	Months			
		III	IV	V	VI
Average monthly temperature (°C)	2016	11.2	15.2	20.2	21.2
	2017	9.1	14.0	18.7	19.0
	2018	12.7	18.1	19.5	20.4
	2019	9.8	15.3	22.2	18.4
	Long-term average	9.3	15.2	18.7	20.5
Total precipitation	2016	21.6	44.0	29.8	79.6
	2017	33.4	57.4	19.6	80.2
	2018	10.0	20.8	135.8	100.9
	2019	53.9	70.8	20.8	17.2
	Long-term average	33.0	59.5	74.6	71.4

In 2016 the average monthly temperatures in April and June were respectively by 1.9°C and 1.5°C higher than normal. In April, May and June the monthly amount of precipitation was respectively by 11.4, 15.5 and 44.8 mm lower than long-term average annual rates. May 2017 was characterised by chilly weather. A monthly temperature was by 1.2°C lower than normal. The air temperature during April and June did not differ from long-term average annual rates. The amount of precipitation in June was by 55 mm (73.7%) lower than long-term average annual rates.

Spring of 2018 came late. The average monthly temperatures in April and June were, respectively, by 3.4°C and 2.9°C higher than normal. As to rainfalls, the situation was different: in spring there was plenty of warmth but increasingly small amount of precipitation. Thus, the amount of precipitation in the middle and at the end of spring equalled 66.7% from normal. The deviations from long-term average annual rates equalled in April - 23.0 mm and in May - 38.7 mm. Warm and dry weather, low relative humidity worsened the blue lupine growth and development.

There was some excess in the amount of precipitation at the beginning of summer in 2018. In June and July, the average monthly amount of precipitation was higher than normal, respectively, by 61.2 mm (82.0%) and 29.5 mm (41.3%). Very few rainfalls during April and May (by 69.7 and 65.0%, respectively, lower than normal), higher temperature (by 3.4 and 2.9°C, respectively) caused intensive loss of moisture in soil and created unfavorable conditions for crops growth and development. There was some excess in the amount of precipitation (by 61.2 mm higher than normal) in June, the average monthly temperature exceeded standard indicators by 0.8°C.

April and May were characterized by irregular rainfalls like short-term showers. The amount of precipitation during a 2 month period equalled 135% as compared to average monthly rates. In June and July the amount of precipitation was by 78 mm (32.8%) lower than the long-term average annual rates. Average monthly temperature in April and May exceeded long-term average annual rates only by 0.3-0.5°C. June of 2019 was characterised by an increase in temperature by 3.5°C. In July, on the contrary, the average monthly temperature decreased by 2.1°C as compared to long-term average annual rates.

Analysing the weather conditions preveiling during the period of 2016-2019 it can be admitted that temperature regeme and the amount of precipitation were mostly favourable for blue lupine plants growth and development except for certain seasons. Similar studies, conducted by the researchers all over the world, confirm the data concerning the increase in temperature and the decrease in the annual amount of precipitation (Mitrică et al., 2015). All mentioned above implies that some extreme weather conditions occur particularly during the crops growing season (Mazur et al., 2019).

Grain yield is the main index when growing agricultural crops. The yield significantly depends on weather conditions during the growing season. The analysis of the research results show that grain yield of blue lupine on sod-podzol sandy-loam soil on average during a 4-year period equalled 1.15-2.26 t/ha depending on the system of plants fertilization (Table 3).

On test areas, depending on foliar fertilizing, grain yield of blue lupine equalled 1.15-1.55 t/ha. Foliar fertilizing of plants during the growing season in the course of budding contributed to lupine grain yield enhancement.

Separate application of fertilizers - Crystallon (3.0 kg/ha), Magnesium sulfate (2.5 kg/ha) and Humifield (0.04 kg/ha) by means of plants spraying during the growing season increases the lupine grain yield by 0.10-0.16 t/ha as compared to control. The highest gain of grain yield (0.32 t/ha or 27.8%) was received under a combined application of - Crystallon, Magnesium sulfate and Humifield.

The investigation has established that the application of sulfur for foliar fertilizing was more efficient than its application into the soil (Barczak et al., 2014).

A combined application of ammonium Saltpeter (50 kg/ha), Ammophos (115 kg/ha), and Potassium chloride (100 kg/ha) has contributed to grain yield enhancement by 0.34-0.42 t/ha as compared to control. A combined application of above mentioned fertilizers during budding period results in the increase of grain yield by 6.1-15.7% as compared to control.

When applying ammonium nitrate lime (70 kg/ha) and Ecoplant (200 kg/ha) into the soil, lupine grain yield increased by 0.41-0.52 t/ha. Foliar fertilization has increased the grain yield by 0.05-0.23 t/ha. On the average, during the research period the highest level of realization of production potential of blue lupine was provided by a system of fertilization requiring the application of mineral fertilizer Arvy in a norm of 300 kg/ha ($N_{30}P_{60}K_{60}$).

Table 3. Grain yield of blue lupin depending on nutrition optimization, t/ha

Application of fertilizers into soil	Foliar fertilizing	Years				Average during 2016-2019	Coefficient of variation, %
		2016	2017	2018	2019		
Control (without fertilizers)	1*	1.19	1.32	0.98	1.12	1.15±0.16	12.3
	2	1.26	1.41	1.12	1.22	1.25±0.14	9.6
	3	1.54	1.68	1.21	1.28	1.43±0.25	15.4
	4	1.45	1.62	1.18	1.22	1.37±0.23	15.1
	5	1.67	1.83	1.27	1.44	1.55±0.28	15.9
Variant 1	1	1.31	1.46	1.08	2.13	1.5±0.51	30.2
	2	1.48	1.64	1.29	2.16	1.64±0.42	22.7
	3	1.82	2.00	1.38	2.20	1.85±0.4	18.9
	4	1.69	1.86	1.36	2.20	1.78±0.4	19.7
	5	1.94	2.13	1.47	2.31	1.96±0.41	18.4
Variant 2	1	1.43	1.59	1.16	2.19	1.59±0.49	27.4
	2	1.54	1.72	1.28	2.24	1.7±0.46	23.9
	3	1.89	2.06	1.38	2.36	1.92±0.46	21.4
	4	1.77	1.96	1.47	2.34	1.89±0.41	19.3
	5	2.03	2.24	1.52	2.42	2.05±0.44	19.0
Variant 3	1	1.50	1.67	1.19	2.17	1.63±0.46	25.1
	2	1.72	1.91	1.31	2.23	1.79±0.43	21.4
	3	2.19	2.37	1.42	2.28	2.07±0.49	21.1
	4	1.83	2.04	1.62	2.31	1.95±0.33	15.1
	5	2.32	2.54	1.71	2.45	2.26±0.42	16.6
LSD_{05}					0.27/ 0.12		24.2

*1. Control (without fertilizers); 2. Crystallon $N_3P_{11}K_{38}$ (brown), 3.0 kg/ha; 3. Humifield, GR, 0.04 kg/ha; 4. Magnesium sulfate, GR, 2.5 kg/ha; 5. Crystallon $N_3P_{11}K_{38}$ (brown), 3.0 kg/ha + Humifield, GR, 0.04 kg/ha + Magnesium sulfate, GR, 2.5 kg/ha.

Foliar fertilizing with a mixture of fertilizers - Crystallon (3.0 kg/ha), Magnesium sulfate (2.5 kg/ha) and Humifield (0.04 kg/ha) in a budding period increased grain yield by 0.06-0.28 t/ha or 5.2-24.3%.

The highest grain yield of blue lupine of a sort Peremozhets (2.26 t/ha) was received under the application of mineral fertilizer Arvy in a norm of 300 kg/ha and under a combined application of fertilizers - Crystallon, Magnesium sulfate and Humifield. Herewith, the yield gain equalled 0.70 t/ha as compared to the variant without mineral fertilizers application.

Significant variability level of blue lupine yield during the period of research (V=24.2% when n=80) was caused, first of all, by the effects of weather conditions (Figure 3).

A level of effects of weather conditions on lupine grain yield was nearly 40%. As a comparison, the level of effects of fertilizers application into soil equalled 21%, and that of foliar fertilizing with liquid complex fertilizers - 33%. It should be mentioned that the ratio of weather factor effects on the variants of agrotechnologies was different. Thus, in a control variant (without fertilizers) was recorded the average level of index variability divided up by year (V=12.3%), under condition of fertilizers application into soil this index was high (V=25.1-30.2%).

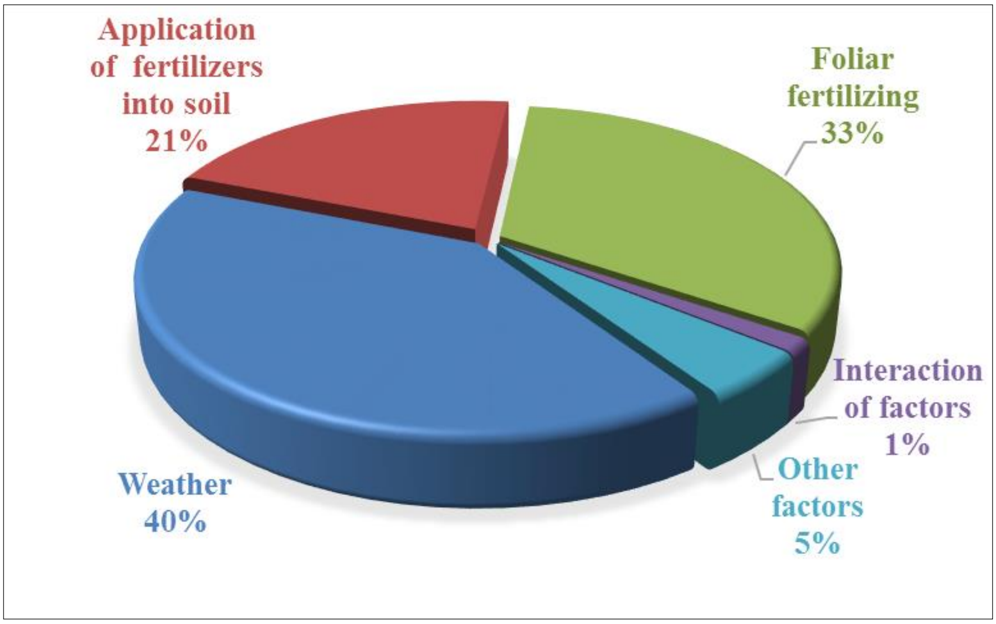

Figure 1. Ratio of effects of some factors on blue lupine yield (during 2016-2019)

It was probably caused by the fact that the effectiveness of fertilizers application depended on weather conditions. Under condition of foliar fertilizing the level of lupine yield variability during the years of studies decreased, that was connected with positive effects of preparations on increasing the crops tolerance to unfavourable weather conditions.

CONCLUSIONS

The results of field experiments as well as the correlation regressive analysis show that the formation of blue lupine grain yield was determined, first of all, by crop management practices (55%), including: foliar fertilizing (33.0%) as well as applying fertilizers into the soil (21%). It should be mentioned that during 2016-2019 the meteorological effects ratio equalled 40%.

A significant dependence of lupine yield on weather conditions of a certain year increases the risks when growing a crop. Under field experiment condition, it has been proved that the effects of stress situations (drouhgt, low temperatures, agent of disease) reduced in variants where foliar fertilizing with liquid fertilizers was applied.

The application of liquid fertilizers caused better plants growth and development. Maximal elasticity (resistance to stress weather conditions) and grain yield of blue lupine of a sort Peremozhets (2.26 t/ha) was formed under the application of a mineral fertilizer Arvy ($N_{30}P_{60}K_{60}$) as well as under a complex foliar fertilizing with a mixture of - Crystallon (3.0 kg/ha), Magnesium sulfate (2.5 kg/ha) and Humifield (0.04 kg/ha).

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