Agronomy Research **18**(X), xxx–ccc, 2020
https://doi.org/10.15159/AR.20.181

Agroecological substantiation of *Medicago sativa* cultivation technology

N. Telekalo* and M. Melnyk

Vinnytsia National Agrarian University, Faculty of Agronomy and Forestry, Soniachna street 3, UA21008 Vinnytsia, Ukraine
*Correspondence: nataliiatelekalo@gmail.com

Abstract. *Medicago sativa* is one of the most productive legumes, which provides high protein production. Application of the biostimulant and microfertilizers is quite relevant and effective. Theoretically substantiates and presents ways to solve the scientific problem of formation of *Medicago sativa* productivity and the impact on them of seed treatment and foliar nutrition, taking into account the conditions of the Forest-Steppe right bankof Ukraine. The research was conducted in the research field of Vinnytsia National Agrarian University in the village of Agronomichne, Vinnytsia district during 2016–2018. Sinyukha variety was sown (2010). There has been established that the use of pre-sowing treatment of seeds and crops of *Medicago sativa* with biostimulant and microfertilizer improves the conditions of growth and development of the crop and increases individual productivity. On the researches it is established that fodder productivity of *Medicago sativa* sowing is provided by application of biostimulators of growth and microfertilizers on crops, genetic potential the culture realized as much as possible on the 2nd year of cultivation. The effect of growth stimulants on *Medicago sativa* productivity was defined and the optimal combination of macro- and microelements in modern complex fertilizers was determined, which contributes to the maximum possible yield of *Medicago sativa* green mass. New technological regulations for the use of bioorganic preparations and components in the technological scheme of *Medicago sativa* cultivation have been developed. It was found that on average for three years of vegetation of *Medicago sativa* sown on gray forest soils in the Forest-Steppe Right Bank, the highest yield of seeds and green mass provides the option of treatment with biostimulator Saprogum® and microfertilizer Wuxal®. Creating optimal conditions for mineral nutrition for *Medicago sativa* plants through the use of bacterial fertilizers and foliar nutrition contributed not only to the formation of high grain yields, but also significantly improved biochemical parameters and, consequently, increased crude protein content in grain, which is important for solving the problem of vegetable protein and balancing the diets of farm animals. The research results are aimed at solving current problems of technological renewal and development of agro-industrial complex on the basis of development of bioorganic models of varietal technology of *Medicago sativa* cultivation with orientation at the level of adequate arable productivity and climate fertility.

Key words: *Medicago sativa*, technology, cultivation, yield, seed quality.

INTRODUCTION

Medicago sativa is one of the most productive and valuable forage crops that are able to help in most regions to address the problem of eliminating plant protein in the diet of animals. An advantage of the use of leguminous perennial dicotyledon plants is their environmental, which is determined by the nitrogen-fixing ability and the enrichment of soil organic matter formed from the root and stem residues (Antoniou Chrystalla et al., 2020; Cen Huifang et al., 2020; Martinez-Hidalgo Pilar et al., 2020; Rezaeian Mohammad et al., 2020). After *Medicago sativa* in the second year of growing in the soil layer 0-20 cm, the number of water-resistant structural units was 41.5%, while in areas where dicotyledon plants were not grown – only 29.8% (Lemus Ramirez et al., 2020; Tucak Marijana et al., 2020). Leguminous perennial dicotyledon plants provide environmentally friendly production, and the agrophytocenoses created by them become an important component of agro-landscapes that provide environmental cleanliness, support human health and safety (Li Danqi et al., 2020; Seddighfar Masoud et al., 2020).

Despite the convincing forage value of *Medicago sativa*, its cultivation in the Forest-Steppe zone of Ukraine is limited. The main reasons for this are the decline of animal husbandry and the transition to monotonous forage, the acidification of soils on which *Medicago sativa* significantly reduces its productivity, forage value of the crop and the duration of economic use. The significant reasons for decrease in the sowing area of *Medicago sativa* include extreme weather conditions, lack of seed sources (El-Zaidy Mohamed et al., 2020; Liu Xiuming et al., 2020; Zhao Yaodong et al., 2020).

Given the current realities, when the emphasis is on reducing the cost of growing crops, micro- and nanotechnology, the use of growth regulators and microfertilizers, the urgent task of plant growing should be to improve cultivation technology *Medicago sativa* on green mass and seeds at the expense of these factors (Hadidi Milad et al., 2020; Li Haiyun et al., 2020). An important element of modern resource-saving technologies for growing crops is the use of new types of fertilizers and biological products – plant growth regulators, liquid complex fertilizers and bacterial enhancersthe efficiency of the use of mineral fertilizers, improving plant nutrition and yield (Cao S. et al., 2020; Wang Jing et al., 2020).The use of these fertilizers and preparations can significantly reduce the volume of application of traditional mineral fertilizers, which significantly reduces the loss of plant nutrients and makes it impossible to pollute the environment (Jiang Peng et al., 2019; Liatukiene Aurelija et al., 2020; Wassie Misganaw et al., 2020).

In the research papers, there is enough information about the complex researches studied the mechanism of the physiological action of growth regulators, both during the treatment of seeds and for foliar nutrition. Plant growth regulators affect growth processes, cause changes in the assimilation apparatus, photosynthesis and carbohydrate metabolism, which improves crop yields (El Husseini, 2019; Xu Hongyu et al., 2020a; Xu Hongyu et al., 2020b). The growing needs of modern agricultural production determine the need to find new ways and methods to improve the crop and its quality (Palamarchuk et al., 2018; Palamarchuk & Telekalo, 2018; Mazur et al., 2018; Mazur et al., 2019; Benabderrahim Mohamed Ali et al., 2020; Sezmis Gurkan & Gursoy Esra, 2020; Yesilayer Nihat et al., 2020). Plant growth regulators are an important component of modern plant growing technologies. Interest in this group of compounds is due to a wide range of their effect on plants, the opportunity is directed to regulate the individual stages of growth and development to mobilize the potential of the plant organism, and accordingly – to enhance yields and quality of agricultural products (Garriga et al., 2020; Min Xueyang et al., 2020). In addition to being used purely, growth regulators can also be used in combination with micro- and macro-elements in foliar nutrition, which is especially important in the critical phases of plant development. Therefore, foliar nutrition during this period has a significant effect, plant viability increases during storage after harvesting, creates better conditions for fertilization and seed formation (Hou Lifeng et al., 2020). However, all of these drugs have been researched mainly in field crops, and for *Medicago sativa,* such researches are practically absent. This requires a detailed study of the application of such environmental measures to improve the productivity of this leguminous perennial plant (Chen Tao et al., 2020; Mbarki Sonia et al., 2020).

The purpose of paper is to research into the efficiency of introduction of biological elements of technology of growing *Medicago sativa*, which involves the use of growth biostimulant and microfertilizer to increase seed productivity and vegetative mass, improve quality of sowing indicators of seeds and chemical composition of green fodder.

MATERIALS AND METHODS

Field experiments were conducted at the experimental field of Vinnytsia National Agrarian University in the village of Ahronomichne Vinnytsia region during 2016–2018. Soils are grey mid-loamy forest. The humus content in the arable layer is 1.85%. The reaction of the soil solution of acidic is pH 5.4. Hydrolytic acidity ranges from 3.5–3.8 mg-eq 100 g^{-1} soil, absorption capacity – 30.7–32.5 mg-eq 100 g^{-1} soil. These soils contain 3.4–5.4 mg 100 g^{-1} of soil available to nitrogen plants, 10–12 mg 100 g^{-1} of mobile phosphorus and 12–14 mg 100 g^{-1} of potassium exchange. Low humus content and the use of organic and mineral colloids from the arable layer do not contribute to the formation of an agronomically valuable structure on these soils.

The investigations were focused on the growth, development and formation of seed yield and green mass and forage productivity of *Medicago sativa* of the Sinyukha variety with the use of new growth biostimulants – Saprogum® and microfertilizers – Wuxal®. The treatment of seeds of *Medicago sativa* growth biostimulant Saprogum® was carried out at a dose of 7 mL L^{-1} of water. The cultivation of *Medicago sativa* Saprogum® growth biostimulant was carried out at a rate of 2.1 L ha^{-1} at a water flow of 300 L ha^{-1}. On the day of sowing, *Medicago sativa* seeds were treated growth biostimulants Saprogum® using PKC-20 Super. Foliar nutrition of *Medicago sativa* microfertilizer Wuxal® was performed at a rate of 3 L ha^{-1}. For control, an option is adopted without biostimulant treatment and without foliar nutrition the microfertilizer.

The acreage of the plot is 30 m², the accounting area – 25 m². Replication in the experiments was 4 times. The sites were located by the method of randomized blocks. Accounting for seed productivity of *Medicago sativa* plants was carried out following with the Methodology of examination of plant varieties. The accounting of the harvest of green mass was carried out by the method of continuous mowing of the grass with the accounting area and weighing. Laboratory germination of seeds of *Medicago sativa* was determined in four repetitions of 100 seeds in Petri dishes on filter paper at a germination temperature of 20 °C. The germination energy of seeds of *Medicago sativa* was determined on the third day of laying the seeds for germination.

Germination of *Medicago sativa* seeds in the laboratory began on the 2nd day after laying for germination and ended on the 7th day. The highest germination energy on the 3rd day after laying the seeds for germination was observed in *Medicago sativa* sowing – 65%. The weight of thousands of seeds was determined by weighing in four repetitions. Determination of biochemical indicators of quality of green fodder was carried out based on the standard methodology of general zootechnical analysis of forages in the certified laboratory of the Institute of feed and agriculture of Podillya NAAS. The solids content was determined by thermostatic-weight method, total nitrogen and crude protein content by Kiel'dalia method, crude fat by Rushkovs'kyi method by the amount of fat-free residue, crude fiber content was determined by Henneberg and Shtoman in the CINAO modification, crude ash – dry ash content, non-nitrogenous extractives (NEC) content – by calculation. Statistical analysis of the experimental data was carried out using the computer program STATICA – 6. Validity of the difference of the experimental data regarding the control was determined using Student's t-criterion.

Saprogum® is a humic preparation made by dispersing the deposits of freshwater lakes (sapropel). Highly humus liquid biostimulator, the main active ingredient of which is physiologically active salts of humic acids, which are easily and quickly absorbed by plants and, as a result, stimulate their growth and development and improve product quality. Agrochemical characteristics of the humic biostimulant Saprogum® are given in Table 1.

Table 1. Agrochemical composition of the biostimulant Saprogum® (on dry matter)

Acidity (pH)	10.0
Total nitrogen,%	1.3
Total phosphorus,%	0.6
Total potassium,%	11.7
Total humic acid carbon,%	10.0
Total humic acid,%	2.0
Copper, mg L^{-1}	6.2
Manganese, mg L^{-1}	100.0
Zinc, mg L^{-1}	2.4

The main active substance of the preparation is physiologically active salts of humic acids. The humic acids of sapropels are in the readily available form (60–80%). Biochemical fractions of sapropels are restored, and therefore have a more effective stimulating effect on plant photosynthesis. Associations of molecules have the smallest size and small molecular weight, which contributes to their active and unobstructed penetration into the roots and leaflets of plants, as a result, stimulate their growth and development and improve product quality.

The preparation is used as a working solution, which is prepared by diluting the initial concentrate with water to obtain the desired concentration of humic acid salts and neutral pH of the solution. Nutrition is carried out in the morning, evening or on cloudy days to prevent burns and intense evaporation of the solution from the leaf surface.

Wuxal® is a complex fertilizer used for foliar fertilization, which provides additional nutrition for all crops to prevent or control the basic nutrients, as well as deficiency of boron and zinc, to support plant growth processes under physiological stress. Wuxal® is great for use on many crops in the early stages of development, when the young root system is not yet able to fully provide the plant with full nutrition, optimizing nutrition, Wuxal® also provides growth, development of plants and their resistance to diseases (Table 2).

Table 2. Agrochemical composition of the microfertilizer Wuxal®

Composition, g L^{-1}	N	P_2O_5	K_2O	SO_3	B	Cu	Fe	Mn	Co	Zn	Mo
Wuxal®	160	160	120	14.0	10	0.21	0.44	0.37	0.008	10	0.028

Benefits of the preparation are excellent buffering properties – at a concentration of 0.2% (200 mL per 100 L of working solution) neutralizes the pH to a neutral level (pH about 7). Compatible with most pesticides and optimizes their action. It provides excellent coverage, adhesion and penetration into the plant. The preparation has well-balanced composition of macronutrients for crops. Suitable for all crops in all climatic zones with high demand for B and Zn. Over-chelating reduces the hardness of water to prepare the working solution.

RESULTS AND DISCUSSION

Productivity of *Medicago sativa* sowing provides the use of growth stimulants and microfertilizers on crops, the genetic potential of the culture is maximally realized in the 2nd year of cultivation, with a long general growing season of 4 years. On average, in the second, fourth year of vegetation, the weight of seeds from one plant of *Medicago sativa*, without treatment with plant growth biostimulant and microfertilizers, was 0.89 g (Table 3).

Table 3. Individual seed productivity of plants of *Medicago sativa* and seed yield depending on the treatment with biostimulant and microfertilizers (average for 2–4 years of vegetation)

Seed treatment	Duration and combination of growth biostimulant and microfertilizer application	Weight of seeds from 1 plant, g	Seed yield, t ha-1
Without treatment seed	Without biostimulant and microfertilizer treatment	0.89 ± 0.02	0.41 ± 0.01
Seed treatment with growth biostimulant Saprogum® (background)	Background + Saprogum® sowing in branching phase	0.93 ± 0.01	0.43 ± 0.02
	Background + Saprogum® sowing in budding phase	0.96 ± 0.02	0.44 ± 0.01
	Background + Saprogum® sowing in branching and budding phase	0.97 ± 0.03	0.44 ± 0.02
	Background + foliar nutrition of Wuxal® sowing in budding phase	0.96 ± 0.02	0.44 ± 0.01
	Background + sowing treatment with growth biostimulant Saprogum® in the branching and budding phase + foliar nutrition in the budding phase with microfertilizer Wuxal®	1.00 ± 0.03	0.46 ± 0.02

$LSD_{0.5}$: A-0.010; B-0.010; AB-0.020.
2016 $LSD_{0.5}$ t ha^{-1}: A-0.010; B-0.010; AB-0.10. 2017 $LSD_{0.5}$ t ha^{-1}: A-0.008; B-0.009; AB-0.16.
2018 $LSD_{0.5}$ t ha^{-1}: A-0.012; B-0.011; AB-0.24.

Note: A – Seed treatment; B – Duration and combination of growth biostimulant and microfertilizer application.

On the variant of sowing treatment with the growth biostimulant Saprogum® in the branching phase, the weight of seeds from one plant was 4.3% higher than on the control and was 0.93 g. When using the growth biostimulant Saprogum® in the budding phase, the yield of seeds from one plant was 0.96 g, which is 7.2% more than in the variant without sowing treatment with growth biostimulant. A similar mass of seeds from one plant was obtained on the variant of sowing by microfertilizer Wuxal® in the budding phase.

Sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase resulted in 0.97 g of seeds being obtained from one plant, which is 8.2% more than the variant without sowing. The highest yield of seeds from one plant was recorded on the variant of sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing in the budding phase with Wuxal® microfertilizer – 1.0 g, which is 11.0% more than in the variant without sowing treatment with biostimulant and microfertilizers, which is significant at the 5% level of significance. The use of Saprogum® gives a significant increase in seed yield by the value of the average deviation ($LSD_{0.5}$ factor A = 0.010 t ha^{-1}). The application of Wuxal® is significant at the 5% level of significance ($LSD_{0.5}$ factor B = 0.010 t ha^{-1}). Monitoring the productivity of seeds of *Medicago sativa*, depending on the sowing treatment with growth biostimulants and microfertilizers showed that 0.41 t ha^{-1} of seed was harvested without treatment. Sowing treatment with the Saprogum® growth biostimulant during the branching phase led to a seed yield increase of 0.02 t ha^{-1} and a yield of 0.43 t ha^{-1}. Saprogum® in the branching phase, budding phase, dual application of the growth biostimulant in the branching and budding phase, and when treating microfertilizer sowing Wuxal® provided in the budding phaseyield increase by 0.03 t ha^{-1} to 0.44 t ha^{-1}.

The highest seed yield was ensured by the Saprogum® growth stimulation variant in the branching and budding phase by the use of fertilizing the sowing in the Wuxal® microfertilizer budding phase – 0.46 t ha^{-1}, which is 0.05 t ha^{-1} more than without the application growth biostimulants and microfertilizers.The treatment of sowing of *Medicago sativa* with growth biostimulants and microfertilizers has helped to improve the sowing qualities of seeds, including the mass of thousands of seeds, laboratory seed germination and germination energy.

Sowing treatment with the growth biostimulant Saprogum® in the branching phase led to an increase in the mass of thousands of seeds of *Medicago sativa*, by comparison, by 0.02 g to 1.82 g. Saprogum® sowing in the budding phase contributes to the increase in the mass of thousands of seeds by 0.03 g, double sowing in the branching and budding phase – by 0.04 g the use of microfertilizer Wuxal® in the budding phase helped to increase the mass of thousands of seeds of *Medicago sativa* by 0.03 g, which was equivalent to sowing the Saprogum® growth biostimulants in the budding phase. The highest mass of thousands of seeds is provided by the sowing treatment of the Saprogum® growth biostimulant in the branching and budding phas, and the budding phase – by Wuxal® microfertilizer – 1.85 g, which is 0.05 g more than the variant without sowing treatment, which is significant at the 5% level of significance The application of Saprogum® gives a significant increase in the mass of 1,000 seeds by the value of the average deviation ($LSD_{0.5}$ factor A = 0.015 t ha^{-1}). The application of Wuxal® is significant at the 5% significance level ($LSD_{0.5}$ factor B = 0.009 t ha^{-1}) (Table 4).

Table 4. Sowing qualities of seeds of *Medicago sativa* depending on the treatment with biostimulants and microfertilizers (average for 2–4 years of vegetation)

Seed treatment	Duration and combination of growth biostimulant and microfertilizer application	Weight of 1,000 seeds, g	Laboratory germination of seeds, %	Seed germination energy, %
Without treatment seed	Without biostimulant and microfertilizer treatment	1.80	83	56
Seed treatment with growth biostimulant Saprogum® (background)	Background + Saprogum® sowing in branching phase	1.82	86	58
	Background + Saprogum® sowing in budding phase	1.83	86	59
	Background + Saprogum® sowing in branching and budding phase	1.84	87	62
	Background + foliar nutrition of Wuxal® sowing in budding phase	1.83	86	60
	Background + sowing treatment with growth biostimulant Saprogum® in the branching and budding phase + foliar nutrition in the budding phase with microfertilizer Wuxal®	1.85	89	64

$LSD_{0.5}$: A-0.015; B-0.009; AB-0.015. 2016 $LSD_{0.5}$ g: A-0.011; B-0.009; AB-0.04.
2017 $LSD_{0.5}$ g: A-0.007; B-0.009; AB-0.01. 2018 $LSD_{0.5}$ g: A-0.017; B-0.013; AB-0.03.

Note: A – Seed treatment; B – Duration and combination of growth biostimulant and microfertilizer application.

The magnitude of laboratory germination of seeds of *Medicago sativa* with the introduction of a growth biostimulant Saprogum® and microfertilizers Wuxal® increased by 3–6% and amounted to 86–89%. The lowest increase in laboratory germination of seeds compared to the control was found in the variant of sowing cultivation with biostimulant Saprogum® in the branching phase, and the highest in the treatment of sowing with growth biostimulant Saprogum® in the branching phase and budding by the use of fertilizing the sowing phase of microfertilizer budding Wuxal®

Foliar feeding of sowing of *Medicago sativa* microfertilizer Wuxal® helped to obtain laboratory germination of seeds similar to the sowing treatment with the growth biostimulant Saprogum® separately in the branching or budding phase.

The germination energy of seeds of *Medicago sativa* increased by 2–8%.The smallest increase in the germination energy of seeds of *Medicago sativa* was observed with the introduction of the plant growth biostimulant Saprogum® in the branching phase, and the highest in the variant of sowing cultivation with the Saprogum® growth factor in the branching phase and budding by the use of fertilization of the sowing in the budding phase with Wuxal ® microfertilizer, where the seed germination energy was 64%.

In the year of non-cover sowing of *Medicago sativa* on the variant without introduction of growth biostimulant and microfertilizers the yield of green mass was 32.9 t ha^{-1}. Saprogum® growth biostimulant treatment in the branching phase contributed to a 12.9% increase in the green yield of *Medicago sativa* to 37.8 t ha^{-1}. Saprogum® growth budding in the budding phase contributes 12.7% to a green mass yield of up to 37.7 t ha^{-1}, which is 0.1 t ha^{-1} less than when using the Saprogum® growth branch in the branching phase. Double introduction of the growth biostimulant Saprogum® in the branching and budding phase causes the yield of green mass to increase by 13.1% – up to 37.9 t ha^{-1}, which is 0.1 t ha^{-1} and 0.2 t ha^{-1} more, respectively, than at a single introduction to these phases.

Foliar feeding of microfertilizer sowing Wuxal® in the phase of budding of *Medicago sativa* helps to increase the yield of green mass by 13.1% – to the level of 37.6 t ha^{-1}, which is 0.1 t ha^{-1} less than when introduced into the budding phase of the biostimulant growth of Saprogum®. The highest yield of green mass in the first year of vegetation is provided by the sowing treatment of the Saprogum® growth biostimulant in the branching and budding phase by the use of the fertilization in the sowing phase in the Wuxal® microfertilizer budding phase – 38.2 t ha^{-1}, which is 13.9% more than onversion without biostimulant and microfertilizer treatment, 0.6 t ha^{-1} more than when processing microfertilizer sowing Wuxal® in budding phase, 0.5 t ha^{-1} more than in processing with growth biostimulant Saprogum® in budding phase, 0.4 t ha^{-1} – than attreatment with the same preparation in the branching phase and by 0.3 t ha^{-1} more than in the double treatment of sowing with the growth biostimulant Saprogum® in the branching and budding phase (Table 5).

Table 5. The yield of green mass of alfalfa sowing *Medicago sativa* depending on the treatment with biostimulant and microfertilizers (1–4th year of vegetation), t ha^{-1}

Seed treatment	Duration and combination of growth biostimulant and microfertilizer application	1-st year	2-nd year	3-d year	4-th year	Average for all years
Without treatment seed	Without biostimulant and microfertilizer treatment	32.9 ± 0.3	42.7 ± 0.3	35.7 ± 0.1	25.4 ± 0.2	34.2 ± 0.1
Seed treatment with growth biostimulant Saprogum® (background)	Background + Saprogum® sowing in branching phase	37.8 ± 0.2	49.0 ± 0.1	42.5 ± 0.2	30.8 ± 0.2	40.0 ± 0.2
	Background + Saprogum® sowing in budding phase	37.7 ± 0.4	48.7 ± 0.2	42.4 ± 0.3	30.6 ± 0.1	39.8 ± 0.3
	Background + Saprogum® sowing in branching and budding phase	37.9 ± 0.3	50.0 ± 0.3	42.7 ± 0.3	31.1 ± 0.3	40.4 ± 0.3
	Background + foliar nutrition of Wuxal® sowing in budding phase	37.6 ± 0.2	48.9 ± 0.3	42.6 ± 0.2	30.7 ± 0.3	40.0 ± 0.2
	Background + sowing treatment with growth biostimulant Saprogum® in the branching and budding phase + foliar nutrition in the budding phase with microfertilizer Wuxal®	38.2 ± 0.3	50.8 ± 0.2	43.0 ± 0.2	32.0 ± 0.2	41.0 ± 0.3

$LSD_{0.5}$: A-0.09; B-0.09; AB-0.025. 2016 $LSD_{0.5}$ t/ha^{-1}: A-0.010; B-0.010; AB-0.06.
2017 $LSD_{0.5}$ t/ha^{-1}: A-0.008; B-0.015; AB-0.16. 2018 $LSD_{0.5}$ t/ha^{-1}: A-0.019; B-0.016; AB-0.23

Note: A – Seed treatment; B – Duration and combination of growth biostimulant and microfertilizer application.

In the second year of the growing season, the highest yield of green mass was also provided by the option of sowing treatment with the Saprogum® growth biostimulant in the branching and budding phase by the use of fertilizing the sowing in the budding phase by Wuxal® microfertilizer – 50.8 t ha^{-1}, which is 16.0% more than in the version without the introduction of preparations. Saprogum® cultivation treatment with branching and budding promoted green mass yields of 0.8 t ha^{-1} less than the best option and 14.6% more than the control.

Introduction of the Saprogum® growth biostimulant in the branching phase of *Medicago sativa* yields a green mass yield of 1.8 t ha^{-1} less than with the complex application of the Saprogum® and microfertilizer Wuxal® and 12.9% more than in control.

Foliar planting by microfertilizer Wuxal® in the budding phase provides a 12.7% increase in the green yield of *Medicago sativa* than in the control. Saprogum® growth stimulation treatment in the budding phase contributes to a 12.3% increase in green mass yield compared to control.

In the third year of the growing season, the yield of green mass of *Medicago sativa* decreasesits highest value was observed for sowing treatments with a growth stimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing phase in the Wuxal® microfertilizer budding phase – 43.0 t ha^{-1}, which is 17.0% more than the control. Saprogum® growth and sapling treatment in the branching and budding phase provides a yield of 0.3 t ha^{-1} less green yield, but 16.4% higher than the control. Processing of sowing by microfertilizer Wuxal® in the budding phase, the growth biostimulant Saprogum® in the branching and budding phase allows to obtain the yield of green mass by 16.2; 16.0 and 15.8% more than controls.

In the fourth year of vegetation, the yield of green mass of *Medicago sativa* with the use of growth biostimulant and microfertilizer was 30.6–32.0 t ha^{-1}, which is 17.0–20.6% higher than on the control. The highest yield of green mass was provided by the variant of sowing cultivation of Saprogum® in the branching and budding phase by the use of fertilizing of the sowing in the budding phase by Wuxal® microfertilizer, and the smallest – processing of sapling by the Saprogum® growth biostimulantthe budding phase.

For an average of four years of vegetation of *Medicago sativa*, the highest yield of green mass provides a variant of sowing with a stimulant of growth of Saprogum® in the branching and budding phase by the use of fertilizing of the sowing in the budding phase Wuxal® microfertilizer – 41.0 t ha^{-1}, which is 16.6% more than on the control. The application of Saprogum® gives a significant increase in the yield of green mass by the value of the average deviation ($LSD_{0.5}$ factor A = 0.09 t ha^{-1}). The application of Wuxal® is significant at the 5% level of significance ($LSD_{0.5}$ factor B = 0.09 t ha^{-1}). The green mass yield of 40.4 t ha^{-1} provided the Saprogum® growth stimulant in the branching and budding phases, which is 0.6 t ha^{-1} less than the best case and 15.3% more than the control. 40.0 t ha^{-1} of green mass yields were provided by Saprogum® growth stimulation options for branching and microfertilizer Wuxal® for budding, which is 14.5% more than the control. The smallest increase in the yield of green mass of *Medicago sativa* provides the introduction of a growth stimulant Saprogum® in the budding phase – 14.1% more than in the version without the use of preparations.

The yield of green mass of *Medicago sativa* of Sinyukha variety is closely correlated with plant density (r = 0.985), as well as with height (r = 0.950), which is significantly at the 1% level of significance. The dependences we found, presented in the form of regression equations, indicated a significant influence of weather conditions on the yield of green mass of the Sinyukha variety (Table 6).

Table 6. Regression dependence of *Medicago sativa* green mass yield between height, plant density and weather conditions (2–4th year of vegetation)

Yield of green	Regression equation	Rмн	R^2	F	Fт
mass (Y),	$У = 0.1289X_1 + 17.097$	0.986	0.985	232.35	6.70*
t ha^{-1}	$У = 0.7679X_2 + 21.258$	0.973	0.950	116.47	
	$У = -6.956 - 0.001X_3 + 0.0094X_4$	0.978	0.956	141.52	

Note: Y – Sinyukha; X_1 – plant density, units m^{-2}; X_2 – plant height, cm; X_3 – the amount of precipitation, mm; X_4 – the sum of active temperatures, °C; Rmn – the coefficient of multiple correlation; R^2 – the coefficient of determination; F is Fisher's criterion; F_t – tabular value of Fisher's criterion; * – reliably at 1% significance level.

The productivity of *Medicago sativa* agrophytocenoses on seeds depends on many factors, but the main one is the presence of productive moisture in the soil during the growing season and providing plants with rainfall in critical periods.

The expected results of research are aimed at increasing the level of realization of fodder varietal potential of perennial grasses, namely *Medicago sativa* sowing, increasing the profitability of its production in combination with environmental and social effects. The dry matter content of the green mass of *Medicago sativa* in the non-medicated version was 19.2%. The introduction of a growth biostimulant Saprogum® and microfertilizers Wuxal ® caused a decrease in the dry matter content by 0.4–1.0%. The smallest decrease in the dry matter content of the green mass of *Medicago sativa* was found on the variant of sowing treatment with the growth biostimulant Saprogum® in the branching phase. The greatest reduction of the dry matter content was found on the variant of sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing in the budding phase with microfertilizer Wuxal®. Reducing the dry matter content of the green mass of *Medicago sativa* by the introduction of a growth biostimulant and microfertilizer caused by the accumulation of moisture in the vegetative mass, similar to the effect of organic and mineral fertilizers on the accumulation of dry substances (Table 7).

Protein content in the completely dry matter of *Medicago sativa* for the application of preparations was 23.4–24.0%. Protein is a major nutrient in feed, so the higher its content, the greater the value of green mass. The highest protein content was observed in the completely dry matter of *Medicago sativa* from the variant of sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing in the budding phase of microfertilizer 1.2% more than the control 0.2% less protein content was observed in the Saprogum® stimulant treatment in the branching and budding phase. By 0.3% less – on the variant of foliar fertilization of sowing by microfertilizer Wuxal ® in the budding phase, by 0.4% less – on the variant of sowing treatment with the growth biostimulant Saprogum® in the budding phase and by 0.6% less – on the variant of Saprogum® sowing branching phase.

Table 7. Chemical composition of the green mass of *Medicago sativa* depending on the treatment with stimulants and microfertilizers (average for all years of vegetation), %

Seed treatment	Duration and combination of growth biostimulant and microfertilizer application Without biostimulant and microfertilizer treatment	Dry matter	chemical composition on absolutely dry matter				
			protein	fat	cellulose	ash	NES
Without treatment seed	Background + Saprogum® sowing in branching phase	19.2	22.8	2.2	28.5	9.4	37.1
Seed treatment with growth biostimulant Saprogum® (background)	Background + Saprogum® sowing in budding phase	18.8	23.4	2.2	27.9	9.3	37.2
	Background + Saprogum® sowing in branching and budding phase	18.6	23.6	2.3	28.2	9.4	36.5
	Background + foliar nutrition of Wuxal® sowing in budding phase	18.3	23.8	2.2	28.0	9.5	36.5
	Background + sowing treatment with growth biostimulant Saprogum® in the branching and budding phase + foliar nutrition in the budding phase with microfertilizer Wuxal®	18.6	23.7	2.1	28.0	9.3	36.9
	Duration and combination of growth biostimulant and microfertilizer application	18.2	24.0	2.2	27.8	9.4	36.6
$LSD_{0.05}$		0.52	0.06	0.08	0.08	0.07	0.25

Note: A – Seed treatment; B – Duration and combination of growth biostimulant and microfertilizer application.

The fat content of the completely dry matter of *Medicago sativa* did not depend on the sowing treatment with a stimulant and microfertilizer and was in all variants, including controls, 2.1–2.3 %, which was within the margin of error of the experiment. The fiber content of the variant cultivation of *Medicago sativa* without the introduction of growth biostimulant and microfertilizer was 28.5%. Sowing with preparations reduced the fiber content in the absolutely dry matter by 0.3–0.7%. The lowest fiber content was detected on the Saprogum® growth stimulant in the branching and budding phase by the use of the sowing in the Wuxal® microfertilizer budding phase, and 27.8% and the highest on the Saprogum® sowing variant the budding phase is 28.2%.

The ash content did not depend on the cultivation of crops by growth biostimulants and microfertilizers and amounted to 9.3–9.5%. The content of nitrogen–free extractive substances (NES) in the absolutely dry matter of *Medicago sativa* was 36.5–37.2%. The lowest NES content was detected in the feed of *Medicago sativa* from the cultivation variant of the Saprogum® growth biostimulant in the budding phase, as well as its dual use in the branching and budding phase, and the highest in the variant of Saprogum® sowing in the branching phase.

CONCLUSIONS

The highest yield of seeds from one *Medicago sativa* plant was recorded on the variant of sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing in the budding phase with Wuxal® microfertilizer – 1.0 g, which is 11.0% more than without biostimulant Saprogum® and Wuxal® foliar nutrition.The highest seed yield of *Medicago sativa* also provided the variant of sowing treatment with the Saprogum® growth biostimulant in the branching and budding phase by the use of the fertilization of the sowing in the budding phase with microfertilizer Wuxal® – 0.46 t ha^{-1}.

The highest mass of thousands of seeds is provided by the sowing treatment of the Saprogum® growth biostimulant during the branching and budding phase by the use of fertilization of the sowing phase by the budding Wuxal® microfertilizer – 1.85 g. For an average of four years of vegetation of *Medicago sativa*, the highest yield of green mass provides a variant of sowing with a biostimulant of growth of Saprogum® in the branching and budding phase by the use of feeding of the sowing in the budding phase Wuxal® microfertilizer – 41.0 t ha^{-1}, which is 16.6% more than on the control than on the control without biostimulant Saprogum® treatment and without foliar nutrition the Wuxal® microfertilizer. The highest protein content was observed in the completely dry matter of *Medicago sativa* from the variant of sowing treatment with the growth biostimulant Saprogum® in the branching and budding phase by the use of fertilizing the sowing in the budding phase of microfertilizer Wuxal® 1.2% more than the control.

REFERENCES

Antoniou Chrystalla, Xenofontos Rafaella & Chatzimichail Giannis, Christou Anastasis, Kashfi Khosrow & Fotopoulos Vasileios. 2020. Exploring the Potential of Nitric Oxide and Hydrogen Sulfide (NOSH)-Releasing Synthetic Compounds as Novel Priming Agents against Drought Stress in *Medicago sativa* Plants. *Biomolecules* **10**(1), 120.

Benabderrahim Mohamed Ali, Guiza Marwa & Haddad Mansour. 2020. Genetic diversity of salt tolerance in tetraploid alfalfa (*Medicago sativa L.*). *Acta physiologiae plantarum* **42**(1), 5.

Cao, S., Liang, Q.W. & Nzabanita, C. 2019. Paraphoma root rot of alfalfa (Medicago sativa) in Inner Mongolia, China. *Plant pathology* **69**(2), 231–239.

Cen Huifang, Wang Tingting, Liu Huayue, Tian Danyang & Zhang Yunwei. 2020. Melatonin Application Improves Salt Tolerance of Alfalfa (*Medicago sativa L.*) by Enhancing Antioxidant Capacity. *Plants-basel* **9**(2), 220.

Chen Tao, Wang Bo & Power Robert C. 2020. The first archaeobotanical evidence of *Medicago sativa L.* in China: hay fodder for livestock. *Archaeological and anthropological sciences* 12, 1.

El Husseini, M.M.M. 2019. Management of the Egyptian alfalfa weevil, *Hypera brunneipennis* (Boheman) (Coleoptera: Curculionidae), in the alfalfa, *Medicago sativa L.*, using the entomopathogenic fungus, *Beauveria bassiana* (Balsamo) Vuillemin. *Egyptian journal of biological pest control* **29**(1), 82.

El-Zaidy Mohamed, Almusalim Abdulrahman & Alsahli Abdulaziz. 2020. Effects of ozone on cell organelles of alfalfa (*Medicago sativa L.*) Seedlings. *Saudi journal of biological sciences* **27**(1), 60–66.

Garriga, M., Ovalle, C. & Espinoza, S. 2020. Use of Vis-NIR reflectance data and regression models to estimate physiological and productivity traits in lucerne (*Medicago sativa*). *Crop & pasture science* **71**(1), 90–100.

Hadidi Milad, Ibarz Albert & Pagan Jordi. 2020. Optimisation and kinetic study of the ultrasonic-assisted extraction of total saponins from alfalfa (*Medicago sativa*) and its bioaccessibility using the response surface methodology. *Food chemistry* **309**, 125786.

Hou Lifeng, Yu Jie & Zhao Lili. (2020). Dark Septate Endophytes Improve the Growth and the Tolerance of *Medicago sativa* and Ammopiptanthus mongolicus Under Cadmium Stress. *Frontiers in microbiology* **10**, 3061.

Jiang Peng, Shao Jonathan & Nemchinov Lev G. 2019. Identification of emerging viral genomes in transcriptomic datasets of alfalfa (*Medicago sativa L.*). *Virology journal* **16**(1), 153.

Lemus Ramirez Vicente, Guevara Escobar Aurelio & Garcia Rodriguez Juan Antonio. (2020). Milk production in dairy cows grazing alfalfa (*Medicago sativa*) in the central Mexican highlands. *Revista mexicana de ciencias pecuarias,* **11**(1), 1–18.

Li Danqi, Liu Da & Lv Mengchao. 2020. Isolation of triterpenoid saponins from *Medicago sativa L.* with neuroprotective activities. *Bioorganic & medicinal chemistry letters* **30**(4), 126956.

Li Haiyun, Qiu Yizhi, Yao Tuo, Ma Yachun, Zhang Huirong & Yang Xiaolei. 2020. Effects of PGPR microbial inoculants on the growth and soil properties of *Avena sativa*, *Medicago sativa*, and *Cucumis sativus* seedlings. *Soil & tillage research* **199**, 104577.

Liatukiene Aurelija, Skuodiene Regina & Tomchuk Donata. 2020. Evaluation of agro-biological traits of *Medicago sativa* and M. varia in a Cambisol and Retisol. *Zemdirbyste-agriculture,* **107**(1), 41–48.

Liu Xiuming, Ahmad Naveed & Zhang Jiwei. 2020. Codon-optimized recombinant expression assay for a monomeric 17kda basic fibroblast growth factor (bfgf) in transgenic alfalfa (*Medicago sativa L.):* blueprints towards human therapeutic proteins. *Journal of Botany* **52**(2), 501–507.

Martinez-Hidalgo Pilar, David Flores-Felix Jose & Velazquez Encarna. 2020. High taxonomic diversity of Micromonospora strains isolated from *Medicago sativa* nodules in Western Spain and Australia. *Systematic and applied microbiology* **43**(1), 126043.

Mazur, V.A., Didur, I.M., Pantsyreva, H.V. & Telekalo, N.V. 2018. Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology* **8**(4), 26–33.

Mazur, V.A., Pantsyreva, H.V., Mazur, K.V. & Didur, I.M. 2019. Influence of the assimilation apparatus and productivity of white lupine plants. *Agronomy Research* **17**(1), 206–219.

Mbarki Sonia, Skalicky Milan & Talbi Ons. 2020. Performance of *Medicago sativa* Grown in Clay Soil Favored by Compost or Farmyard Manure to Mitigate Salt Stress. *Agronomy-basel* **10**(1), 94.

Min Xueyang, Jin Xiaoyu & Zhang Zhengshe. 2020. Genome-Wide Identification of NAC Transcription Factor Family and Functional Analysis of the Abiotic Stress-Responsive Genes in *Medicago sativa* L. *Journal of plant growth regulation* **39**, 324–337.

Palamarchuk, V. & Telekalo, N. 2018. The effect of seed size and seeding depth on the components of maize yield structure. *Bulgarian Journal of Agricultural Science* **24**(5), 785–792.

Palamarchuk, V., Honcharuk, I., Honcharuk, T. & Telekalo, N. 2018. Effect of the elements of corn cultivation technology on bioethanol production under conditions of the right-bank forest-steppe of Ukraine. *Ukrainian Journal of Ecology* **8**(3), 47–53.

Rezaeian Mohammad, Moghadam Mahmoud Tohidi & Kiaei Mohammad Mehdi. 2020. The effect of heavy metals on the nutritional value of Alfalfa: comparison of nutrients and heavy metals of Alfalfa (Medicago sativa) in industrial and non-industrial areas. *Toxicological research* **36**(2), 183–193.

Seddighfar Masoud, Mirghazanfari Sayid Mahdi & Dadpay Masoumeh. 2020. Analgesic and anti-inflammatory properties of hydroalcoholic extracts of Malva sylvestris, Carum carvi or Medicago sativa, and their combination in a rat model. *Journal of integrative medicine–jim* **18**(2), 181–188.

Sezmis Gurkan & Gursoy Esra. 2020. Determination of relative feed value, net energy lactation and metabolic energy contents of alfalfa (*Medicago sativa L.*). Fresenius environmental bulletin. 29. 3. 1637–1642.

Tucak Marijana, Cupic Tihomir & Horvat Daniela. 2020. Variation of Phytoestrogen Content and Major Agronomic Traits in Alfalfa (*Medicago sativa L.*) Populations. *Agronomy-basel*, **10**(1), 87.

Wang Jing, Xu Xing & Ma Dongmei. 2020. Establishment of an efficient alfalfa regeneration system via organogenesis and the co-expression of Arabidopsis SOS genes improves salt tolerance in transgenic alfalfa (*Medicago sativa L.*). *Canadian journal of plant science* **100**(1), 136–139.

Wassie Misganaw, Zhang Weihong & Zhang Qiang (2020). Exogenous salicylic acid ameliorates heat stress-induced damages and improves growth and photosynthetic efficiency in alfalfa (*Medicago sativa L.*). *Ecotoxicology and environmental safety* **191**, 110206.

Xu, Hongyu, L, Zhenyi & Tong Zongyong. 2020a. Metabolomic analyses reveal substances that contribute to the increased freezing tolerance of alfalfa (*Medicago sativa L.*) after continuous water deficit. *Bmc plant biology* **20**(1), 15.

Xu, Hongyu, Tong Zongyong & He, Feng. 2020b. Response of Alfalfa (*Medicago sativa L.*) to Abrupt Chilling as Reflected by Changes in Freezing Tolerance and Soluble Sugars. *Agronomy-basel* **10**(2), 255.

Yesilayer Nihat, Mutlu Gamze & Yildirim Arda. 2020. Effect of nettle (Urtica spp.), marigold (Tagetes erecta), alfalfa (*Medicago sativa*) extracts and synthetic xanthophyll (zeaxanthin) carotenoid supplementations into diets on skin pigmentation and growth parameters of electric yellow cichlid (Labidochromis caeruleus). *Aquaculture* **520**, 734964.

Zhao Yaodong, Ma Wenjing & Wei Xiaohong. 2020. Identification of Exogenous Nitric Oxide-Responsive miRNAs from Alfalfa (*Medicago sativa L.*) under Drought Stress by High-Throughput Sequencing. *Genes* **11**(1), 30.