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BIOLOGICAL SIGNIFICANCE OF ALFALFA IN THE DEVELOPMENT OF ORGANIC FARMING IN SOUTH-EASTERN KAZAKHSTAN

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SUMMARY

The ecological situation and modern agro-landscape improvement, soil fertility maintenance and uplifting, formation of ecologically safe agro-ecosystems with germplasm diversity in crop rotation, and cultures-soil conditioners are the focus of the study. Nitrogen is a vital element required in larger quantities by plants; however, lack of it has become a problem in organic farming. The presented study suggests ways organic farming can boost up nitrogen in return to address nitrogen deficiency. The research shows data on the harvest of three-year standing alfalfa and indicators of the efficiency of annual crops' use in the crop rotation of organic farming. The study findings exhibited that alfalfa accumulates residues of up to 13–17 t ha^{-1} in three years of standing, containing more than 280–300, 63–80, and 66–120 kg NPK ha^{-1}, respectively. In the efficiency of different crop rotations, the alfalfa accumulated 13 and 20 t ha^{-1} organic residues in the two- and three-year periods, respectively. More than 11 t ha^{-1} of green mass containing 65 to 70 kg of nitrogen, 20 to 25 kg of phosphorous, and 55 to 60 kg of potassium accumulates in the soil in welded form. By sowing in good time, mixed with oats, leave the soil with up to 12–15 t of organic matter, containing 190–200, 35–40, and 230–250 kg NPK ha^{-1}, respectively. A pea-oat mixture of about 12.0 t ha^{-1} of green mass resulted in 132, 46, and 102 kg NPK ha^{-1}, respectively. The latest findings can serve as a basis for the development of new approaches related to the organic farming system in Southeast Kazakhstan.

Keywords: Alfalfa, Southeast Kazakhstan, organic farming, crop rotation, soil fertility, green manure, light chestnut soil

Key findings: The presented findings revealed that alfalfa accumulates residues up to 13–17 t ha^{-1} in three years of standing, containing more than 280–300, 63–80, and 66–120 kg NPK ha^{-1}, respectively. In various crop rotations' efficiency, alfalfa accumulated 13 and 20 t ha^{-1} organic residues in two- and three-year periods, respectively.

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INTRODUCTION

Organic agriculture is an environmentally friendly alternative to traditional farming systems used worldwide, which strives for the principles of ecology and healthcare (Luttikholt, 2007; Gusev *et al.*, 2022). Its fundamental agronomic core characteristic aims at a circular

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process by reducing inputs, particularly the ban on chemical inputs, such as, synthetic pesticides and mineral fertilizers (Reganold and Wachter, 2016).

Preservation and enhancement of the natural resource - soil includes the regulation of the nutrient regime with limited or no use and attracting pollinators for increased productivity of entomophilous crops. The biological control of diseases and pests through insects, cultural weed control, and the introduction of disease-resistant cultivars are the main subjects of research in organic farming. In general, these methods help restore the soil biota by eliminating the use of chemicals and thus producing environment-friendly end products (Mishustin and Emtsev, 1987; Sheudzhen, 2003; Chozin *et al*., 2017). With the use of that natural processes, the cost of production gets reduced by excluding chemical agents.

The organic farming system should adhere to the introduction of crop rotation using the unique properties of alfalfa and green manure in the South and Southeast of Kazakhstan. Alfalfa, like other legumes, plays an important role in the organic processing of agriculture. Past findings revealed that every million hectares occupied by alfalfa enriched the soil with a vast amount of nitrogen, requiring several factories to produce the mineral nitrogen fertilizers (Fageria and Baligar, 2005; Schweinzer *et al*., 2017; Clement, 2021). It is critical for saving energy and economic costs for the production of nitrogen fertilizers.

Alfalfa (*Medicago sativa* L.), also called Lucerne, is the most valuable legume crop with forage, medicinal and phytosanitary values widely used in irrigated agriculture (Nurpeisov *et al*., 2011). Among legumes and cereals, alfalfa has the highest yield of feed units, digestible protein, minerals, and carotene. It is also rich in micro-elements, which are necessary to physiological processes in animals and birds (Schweinzer *et al*., 2017; Paczkowski *et al*., 2018). Lucerne provides high yields, enriches the soil with organic matter, improves its physical and physio-chemical properties, enhances the life activity of helpful microorganisms, soil fertility, and crop yield, and is, therefore, an indispensable precursor in the crop rotation (Gekhaev, 2008; Kozyrev and Farniev, 2010; Clement, 2021). Nitrogen fixed through legume pastures and forages is an essential contribution (Peoples *et al*., 2015) and provides a substitute for chemical fertilizer to increase soil nitrogen availability that can promote non-legume forage production in grasslands (Yuan *et al*., 2016).

The results of previous studies determined the efficiency of alfalfa with three-year grass standing in a system of five-field and eight-field organic crop rotation on irrigated lands in Southeast Kazakhstan (Molyuga, 2007). In arable soils, fertility enhancement is one of the priority problems in modern agriculture. On the irrigated lands of Southeastern Kazakhstan, the three-year alfalfa crop has established the said technology. With perennial grasses, the increase in humus is primarily due to the various soil processes that restore the imbalance between organic matter intake and degradation (Verbitskaya, 2007). In the absence of intensive mechanical treatment on perennial herbs, the organic matter input to the soil prevails over its decomposition, determined by the boost in the biochemical processes toward optimal humus formation regimes.

The heat resistance, ability to tolerate high temperatures and dry air with good productivity and high protein content in the green mass placed the alfalfa at one of the leading sites in the organic farming system. Since the alfalfa plant can accumulate more than 20 t ha^{-1} of organic matter and more than 200 kg ha^{-1} of nitrogen in a meter of soil, the deep-penetrating root system consumes a significant amount of groundwater improving soil reclamation (Schweinzer *et al*., 2017; Paczkowski *et al*., 2018). Thick grasses and alfalfa reduce the salt content of the soil. Nitrogen (N) fertilizer is generally unnecessary for alfalfa production since alfalfa can obtain its N from N-fixing nodules. Alfalfa fixes most (70%–90%) of its N needs from the air through rhizobium bacteria residing in alfalfa root nodules (Long *et al*., 2013; Massaliyev *et al*., 2015). Since 78% of the atmosphere consists of nitrogen gas, this supply of free fertilizer' is inexhaustible.

The findings of these studies laid the scientific foundation for the transition to organic farming. A new science concept introduces organic crop rotation. Here, the basic principle that needs recognition is using formation and turnover of the alfalfa layer (Sadvakassov and Usipbaev, 2015). Allowing to plant of other crops like cereals, vegetables, and oilseeds after alfalfa could continue based on the market demand. Alfalfa biomass-based foods are in high necessity for organic livestock. Combining these two types of food and feed is more acceptable to farmers, particularly with small holdings. For an introduction to organic agriculture, high-yielding varieties of alfalfa (i.e., Kokorai, Osimtal, and Kokbalaousa) underwent isolation at the Kazakh Research Institute of Agriculture and Crop Production for the symbiotic activity to indigenous strains of nodule bacteria and industrial preparations of 'Rizovit AKS.' In addition, other options are also possible for planting annual legumes, for independent use, and as part of crop rotation using the formation and rotation of three-year alfalfa. The objective of the present study was to increase irrigated arable land through the effective use of biologization and crop rotation tools and to obtain a profitable crop yield in the organic farming system.

MATERIAL AND METHODS

The completed research ensued in the irrigated zone of the foothills of the Zaillian Alatau plains, Khazakstan. The study focused on light chestnut soils, and the climate of the foothills was extremely continental. The stationary plot of organic agriculture situates in the experimental fields of the Kazakh Research Institute of Agriculture and Crop Production, Almaty Region, Kazakhstan. The study on the influence of alfalfa and green manures on soil fertility and crop productivity proceeded in 2012–2018 with sidereal units on 8-field and 5-field crop rotations. Crop rotations and experiment schemes were as follows:

A. 8-field grass-grain rowed

1. Winter wheat + alfalfa
2. Alfalfa in the two years of life
3. Alfalfa in the three years of life
4. Winter wheat + green manure (oat-pea mixture [11.7 t ha^{-1}], Vico-oat mixture [12.8 t ha^{-1}], and white clover [9.7 t ha^{-1}])
5. Sugar beet
6. Soybean
7. Sugar beet
8. Corn

B. 5-field crop rotation (two rotations)

1. Barley or winter wheat + alfalfa
2. Alfalfa in the second year of life
3. Alfalfa in the third year of life
4. Winter wheat
5. Sugar beet or corn on silage

C. 3-field grain-rowed

1. Winter wheat + siderats (10.0 t ha^{-1})
2. Sugar beet
3. Soybean

In the 8-field grassland crop rotation, the application of organic and mineral fertilizers under the sugar beet and seeded-winter wheat ensued on the turnover of the alfalfa layer with three years of standing. The experience examined options for manure application (20 t ha^{-1}), estimated mineral fertilizer dose (50 t ha^{-1} per root crops), as well as weathering of green fertilizers, grain straw, and humus application, their action, and after-market under crops, the most productive users of the growing season to maximize the accumulation of organic matter. An overview of the experience with 8-field crop rotation, the different elements of biology, and the number of nutrients applied with mineral and organic fertilizers to the soil appear in Table 1.

The experience used two controls. The first control was the option without fertilization. The second control was applying mineral fertilizers to sugar beet at balance-sheet doses (Molyuga, 2007; Schweinzer *et al*., 2017; Clement, 2021). The principle of calculating fertilizer doses was as follows: for the average yield over the years obtained by applying the recommended doses of fertilizer, the additional use of fertilizers determined the further increase of the crop.

Table 1. Quantity of NPKs introduced with mineral and organic fertilizers in 8-field crop rotation N.

Fertilizer variants	Fertilizers used (t ha^{-1})	Added nutritious substances (kg ha^{-1} of active ingredient)		
		Nitrogen	Phosphorus	Potassium
Without fertilizers	0	0	0	0
NRK	-	80	50	140
Dung	20	96	54	180
Vetch-oats mixture	10	116	57	135
$LSD_{0.05}$ Fertilizer variants	6.02			
$LSD_{0.05}$ Nutritious substances		1.57	2.12	1.39

In the 3-field crop rotation after winter wheat, a vetch-oats mixture was grown, with the green vegetable mass planted at 10 t ha^{-1} into the soil. The field area was 1.5–2.0 ha. The efficiency of the crop rotation and the values of each crop took account of the yield and properties of the soil: the volume, mass, water content of the macro-aggregates (greater than 0.25 mm), the accumulation of organic root and crop residues, and the content of the nutrients therein. The chemical analyses of soil and plants proceeded according to GOST (Generic Ordinal Sequential Trial) as per the following methodological guidelines:

— Definition of general and labile humus (Kenenbaev *et al*., 2005)
— Definition of nitrogen (total nitrogen, NH4, N-NO3) GOST 26107-84 (Kenenbaev *et al*., 2005)
— Determination of mobile phosphorus and potassium exchange by Machigin (Kenenbaev *et al*., 2005)
— Determination of mobile sulfur by CINAO GOST 26490-85 (Kenenbaev *et al*., 2005)
— Determination of soil pH by CINAO GOST 26483-85 (Kenenbaev *et al*., 2005)

Data collection and analysis employed the basics of statistical processing (Dospekhov, 1985).

RESULTS

Soil fertility is a determining factor in higher and more stable crop yields. In turn, for the creation and maintenance of soil fertility, one cannot ignore the leading role of organic substances, which is the primary source of humic substances and predetermines all processes occurring in the soil. Therefore, there is a direct relationship between the quantity and quality of organic matter found in the ground and the productivity levels of cultivated crops. Perennial legumes play a significant role and make it possible to simultaneously address the issues of amelioration and soil fertility improvement, growth, yield, and protein content in the forage, and improving the ecosystem in general (Verbitskaya, 2007; Schweinzer *et al*., 2017).

Earlier works authenticated and established that different crops, due to their biological features and technological methods applied, keep the soil with various stubbles, roots, and other crop residues. Table 1 summarizes the accumulation of organic residues and their mineral nutrient content under major field crops, depending on their productivity. Table 1 also shows the data on the accumulated nitrogen, phosphorus, and potassium of various types. The mineral fertilizers used compared with organic fertilizers enters the soil in a ready-made form. Thus, when introducing nitrogen, phosphorus, and potassium, their contents in the soil were 80:50:140 kg ha^{-1}, respectively. Mineral fertilizers actively mineralize organic matter, which leads to deterioration of the soil structure, compaction, reduction of porosity, and a decrease in the proportion of granular aggregates. The introduction of 20 t ha^{-1} of manure increased the NPK content to 96:54:180 kg ha^{-1}.

The introduction of manure improved the physicochemical properties of the soil and its water and air regime and increased the absorption capacity of soil buffering. The organic matter of manure influences the enhancement of microbiological processes of decomposing fiber, with the content of assimilable phosphates increased in the soil. As a result of the release of the waste products of microorganisms, when they die off, they turn into compounds that are easily accessible to plants. The introduction of siderates in a mixture of vetch and oats increased the NPK content to 116:57:135 kg ha^{-1}. Sideral crops serve as an organic fertilizer obtained from the green mass of cultivated crops and their root and crop residues. The role of siderates is great in improving the physicochemical properties of the soil, increasing its biological activity.

Crop and root residues play an influential role in replenishing the soil with organic matter, which, in decomposing, cause the formation of organic colloids in the arable layer. At the same time, alfalfa, the core component in all crop rotation types, has the most favorable impact on the soil under irrigated conditions. Using green manure as an organic fertilizer is one of the most vital methods of farming biologization. The data in Table 2 shows that the accumulation of organic residues and the content of nutrients under the main field crops depend on the plants and their yield. According to this study data, the recorded lowest content of nitrogen, phosphorus, and potassium emerged under sugar beet and grain crops, i.e., NPK: 55–150, 12–30, and 27–100 kg ha^{-1}, respectively. Under soybean and alfalfa crops for three years, relatively high NPK content resulted, i.e., NPK: 150–300, 35–80, and 45–120 kg ha^{-1}, respectively. Over three years, the alfalfa crop collects 6 to 12 t ha^{-1} of hay and

Table 2. Accumulation of organic residues and their mineral nutrient content under major field crops.

Crop	Yield (t ha^{-1})	Plant residues (t ha^{-1})	Nutritious substances (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium
Winter wheat	4.5-5.3	5-13	85-150	15-30	45-100
Sugar beet	45.0-53.0	5-8	70-80	17-24	50-61
Corn per silo	6.0-6.5	6-11	60-100	15-30	40-60
Soybean	2.8-3.0	7-8	150-180	35-40	45-50
Alfalfa 3 years	6.0-12.0	13-17	280-300	63-80	80-120
Cereals	2.7-3.5	3-8	55-75	12-23	27-70
$LSD_{0.05}$ Crop yield	2.27				
$LSD_{0.05}$ Nutritious substances		0.88	0.84	0.68	1.26

accumulates up to 13 to 17 t of residues on a hectare of soil, depending on the dirt, and contains more than 280–300, 63–80, and 120 kg NPK ha^{-1}, respectively, and 66–80 kg of root residues ha^{-1} (Table 2).

The scientific evidence also showed that the productivity of cultivated crops does not decrease in the next 2–3 years. Using alfalfa and other sidereal crops has instilled the shift to organic production as a basis for the development of a new direction (Nurpeisov, 2011; Long *et al*., 2013). One must also realize that this positive role of alfalfa reveals only by its high productivity since the root mass left by alfalfa is proportional and, in most cases, equal to the above-ground bulk of plants. The deep-running root system of 2.0–3.0 m moves the power cells from the deep to the arable horizon. Alfalfa culture in South Kazakhstan gives 5–6 hay harvests, and in the Southeast provides 3–4 hay harvests in irrigated conditions, showing more as an effective measure to reduce the pollution of fields. In crop rotation, agro-technical and ameliorative values of alfalfa and other leguminous crops are well known for boosting and maintaining soil fertility (Molyuga, 2007; Gekhaev, 2008; Paczkowski *et al*., 2018).

According to the presented results, long-term experiments at the Kazakh Research Institute of Agriculture and Crop Production, Kazakhstan, to study the effectiveness of various types of field rotations of alfalfa and its two-year standing accumulated organic residues of 13 t ha^{-1} and three-year duration, observed with 20 t ha^{-1}. Before the alfalfa split of two years of life, the humus content in the soil was within 1.7% in the root zone, with nitrogen (86 kg ha^{-1}), phosphorus (22 kg ha^{-1}), and potassium (57 kg ha^{-1}) residues, and at three years of alfalfa life, respectively, depends mainly on the crop rotation and tillage techniques. Alfalfa uniqueness displays in the management processes of plant nutrition, weed pollution, the salt regime of the soil, and suppression of pathogens (Molyuga, 2007; Schweinzer *et al*., 2017).

Recent studies have also shown that degradation of organic substances was most intense in crop rotation with high saturation of sugar beet, as well as, due to frequent inter-annual treatments and irrigation. The decomposition of the alfalfa layer on light chestnut soils was as follows: in the year of sowing sugar beet (60.4%), in the second year (72.2%), in the third year of the original (84.4%), and for the fourth year in the same field, the supply of organic material becomes close to the area of sugar beet monoculture. On the contrary, in the autumn and winter seasons, one and two years of alfalfa did not show any unique difference in varieties and variants (Kenenbaev *et al*., 2005; Massaliyev *et al*., 2015), which may refer to diverse soil physio-chemical properties and environmental conditions.

In the case of using the alfalfa layer for winter wheat and sugar beet seeding in the following year, the decomposition rate of organic matter in one year after the grass sloughing was significantly lower (21.6%) compared with the placement of sugar beet. Thus, the conclusion is that in biologized crop rotation on irrigated lands, three-year alfalfa forms a more fertile baseline for the placement of subsequent crops. It authenticates maintaining stable and maximum crop productivity in the main crop rotation. The three-year term of alfalfa provides a nine-fold boost, which allows for effective weed control, and the crop is well maintained. The use of alfalfa crops during the most productive period of their life, up to three years, ensures maximum accumulation of root and stubble residues, which play a vital role in improving the water-physical properties and food regime of the soil (Sdobnikova, 1971; Sadvakassov and Usipbaev, 2015).

Table 3. Quantity and quality of recommended organic fertilizers.

Crop	Plowed dry biomass (t ha^{-1})	Nutritious substances (kg ha^{-1})		
		Nitrogen	Phosphorus	Potassium
Pease oat mixture	11.7	132	46	100
Oatmeal	12.8	116	57	135
White donnik	9.7	190	35	152
Dung	20	96	50	180
Straw	6.0	19.1	6.9	12.6
Biohumus	1.2	43	46	170
$LSD_{0.05}$ Crop biomass	2.5			
$LSD_{0.05}$ Nutritious substances		1.19	1.73	1.13

Studies showed that the maximum amount of plant residues with the highest accumulation of nutrients leaves in the soil with alfalfa three-year of life before sloughing cultivated in the grass rotation. The data in Table 2 also present that three-year alfalfa root masses of 14.6 t ha^{-1} provided a minimum of 280:63:80 kg NPK ha^{-1} for the soil. The presented results further revealed that organic residues of three-year alfalfa standing, as well as cultivated crops, due to the active mineralization of the Asian grey earth, were unable to maintain high soil fertility for more than three years. Maintaining soil fertility in subsequent years requires planting pulses as a green fertilizer, which is of greater importance, significantly enriching the soil with organic matter (Table 3).

The results further revealed that the highest indicators of nutrients appeared with white clover crops (Table 3). When plowing 9.7 t ha^{-1} of siderate into the soil, the NPK content increased to 190:35:152 kg ha^{-1}. A massive amount of phosphorus also emerged when plowing a vico-oat mixture of 57 kg ha^{-1}. The recorded highest potassium content (180 kg ha^{-1}) resulted from applying manure at a dose of 6 t ha^{-1}, whereas the lowest (12.6 kg ha^{-1}) surfaced by plowing the straw. Vermicompost also positively influenced the phosphorus and potassium content (46 and 170 kg ha^{-1}, respectively). The above-recommended doses of organic fertilizers and siderates have an enhanced effect on soil fertility. The data also indicated that tillage yields 12.8 t ha^{-1} of organic residues and up to 190 kg ha^{-1} of nitrogen to the cropland. Most importantly, alfalfa accumulates biological nitrogen in the soil, leaving behind 300–400 kg of nitrogen (Long *et al.*, 2013; Sadvakassov and Usipbaev, 2015).

The *P*-value is of great importance in the analysis of data processing. According to the data obtained (Tables 1-3), the *P* value is higher than 0.05, which indicates that the data are not statistically significant. At $P > 0.05$, not enough arguments can reject the null hypothesis exist. Without rebuffing the null hypothesis, the results insignificant at the 5% level.

When cultivating alfalfa (three years or more), up to 4.91 t ha^{-1} of root residues remain in the soil, wherein the transformation releases up to 90 kg of nitrogen. Under alfalfa, the soil is structured, that is, the number of aggregates resistant to destruction under the influence of water and wind increases. In addition, alfalfa roots accumulate a sizeable amount of nutrients in the tissues of the root neck, including protein, which contains a significant amount of sulfur and calcium. Thus, alfalfa cultivation increases humus by 0.08% and 5.5% in water-resistant structural aggregates > 0.25 mm (Zelensky *et al.*, 2006; Zykov, 1967).

In the present era, the reduction in soil fertility and pollution of the environment requires strengthening of crop production by more contribution of inexhaustible natural resources in the formation of a favorable environment through its biologization rather than through synthetic and technological methods (Massaliyev *et al.*, 2015). Along with alfalfa in the future, the study of the crop rotational effect of other common perennial forage herbs in Kazakhstan is necessary, such as, sweet clover (yellow and white). In addition, these crops are also good honey crops. Based on the above findings, the study concluded that the means of biologization of crop rotation and the use of green fertilizers, annual legumes, and perennial herbs (alfalfa) allow for increasing the productivity of the arable, creating conditions for maintaining and increasing soil fertility and obtaining a profitable yield since cultures (The Program for Development of Agriculture in the Republic of Kazakhstan in 2013-2020 “Agribusiness - 2020”).

CONCLUSIONS

The transition to the production of primary products based on organic farming started with the sowing of alfalfa and its after effects, as well as, other sideral crops, as the basis for developing a new direction. The alfalfa crop use of up to three years ensures maximum accumulation of root and crop residues and is essential in improving the soil's water-physical properties and nutritional regime. A three-year-old alfalfa crop makes it possible to maintain stable maximum productivity of crops. Thus, in conclusion, the biologization crop rotation, the use of green manure, annual legumes, perennial grasses (alfalfa), and other crops can increase the productivity of arable land, create conditions for maintaining and enhancing soil fertility, and obtaining high crop yields.

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REFERENCES

Chozin M, Sudjatmiko S, Setyowati H, Fahrurrozi F, Muktamar Z (2017). Analysis of traits association in sweet corn inbred lines as grown under organic crop management. *SABRAO J. Breed. Genet*. 49(4): 361–367.

Clement CBLR (2021). Deep water uptake of perennial crops. A case study on intermediate wheatgrass and alfalfa. PhD Thesis, Department of Plant and Environmental Sciences, University of Copenhagen, Denmark.

Dospekhov BA (1985). Methodology of field experience (with the basics of statistical processing of research results). - 5th ed., supplement and revision. M. Agropromizdat, 1985. pp. 351.

Fageria NK, Baligar VC (2005). Enhancing nitrogen use efficiency in crop plants. *Adv. in Agron*, 88: 97-185.

Gekhaev TY (2008). Evaporation and transpiration as factors of abiogenic and biological cycling of nutrients in agrocenoses of the North Caucasus. Abstract for the Academic Degree, Moscow, pp. 39.

Gusev VN, Bastaubayeva ShO, Khidirov AE, Zhusupbekov EK, Tabynbayeva LK (2022). Nitrogen nutrition of crop plants in the precision farming system in the South and Southeast Kazakhstan. *SABRAO J. Breed. Genet.* 54(4): 842-850. http://doi.org/10.54910/sabrao2022.54.4.15.

Kenenbaev SB, Tureshev O, Iorgansky AI (2005). Biologized crop rotations and energy-saving technologies of cultivated crops on irrigated lands of the southeastern region of Kazakhstan. Recommendation, Almalybak, pp. 19.

Kozyrev AKh, Farniev AT (2010). Lucerne as a predecessor in the Central Part of the Northern Caucasus. *Agriculture* 2010(7): 24-25.

Long RF, Putnam DH, Meyer R (2013). **W**hen is nitrogen fertilization of alfalfa beneficial? Almost never! Alfalfa and Forage News: News and information from UC Cooperative Extension about alfalfa and forage production. Available at: https://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=10478.

Luttikholt LWM (2007). Principles of organic agriculture as formulated by the International Federation of Organic Agriculture Movements NJAS - Wageningen. *J. Life Sci.* 54(4): 347-360.

Massaliyev NM, Ramazanova SB, Rakhymzhanov BS (2015). Influence of alfalfa varieties on changes in the composition of mobile forms of phosphorus in the soil in South-Eastern Kazakhstan. *Biosci. Biotechnol. Res. Asia* 12(2): 691-698.

Mishustin EN, Emtsev VT (1987). *Mikrobiologiia* (Microbiology). Moscow, Kolos pp. 368 (in Russ.).

Molyuga NG (2007). Peculiarities of agrotechnical cultivation of winter wheat variety Batko after the predecessor of alfalfa in the conditions of the central zone of Kuban, NG Malyuga, VT Zakharov, EG Kutnyak, AM Kravtsov. Proceedings of KubGAU - Krasnodar 2007(5): 77-82.

Nurpeisov IA, Tureshev OT, Bastaubaeva ShO, Suleimenova MSh, Iorgansky AI, Bekbatyrov MB, Tureshev KO (2011). Biological farming system for grain production in the Southeast of Kazakhstan - Almalybak, pp. 19.

Paczkowski A, Isselstein J, Hartmann S (2018). Sortenunterschiede in Blattmasseertrag bei Rotklee und Luzerne In: Leistungen von Gras und Klee-Gras auf Acker und Grünland- 62. Jahrestagung der AGGF Christian-Albrechts-Universität zu Kiel, D-Kiel, Tagungsband, pp. 89-94.

Peoples MB, Chalk PM, Unkovich MJ, Boddey RM (2015). Can differences in ^{15}N natural abundance be used to quantify the transfer of nitrogen from legumes to neighboring non-legume plant species? *Soil Biol. Biochem.* 87: 97-109.

Reganold J, Wachter J (2016). Organic agriculture in the twenty-first century. *Nature Plants* 2: 15221. https://doi.org/10.1038/nplants.2015.221.

Sadvakassov SS, Usipbaev NB (2015). Characteristics of alfalfa growth and development in the year of sowing in the foothill and the steppe areas of the South-East of Kazakhstan. Climate, Ecology, Agriculture in Eurasia: Proceedings of the IV Int. Research and Production Conference dedicated to the 70th Anniversary of Victory in Great Patriotic War (1941-1945) and the 100-year Anniversary of A.A. Ezhevsky (May 27-29, 2015). Part I. Irkutsk: Publishing house of the Irkutsk State Agricultural University, pp. 296.

Schweinzer A, Kikuta S, Friedel JK (2017). Wasserökonomie von Luzerne (*Medicago sativa* L.) unter Freiland- und Laborbedingungen. Poster at: 14. Wissenschaftstagung Ökologischer Landbau, Campus Weihenstephan, Freising-Weihenstephan, März 2017: 07-10.

Sdobnikova OV (1971). Conditions of soil nutrition and usage of fertilizers in Northern Kazakhstan and Western Siberia. PhD Thesis, Moscow, pp. 34.

Sheudzhen AKh (2003). Biogeochemistry. Maikop, pp. 1027.

The program for the development of the agriculture complex in the Republic of Kazakhstan in 2013-2020 "Agribusiness - 2020" (2013). Retrieved from http://adilet.zan.kz/rus/docs/P1300000151http://adilet.zan.kz/rus/docs/P1300000151Izotov, V.I. (1983). Influence of mineral fertilizers on the yield and chemical composition of alfalfa hay irrigated on light brown soils (Candidate's Thesis, pp. 155). Moscow.

Verbitskaya LP (2007). Lucerne for food and seeds in the Krasnodar region. KubGAU - Krasnodar, pp. 239.

Yuan ZQ, Yu KL, Epstein H, Fang C, Li JT, Liu QQ, Liu XW, Gao WJ, Li FM (2016). Effects of legume species introduction on vegetation and soil nutrient development on abandoned croplands in a semi-arid environment on the Loess Plateau, China. *Sci. Total Environ*. 541: 692-700.

Zelensky NA, Zelenskaya GM, Avdeenko AP (2006). Joint sowing of winter wheat with alfalfa – The future of crop production. *J. Fundam. Res.* 6: 53-56.

Zykov YuD (1967). Semirechenskaya alfalfa-Alma-Ata: Kainar, pp. 246.