International Journal of
Biological Engineering and Agriculture

ISSN: 2833-5376
Volume 2 | No 12 | Dec -2023

Assessing the Potential of Using Sheep's Wool to Fertilise Beans in the Context of Ensuring Nutritional Safety

Marcin Niemiec [1], Monika Komorowska [2], Edyta Molik [3], Dagmara K. Zuzek [4], Shakhista Ishniyazova [5], Piotr Szatkowski [6], Atilgan Atilgan [7]

[1, 2] department of Agricultural and Environmental Chemistry, Faculty of Agriculture and Economics, University of Agriculture in Krakow, 30-149 Krakow, Poland

[3] department of animal nutrition and biotechnology, and fisheries, faculty of animal science, university of agriculture in krakow, al. mickiewicza 24/28, 31-059 krakow, Poland;

[4] department of Statistics and Social Policy, Faculty of Agriculture and Economics, University of Agriculture in Krakow, 30-149 Krakow, Poland;

[5] department of Processing Technology, Standardization and Certification of Agricultural Products, Faculty of Processing Technology and Product Standardization, Samarkand State University of Veterinary Medicine, Livestock and Biotechnology, 140103 Samarkand, Uzbekistan;

[6] departments of biomaterials and composites, faculty of materials science and ceramics, university of science and technology in krakow, al. mickiewicza 30, 30-059 krakow, Poland;

[7] departments of Biosystems Engineering, Faculty of Engineering, Alanya Alaaddin Keykubat University, 07425 Alanya, Turkey. *Correspondence:

Abstract: The aim of this study was to assess the feasibility of using sheep wool as a fertiliser in bean cultivation. Converting the nitrogen contained in wool which is a waste product in meat sheep production into food protein could be a strategic element of a closed loop economy in the Central Asian region. The adopted objective was realised based on a vegetation experiment established on a bean farm near the town of Talas in northern Kyrgyzstan. The experiment was implemented in 2020. The experimental factor was different doses of wool applied pre-sowing. The results of the realised experiment indicate that sheep's wool can be an effective fertiliser in bean cultivation and under the climatic and soil conditions of Kyrgyzstan, the transformation of keratin contained in wool into food protein is effective. The applied wool was not only a source of nutrients for plants, but also influenced the intensification of atmospheric nitrogen fixation by symbiotic bacteria. In order to optimise the technology of bean cultivation in the Central Asian region, it is necessary to continue research on the degree of utilisation of nutrients contained in wool and to determine the sustainability of changes in the biological physicochemical and chemical properties of the soil. At the same time, it is important to promote increasing the share of beans in the diet of societies whose diet is traditionally based on mutton.

Keywords: Nutritional Safety.

Introduction.

An indispensable element of sustainable agricultural development is the introduction of elements of a closed loop economy and the use of renewable energy sources [Komorowska et al. 2023]. One of the most energy-intensive elements of agriculture is the production and use of mineral fertilisers. The use of waste generated in agriculture for fertiliser purposes is recognised as one of the most important elements in the rationalisation of food production. Biogenic elements and macronutrients contained in organic waste can provide a source of nutrients for plants and thus do not need to be supplied with conventional fertilisers [Zheljazkov et al. 2009]. The use of organic waste as fertiliser is also part of organic carbon rationalisation. Activities related to reducing soil degradation and optimising nutrient use, are part of the principles of the most important quality management systems in primary production [Sikora et al. 2020, Niemiec et al. 2019]. Under conditions of sheep rearing for meat, sheep wool is a waste product, the management of which is an organisational and technological problem. At the same time, it is a special product from the point of view of carbon sequestration. Sheep convert the organic carbon contained in plants into wool, which contains almost 50% of this element by dry weight.

Sheep benefit from the carbon stocks bound by plants in pastures, often in disadvantaged areas. In the long term, areas with water deficits and sparse vegetation will increase, so the size of the sheep population is likely to increase. Due to the fibre characteristics of wool, the share of this raw material in textile production is only 1.5%. Due to the large supply of this raw material, not only in mountainous areas but also in large dry areas, there are rationales for its use as fertilisers [Slamič and Jug 2017]. The properties of wool related to its rapid decomposition in the environment are assessed as favourable for its use as fertiliser [Lal et al. 2020].

The aim of this study was to evaluate the effect of sheep wool fertilisation on the yield and chemical composition of bean seeds.

Material and methods

The adopted objective was realised based on a vegetation experiment established on a bean farm near the town of Talas in northern Kyrgyzstan. The test plant was beans. The experiment was set up on 10 May 2020 while the plants were harvested on 29 August of that year. Sowing was carried out on soil with a granulometric composition of medium clay. In the experiment conducted, the experimental factors were the type of fertiliser and its dose.

The field experiment included 3 doses of wool at 0.5 t, 1t and 2t per ha. The reference point was a site fertilised with mineral fertilisers, according to production practice in the studied area.

The scheme of the experiment is shown in Table 1. In the case of sites with the addition of wool at 1 and 2 t/ha, amounts of nitrogen were introduced into the soil far in excess of the nutritional requirements of the beans. High doses of wool were introduced to determine the effect of excessive doses of this waste on bean yields under experimental conditions.

Wool was applied to the soil in autumn 2019. Prior to application, the wool was shredded using a flail shredder then heaped for 4 weeks by periodically spraying the heap. The wool was mixed into the soil after application.

Table 1. Scheme of the experiment

Object number	Wool	Ammonium sulphate	Potassium salt	Triple superphosphate	S	N	P_2O_5	K_2O
1	-	-	-	-	-	-	-	-
2	-	156	200	136	-	50	60	120
3	0.5	-	192	129	9.91	57.2	60	120
4	1	-	183	123	19.82	114.3	60	120
5	2	-	167	111	39.64	228.6	60	120

The values of the required nutrients for the tested plant were estimated at the following levels: nitrogen (N) - 55 Mg· ha^{-1}, phosphorus (P_2O_5) – 68 Mg· ha^{-1} and potassium (K_2O) – 130 Mg· ha^{-1}. In the objects where sheep wool was used for fertilisation, fertilisation with potassium and phosphorus was applied in the amount corresponding to the fertilisation needs. In the wool objects, all fertilisers were applied pre-sowing.

For mineral-fertilised objects, the nitrogen dose was divided into two parts - 50% of the dose was applied before sowing and the remaining 50% was applied at the beginning of plant flowering.

Before setting up the experiment, soil samples were taken to determine its basic parameters. And based on these, the yield potential of the habitat was estimated. In addition, wool samples were also taken.

Soil pH was determined using the potentiometric method, while organic carbon and total nitrogen were determined by elemental analysis using an Elementar's Vario Max Cube apparatus. Mineral nitrogen in soil was determined by distillation after extraction with a 1 mol · dm^{-3} potassium sulphate solution.

The content of available forms of phosphorus and potassium was determined by the Egner-Riehm method, while the content of available forms of calcium and magnesium was determined by the Schachtschabel method.

Table 2. Properties of the soil on which the experiment was conducted

		Ntotal	Corg.	Nmin.	P	K	Mg	Ca
pHH2O	pHKCl	[g · kg^{-1} s.m.]		[mg · kg^{-1}s.m.]				
6.24	5.72	0.118	1.34	24.7	52.88	128.6	176.9	319.8

An Anton Paar Multiwave 3000 microwave system was used for the mineralisation of the wool. Analytical weights of approximately 0.5 g (on a dry weight basis) were dissolved in a mixture of HNO_3 and H_2O_2 at a ratio of 5:1, v/v. The elemental concentrations in the resulting solutions were determined by inductively excited plasma atomic emission spectrometry in a Perkin Elmer's Optima 7600 DV instrument.

The properties of the soil are shown in Table 2, while the macronutrient content of the wool is given in Table 3. Based on the results of the soil analysis, the production potential of the habitat was estimated at 4 t seeds · ha^{-1}.

Table 3. Properties of the wool used in the experiment

C	N	Ca	S	Mg	P	K	Na
%		g □ kg^{-1}					
41.81	11.42	5.822	5.012	1.420	2.681	16.35	1.128

Table 4. Results and discussion

Yield and chemical composition of beans from each study site

Object No.	Yield [t · ha^{-1}]		Macronutrients content g · kg^{-1}				
	Seeds	Protein	N	P	K	Ca	Mg
1	1.78	0.342	30.74	2.788	8.467	0.987	0.223
2	2.99	0.625	33.44	2.637	9.657	0.933	0.211
3	2.65	0.568	34.32	2.598	9.794	1.007	2.225
4	3.48	0.780	37.88	2.522	10.23	1.132	0.245
5	3.54	0.833	39.65	2.487	10.18	1.178	0.265

Beans are one of the most important crops that contribute to the food security of societies, especially in developing countries [Nchanji et al. 2023]. The high content of protein and macronutrients and micronutrients is the most important asset of this plant as part of the human diet. Due to its high content of protein, macronutrients and fibre, beans may be an important part of the future nutritional security of human populations in developing countries [Vieira et al. 2023]. The results of this study clearly show the positive effect of applied sheep's wool as a fertiliser on plant yield. In the control plot, without fertiliser, the commercial yield was 1.78 t· ha^{-1} [Table 4]. Fertilisation with mineral fertilisers resulted in a yield of 2.99 t· ha^{-1}. Achieving such a yield, however, required the application of 50 kg of mineral nitrogen per pure component. Despite the fact that beans belong to the Fabaceae whose characteristic feature is the ability to induce atmospheric nitrogen fixation, a clear effect of the applied mineral nitrogen on the yield of this plant was observed. Thus, the results of the presented research indicate that the omission of bean fertilisation is an agrotechnical error that translates into a reduction in bean yield. The introduction of sheep's wool at a rate of 0.5 t· ha^{-1} into the soil a few months before planting resulted in an increase in bean yield by 870 kg of dry bean seeds · ha^{-1} [Table 3]. In terms of nitrogen, each kg of this element introduced with sheep's wool resulted in a yield increase of about 17 kg of bean seeds. Introducing 1 kg of nitrogen with mineral fertilisers resulted in a yield increase of more than 21 kg. Assuming a nitrogen utilisation rate from organic fertilisers of 35%, fertilisation with mineral wool is more beneficial from a production point of view.

The introduction of wool into the soil at a level of 1 t· ha^{-1} resulted in a further increase in yield, up to 3.48 t seeds ·ha^{-1} . The increase in yield of the tested crop after the application of sheep's wool may have resulted not only from the introduction of additional nutrients, but also from a change in air-water properties.

This resulted in an increase in atmospheric nitrogen fixation potential. Tang et al. 2023 indicate that the nitrogen fixation efficiency of symbiotic bacteria is closely correlated with nutrient availability, but also with the physicochemical and physical properties of the soil. The application of wool at 2 t· ha^{-1} no longer significantly increased the amount of marketable bean yield obtained. The reason for this was probably the occurrence of a limiting factor for plant yield. This factor could have been water shortage at critical periods for plant development. Cultivated plants were irrigated three times during the growing season by surface sprinkling. From the point of view of water resource management and from the point of view of maintaining plant productivity, this is the worst irrigation method. However, infrastructural constraints in the studied area do not allow the introduction of more efficient watering methods. Under such conditions, a critical component of fertilisation technology is a proper assessment of the productive potential of the habitat, which is difficult under irrational irrigation conditions. Over-intensive fertilisation, especially of nitrogen, leads to dispersion of this element in the environment which intensifies the greenhouse effect and eutrophication of waters.

The fertilisation technology tested is based on sweat sheep's wool, which is a troublesome waste in the studied area. Even the smallest dose of the material tested reduced the level of the greenhouse effect resulting from nitrogen fertilisation. It is assumed that the production of 1 kg of nitrogen in mineral fertilisers results in carbon dioxide emissions of 7.99 kg of CO_2. From the point of view of strategic management of food production in the context of food security, white yield in legume cultivation is a more important parameter than seed yield.

The results of the study indicate that the total protein yield in the object where fertilisation was abandoned was 0.342 t· ha^{-1} [Table 4]. In the object fertilised with mineral fertilisers, the protein yield was almost twice as high and amounted to 0.625 t· ha^{-1}. The use of wool as a source of nutrients and a means of improving soil properties resulted in an increase in the total protein yield to 0.780 t· ha^{-1} when 1 t of wool was applied as a soil additive. The transformation of animal protein contained in wool into plant protein with a valuable amino acid composition should be a strategic part of the economy, not only in developing countries, but wherever this type of organic waste is generated [Huppertz et al. 2023]. Cucci et al. 2019 demonstrated that the use of organic waste to fertilise the Fabaceae bean crops can be part of an effective method of nitrogen management, especially in areas where a significant amount of organic waste is generated. Similarly, Bordin-Rodrigues et al. [2021] found a statistically significant change in bean yield depending on nitrogen and phosphorus fertilisation strategies. These authors emphasise that the increase in plant yield is not only due to the supply of nutrients to the plants but, above all, to the improvement of microbial conditions.

The applied sheep's wool had a positive effect on the potassium and calcium content of bean biomass in the object where 1 t of sheep's wool was applied per ha. Compared to the object where mineral fertilisation was applied, a 21% higher calcium content and a 6% higher potassium content were found.

Summary

The results of the conducted experiment clearly show the high potential of sheep's wool to increase food safety, especially in regions with high meat sheep production. Beans are a plant with a relatively short vegetation period whose cultivation gives good results under unfavourable environmental conditions.

The wool used not only provided a source of nutrients for the plants, but also intensified the fixation of atmospheric nitrogen by symbiotic bacteria. In order to optimise the technology of bean cultivation in the Central Asian region, it is necessary to continue research on the degree of utilisation of nutrients contained in wool and to determine the sustainability of changes in the biological physicochemical and chemical properties of the soil. At the same time, it is important to promote increasing the share of beans in the diet of societies whose diet is traditionally based on mutton.

Literature

1. Niemiec M., Komorowska M. 2019 Assessment of the possibility of implementing the GLOBAL GAP standard in selected bean producing farms in western Kyrgyzstan E3S Web of Conference, 132, 02005. https://doi.org/10.1051/e3sconf/201913202005
2. Sikora J., Niemiec M., Szeląg-Sikora A., Gródek-Szostak Z., Kuboń M., Komorowska M. 2020. The Impact of a Controlled-Release Fertilizer on Greenhouse Gas Emissions and the Efficiency of the Production of Chinese Cabbage, Energies 13, 8, 2063. https://doi.org/10.3390/en13082063
3. Slamič B., Jug T. 2017. Influence of Different Substrate on Nutrients in Lettuce. Global Journal of Botanical Science, 2017, 5, 50-54. DOI: 10.12974/2311-858X.2017.05.02.2.
4. Zheljazkov V.D., Stratton G.W., Pincock J., Butler S., Jeliazkova E.A., Nedkov N.K., Gerard P.D., 2009. Wool-waste as organic nutrient source for container-grown plants. Waste Management 29 [2009] 2160–2164. doi: 10.1016/j.wasman.2009.03.009. Epub 2009 Apr 3.
5. Nchanji E.B., Ngoh S.B., Toywa J., Cosmas L. 2023. Analysis of common bean [Phaseolus vulgaris L.] trade in Cameroon: A trader's perspective of preferred varieties and market traits. Journal of Agriculture and Food Research, Available online 7 November 2023, 100839
6. Vieira N.M., Peghinelli V.V., Monte M.G., Costa N.A., Pereira A. G., Seki M.M., Azevedo P,S., Polegato B.F., Rupp de Paiva S.A., Mamede Zornoff L.A., Minicucci M. 2023. Beans comsumption can contribute to the prevention of cardiovascular disease. Clinical Nutrition ESPEN. 54, 73-80.
7. Cucci G., Lacolla G., Summo C., Pasqualone A. 2019. Effect of organic and mineral fertilization on faba bean [Vicia faba L.]. Scientia Horticulturae, 243, 338-343.
8. Bordin-Rodrigues J.C., Benetoli da Silva T.R., Del Moura Soares D.F., Stracieri J., Pereira Ducheski R.L., da Silva G.D. 2021. Bean and chia development in accordance with fertilization management. Heliyon, 7, 6, e07316.
9. Huppertz M., Manasa L., Kachhap D., Dalai A., Yadav N., Baby D., Khan M.A., Bauer P., Panigrahi K.C.S. 2023. Exploring the potential of mung bean: From domestication and traditional selection to modern genetic and genomic technologies in a changing world. Journal of Agriculture and Food Research, 14, 100786.
10. Komorowska M., Niemiec M., Sikora J., Gródek-Szostak Z., Gurgulu H., Chowaniak M., Atilgan A., Neuberger P. 2023. Evaluation of Sheep Wool as a Substrate for Hydroponic Cucumber Cultivation. Agriculture, 13, 3, 554
11. Lal B., Sharma S.C., Meena R.L., Sarkar S., Sahoo A., Balai R.C., Gautam P., Meena B.P. 2020. Utilization of byproducts of sheep farming as organic fertilizer for improving soil health and productivity of barley forage. Journal of Environmental Management, 269, 110765.
12. Tang S., Ma Q., Marsden K.A., Chadwick D.R., Luo Y., Kuzyakov Y., Wu L., Jones D.L. 2023.

Microbial community succession in soil is mainly driven by carbon and nitrogen contents rather than phosphorus and sulphur contents. Soil Biology and Biochemistry, 180, 109019.

13. Muminov, N., Odinaev, M., Vasiev, K., Abdirayimov, A., & Kurambayev, M. (2022, July). Development and implementation of technological processes and modes of preparation of cotton fold for extraction of pectin substances. In IOP Conference Series: Earth and Environmental Science (Vol. 1068, No. 1, p. 012009). IOP Publishing.
14. XAKIMOV, D., MUMINOV, N., JARQINBOYEV, S., & Abdumalik, O. K. (2022). Measurement system analysis” metodi asosida o ‘lchash jarayonlarining ishonchliligini tahlil qilish.
15. Muminov, N., & Abdirayimov, A. (2023). Oq boshli karam (Brassica oleracea var. Capitata l.) Tarkibidagi pektin moddalarini o ‘ziga xos xususiyatlari. Евразийский журнал академических исследований, 3(4 Part 4), 74-80.
16. Tilavov, X. M., Mixliyev, T. R., & Devletshayeva, E. S. (2022). DON EKINLARINI SAQLASHDA TOZALASH VA SARALASH MASHINALARIDAN FOYDALANISH SAMARADORLIGI. Academic research in educational sciences, (Conference), 469-474.
17. Остонакулов, Т. Э., & Исмойилов, А. И. (2019). Особенности ускоренной схемы и методики элитного семеноводства ранних и среднеранних сортов картофеля и их продуктивности в репродуцировании. Актуальные проблемы современной науки, (1), 108-113.
18. Xudayberdiev, A., Ishniyazova, S., Mo‘minov, N., & Fayziev, J. (2022). Go ‘sht mahsulotlarini saqlash va qayta ishlashda innovatsion texnologiyalar. O ‘quv qo ‘llanma. Toshkent.
19. Kadirova, B., & Muminov, N. (2020). Evaluation of quality indicators of turkey meat. In WORLD SCIENCE: PROBLEMS AND INNOVATIONS (pp. 283-285).
20. Остонакулов, Т. Э., Санаев, С. Т., & Хонкулов, Х. Х. (2014). Подбор сортов картофеля, пригодных для выращивания ростками. The Way of Science, 27.
21. Ишниязова, Ш. А., & Рузикулов, Н. Б. (2021). СОДЕРЖАНИЕ ТОКСИКАНТОВ В ОРГАНАХ И ТКАНЯХ РЫБ. ВЕСТНИК ВЕТЕРИНАРИИ И ЖИВОТНОВОДСТВА, 1(1).
22. Tashmanov, R. K., Muminov, N., Ishniyazova, S. A., & Saidmuradova, Z. T. (2020). Poultry Processing Characteristics on the Basis of Waste-Free Technology. Editorial Team, 13.
23. Пулатов, И. Б., Ишниязова, Ш. А., Додаев, Қ. О., & Турсунов, А. (2023). STUDY OF THE CONTENT OF TOXICANTS IN FISH ORGANS AND TISSUES. КазУТБ, 3(20).
24. Xudayberdiev, A. Y., & Mamarasulov, Z. E. (2023). KOMPLEKS ISHLOV BERIShNING O ‘ZIGA XOS XUSUSIYATLARI. AGROBIOTEXNOLOGIYA VA VETERINARIYA TIBBIYOTI ILMIY JURNALI, 33-38.