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Effects of sheep wool-based amendments on yield, technological quality, and phytochemical profiles of crops: a review

Abstract

Sheep wool unsuitable for textile use is classified as special waste. However, it has the potential to be used as a sustainable and inexpensive input in agricultural production. This review comprehensively evaluates the yield, product quality, and bioactive content of raw wool, pellets, hydrolysates, and carbonized derivatives after their use as organic fertilizers, soil conditioners, and mulches. Studies have shown that sheep wool-based materials function as slow-release organic nitrogen sources and increase the soil's water-holding capacity. This feature has resulted in yield performance comparable to commercial organic fertilizers. Some studies have reported maintaining product quality, while others have reported improving it. When applied as mulch, sheep wool improved the sugar-acid balance in fruits and increased phenolic and flavonoid content. Sheep wool-based soil conditioner application supported yield and quality. Variations in yield and quality were observed depending on the product and application. Overall, it was concluded that the use of sheep wool as an agricultural input does not lead to yield or quality loss and can be used as an inexpensive agricultural input.

Keywords: organic fertilizer, crop yield, product quality, bioactive compounds, sustainable agriculture, circular economy

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Introduction

Sheep wool that is unsuitable for use in the textile industry is classified as "special waste" by the European Commission.[1] In parallel, an increasing number of scientific studies report that fertilizers produced in different forms from sheep wool can be utilized in agricultural production and may enhance both crop yield and quality. Recent research further indicates that sheep wool and its residues can be valorized as organic fertilizers and represent valuable inputs in organic farming systems. Particularly promising results have been reported for crops grown in sandy-loam soils.[2]

Sheep wool is characterized by its relatively high nitrogen content and notable water-holding capacity, making it not only a fertilizer but also a potential organic mulching material.[3] Due to its keratin-rich structure, sheep wool decomposes gradually in soil and thus functions as a slow-release nitrogen source. This characteristic has been suggested to positively influence agricultural product quality.[4] Studies evaluating sheep wool and wool-derived agricultural inputs have examined not only their effects on yield and conventional quality parameters, but also on bioactive compounds. In one such study, raspberries cultivated in substrates containing sheep wool exhibited a 37.7% increase in total polyphenol content compared to the control group.[5]

Overall, current research suggests that sheep wool can function as an environmentally friendly mulch and soil amendment, contributing to soil moisture conservation, reduction of plant stress particularly under drought conditions and improvement of product quality.[1,2,6] While determining the effects of sheep wool–based fertilizers on yield, quality, and bioactive compound content may be relatively straightforward and rapid in annual crops such as vegetables and cereals, evaluating these effects in perennial species such as plum requires longer-term studies. Therefore, comprehensive and long-term research focusing on quality parameters and bioactive compound profiles is still needed.[6]

Sheep wool and its various derivatives are increasingly defined as sustainable and environmentally friendly inputs for crop production.[1,2,6] The aim of this review is to compile and evaluate published studies investigating the effects of waste sheep wool and its processed forms-such as pellets, hydrolysates, and carbonized materials-when used as fertilizers or mulch in agricultural production, particularly with respect to crop yield, quality attributes, and bioactive compound content. The review also synthesizes findings regarding their role as soil amendments and organic fertilizers influencing product quality. Special emphasis is placed on physical, chemical, technological, and bioactive quality parameters of crops, as well as their relationship with water-use efficiency and climate-resilient agricultural practices, which have gained increasing importance in recent years.

Some characteristics of sheep wool relevant to crop production

Sheep wool is a protein-based waste material rich in keratin. It is an organic material composed of approximately 95% keratin and contains around 10% total nitrogen.[7,8] Keratin contains high levels of carbon, oxygen, nitrogen, and sulfur and is composed of a copolymeric structure of 18 different amino acids which includes predominantly glutamic acid, serine, glycine and cysteine.[8,9] Protein hydrolysates are known to function as biostimulants in agriculture, enhancing nutrient uptake and metabolic activity in plants.[10,11] It has been reported that one ton of raw wool consists of approximately 640 kg of wool fiber, 150 kg of lanolin (if not scoured), 40 kg of suint (water-soluble contaminants such as potassium salts derived from sweat and feces), 150 kg of mineral residues (soil), and around 20 kg of vegetable matter that may contain insecticide residues.[1]

Globally, more than 5 million tons of wool and other keratin-rich wastes are generated annually,[12] while Türkiye alone has an estimated potential of approximately 85,000 tons of sheep wool.[13] However, the highly resistant structure of keratin has limited the effective valorization of these wastes.

Numerous studies have demonstrated that different types of wool waste and wool residues can positively affect soil properties and fertility. Wool keratins degrade slowly in soil, gradually releasing nutrients over an extended period.[14–17] Researchers have also reported that wool waste contains significant amounts of phosphorus (P), calcium (Ca), potassium (K), copper (Cu), zinc (Zn), and manganese (Mn), which become available to plants after mineralization.[18–20,17]

Keratin extraction from sheep wool is commonly performed through hydrolysis processes, and the resulting hydrolysates are nitrogen-rich materials that can be used as agricultural fertilizers.[21] Sustainable production approaches have also been developed using superheated water hydrolysis (heated up to 180–187.5 °C), allowing keratin extraction without chemical additives.[1]

Agronomic applications of sheep wool in crop production

Uncomposted wool waste[19] hydrolyzed wool,[22,14,17] wool pellets,[23] and scoured wool,[24] have been reported to function effectively as organic fertilizers in various field crops[25] and vegetable species.[19,20,22–27] A review by Camilli et al.[28] summarized research on the use of sheep wool and its derivatives in crop production. According to this review, vegetables were the most studied group (28 publications), followed by field crops (15), ornamental plants (10), forage crops (9), medicinal plants and fruit trees/shrubs (3), and aromatic plants (2). Among vegetables, tomato was the most frequently investigated crop (7 studies), covering almost all types of wool-based applications except scoured wool and wool management practices. Lettuce was examined in five studies using raw wool, wool pellets, wool mats, substrates, and wool compost, while pepper was studied mainly with raw wool and wool hydrolysates.

Research on the direct use of sheep wool or its acid/alkaline hydrolysates in agriculture indicates considerable potential for improving soil fertility and plant nutrition. Wool applications have been shown to increase total nitrogen and protein content in plant tissues, stimulate microbial biomass, and influence root mycorrhizal colonization.[15] Due to its hygroscopic structure, wool can retain up to 30% of its weight in water,[14,29] making it suitable both as a mulching material[30] and as a slow-release fertilizer.[31] Hydrolyzed wool, in particular, has been reported to enhance plant nutrient availability and promote growth.[21,22,32]

In the context of climate change, increasing drought events and the rising use of synthetic fertilizers to maximize yields pose significant environmental risks. The IPCC[33] recommends promoting agricultural practices that enhance soil fertility and carbon sequestration while reducing greenhouse gas emissions. Improving water-use efficiency is also emphasized as a priority[34] Within this framework, the valorization of agricultural by-products such as sheep wool as organic soil amendments or fertilizers represents a sustainable and environmentally sound strategy.[35,36]

Impact on yield and physical quality attributes

Studies have examined the effects of sheep wool–based materials on crop yield and physical quality. Abdallah et al.[2] evaluated carbonized and non-carbonized sheep wool waste as soil amendments and nitrogen sources in pot experiments. In ornamental sunflower, most wool treatments increased plant growth and biomass, with carbonized wool showing the strongest effect. In maize, a 1% wool application-especially in carbonized form-improved plant growth even without additional mineral nitrogen. In contrast, excessive mineral nitrogen reduced biomass. These results suggest that carbonized wool waste may function as an effective organic nitrogen source and help reduce mineral fertilizer use.

In horticultural crops, positive yield responses have also been reported. Washed wool increased tomato yield by about 30% compared to standard commercial fertilization.[24] Wool pellets produced similar yield improvements in some studies,[37] although other research found no significant difference between wool pellets and conventional fertilizers.[38] Zheljazkov et al.[15] reported yield increases in several medicinal and aromatic plants, including basil, sage, mint, and valerian, following wool application.

In terms of quality, most studies indicate that wool-based fertilization does not negatively affect key physical parameters. Ordiales et al.[23] found no significant differences in °Brix, viscosity, color, or firmness in tomato, nor in head size and compactness in broccoli, when wool fertilizers were used. In pepper, wool fertilizer significantly improved plant height, biomass, fruit length, soluble solids content, and fruit number, although fruit weight and diameter remained unchanged.[31] Bradshaw and Hagen[38] reported that higher nitrogen levels increased total tomato yield, but fruit number and physical quality traits were not significantly affected by fertilizer type. Similarly, in spinach, wool pellet application did not significantly influence leaf dry matter content or leaf number per plant.

In fruit crops, promising results have been observed. In plum, the combined use of sheep wool and a soil conditioner increased yield by 37%, while wool mulch alone resulted in a 27% increase. Fruit weight and the proportion of first-quality fruits were also highest under combined treatments.[6] In sugar beet, reducing chemical fertilizer by 33% did not harm plant growth when wool or wool plus hydrolysate was applied. Under reduced fertilization, shoot yield increased by up to 52%, while root yield also improved.[39] Wool pellets also increased lettuce yield by approximately 20% compared to commercial fertilizers.[37] Additionally, raw wool used as mulch has shown positive yield effects and may serve as a sustainable alternative to polyethylene mulch.[40] Broccoli trials with wool pellet fertilizer (8% N) showed a 47% increase in total yield compared to the control, without reducing marketable quality. Yield increases were mainly due to a higher number of heads rather than larger head size.[23]

Most reported studies indicate that sheep wool-based fertilizers improve or maintain yield without negatively affecting physical quality parameters. They offer a sustainable alternative to mineral fertilizers and provide a valuable use for low-grade wool waste, although further research is needed to better understand their long-term effects on soil properties.

Impact on chemical and technological quality attributes

Several studies have evaluated the effects of sheep wool-based fertilizers on chemical quality traits in different crops. In plum production, total soluble solids were higher under a corn starch–based superabsorbent soil conditioner compared to sheep wool treatment. However, the total soluble solid to titratable acidity ratio (sugar/acid balance), an indicator of taste and commercial maturity, was higher in wool-treated plants than in the control. This suggests that reduced drought stress under wool application may positively influence sugar accumulation and flavor profile.[6]

In one study, the effects of using wool pellet fertilizer in tomato cultivation on technological quality parameters such as water-soluble solids content, viscosity, color and fruit firmness of tomatoes were investigated and no statistically significant difference was reported in terms of these values when compared with control fertilizer applications. These findings show that wool-based fertilizers can be an alternative to commercial organic fertilizers and do not cause any decreases in product quality.[23]

In sugar beet, the impact of chemical fertilizer reduction, sheep wool, and sheep wool plus hydrolysate applications on quality parameters has been investigated. Fertilizer reduction did not result in a marked decrease in sugar content. However, wool and wool plus hydrolysate treatments generally led to a significant reduction in both total sugar content and refined sugar concentration. Despite this decrease, refined sugar yield at harvest was not negatively affected.[39] Bradshaw and Hagen[38] reported that most elemental concentrations in spinach treated with wool pellet fertilizer did not differ significantly from those of the control group.

In sugarcane production, increased accumulation of α-amino nitrogen in roots has been associated with quality losses, as elevated α-amino N enhances sugar transfer to molasses during processing, thereby increasing refining losses.[41–43] Wool and wool plus hydrolysate applications increased shoot nitrogen concentration, which in turn elevated α-amino N accumulation in roots. However, the increase in root biomass compensated for the partial decline in quality parameters, and total refined sugar yield at harvest remained unaffected.[39]

Impact on bioactive compounds and antioxidant capacity

Sheep wool-based soil amendments and mulching applications have shown promising effects on bioactive compound accumulation in several crops. In apple, total polyphenol content in the control group was approximately 210-220 mg gallic acid equivalents (GAE)/100 g fresh weight. This value increased to about 240 mg GAE/100 g under sheep wool–based soil conditioner treatment and to approximately 250 mg GAE/100 g with wool mulch alone. When both wool-based soil conditioner and wool mulch were applied together, total polyphenol content reached 280–290 mg GAE/100 g, representing an increase of approximately 30–35% compared to the control.[44]

In plum, the highest total phenolic content (1.30 ± 0.09 mg GAE/g dry weight) was observed under the combined wool + soil conditioner treatment, compared to 1.16 ± 0.09 mg GAE/g dry weight in the control.[6] In contrast, in tomato, most chemical parameters were not significantly affected by fertilization treatments, and total polyphenol content was reported to be higher in the control than in the wool fertilizer treatment.[38]

Wool fertilizer has also been associated with increased secondary metabolite production in medicinal and aromatic plants. Zheljazkov et al.[15] reported enhanced levels of essential oils and alkaloids in basil, sage, mint, and valerian following wool application.

Antioxidant capacity, assessed using different assays (DPPH, FRAP, and CUPRAC), was highest in the combined wool plus soil conditioner treatment, and a strong positive correlation between total phenolic content and antioxidant activity was reported.[6] In apple, total flavonoid content increased from approximately 85–90 mg catechin equivalents/100 g fresh weight in the control to around 100 mg under wool-based soil conditioner treatment and 105 mg with wool mulch. The combined application resulted in 120–125 mg catechin equivalents/100 g, corresponding to a 35–40% increase compared to the control.[44]

Conclusion

Research indicates that fertilizers and mulches derived from sheep wool, when used in crop production, do not pose a problem in terms of yield and quality, and sometimes even provide advantages. Wool pellets used as fertilizer have shown comparable success to commercial organic fertilizers in tomato and broccoli production. Sheep wool or wool-derived fertilizers have been considered as alternatives to other organic or non-organic fertilizers. In drought-stricken regions, the use of sheep wool as organic mulch has been reported to have positive effects on fruit quality. Improvements have also been reported in properties such as sugar-acid balance, phenolic content, and antioxidant capacity. Using sheep wool not alone, but in combination with other inputs, has positively contributed to product yield and quality.

Raw sheep wool, pellet, hydrolysate, and carbonized forms, can be used as an alternative organic nitrogen and soil conditioner source by crop producers, especially those practicing organic and good agricultural practices. Long-term sheep wool trials may offer unique research areas in terms of cultivation and product quality studies. Enhancing the use of sheep wool in crop production can promote a circular economy, environmentally friendly approaches, and reduce fertilizer use. Farmers are expected to reduce input costs without experiencing losses in product quality or yield by using sheep wool and/or its derivatives as inexpensive fertilizer and mulch raw materials.

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Conflicts of interest

The authors declare that there are no conflicts of interest.

References

1. Bhavsar P, Zoccola M, Patrucco A, et al. Superheated water hydrolysis of waste wool in a semi industrial reactor to obtain nitrogen fertilizers. *ACS Sustain Chem Eng*. 2016;4:6722–6731.
2. Abdallah AM, Ugolini F, Baronti S, et al. Assessment of two sheep wool residues from textile industry as organic fertilizer in sunflower and maize cultivation. *J Soil Sci Plant Nutr*. 2019;19:793–807.
3. Juhos K, Papdi E, Kovács F, et al. The effect of wool mulch on plant development in the context of the physical and biological conditions in soil. *Plants*. 2023;12(4):684.
4. Mattiello S, Guzzini A, Del Giudice A, esst al. Physico–chemical characterization of keratin from wool and chicken feathers extracted using refined chemical methods. *Polymers*. 2023;15:181.
5. Balawejder M, Matłok N, Piechowiak T, et al. The modification of substrate in the soilless cultivation of raspberries *(Rubus idaeus L.)* as a factor stimulating the biosynthesis of selected bioactive compounds in fruits. *Molecules*. 2023;28:118.
6. Gitea MA, Borza IM, Domuta CG, et al. A sustainable approach based on sheep wool mulch and soil conditioner for *Prunus domestica* (*Stanley variety*) trees aimed at increasing fruit quality and productivity in drought conditions. *Sustainability*. 2024;16:7287.

7. Wang ZH, Zhang H, Yang S, et al. Genome–wide association study for wool production traits in a Chinese Merino sheep population. *PLoS One*. 2014;9:e107101.

8. Rippon JA. The structure of wool. In: Lewis DM, ed. Wool Dyeing. Bradford: Society of Dyers and Colourists. London, *Blackie Academic*; 1992.

9. Marchelli F, Rovero G, Curti M, et al. An integrated approach to convert lignocellulosic and wool residues into balanced fertilisers. *Energies*. 2021;14:497.

10. Eriksson BG. Organic textile waste as a resource for sustainable agriculture in arid and semi–arid areas. *Ambio*. 2017;46:155–161.

11. Houben D, Daoulas G, Faucon MP, et al. Potential use of mealworm frass as a fertilizer: impact on crop growth and soil properties. *Sci Rep*. 2020;10:4659.

12. Zoccola M, Aluigi A, Tonin C. Characterisation of keratin biomass from butchery and wool industry wastes. *J Mol Struct*. 2009;938:35–40.

13. Anonymous. *Hayvansal Uretim Istatistikleri 2022*. Turkish Statistical Institute. Published 2023. Accessed November 2, 2023.

14. Nustorova M, Braikova D, Gousterova A, et al. Chemical, microbiological and plant analysis of soil fertilized with alkaline hydrolysate of sheep's wool waste. *World J Microbiol Biotechnol*. 2006;22:383–390.

15. Zheljazkov VD, Stratton GW, Pincock J, et al. Wool and hair waste as nutrient source for high–value crops. *HortScience*. 2005;40:1133A–1133.

16. Zheljazkov VD, Stratton GW, Sturz T. Uncomposted wool and hair–wastes as soil amendments for high–value crops. *Agron J*. 2008;100(6):1605–1614.

17. Zoccola M, Montarsolo A, Mossotti R, et al. Green hydrolysis as an emerging technology to turn wool waste into organic nitrogen fertilizer. *Waste Biomass Valoriz*. 2015;6:891–897.

18. Böhme M, Schevchenko J, Pinker I, et al. Sheep wool as fertiliser for vegetables and flowers in organic farming. *Acta Hortic*. 2008;933:195–202.

19. Suruchi G, Anshumala S, Sarika S, et al. Growth, macro and micronutrient concentration in clusterbean (*Cyamposis tetragonoloba*) plant tissue as well as in soil when amended with wool as fertilizer. *J Environ Res Dev*. 2014;8(3):607–613.

20. Zheljazkov VD, Stratton GW, Pincock J, et al. Wool–waste as organic nutrient source for container–grown plants. *Waste Manag*. 2009;29:2160–2164.

21. Gousterova A, Nustorova M, Goshev I, et al. Alkaline hydrolysate of waste sheep wool aimed as fertilizer. *Biotechnol Biotechnol Equip*. 2003;17:140–145.

22. Gogos A, Evangelou MWH, Schäffer A, et al. Hydrolysed wool: a novel soil amendment for zinc and iron biofortification of wheat. *N Z J Agric Res*. 2013;56:130–141.

23. Ordiales E, Gutiérrez JI, Zajara L, et al. Assessment of utilization of sheep wool pellets as organic fertilizer and soil amendment in processing tomato and broccoli. *Mod Agric Sci Technol*. 2016;2:20–35.

24. Górecki RS, Górecki MT. Utilization of waste wool as substrate amendment in pot cultivation of tomato, sweet pepper, and eggplant. *Pol J Environ Stud*. 2010;19:1083–1087.

25. Mubarak AR, Ragab OE, Ali AA, et al. Short–term studies on use of organic amendments for amelioration of a sandy soil. *Afr J Agric Res*. 2009;4:621–627.

26. Vončina A, Mihelič R. Sheep wool and leather waste as fertilizers in organic production of asparagus (*Asparagus officinalis L.*). *Acta Agric Slov*. 2013;101:191–200.

27. Gupta S, Sharma A. Evaluation of plant yield and nutrient concentration in spinach amended with hair as fertilizer. *Int J Chem Sci*. 2014;12:73–82.

28. Camilli F, Focacci M, Dal Prà A, et al. Turning waste wool into a circular resource: a review of eco–innovative applications in agriculture. *Agronomy*. 2025;15(2):446.

29. Kadam VV, Meena LR, Singh S, et al. Utilization of coarse wool in agriculture for soil moisture conservation. *Indian J Small Ruminants*. 2014;20:83–86.

30. Sharma SC, Sahoo A, Chand R. Potential use of waste wool in agriculture: an overview. Indian J Small *Ruminants*. 2019;25:1–2.

31. Karaca UÇ, Yarımoğlu İ, Saba M, et al. The effect of sheep wool manure on growth and yield of pepper (*Capsicum annuum)* plant. *Int J Agric Nat Sci*. 2022;15:45–52.

32. Gillespie GD, Dada O, McDonnell KP. The potential for hydrolysed sheep wool as a sustainable source of fertiliser for Irish agriculture. *Sustainability*. 2021;14(1):365.

33. Intergovernmental Panel on Climate Change. *Global Warming of 1.5°C: Summary for Policymakers*. 2018.

34. Alagöz Z, Yılmaz E. Effects of different sources of organic matter on some soil fertility properties: a laboratory study on a Lithic Rhodoxeralf from Turkey. *Commun Soil Sci Plant Anal*. 2011;42:962–970.

35. Leskovar DI, Othman YA. Organic and conventional farming differentially influenced soil respiration, physiology, growth and head quality of artichoke cultivars. *J Soil Sci Plant Nutr*. 2018;18(3):865–880.

36. Truong THH, Marschner P. Respiration, available N and microbial biomass N in soil amended with mixes of organic materials differing in C/N ratio and decomposition stage. *Geoderma*. 2018;319:167–174.

37. Böhme M, Schevchenko J, Pinker I, et al. Sheep wool as fertiliser for vegetables and flowers in organic farming. *Acta Hortic*. 2012;933:195–202.

38. Bradshaw T, Hagen K. Wool pellets are a viable alternative to commercial fertilizer for organic vegetable production. *Agronomy*. 2022;12(5):1210.

39. Taskin MB. Reducing mineral fertilizer usage: utilizing sheep wool and alkaline hydrolysate for enhanced sugar beet cultivation. *Sugar Tech*. 2024;26(6):1653–1664.

40. Jungić D, Turk P, Benko B. Moisture regime in Hortisol and lettuce yield under different mulching conditions. *J Cent Eur Agric*. 2020;21:354–365.

41. Rahimi A, Kiralan M, Ahmadi F. Effect of humic acid application on qualitative parameters of sugar beet Cv. Shirin. *Middle East J*. 2020;9:121–129.

42. Noshad H, Mohammadian R, Khayamim S, et al. Effect of amino acid containing organic fertilizers on nitrogen use efficiency and qualitative and quantitative properties of sugar beet. *J Sugar Beet*. 2015;30:95–102.

43. Mosaad IS, Serag AH, Sheta MH. Promote sugar beet cultivation in saline soil by applying humic substances in–soil and mineral nitrogen fertilization. *J Plant Nutr*. 2022;45:2447–2464.

44. Borza IM, Rosan CA, Gitea D, et al. Influence of organic mulching strategies on apple tree (*Malus domestica Borkh.*) development, fruit quality and soil enzyme dynamics. *Agronomy*. 2025;15(9):2021.