

Safe utilization of waste wool

in agriculture

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Wool is a biodegradable fibre that is readily recycled, with significant benefits accruing from returning to the earth as a fertilizer, rich in nitrogen and sulphur. Wool waste comes in many forms like shearing waste, carpet disposal, textile industries, wool scour, sludge, and excess wool that cannot be processed. The article focuses on applications and potential benefits of wool-waste as a soil amendment, and to identify areas where there is insufficient knowledge to implement its usage. Along with growing public concern for the environment and costs of the landfill in recent years, it is utmost urgent to look for alternative uses for inevitable wool waste.

Keywords: Keratin, Moisture, Nutrient, Waste wool

THE generation of bio-waste of both crop residues and animal waste has increased due to the rapid growth in food production leading to huge piles of organic waste in agriculture. The crop residue is generally used as animal feed, so the piling and pressure of animal waste are more, examples include sheep wool-waste generated during the process of cleaning raw wool. Globally, India ranks seventh in wool production (1.8%), especially coarse wool with productivity of 0.6 kg/sheep/year. In wool processing industries, nearly 10-15% wool is considered as waste, which is obtained during processing and discarded or dumped on the ground. Waste wool is light, voluminous and keratinous (protein) in nature and may cause serious environmental hazards. The air floating fine particles of wool may be harmful to human health, they can cause severe allergies. There is a need to have an efficient environment-friendly wool waste disposal system to overcome the problem. In today's agriculture, recycling of wastes is of major importance due to the increasing demand for conserving natural

resources and energy. Scientific and logical recycling of organic waste will help in reducing environmental pollution, improving crop productivity, and soil health. The waste or by-products were used as nutrient sources for crop plants from ancient times; however, many waste products have the potential to be used as fertilizer but not utilized yet. All organic materials available in any form are hygroscopic in nature and have got the property to hold the water for a longer duration. Organic amendments in the soil are increasingly promoted whether of plant or animal origin as an alternative to synthetic fertilizers as a tool for better soil health and long term sustainability. The other benefits are soil build-up of P, K, and Mg, organic matter, aggregate stability, moisture retention, and microbial population. Coarse wool can act as a water conservation substrate in the agriculture sector as it withholds a substantial amount of moisture if used as manure. Essential plant growth nutrients like C, N, and S are in ample quantity in wool and its partial break down of wool by alkaline hydrolysis can make it a

slow-release fertilizer. Use of waste wool as manure can answer to both the recycling of organic wastes and the safe disposal of large quantities of waste wool. Therefore, strategies for safe use of organic waste such as waste wool, sheep manure in agriculture must be developed.

Physico-chemical properties of wool

Wool is stable through alpha-keratin peptide linkages and a highly cross-linked network of disulfide bonds. Wool is quite resistant to the attack of micro-organisms, which can breakdown the keratinous fibre only in hydrophilic conditions. The degradation usually takes months, i.e. the representative functional groups of wool start to degrade and convert into biomass after 4 weeks, and in hydrophilic conditions, it decomposes 33% of the applied wool in three months. Wool is not easily degraded in nature and causes serious pollution. Greasy (uncleaned) raw sheep wool is composed of protein 'keratin' with an abundance of carbon (50%), Nitrogen (16-17%) and Sulphur (3-4%), which play an essential role in plant nutrition. Waste wool have higher

content of C and N, so, its disposal in soil for agriculture production may be good option for its use as fertilizer apart from safe disposal.

Safe utilization of waste wool in agriculture

Moisture conservation

Wool fibres absorb and retain moisture very effectively; this property can be a benefit when applied to soils where it can reduce runoff of contaminants such as pesticides, and can aid in water conservation. Wool containing media are lighter and can absorb a higher amount of moisture without adding the weight. Researchers reported that wool in any form retained a higher amount of moisture than the control sample and could be attributed to hygroscopic nature of the wool fibre. Wool can absorb 30% moisture of its weight because of the polarity of the peptide group, salt linkage, and its amorphous nature. Some researchers also opined that wool naturally absorbs water about 20 times its weight, so farmers can conserve more water by applying waste wool as mulching material in the soil or bunds. Moisture retention in soil and water use by crops largely depends on pore size and particle-size distribution, which are governed by soil structure and texture and bulk density, OC content and crop cultivated. The water retention capacity can be influenced by exogenous OM addition in any form, which has multiple effects, but hydrophilic or hydrophobic nature of OM also governs soil water retention. In our study, addition of all the organic amendments significantly improved the consumptive use (CU), rate of moisture use and water use efficiency (WUE). Sheep based manures gave more promising results over waste wool in water use by the crop. By addition of sheep and wool manure, consumptive use and rate of moisture use was enhanced by 2.2 and 1.8% over control, respectively. Whereas, WUE was higher with waste wool application (33.5% over control) may be the factor governed by yield and yield was higher in waste wool treatment (Table 1).

Table 1. Effect of sheep based organic waste and irrigation schedules on consumptive use, rate of moisture and water use efficiency in barley

	Consumptive use (mm)	Rate of moisture use (mm/day)	Water use efficiency (kg/ha/cm)
Control	343.6	2.75	97.7
Sheep Manure	351.8	2.81	123.7
Avikhad	350.2	2.80	129.0
Waste wool	348.5	2.79	145.0

Use as organic mulch

Mulch is placed on top of the soil around trees and crop plants. The mulch acts as an insulator and keeps the soil cooler in the summer and warmer in the winter. It also helps the soil retain moisture, limits evaporation and helps prevent weeds from germinating and growing in the mulched areas. Like other mulch materials, the wool helps in suppressing weed growth and advantage might be that the wool could be a source of N, yet still be more resistant to breakdown (lasting longer) than some other mulch materials. Wool mulch lasts for two years before needing to be replaced. The wool absorbs water, herbicides, pesticides, and fertilizers, releasing them slowly into the soil. Some findings opined that the plants that received the wool mulch were more resilient than other sources of mulching and crop plants had more greenness, number of leaves, greater vitality, and higher yield.

Soil amendment and organic nutrient source

Limited research on the use of poor grade wool for agricultural crops has been carried out. Research show that amending the soil with sheep wool caused beneficial effects on the productivity of several plant species. Wool is a rich source of important nutrients that are necessary for plant growth. It contains high quantities of N, S and C. Sheep wool hydrolyzate improves growing conditions by increasing the contents of total N, C, and P in the soil. The findings of a research on use of waste carpet as a source of wool to improve the pastureland showed that increased levels of availability of essential elements where wool was applied *e.g.* 25% S, 17% Mg, 15% K, 10% N and 7% P in grass after 10 weeks of seeding on soil with

ground-up carpet compared with grass grown on adjacent soil with no wool. The dry-weight of grass after 15 weeks found 24% more from the carpet-fertilized area. There is significant evidence that the incorporation of carpet waste may improve some structural characteristics of soil as well as water-holding capacity. The coarse wool provided a significantly higher quantity of available N, phosphorus, and potash for plants irrespective of wool form and depth. This might be due to the property of wool for the slow releasing of micro and macronutrients into the soil than other sources of organic manures. After one growing season soil contained an abundance of easily accessible mineral compounds and organic un-decomposed particles that becomes a rich source of nutrients for the forthcoming season. However, micronutrient availability and other soil properties like soil organic C and pH were unaffected by wool application in any form. Moreover, as the wool soaks up in the soil, it fluffs up and expands, increasing soil porosity and improving the soil's ability to retain oxygen has also been reported.

Composting of waste wool

One way to increase the economic, environmental, and social sustainability of wool production is to compost the waste wool into soil amendments and landscaping aids that can provide farmers with additional income, provide horticulturalists with an environmentally friendly alternative to other soil amendments, and provide communities that depend on sheep pride in the value of all parts of the life cycle. Materials such as wool waste frequently require composting before use as soil amendments, largely to provide

appropriate substrate qualities for plant growth, including lowering of C:N ratio and provision of available plant nutrients. Researchers reported that wool-waste compost applied at 10 t/ha in a growth study involving chickpea and wheat crops and found trends in response by the reduction in C:N ratio of the degraded wool-waste compost.

Slow-release fertilizer

Most of the inorganic fertilizers are costly and subjected to many types of losses resulting in poor fertilizer use efficiency. Further, these fertilizers are hazardous when used in excess causing soil pollution. However, organic fertilizers contain a lot of organic N, but it is not mineralized fast enough to meet the needs of the plants during critical periods. Since wool is a rich source of important nutrients (N, S, and C) for plant growth, it is imperative to explore its environmental-friendly usage. The wool and its by-products are richer in organic N (over 5%) and C (30-50%) than manure and compost. One of the main qualities of wool is biodegradability, which means that when buried into soil, the keratin biopolymer is degraded by microorganisms and releases nutrients essential to the crops. Because wool slowly decomposes in the soil it can be used as a slow-release fertilizer and will act as a source of N-based nutrients and S over a much longer period than conventional fertilizers. Low-grade raw wool or wool waste can be used as agricultural amendments, laid directly on the bottom of the planting pits, or added to the compost mixture, to improve the N content and water retention.

Effects of waste wool on plant chemical composition, growth, and yield

Studies reported that wool or its hydrolyzed addition influences the chemical composition of plants. Addition of wool waste to soil increased total N (and protein) content in plant tissue. Wool waste

Table 2. Effect of sheep based organic waste and irrigation schedules on yield attributes of barley

	Plant height (cm)	Effective tillers/plant	No. of grains/earhead	Weight of earhead (g)	Length of earhead (cm)	1000-seed weight (g)	Grain yield (g/plant)
Control	63.5	2.46	37.2	1.54	6.19	38.0	5.28
Sheep Manure	69.2	2.87	40.4	1.71	7.04	39.9	6.65
Avikhad	70.0	2.92	40.7	1.74	7.08	40.1	7.01
Waste wool	71.4	3.14	42.8	1.81	7.38	40.9	7.46

additions to soil altered slightly the content and composition of plant secondary metabolites (essential oils or alkaloids). Due to the amendment of wool hydrolysate, the content of K, Mg, and Ca increased in general in the biomass of ryegrass. In our study, yield attributes were significantly higher in waste wool treatment during both the years, and slight variation was recorded among other treatments. Number of effective tillers, number of grains, weight of earhead and test weight of barley was 27.8, 15.4, 19.5 and 8.3% higher with waste application as compared to control, respectively (Table 2). Better growth parameters led to better yield attributes and they resulted in better yield, as with waste wool application and under normal irrigated conditions. Among the manuring treatments, waste wool produced 51.2, 17.1 and 13.5% higher grain yield over control, sheep and Avikhad, respectively. It might be concluded that waste sheep wool is a valuable fertilizer in the production of many species of plants.

Other agricultural benefits

Non-woven wool mats are placed around seedlings to inhibit weed growth when the plants are young and then break down and fertilize the soil as the trees grow. Wool in non-woven form can be also used as weed-mats, which initially inhibit weed growth but then slowly break down to release nutrients for the crops. Wool mulching helped in keeping the weed competition low for water and nutrients plant growing media as it acts as a barrier for weeds.

The wool row also had less deer damage, which might suggest that it serves as a natural repellent. Studies also reported that wool could be used to repel snails. Composting also removes parasites and pathogens and, to some extent, degrades potential contaminants.

Conclusion

Waste wool treatment produced 51.2, 17.1 and 13.5% higher grain yield over control, sheep and wool manure, respectively and improved water use efficiency also. Managing sheep in many regions of the globe results in excess or waste wool that is not suitable for the textile supply chain. Waste wool is a valuable fertilizer for plants and has got enormous possibility of organic manure production that helps in organic animal products, be it wool, meat, milk, skin or manure. Utilization of waste wool is also a way to increase the economic, environmental, and social sustainability of wool for its utilization as soil amendments and landscaping aids that can provide producers with additional income with an environmentally friendly alternative to other soil amendments. Our investigations will help in distinguishing choices for safe use of organic waste (waste wool) with upgrading soil health and crop water utilization, particularly in nutrient poor soils of arid and semi-arid region of India.

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