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Short Communication

Utilization of Waste Wool as Substrate Amendment in Pot Cultivation of Tomato, Sweet Pepper, and Eggplant

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Abstract

Sheep wool can be a waste products of sheep husbandry. Its safe utilization evokes several serious problems. Therefore, it was of interest to check out the usefulness of wool as a fertilizer and/or substrate. The aim of the experiments reported in this paper was to evaluate the effect of the washed sheep wool used as an amendment to peat-based growing substrate on growth and yield of tomato, sweet pepper, and eggplant. The layer of wool was spread on 5 cm thick strata of substrate and covered with the same substrate at a rate of 10 g wool per 1 dm^3 of substrate. Plants were grown individually in containers. It was stated that the addition of wool caused up to 33% higher yields, especially for tomato and pepper. Wool amendment caused changes in nutrients content of substrate and leaves. Thus, sheep wool can serve as a valuable and environmentally friendly fertilizer.

Keywords: organic substrate, *Lycopersicon esculentum*, *Solanum melongena*, *Capsicum annuum*, yield

Introduction

Sheep wool can be a waste product of sheep husbandry, along with other keratinous materials such as poultry feathers or human hair [1-4]. Its safe utilization creates several serious problems. In normal conditions wool biodegradation is a slow process. Sweat wool before processing contains fats, dirt, and other compounds like weeds, feces, etc. Because of the presence of the fats delaying microbiological decomposition, such a raw wool is less suitable for amending growing substrates in short-term vegetable cultivation under glass. Also, sweat wool is hydrophobic, so the amount of water and nutrient solution it adsorbs is smaller [5, 6]. On the other hand, degradation of washed wool is faster than of sweat wool. However, scouring and washing of the sweat wool is costly and gives rise to a new problem: safe utilization of scouring wastes and sludge [7, 8].

The addition of wool to organic and mineral components of growing substrates changes their chemical and physical properties. Wool is a rich source of important nutrients for plant growth. It contains high quantities of nitrogen, sulphur and carbon [9]. As a result of partial break-down of wool, keratinous materials are formed which may be purposely produced, e.g. in the process of alkaline hydrolysis [10]. Keratins are easily available sources of nutrients and can be used for the development of slow-release fertilizers [11]. Wool-containing media are lighter and their air-water relations are modified [12, 13]. The results depend on wool rate per unit of substrate volume. The expected advantages of wool addition to growing media would be inhibited leaching of nutrients and better nutrient utilization, suitability for combining with different

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Table 1. The effect of growing medium amendment with sheep wool on the yield of tomato, 2005-08.

Growing medium	Fruit yield per plant		Fruit number per plant		Mean weight of 1 fruit
	kg	%	No.	%	g
2005 *n*=24					
Control-without wool	2.764 a	100	21.1 a	100	131
Substrate+wool	3.629 b	131	25.2 b	119	144
2006 *n*=24					
Control-without wool	2.431 a	100	18.7 a	100	143
Substrate+wool	3.240 b	133	21.6 a	116	150
2007 *n*=24					
Control-without wool	3.405 a	100	22.4 a	100	152
Substrate+wool	4.004 b	118	25.5 a	114	157
2008 *n*=24					
Control-without wool	2.407 a	100	19.7 a	100	122
Substrate+wool	3.180 b	132	24.7 b	125	129

Data marked within columns and years with the same letter did not differ significantly according to Newmann-Keuls test at p=0.05 probability level.

organic and inorganic compounds and creating more desired physical properties of media. The aim of the experiments reported in this paper was to evaluate the effect of the washed sheep wool used as amendment to peat-based growing substrate on growth and yield of tomato *Lycopersicon esculentum*, sweet pepper *Capsicum annuum,* and eggplant *Solanum melongena*. According to our best knowledge ours is the first attempt to evaluate sheep wool as a fertilizer in the cultivation of these commercially important solanaceous vegetables.

Material and Methods

Experiments were carried out in 2005-09 at the Research Institute of Vegetable Crops in Skierniewice, Poland. The experiments were located in an unheated greenhouse. Seeds of greenhouse tomato cv. Merkury F1 , sweet pepper cv. Erecta and eggplant cv. Rugby were planted usually at the end of April. Transplants were transferred to growing containers 6 weeks (tomato), 7 weeks (pepper) or 8 weeks (eggplant) later and experiments ended in September. The tomato plants were grown in 12 dm^3 containers, and sweet pepper and eggplant in 10 dm^3 containers filled with peat substrate. The control substrate of pH 6.2 contained per 1 dm^3: N-NO_3 140 mg, P 110 mg, K 160 mg, Ca 2,250 mg, Mg 165 mg, and micronutrients. In 2009 treatments were included with a substrate composed of the above peat substrate mixed with clay soil 2:1 (v/v). Tomato plants were pruned back to 1 shoot and decapitated above fourth truss; in the cases of pepper and eggplant two shoots were left. Experimental treatment was control substrate amended with dry, washed wool at the rate of 10 g per 1 dm^3 of substrate. At the bottom of a container a 5-cm layer of substrate was placed, and then wool was added and covered with the remaining portion of substrate. This was done in order to force root penetration through wool. Such a substrate stratification was decided on the basis of preliminary experiments with cultivation of tomato in media amended with sheep wool, which were performed in 2005 (results not included here). The experiments were done with 3 different ways of wool washing: using detergent, hot water, and soaking wool in water until spontaneous fermentation. All washing procedures seemed to be satisfactory, so it was decided to use wool soaked for a fortnight and then rinsed with tap water. The resulting wool was used after drying. Every year each treatment consisted of 12 plants (3x4 replications). During growing season plants were watered with tap water and fertilized once a week with a liquid fertilizer (0.2 or 0.3%) depending on species and phase of growth. Fruits were collected weekly and yield was calculated. For chemical analysis substrates and plant material were extracted with acetic acid at concentrations of 0.02% and 2%, respectively. The chemical analyses of growing media and leaves were performed using ICP analyzer. Phosphorus was analyzed with colorimetric method using Specol apparatus and N-NO_3 with colorimetric automatic flow system. The results were evaluated statistically with ANOVA. Mean values were compared accordingly to Newmann-Keuls test at p=0.05.

Results

The results obtained with tomato, eggplant, and pepper growing in an unheated greenhouse are given in Tables 1-3. It is clearly visible that in all years considered a substrate amendment with wool contributed to a significant increase in tomato fruit yield (Table 1). The other side-effects were

Table 2. The effect of amendments with sheep wool of two growing substrates on the yield of tomato, 2009 (n=48).

Substrate	Fruit yield per plant		Fruit number per plant		Mean weight of 1 fruit
	kg	%	No.	%	g
1.1.peat +soil (2:1v/v)	2.26 a	100	21.4 a	100	106
1.2. peat +soil+wool	2.91 b	129	26.6 b	124	109
2.1. peat	2.71 a	100	25.8 a	100	105
2.2. peat+wool	3.18 b	117	29.5 a	114	108

Data marked with the same letters within columns and substrates are not significantly different according to Newman-Keuls test at p=0.05 probability level.

Table 3. The effect of growing substrate amendments with wool on the yield of eggplant and sweet pepper, 2006.

Substrate	Fruit yield per plant		Fruit number per plant		Mean weight of 1 fruit
	kg	%	No.	%	g
1. Eggplant *n*=24					
Control-without wool	1.040 a	100	3.7 a	100	281
Substrate +wool	1.008 a	97	4.2 a	114	242
2. Pepper *n*=24					
Control-without wool	1.544 a	100	9.7 a	100	155
Substrate +wool	2.011 b	130	11.3 a	116	178

Data marked within columns and species with the same letter did not differ significantly according to Newmann-Keuls test at p=0.05 probability level.

taller plants, higher fresh weights of plants, and more green appearance of leaves. Also, the tendency was observed to prolong the vegetation period and delay aging. It seems that an increase in yield was caused rather by increased fruit numbers and not fruit weight. It was also noted that peat-based substrate amended with wool required more watering. The addition of clay soil to the basic peat substrate caused some decrease in tomato plants fruiting, but even so, enrichment of this substrate with sheep wool still evoked a yield increase of 29% as compared to the control substrate (Table 2).

In the case of eggplant, the addition of sheep wool to culture substrate did not cause yield increase, but insignificantly increased the number of eggplant fruits (by 14%; Table 3). Pepper responded to wool amendment into substrate giving higher yield (30%) and fruit number (16%; Table 3). The plants were grown on these substrates for a relatively short time and therefore the wool was only partially decomposed (Table 4). After one growing season this wool contained still an abundance of easily accessible mineral compounds and organic undecomposed particles and thus indicated a rich source of nutrients in the forthcoming season. Amending substrate with wool also caused changes in chemical composition of growing medium, especially regarding increased salinity and nitrogen content and decreased content of P, K, Mg, and Ca, which might in part be caused by dilution effect. Besides the effect of wool on the yield of fruits, it also altered chemical composition of tomato leaves (Table 5). The content of N-NO_3 and K was almost two times lower than in the control substrate, and content of P, Mg, and Ca was increased.

Discussion

Sheep wool is a rich source of nutrient compounds. Wool is composed of protein keratin containing an abundance of nitrogen, carbon, and sulphur, which play an essential role in plant nutrition. It has been stated that amending soil with sheep wool or human hair caused beneficial effects on productivity of several plant species [4, 14]. Plants cultivated in wool-amended soil yielded 40-142% more [14]. McNeil et al. [9] found the suitability of ground-up wool carpet as fertilizer in cultivation of Italian ryegrass. Fertilized grass yielded 33 or 95% higher (depending on the number of days after planting). Böhme et al. [15] successfully used sheep wool – coconut fiber slabs for cucumber cultivation. In general, cucumbers grown in wool containing slabs yielded 19-42% more than plants cultivated in coconut fiber slabs. In the case of cucumber plants in first cultivation in wool-containing slabs, additionally treated with biostimulators, yield increased by even 130%. Also, alkaline hydrolysate of waste sheep wool used as soil fertilizer caused an increase in biomass of ryegrass and better seed germination, as well as beneficial effect of microbial life of soil [10, 11]. Our research was the first attempt to evaluate sheep wool as a fertilizer in cultivation of solanaceous species. Our results obtained with tomato

Table 4. Content of mineral compounds in tomato-growing substrate at the end of growing season, 2008.

Growing substrate	pH	salinity	$N-NO_3$	P	K	Mg	Ca
		g NaCl·dm^{-3}	mg·dm^{-3} of substrate				
Control-without wool	7.4	1.03	13	104	81	312	2,952
Substrate+wool	7.2	1.91	134	99	24	268	2,232
Wool after growing season	6.7	3.29	147	52	46	86	709

Table 5. The effect of substrate amendments with sheep wool on mineral compound content in tomato leaves, 2008.

Substrate	$N-NO_3$	P	K	Mg	Ca
	mg·kg^{-1} dry weight				
Control-without wool	4,470	1,270	22,066	8,597	27,890
Substrate+wool	2,200	1,510	12,894	9,917	34,920

Lycopersicon esculentum, eggplant *Solanum melongena* and sweet pepper *Capsicum annuum* cultivation confirmed findings of authors cited above. Our data indicate that enrichment of basic substrates with sheep wool caused an increase in yields or fruit number, or both in all of the tested species. Yields of tomato and pepper increased by ca 30% in our experiments.

The authors mentioned above [4, 9], who collected all above-ground herbaceous parts of plants, in general observed higher yield increases due to wool amendment to the substrate, whereas Böhme et al. [15] obtained results similar to ours with cucumber. These authors [15] also found that the same slabs could be used for two growing cycles. Also, our observations indicate that growing substrates contain undecomposed wool, which can still serve as rich sources of nutrients in the forthcoming growing period. Published data on wool or its hydrolysate addition influence on chemical composition of plants deal only with ryegrass and are inconsistent, according to our knowledge. McNeil et al. [9] found that content of Ca did not change in ryegrass plants due to fertilizing with post-consumer carpet, content of Mg did not change or increased 7% (depending on the number of days after planting), whereas content of P and K decreased (35 or 8% and 10 or 8%, respectively). On the other hand, Nustorova et al. [11] reported that, due to amendment of wool hydrolysate, content of K, Mg, and Ca increased in general in the biomass of ryegrass collected during the first mowing, whereas content of these elements in the biomass of ryegrass from the second mowing decreased. We observed that due to wool amendment to the substrate, content of $N-NO_3$ and K decreased in tomato leaves (49 and 42%, respectively), whereas content of P, Mg, and Ca increased (19, 15, and 25 %, respectively). It might be concluded that waste sheep wool is a valuable fertilizer in production of many species of plants. Both sweat and washed wool (also wool carpets) and its hydrolysates appeared to be fully valuable and environmentally friendly fertilizers.

References

1. EVANS M.R., KARCHER D. Properties of plastic, peat, and processed poultry feather fiber growing containers. HortSci. **39**, (5), 1008, **2004**.
2. EVANS M.R., VANCEY L. Physical properties of processed poultry feather fiber-containing greenhouse root substrates. HorTech. **17**, (3), 301, **2007**.
3. WNUK J., BRAŃSKI L. Alternative ways of utilisation and management of sheep wool with reference to logistic and economical aspects. Zeszyty Nauk. Katedry Hodowli Owiec i Kóz SGGW "Aktualne problemy oraz znaczenie użytkowania wełnistego owiec w warunkach gospodarki rynkowej" **2**, 13, **1998** [In Polish].
4. ZHELJAZKOV V. D., SILVA J L, PATEL M, STOJANOVIC J., YOUKAI L., KIM T., HORGAN T. Human hair as a source of horticultural crops. HorTech. **18** (4), 592, **2008**.
5. MAZUR T., MALICKI M. Processing of fatty sludges into composts. Zeszyty Probl. Post. Nauk Roln. **409**, 77, **1993** [In Polish].
6. MICHEL J.-C., NAASZ R., CHARPENTIER S. Water repellency of organic growing media and its consequences on their hydraulic properties . Proc. IS on Growing Media, ed. Michel J.-C., Acta Hort. **779** ISHS, 121, **2008**.
7. POOLE A.J., CORD-RUWISCH R., JONES F.W. Mechanism of aerobic biological destabilisation of wool scoure effluent emulsion. Water Res. **39**, 2756, **2005**.
8. WONG W.Y., LU Y., NASSERZADEH V.S., SWITHENBANK J., SHAW T., MADDEN M. Experimental investigation into the incineration of wool scouring sludges in a novel rotating fluidisided bed. J. Hazardous Materials **B73**, 143, **2000**.
9. MCNEIL S.J., SUNDERLAND M.R., ZAITSEVA L.I. Closed-loop wool carpet recycling. Resources, Conservation and Recycling **51**, 220, **2007**.
10. GOUSTEROVA A., NUSTOROVA M., GOSHEV I., CHRISTOV P., BRAIKOVA D., TISHINOV K., HAERTLE T., NEDKOV P. Alkaline hydrolysate of waste sheep wool aimed as fertilizer. Biotechnology and Biotechnological Equipment **17**, (2), 140, **2003**.
11. NUSTOROVA M., BRAIKOVA D., GOUSTEROVA A.,

VASILEVA-TONKOVA E., NEDKOV P. Chemical, microbiological and plant analysis of soil fertilized with alkaline hydrolysate of sheep's wool waste. World J. Microbiol.Biotech. **22**, 383, **2006**.

12. JAROSZUK M., SŁOWIŃSKA-JURKIEWICZ A. Characteristics of basic water-air properties of horticultural substrates used in container cultivation. Zeszyty Probl. Post. Nauk Roln. **504**, 105, **2005** [In Polish].
13. NOWAK J.S. Air-water properties of growing media. Zeszyty Probl. Post. Nauk Roln. **504**, 175, **2005** [In Polish].
14. ZHELJAZKOV V.D. Assessment of wool waste and hair waste as soil amendment and nutrient source. J. Environ. Qual. **34**, 2310, **2005**.
15. BŐHME M., SCHEVCHENKO J., PINKER I., HERFORT S. Cucumber growth in sheepwool slabs compared with other organic and mineral substrates. Proc. IS on Growing Media, ed. Michel J.-C., Acta Hort. **779** ISHS, 299, **2008**.