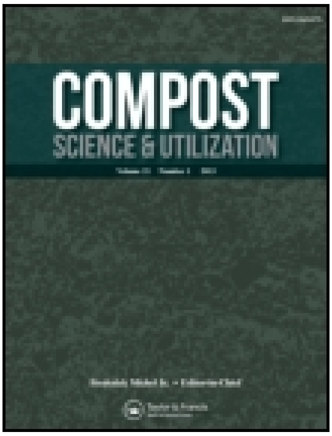

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Yield and Quality of Leek in Response to Compost Applied as a Mulch or Incorporated Into the Soil

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Compost is widely used to increase soil fertility, usually practiced by incorporating the compost into the upper soil layer. This study questions the rationale behind this practice. Compost was applied as a mulch and compared with compost worked into the soil in a growth experiment with leek (*Allium porrum* L. Var. 'Siegfried Frost'). The compost used was made of source separated organic waste from either gardens and parks, or households. Garden-park compost was applied in 2.5 times greater volumes than household compost to compensate for its lower content of nutrients. The soil was either sandy loam or clay loam. Each of the eight combinations of variables (application method, compost type, and soil type) was repeated three times with 20 leeks in each replicate. Significantly higher yields were obtained with compost applied as a mulch. Here, the yield averaged 78 g fresh weight per leek, compared to 59 g per leek from plots with compost incorporated. Compost mulching also resulted in a significantly higher quality leeks, including more first class leeks, longer and thicker shafts, and a generally better appearance. The advantage of placing the compost on the soil surface rather than thoroughly mixing it with the soil can be attributed to a higher availability of plant nutrients. No significant effect of compost type on leek yield was observed, indicating that the 2.5 times higher volumetric dose of garden-park compost provided the same amount of available nutrients as a single dose of household compost. The soil type did not significantly influence the yields either, which is attributable to both soils being well structured prior to compost amendment.

Introduction

Compost, like other organic soil amendments, is traditionally incorporated and thoroughly mixed with the soil prior to crop introduction. In the "Nordisk Illustreret Havebrugsleksikon," a 1912 encyclopedia and manual for Scandinavian gardeners, incorporation of organic amendments is the only method discussed (Helweg 1912). The encyclopedia made no distinction between the fertilizing value of organic soil amendments and their ability to improve soil structure. Moreover, the potential benefits of mulching were not considered. In a well-structured soil, mulching with compost may be more beneficial than incorporating compost. In addition to considerable labor savings, surface application of compost may result in a higher availability of nutrients, as described in the discussion of results. It is also well known that compost mulching protects the soil from compaction during rain and reduces moisture evaporation from the soil. In addition, mulching with compost can be performed several times with split doses of compost during the growing season, thus meeting the nutritional needs of the crop in a more timely manner.

The main objective of the study presented here was to compare the yield and quality of leeks that were grown either in soil amended with a mulch of compost or in soil with incorporated compost. The second objective was to compare the effect of two types of compost; compost derived from organic waste from gardens and parks and compost made of organic household waste, as well as two types of soil (sandy loam and clay loam) on yield and quality of leek.

Materials and Methods

Leek (*Allium porrum*, L. var. 'Siegfried Frost') was selected as the test crop. It has a long growing season and can thus utilize nutrients that are being slowly released, as is the case for nitrogen release from compost (Jørgensen 1987). The nutrient demands of leeks are high, but the plant is particularly ineffective in assimilating N. Båth & Rämert (2000) found that leeks assimilated only 1-2 % of 465 kg total-N ha^{-1} that was applied with compost, which they attributed to the limited root system of leeks. Thus, the species is expected to be sensitive to the changes in N-availability that may result from the different treatments.

Leeks were grown in outdoor drained boxes (depth 0.5 m, area 1.44 m^2). There were 2^3 (eight) combinations of treatments: compost application method (mulching or incorporation), compost type (garden-park compost or household compost) and soil type (sandy loam or clay loam). The treatments were randomly distributed over 24 boxes with three replicates of each treatment combination. The boxes were filled up to a depth of 0.4 m with the different soil-compost mixtures as described in Table 1. Physical and chemical characteristics of the soils and composts are shown in Table 2. To compensate for the higher nutrient content in household compost than in garden-park compost, garden-park compost was applied in 2.5 times

TABLE 1.
Preparation of growth media

	Garden-Park Compost	Household Compost
Mulch[1])	5 cm of compost placed on top of 35 cm soil[2]	2 cm of compost placed on top of 38 cm soil[2]
Incorporation	5 cm of compost mixed with 10 cm of soil and placed on top of 25 cm soil[2]	2 cm of compost mixed with 8 cm of soil and placed on top of 30 cm soil[2]

[1]The compost mulch was applied after leek planting to avoid mixing of compost with soil. [2] The soil was either clay loam or sandy loam, resulting in eight types of growth media.

TABLE 2.
Physical and chemical properties of materials used in growth media

		Clay Loam	Sandy Loam
Soil texture	g pr. 100 g dry soil		
Coarse sand	(0.2-2.0 mm)	37.1	58.8
Fine sand	(0.02-0.2 mm)	34.3	28.4
Silt	(0.002-0.02 mm)	13.1	5.9
Clay	(< 0.002 mm)	11.4	5.4
Humus		4.1	1.5
pH_{H2O}		7.2	6.8
Electric conductivity	10mS cm^{-1}	1.7	0.4
		Garden-Park Compost	**Household Compost**
Approx. processing age	month	9	6
Dry matter	% of site compost	61	38
Bulk density	ton m^{-3} of site compost	0.63	0.43
Ash	% of dry matter	82	25
Organic matter	% of dry matter	18	75
pH_{H2O}		8.0	7.0
Electrical conductivity	10mS cm^{-1}	3.8	19.0
g kg^{-1} dry matter			
$Nitrogen_{total}$		5.7	30.0
$Nitrogen_{water\ soluble}$		<0.03	<0.06
$Phosphorus_{total}$		0.89	3.7
$Phosphorus_{citratesoluble}$		0.78	3.1
$Potassium_{watersoluble}$		1.6	12.2
$Boron_{watersoluble}$		2.9	28.2
mg kg^{-1} dry matter			
Cd		0.32	<0.3
Hg		0.11	<0.06
Pb		39	34
Ni		16	8.5
Cr		8.7	9.5
Zn		120	124
Cu		27	61

greater volumes. This resulted in similar application rates of N, P, K and dry matter (Table 3). The leeks were sown under glass in February, and in May they were trimmed and transferred to the boxes. Each box contained 20 leeks at a row distance of 20 cm and a distance in row of 10 cm. The plants were watered and weeded as required for

TABLE 3.
Amounts of N, P, K and dry matter applied with compost

	N_{total}	P_{total}	$K_{water\ soluble}$	Dry Matter
	kg ha^{-1}			ton ha^{-1}
5 cm garden-park compost	1100	170	300	192
2 cm household compost	980	120	400	33

TABLE 4.
Results

	Compost Mulch					Compost Incorporation				
	Household Compost		Garden-Park Compost			Household Compost		Garden-Park Compost		
	Clay Loam	Sandy Loam	Clay Loam	Sandy Loam	avg.[8]	Clay Loam	Sandy Loam	Clay Loam	Sandy Loam	avg.[8]
Shaft length[1]	8.0	8.3	10.3	9.4		7.4	8.3	8.0	7.4	
(cm)	8.6	6.6	8.4	8.3		8.1	7.3	8.6	7.4	
	8.4	8.4	7.1	8.0	*8.3*	7.7	8.0	7.7	8.0	*7.9*^{ns}
avg.[7]	*8.3b,c*	*7.8a,b*	*8.6c*	*8.6c*		*7.8a,b*	*7.9a,b*	*8.1a,b,c*	*7.6a*	
Shaft diam.[2]	3.1	2.7	3.1	2.8		3.0	2.6	2.4	2.0	
(cm)	3.1	2.9	2.9	3.3		2.3	1.9	2.3	2.4*	
	2.5	3.1	2.3	2.5	*2.9*	2.3	1.9	2.4	2.5	*2.3**
avg.[7]	*2.9d*	*2.9d*	*2.8c,d*	*2.9d,e*		*2.5b,c,d*	*2.1a*	*2.4a,b*	*2.3a,b*	
Total number[3]	17	20	20	18		18	20	20	18	
	18	13	18	18		20	19	20	20	
	17	20	20	20	*18.3*	19	20	20	21	*19.6**
avg.[7]	*17.3a*	*17.7a,b*	*19.3c*	*18.7a,b,c*		*19.0b*	*19.7c*	*20.0c*	*19.7c*	
Class 1[4]	17	17	15	16		11	14	9	11	
	17	12	17	18		16	13	13	17	
	16	16	17	19	*16.4*	19	11	18	13	*12.9**
avg.[7]	*16.7c,d*	*15.0b,c,d*	*16.3c,d*	*17.7d,e*		*15.3b,c,d*	*12.7a,b*	*13.3a,b,c*	*10.3a*	
Fresh weight yield[5]	1661	1560	383	1141		1193	1571	1183	694	
(g)	1869	884	1373	2041		1237	803	1091	1271	
	1564	2046	1220	1454	*1433*	1088	786	1131	1755	*1151**
avg.[7]	*1698d*	*1497b*	*992a*	*1546c,d*		*1173a,b*	*1054a*	*1135a*	*1240a,b,c*	
Dry matter yield[6]	211	186	226	141		134	190	137	77	
(g)	226	117	165	275		174	114	149	166	
	180	234	174	171	*192*	130	77	140	225	*143***
avg.[7]	*206e*	*179b*	*188c*	*196d,e*		*146a,b,c*	*127a*	*142a,b*	*156ab,c,d*	

[1] Leek no. 1, 4, 7, 10, 13, 16, and 19 were measured with a slide gauge from above thick basis. Average of measurements. [2] Leek no. 1, 4, 7, 10, 13, 16, and 19 were measured with a slide gauge right above thick basis. Average of measurements. [3] Total number of leeks in box. [4] Number of leeks in box that passed the EU class 1 criteria for leeks (EU, 1989). This includes among other things: Good quality although minor superficial defects are accepted as long as these do not lower the appearance, quality, shelf-life, or sight of the leeks. The leeks shall appear white or greenish-white on at least 1/2 of the shaft. [5] Total fresh weight yield per box. [6] Total dry matter yield per box. The leeks were dried at 70°C for 57 hours, and at 106°C for another 46 hours. [7] Average of the three box replicates in each treatment. Numbers followed by same letter are not significantly different. [8] Cross average of compost application method (12 box replicates). ns: No significant difference. *: The difference is significant at the 95 % level. **: The difference is significant at the 99 % level. ***: The difference is significant at the 99,9 % level.

commercial production during the growing season. They were harvested in February of the following year. After washing and removal of roots and other non-usable parts, the following data were collected: shaft length, shaft diameter, number of leeks, number of first class leeks, number of non-usable leeks, fresh weight yield, and dry matter yield. This is described in the footnotes of Table 4.

Data were subjected to statistical analysis of the variance by use of the General Linear Model in SAS (SAS Institute Inc. 1989).

Results

Compost mulching resulted in higher quality and yield of leeks than incorporation of compost (Table 4). Average dry matter yields of leek in size of 192 g were obtained from boxes amended with a mulch of compost, as compared to only 143 g in boxes with compost mixed into the soil. Likewise compost mulching resulted in leeks with significantly thicker shafts, as well as more first class leeks.

The compost application method was the main explanatory factor in the experiment. Very few significant differences related to compost type and soil type could be observed.

In July, three months after transplanting, the leeks cropped with a mulch of household compost on sandy soil showed a poorer establishment compared to other treatments. However, this was a temporary effect that was more than offset by the time of harvest (Table 4).

Discussion

The results point to mulching as the most favorable way to apply compost, which is in accordance with the work of others. Agassi *et al.* (1998) demonstrated an 85% increase in water infiltration rate for mulching compared to 52% for incorporated compost and 42% for pure soil. Tripepi *et al.* (1996) found better growth response for cottonwood (*Populus deltoides)* with a heavy mulching (90 Mg ha^{-1} and above) of raw and composted paper sludge compared to incorporation.

The study's experimental setup has not provided data that can explain the superiority of mulching with compost compared to compost incorporation in terms of supporting leek growth. The difference is thought to be related to one or more processes that take place either in the soil, where the soil-embodied compost will be more affected, or at the soil-air interface, where the compost as a mulch is more exposed. Nutrients derived from soil incorporated compost, for example, are assumed to be more subjected to immobilization in the soil than compost applied as a mulch, simply due to the difference in degree of physical contact between soil and compost. Such immobilization of nutrients can be caused by microbial uptake (N and P) or sorption onto soil aggregates (P). It may also be speculated that infiltrating water more effectively takes up nutrients released from a compost mulch than from compost mixed with the soil. When compost is mixed with the soil, part of the compost may end up at locations that are not bypassed by percolating soil water. In this case, the soil solution that constitutes the mass flow (convection flow) to the roots may be more nutritious in soils with a mulch of compost compared to soils with compost incorporated (Nye and Tinker 1977). This difference is likely to be more extreme the smaller the root system of the crop is. The root system of leek is shallow and consequently the soil volume from which leek can take up nutrients by diffusion is limited, making it difficult to compensate for a low mass flow supply of nutrients. More experiments are needed to clarify these aspects of how compost works.

The fact that the leeks responded similarly to garden-park compost and household compost indicates that the experimental application of 2.5 times more garden-park compost than household compost by volume effectively offset the difference in nutrient content between the compost types.

The lack of effect of soil type on leek yield and quality is attributed to the two soils being rather alike (Table 2) and well structured prior to compost application. Consequently, the observed results should be transferred to well structured, loamy soils only.

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