A field growing system to reduce sulphur uptake of a crop grown in a moderately high sulphur soil - preliminary report

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Abstract

The nutrient composition of crops affects a range of characteristics, including yield, storage, protein composition, disease resistance, and flavour, e.g. low sulphur onions are milder than high sulphur onions. Vegetable growers have a limited range of options to manage the nutrient uptake of their crops. Uptake of specific nutrients can be increased by applying fertiliser, but there are no commonly practised techniques for reducing uptake of major nutrients.

Here we report the early testing of a new growing system to help control nutrient uptake. In this system, the plants are grown in 'V'-shaped furrows filled with sawdust and supplied with nutrients via drip tape. We compared five treatments for their ability to reduce sulphur (S) uptake in onions. The treatments were: sawdust-filled furrows (Sawdust), sawdust-and-soil-filled furrows (2:1 mix) (S&S), soil-filled furrows (SFF), barley straw (4 t DM ha-1) + urea (40 kg N ha-1) (BS), and soil (Control). All treatments were fertigated with the same amount of water and nutrients.

Crop bulb yields were 61, 59, 71, 65 and 69 t FW ha-1 of bed (LSD0.05 = 7 t FW ha-1) and bulb S concentrations were 0.27, 0.31, 0.60, 0.48 and 0.51% (LSD0.05 = 0.06%) for the Sawdust, S&S, SFF, BS and Control treatments, respectively. Preliminary analysis suggests that the Sawdust treatment may have reduced S content by both immobilisation and by excluding 38% of the roots from the soil.

Additional key words: nutrient composition, crop management, onions.

Introduction

The nutrient composition of produce is important as it affects a range of characteristics such as yield, flavour, protein content, appearance, disease resistance and storage. In some cases growers may want to increase the uptake of a particular nutrient, e.g. applying nitrogen to increase the protein content of wheat grain (Ames et al., 2003). In other cases growers may want to decrease the uptake of a particular nutrient, e.g. reducing the sulphur (S) uptake to produce a milder flavoured onion (Randle et al., 1995), or decreasing the uptake of phosphorus (P) but increasing uptake of calcium (Ca) and magnesium (Mg), to enhance the leaf oil content of mint (Borlina et al., 2001). However, vegetable growers have a limited range of options to manage the nutrient uptake of their crops. Current cropping practices enable growers to increase crop uptake of specific nutrients by applying fertiliser, but there are no commonly practised techniques for reducing uptake of a specific nutrient, particularly the macro-nutrients. It is important that any crop management system developed to control nutrient uptake is both environmentally sustainable and easy for growers to use.

The sustainability of current continuous cropping systems is questionable due to the observed decline in soil structure that is associated with declining soil carbon (C) concentrations and soil microbial activity (Shepherd et al., 2001). While cropping soils are suffering from declining C concentrations, the timber industry is seeking ways to dispose of large stockpiles of C-rich waste (sawdust and wood pulp). The cropping system trialled in this paper seeks to provide a solution to both of these problems while providing a method growers can use to control the nutrient content of their crops. It was postulated that nutrient control could be achieved by two possible means. First, providing large quantities of C-rich organic matter would cause a large increase in microbial activity, which would immobilise large amounts of all nutrients, and then the desired nutrients would be supplied by the grower. Second, if organic matter was placed in furrows, then a proportion of the roots would be excluded from the soil, reducing access to nutrients in the soil.

The purpose of this experiment was to determine whether the cropping system described above could reduce the S content of a field-grown crop. The test crop in this experiment was onion because S uptake affects flavour and storage (Lancaster et al., 2001), and there is consumer demand for mild (low S) onions, especially in Japan.

Methodology

Treatments

There were five treatments (arranged in four randomised blocks):

- Fertigation in sawdust-filled furrows (Sawdust)
- Fertigation in furrows filled with 67% sawdust, 33% soil (S&S)
- Fertigation in soil mixed with barley straw (4 t DM ha-1) + urea (40 kg N ha-1) (BS)
- Fertigation in soil-filled furrows (SFF)
- Fertigation in soil without furrows (Control)

Soil preparation

A Mangateretere silt loam (chemical properties given in Table 2) that had previously been used for growing apples was ploughed then worked with a power harrow to a fine seedbed. Gypsum was incorporated (by powerharrow) into the soil of all plots at the rate of 83 kg S ha-1 to create a moderately high S soil. Four triangular furrows (30 cm wide by 15 cm deep, 30 cm apart) were made by dragging a heavy iron sled along the worked plots (Fig. 1). The treatments without furrows (Control and BS) were then reworked with a rotary hoe to remove the furrows and incorporate a background dressing of dolomite (24% Ca and 11% Mg at 1.5 t ha-1) and nutricote® slow release fertiliser (supplying 81 kg nitrogen (N), 24 kg P and 49 kg potassium (K) ha-1), plus the barley straw for the BS treatment. The remaining furrows were filled with a mixture containing the background dressing of dolomite and nutricote® and 113 L plot-1 of either: sawdust, 33% soil: 67% sawdust (by volume), or the gypsum amended soil described above. Note that the depth of the furrows by harvest time was 12.5 cm, due to the sawdust settling and some crumbling on the soil ridges.

Each plot was 1.2 m wide and 1.5 m long, with a 0.5 m gap between plots. The sawdust came from Pinus radiata D. Don trees milled at Whirinaki, Hawke's Bay, and the barley (Hordeum vulgare L.) straw from a farm in Havelock North. Elemental analyses of these organic amendments are given in Table 1.

Table 1. Total (% of DM) C, N, P, K and S in the sawdust and barley straw used for the experiment.

	C	N	P	K	S
Sawdust	49.19	0.08	0.01	0.11	<0.01
Barley straw	44.44	0.88	0.09	1.48	0.17

Water supply

Eight irrigation tapes (0.98 L h-1 emitters spaced 20 cm apart) were laid on the surface of each plot, in four pairs, each pair 30 cm apart (and centred on the furrows in treatments that had furrows). The emitters in each pair of tapes were staggered, to provide water every 10 cm. Water was supplied to the tapes from two tanks: nutrient solution was supplied by the first tank and then flushed through with water from the second tank.

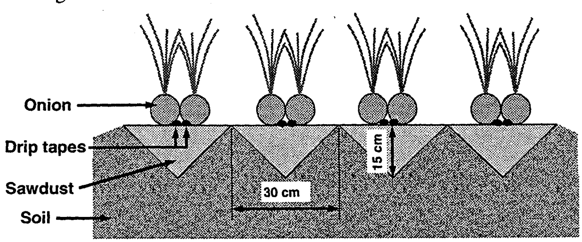

Figure 1. Cross section of a plot from the sawdust treatment. Note that the furrows were initially 15 cm deep but settled to 12.5 cm deep by the end of the experiment.

Table 2. Soil test values for the trial site and the recommended ranges1 for onions.

	pH	ρ (field)	Olsen- P	CEC	Ca	Mg	K	Na	Mineral isable N2	SO4-S
		Mg m-3	mg P L-1		meq (100 g soil)-1				kg N ha-1	mg S kg-1
Sawdust3	5.8	0.20	6	9	4	1.3	1.8	1.0	<1	16
Soil sample	6.2	0.99	52	20	13	2.3	1.6	0.14	72	6
Recommended range for soil	5.8-7.0		75-90		10-154	1.7-2.84	0.94-1.64	0.02-0.234	100-150	7-12

1Recommended ranges provided by Analytical Research Laboratories Ltd (ARL), 890 Waitangi Rd, Napier
2Keeney and Bremner (1966)
3These analyses are for a Pinus radiata sawdust sample collected from the same mill in 2002
4Converted from MAF Quicktest values using the soil sample ρ of 0.77 and formulae obtained from ARL

Planting

A late maturing onion (Allium cepa L. cv. Viking) was sown into Basics® potting mix in transplanting trays on 10 October 2001. Trays were kept at 23°C to hasten germination then placed in a glasshouse after emergence. Onions were transplanted in their plug of potting mix at the one (fully extended) true leaf stage. They were planted in four double rows with the drip tape in the centre of each double row. The double rows were 6 cm wide and there was 10 cm between plants within a row. This gave a planting density of 67 onions m-2 within the bed, which, at 1.2 m beds and 1.7 m between wheel-track centres, equates to 470,000 onions ha-1. The planting was done in two stages, half on 10 and the other half on 12 November. All plots were watered by watering can for two days following transplanting.

Fertigation

Two drums of stock nutrient solution (half-strength Hoagland's) were prepared as described by Jones (1983) except that MgSO4 was replaced with half strength MgCl2, and H2MoO4 with Na2MoO4. Nutrient solution was applied daily from 10 November to provide nutrients at the following rates: 0.73 kg N, 0.23 kg P and 0.99 kg K ha-1 day-1 plus the other essential elements except for S. This rate was increased by a factor of 7.3 after 17 December to correct an observed N deficiency. This high rate of nutrient application was maintained because the leaves of the onions in the sawdust treatments continued to be noticeably paler than the soil treatments. This symptom persisted until 23 January. Plots were sprayed with copper (Cu) (0.18 kg Cu ha-1) and zinc (Zn) (0.15 kg Zn ha-1) supplied in chelate form and boron (B) (0.20 kg B ha-1) on 9 January, because herbage test results showed low leaf concentrations of these elements. The total amount of nutrients supplied is given in Table 3.

Table 3. Nutrients applied to the experimental plots (kg ha-1).

Source	N	P	K	S	Ca	Mg	Fe	Mn	Cu	Zn	B	Mo
KNO3	137		385									
Ca(NO3)2	284				407							
KH2PO4		132	166									
MgCl2						50						
FeEDTA							12					
MnSO4				0.56				0.97				
H3BO3											1.00	
ZnSO4				0.05						0.11		
CuSO4				0.01					0.03			
Na2MoO4												0.03
Nutricote®	81	24	49									
Dolomite					361	163						
SoluBor											0.20	
SuperZinc										0.15		
SuperCopper									0.18			
Irrigation water			4	12.35	75	13					0.44	
Total	502	156	604	13	843	226	12	0.97	0.21	0.36	1.64	0.03

Plots were not fertigated on wet days, and compensatory nutrients were applied on the next fine day. Water was applied to replace estimated losses due to evapotranspiration and the soil water status checked by weekly monitoring by time domain reflectometry (TDR) beginning from 5 December. Short TDR rods (20 cm) were placed in one plot of each treatment; inserted into the furrows at an angle of 37° to the horizontal so that they did not penetrate into the soil below the furrows.

Nine mm of water was applied to the experiment by drip tape at planting to wet the sawdust. An additional 1 L per row was applied to all rows by watering-can for the two days following planting. All subsequent irrigation was supplied by the drip tape. All plots received the same amount of water and nutrients. Nutrient application ceased 18 days prior to harvest.

Crop management during growth

Five weeks after transplanting all leaves from onions grown in the two sawdust treatments were paler green than those grown in the soil. The youngest mature leaf from 16 plants per plot was removed and analysed for macro- and micro-nutrients.

The crop showed signs of downy mildew (Peronospora destructor (Berk.) Casp. in Berk.) and thrips (Thrips tabaci (Lindeman)) on 3 January 2002 so was sprayed with Mancozeb (Dithiocarbamate) and Decis® Forte (synthetic pyrethroid) at the recommended rates to control the respective pest and disease problems. Weather conditions were conducive to downy mildew development and so the crop was again sprayed on 10 January for downy mildew with Max® MZ (mancozeb + metalaxyl). Applications of copper oxychloride were made in between times to protect the crop against further downy mildew infections, but a large infection in the middle of February necessitated sprayed with Amistar®1 (strobilurin) at 250 g ha-1 on 19 February. The crop also received a spray of Fastac® (synthetic pyrethroid) on 1 February for thrip control. Weeds were removed by hand.

Harvest

Bulbs were harvested on 12 March when 65% tops were soft or had fallen down. All onions were collected and dried outdoors in mesh bags on wooden pellets for 2 weeks, and then fresh weights and bulb diameters were recorded. Onions from the two central rows (except within 25 cm of either end) were divided into 3 size classes (<40, 40-55, and 55-75), and onions from each class analysed for total S content. Total N, P, K, S, Ca, Mg, sodium (Na), iron (Fe), manganese (Mn), Cu, Zn, and B were determined on onions from the Sawdust and Control treatments.

Onion root length at harvest was measured in the Control, Sawdust and SFF treatments. Plots were sampled by digging a trench across the two inner double-rows of the plot and sampling a 5 cm-thick 'slice' of soil from either side of the trench wall. Samples were collected using a 'V'-shaped trowel that had the same dimensions as the furrows. Soil was taken from three separate regions of the soil profile: (1) within the furrow, (2) 0-12.5 cm depth in the soil outside the furrow, and (3) 12.5-30 cm depth. In the Control and SFF treatments, where the furrows were not present or not visible, the 'furrow' samples were collected by centring the 'V'-shaped trowel directly below the middle of the double row. The roots in the soil were then cut into lengths of approximately 4 cm, thoroughly mixed and one subsample taken. Roots were washed from the soil (or dry-picked in the case of the sawdust-filled furrows) and root length measured using the line-intersect technique of Tennent (1975).

Statistics

Data were analysed as a randomised complete block by ANOVA. Weeding time data were log transformed prior to ANOVA. When bulbs were divided into three size classes per plot this was analysed as a split plot design. Differences are reported as being significant at $P<0.05$ unless otherwise stated.

Results and Discussion

Observations during growth

Weeding time was significantly reduced ($P<0.001$) in the two sawdust treatments (Table 4). The only weeds that grew in the Sawdust treatment were on the shoulders of the furrows where bare soil was exposed. If the shoulders were covered with sawdust it may be possible to avoid weeding altogether. Good weed control persisted throughout the growing season in the sawdust treatments, although no further data were collected.

1 Note that Amistar® was not registered for use on onions in New Zealand, but was used because other systemic fungicides were unavailable.

The fourth block in the experiment was badly infected with downy mildew on 10 January. Approximately 25% of the onion leaf area in the two soil-grown treatments either side of the Sawdust treatment was covered with conidiophores whereas only about 5% of the leaf area was infected in the Sawdust treatment. Growing the bulbs in sawdust would have reduced root contact with soil-borne oospores, which may have provided a degree of protection from the disease.

Table 4. Time taken for two people to hand-weed one plot 4.5 weeks after transplanting, and onion yield and sulphur uptake data. Bulb S % are weighted means across the three bulb size classes, since there was no bulb size × S% interaction.

Treatment	Weeding time1 (mins)	Cured bulb yield (t FW ha-1 of bed)	Bulb DM (%)	Onion leaf yield at harvest (t DM ha-1 of bed)	Bulb S (%)	Bulb S uptake (kg S ha-1 of bed)
Sawdust	1.1	61.4	9.20	3.2	0.28	16
S&S	2.1	58.9	9.15	3.0	0.33	18
BS	5.7	64.9	8.80	3.1	0.48	29
SFF	6.4	71.4	8.63	2.3	0.60	37
Control	5.8	68.6	8.60	2.4	0.52	31
Significance	***	**	*	NS	***	***
LSD	1.9	6.7	0.45	—	0.11	9

1 Back transformed means are presented
*, **, *** significant at P<0.05, P<0.01 and P<0.001, respectively. NS = non significant

Yield

Bulb yields (Table 4) were probably reduced by the downy mildew infection. (Note that 65 t FW ha-1 of bed ≈ 46 t ha-1 when allowing for the wheel tracks). The two sawdust treatments yielded significantly (P<0.01) less than the Control and SFF treatments. This was probably due to N stress (see "Bulb nutrient concentration").

Root growth

On average, 38% of the total onion roots in the Sawdust treatment were found in the sawdust-filled furrows (Fig. 2). Thus, root growth was not restricted to the furrows, moreover, filling the furrows with sawdust resulted in a highly significant (P<0.001) increase in both the proportion of root length, and actual root length, in the soil between the furrows. This may have been either a stress-induced response so that the plants could take up more N and S, since these nutrients would have been present in extremely low concentrations in the sawdust-filled furrows (refer to plant nutrient concentrations, Table 5), or simply a consequence of the roots growing faster through the sawdust than through the more dense soil, and thus spending more time growing in the soil between the furrows. Note also that the distribution of roots in the SFF treatment was very similar to the Control treatment, which had no furrows. There were no roots observed below 30 cm depth. The reason for the shallow distribution of roots in all treatments measured was probably because of the small bulb size, and the fact that adequate water and nutrients were supplied daily to the soil surface

Plant nutrient concentration

Five weeks after transplanting, considerable differences in leaf nutrient concentration were evident between onions from the Sawdust treatment and those from the Control treatment (Table 5). Uptake of N and trace elements was reduced in the Sawdust treatment. In part, this unavailability would have been due to immobilisation by microbial breakdown of the sawdust. Nitrate and ammonia would also have been easily leached from the sawdust into the soil below because sawdust has a very poor ability to hold on to nitrate (Bugbee 1999) and a very low CEC for retaining NH4+ (only 2 cmolc L-1 sawdust compared with 20 cmolc L-1 Mangateretere silt loam). A portion of the trace elements may have been bound to the sawdust in unavailable forms. The presence of organic matter reduces the plant-availability of copper (Hagin and Tucker 1982), although Handreck (1990) showed that half to one-quarter of added Cu was plant-available (DTPA-extractable) 15 days after addition to pine and eucalyptus sawdust.

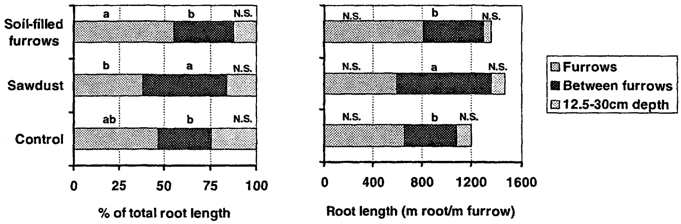

Figure 2. (a) The percentage of root length, and (b) actual root length, in the furrows, between the furrows, and below 12.5 cm depth in three treatments. Treatments with the same letter are not significantly different by Fisher's Protected LSD0.05. N.S. = non significant.

Table 5. Elemental concentrations (dry weight basis) of onions grown in the Sawdust or Control treatments. Leaf data are from the youngest mature leaf 5 weeks after transplanting and bulb data from after curing.

		Leaf nutrient concentration				Bulb nutrient concentration		
Element	**Unit**	**Sawdust**	**Sig.**	**Control**	**Normal[1]**	**Sawdust**	**Sig.**	**Control**
N	%	2.5	***	3.8	2.5-4	1.4	*	2.0
P	%	0.38	*	0.24	0.25-.4	0.38		0.42
K	%	4.8	*	5.5	2.5-5	2.0		2.2
S	%	0.71		0.76	0.5-1	0.292	*	0.462
Ca	%	1.70	*	1.30	1.5-3	0.31		0.32
Mg	%	0.32	*	0.22	0.3-0.5	0.11		0.11
Na	%	0.07		0.06	0-0.4	0.02		0.03
Fe	mg kg-1	82	*	108	60-300	59		68
Mn	mg kg-1	55	***	30	30-300	12		11
Cu	mg kg-1	4.8		6.0	6-20	10		10
Zn	mg kg-1	19		27	25-100	31		32
B	mg kg-1	18		19	25-50	17		19

1Nutrient concentration in the youngest mature leaf of a normal, healthy onion (Weir and Cresswell, 1993)
2These values are slightly different to those given in Table 4, as different subsamples were sent for onion size × S% analysis and the complete nutrient analysis.
*, *** significant at $P<0.05$ and $P<0.001$, respectively

The lower Ca and Mg uptake by plants from the Control treatment 5 weeks after transplanting (Table 5) is probably a consequence of a high concentration of K, in both the soil (Table 2) and Hoagland's nutrient solution, relative to the amounts of Mg and Ca. Handreck (1991) suggests that a K:Ca:Mg ratio (in mg L-1) of 1:1.3:0.5 may be suitable for potting media, although he acknowledges that more work needs to be done in this area. In the Hoagland's nutrient solution the K:Ca:Mg ratio was 1:0.74:0.09. In the sawdust and the soil the Ca and Mg component of this ratio would be slightly greater due to the presence of dolomite. However, because dolomite is only slowly soluble, the K:Ca:Mg ratio would have been unfavourable during plant establishment. Hence, the unfavourable K:Ca:Mg ratio in the added nutrients plus the high soil K test may explain the high K, but low Ca and Mg, observed in the leaf tissue of the Control treatment. Note that there was no significant difference in bulb Ca, Mg, or K concentration between the Sawdust and Control treatments by harvest time.

The reason for the lower P concentration in leaves from the Control treatment is probably due to both a dilution effect (where the P in leaves from the Control treatment is diluted by a larger plant biomass) and because the P applied to the soil is adsorbed to the clay and less available for uptake.

The bulb S content of onions grown in sawdust-filled furrows was approximately half that of the onions in the Control treatment (Table 4). Onions in the SFF treatment took up more S than those in the Control treatment, presumably because they received more S than the Control treatment: the 83 kg S ha-1 basal dressing plus an additional 31 kg S ha-1 in the soil that was used to fill the furrows.

There was no significant effect of bulb size on S content, nor was there a significant treatment×bulb size interaction. Thus, any dilution effect caused by larger bulb size must have been compensated for by a greater S uptake by these larger plants, presumably due to the development of a more extensive root system or greater water uptake, resulting in more S uptake by mass flow.

Bulb S uptake of onions in the two sawdust treatments was approximately half that of the soil-grown onions (Table 4). This was largely due the lower S content of the bulbs (Table 4).

Discussion

Why was the onion S content reduced in the Sawdust treatment?

The onions grown in the Sawdust treatment took up approximately 18 kg S ha-1 less than onions grown in the Control treatment2. There are three main processes that may explain this: immobilisation, exclusion of roots from the soil, and leaching.

Immobilisation

Immobilisation of 18 kg of S would require the immobilisation of 360 kg of N per hectare because the ratio of N:S in micro-organisms is approximately 20:1 (Duboc et al., 1995). Such a large immobilisation of N may seem unlikely, given that in the 2002/03 season an onion crop was grown in the same sawdust system using only 127 kg N ha-1 (Reid and Trolove, unpublished data). However, immobilisation of 360 kg N ha-1 is possible given that 502 kgN ha-1 was applied and plant uptake was approximately 127 kg N ha-1 (3). Data from Handreck (1993) suggests that hammermilled Pinus radiata bark immobilises 40 mg N L-1 bark per week, which equates to 523 kg N ha-1 for the 122 day cropping period (sawdust will immobilise at least as much N as bark because it has a higher C:N ratio). Similarly, Bird and Scholes (2003) found that N immobilisation rates were up to 25 µgN g-1 soil over a 3 month period in a laboratory study. Extrapolating these results to our study would equate to 1,300 kgN ha-1. Their study also showed that rates of N immobilisation were higher in treatments receiving more N. If immobilisation rates can be controlled by the amount of N applied, it may be possible to manipulate the amount of S immobilised based on the amount of N applied to the system. This hypothesis requires more research.

Root exclusion

One might assume that root exclusion from the soil might account for a reduction in S uptake of 38% because 38% of the total root system was in the sawdust-filled furrows (Fig. 2), and thus excluded from the S in the soil. These data were collected at harvest time, and a subsequent study (Trolove and Reid, unpublished) shows that a similar proportion of roots were present in the furrows during bulbing - the period of peak nutrient uptake. However, the reduction in S uptake accounted for by root exclusion will be less than 38% because these roots in the sawdust-filled furrow received 13 kg S ha-1 added in the irrigation water so were not excluded from S altogether. Therefore, root exclusion alone cannot account for the 43% reduction in S uptake by onions grown in the Sawdust treatment.

Leaching

Some SO4-S supplied to the sawdust-filled furrows may have been leached into the soil below the furrows. Handreck (1986) showed that SO4 is poorly retained by sawdust. However, because the SO4-S content of the irrigation water was low (2 µg S mL-1), and significant rainfall events infrequent (only 8 days with more than 15 mm of rain), the amount of S leached from the sawdust is likely to have been small. Sulphur leached from the sawdust would probably have been retained in the soil. The

2 The Control treatment took up 43 kg S ha^{-1} (31 in the bulbs, and an estimated 12 from the leaves, assuming that the leaves have the same S concentration as the bulbs) and the Sawdust treatment took up 24 kg S ha^{-1} (16 in the bulbs and 9 in the leaves)

3) 81 in the bulbs, and an estimated 46 from the leaves, assuming that the leaves have the same N concentration as the bulbs

fact that little plant-available S was leached from the soil is attested to by the large S uptake of onions in the soil-grown treatments (Fig. 5). It appears therefore, that the S content of the onions in the Sawdust treatment was reduced mainly by immobilisation and the exclusion of roots from the soil.

Amounts of fertiliser applied

The total amount of N applied during the growing season was 502 kg N ha-1. As mentioned previously, the need for the large application of N in the current study could have been due to immobilisation or to leaching by rainfall and overwatering. Preliminary results from a study in 2002/03 (Reid and Trolove, unpublished) suggest that the furrows in the current study (2001/02) were overwatered, and that N may have been leached into the soil below the furrows. This hypothesis is backed up by the observation that plants appeared paler after heavy rain, suggesting they were N deficient. Also, applying excess N may simply increase immobilisation rates, as mentioned above. Thus, it could be possible to markedly reduce N application rates, but will this reduce the immobilisation of S and thus render the system ineffective at controlling plant S content? More research is required to elucidate the mechanism by which plant S uptake was reduced in this system.

Potential uses for this system

It is too early to discuss the commercial potential for this system. In its current form, the system is too expensive for adoption commercially, but preliminary results from studies in the 2002/03 season show that there is considerable scope for cost saving. In the 2002/03 study nutricote® fertiliser was not used; solid fertiliser replaced expensive fertigation-quality P, Ca and Mg; and the amount of nutrients supplied via the drip tape was reduced by 75%. Another study (Trolove and Reid, unpublished) suggests that onions can be direct seeded into the sawdust. All of these factors combine to considerably reduce costs. More research is needed on how the system works in order to determine whether the amounts of sawdust required can be reduced. If the low S uptake is largely due to immobilisation, then the need for furrows and drip tape would disappear, reducing costs further. And perhaps a source of nutrient-poor organic matter that decayed faster than sawdust (thus immobilising more N) could be used. This would reduce the amount of C necessary to add to the soil and greatly reduce transport and application costs. Longer-term trials need to be conducted to determine whether the furrows can be reused for a subsequent crop, thus spreading the set-up costs over more than one crop. Long-term studies would also indicate the point at which the sawdust would no longer immobilise nutrients. The sawdust could then be ploughed in and would act as a slow-release nutrient source, offsetting fertiliser costs.

This system appears to have potential for crops where there is a large premium for quality, such as essential oils and nutriceutical crops, and for crops where weeding costs are high. The system would fit well as a high-value restorative crop in a rotation where soil structure is deteriorating due to a low organic carbon content. The system will also be useful for scientific studies in which crop nutrient content needs to be controlled in field studies and it is not possible to grow the plants in sand.

Conclusions

The main finding of this study is that this system does allow growers to control the S uptake (and hence S content) of onions. Further research may show that this system enables growers to control the uptake of all macro- and possibly micro-nutrients for a range of crops on all soil types. Growers will also achieve good weed control, may get some degree of protection from soil-borne diseases, and will improve the carbon content of their soils. However, further research is required to determine how the system works and to reduce the cost of the system to make it commercially viable.

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