Compost Trials 2016/17

Liz Mann and Ann Morrison, Australian Processing Tomato Research Council Inc.
Nick O'Halloran, Department of Economic Development, Jobs, Transport and Resources

Supported by Goulburn Broken CMA's Beyond Soilcare Program thanks to funding from the Australian Government National Landcare Program

Aim

This trial aimed to evaluate the effects of compost, applied at three different rates, on processing tomato crop yield, quality and soil properties. The same trial was carried out at two different locations.

Method

Sites were located 10km north of Rochester, Vic (Geltch) and 10km North West of Mathoura, NSW (Hibma). Both sites consisted of raised beds of 1.52m, irrigated by sub-surface drip. Further site characteristics are detailed in Table 1.

	Geltch	**Hibma**
Type of planting	Transplant	Transplant
Planting/seeding date	22/10/16	11/10/16
Fruit sample date	7/3/17	19/2/17
Harvest date	9/3/17	27/2/17
Variety	H3402 Mix	H1015
Row length (m)	297	342
Row width (m)	1.52	1.52
Row area (ha)	0.045	0.052
Compost Application	3/5/16	6/5/16

Table 1. Site characteristics

Each plot consisted of three whole rows. At harvest, each row was divided into four, with yield data obtained from each quarter of the row. The yield and fruit quality results were taken from the middle row of each of these plots. The reason for this was to effectively create a buffer zone between each treatment. Compost was applied in early May 2016, with a Seymour spreader. The spreading plates were removed, and compost was deposited in the middle of each bed to a width of 75cm. Following this application the final bed preparation occurred which lightly incorporated the compost into approximately the top 10cm of the bed. The spreader was calibrated using plastic covering one square metre of the bed. This sample was then weighed to work out the actual application rate. Compost was applied at 10, 20 and 30 t/ha to the banded area, which equated to 5, 10 and 15 t/ha across the entire area. Treatments are detailed in Table 2.

Figure 1:Compost applied to trial sites

The trial design for both sites was identical, with each plot consisting of 3 beds, but all measurements were taken from the middle bed.

Replicate 1				Replicate 2				Replicate 3				Replicate 4			
Control	20 t/ha Biomix	10 t/ha Biomix	30 t/ha Biomix	30 t/ha Biomix	10 t/ha Biomix	Control	20 t/ha Biomix	30 t/ha Biomix	Control	10 t/ha Biomix	20 t/ha Biomix	10 t/ha Biomix	Control	30 t/ha Biomix	20 t/ha Biomix

Figure 2: Trial plan for both sites

A sample of the compost (from Biomix at Stanhope, Vic) was collected on 3 May 2016, upon delivery to the Geltch property, and sent to SWEP Pty. Ltd. for analysis.

Soil samples were taken from both sites on 14 May 2016 from the control plots, and also in May 2017 from the control and 30t/ha plots at each site to a depth of 20cm. Soil samples were sent to AgVita for an Express Soil Laboratory Analysis. The soil collected in May 2017 from both sites was also sent to A & L Laboratories, Canada for soil pathogen testing of the following pathogens that are known to affect tomatoes:

- *Colletotrichum coccodes*
- *Fusarium oxysporum*
  Phytophthora spp
- *Pythium* spp.
- *Rhizoctonia solani*
- *Sclerotinia sclerotiorum*
- *Verticillium* spp

Soil bulk density and strength were also measured across the site at Rochester. Bulk density was measured by collecting a known volume of soil using a metal ring pressed into the soil. The weight of the soil was then determined after drying. Soil strength was measured using a cone penetrometer.

Fruit was sampled by hand one to two days prior to machine harvest (Geltch) and eight days prior to machine harvest (Hibma). Twenty pieces of fruit were randomly collected from each plot and given to the Kagome laboratory to test pH and °Brix for each sample. In the laboratory, each sample was blended for the same period of time. °Brix was then measured with a refractometer and pH with a pH meter on the raw blended sample.

Figure 3: Geltch trial 1/3/17

Figure 4: Hibma trial 16/2/17

Yields were determined at the time of machine harvest. Plot yields were recorded using the Kagome load cells on the bulk trailers.

All results were statistically analysed using the ARM 9 program, with significant difference determined using Tukey's HSD P = 0.05.

Results

The results of the compost test conducted by SWEP Pty. Ltd are shown in the following table:

Nutrient	% w/w (dry basis)	% w/w (wet basis or as applied)	kg per tonne
N	1.57	1.24	12.36
P	0.266	0.21	2.09
K	1.34	1.05	10.55
S	0.245	0.19	1.93
Ca	3.27	2.57	25.73
Mg	0.528	0.42	4.16
Na	0.378	0.30	2.97
Fe	1.12	0.88	8.81
Total Organic C	19.4	15.27	152.68
Moisture Content	21.3%		
C/N ratio	12.36		

Table 1:Compost analysis results.

Based on nutrient availability rates (Eghball, et al. 2002, and Rosen, C. J and Bierman), it could be assumed in the first year following a compost application that 10% of the nitrogen, 40% of the phosphorus, 80% of the potassium, 50% of the sulphur and perhaps 50% of the calcium and magnesium would be available for plant growth. Considering these availability rates and that half of the total surface area was treated, hence an application rate of 10t/ha to the banded area equated to

5t/ha of entire surface area of the paddock, the nutrients applied in the compost equated to an application rate of the following nutrients:

Nutrient	10 t/ha treatment		20 t/ha treatment		30 t/ha treatment	
	entire area (kg/ha)	banded area (kg/banded ha)	entire area (kg/ha)	banded area (kg/banded ha)	entire area (kg/ha)	banded area (kg/banded ha)
N	6.2	12.4	12.4	24.7	18.5	37.1
P	4.2	8.4	8.4	16.7	12.6	25.1
K	42.2	84.4	84.4	168.7	126.5	253.1
S	4.8	9.6	9.6	19.3	14.5	28.9
Ca	64.3	128.7	128.7	257.3	193.0	386.0
Mg	10.4	20.8	20.8	41.6	31.2	62.3
Total Organic C	763.4	1526.8	1526.8	3053.6	2290.2	4580.3

Table 2: Available nutrients applied in each treatment

	Treatment	Pre compost	Control	30 t/ha compost
pH	pH (H_2O)	6.28	6.05	6.28
	pH ($CaCl_2$)	6.06	5.28	5.53
dS/m	EC	0.6	0.15	0.15
%	Organic Carbon	1.12	1.32	1.21
meq/100g	Potassium (NH_4Cl)	0.93	0.77	0.78
	Calcium (NH_4Cl)	12.07	10.15	10.33
	Magnesium (NH_4Cl)	11.56	9.27	10.20
	Sodium (NH_4Cl)	1.75	0.77	0.97
	Aluminium (KCl)	0.17	0.11	0.11
	CECe	26.3	20.97	22.26
ppm	Chloride	68.5	9.43	12.85
	Nitrate-N (H2O)	42.5	14.68	13.83
	Olsen P	39.2	62.13	65.58
	PBI	91	104.20	102.20
	Potassium	363.6	302.0	304.0
	Sulphur (MCP)	430.5	55.93	67.38
	Boron (hot water)	2.85	2.35	2.56
	Copper (DTPA)	1.6	4.75	4.05
	Iron (DTPA)	27.71	97.98	92.36
	Zinc (DTPA)	0.21	0.54	0.59
	Manganese (DTPA)	14.33	32.05	32.50
% CEC	Calcium	45.9	48.38	46.38
	Magnesium	43.94	44.25	45.78
	Potassium	3.53	3.69	3.49
	Sodium	6.63	3.69	4.36
Ratio	Ca:NO_3	1.42	3.49	3.77
	Mg:K	12.45	11.99	13.14
	Ca:Mg		1.10	1.02

Table 3: Soil test results Geltch (0-25cm)

	Treatment	Pre compost	Control	30 t/ha compost
pH	pH (H_2O)	5.49	6.12	5.86
	pH ($CaCl_2$)	5.27	5.29	5.08
dS/m	EC	0.48	0.15	0.14
%	Organic Carbon	1.8	1.15	1.38
meq/100g	Potassium (NH_4Cl)	0.43	0.35	0.35
	Calcium (NH_4Cl)	8.96	7.41	7.10
	Magnesium (NH_4Cl)	1.85	5.04	4.25
	Sodium (NH_4Cl)	0.7	0.83	0.65
	Aluminium (KCl)	0.5	0.11	0.15
	CECe	11.94	13.63	12.34
ppm	Chloride	37.6	9.85	10.53
	Nitrate-N (H2O)	60	22.55	25.10
	Olsen P	50.7	41.00	39.45
	PBI	45.5	70.00	67.75
	Potassium	168.1	138.0	134.9
	Sulphur (MCP)	185.5	59.90	52.23
	Boron (hot water)	0.98	1.69	1.47
	Copper (DTPA)	0.63	1.71	1.82
	Iron (DTPA)	64.64	70.51	89.14
	Zinc (DTPA)	0.69	0.56	0.95
	Manganese (DTPA)	17.32	25.72	29.72
% CEC	Calcium	75.1	54.48	57.75
	Magnesium	15.5	36.79	34.19
	Potassium	3.57	2.61	2.82
	Sodium	5.88	6.10	5.26
Ratio	Ca:NO_3	0.75	1.74	1.47
	Mg:K	4.34	14.08	12.12
	Ca:Mg		1.49	1.72

Table 4: Soil test results Hibma (0-25cm)

NB. Cells coloured yellow and blue are significantly different at the 95% confidence level

Soil pathogen tests did not find any detectable pathogen in either the control or 30t/ha treatment.

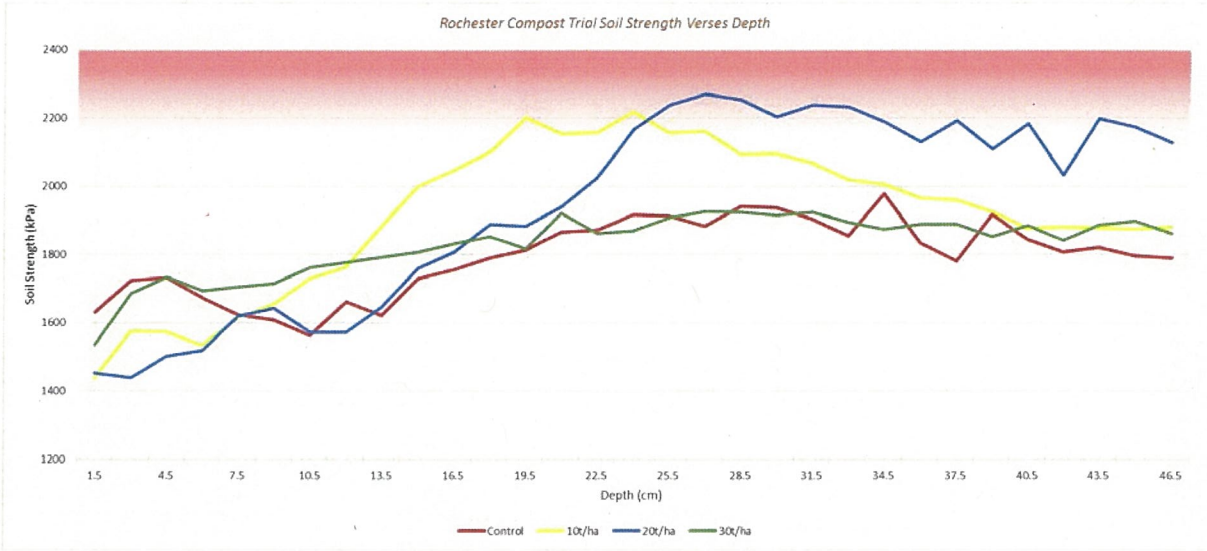

Figure 5: Soil Strength at Rochester

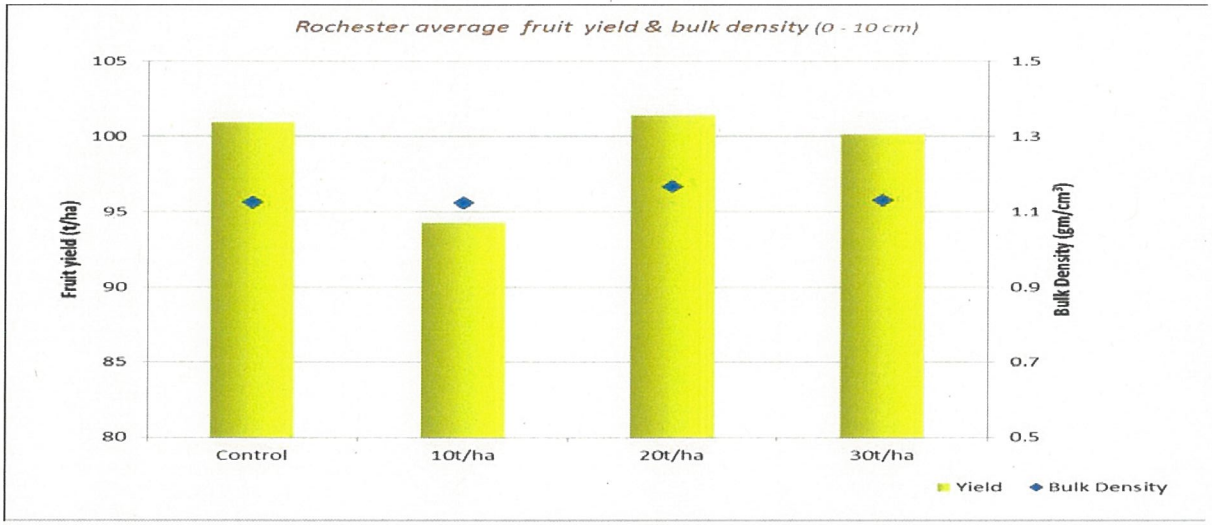

Figure 6: Soil bulk density and yield

Machine harvest occurred in early March and late February at the Geltch and Hibma sites respectively.

Treatment	Yield (t/ha)		°Brix		pH	
Control	100.93	a	5.83	a	4.45	a
10t/ha	94.24	a	5.85	a	4.50	a
20t/ha	101.43	a	5.85	a	4.49	a
30t/ha	100.11	a	5.95	a	4.43	a
Tukey's HSD (P=.05)	34.01		0.35		0.14	
Treatment F	0.187		0.501		1.171	
Treatment Prob (F)	0.9026		0.6906		0.3736	
Replicate F	0.634		0.501		0.779	
Replicate Prob(F)	0.6113		0.6906		0.5348	

Table 5: Geltch harvest results

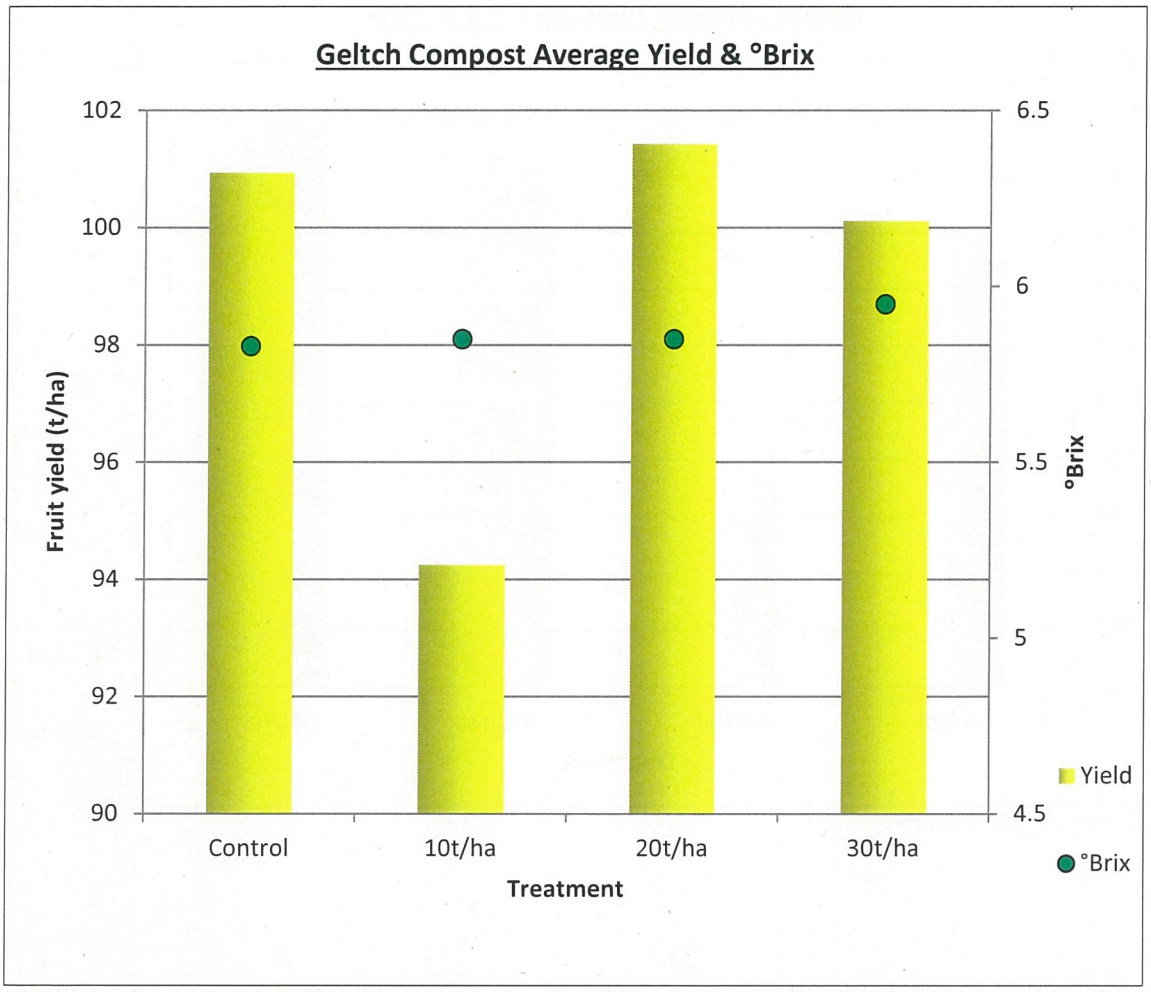

Figure 7: Geltch yield and brix results

Treatment	Yield (t/ha)		°Brix		pH	
Control	113.8	a	5.80	a	4.41	b
20t/ha	116.7	a	5.93	a	4.48	ab
10t/ha	105.4	a	5.88	a	4.54	a
30t/ha	117.7	a	6.05	a	4.48	ab
Tukey's HSD (P=.05)	28.872		0.327		0.109	
Treatment F	0.734		2.013		5.013	
Treatment Prob (F)	0.5575		0.1827		0.0259	
Replicate F	0.263		3.152		9.467	
Replicate Prob(F)	0.8505		0.0791		0.0038	

Table 6: Hibma harvest results

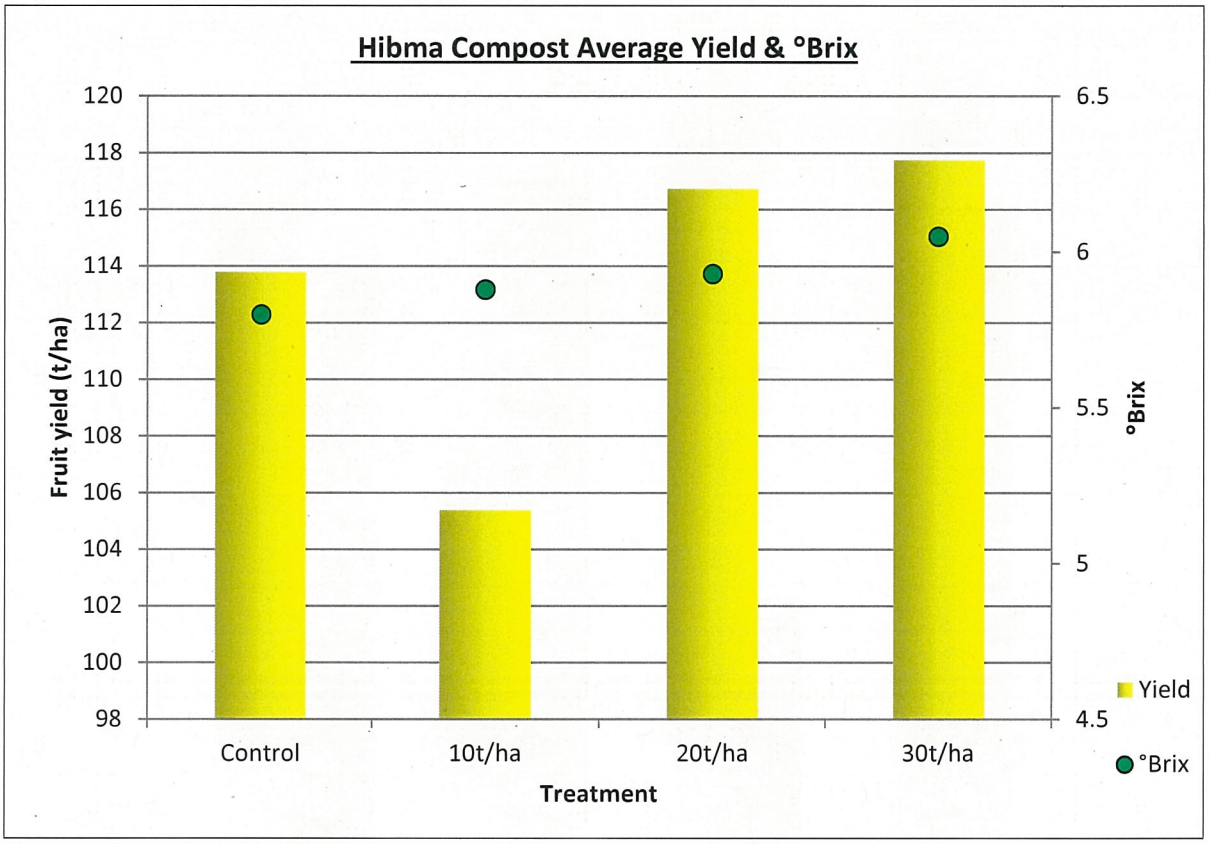

Figure 8: Hibma yield and brix results

																	Yield Range
	Geltch	t/ha						N↑									
	115.8	117.5	131.6	85.1	108.8	98.2	106.1	113.2	120.2	117.5	76.3	110.5	110.5	103.5	116.7	123.7	120-140
	124.6	98.2	121.9	78.8	114.0	76.3	95.6	107.9	93.9	119.3	64.9	93.9	107.9	111.4	120.2	127.2	110-120
	112.3	107.0	111.4	98.2	107.9	85.1	88.6	97.4	86.0	108.8	80.7	91.2	112.3	90.4	113.2	118.4	100-110
	79.8	55.3	96.5	72.8	94.7	65.8	77.2	93.0	78.9	107.9	62.3	81.6	106.1	56.1	111.4	86.8	90-100
Treatment	1	3	2	4	4	2	1	3	4	1	2	3	2	1	4	3	80-90
Row Average	108	95	115	84	106	81	92	103	95	113	71	94	109	90	115	114	70-80
																	<70
	Hibma	t/ha						N←									>140
	119.3	127.7	94.6	119.3	147.0	116.2	107.0	86.9	119.3	54.6	86.9	107.7	61.6	124.7	83.9	100.8	120-140
	113.9	126.2	95.4	113.9	94.6	127.0	125.4	97.0	133.9	117.0	118.5	140.8	100.0	132.3	115.4	118.5	110-120
	93.9	108.5	89.3	104.6	107.7	111.6	116.2	90.0	122.3	108.5	121.6	127.7	122.3	145.4	123.1	141.6	100-110
	114.7	128.5	102.3	121.6	113.1	111.6	112.3	100.0	133.9	115.4	117.7	123.9	109.3	120.0	130.0	141.6	90-100
			spray row					spray row					spray row				80-90
Treatment	1	3	2	4	4	2	1	3	4	1	2	3	2	1	4	3	70-80
Row average	110	125	95	115	116	116	115	93	127	99	111	125	98	131	113	126	<70

Figure 9: Yield variation across the two trial sites

Discussion

Based on the compost test (Table 1 and 2) the compost could be considered to be a source of plant-available potassium and organic carbon. In the 30t/ha compost treatment 126.5 kg/ha, or 253.1 kg/banded ha area of potassium was applied, in addition to 2.2 t/ha, or 4.6 t/banded ha area of organic carbon.

Based on the 30t/ha treatment, the applied organic carbon in the compost would be expected to increase the soil organic carbon content by 0.1%.

Potassium is primarily used within a tomato plant to promote carbohydrate and protein synthesis, water balance control and electrical balance (Blaesing, 2010). In a 100t/ha crop, the average amount of potassium removed with the fruit is estimated to be 399.2kg/ha (Stewart, 2004). In Australia,

growers apply differing rates of potassium, from none to 80kg K/ha. As result it could be expected that the production of processing tomatoes may result in a decrease in soil potassium.

Studies conducted in California by Dr. Tim Hartz and Gene Miyao over a number of years have concluded that the application of additional potassium does not result in a significant difference in crop yield or the majority of quality attributes. The exception to this appears to be when soil contains less than 150ppm of potassium, although some previous work in California has indicated that soil containing up to 250ppm of potassium may be responsive. Dr Tim Hartz in California has summarised the work he has done on potassium, by saying a response to applied potassium is unlikely if the soil test shows the following (Hartz, 2007):

- > 200 ppm exchangeable K
- > 3% of base exchange (meq basis)
- < 10:1 Mg/K ratio (High soil levels of Mg may suppress the uptake of K)

Based on the pre compost soil tests shown in Table 3 and 4 no potassium response would be expected at the Geltch site as the initial ppm of potassium is in excess of 360. At the Hibma site on the other hand the potassium is at 168ppm, but the potassium is >3% of base exchange and the Mg:K ratio is 4.3, hence a response may still be unlikely due to the high level of magnesium.

Following harvest, soil tests were conducted on the control and 30t/ha treatment at both sites. No significant differences were observed at the Geltch site, whereas significant differences were observed only in the sodium levels at the Hibma site. It was interesting to note that at both sites no significant differences were observed in the potassium levels post-harvest, although the potassium levels did drop at each site following harvest. Post-harvest the potassium levels at the Geltch site would still be considered to be high and no response would be expected from applied potassium, but at the Hibma site the potassium levels are low, at 135-138ppm, with <3% of base exchange and the Mg:K ratio at 12-14. Given the work that has been conducted in California a potassium response would be expected at this site if tomatoes were to be grown again during 2017/18.

In addition to the decrease in potassium pre-compost and after harvest (control and 30t/ha treatment) a number of chemical properties of the soil appear to have decreased. In particular pH, sodium, aluminium and CECe at the Geltch site and Organic C and sodium at the Hibma site. These decreases could be attributed to nutrient removal in the crop, or possible leaching during the wet winter and autumn.

Soil strength and bulk density were measured at the Geltch site, with results shown in Figure 5 and 6. There was no significant variation between any of the treatments for either soil strength or bulk density, although the soil strength in the control plots seemed to be at the lower end of the spectrum at depth. There was also no obvious correlation between fruit yield and bulk density (0-10cm).

Research on tomatoes overseas by Greig et al. (1964) and Flocker and Nielsen, (1962) has shown that tomato root penetration, vine growth, and marketable fruit yield were reduced when a Geary silt loam soil was compacted to a density of 1.7 g/cm^{-3} and increasing bulk density alone did not affect tomato yields. The level of bulk density affected tomato growth and yield only at high soil suctions, when soil strength increased sufficiently to impede root growth. In general, crop root growth starts to be restricted when the penetration resistance exceeds 1500 kPa and is severely restricted at 2500 kPa or more (Cotching and Davies). Based on this, and the results shown in Figure 5, it is possible that tomato root growth may have been impeded at depths below 16.5cm across all treatments.

Overseas research has shown that amending soils with composted materials can suppress certain diseases (Hadar 2011, Hoitink and Boehm 1999, Noble 2011). Unfortunately, the soil pathogen testing using DNA sequences to a Basic Local Alignment Search Tool (BLAST) database comparing more than 1 million species of bacteria and fungi conducted by A & L Laboratories did not detect the presence of any pathogens. This was unexpected as other work conducted during the season by a PhD

student (Sophia Callaghan) has found Fusarium and Pythium in a large number of soil samples collected across the industry

No significant difference was observed at either site in either fruit yield or °Brix (Table 5 and 6). It was observed however at both sites that the 10 t/ha treatment resulted in a lower yield than all other treatments, although this was not a significant decrease. Statistical analysis has also indicated that the yield at the Geltch site showed a greater level of variation between replicates than between treatments (based on the Replicate F being greater than the Treatment F). At the Hibma site statistical analysis indicated that there was more variation in treatments than between replicates (based on the Replicate F being less than the Treatment F).

A significant difference was obtained in the fruit pH only at the Hibma site. Based on work conducted by Anthon and Barrett (2012) pH measured on tomatoes that have been homogenised as raw fruit may not be accurate. Once a tomato is homogenised, the enzymes pectin methylesterase (PME) and polygalacturonase (PG) become extremely active, causing rapid pectin breakdown and may alter the pH.

During harvest the rows were divided into quarters to further determine if yield varied along the length of the row. These results are shown in Figure 9. From this figure, it appears that at the Geltch site the top half of the block yielded better than the bottom half, with yield variation across the entire site and treatments being less than the variation along the row. At the Hibma site perhaps there is some evidence that the bottom three quarters of each row in the bottom right are yielding better than the rest of the block, and in particular the top left corner.

This variation across the site does indicate that there is something else impacting upon crop yield rather than the compost treatments.

Conclusion

While very few significant differences have been found as a result of the compost treatments, the trials have indicated areas that perhaps growers and the industry should be placing more focus on in the future. In particular:

- Regular soil chemistry tests, from constant points in the paddock (recorded using a GPS) using the same laboratory to track changes in potassium levels over time.
- Soil pathogen testing conducted by A & L Laboratories did not appear to detect known pathogens. The reasons why are not currently known but could be related to:
  - The species of the pathogens in Victoria are species not occurring in Canada, hence they were not detected. The primers used in the PCR and Elisa were not designed for the pathogens in the Australian soil samples but for species in the Canadian situation.
  - Soil samples were affected in transport that killed any pathogens through becoming dry.
  - Alternatively, if the soil samples were too wet that may have allowed the multiplication of soil microorganisms that may have killed the target fungi in the samples i.e. an imbalance of the microbial flora. (pers. Com Paul Taylor, University of Melbourne)
- Is the growth of tomato roots being affected by soil compaction below 16.5cm depth?
- What factors are influencing tomato yield and causing the yield variation observed along the length of the row?

References

Anthon, G. E and Barrett, D. M 2012. Pectin methylesterase activity and other factors affecting pH and titratable acidity in processing tomatoes. Food Chemistry 132 (2012) 915–920

Cotching, B and Stephen Davies, S. http://soilquality.org.au/factsheets/soil-compaction-tas

Eghball, B., Wienhold, B.J., Gilley, J.E., and Eigenberg, R.A., (2002), Mineralization of manure nutrients Journal of Soil and Water Conservation 57: 470-473

Flocker, W.J., and D.R. Nielsen. 1962. The absorption of nutrient elements by tomatoes associated with levels of bulk density. Soil Sci. Soc. Am. J. 26:183-186.

Greig, J.K., M.E. Fogleman, and L.E. Wittsell. 1964. Soil compaction effects on transplanted tomatoes. Am. Soc. Hort. Sci. Proc. 85:491-496.

Hadar, Yitzhak. 2011. Suppressive compost: when plant pathology met microbial ecology. Phytoparasitica 39: 311-314.

Hartz, T (2007). Research update: Soil fertility effects on processing tomato yield and fruit quality (Presented to World Processing Tomato Council, January 2007)

Hoitink, H.A.J. and M.J. Boehm. 1999. Biocontrol within the context of soil microbial communities: a substrate-dependent phenomenon. Annual Review of Phytopathology 37: 427-46.

Noble, R. 2011. Risks and benefits of soil amendment with composts in relation to plant pathogens. Australasian Plant Pathology 40(2): 157-67.

Rosen, C. J and Bierman, P. M. https://www.extension.umn.edu/garden/fruit-vegetable/using-manure-and-compost/

Stewart, M.R. (2004) Nutrients Balancing Yield and Soluble Solids for the Processing Tomato, Honours Thesis, Agricultural Science at the Institute of Land and Food Resources, University of Melbourne