Performance of Line Source Emitters under Fertigation Using Leachate from an On-Farm Anaerobic Digester.

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With appropriate treatment, it is possible to use the effluent from the anaerobic digester for injection directly into a drip system for fertigation. Three types of drip irrigation lines under seven treatments for clogging control were evaluated during two seasons on an organic farm that is currently receiving food waste and recycle it using anaerobic digestion and fertigation using the liquid fraction from the digestion process. Following treatments were used to prevent emitter clogging: T1: filtration, T2: filtration and chlorine, T3: filtration and acid, T4: filtration, acid and chlorine, T5: ozone, T6: well water (no effluent), T7: well water and chlorine. The change in uniformity and in flow rate with time was evaluated. Two of the drip tapes RoDrip and Chapin were used in both seasons, however TigerTape was substituted with Queen Gil in the second season. Sand media filtration without chemical injection was not sufficient to prevent clogging of all three types of drip line, especially during the first season. The quality of the effluent was much better in the second season resulting in less clogging problems in all treatments.

INTRODUCTION

There are very few liquid, organic fertilizers currently available. Most organic forms of fertilizer are not sufficiently soluble in water to be suitable for fertigation. An exception is fish emulsion, which however, is ten times more expensive than comparable forms of soluble fertilizer (Burt et al., 1995). The liquid fertilizer from anaerobic digestion should be less costly than fish emulsion which is imported into the region from as far away as Alaska (Full Circle Solutions, Inc., 1997).

Some of the characteristics of the digester liquid fertilizer may contribute to clogging of micro-irrigation emitters. Emitter clogging is still a major problem and is related to the quality of the irrigation water (Gilbert and Ford, 1986). Factors such as microbial activity, suspended solids, and chemical activity determine the type of water treatment required to prevent clogging (Gilbert and Ford, 1986). Suspended solids in the range of 50 – 100 ppm and bacterial populations of 10,000 – 50,000 per L can cause moderate clogging problems (Burt et al., 1995). Other than using high quality water sources, methods to prevent clogging include water filtration, flushing and chemical treatment. Chlorine, acids, and ozone are some of the chemical treatments used to prevent clogging (Burt et al., 1995; Burt and Styles, 1994).

Emitter clogging in micro systems can be the biggest problem with fertigation. Usually, sodium hypochlorite (chlorine) is used for periodic cleaning of irrigation lines and emitters. Currently, chlorine is still permitted for irrigation cleaning purposes on organic farms. Other methods, such as

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ozone treatment, are more expensive but promising for organic production. Clogging problems can also be minimized through careful selection of irrigation and filtration equipment. Five types of treatment (filtration, chlorination with filtration, acid injection, acid combined with chlorine, and ozone treatment with filtration and flushing) were compared to control treatment of direct well water and chlorinated water. The systems were evaluated for clogging and changes in application uniformity by using a statistical uniformity coefficient (Bralts and Kesner 1983, Haman et al., 1997).

IRRIGATION AND FERTIGATION TREATMENTS

Effluent was injected into drip irrigation system during two vegetable seasons 2001 and 2002. Three types of drip irrigation lines under seven treatments for clogging control were evaluated in each season. Continuous fertigation using the liquid fraction from the digestion process was used during each growing season using peristaltic injection pump (Masterflex, Cole-Parmer Instrument Company, Vernon Hills, IL). The injection rate of the effluent was 1 gallon per minute (gpm). Approximately, 60 gallons of effluent were injected into 5 irrigation treatments during each irrigation cycle.

The test included seven treatments. Five included effluent injection and two were used as controls. One control included typical chlorine treatment of well water often used by the growers and one was well water without any treatment. The treatments are summarized in Table 1.

Table 1. Summary of treatments for emitter clogging prevention.

Treatment symbol	Treatment description
T1	Effluent + sand and screen filtration
T2	Effluent + sand and screen filtration + chlorine
T3	Effluent + sand and screen filtration + acid
T4	Effluent + sand and screen filtration + acid + chlorine
T5	Effluent + sand and screen filtration + ozone
T6	Well water
T7	Well water + chlorine

All filtration was accomplished using a sand media filter with a #20 media followed by 200-mesh screen filter and small, secondary 200–mesh screen filters in each treatment. Each manifold (one for each treatment) included a pressure regulator, a flowmeter, a pressure gauge and a secondary 200-mesh screen filter. The layout of the microirrigation system control head and chemigation treatments is presented in Figure 1. Injection of acid and chlorine were accomplished using peristaltic pumps with a flow rate of approximately 1 gal/ hour (gph). Acid (hydrochloric, 35%) and ozone were injected continuously during irrigations (treatments T3,T4,T5). Chlorine injection was performed once a week using 10% household bleach. Initially, it was attempted to inject chlorine continuously at a rate that would maintain the concentration of 2 ppm at the end of the farthest lateral line. However, due to varying quality of effluent and changing amount of organic matter in the lines it was decided to chlorinate at high concentration once a week. Full strength of chlorine was injected for one hour/week at approximately 1gph into treatments T2 and T4. The objective of acid injection was to lower the pH of water to inhibit bacterial growth and to increase the activity of chlorine in the treatment where chlorine was injected. Again, due to variation in effluent quality and very high buffering capacity of the effluent in the first season frequent adjustment was necessary.

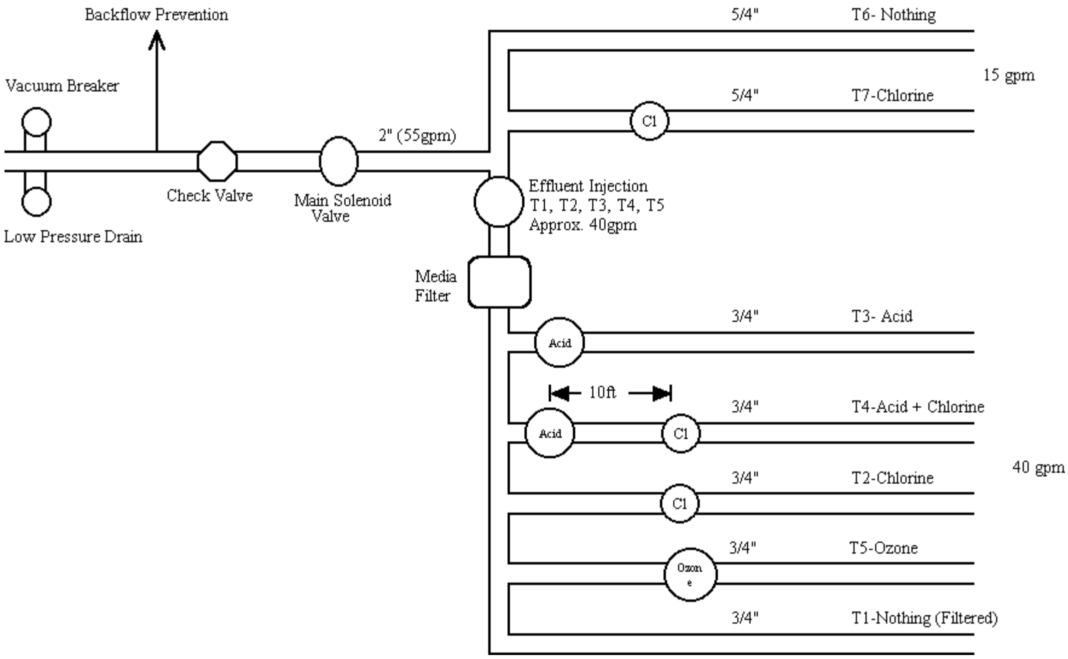

Figure 1. Control head and injection schematic for irrigation/fertigation treatment

Ozone was generated using model CS-4 ozone generator (Ozonology Inc. Northbrook, IL) and injected into the system using a venturi (Mazzei Injector Cooperation, Bakersfield, CA) injector. The rate of air intake into the ozone generator was approximately 2-3 cubic feet per hour. The average rate of ozone that could be detected at the end of the line was approximately 0.2 ppm. The water collected at the end of the lines was periodically tested for pH, free chlorine and ozone, depending on the treatment.

Three blocks with different drip tape were tested. Seven treatments were completely randomized throughout the block and replicated three times. Each replication consisted of two 50-ft long drip lines (100 ft per replication). The layout of the drip tape is presented in Figure 2. All three tapes were 8 mil thick with 8 inch spaced emitters and with very similar flow rates. In 2001 following tapes were evaluated: TigerTape (40 gph/100ft) RoDrip (40 gph/100 ft) Chapin (39 gph/100 ft). In 2002 season the Tigertape was substituted with Queen Gil, emitter spacing of 4” with (4 emitters per outlet) with approximately 40 gph flow rate due to its poor performance of TigerTape in the first season. Queen Gil was selected since it has a very different design and emitter flow and there is a lot of interest among vegetable growers in this new drip tape.

Water was applied daily for one hour. All treatments were watered at the same time. Effluent was injected into T1-T5 whenever the irrigation system was on. Water application to each treatment was recorded using a flow meter. The system was turned off after major rainfall and on some days during winter season (second season). This was controlled by the farm owner.

The uniformity of water application was tested twice during the first season and three times during the second season. In both seasons the tests were performed at the beginning and at the end of the season. Since the second season was much longer, an additional uniformity test was performed in the middle of the season. Water was collected into the trays from three emitters at 4 random locations along each lateral. Since each treatment consisted of two lines replicated 3 times, water was collected at 24 locations for each treatment. The uniformity of water application was calculated using the following equation: U = (1-V) 100% , where V is a statistical coefficient of variation.

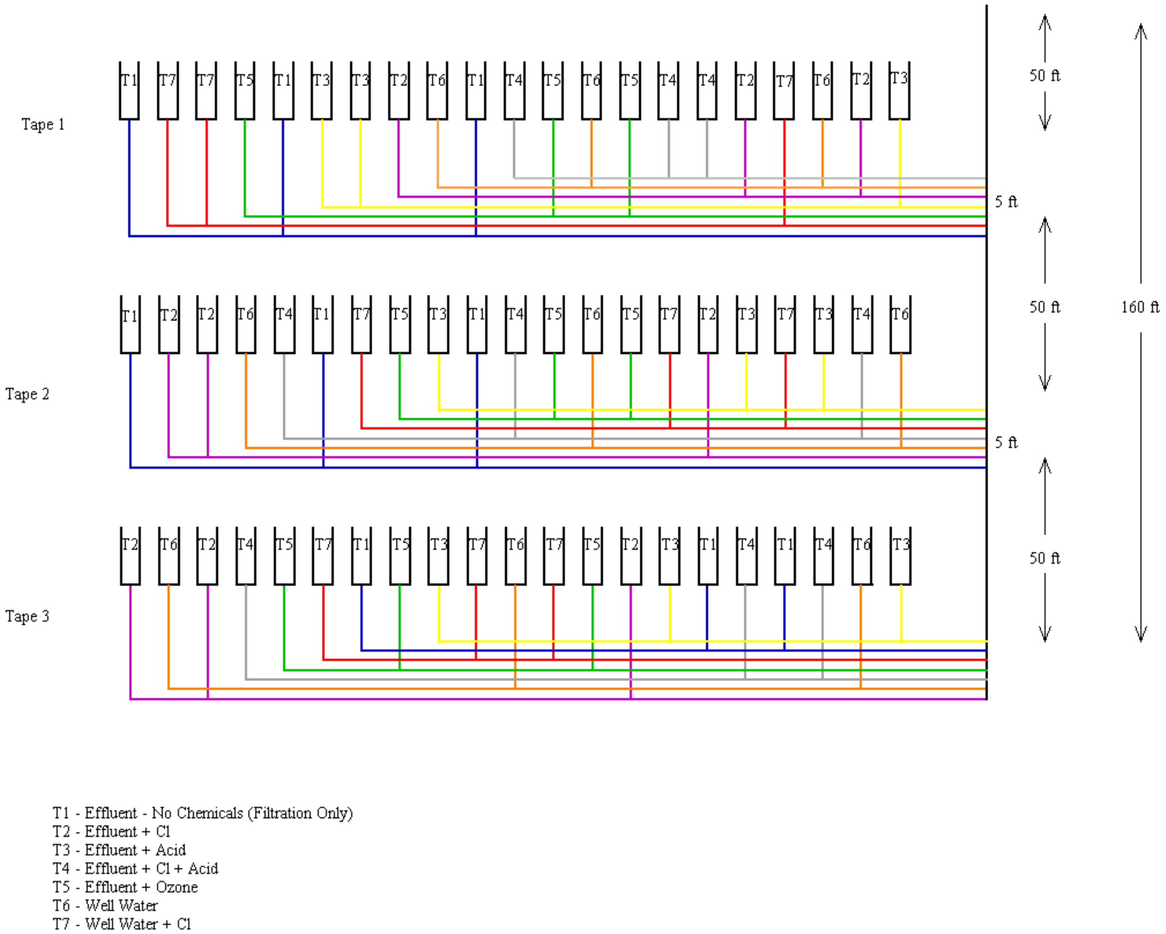

Figure 2. The layout of drip tape treatments in the field.

Irrigation System Performance

The change in uniformity and in flow rate with time was evaluated. Two tests were performed in 2001 season and three were performed in 2002. The number of uniformity tests was increased in 2002 since the tape was installed earlier (November 2001) and the fertigation trials started before plans were planted at the beginning of 2002. At this farm, plants are added gradually, so there is no specific day of planting.

The quality of the effluent was quite variable and there was a big difference in the quality of effluent used in the first season as compared to the second season. In 2001 all kind of food waste was used in the digester where in 2001 the waste used was mainly vegetable waste. This change may have contributed to the lower clogging problems in the second season (see tables 2-6).

Table 2. Statistical uniformity (%) of 3 drip tapes at the beginning of the 2001 season 02/13/01

	T1	T2	T3	T4	T5	T6	T7
TigerTape	89	87	94	87	91	81	87
RoDrip	94	91	90	91	95	91	88
Chapin	93	95	94	95	97	96	94

Table 3. Statistical uniformity (%) of three drip tapes at the end of 2001 season 04/24/01

	T1	T2	T3	T4	T5	T6	T7
TigerTape	**	5 6	43	78	61	64	67
RoDrip	**	86	56	81	54	71	86
Chapin	51	88	85	89	74	90	74

** too low uniformity to evaluate

Table 4. Statistical uniformity (%) of three drip tapes at the beginning of 2001/2002 season11/08/01

	T1	T2	T3	T4	T5	T6	T7
QueenGil	91	92	94	90	90	91	91
RoDrip	94	97	96	95	97	92	96
Chapin	92	97	92	97	97	96	95

Table 5. Statistical uniformity (%) of three drip tapes the middle of 2001/2002 season 03/07/02

	T1	T2	T3	T4	T5	T6	T7
QueenGil	83	89	66	71	81	82	71
RoDrip	96	88	94	97	86	91	90
Chapin	96	97	97	89	92	95	97

Table 6. Statistical uniformity (%) of three drip tapes at the end of 2001/2002 season 04/26/02

	T1	T2	T3	T4	T5	T6	T7
QueenGil	39	57	66	35	44	59	69
RoDrip	81	93	85	91	91	89	93
Chapin	83	83	86	90	78	91	87

The flow rate to each individual treatment was recorded using ¾" flowmeters every week or more often. The changes of low throughout the season are presented in Figures 3 and 4. In the first season the flow rates were reduced at the end of the season in all treatments where effluent was injected. Only two treatments without injection maintained approximately the same flow rate (300 gph). Treatment T1 (effluent injection without any chemical treatment) experienced the lowest flow rate at the end of the season. Media filtration followed by 200-mesh screen without chemical treatment of chlorine, acid or ozone was not sufficient to prevent significant clogging of emitters. Treatments T2,T3,T4, and T5 had the flow rates reduced by approximately 50% but the uniformity was still high at the end of the season (88%, 85%, 89%, and 74% respectively). This indicates “relatively uniform clogging” along the lines. To deliver the required amount of water to the plants, due to the flow rate reduction, the watering time would have to be double by the end of the season.

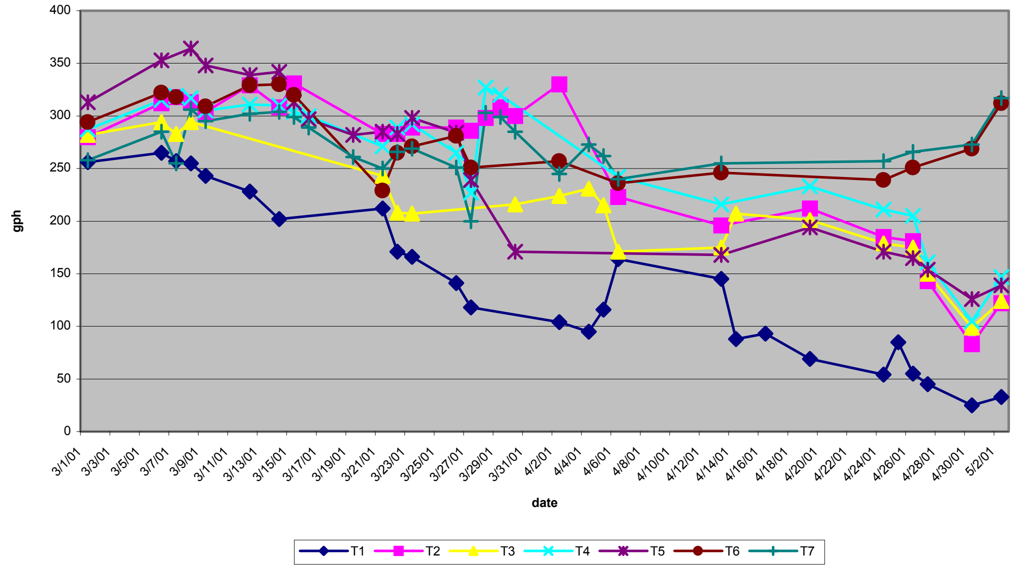

Figure 3. The changes of flow rates to the individual treatments during the first season.

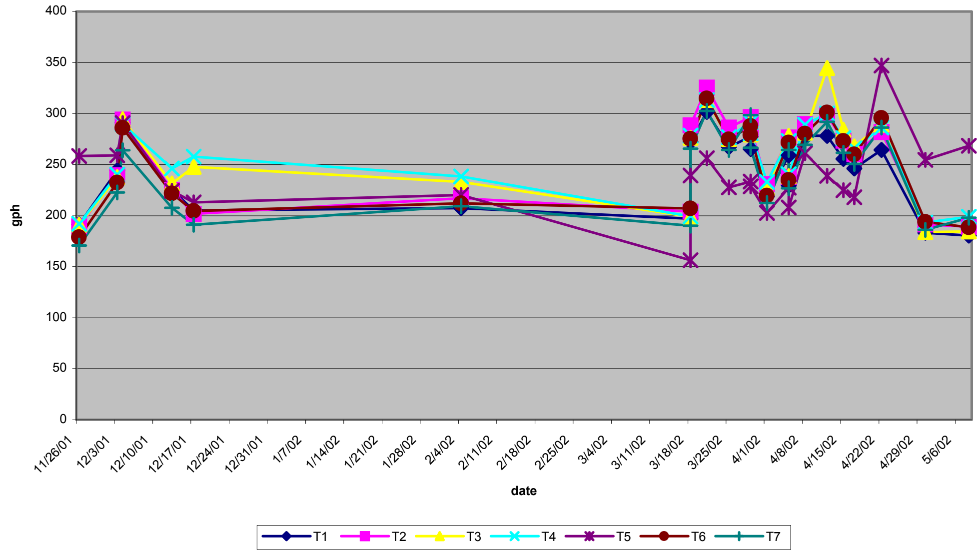

Figure 4. The changes of flow rates to the individual treatments during the second season.

In the second season there were no differences in the flow rates between the beginning and the end of the season (no measurable emitter clogging) and among the treatments. Based on the results, it can be concluded that with appropriate chemical treatment, it is possible to use the effluent from the anaerobic digester for injection directly into the drip system with minimal loss of uniformity throughout the growing season. Differences in the results between the first and second season are probably attributable to improved management and operation of the digester during the second season. Improved management and operation of the digester led to more consistent effluent properties and more thoroughly treated effluent. During the first season effluent was being drawn from the leach bed portion of the digester due to plumbing difficulties associated with the choice of high-rate centrifugal pumps for recirculating effluent. This problem was rectified by the second seasons trial by using low-rate peristaltic pumps. As a result we were able to use the effluent from the second stage (pack bed) that was lower in both total and volatile solids. Average total and volatile solids for effluent drawn from the leach bed portion of the digester were 1.3% and 56.6% respectively, while for effluent drawn from the packed bed portion of the digester they were 0.9% and 50.4%. As a result, effluent drawn from the leach bed portion of the digester had higher inert particulates and carbohydrates to encourage bacterial growth. Both of these factors can increase clogging of emitters. In addition, during the irrigation trials the first season the digesters were cleaned out and restarted using air potatoes. As a result the effluent was affected by both the change in digester feed stocks and effluent changes during the digester startup after the cleanout. During the second trial the digester had been running for over six months at "steady state" conditions treating only food waste. The change may have contributed to the lower clogging problems in the second season (Table 2-6). The first season's trial conditions should be considered close to a worst-case scenario for effluent quality and the second season conditions to be normal.

Irrigation Water Quality

Periodically the pH and Electrical Conductivity (EC) was measured at the plots. These results are presented in table 7.

Table 7. Electrical conductivity and pH of water in different irrigation treatments throughout the second season.

Date: 3/18/02

	T1	T2	T3	T4	T5	T6	T7	Effluent	Well Water
pH	6.84	6.91	6.95	2.24	7.0	6.54	6.67	8.21	6.42
EC (*100 umol/cm)	6.20	6.60	6.20	7.00	5.3	3.40	4.40	20	2.00
Ozone Detected					yes				

Date: 4/5/02

	T1	T2	T3	T4	T5	T6	T7	Effluent	Well Water
pH	7.03	7.02	6.49	2.61	6.94	6.70	6.75	8.5	6.54
EC (*100 umol/cm)	5.80	5.60	6.00	9.40	5.20	3.60	4.00	18.4	3.60
Ozone Detected					yes				

Date: 4/15/02

	T1	T2	T3	T4	T5	T6	T7	Effluent	Well Water
pH	7.13	7.06	5.89	5.72	7.01	6.75	6.90	8.3	6.51
EC (*100 umol/cm)	5.00	5.00	6.10	6.10	5.20	3.60	3.80	18.6	3.40
Ozone Detected					yes				

A sample of effluent was tested every time the tank was filled. The results of the tests are presented in table 8. There was a significant variation in nutrient content of the effluent throughout the season.

Table 8. Effluent analysis

Date	TS %	VS (% of TS)	Ammonia mg/l	TKN mg/l	Total P mg/l	K mg/l	COD mg/l
12/14/01	0.7	34.2	2515	2826	62	811	8120
12/10/01	0.6	54.4	2467	2861	59	807	7920
02/12/02	0.6	37.1	2454	2800	43	801	5192
03/21/02	Nd*	Nd	1770	3500	17	478	2226
03/27/02	Nd	Nd	1143	3290	16	454	2448
04/01/02	Nd	Nd	611	2250	7.6	202	1416
04/22/02	Nd	Nd	1361	2370	16.8	522	2680
05/01/02	Nd	Nd	1584	1991	24	570	3496

* Not determined

Conclusions

It can be concluded that effluent can be injected into the drip line if appropriate clogging prevention method is used to prevent the decrease of uniformity. The quality of effluent is very important in drip tape performance. Drip tape selection is an important factor in maintaining high application of uniformity throughout the season.

References

Burt, C.M., and S.W. Styles. 1994. Drip and Microirrigation for Trees, Vines and Row Crops. Irrigation Training and Research Center, San Luis Obispo, CA pp. 261

Burt, C., O'Connor, K. and T. Ruehr. 1995. Fertigation. Irrigation Training and Research Center, San Luis Obispo, CA. pp. 295.

Bralts, V. F. and C. D. Kesner. 1983. Drip Irrigation Field Uniformity Estimation. Transactions of the Amer. Soc. Ag. Eng. 26(5):1369-1374.

Full Circle Solutions. 1997. Project Final Report: Percolating-bed anaerobic composting of food waste. Unpublished data.

Gilbert, R.G. and H.W. Ford.. 1986. Emitter Clogging. In: Trickle Irrigation for Crop Production: Design, Operation and Management. Eds: F.S. Nakayama and D.A. Bucks. pp.142-163. Elsevier.

Haman, D. Z., A. G. Smajstrla and D. J. Pitts. 1997. Uniformity of Sprinkler and Microirrigation Systems for Nurseries. Bulletin 96-10:1-7, Fla. Coop. Ext. Ser. Univ. of Fla., Gainesville, Florida.