Fertigation Uniformity Affected by Injector Type

Regina P. Bracy,[1]
Richard L. Parish,[2] and
Roger M. Rosendale[3]

ADDITIONAL INDEX WORDS. drip irrigation, microirrigation, injection, precision agriculture

SUMMARY. Application uniformity of fertilizers and pesticides is critical for crop uniformity, but can be difficult to determine when a fertilizer or chemical (fertigation/chemigation) is applied via drip irrigation or deep irrigation tape. Three injectors (venturi, pump, and proportional) were compared in a greenhouse experiment with a continuous-injecting experimental plot injector for fertilizer distribution uniformity in a drip irrigation system. Injection rate and solution volume were evaluated in a field experiment. Injection rate had a significant effect on fertilizer distribution uniformity. Better fertilizer distribution in the greenhouse experiment was obtained with venturi and proportional injectors. In the field, better distribution was obtained with the 1 gal/min (0.06 L·s^{-1}) positive-displacement pump than with the 3 gal/min (0.19 L·s^{-1}) pump. Injection times were longer with these injectors than with the other treatments, with the exception of the continuous injector. Injectors tested in this experiment will give uniform fertilizer distribution if the injector is properly sized with the water flow rate of the system.

Application uniformity of fertilizers and pesticides is critical, but it can be difficult to determine when a fertilizer or chemical (fertigation/chemigation) is applied through drip irrigation tape. Several factors such as injector type, injection rate, and flow rate affect uniformity (Clark et al., 1999).

Several types of injectors are commonly used for fertigation of horticultural crops (Haman et al., 1994). Venturi-principle injectors use differential pressure to draw the fertilizer solution into the irrigation supply line. A second type, i.e. a positive-displacement pump, forces the fertilizer solution into the pressurized irrigation supply line. A third type is the water-driven-piston proportional meter that injects a predetermined amount of solution into the water that powers the main piston.

Lancaster et al. (1998) developed a continuously diluting injector, primarily for experimental and demonstration plots. Unlike the venturi and pump systems, this injector continuously adds fresh water to the fertilizer reservoir while simultaneously drawing solution out into the irrigation supply line. Lancaster et al. offered their design as a means of more easily applying multiple fertigation treatments to small plots.

Much research has been conducted investigating drip irrigation system design (Bralts, 1987; Wu, 1987) and water distribution uniformity (Camp, 1997; Capra, 1998; Phene, 1992; Smajstrla et al., 1990). Townsend (1988) reported that fertilizer uniformity can be greatly influenced by injection method and management during the injection process. Little work, however, has been conducted evaluating injector type and injection rate on fertigation uniformity in a drip irrigation system.

Studies were conducted in a greenhouse and field. The objective of the greenhouse experiment was to evaluate the effects of injector type and fertilizer type on fertilizer distribution uniformity in a drip irrigation system in a controlled environment. Most growers in southeastern Louisiana use positive-displacement pumps to inject fertilizer and chemicals into their drip irrigation systems. The objective of the field experiment was to evaluate the injection system used by the growers in terms of injection rate and solution volume on fertilizer application uniformity with this system.

Materials and methods

GREENHOUSE EXPERIMENT. This experiment was designed to evaluate application uniformity of four types of injectors with three different fertilizers

Louisiana State University AgCenter, Hammond Research Station, 21549 Old Covington Hwy., Hammond, LA 70403.

Approved for publication by the Director of the Louisiana Agricultural Experiment Station as manuscript number 02-53-0452. Use of trade names does not imply endorsement by the LSU AgCenter of products named nor criticism of similar ones not named.

[1]Professor of horticulture.

[2]Professor of agricultural engineering

[3]Research associate.

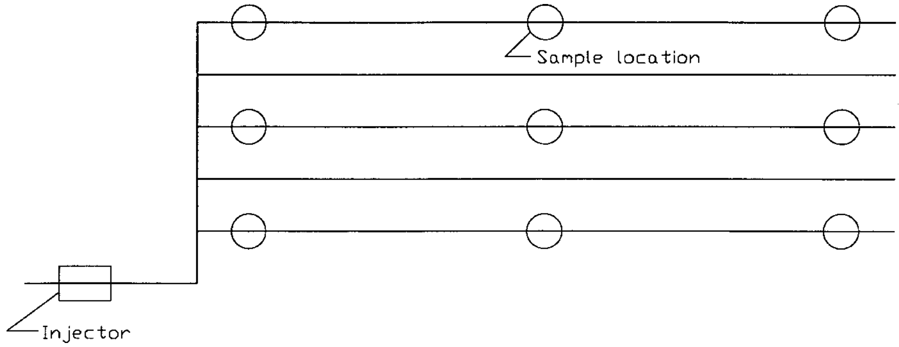

Fig. 1. Layout of sample collection locations along drip irrigation tape in greenhouse experiment.

in a controlled environment. A test apparatus was built consisting of 10 drip irrigation lines, each 40 ft (12.2 m) long, laid out emitters up in parallel lines on a series of greenhouse tables with wire mesh tops. Turbulent Twin-Wall (Chapin Watermatics Inc., Watertown, N.Y.) 8-mil [0.008-inch (0.2032-mm)] drip irrigation tape rated for 0.3 gal/min (0.02 $L{\cdot}s^{-1}$) per 100 ft (30 m) with emitters spaced 12 inches (30 cm) apart was used. Total flow rate for this system was 1.2 gal/min (0.07 $L{\cdot}s^{-1}$). Samples of emitted solution were collected under individual emitters at nine points (Fig. 1). Samples were collected at the beginning, center, and end of three lines. The other lines served to load the system.

The injector types tested were venturi (model 287; Mazzei Injector Corp., Bakersfield, Calif.), pump (diaphragm 12-v pump model 2088-343-135 with a nominal delivery rate of 3 gal/min; Shurflo, Garden Grove, Calif.), proportional (model A30-2; Dosmatic, Carrollton, Texas), and continuous (experimental plot injector, Lancaster et al., 1998). Three fertilizer materials [calcium nitrate (greenhouse grade, 15.5N–0P–0K), ammonium nitrate (34N–0P–0K), and liquid 10–10–10 (10N–4.4P–8.3K; Quachita Chemical Company, Monroe, La.)] were injected using each of the four injectors. Four repetitions of each fertilizer and injector combination were conducted.

For each test run, the amount of fertilizer required to provide 15 lb/acre (16.8 $kg{\cdot}ha^{-1}$) N was dissolved in sufficient water to make 1 gal (3.8 L) of solution. About 15 mL (0.5 oz) of Blazon Blue Spray Pattern Indicator (Milliken Chemicals, Inman, S.C.) was added to each gallon of solution to allow visual monitoring of injection. Prior to sample collection, the drip irrigation system was stabilized (all emitters were flowing consistently and pressure at the end of the line was 11 to 12 $lb/inch^2$ (76 to 83 kPa). Collection bottles were placed under designated emitters and injection begun. After 1 h of run time (with the exception of the continuous injector), the sample bottles were removed for analysis of emitted solution. This allowed complete injection and flushing of fertilizer solution from the lines. Because of the slow injection rate of the continuous injector, 2-h runs were necessary to get complete injection and flushing. All lines and injectors were thoroughly flushed between runs.

FIELD EXPERIMENT. The field experiment was conducted in a similar manner as the greenhouse experiment. A 0.5-acre (0.20-ha) polyethylene-mulched field previously planted to staked tomatoes (*Lycopersicon esculentum*) was used for the field experiment. Field preparation consisted of the removal of tomato plants and stakes. Drip tape was Eurodrip (Eurodrip Inc., San Diego, Calif.) 8-mil tape rated for 0.4 gal/min (0.03 $L{\cdot}s^{-1}$) per 100 ft with emitters spaced 12 inches apart. Total flow rate for the field was 12.6 gal/min (0.8 $L{\cdot}s^{-1}$). A hole was dug in the bed under emitters at nine locations across the field (similar to layout in greenhouse experiment) to allow placement of catch bottles under the emitters. Samples were collected at the beginning, center, and end of three lines. The other lines served to load the system.

Two injection rates and three solution volumes were evaluated in the field experiment. Two diaphram 12-V pumps (model 2088-343-125 and model 2088-343-135; Shurflo) were used to deliver a nominal low injection rate of 1 gal/min and a nominal high injection rate of 3 gal/min, respectively. For each test run, the amount of ammonium nitrate fertilizer required to provide 10 lb/acre (11.2 $kg{\cdot}ha^{-1}$) N was dissolved in sufficient water to make 5, 10, and 20 gal (18.9, 37.8, and 75.7 L) of solution. About 0.5 fl oz (15 mL) of Blazon Blue Spray Pattern Indicator was added to each batch to allow visual monitoring of injection.

Before sample collection, the drip irrigation system was stabilized [all emitters were flowing consistently and pressure in the line was 10 to 11 $lb/inch^2$. Collection bottles were placed under designated emitters and injection begun. After 1 h of run time, the bottles were removed for analysis of emitted solution. This allowed complete injection and flushing of fertilizer from the lines. Four repetitions of each rate and solution volume combination were conducted.

Samples from the greenhouse and field experiments were analyzed by first recording the total volume per sample and then determining its electrical conductivity with a Beckman Solu-bridge Conductivity Indicator (model SD-B15; Beckman Instruments, Inc., Cedar Grove, N.J.). A calibration equation was empirically developed for each of the fertilizer materials. First order regression equations were fitted to each set of empirical data using CoStat (CoHort Software, Monterey, Calif.). The r^2 values were higher than 0.99 for each of the equations. The equations were then used (in a spreadsheet) to convert conductivity readings to grams of fertilizer, which were then corrected based on the sample volumes. Coefficients of variation were calculated for each of the sample data sets. An analysis of variance procedure (CoStat) was used to compare the uniformity for each treatment.

Results and discussion

GREENHOUSE EXPERIMENT. Injector type had a significant effect on fertilizer distribution uniformity through drip irrigation tape (Table 1). More uniform fertilizer distribution was obtained with the venturi and proportional injectors. Poor uniformity was obtained with the pump and continuous injectors. In both situations, it appeared that the injectors were not correctly sized to the water flow rates. In the case of the pump injector, a bolus effect (Townsend, 1988) occurred because of the rapid injection with a slug of fertilizer solution that remained intact in the irrigation stream. With the continuous injector,

Table 1. Coefficients of variation (CV) of injected fertilizer for four different injectors and three fertilizer materials in greenhouse experiment.

Variable	CV	Injection time (min)
Injector type[z]		
Venturi	0.21 b[y]	32-38
Pump	1.18 d	0.5
Proportional	0.09 a	33-48
Continuous	0.58 c	120 (variable)
Fertilizer		
Calcium nitrate	0.55 a	
Ammonium nitrate	0.46 a	
Liquid 10–10–10 (10N–4.4P–8.3K)	0.53 a	
Significance		
Injector type	***	
Fertilizer	NS	
Type × fertilizer	NS	

[z]Injector type: venturi (model 287; Mazzei Injector Corp., Bakersfield, Calif.), pump (diaphragm 12-v pump model 2088-343-135 with a nominal deliver rate of 3 gal/min; Shurflo, Garden Grove, Calif.), proportional (model A30-2; Dosmatic, Carrollton, Texas), and continuous (experimental plot injector, Lancaster et al., 1998).
[y]Means followed by the same letter are not significantly different (Duncan's multiple range test).
NS,***Nonsignificant and significant at $P \leq 0.001$, respectively.

Table 2. Coefficients of variation (CV) of injected fertilizer for two different injection rates and three fertilizer solution volumes in field experiment.

Variable	CV	Injection time (min)
Injection rate[z]		
1 gal/min (0.06 $L \cdot s^{-1}$)	0.10 b[y]	8–33
3 gal/min (0.19 $L \cdot s^{-1}$)	0.19 a	3–15
Injection volume		
5 gal (18.9 L) solution	0.18 a	3–8
10 gal (37.8 L) solution	0.14 a	6–16
20 gal (75.7 L) solution	0.10 a	14–33
Significance		
Rate	*	
Volume	NS	
Rate × volume	NS	

[z]ShurFlo diaphragm pumps with nominal deliver rates of 1 and 3 gal/min.
[y]Means followed by the same letter are not significantly different (Duncan's multiple range test).
NS,*Nonsignificant and significant at $P \leq 0.05$, respectively.

fertilizer solution appeared to be left in the canister even after 2-h of injection time, which reduced distribution of the fertilizer material. Lancaster (1998) reported that a limitation of the continuous injector was the time required to verify application uniformity relative to a specific delivery system. Because all the fertilizers dissolved readily, fertilizer type did not have an effect on uniformity distribution.

FIELD EXPERIMENT. Uniformity of fertilizer distribution in the field was greater with a low injection rate than with the high injection rate (Table 2). Injection time with the low-flow pump took twice as long as the injection time with the high-flow pump. Townsend (1988) suggested that injecting fertilizer over the longest possible time produces the greatest field uniformity.

Although there was a trend toward more uniformity as solution volume increased, differences in uniformity distribution among 5, 10, and 20 gal fertilizer solutions were not significant.

Conclusions

Injection rate had a significant effect on uniformity of fertilizer distribution. Better fertilizer distribution in the greenhouse experiment was obtained with the venturi and proportional injectors. In the field, better distribution was obtained with the 1-gal/min pump. Injection times were longer with these pumps than with the other treatments in the greenhouse experiment, with the exception of the continuous injector.

A problem with using long injection times is that the total irrigation time (time to fill lines, inject, and then flush system) may be longer than necessary to meet plant water needs. Injectors tested in this experiment will give uniform fertilizer distribution if the injector is properly sized with the water flow rate of the system.

In field situations, the problem encountered in the greenhouse with injectors not being properly sized with the water flow rates of the system is not a concern because flow rate in a field would be expected to be 10 to 50 times greater than in the greenhouse experiment.

Literature cited

Bralts, V.F. 1987. Drip irrigation design and evaluation based on the statistical uniformity concept. Adv. Irr. 4:67–117.

Camp, C.R. 1997. A comparison of uniformity measures for drip irrigation systems. Trans. Amer. Soc. Agr. Eng. 40(4):1013–1020.

Capra, A. 1998. Water quality and distribution uniformity in drip/trickle irrigation systems. J. Agr. Eng. Res. 70(4):355–365.

Clark, G.A., D.Z. Haman, and F.S. Zazueta. 1999. Injection of chemicals into irrigation systems: rates, volumes, and injection periods. Fla. Coop. Ext. Serv. Bul. 250.

Haman, D.Z., A.G. Smajstria, and F.S. Zazueta. 1994. Chemical injection methods for irrigation. Fla. Coop. Ext. Serv. Circ. 864.

Lancaster, M.E., J.M. Davis, and D.C. Sanders. 1998. A continuously diluting injector for applying fertilizer to experimental and demonstration plots. HortTechnology 8(2):221–224.

Phene, C.J. 1992. Distribution uniformity of subsurface drip irrigation systems. Amer. Soc. Agr. Eng. Paper No. 92-2551.

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.J. Pitts, and F.S. Zazueta. 1990. Field evaluation of microirrigation water application uniformity. Inst. Food Agr. Sci. Ext. Bul. 265.

Townsend, J.D. 1988. Fertigation—Uniformity of fertilizer application through drip irrigation systems. Proc. 4th Intl. Micro-Irrigation Congr., Albury-Wodonga, Australia, 23–28 Oct. 1988.

Wu, I. 1987. Evaluation of uniformity parameters for drip irrigation design. Amer. Soc. Agr. Eng. Paper No. 87-2522.