APPLICATION OF CHEMICALS THROUGH A TRICKLE SYSTEM FOR SOIL-BORNE PEST CONTROL. II. THE DESIGN OF A PROTOTYPE SYSTEM AND TEST RESULTS

J.C.W. Keng[1], T.C. Vrain[2], and J.A. Freeman[1]

[1]Research Station, Agriculture Canada, Agassiz, British Columbia V0M 1A0; and [2]Research Station, Agriculture Canada, Vancouver, B.C. V6T 1X2

Contribution no. 319[1], received 9 August 1984, accepted 14 December 1984.

Keng, J.C.W., T.C. Vrain, and J.A. Freeman. 1985. Application of chemicals through a trickle system for soil-borne pest control. II. The design of a prototype system and test results. Can. Agric. Eng. 27: 35–37.

Nematode infestation is one of the major causes of raspberry yield depression in the Fraser Valley of British Columbia, Canada. Current pest management techniques cannot control the level of root lesion nematodes in established raspberry fields. A trickle system was designed, based on previous theoretical discussion (Keng and Vander Gulik 1985), to apply postplanting nematicides to the raspberry root zone. Reasonable agreement between the predicted irrigation water movement and the field soil moisture profile was noticed. Two nematicides, Nemacur and Furadan, at two rates, 4 kg and 8 kg active ingredient per hectare were applied in March 1982. Significant depression in nematode densities were noticed in all Nemacur-treated plots and in high-rate Furadan-treated plots. Results suggested that low-rate (4 kg a.i/ha), Nemacur may be used with the tested trickle system to effectively control root lesion nematodes in mature raspberry fields and at the same time minimize pollution risk.

INTRODUCTION

The Fraser Valley of British Columbia produces 95% of Canada's red raspberries. Under normal growing conditions, the hand-picked raspberry should yield between 9 and 11 tonnes/ha. However, in recent years, the region's average yield has been around 6.5 tonnes/ha. According to a disease survey conducted by a local producers cooperative in 1982, high levels of root lesion nematodes (over 500 counts per gram of root sample) were found in 74% of the raspberry farms sampled. Nematodes cause direct tissue damage and also carry viruses that can cause crumbly berry and other diseases. They also produce wounds which allow damaging organisms to enter the plants. It is generally believed that nematode infestation is one important factor which causes depression in raspberry yield.

The usually recommended practice of nematode control is preplanting fumigation (British Columbia ministry of Agriculture and Food 1983; Stouffer 1978). However, postplanting nematode control is necessary for optimal yield if nematode infestation of mature plants becomes apparent. Postplant granular nematicide application (Funt et al. 1982) has been tried on young peach trees. Supplemental moisture is required to dissolve and carry the nematicide into the root zone and the distribution of the applied chemical is very unpredictable. The purpose of this experiment is to develop a trickle pesticide application technique to be employed in established raspberry fields. Theoretical analysis of such techniques has been reported in an earlier publication (Keng and Vander Gulik 1985).

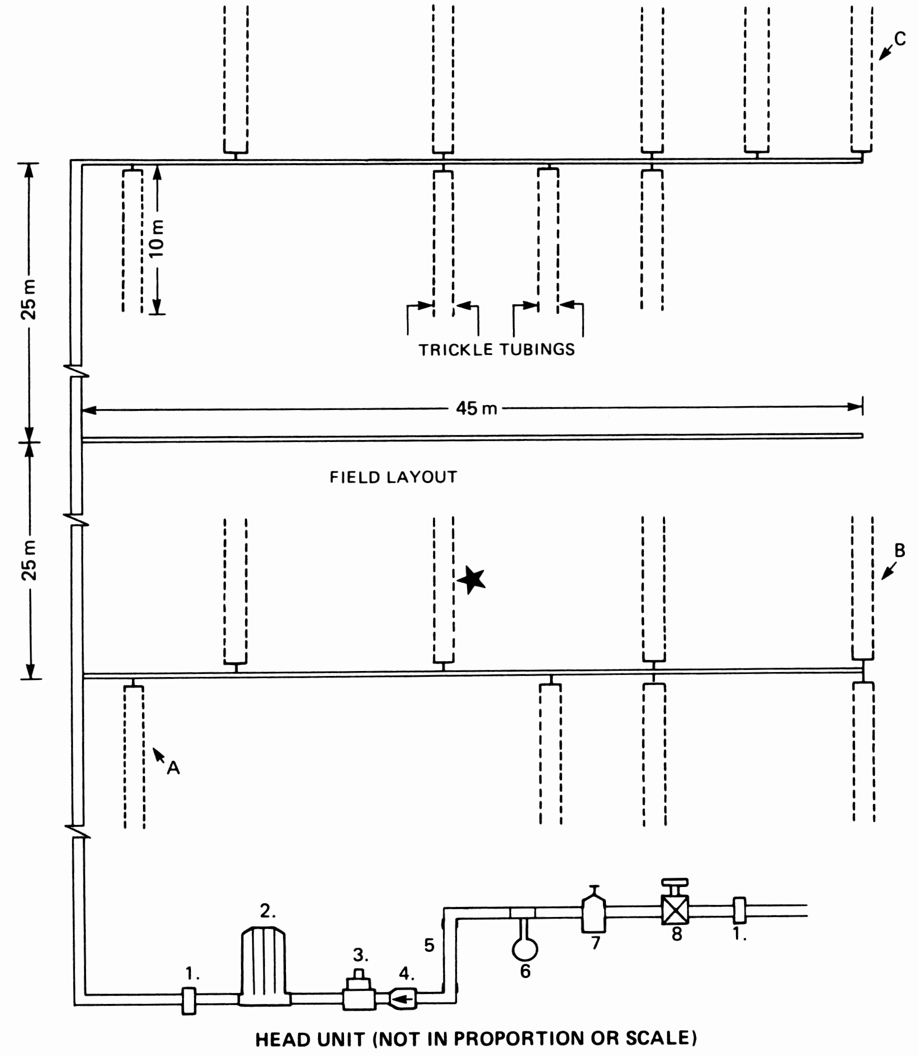

Figure 1. The design of trickle system head unit and field layout. The A, B and C arrow signs indicate the positions where methylene blue dye outflow were collected. The star indicates the location where the soil moisture profile was examined. List of parts of the head unit: (1) universal joints; (2) filter; (3) inlet for chemical injection; (4) check valve; (5) flow meter; (6) pressure gauge; (7) pressure regulator; (8) on-off valve.

This report will discuss the engineering design system characteristics and its potential application in commercial raspberry productions.

MATERIALS AND METHODS

Site Description

The field test was conducted on a 7-yr-old raspberry field as described in Case 1 of the Keng and Vander Gulik (1985) report. The soil was well drained sandy silty loam eolian deposits over gravelly glacial outwash deposits. Laboratory-measured saturated hydraulic conductivity of the root zone soil, using soil cores 7 cm high × 7 cm in diameter, averaged 0.3 cm min.^{-1}.

System Design

Figure 1 is a design diagram of the trickle irrigation head unit. It may be connected with an existing trickle irrigation system or used separately as a portable pesticide application system. The designed system flow rate is 12.7 L min^{-1} at an operation pressure of 103 kPa. Twin-wall plastic trickle tubing with discharge rate of $0.6 \pm .05$ $\text{mL}\cdot\text{cm}^{-1}\cdot\text{min}^{-1}$ was used to deliver pesticide solution and irrigation water.

Due to the fact that the wetting patterns under a trickle emitter are usually in the form, more or less, of an onion shape, to achieve a 160-cm horizontal spread with 15-cm infiltration, two twin wall tubings, spaced 20 cm apart or 10 cm on each side of the raspberry row, were considered necessary. One other advantage of laying trickle tubings 10 cm away from the plant base is that the applied irrigation water or nematicide would pond and spread on a relatively smooth soil surface rather than being directed in undesirable directions by the accumulated live and dead biomass near the base of the raspberry plants.

To simplify the design calculation, the total discharge rate, $0.6\ \text{mL}\cdot\text{cm}^{-1}\cdot\text{min}^{-1} \times 2 = 1.2\ \text{mL}\cdot\text{cm}^{-1}\cdot\text{min}^{-1}$, was considered to originate at the center line of the raspberry row. Using Eq. 9 from Keng and Vander Gulik (1985) to determine irrigation time

$$t^{0.5} = Z(\epsilon q(t) + e)^{-1}$$

where soil constant $\epsilon = 0.87$ and $e = 0.62$ (Keng and Vander Gulik 1985), infiltration depth $Z = 15$ cm, then the calculated $t = 81$ min. The surface wetted half width $\phi(t)$ is checked by using Eq. 4 (Keng and Vander Gulik 1985).

$$\phi(t) = \frac{Q}{2\delta \cdot K_s}$$

$$= \frac{1.2\ \text{mL}\cdot\text{cm}^{-1}\cdot\text{min}^{-1}\cdot 81\ \text{min}}{2 \times 2\ \text{cm}\cdot\text{min}\cdot 0.3\ \text{cm}\cdot\text{min}^{-1}} = 81\ \text{cm}$$

Soil samples were collected every 20 cm vertically and horizontally from the raspberry rows immediately after irrigation. Gravimetric water contents were then determined in the laboratory to study the active wetting pattern.

Three nematicide applications of Nemacur and Furadan were conducted using this system on 1 Mar., 15 Sept. and 18 Oct. 1983. Soil and root samples were taken before each application for nematode population study.

To study the uniformity of delivery of injected pesticide through the system, a total of 3060 mL concentrated (400 ppm) methylene blue (MB) dye solution was injected into the head unit with a chemical metering pump. The injection rate was 102 $\text{mL}\cdot\text{min}^{-1}$. Outflows were collected at 5 m, 50 m and 100 m locations (as indicated, Points A, B and C, on Fig. 1) from the injection point at 5-min intervals. The concentrations of collected methylene blue dye solution were determined with a laboratory spectrophotometer.

RESULTS AND DISCUSSION

System Delivery Uniformity of Injected Chemicals

Figure 2 shows the break through curves (BTC) and tailing rates of the injected MB dye solution in irrigation discharges. All the BTCs and tailing rates are identical with expected time lags from location to location. The results indicated laminar flow through the system. The same maximum MB dye concentration of 3.2 ppm was noticed in all three locations. The designed dilution factor is

$$\frac{\text{rate of injection}}{\text{system flow rate}} = \frac{102\ \text{mL}\cdot\text{min}^{-1}}{12700\ \text{mL}\cdot\text{min}^{-1}} = 0.008$$

which agrees with the measured dilution factor

$$\frac{\text{discharged dye concentration}}{\text{injected dye concentration}} = \frac{3.2\ \text{ppm}}{400\ \text{ppm}} = 0.008$$

The verified system dilution factor is used to calculate the amount of chemicals to be delivered with the system. Figure 2 also shows that a minimum of 30 min after injection is needed to flush out the last trace of dye through the system. As discussed later in this report, a longer flushing time was needed to ensure that the injected chemicals were carried into the desired width and depth of the root zone.

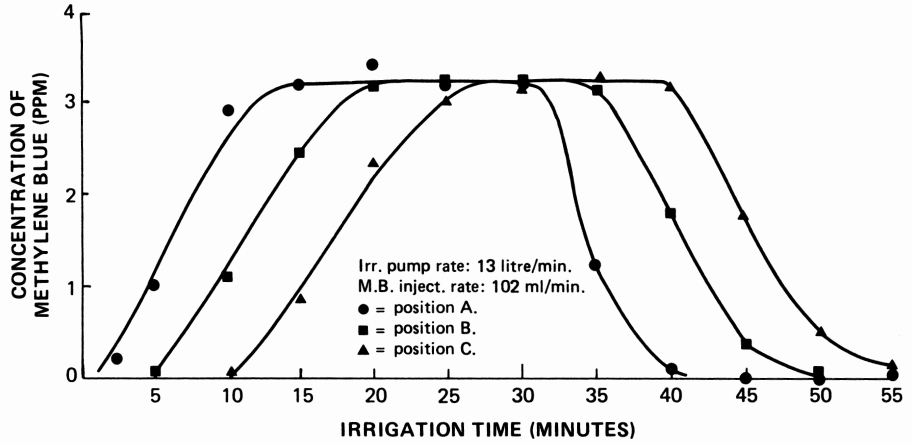

Figure 2. Break-through-curves of the methylene blue dye solution at three positions of the trickle system.

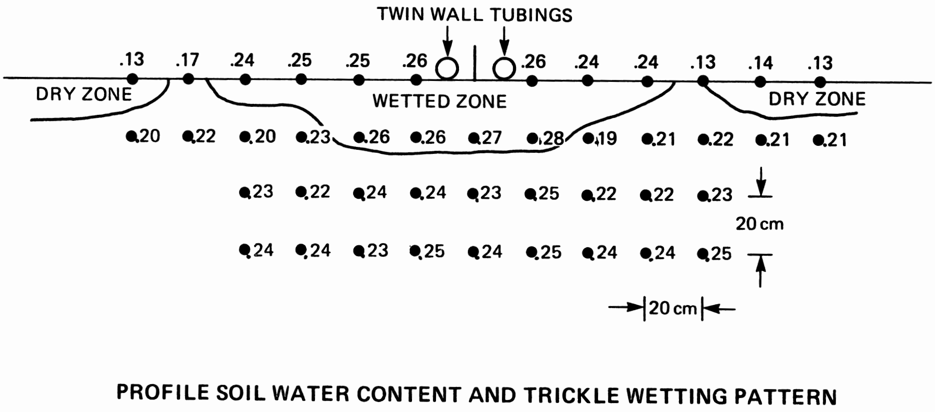

Figure 3. The soil water content profile immediately after irrigation.

The Trickle Wetting Pattern

The Trickle Wetting pattern was obtained in mid August 1983 after a dry period of 11 days without rainfall. The field was irrigated for 90 min. Unwanted plant materials near the irrigation tubings were removed and the soil surface was smoothed manually. The soil water distribution profile (Fig. 3) indicates that the soil water contents of the surface layer was between 13 and 14% by weight, while the water contents beyond the surface 10 cm depth were all above 20%. This strongly reflects the self-mulching effect of the rototilled loose surface soil.

Surface ponding was noticed 30 min after the start of irrigation. The expansion of the ponded width was in the form of surface runoff and was affected by the microtopography and the unevenness at the base of the raspberry grove. At the end of irrigation the ponded widths were measured 65 cm on one side and 95 cm on the other, or a variation of ± 18.5% from the predicted 81-cm half-width (Keng and Vander Gulik 1985).

Advance of wetting depth (directly below the raspberry plant as shown in Fig. 3) was 25 cm instead of the 15 cm as designed for an isotropic soil profile. It has been known that under field conditions, bio-channels, such as decayed root canals and earthworm holes often increase the initial infiltration rate and result in greater wetting depth. This kind of soil macropore network is also subject to large spatial variations and presents a constant challenge to soil and water management designs. Equations 7, 8 and 9 in Keng and Vander Gulik (1985) were developed for a uniform soil profile free from bioactivities, and are therefore not expected to predict the exact field soil water movement. These equations, however, are useful tools to acquire a general wetting pattern under a given discharge rate and irrigation time, or vice versa. In this particular case, the shallow but widely spread raspberry root system requires a trickle wetting pattern with a large horizontal to vertical ratio. A ratio of 160:25 cm or 6.4:1 was realized under field conditions. The wetting pattern shown in Fig. 3 reached the majority of the active root system and indicated no leaching risk; therefore, the equations and associated design criteria were considered adequate.

Reduction of Nematode Population

The first application of nematicides in March significantly reduced the root lesion nematode density in the raspberry roots and in the soil. Densities were still significantly depressed in August when Nemacur had been applied at 4 or 8 kg a.i.$\cdot$ha^{-1} (active ingredient per hectare) or Furadan had been applied at 8 kg a.i.$\cdot$ha^{-1}. There were no significant differences in roots or soil in August when only 4 kg a.i.$\cdot$ha^{-1} of Furadan was applied in March. With two more applications of Nemacur or Furadan at 1 or 2 kg a.i.$\cdot$ha^{-1} in August and September the same pattern of depressed nematode densities in roots or soil was maintained.

Engineering and Agronomic Benefits

In the Fraser Valley over 80% of the raspberries are produced on upland and rolling terrain. Sprinkler irrigation often causes undesirable surface run-off and soil erosion. When agricultural chemicals are applied through a sprinkler system, surface run-off may result in uneven distribution and sometimes raises environmental concerns in adjacent lowland farms. Therefore, granular or other solid forms of pesticides are usually suggested. Solid chemicals must be mechanically incorporated into the soil. Because of the systemic nature and residue effect of nematicides, they should be applied in very early spring when the field is usually too wet for machine traffic. Trickle "pest-gation" greatly simplifies the application procedures and eliminates the use of energy, labor and time needed for farm machines. Since many farmers have applied fertilizer through their trickle irrigation systems, applying pesticides through the same system will maximize the use of existing equipment. This study and the Keng and Vander Gulik (1985) report enables irrigation agronomists to manage the wetting pattern better with whatever system is available.

According to the measured wetting pattern (Fig. 3) and the significant reduction in root zone nematode populations, trickle pest-gation technique is considered effective, efficient and with very low pollution risk.

REFERENCES

BRITISH COLUMBIA MINISTRY OF AGRICULTURE AND FOOD. 1983. Production Guide. Berry, B.C.

FUNT, R.C., L.R. KRUSBERG, D.S. ROO and B.L. GOULART. 1982. Effect of postplant nematicides and trickle irrigation on newly planted peach trees. J. Am. Soc. Hortic. Sci. 107(5):891–895.

KENG, J.C.W. and T. VANDER GULIK. 1985. Application of chemicals through trickle system for soil-borne pest control. I. Derivation of basic theory for practical use. Can. Agric. Eng. 27:

STOUFFER, R.F. 1978. Soil fumigation — an important part of orchard establishment. Pa. Fruit Notes 57:57–58.