J. Palti
Agricultural Research Organization, Bet Dagan, Israel

H. Shoham
Ministry of Agriculture, Tel Aviv, Israel

Trickle Irrigation and Crop Disease Management

Trickle or drip irrigation consists of low-rate application of water to the root zone over a period of several hours through specially adapted emitters in plastic irrigation lines. Initial difficulties caused by clogging of nozzles have largely been overcome by perfection of filtering systems and the introduction of "self-cleaning" nozzles.

Trickle irrigation was introduced in glasshouses in England some 20 years ago and has since been developed by research initiated in Israel for use in field, orchard, and greenhouse crops. It is now applied worldwide to hundreds of thousands of hectares of such crops, including about 200,000 ha in the United States (2). Some of the reasons for its success are:

1. Maintenance of water supply to crops, on a commercially viable scale, at a constant low negative supply potential in soil of a wide range of permeability (3).
2. Applicability to topographic situations that previously defied irrigation, especially steep slopes, without runoff, erosion, or excessive loss by deep percolation. Avoidance of erosion has been demonstrated convincingly by Aldon et al (1), but occasional dangers of erosion owing to sudden heavy rainfall on soil with moisture kept near field capacity by trickle irrigation have been pointed out by Tulang and Bedish (18).
3. Greater latitude in the use of saline water (7) and fewer restrictions on the use of sewage water.
4. Simultaneous application of water and nutrients through the trickler system, of special importance in shallow or poor soils with low water-retention capacity.
5. Facilitated use of plastic mulches, with trickler lines laid out under the mulch.
6. Pronounced economy of water, with savings of at least 10% (14), even in fields with good water management, and frequently much greater, especially in young plantations with widely spaced rows. Weight of yield per unit of water can be much increased or even doubled, as was found in trials with oranges in California (6).

Hundreds of papers are published every year on the techniques and benefits of trickle irrigation. But the effects of such irrigation on infectious crop diseases are mentioned only rarely, while the effects on nonparasitic disorders, especially damage from salinity, are referred to occasionally.

Contribution No. 176-E from the Agricultural Research Organization, Bet Dagan.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

Nonparasitic Disorders

Frost. Trickle-irrigated crops grown on slopes are largely protected from frost if temperatures do not fall much below the freezing point. In fact, ever since trickle irrigation became available, susceptible crops such as avocado and banana have been planted on slopes in Israel, California, and elsewhere, wherever there is danger of frost.

Salinity damage. Effects of trickle irrigation in relation to the use of saline water have been described by Shalhevet (13) and Yaron et al (20). Trickle irrigation keeps soil moisture constantly high, at least in the greater part of the root zone. This results in leaching in the zone below the tricklers, and a low level of salt concentration is thus maintained. Because roots tend to cluster in this leached zone of high moisture, contact with salt is largely avoided and the salt accumulates at the periphery of the zone wetted (13). Unless salts are leached out by rain or heavy sprinkling in the period between successive crops, crop rows and trickle lines should be left in place. Shifting the rows or lines sideways could result in roots growing into the peripheral zone in which salt has accumulated and, thus, in severe salt damage.

On crops trickle-irrigated with saline water in normally rainless seasons, occasional light rain may result in salt damage, as the rain may wash salt accumulated at the soil surface into the root zone. This has frequently been experienced in Israel's Arava region.

Salt damage can also be avoided where the soil surface of trickle-irrigated crops is covered by plastic mulching, which prevents evaporation and accumulation of salts at the soil surface. The salts are displaced and rise outside the mulched area. Mulching also excludes the danger of salt damage by occasional rains.

Direct salt injury to foliage occurs when saline water is applied by sprinkling at rates corresponding to evaporation values. Goldberg et al (7) reported that salt injury was completely avoided in trials in which water with a chlorine content of 834 ppm was applied at such rates by trickle irrigation to crops of cucumbers and tomatoes; large increases in yields resulted.

Mineral deficiency. Application through the trickler system of constantly repeated small doses of nutrient elements widens the range of crops that can be grown on many types of soil without nutrient strain. Rolston et al (11) recently reviewed this subject in relation to crops grown in California. Nitrogen deficiency can be corrected most efficiently and economically in this way in numerous crops, and potassium deficiency has been readily corrected in deciduous fruit crops. Trickler application of iron or zinc chelates to correct minor element deficiencies is efficient and considerably cheaper than foliar application. Correction of iron deficiency by application of chelates through the trickler system has also been reported from Israel for vineyards (12) and for tomatoes and eggplants (19).

Infectious Diseases

Effects on the pathogen and its dispersal. The impact of trickle irrigation on the foliosphere climate, and thus indirectly on disease and pest development, depends largely on the macroclimate. Where this is extremely dry, the effect of any irrigation practice is minimal. Where atmospheric humidity is low in the daytime and dew dries up rapidly, however, trickle irrigation has adverse effects on a number of pathogens, especially when compared with sprinkling. Leaves in crops under trickle irrigation are not wetted directly, ie, the wet period provided by dew is not extended into daytime, and the development of pathogens with affinities to free moisture (eg, downy mildews and bacteria) is consequently restricted. In fact, in comparative trials in Israel on light soil, downy mildew (*Pseudoperonospora cubensis*) attacked melons under trickle irrigation much less severely than adjacent plots of melons under frequent sprinkler irrigation.

Splashing of inoculum formed on leaves or fruit or near the soil surface is an

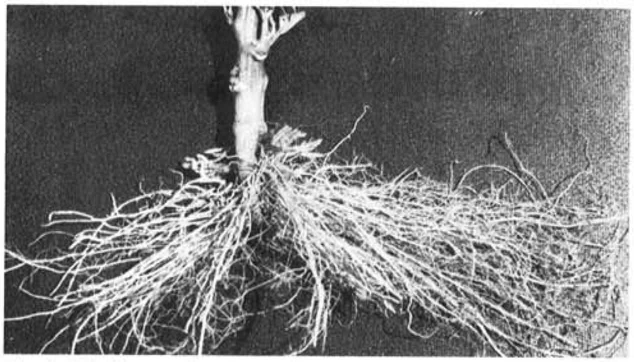


Fig. 1. Shallow root system of pepper plant irrigated by trickling. Such root development facilitates use of shallow soils and makes soil applications of pesticides more effective, but the danger of moisture stress is aggravated if the water supply is interrupted.

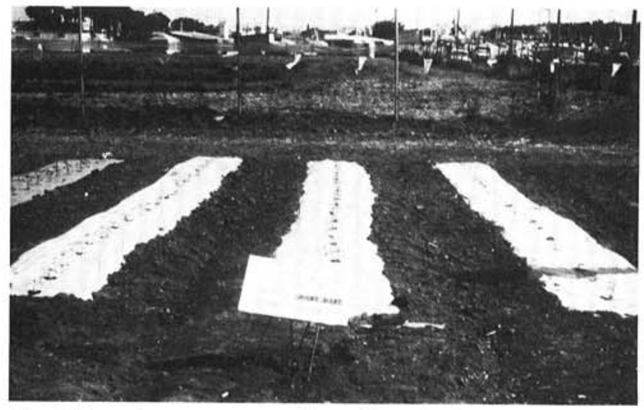


Fig. 2. Tomato crop sown under yellow plastic sheeting to repel virus vectors. Trickle irrigation facilitates use of plastic mulches.

Table 1. Fruit diseases reduced by use of trickle irrigation

Crop	Location	Pathogen	Remarks	Reference
Citrus	Texas	*Phytophthora parasitica*	Foot rot reduced in trees planted on ridges	17
Citrus	Corsica	*Phytophthora* spp.	Gummosis reduced when proper placement of trickler lines avoided wetting of trunks	E. Laville (*pers. commun.*)
Avocado	California	*Phytophthora cinnamomi*	Considerably slower spread among seedlings	21
Apple	Israel	*Glomerella cingulata*	No splashing of inoculum	16
		Sclerotium rolfsii	Lower soil temperature stimulated antagonistic and competitive microflora	16

important drawback of sprinkling and, sometimes, of flooding. Distribution of inoculum along furrows and beds and by runoff from field to field has been demonstrated for numerous pathogens. Palti (10) listed major pathogens spread by splashing, runoff, and in-field transport of inoculum by irrigation water. All these forms of inoculum dispersal are minimized by trickle irrigation. In Israel, infection of apples by *Glomerella cingulata* has become quite rare since trickle irrigation replaced sprinkling and splashing of inoculum has been avoided (16).

Effects on crop growth and susceptibility. *Stress.* Irrigation applied intermittently by sprinkling, flooding, or furrows often induces periodic stress owing to low soil water content at the end of the irrigation intervals, especially in crops grown in hot climates. This type of stress can be minimized by frequent trickle irrigation. Moreover, application of nutrients through the trickler system serves to avoid or correct nutrient stress. The effects of stress on infectious crop diseases, especially those caused by facultative pathogens, have recently been summarized by Palti (10). Such effects are exemplified by the rising susceptibility to charcoal rot (*Macrophomina phaseolina*) of numerous crops under heat and drought stress.

Root growth. Root systems in trickle-irrigated crops tend to be shallow (Fig. 1). This has various disease-related effects. If the water supply in irrigated crops breaks down even for a limited period, shallow-rooted plants are more sensitive to drought stress. On the other hand, restriction of root growth to upper layers of the soil prevents roots coming in contact with pathogens in deeper soil layers. This may be of special importance in crops grown on soil subjected to disinfection by chemicals or heat, since beneficial effects of such treatments decrease or fail to materialize in deeper soil layers.

Rate of crop growth. Trickle irrigation helps crop growth to proceed steadily, with young leaves formed at a more uniform rate, whereas intermittent irrigation by other methods may induce irregular spurts of growth. This is important in relation to diseases that predominantly attack soft, young growth, eg, downy mildew of vine (*Plasmopara viticola*) and Stemphylium leaf spot of tomato (*Stemphylium botryosum*). Trickle irrigation helps protect young growth, especially since sprays can be applied regardless of soil moisture conditions.

Aid to disease management. All types of irrigation afford the grower certain opportunities for disease management by controlling the timing and rate of water application. With trickle irrigation, where the trickler line is placed in relation to the crop row can also be important.

Table 1 presents a few examples of major fruit diseases reported to have been reduced by the use of tricklers and the reasons given by authors for the reductions. Shifting of trickler lines from their initial position on plant beds to a position between the beds has proved beneficial in reducing Rhizopus fruit rot of unstaked tomatoes, since the soil on which the fruit lies is not wetted (H. Shoham, *unpublished*). Of course, trickler lines must never be shifted in this way where saline water is applied. Weed development is also reduced (7), since irrigation by trickling wets only part of the soil surface.

Use with plastic mulches. The use of plastic mulching is expanding rapidly, especially for the production of vegetables and flowers. Use of such mulching for irrigated crops depends largely on the availability of facilities for trickle irrigation. The benefits of plastic mulching include: 1) preventing contact between plant organs and soil, thus minimizing infection by soilborne pathogens, eg, *Botrytis cinerea* and *Rhizopus stolonifer*, the causes of strawberry fruit rot (15); 2) repelling virus vectors, eg, aphids and *Bemisia tabaci*, with colored mulches, including vectors of watermelon virus (4), tomato yellow leaf curl virus (5), and various pepper viruses (8) (Fig. 2); and 3) suppressing weed growth with opaque mulches.

Application of pesticides. Integrating irrigation schedules with ground application of pesticides often presents a problem. Application to leaves and fruit frequently cannot be made immediately after irrigation, just the time when protectant sprays are needed most to control pathogens thriving under wet conditions. With trickle irrigation, however, pesticide deposits are not washed off and foliage is not wetted, as with sprinkler irrigation. Paths between rows or beds remain dry, and pesticides can be applied as and when required. This is an important point in controlling downy mildews and many other diseases and in controlling pests attracted by moisture, eg, the Egyptian cotton leaf worm (*Spodoptera littoralis*).

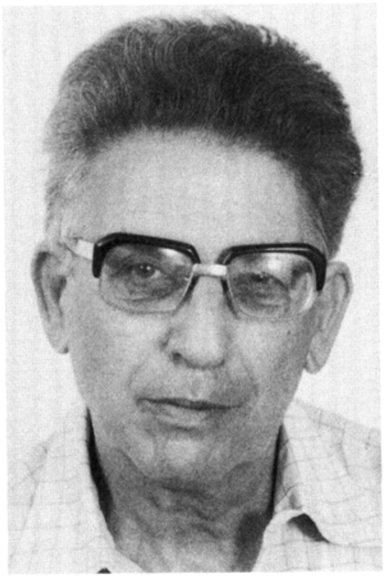
In crops covered by plastic mulching, pesticides can be applied to the soil only through the trickler system. Where practicable, this is efficient and economical. Roots under trickle irrigation develop only in the limited soil zone wetted. When applied through the trickler system, pesticides, including systemic insecticides and fungicides as well as fumigant nematicides, reach the roots in this zone and are not wasted in rootfree zones.

Overman (9) summarized the advantages of nematicide application through trickler systems: 1) remote control of hazardous chemicals, 2) economy in use of expensive chemicals, and 3) opportunity to control nematodes in crops already established under full-bed mulch. Use of the trickle system is especially economical for applying pesticides to the root zone of individual trees in widely spaced tree crops. In some cases, pesticides that would be too expensive to apply through a sprinkler system can be used with trickle irrigation.

A cucumber trial in Israel is an example of the economies possible with trickler application of systemic fungicides. Application of benomyl (Benlate 50WP) through tricklers was compared with drench application at the rate of 0.3 gr per plant (300 cc of a 0.05% suspension of benomyl). Quantities of benomyl needed to effectively control *Sclerotinia sclerotiorum* were much lower with tricklers. In fact, when the quantities of benomyl used in drenching were applied through the trickler system, the cucumber plants were harmed (R. Ausher, *personal communication*).

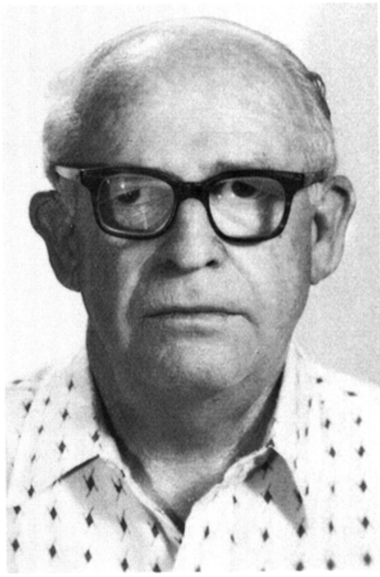
Literature Cited

1. Aldon, E. F., Cable, D., and Scholl, D. 1977. Plastic drip irrigation systems for establishing vegetation on steep slopes in arid climates. Pages 107-112 in: Proc. Int. Agric. Plast. Congr.
2. Anonymous. 1981. 1981 Irrigation survey. Irrig. J. 31(6):8.
3. Black, J. D. F. 1976. Trickle irrigation—a review. Part 1. Hortic. Abstr. 46:1-7.
4. Chalfont, R. B., Jaworski, C. A., Johnson, A. W., and Sumner, D. R. 1977. Reflective film mulches, millet barriers and pesticide effects on watermelon mosaic virus, insects, nematodes, soil-borne fungi, and yield of yellow summer squash. J. Am. Soc. Hortic. Sci. 102:11-15.
5. Cohen, S., and Melamed-Madjar, V. 1978. Prevention by soil mulching of the spread of tomato yellow leaf curl virus transmitted by *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in Israel. Bull. Entomol. Res. 68:465-470.
6. Davis, S., Pugh, W. S., and Davis, K. P. 1977. Drip subsurface and sprinkle irrigation compared. Pages 73-79 in: Proc. Int. Agric. Plast. Congr.
7. Goldberg, D., Gornat, B., and Rimon, D. 1976. Drip Irrigation: Principles, Design and Agricultural Practices. Drip Irrigation Scientific Publications, Kfar Shmaryahu, Israel. 296 pp.
8. Loebenstein, G., Alper, M., Levy, S., Palevitch, D., and Menagem, E. 1975. Protecting peppers from aphid-borne viruses with aluminum foil or plastic mulch. Phytoparasitica 3:43-53.
9. Overman, A. J. 1977. Crop response to nematicides and drip irrigation on sandy soil. Pages 172-179 in: Proc. Int. Agric. Plast. Congr.
10. Palti, J. 1981. Cultural Practices and Infectious Crop Diseases. Springer-Verlag, Heidelberg, West Germany.
11. Rolston, D. E., Rauschkolb, R. S., Phene, C. J., Miller, R. J., Uriu, K., Carlson, R. M., and Henderson, D. W. 1979. Applying nutrients and other chemicals to trickle irrigated crops. Univ. Calif. Bull. 1893. 14 pp.
12. Safran, B., Bravdo, B., and Bernstein, Z. 1974. L'irrigation de la vigne par goutte á goutte. Bull. Off. Int. Vigne Vin 48:406-429.
13. Shalhevet, J. 1973. Irrigation with saline water. Pages 263-276 in: Arid Zone Irrigation. B. Yaron, E. Danfors, and Y. Vaadia, eds. Springer-Verlag, Heidelberg, West Germany.
14. Shalhevet, J., Shimshi, D., and Meir, T. 1982. Irrigation of spring potatoes in the northern Negev. Hassadeh 62:984-988. (In Hebrew; English summary)
15. Solari, J. 1980. Irrigation goutte á goutte et culture des fraisiers en semi forcage. Pages 48-53 in: L'Irrigation Localisée. Chambre d'Agriculture des Bouches du Rhône.
16. Sztejnberg, A., and Golan, J. 1980. Changes in the occurrence of fruit crop diseases as a result of changes in irrigation measures. Pages 127-128 in: Proc. Congr. Mediterr. Phytopathol. Union 5th.
17. Timmer, L. W., and Leyden, R. F. 1976. Effect of irrigation and soil management practices on the incidence of Phytophthora foot rot of citrus. J. Rio Grande Val. Hortic. Soc. 30:19-25.
18. Tulang, M. C., and Bedish, J. W. 1975. The soil conservation service and drip irrigation. Pages 35-40 in: Proc. Hawaii Sugar Technol. Conf. 33rd.
19. Uzrad, M., and Rimon, D. 1975. Fertilization of winter solanaceous crops in the Arava desert with iron chelates. Pages 51-58 in: Special Publication 46. Agricultural Research Organization, Bet Dagan, Israel. (In Hebrew; English summary)
20. Yaron, B., Shalhevet, J., and Shimshi, D. 1973. Patterns of salt distribution under trickle irrigation. Pages 389-394 in: Physical Aspects of Soil, Water, and Salts in Ecosystems. A. Hadas, D. Swartzendruber, P. E. Rijtema, M. Fuchs, and B. Yaron, eds. Springer-Verlag, Heidelberg, West Germany.
21. Zentmyer, G. A., Guillemet, F. B., and Johnson, E. L. V. 1974. The relation between drip irrigation, Phytophthora root rot of avocado, and fungicides. Pages 512-514 in: Int. Drip Irrig. Congr. Proc., San Diego.



J. Palti

Dr. Palti founded the Extension Service's Department for Plant Protection of Israel's Ministry of Agriculture in 1960 and directed the work of that department until 1973. Since then, he has been involved in plant disease research at the Agricultural Research Organization in Bet Dagan. His work and writings center on the epidemiology of crop diseases and the effects of cultural practices on their development.



H. Shoham

Mr. Shoham is chief advisor for Protection of Field and Vegetable Crops in the Extension Service of Israel's Ministry of Agriculture. His work covers survey and control of diseases, pests, and weeds. He is devoting much of his work to integrating pest and disease control by combined cultural and chemical means.