RUTGERS COOPERATIVE EXTENSION

NEW JERSEY AGRICULTURAL EXPERIMENT STATION

Best Management Practices for Irrigating Vegetables

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Basic Principles

Moisture management throughout the growing season is a critical factor for production of high quality vegetables. Even relatively short periods of inadequate soil moisture can adversely affect many crops. Thus, supplemental irrigation is beneficial in most years, since rainfall is rarely uniformly distributed even in years with above-average precipitation. Moisture deficiencies occurring early in the crop cycle may delay maturity and reduce yields. Shortages later in the season often lower quality, as well as yields. However, over-irrigating, especially late in the season, can reduce quality and postharvest life of the crop. Table 1 shows the periods of crop growth when an adequate supply of water is critical for high quality vegetable production.

Applying the proper amount of water at the correct time is critical for achieving the optimum benefits from irrigation. The crop water requirement, termed evapotranspiration or ET, is equal to the quantity of water lost from the plant (transpiration) plus that evaporated from the soil surface. The ET rate is important in effectively scheduling irrigations. Numerous factors must be considered when estimating ET. The amount of solar radiation, which provides the energy to evaporate moisture from the soil and the plant, is the major factor. Other important factors include air temperature, wind speed, and humidity level.

Table 1. Critical Periods of Water Need by Crops

Crop	Critical Period
Asparagus	Brush
Beans: lima	Pollination and pod development
snap	Pod enlargement
Broccoli	Head development
Cabbage	Head development
Carrots	Root enlargement
Cauliflower	Head development
Corn	Silking and tasseling, ear development
Cucumbers	Flowering and fruit development
Eggplants	Flowering and fruit development
Lettuce	Head development
Melons	Flowering and fruit development
Onions: dry	Bulb enlargement
Peas	Seed enlargement and flowering
Peppers	Flowering and fruit development
Potatoes: white	Tuber set and tuber enlargement
sweet	Root enlargement

Plant factors that affect the crop irrigation requirement are crop species; canopy size and shape; leaf size, shape, and orientation; plant population; rooting depth; and stage of growth and development of the crop. The plant canopy size and shape influences light absorption, reflection, and the rate at which water evaporates from the soil. Crops which completely shade the soil surface (mature corn, potatoes, snap beans) use more water than crops which do not have a complete canopy (immature plants, recently transplanted crops, certain species grown on mulched beds). Leaf architecture affects the transpiration rate from individual leaves. Rooting depths vary with crop species and may be affected by compaction or hard pans which may exist. Rooting depth determines the volume of soil from which the crop can draw water and is important when determining to what depth the soil must be wetted when irrigating.

Plant growth stage also influences the susceptibility of crops to moisture stress. Irrigation is especially useful when establishing newly seeded or transplanted crops. Irrigation after transplanting can significantly increase plant survival, especially when soil moisture is marginal and ET is high. Irrigation can also increase the uniformity of emergence and final stand of seeded crops. For seeded crops, reduce the rate of application and the total amount of water applied to avoid crusting. If crusting is present, apply low rates and amounts of irrigation water to soften the crust while seedlings are emerging.

Cultural practices also influence ET. Cultivation, mulching, weed growth, and method of irrigation are factors to consider. Cultivation generally does not reduce evaporation significantly, but if crop roots are pruned by cultivating too close, water uptake and, thus, transpiration may be reduced. Shallow cultivation may help eliminate soil crusts and, therefore, improve water infiltration. The effects of mulching are discussed in the next section. Weeds compete with the crop for water and increase the amount lost through transpiration. Sprinkler irrigation wets the entire crop area and, thus, has a greater evaporation loss than does trickle irrigation which wets only the area in the region of the crop.

Soil factors must also be considered. Soils having high levels of silt, clay, and organic matter have greater available water-holding capacities than do sandy soils or soils which are compacted (Table 2). Available water refers to the amount of water that a plant is able to withdraw from the soil. Soils with high available water-holding capacities require less frequent irrigation than soils with low available water-holding capacities. However, when irrigated less frequently, a greater amount of water must be applied per application.

Table 2. Available Water Holding Capacity Based on Soil Texture

Soil Texture	Available Water Holding Capacity (inch of water/inch of soil)
Coarse sand	0.02 - 0.06
Fine sand	0.04 - 0.09
Loamy sand	0.06 - 0.12
Sandy loam	0.11 - 0.15
Fine sandy loam	0.14 - 0.18
Loam and silt loam	0.17 - 0.23
Clay loam and silty clay loam	0.14 - 0.21
Silty clay and clay	0.13 - 0.18

Another soil factor which influences irrigation practices is the soil infiltration rate. Water should not be applied to soils at a rate greater than the rate at which soils can absorb water. Table 3 lists the typical infiltration rates of several soils.

Table 3. Soil Infiltration Rates Based on Soil Texture

Soil Texture	Soil Infiltration Rate (inch/hour)
Coarse sand	0.75 - 1.00
Fine sand	0.50 - 0.75
Fine sandy loam	0.35 - 0.50
Silt loam	0.25 - 0.40
Clay loam	0.10 - 0.30

There is no simple method to accurately schedule irrigations since all the above factors interact to determine water loss. Research is currently under way to develop methods for growers to use in scheduling irrigations. The following factors should be kept in mind when deciding when and how much to irrigate:

1. Soils vary greatly in water-holding capacity and infiltration rate. Silt and clay soils and those high in organic matter can hold much more water than sandy soils low in organic matter.
2. Water loss from plants is much greater on clear, hot, windy days than on cool, overcast days. During periods of hot, dry weather, ET rates may reach 0.25 inch/day or higher. ET can be estimated by the use of a standard evaporation pan (check with your county extension office for information on using pans).
3. Results from recent research indicate that maintaining soil moisture levels in a narrow range, just slightly below field capacity (75 to 90 percent soil moisture), maximizes crop response. This may mean that more frequent irrigations of smaller amounts are better than delaying irrigations until the soil moisture reaches a lower level (40 to 50 percent soil moisture) and then applying a heavy irrigation.
4. Mulches reduce evaporation from the soil but also reduce the amount of water that can reach the root zone from rains. Thus, much of the natural precipitation should be ignored when scheduling irrigations for crops grown under plastic mulch.
5. In general, apply 0.25 inch of water or more in any one irrigation, except when used for establishing crops.

Trickle Irrigation

Trickle (or drip) irrigation is a method of slowly applying small amounts of water directly to the plant root zone. Water is applied frequently, often daily, to maintain favorable soil moisture conditions. The primary advantage of trickle irrigation systems is that less water is used than with sprinkler or surface irrigation systems. In many cases, one-half of the water applied with sprinkler or surface systems is required with trickle systems. In addition, fertilizers applied through the trickle irrigation system are conserved along with water. Trickle irrigation is used on a wide range of fruit and vegetable crops. It is especially effective when used with mulches; on sandy soils; and on crops such as muskmelons, watermelons, squash, peppers, eggplants, and tomatoes.

Trickle irrigation systems also have several other advantages over sprinkler and surface irrigation systems. Low flow rates and operating pressures are typical of trickle systems. These characteristics lead to lower energy and equipment costs. Once in place, trickle systems require little labor to operate, can be automatically controlled, and can be managed to apply precisely the amount of water needed by the crop. These factors also reduce operating costs.

With most trickle systems, disease and insect damage is reduced because leaves are not wetted. The areas between rows also remain dry. This reduces weed growth between rows and reduces the amount of water lost to weeds. In addition, field operations can continue during irrigation.

There are also several potential problems which are unique to trickle irrigation systems. Most of these require that a higher level of management be used with trickle systems than is used with other irrigation systems. Moisture distribution in the soil is limited with trickle systems. In most cases, a smaller soil water reserve is available to plants. Under these conditions, the potential to stress plants is greater than with other types of irrigation systems. This requires that the trickle system be carefully managed.

The equipment used in trickle systems also presents potential problems and drawbacks. Trickle equipment can be damaged by insects, rodents, and laborers, and often has a higher initial investment cost than other system types. Pressure regulation and filtration require equipment not commonly found on sprinkler or surface systems. The trickle system, including pump, headers, filters, and connections must be checked and ready to operate before planting. Failure to have the system operational could result in costly delays, poor plant survival or irregular stands, and reduced yield. In addition, it is not practical to use trickle systems for frost control and the irrigation of solid-stand crops, such as forages and cereals.

Calculating the length of time required to apply a specific depth of water with a trickle irrigation system is more difficult than with sprinkler systems. Unlike sprinkler systems, trickle systems apply water to only a small portion of the total crop acreage. Usually, a fair assumption to make is that the mulched width approximates the extent of the plant root zone and should be used to calculate system run-times. Table 4 has been prepared to calculate the length of time required to apply one inch of water with a trickle irrigation system, based on the trickle tube flow rate and the mulched width. The use of this table requires that the trickle system be operating at the pressure listed in the manufacturers specifications.

On coarse-textured soils, applying an inch of water to the mulched width may be inappropriate. Doing so can move water below the plant root zone, carrying nutrients and pesticides beyond the reach of the plant roots. Table 5 has been prepared to calculate the maximum recommended irrigation period for trickle irrigation systems. The irrigation periods listed are based on the assumption that 50 percent of the available water in the plant root zone is depleted (see next section on the use of tensiometers for determining when this occurs). Soil texture directly influences the water-holding capacity of soils and, therefore, the depth reached by irrigation water. The irrigation periods listed in Table 5 will result in a water infiltration depth of 12-18 inches.

Table 4. Hours Required to Apply 1 Inch Water to Mulched Area

Trickle Tube Flow Rate		Mulched Width (ft)				
(gph/100 ft)	(gpm/100 ft)	2.0	2.5	3.0	3.5	4.0
8	0.13	15.5	19.5	23.5	27.0	31.0
10	0.17	12.5	16.5	18.5	22.0	25.0
12	0.20	10.5	13.0	15.5	18.0	21.0
16	0.27	8.0	10.0	11.5	13.5	15.5
18	0.30	7.0	8.5	10.5	12.0	14.0
20	0.33	6.0	8.0	9.5	11.0	12.5
24	0.40	5.0	6.5	8.0	9.0	10.5
30	0.50	4.0	5.0	6.0	7.0	8.5
36	0.60	3.5	4.5	5.0	6.0	7.0
40	0.67	3.0	4.0	4.5	5.5	6.0
42	0.70	3.0	4.0	4.5	5.0	6.0
48	0.80	2.5	3.0	4.0	4.5	5.0
50	0.83	2.5	3.0	4.0	4.5	5.0
54	0.90	2.5	3.0	3.5	4.0	4.5
60	1.00	2.0	2.5	3.0	3.5	4.0

Table 5. Maximum Irrigation Periods (Hours) for Trickle Irrigation Systems

Trickle Tube Flow Rate		Soil Texture				
(gph/100 ft)	(gpm/100 ft)	Sand	Loamy Sand	Sandy Loam	Clay Loam	Silt Loam
12	0.2	5.0	8.0	11.5	15.5	17.5
18	0.3	3.5	5.0	7.5	10.5	11.5
24	0.4	2.5	4.0	5.5	8.0	8.5
30	0.5	2.0	3.0	4.5	6.5	7.0
36	0.6	1.5	2.5	4.0	5.0	6.0
42	0.7	1.5	2.0	3.0	4.5	5.0
48	0.8	1.5	2.0	3.0	4.0	4.5

Trickle irrigation scheduling with tensiometers. Irrigation scheduling is a management practice used to determine how often to irrigate and how much water to apply with each irrigation. Irrigation duration was discussed in the previous section, and should be based on soil available water-holding capacity, soil moisture depletion level, and trickle tube flow rate. Tensiometers are excellent tools for determining irrigation frequency.

Tensiometers measure soil tension. This is also often referred to as soil suction or vacuum. Soil tension is a measure of how tightly water is held in the soil, and is measured in pressure units of centibars (cb) or kilopascals (kPa). These are equivalent units. One hundred centibars equal approximately 15 psi.

Soil tension increases as moisture in the soil is depleted. This force also draws water out of the tensiometer through its porous tip, creating a vacuum inside the tensiometer. This negative pressure, or tension, is registered on the tensiometer vacuum gauge. The soil tension measured with tensiometers is an indirect indication of soil moisture content and can be used as an indicator of irrigation need.

Table 6 contains guidelines for using soil tension data to schedule irrigation events. Field capacity is the moisture content at which a soil is holding the maximum amount of water it can against the force of gravity. This moisture content is reached 24 to 72 hours after a saturating rain or irrigation. Field capacity corresponds to soil tension levels ranging from 5 to 10 cb in coarse-textured soils and as high as 40 cb in fine-textured soils.

Table 6. Irrigation Guidelines When Using Tensiometers

Soil Texture	Soil Tension (cb)	Soil Moisture Status and Irrigation Requirement
Sand, loamy sand	5 - 10	Soil at field capacity; no irrigation required
Sandy loam, loam, silt loam	10 - 20	
Clay loam, clay	20 - 40	
Sand, loamy sand	20 - 40	50% of available water depleted; irrigation required
Sandy loam, loam, silt loam	40 - 60	
Clay loam, clay	50 - 100	

The soil tension range corresponding to the time when irrigation should begin is also influenced by soil texture. In coarse-textured soils, irrigation should begin at soil tensions of 20 to 40 cb. In extremely coarse-textured soils, irrigation may be necessary at even lower tensions. Medium- and fine-textured soils do not need to be irrigated until soil tensions reach higher values, as shown in Table 6. In all soils, irrigate when 50 percent of available water has been depleted.

The utility of tensiometers in fine-textured soils is limited because of the upper limit of tension that can be measured with tensiometers. When soil dries beyond the 80 cb tension level, the column of water in the tensiometer "breaks," allowing air to enter the device. After breaking tension, the device ceases to operate correctly until it is serviced. Thus, tensiometers are more practical in coarse-textured soils where appropriate soil tension levels are well below the point of breaking tension.

Use four tensiometers per management zone to account for variability in soil texture. Install at least one in the most droughty area of the zone that will require water sooner than other areas of the field.

Tensiometer placement influences measured soil tension levels. Tensiometers should be placed where plant roots are actively growing. Therefore, it is appropriate to monitor soil tension 6-12 inches below the soil surface and within 6-12 inches from the plant base. If using trickle irrigation, place the tensiometer close to the trickle tape or hose. This will insure that tensiometer readings decrease when an irrigation occurs. Placement near the trickle tape is even more important when growing in coarse-textured soils and on raised, mulched beds. In these situations, the bed shoulders often remain very dry. Placing tensiometers in the bed shoulders will not give an accurate measure of soil tension in the active crop root zone.

Tensiometers can also be used in other ways. Placing tensiometers at various soil depths at the same location is useful for determining whether or not an irrigation or rainfall has reached a certain depth. Placing tensiometers at various depths is also useful for determining the depth from which plants draw the most water.

Maintaining trickle systems with chlorine. In trickle systems, water is carried through plastic tubing and distributed along the tubing through devices called emitters. The emitters dissipate the pressure from the system by forcing the water exiting from an emitter through orifices, tortuous flow paths, or long flow paths, thus allowing a limited flow of water to be discharged. The pressure-reducing flow path also allows the emitter to remain relatively large, allowing particles that could clog an emitter to be discharged.

Although modern emitter design reduces the potential for trapping small particles, emitter clogging remains the most serious problem with trickle irrigation systems. Clogging can be attributed to physical, chemical, or biological contaminants. Filtration and occasional water treatment may both be necessary to keep trickle systems from clogging.

Bacteria can grow inside trickle irrigation tubes and form a slime that can clog emitters. Algae present in surface waters can also clog emitters. Bacteria and algae can be effectively controlled by chlorination of the trickle system. Periodic treatment **before** clogging develops can keep the system functioning efficiently. The frequency of treatment depends on the quality of the water source. Generally two or three treatments per season should be adequate.

Irrigation water containing high concentrations of iron (greater than 1 ppm) can also result in clogging problems due to a type of bacteria that "feed" on dissolved (ferrous) iron. The bacteria secrete a slime called ochre that may combine with other solid particles in the trickle tubing and plug emitters. The precipitated (ferric) form of iron, known commonly as rust, can also physically clog emitters. Treating water containing iron with chlorine will oxidize the dissolved iron, causing the iron to precipitate so that it can be filtered and removed from the system. **Chlorine treatment should take place upstream of filters in order to remove the precipitated iron and microorganisms from the system.**

Chlorine is available in either gas, liquid, or solid forms. Chlorine gas is extremely dangerous and not recommended for agricultural purposes. Solid chlorine is available as granules or tablets containing 65 to 70 percent calcium hypochlorite. Liquid chlorine is available in many forms, including laundry bleach and postharvest wash materials. Liquid forms typically contain between 5 and 15 percent sodium hypochlorite. **Use chlorine only if the product is labeled for use in irrigation systems.**

Since chlorination is most effective at pH 6.5 to 7.5, some commercial chlorination equipment also injects buffers to maintain optimum pH for effective kill of microorganisms. This type of equipment is more expensive but more effective than simply injecting sodium hypochlorite solution. The rate of chlorine injection required is dependent on the amount of microorganisms present in the water source, the amount of iron in the irrigation water, and the method of treatment being used. To remove iron from irrigation water, start by injecting 1 ppm of chlorine for each 1 ppm of iron present in the water. **For iron removal, chlorine should be injected continuously**. Adequate mixing of the water with chlorine is essential. For this reason, be certain to mount the chlorine injector 50 to 100 feet upstream from filters. An elbow between the injector and the filter will also insure adequate mixing.

For treatment of algae and bacteria, a chlorine injection rate that results in the presence of 1 to 2 ppm of "free" chlorine at the end of the furthest lateral will assure that the proper amount of chlorine is being injected. Free, or residual, chlorine can be tested using an inexpensive DPD (diethyl-phenylene-diamine) test kit. A swimming pool test kit can be used but it must measure free chlorine. Many pool test kits measure only total chlorine.

If you are without a chlorine test kit, one of the following schemes is suggested as a starting point:

For iron treatment:

Inject liquid sodium hypochlorite continuously at a rate of 1 ppm for each 1 ppm of iron in irrigation water. In most cases, 3 to 5 ppm is sufficient.

For bacteria and algae treatment:

Inject liquid sodium hypochlorite continuously at a rate of 5 to 10 ppm where the biological load is high.

Inject 10 to 20 ppm during the last 30 minutes of each irrigation cycle.

Inject 50 ppm during the last 30 minutes of irrigation cycles one to two times each month.

Superchlorinate (inject at a rate of 200 to 500 ppm) once per month for the length of time required to fill the entire system with this solution and shut down the system. After 24 hours, open the laterals and flush the lines.

Chlorine can be injected using many types of fertilizer/pesticide injectors, including positive displacement injection pumps. These types of pumps are powered by gasoline or electric motors and include piston, diaphragm, gear or lobe, and roller (or peristaltic) types. The injection rate for positive displacement injection pumps can be calculated from the following equation:

$$\text{Injection rate of chlorine solution in gallons/hour} = \frac{(0.006) \times (\text{desired chlorine concentration in ppm}) \times (\text{gpm of irrigation})}{\text{\% chlorine in bleach or concentrate}}$$

As an example, assume household bleach (5.25% sodium hypochlorite) is being used as a chlorine solution, that a treatment level of 5 ppm of chlorine is desired, and that the trickle system has a 200-gallon-per-minute flow rate.

$$\text{Injection rate} = \frac{0.006 \text{x} 5 \text{x} 200}{5.25} = 1.14 \text{ gal chlorine bleach/hour}$$

Proportional injectors are also commonly used to inject chlorine. Proportional injectors are powered by the water pressure of the irrigation system and inject materials at a rate which is proportional to the irrigation system flow rate or system pressure. Injection rates are often adjustable and are usually specified as ratios, percentages, or ppm. Table 7 lists equivalent values of these injection rate units.

For proportional injectors, the following equation can be used to calculate the required chlorine solution injection rate:

$$\text{Injection rate of chlorine solution in ppm} = \frac{(100) \times (\text{desired chlorine concentration in ppm})}{\text{\% chlorine in bleach or concentrate}}$$

As an example, assume postharvest wash material (12.5% sodium hypochlorite) is being used as a chlorine solution and that a treatment level of 10 ppm of chlorine is desired.

$$\text{Injection rate} = \frac{100 \text{ x } 10}{12.5} = 80 \text{ ppm}$$

It is important to note that both liquid and solid forms of chlorine will cause water pH to rise. This is critical because chlorine is most effective in acidic water. If water pH is above 7.5, it must be acidified for chlorine injection to be effective.

Table 7. Equivalent Injection Proportions

Ratio	ppm	Percent
1:10,000	100	0.01
1:5,000	200	0.02
1:2,000	500	0.05
1:1,000	1,000	0.1
1:500	2,000	0.2
1:200	5,000	0.5
1:100	10,000	1
1:50	20,000	2
1:20	50,000	5
1:10	100,000	10

Important Notes.

1. **Approved backflow control valves and interlocks must be used in the injection system to prevent contamination of the water source.**
2. **Chlorine concentrations above 30 ppm may cause phytotoxicity.**

Fertilization. Before considering a fertilization program for mulched-trickle irrigated crops, the grower should have the soil pH checked. If a liming material is needed to increase the soil pH, the material should be applied and incorporated into the soil as far ahead of mulching as practical. For most vegetables, adjust the soil pH to around 6.5.

When using trickle irrigation in combination with mulch, apply the recommended amount of preplant fertilizer and incorporate 5-6 inches into the soil before laying the mulch. If equipment is available, apply the preplant fertilizer to the soil area that will be covered by the mulch. This is more efficient than a broadcast application to the entire field.

The most efficient method of fertilizing an established mulched row crop is through a trickle irrigation system which is usually installed during the mulching operation. Due to the very small holes or orifices in the trickle tubing, a completely soluble fertilizer must be used through the irrigation system. Best results have been achieved by using a 1-1-1 (N-P_2O_5-K_2O) ratio of completely soluble fertilizer, such as a 20-20-20. Including the essential micronutrients with the completely soluble N-P_2O_5-K_2O fertilizer has resulted in positive yield responses. Including boron with the completely soluble N-P_2O_5-K_2O fertilizer on sandy loam Coastal Plain soils testing low to low-medium in boron has produced superior results.

***Fertilized-mulched acre*:**
All rates of soluble fertilizers applied through the trickle irrigation system are determined on a 3-foot soil surface area under the plastic mulch (fertilized-mulched acre), even though the crops are grown on 5-foot rows.

A fertilized-mulched acre is an acre (43,560 square feet) of fertilized-mulched soil. A fertilized-mulched acre is the surface area of soil covered by the mulch. For example, when 4-foot-wide plastic is laid on 5-foot row centers with 6 inches of each edge buried, 2 feet of the 5-foot row is uncovered and 3 feet is covered with mulch. This means that 3/5, or 60 percent, of the field acre is mulched and fertilized with trickle. All recommendations for fertilization through trickle are based on a fertilized-mulched acre.

***Calculating fertilizer rates for trickle under mulch*:**

1. First, determine the number of fertilized-mulched acres in the field using the following formula:

$$\frac{\text{width of soil surface covered by mulch (ft)}}{\text{row center width (ft)}} \text{ x field acres} = \text{fertilized-mulched acres}$$

Example:

$$\frac{\text{3 feet}}{\text{5 feet}} \text{ x 10 field acres} = \text{6 fertilized-mulched acres}$$

Using the same mulch and bed width example:

1-2/3 field acres or 14,520 lin ft of mulched row = 1 fertilized-mulched acre

2. Second, calculate the fertilizer requirements for a fertilized-mulched acre.

   a. *Example for a soluble dry fertilizer to be dissolved and distributed through trickle.*
   If 40 pounds of nitrogen (N), 40 pounds of phosphate (P_2O_5), and 40 pounds of potash (K_2O) per fertilized-mulched acre per application are recommended, select a dry, completely soluble fertilizer with a 1-1-1 ratio, such as a 20-20-20. To determine the amount of 20-20-20 needed per fertilized-mulched acre, divide the percent N, P_2O_5, or K_2O contained in the fertilizer into the quantity of the respective plant nutrient needed per acre and multiply the answer by 100.

$$\frac{\text{40 lb N/A needed}}{\text{20\% N in fertilizer}} = 2 \text{ x } 100 = \text{200 lb of 20-20-20 needed per fertilized-mulched acre}$$

   b. *Example for a liquid fertilizer distributed through trickle.*

   Assume the same 40 lb N-P_2O_5-K_2O is needed and a 10-10-10 liquid is used. If a gallon of this fertilizer weighs 10 pounds, 40 gallons of 10-10-10 liquid fertilizer per fertilized-mulched acre per application is required.

1 gal (10 lb) of 10-10-10 contains:
10 lb x .10 (10% N) = 1 lb N in each gallon

$$\frac{\text{40 lb N/A needed}}{\text{1 lb N/gal of 10-10-10}} = \text{40 gal of 10-10-10 needed per fertilized-mulched acre}$$

3. Conversion of fertilizer rates from mulched acre to linear foot equivalent.
When mulched beds are on 4.5- to 5.5-foot centers with 3 feet of the soil surface covered by mulch, the pounds of nutrients or fertilizer per mulched acre can be converted to pounds per linear feet of mulched row. A mulched acre on 5-foot centers has 14,520 linear feet of mulched row. See example in 1. above.

   Example: If 40 pounds of nitrogen (N), phosphate (P_2O_5) and potash (K_2O) are to be applied (equal to 200 pounds of 20-20-20 per fertilized-mulched acre in example 2a. above) then apply 200 pounds 20-20-20 per 14,520 linear feet or 13.8 pounds of 20-20-20 per 1,000 linear feet of mulched row.

See table below for convenient conversion of fertilizer rates from pounds of nutrient per mulched acre to pounds of nutrient per linear foot of mulched row. This conversion can be used when mulch is laid on 4.5 to 5.5 row centers.

Equivalent Pounds of Nutrients

Mulched Acre	1,000 Linear Feet
0.5	0.034
1	0.069
2	0.138
5	0.344
10	0.69
15	1.03
20	1.38
25	1.72
30	2.07
35	2.41
40	2.75
45	3.10
50	3.44

Chemigation. Chemigation is the application of any pesticide through any irrigation system and includes furrow, border, overhead and trickle irrigation systems.

Posting of areas to be chemigated is required when (1) any treated area is within 300 feet of sensitive areas such as residential areas, labor housing, businesses, hospitals, or any public areas such as schools, parks, playgrounds, etc., or (2) when the chemigated area is open to the public such as golf courses or retail greenhouses.

Rates of water penetration and percolation vary with method of irrigation, soil type, texture, organic matter, pH, slope and grade. Irrigate to first wet the root zone, then introduce the pesticide uniformly over the crop being irrigated. After chemigation, flush the irrigation system with fresh water. Do not overwater to avoid removing the pesticide from the root zone.

The pesticide label must allow the use of chemigation before any pesticide can be applied in the irrigation system. Consult label for all rates and restrictions before use.

Chemigation systems connected to public water systems:
These systems must contain a functional, reduced-pressure zone, backflow preventer or the functional equivalent in the water supply line upstream from the point of pesticide introduction. The pesticide injection pipeline must contain a functional, automatic, quick-closing check valve to prevent flow of fluid back toward the injection pump. The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the system is either automatically or manually shut down. A functional interlocking control to automatically shut off the pesticide injection pump when the water pump motor stops is also required, or if there is no water pump, when the water pressure decreases to the point where pesticide distribution is adversely affected.

Chemigation systems must use a metering pump, such as a positive displacement pump capable of being fitted with a system interlock.

Trickle and overhead systems:
These systems must contain a functional check valve, vacuum relief valve and low pressure drain on the irrigation pipeline to prevent water source contamination from backflow. The pesticide pipeline

must contain a functional, automatic, quick-closing check valve to prevent the flow of fluid back to the injection pump.

The pesticide injection pipeline must also contain a functional, normally closed, solenoid-operated valve located on the intake side of the injection pump and connected to the system interlock to prevent fluid from being withdrawn from the supply tank when the system is either automatically or manually shut down.

The system must also contain a functional interlocking control to automatically shut off the pesticide injection pump when the water pump motor stops.

The water pump must also include a functional pressure switch which will stop the water pump when the water pressure decreases to the point where pesticide distribution is adversely affected.

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