*Cooperative Extension, University of California*

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***A newsletter from the University of California Cooperative Extension seeking to support productive and judicious use of limited water and land resources in the Northern Sacramento Valley.***

## In This Issue



## Irrigation Management for Almond Trees with a Limited Water Supply

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For maximum growth, yield, crop quality and orchard longevity almonds trees should be supplied with water to meet their full water requirement. There are some disease concerns with hull rot under full water conditions which can be addressed with moderate water stress during hull split. If water availability is limited, growers can react by applying irrigation water when trees are most sensitive to stress and by taking measures to minimize water losses that occur during irrigation events. Supplying less water than the trees can potentially use reduces soil water availability, causes tree water deficits, and reduces transpiration. Cover crops, depending on the coverage and the time of the season can increase the orchard water use by up to 30%. Cover crops should be removed when water is in limited supply.

***A twelve year old almond orchard irrigated with microsprinklers***

Water deficits affect almond orchards not only in the year in which stress occurs, but also in the following seasons. Generally, nut size is reduced in the first season of significant water stress. Because water stress also reduces vegetative growth and potentially decreases productivity per unit canopy volume, nut load can be reduced in subsequent years. Recent research indicates some stages of almond fruit growth are more sensitive to water stress than others. Understanding these stages permits growers to minimize damage to trees and to current and subsequent crops when water is in short supply.

**EARLY SEASON STRESS.** Water stress may affect more tree and crop development processes during the early season – from leaf out through shoot growth and development of terminal and lateral buds. During this period, rapid vegetative development is necessary for canopy development and fruiting positions for the following season. In addition, orchard water use during this time is low compared to summer demand, reducing potential water savings from an early-season deficit irrigation strategy.

***Almonds just after petal drop from the spring bloom. Small fruit begin to develop and the rate of almond hull and nut growth will be rapid for the next several weeks.***

**FRUIT GROWTH AND DEVELOPMENT.** Nuts undergo a rapid growth phase early in the fruit growth and development period and are sensitive to water deficits during this time. Trees can tolerate drought stress fairly well during the two months prior to harvest, allowing for the successful use of deficit irrigation strategies during this period. Providing less than the full water requirement to cause moderate water stress during this period will have little influence on kernel weight. However, severe water stress in the months leading up to hull split will reduce kernel weight and significantly reduce hull splitting. The challenge is to manage for moderate crop stress but not lapse into severe crop stress. In this situation, monitoring orchard water status with a pressure chamber can be very helpful or applying a one-inch irrigation prior to hull split will mitigate stress impacts and will improve hull split and reduce the number of hull-tights. If drip irrigation is used possibly less irrigation can provide the same benefit, but this has not been proven in the field.

***Early stages of hull split in an almond orchard usually occurring in early or mid July depending on the variety and season and leading up to harvest.***

**POST HARVEST STRESS.** The effect of water deficits during the postharvest period are substantially affected by 1) pre-harvest water deficits and 2) the quantity of water use over the remainder of the season. Bud differentiation can continue through mid-September. Moderate stress during this period will have little effect on subsequent year's nut numbers, but severe stress during bud differentiation has been found to dramatically reduce fruit set the following spring. In early harvest (early August) districts, particularly with early varieties, more of the high water use season remains after harvest. This increases the necessity for postharvest irrigation. Later harvest (north State) districts and later varieties have a shorter postharvest period, which occurs at a time of lower crop water demand. These factors reduce the chance of moderate water deficits causing bud differentiation problems.

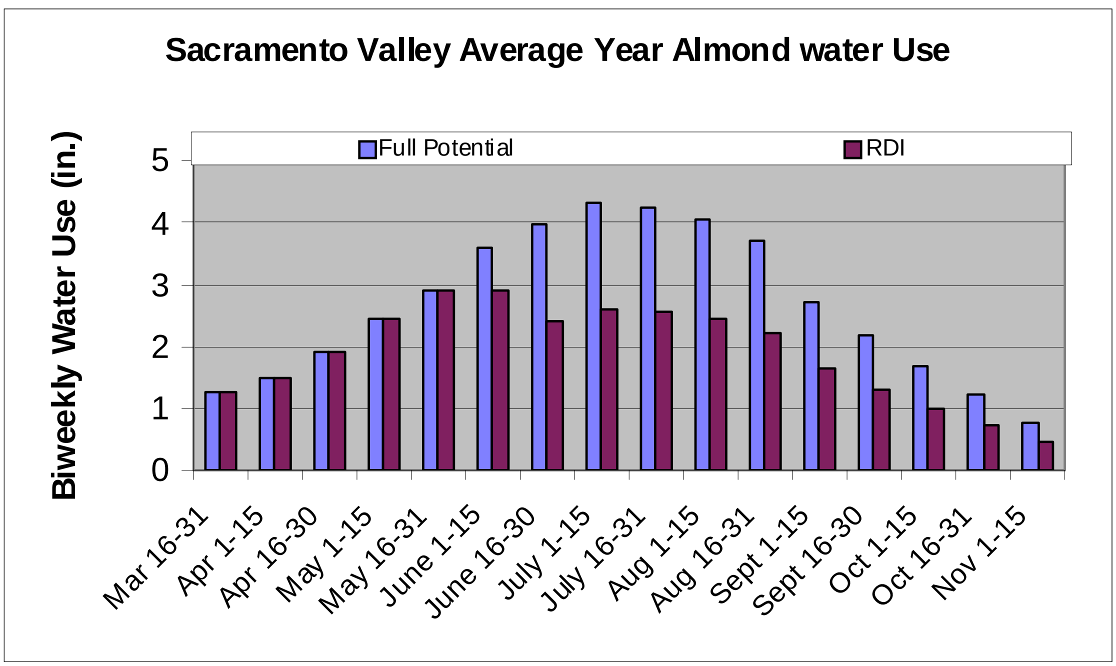
Tree response to postharvest stress can be influenced by the type of irrigation system used and the previous irrigation management. Low volume systems with limited soil water reserves can result in severe water deficits very quickly after irrigation cut off. In the southern San Joaquin Valley where harvest is earlier than in the north, or with drought-sensitive varieties, postharvest irrigation is a necessity. Deep rooted, surface irrigated trees may have enough pre-harvest deep moisture remaining to carry them through the critical period of bud differentiation. This all depends on the irrigation management occurring pre-harvest.

**DEFICIT IRRIGATION STRATEGY.** Almond water use begins when the leaves develop and shoot growth begins. Concurrent with canopy development, the climatic demand increases, driven by longer days, higher temperatures, and lower humidity as the season progresses. Both of these factors result in a seasonal water use starting at a low level, peaking in mid-season and falling as season ends. Sources of water available to trees include: soil-stored moisture (including frost protection water applications if the root zone is less than field capacity when applications are made), any in-season rainfall absorbed by the soil, and applied irrigation water. These all combine to determine the total seasonal water available to the orchard.

Mature conventionally spaced almond trees in the Sacramento Valley can use about 41 to 44 inches of water per acre in an average year of unrestricted water use. Figure 1 shows a typical water use pattern for fully irrigated almonds in the Sacramento area. High-density orchards, long pruned orchards, or those with a cover crop can have even higher use. Soil moisture monitoring demonstrations in more than 40 almond orchards in Kern County indicate that seasonal water use in the southern San Joaquin Valley may be as high as 50 – 54 inches.

**WATER DEFICITS.** Figure 1 also shows the water use pattern for an almond orchard in the Sacramento area that was managed using a deficit irrigation strategy. The moderately deficit irrigated orchard used 28 inches of water (a combination of soil supplied and irrigation water) or about 34 % less than the full potential use for an orchard. Water deficits occur when the climatic water demand exceeds the water absorbed by the roots. As the soil becomes depleted of readily available moisture water uptake by the roots lags behind water use causing plant stress in the mid to late afternoon. Water stress increases as the soil water becomes increasingly difficult to extract. One way to measure "tree stress" is to use a portable pressure chamber to measure "stem water potential". To use this technique a few leaves from representative trees are first covered with an opaque plastic bag while still on the tree. The covers need to remain on the leaves at least 10 minutes before they are detached from the tree and the water potential is measured using a pressure chamber. The pressure chamber measures the amount of pressure needed to force water out of the leaf petiole, indicating the trees water status. Refer to http://cetehama.ucdavis.edu/files/37294.pdf for more information on measuring orchard crop water status with a pressure chamber.

***Figure 1. Typical water use for fully irrigated almonds in the Sacramento Valley and an example of the effect of deficit irrigation on water use.***



**MODERATE WATER STRESS STRATEGY.** From the previous discussion it can be concluded that tree water use from leaf out through mid June should not be compromised. From mid June through harvest, reductions up to 50% of full water use have been successfully used to reduce orchard water use with only minimal reductions in kernel weight. It is important to supply the trees with water near hull split to avoid hull-tights.

There are various approaches growers can take to manage limited water supplies depending upon what types of irrigation scheduling tools interest or are available to them. One relatively effective approach that doesn't rely heavily on field monitoring is to attempt to sustain crop stress uniformly across all stages of tree growth and crop development by using estimates of full potential crop ET. The limited water allocation is applied as a consistent percentage of the seasonal water use pattern. If 24 inches of irrigation water are available, representing about 60 percent of the potential water use, then the irrigation water would be allocated at about 60 percent of real-time or historic rates (see Figure 1) of full potential crop ET over the course of the season. Reductions in irrigation run time or lengthening irrigation intervals can be used to obtain the desired percentage of full potential crop ET.

In a four-year study, almonds were produced with 55, 70, 85 and 100 percent of a 42-inch water allocation. Water was either cut back as a consistent percentage of full potential crop ET to try to sustain less pronounced crop stress across all stages of crop growth, or cutbacks targeted only pre-harvest, or post-harvest crop stages for higher crop stress. The effect of limited water supply was minimized with uniform allocation of water across all crop stages. However, productivity was reduced particularly with 55 and 70 percent allocations. The uniform crop stress strategy gave both the highest four-year yields, and the largest average nut size within each water allocation. The 70% and 85% allocations applied uniformly across the season experienced little early season stress, likely because stored soil moisture supplemented the applied irrigations.

Another approach, that is likely to be an improvement over the approach outlined above, is to schedule irrigations using periodic pressure chamber readings and irrigate when stem water potential reaches a pre-determined threshold stress level. This method effectively extends the irrigation interval, but the interval is determined by tree water status rather than according to a percentage of full potential crop ET or the calendar. Irrigations should be in the volume of a normal set as performed with a full irrigation regime. In a deficit irrigation study conducted on mature almond orchard in the Manteca, a threshold value of –16 to -18 bars mid-day stem water potential beginning in June resulted in 34% less tree water consumption and no significant influence on yield for the 4-year measurement period. It should be noted that a reduction in vegetative growth was measured in this treatment, indicating that use of this threshold for a longer-term strategy (more than 4 years) may reduce yields by reducing nut numbers. Crop stress is much more detrimental on a developing tree canopy than on one that has already reached its full volume.

**MORE SEVERE WATER STRESS STRATEGY.** A more severe strategy that reduces seasonal tree water use by 50% requires that stress be imposed early as well as mid to late season. Using this strategy, irrigations in April and May are withheld until trees reach a midday stem water potential of -12 to -14 bars. Using conventional sprinklers, a normal set time is used. If lighter applications are made, more water is lost by evaporation. From June 1st through hull split, midday stem water potential values should be allowed to reach -20 to -22 bars. This strategy will require a pre-harvest irrigation of about 2 inches with sprinklers—less with micros and drip--to ensure good hull split. Note: this strategy reduces water use significantly but also reduces nut weight the year it is used and the nut number in succeeding years. In the Manteca trial discussed above, it took 2 years of full irrigation for trees to recover.

**"STAYING ALIVE" DROUGHT STRATEGY.** Less is known about this strategy since it is a rarely used option. However, based on past drought conditions, trees may be kept alive with about a foot of applied water. This strategy does not consider growth and yield—just tree survival. This strategy is best conducted using a micro-irrigation system which maximizes water distribution and minimizes evaporative losses from irrigation. Using this strategy no irrigation is applied until water potential reaches -16 bars from leaf out through the end of May. Monitor stem water potential until the threshold is reached again then repeat the cycle. After June 1st, and for the rest of the season allow the stress to climb to -25 bars. As a guide, try to just retain the leaves on the tree. Remember this is a severe deficit strategy, it will take at least 2 years of full irrigation for the trees to recover to normal yields.

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## Sources of Irrigation Scheduling Tools

**Real-time Estimates of Crop ET.** The California Department of Water Resources and the University of California Cooperative Extension work together to provide weekly soil moisture loss reports during the irrigation season for some of the major crops, including almonds, grown in the Sacramento Valley. These reports provide estimates of full potential crop ET for each crop based on current weather conditions. They are published weekly in the following area newspapers:

- Happy Valley Times
- Anderson Valley Post
- Red Bluff Daily News
- Corning Observer
- Orland Press Register
- Chico Enterprise Record
- Willows Journal
- Colusa County Sun Herald

These reports are also available at http://cetehama.ucdavis.edu. When accessing reports at this website select “Irrigation and Water Resources”, the second menu item listed in the center of the home page. When the second web page is in view, select “Weekly Soil Moisture Loss Reports” from the menu on the left.

**Pressure Chamber Suppliers.** As discussed in the previous article on almond irrigation, using a pressure chamber to monitor orchard crop water status can be useful. Pressure chambers are available from:

PMS Instrument Company
1725 Geary Street SE Albany, OR 97322
Phone: (541)-704-2299
Fax: (541)-704-2388
info@pmsinstrument.com
http://www.pmsinstrument.com

Soil Moisture Equipment Corp.
801 S. Kellog Ave.
Goleta, CA 93117
Phone: (805)-964-3525
Fax: (805)-683-2189
http://www.soilmoisture.com

**Soil Moisture Monitoring.** Soil moisture monitoring tools are available and can be used to help guide water management decisions. In recent years, there have been substantial advances with high frequency soil moisture monitoring that can conveniently provide clear trends in soil moisture status within the crop root zone. Some suppliers of soil moisture monitoring equipment include:

**Capacitance Probes and Telemetry**

Irrigate.Net
1770 Serenity Way
Chico, CA 95928
Phone: 530-893-4520
Fax: 530-893-1342
http://www.irrigate.net

AdCon Telemetry
2050 Lyndell Terrace, Suite 120
Davis, CA 95616
(530)-753-1458
http://www.sowacs.com

**Resistance Blocks and Dataloggers**

Irrometer Company
P.O. Box 2424
Riverside, CA 92516
Phone: (951)-689-1701
Fax: (951)-689-3706
http://www.irrometer.com

M. K. Hansen Company
2216 Fancher Blvd.
East Wanatchee, WA 98802
Phone: (509)-884-1396
Fax: (509)-884-3318
http://www.mkhansen.com

***Note:*** *This is a partial list and endorsements of specific products and suppliers are not intended by listing these providers of water management tools.*

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## Controlling Biological Clogging of Drip and Microsprinkler Irrigation Systems with Chlorination

Allan Fulton and Larry Schwankl, UCCE

Chlorine is often added to irrigation water to oxidize and destroy biological microorganisms such as algae, fungi, and bacteria. While these microorganisms may be present in any water source, they are most likely to exist at high levels in surface water from reservoirs, canals, and ponds. When water containing high levels of microorganisms is introduced into a drip or microsprinkler system, it may clog emitters and reduce irrigation uniformity and the average hourly rate of water application. In turn, this may influence the adequacy of an irrigation schedule if an irrigation system no longer performs as it was originally designed.

Using a good filter is the first line of defense to prevent clogging of irrigation systems but some biological organisms will pass through the filter into the irrigation system. If left unattended these organisms can multiply and lead to clogging. Chlorination or some other biocide will be needed to prevent biological clogging or recover a system that has already been affected.

**HYPOCHLOROUS ACID.** Adding chlorine to water mainly produces hypochlorous acid and hypochlorite, in combination referred to as free chlorine. Hypochlorous acid is the primary biocide agent. The concentration of hypochlorous acid that forms in a water supply is dependent on the pH of the water. Irrigation water supplies with pH less than 7.0 will have less or no effect on the availability of hypochlorous acid and will have the greatest reactivity on biological organisms. As the pH of the irrigation water increases the availability of hypochlorous acid and its reactivity declines. Table 1 below illustrates this effect in more detail. Water supplies with a pH above 7.0 require that either higher concentrations of chlorine be injected to account for the negating effect of high pH on hypochlorous acid reactivity or add acid to the water supply to reduce the water pH. If acid is used to adjust water pH, use a second injection system and port to inject the acid upstream of the port where the chlorine will be injected.

**Table 1.** The effect of water pH on the percentage of chlorine in the hypochlorous acid form.

| pH of Irrigation Water Supply | Percent Hypochlorous Acid |
|---|---|
| | |
| 5 | 99 |
| 5.5 | 98 |
| 6.0 | 97 |
| 6.5 | 88 |
| 7.0 | 75 |
| 7.5 | 44 |
| 8.0 | 24 |
| 8.5 | 10 |
| 9.0 | 4 |

**FORMS OF CHLORINE.** Common sources of chlorine include liquid sodium hypochlorite, granule or powder forms of calcium hypochlorite, and chlorine gas. Liquid sodium hypochlorite includes common household bleach and other more concentrated liquid formulations. Liquid sodium hypochlorite forms can contain between 5.25 % (i.e. household bleach) and up to 15 % available chlorine. Liquid formulations of chlorine are typically diluted in water to prepare a stock solution for injection. Granular or powder forms of calcium hypochlorite normally contain 65 to 70 % available chlorine and require that they be dissolved in water to prepare a stock solution. Note that typical forms of calcium hypochlorite require 12.8 lbs of granules or powder per 100 gallons to prepare a 1% chlorine stock solution. Chlorine gas can be dissolved in water. It contains 100 percent available chlorine to react as a biocide because it lowers the pH of water to a level that results in hypochlorous acid and free chlorine forms.

**CHLORINATION APPROACHES.** There are three approaches to injecting chlorine: 1) continuous injection; 2) periodic injection; and 3) superchlorination. Continuous injection of chlorine at a concentration of 1 to 2 ppm free chlorine at the end of the last lateral in the irrigation system is best suited for irrigation water that has high levels of algae and bacteria. Periodic injection of chlorine at concentrations of 10 to 20 ppm free chlorine at the end of the irrigation system may be appropriate for water supplies that have low or moderate levels of algae and bacteria. Superchlorination is an approach to recover irrigation systems that have been clogged by algae and bacteria, recommended concentrations of free chlorine range from 500 to 1000 ppm at the end of the irrigation system. Superchlorination requires special care to avoid damage to plants and irrigation equipment.

**CHLORINE INJECTION RATES.** Table 2 provides chloride injection rates using three different chloride stock solutions, for irrigation flow rates ranging from 100 to 1500 gpm, and for chlorine concentrations suitable for continuous or periodic injection. The basic equation used to calculate the chlorine injection rates in this table is:

$$IR = (0.006 \times Q \times C) \div S$$

Where,

$IR$ = the injection rate in gallons per hour
$Q$ = irrigation system flow rate in gallons per minute (gpm)
$C$ = desired chlorine concentration in the irrigation water at the injection point
$S$ = the strength or concentration of the chlorine stock solution

Table 2 shows a wide range in possible chloride injection rates. As an example using Table 2, a stock chlorine solution of 1% (prepared by adding granular calcium hypochlorite to water in a storage tank) used for continuous injection of 2 ppm free chlorine into an irrigation system with a flow of 300 gpm requires an injection rate of 3.6 gph. As a second example applying Table 2, where the stock solution is 5.25 % chlorine, the irrigation system flow rate is 1200 gpm, and the desired injection rate is 20 ppm free chlorine, the required injection rate is 27.4 gph. Table 2 also illustrates that some stock solutions and associated injection rates may not be practical for some needs. For example, using a 5.25 % percent stock solution for continuous injection to achieve a 2 ppm free chlorine concentration into irrigation flows of less than 500 gpm requires injection rates less than 1.0 gph, It will be difficult to accurately inject chlorine at these low rates and it is more appropriate to use a less concentrated stock solution, perhaps 0.1 % solution. At the other extreme, a 1% chlorine stock solution injected at 180.0 gph (3.0 gpm) into a 1500 gpm irrigation flow achieves a free chlorine concentration of 20 ppm at the point of injection. This injection rate may be too high for some injection equipment and a more concentrated stock solution of chlorine may be more appropriate. Chlorine gas, the most concentrated source of free chlorine may be better suited for irrigation systems with high flow and where superchlorination is desired. Chlorine gas is hazardous and requires professionally trained personnel to inject it. A different equation than provided above is used to calculate injection rates of chlorine gas.

**Table 2.** Chloride injection rates for different chlorine stock solutions and irrigation flow rates to attain desired concentrations of chlorine in drip and microirrigation systems.

| Irrigation Flow (gpm) | 1 % Chlorine Stock Solution (12.8 lbs Calcium Hypochlorite granules per 100 gallons water) | | | 5.25 % Chlorine Stock Solution (common household liquid chlorine, sodium Hypochlorite) | | | 15 % Chlorine Stock Solution (concentrated sodium Hypochlorite) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Continuous Injection at 2 ppm | Periodic Injection at 20 ppm | Super chlorination at 1000 ppm | Continuous Injection at 2 ppm | Periodic Injection at 20 ppm | Super chlorination at 1000 ppm | Continuous Injection at 2 ppm | Periodic Injection at 20 ppm | Super chlorination at 1000 ppm |
| | Chlorine Injection Rate (gph or *gpm*) | | | | | | | | |
| 100 | 1.2 | 12.0 | *10.0* | 0.2 | 2.3 | *1.9* | 0.1 | 0.8 | 40.0 |
| 200 | 2.4 | 24.0 | *20.0* | 0.5 | 4.6 | *3.8* | 0.2 | 1.6 | *1.3* |
| 300 | 3.6 | 36.0 | *30.0* | 0.7 | 6.9 | *5.8* | 0.2 | 2.4 | *2.0* |
| 400 | 4.8 | 48.0 | *40.0* | 0.9 | 9.1 | *7.6* | 0.3 | 3.2 | *2.6* |
| 500 | 6.0 | 60.0 | *50.0* | 1.1 | 11.4 | *9.6* | 0.4 | 4.0 | *3.4* |
| 600 | 7.2 | *1.2* | *60.0* | 1.4 | 13.7 | *11.4* | 0.5 | 4.8 | *4.0* |
| 700 | 8.4 | *1.4* | *70.0* | 1.6 | 16.0 | *13.4* | 0.6 | 5.6 | *4.6* |
| 800 | 9.6 | *1.6* | *80.0* | 1.8 | 18.3 | *15.2* | 0.6 | 6.4 | *5.4* |
| 900 | 10.8 | *1.8* | *90.0* | 2.1 | 20.6 | *17.2* | 0.7 | 7.2 | *6.0* |
| 1000 | 12.0 | *2.0* | *100.0* | 2.3 | 22.9 | *19.0* | 0.8 | 8.0 | *6.6* |
| 1250 | 15.0 | *2.5* | *125.0* | 2.9 | 28.6 | *23.8* | 1.0 | 10.0 | *8.4* |
| 1500 | 18.0 | *3.0* | *150.0* | 3.4 | 34.3 | *28.6* | 1.2 | 12.0 | *10.0* |
| 1750 | 21.0 | *3.5* | *175.0* | 4.0 | 40.0 | *33.4* | 1.4 | 14.0 | *11.6* |
| 2000 | 24.0 | *4.0* | *200.0* | 4.6 | 45.7 | *38.0* | 1.6 | 16.0 | *13.4* |
| 2500 | 30.0 | *5.0* | *250.0* | 5.7 | 57.1 | *47.6* | 2.0 | 20.0 | *16.6* |

(white box) Chlorine Injection Rates in gph (grey box) Chlorine Injection Rates in gpm

**INJECTION CONSIDERATIONS.**

- Chlorine should be injected upstream of the filter to help keep the filter clean and to remove precipitates that may form from the chlorine injection.
- Use a separate injection system if an acid is used to keep the water pH between 6 and 7. Do not use sulfur burners to adjust water pH. They produce sulfurous acid, which deactivates the chlorine.
- Understand the concentration of chlorine at the injection point will decline as the irrigation water travels through the irrigation system as a result of reacting with the algae and bacteria in the lines. As a general rule, expect the free chloride level in the irrigation lines at the end of the system to be approximately one-half of the concentration at the injection point. Use inexpensive chloride test strips available at any pool or spa supply store to check chloride concentrations at the end of the season to assure sufficient treatment. Injection rates may need to be adjusted accordingly.

**CONTACT TIME AND FLUSHING.**

- At least 2 hours of contact time between the chlorinated water and the biological contamination is needed for the treatment to be effective. Longer contact times are preferable and chlorination can continue up to the time the irrigation stops leaving chlorinated water in the lines.

- The drip or microsprinkler system should be flushed with untreated irrigation water preferably a day or two after periodic injections or superchlorination and certainly before the next irrigation. Flushing removes remaining biological contaminants in the line and any residual chlorine to make sure there is no interference with other products that may be injected.

**SAFETY PRECAUTIONS**

- When mixing chlorine stock solutions, use fiberglass storage tanks and always fill the storage tank with water first and then add the chlorine source (liquid or dry formulation), not vice-versa.
- Do not inject chlorine with other fertilizers and pesticides.
- Do not store chlorine compounds and acids in the same room.

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