

N E T A F I M U S A

# ASPARAGUS PRODUCTION MANUAL

USING SUBSURFACE DRIP IRRIGATION



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## PRINCIPLES OF ASPARAGUS PRODUCTION

THIS SECTION IS NOT MEANT TO BE A COMPREHENSIVE GUIDE TO THE PRODUCTION OF ASPARAGUS BUT SIMPLY AN OVERVIEW OF PRODUCTION TECHNIQUES. AS THESE TECHNIQUES VARY FROM CLIMATE TO CLIMATE PLEASE CONSULT YOUR LOCAL EXTENSION SERVICE FOR PRODUCTION INFORMATION SPECIFIC TO YOUR GROWING REGION

### OVERVIEW

Asparagus is a high value specialty crop and the earliest producing spring vegetable. It currently is priced as a gourmet item and will remain in this category until growing, harvesting, and processing costs can be reduced. California is the leading asparagus producing state followed by Washington, Michigan New Jersey and Illinois. Still, many other areas have great production potential climatically and geographically. The cost to establish an asparagus field is substantial, so the decision to grow asparagus is one that should be thoroughly investigated.

### CLIMATE

Production is most successful in areas where freezing temperatures or drought terminates plant growth and provides a rest period. Without this rest period, reduced yields are likely. Asparagus tolerates great temperature variations: it grows in the Imperial Valley of Southern California, where temperatures can reach 115° F, and it grows in Minnesota, where temperatures can plunge to -40° F. Asparagus can be grown in a wide range of soils and under various climatic conditions, but it thrives in fertile well-drained soils in moist temperate regions that have long growing seasons and sufficient light for maximum photosynthesis.

### SITE SELECTION AND PREPARATION

Unlike most other vegetables, asparagus is a perennial crop which can be productive for 15 years or more. Consequently, it is important to pay particular attention to site selection and preparation for this crop. Asparagus is grown on many different soils ranging from sandy coarse-textured soils to clay fine-textured soils. Highest yields are usually obtained on medium-textured sandy loam to loam soils. Asparagus plants have a deep root system that will penetrate at least six feet. Shallow soils or soils prone to a high water table should be avoided. Asparagus roots will not tolerate saturated soil conditions.

### ASPARAGUS VARIETIES

Asparagus varieties should be both high yielding and disease resistant. Asparagus is a dioecious plant, meaning that there are both male and female plants. Generally, females produce larger spears than males, but the males produce greater numbers of smaller diameter spears. Only female plants produce berries. High yielding all male asparagus lines are most typically used in commercial production. The main benefit from an all-male hybrid is that it doesn't produce seed, which can later germinate and create a significant weed problem in the form of several volunteer asparagus seedlings. Asparagus spears produced from all male hybrids are usually very uniform. For many years, the most common varieties have been from the Washington series (Mary, Martha, Waltham), developed by the U.S. Department of Agriculture which are dioecious. However, several of the all-male hybrids developed in New Jersey (Rutgers University) . 'Jersey Giant', 'Jersey Knight', offer proven higher yields and increased rust resistance and tolerance to fusarium crown rot and are often the preferred choice Other all-male hybrid varieties released from the Jersey series with excellent resistance to fusarium include 'Jersey Jewel', 'Jersey King' (green spears with purple bracts), 'Jersey General', and 'Jersey Titan' (green spears with purple bracts). These have done well in Michigan and Canada. A newer all male hybrid released from the University of Guelph called 'Guelph Millenium' has performed very well in Canada However, it should be noted that the Jersey hybrids have had winter kill at temperatures of -30°F with no snow cover. Purple Passion is a variety that produces attractive purple spears for an added twist. This unique variety could provide a niche market opportunity. Varieties from California have been bred for warm climates and do not possess the longevity or hardiness needed in Northern climates. One of the key attributes associated with California varieties has been their strong production potential during very warm conditions and delaying the onset of fern development. However in northern climates, yield decline has often been observed in these varieties shortly after the establishment years.

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## ASPARAGUS BED ESTABLISHMENT

Commercial asparagus plantations can be established either by traditional crown planting or by transplanting seedlings. Direct seeding into a permanent location is discouraged because of the difficulty of establishing a stand. If you are planting a large acreage, asparagus crown nurseries offer the opportunity to produce many crowns per acre easily. Generally, ten production acres can be established from the crowns produced in a one-acre nursery. One pound of asparagus seed will produce enough crowns to plant one acre. Asparagus seed with a high germination percentage should be seeded on level ground about one inch deep and spaced about two inches apart within rows. Row width should accommodate machinery to facilitate mechanical digging. A modified potato digger has been used successfully to dig crowns. Generally, single rows spaced about 24 inches apart will allow enough space for large crown production. This spacing scheme requires 130,000 seeds per acre for the planting. An 80-percent recovery of crowns will net approximately enough plant material to plant ten production acres with four feet between rows and one foot between plants within rows. Usually one ounce of asparagus seed contains 500 to 700 seeds.

To grow high quality crowns, obtain seed with a high germination percentage. Plant the seed in sandy soils so crowns can be easily dug and will be relatively free of soil. Apply and incorporate phosphorus and potassium fertilizers prior to seeding the nursery at the rates suggested in the section on fertilization. Apply approximately 50 pounds per acre of nitrogen after the first shoot ferns out, and topdress an additional 50 pounds per acre in midsummer. This nitrogen may be applied through the drip system as described in the section on fertilization.

The slow rate of germination is a problem with direct seeding. Optimum temperatures for germination range from 77 to 86° F. Although lower soil temperatures slow germination, it is advisable to plant asparagus seed as soon as the soil is workable in the spring. Since the growing season needed to produce large crowns is limited in Northern climates, early spring seeding will allow germination to occur as soon as the soil environment becomes favorable. To prevent infection by soilborne pathogens, asparagus seed should always be treated with fungicides.

Weed control in direct-seeded asparagus presents a second challenge. A few satisfactory preemergence herbicides are labeled for direct-seeded asparagus. Adjust the rate according to the texture of the soil type. Inevitably, mechanical cultivation is necessary in the nursery. Any cultivation should always be shallow to prevent damage to asparagus roots, which are very near the soil surface. Although mature asparagus is quite drought-tolerant, seed beds are shallow rooted and require constant water management. Irrigation should be available on demand.

Asparagus crowns should be dug before the buds have begun to grow. Old plant tops should be mowed and removed from the field if they interfere with crown digging. A potato digger, peanut digger, or common moldboard plow can be used to lift the asparagus crowns from the nursery row. Avoid injury to the crowns during digging and handling. If dug crowns need to be stored prior to replanting, keep them cool (about 38° F) and dry. High humidity will cause rapid decay. Crowns can become overheated if they are stored in a deep pile. Crowns in storage should be stacked only a foot or so deep. Avoid freezing temperatures in storage, since severe injury or even complete loss is probable.

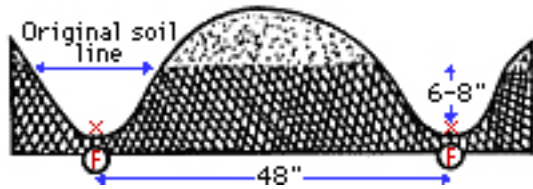
## CROWN PLANTATIONS

For small plantings, it is easiest to buy one-year-old crowns from a reliable grower. Only one-year old crowns are recommended which transplant easier, produce as vigorous plants as two-year-old crowns, and are less expensive. Crowns should be large, with many storage roots and buds (see Figure 1). Each bud will eventually produce a spear. Storage roots contain high levels of sugar that nurture the developing spears. The larger the crown, the more vigorous the resulting asparagus plant will be. Irrigation during fern growth in the summer is very important because that's when the sugar is converted to carbohydrates and eventually is stored in the roots at the end of the season.

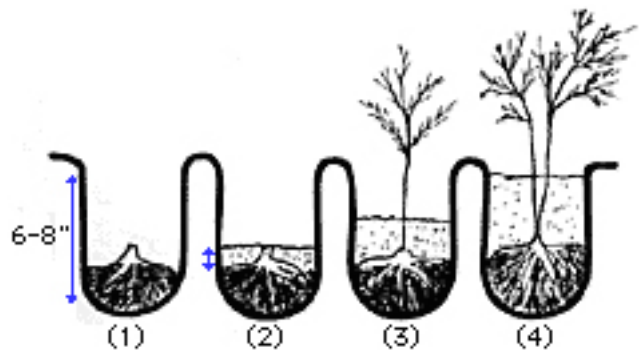
Crowns usually are hand planted with buds up, spaced 12 inches apart within rows in furrows four to five feet apart (9000 to 11,000 crowns per acre). Six to eight inches is the optimum depth for crown planting (see Figure 2). Shallower planting depths cause production of spindly, thin spears, whereas deeply planted crowns produce fewer spears of larger diameter and emergence is delayed. In addition, as crowns grow in mass, they 'migrate' upward making the crown more susceptible to frost damage during first spear emergence. Planting crowns closer than 12 inches results in reduced spear size and quality. Spacing crowns farther than 18 inches apart may result in larger spears but fewer spears per acre.



**Figure 1.** A high-quality asparagus crown.



**Figure 2.** Side view of typical furrow construction. X = crown or transplant placement; F = fertilizer placement (two-three inches below the bottom of the furrow).



**Figure 3.** Planting crowns: (1) set crowns upright in wide furrows, six to eight inches deep, with roots spread. (2) cover with two inches of soil, (3 and 4) gradually fill the furrow as the plants grow.

After placement in the furrows, cover the crowns with two to three inches of soil (see Figure 3). Gradually fill in the furrow as shoots emerge. By the end of the season, the furrows should be entirely filled in, although the developing asparagus fern should never be buried.

Weeds cause the greatest problem in establishing an asparagus bed from crowns. All perennial weeds should be eliminated before planting any asparagus. An appropriate herbicide, applied immediately after the crowns are covered should control weeds until the asparagus is large enough to be cultivated easily and safely.

## SEEDLING TRANSPLANTS

Transplanting seedlings into the field is an acceptable alternative to crown planting if monitored closely. Seedlings are produced in greenhouses and are usually transplanted into permanent commercial fields when they are about 10 to 14 weeks old. The young seedlings can be mechanically transplanted, which reduces planting costs.

Follow the manufacturer's recommendation for mixing. Each transplant should receive at least 4 oz. of transplant solution. For best results, irrigation should be applied if rainfall is insufficient to maintain adequate soil moisture. Seedlings should be thoroughly hardened off before field planting. Place the plants in a moderately shady location and keep them moist. After about three days, transplant them to the field. In many cases, the asparagus fern will totally yellow and die; this is normal.

Transplanting may take place either in the spring (early May) or in the fall (early to mid-September). While spring transplanting is more common, fall transplanting has proved successful in Minnesota, and provides flexibility in the scheduling of both labor demands and greenhouse space. Regardless of the timing, the transplants should be as large and vigorous as the transplant equipment will allow, and without becoming root bound in the original containers.

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In 2008 Michigan State University (MSU) did research on the suitability of elite varieties of Greenhouse grown transplants for field establishment. Results:

**Trial 1:** Plant spacings were at 14" with two rows, staggering the plants and no irrigation. This is the traditional spacing used by growers. Irrigation was applied at time of transplanting, but there was a long period of dry weather during the trial.

**Trial 2:** Plants were spaced at 12" in a single row, with drip irrigation installed for this planting.

Both test plots were fumigated. After the season, in September, the plant stand was evaluated and the seedling survival for trial one was 42 - 85% depending on the variety, while the drip irrigated trial had a 90 - 96% survival rate.

**Conclusion:** Drip irrigation is recommended when using transplants to increase the survival rate.

In another report in 2008 MSU did a study comparing transplants versus crowns. Varieties Millennium and Jersey Knight were used. Results:

All transplants had more shoots per plant on the stand than the one year old crowns from 2006. They were also dealing with 72- and 128-cell plants, apparently the 72-cell was favored because of a stronger root system. The harvest in 2008 shows that transplants can perform equally well compared to field grown crowns.

Millenium performed better as transplants with a larger number of total spears. Again "field establishment" was cited as the critical part, they need more care (irrigation, weed, disease and insect control). A cost analysis should be conducted to determine if transplants would be a cost effective alternative to field grown crowns.

Weed control is a challenge in the transplanting of asparagus. Cultivation will be necessary to fill in the furrows as the fern grows and as herbicides lose their residual activity.

The question of whether to use transplants or crowns is a matter of preference. They are comparable in price, but crowns are one-year old plant material, whereas transplants are only 10 to 12 weeks old. In Northern climes where the growing season is short transplants do not grow to a large size in their first season. Transplants may come into harvest up to a year later than crowns. Still transplants may be easier to handle using semi-automatic equipment saving planting labor.

## INSECT PESTS

Several insect pests affect asparagus. The most damaging insects include the asparagus beetle, spotted asparagus beetle, and asparagus aphid.

The asparagus beetle is a common pest wherever asparagus is grown. Both adults and larvae feed on the plant. In the spring they feed on the spears and reduce the quality of the crop. In the summer they defoliate the ferns and reduce the food supply to the crowns, thus affecting future yields.

Spotted asparagus beetle is also widespread but is more common in the Eastern United States. Adult spotted asparagus beetles emerge later than common asparagus beetles. The injury caused by the adult is similar to that of the common asparagus beetle; however, the larval stage does little damage to the crop because it feeds primarily on the fruits or berries.

Limited pesticide treatments with labeled products are the most common practice for insect control. In organic production, sanitation is one of the principal preventative strategies for suppressing these pests. This usually involves fall/winter burning of dried fronds and other "trash" to eliminate sites where the beetles overwinter. However, this may be undesirable if it leaves the soil vulnerable to erosion. On small acreages, enclosing the asparagus beds and letting hens forage on the beetles is one possible strategy for control. Rotenone or rotenone-pyrethrum mixtures are an organic control measure for larger acreages. Natural predators include a chalcid wasp and lady beetle larvae.

Asparagus aphid is a European native that was first reported in the U.S. in 1969. It has since spread across most of the country. It is the most serious pest requiring extensive control. Asparagus aphid feeding causes bushy, stunted new growth called "witches broom." If not controlled by natural predators and parasites, aphids are readily managed using either a chemical or organic pest control program. Certain pesticides can be applied through the drip irrigation system.



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## DISEASE PESTS

Asparagus is affected by an array of diseases, of which the following are the most common and troublesome:

Fusarium, which causes assorted crown and root rots and wilts, results in poor stands and yellowing and wilting of seedlings in new plantings. In established plants, wilting of individual ferns occurs and the foliage turns yellow to tan. Diseased crowns will have a yellowish-red internal discoloration, and the major roots will be rotted. The severity of fusarium wilt varies between different asparagus growing regions in the country. In most instances, fusarium rarely becomes serious in well-managed plantings. If fusarium does become serious, the field may have to be destroyed and not replanted to asparagus.

Asparagus rust (*Puccinia asparagi*) can be a problem if the cultivars being grown are not rust-resistant. Rust can cause premature defoliation or death of the ferns, reducing yields and increasing the incidence of root or crown diseases. Symptoms generally occur after the cutting season. Small yellow-to-orange spots first appear on the “needles;” in the second stage of the disease, dusty brick-red pustules appear on both the shoots and the needles; later they turn black. Rust is most severe during times of heavy rain, high humidity, or abundant dew. Planting resistant cultivars is the best control. Increasing the planting distance between rows and orienting the rows toward the prevailing summer winds will also help. Needle blight (*Cercospora asparagi*) has recently become a problem disease of asparagus, especially on the newer hybrid cultivars. Like rust, needle blight is a defoliating disease prevalent during periods of high humidity or abundant rain and warm temperatures. A bad infection will severely reduce yield the following season because defoliated ferns do not manufacture and store carbohydrate food reserves very well. Symptoms appear in June, when affected ferns develop buff to gray, somewhat elliptical spots surrounded by a thin purple band. The lush fern growth typical of the new hybrids, especially when grown in rich organic soils, reduces air movement and creates ideal conditions for the disease.

Tillage can reduce needle blight. However, Oklahoma researchers found that burning the fern residue provided significantly greater control than tillage and is recommended as the best cultural option. As with rust, increasing the planting distance between rows (e.g., from 5 ft. to 6 ft.) will improve air flow and help prevent disease buildup.

Purple spot, a fungal disease that infects young spears of asparagus, is caused by *Stemphylium vesicarium*. Infection causes sunken purple spots that reduce the value of the crop. Burying asparagus debris in late fall or late winter significantly reduces the severity of the disease. Burying also reduces the level of infection on young volunteer asparagus—an important control measure because infected volunteers are the source of fungal inoculum during the harvest period.

## WEED CONTROL

Weed control is the most serious challenge facing asparagus producers. Since asparagus is a perennial crop that increases in bed-width each year, cultivation for weeds “in the row” during spear harvest, and following harvest during fern production, is not possible. Thus, elimination of perennial weeds such as bermudagrass, quackgrass, johnsongrass, and nutgrass prior to planting is especially critical. Annual weeds can be controlled through a combination of herbicides, cultural, mechanical, and biological control techniques.

## HERBICIDES

Prior to planting the use of irrigation to germinate weeds followed by cultivation or the use of a post emergence herbicide can aid in reducing weed competition. On established asparagus a pre-emergence herbicide should be applied after the fern is chopped and burned but before the start of the harvest season. Water in the form of rainfall or irrigation may be needed to activate the herbicide. During and immediately after the cutting season spot treatments with herbicide may be required.

## CULTIVATION

To control winter annual weeds that have emerged in the field, cultivate at a shallow depth after the winter ferns (i.e., trash ferns from previous season) have been mowed or burned off. Avoid damage to crowns by straddling the beds. At no time should tractor tires be driven on or across the rows. Following harvest the field should be disked or tilled again to eliminate weeds that have emerged since the last cultivation and to prepare the field for summer fern production.

Cultivation between the rows with a high-clearance tractor and 3-point hitch-mounted row cultivators will control the bulk of interrow weeds during the growing season. During harvest of spears and during fern production, in-row cultivation opportunities are limited. Yet, these in-row weeds pose the greatest threat because weed competition with ferns interferes with crown storage and reduces yield the following growing season.

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## MULCHES AND WEEDER GEESE

During fern production, alternative weed control options in the row include hand weeding, mulching, and/or the use of weeder geese. On large-scale operations, mulching can be mechanized using straw spreaders or forage wagons carrying green chop or shredded dry mulch. Weeder geese are an alternative to mulching, and have a history of use in asparagus. Contact ATTRA for additional information on weeder geese.

## FLAME WEEDING

Flame weeding, which is done with propane flammers, is another possibility for in-row weed control. Hand-held or backpack flammers can be especially useful for spot treatment, though tractor-drawn rigs are available. As a general rule, flame weeding is most effective against annual broadleaf weeds, moderately effective against annual grasses, and a poor option for perennial weed management. Flaming should be considered a potentially useful though experimental tool. ATTRA has additional information on the uses of flame weeding in vegetables, available on request.

## COVER CROPS

Cover crops are another useful tool in asparagus weed management. Two cover crop systems that have potential in asparagus are “dying mulches” and “living mulches.”

## DYING MULCHES

A dying mulch is a cover crop planted out of season. While growing it suppresses weeds; then it dies back out on its own without requiring the use of herbicides, mowing, or tillage. Winter rye—planted in the spring—has been used successfully in this manner in several agronomic and horticultural crops.

In asparagus here’s how this might work. Following post-harvest tillage of the asparagus field, the field is over-seeded with winter rye at 120 lbs. per acre to establish the living mulch. Since the winter rye is planted in late spring, and consequently does not receive normal winter vernalization (cold treatment), it never tillers (i.e., it stays short) and eventually “cooks out” by mid-summer. By this time, the asparagus ferns form a thick canopy that shades out most underlying weeds.

The success of this system is dependent on proper timing and good luck. Timing is critical to get the rye established early enough to promote germination when the soil temperatures are still relatively cool, but at the same time, late enough that a cold spell is avoided. Vernalization can occur when the rye is exposed to only 10 days of 45° F night temperatures.

Dr. Astrid Newenhouse, formerly with the University of Wisconsin, conducted cover crop research in horticultural crops and provided some preliminary insights into dying mulch and living mulch systems for asparagus. Dr. Newenhouse tried the non-vernalized rye system described above. She agreed that timing was critical with respect to a cool spell. As a result of a cold snap one year, her rye headed out and created additional management problems. Biological farming strategies, like conventional farming strategies, don’t always work as expected.

## LIVING MULCHES

Living mulches are cover crops grown in association with annual or perennial crops, primarily for weed suppression and as a soil management practice. The goal is to plant a low-growing cover that suppresses weeds without competing too much with the main crop.

In Wisconsin, Dr. Newenhouse’s living-mulch work in asparagus focused on two cover crops: perennial ryegrass and ‘Dwarf White’ Dutch white clover. Both cover crops were fall-established and managed the following growing season with one to three mowings using a walk-behind sickle-bar mower. Preliminary results indicated that perennial ryegrass performed better than the Dutch white clover the first growing season. However, in the second growing season these results were reversed, with the Dutch white clover performing better. This research found that living mulches could be highly effective in weed suppression but also quite competitive with the crop, especially when there is no rain, reducing asparagus growth 50-75% in some instances. Clearly, more research is required to find living mulch systems that are more viable. Drip is an advantage when using living mulches because the moisture level in the bed can be maintained at a certain minimum level.

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## ASPARAGUS HARVEST

The harvest period in a mature asparagus planting lasts about eight to nine weeks. Spears are hand picked by snapping them just above the ground. Most growers build their own harvest aids to increase harvest efficiency. These low-lying platforms can either be attached to the front or rear end of a tractor, or be self-propelled.

The Oklahoma State University Vegetable Research Station in Bixby, Oklahoma, built a self-propelled harvest aid that seats three workers. The person in the middle steers with their feet while picking. During full harvest it usually takes about 45 minutes to pick an acre using this 3-seater, according to OSU Extension Vegetable Specialist Jim Motes. Motes said that it takes about two person-hours per acre to harvest asparagus, regardless of whether it is picked by stoop labor or with a harvest aid. The main advantage of a harvest aid is the ability to work longer hours without back strain.

Self-propelled harvest aids are also produced commercially. Holland Transplanter Company manufactures units (similar to the one used in Oklahoma) that seat from one to six workers and range in price from \$6,000–\$8,000. A single-seat pedal-powered Crop Cart is available from Rusty's Ag Sales. It sells for \$975 and can be shipped by UPS. Various articles describing other harvesting carts are included among the enclosures.

Well-drained soils, such as a light, sandy loam, are a definite advantage in asparagus production, especially when it comes to harvesting. The ability to drive equipment into the field soon after it rains is especially important. Once harvest begins, picking takes place every other day in cool weather, and every day later in the season.

When harvest is delayed by wet field conditions, the spears may open up and begin to fern out. As loose spears are non-marketable, it is sometimes necessary to clear the whole field. This can be accomplished by using either a sickle-bar mower or brush-hog. Again, care should be taken to keep tractor tires off the rows to avoid crown damage. Spear emergence following "clear-cutting" gets the harvest back on schedule but overall yields and the harvest season may be reduced.

## POST-HARVEST HANDLING

As asparagus is a highly perishable crop, some method of cooling after harvest is necessary. Precooling to remove field heat prior to shipment is commonly practiced via hydrocooling. Hydrocooling is accomplished by flooding, spraying, or immersing vegetables in chilled water. Following hydrocooling, asparagus should be kept refrigerated.

According to the USDA:

Fresh asparagus is highly perishable and deteriorates rapidly above 41° F. Thus, the spears should be cooled immediately after cutting, preferably by hydrocooling, and placed at a low temperature. In addition to general deterioration, growth, loss of tenderness, loss of flavor, loss of vitamin C, and development of decay take place at moderately high temperatures.

Asparagus can be kept successfully for about 3 weeks at 35° F. It can be held for about 10 days at 32° F., but is subject to chilling injury when held longer at this temperature.

High relative humidity (95 to 100 percent) should be maintained, with good ventilation to reduce carbon dioxide and ethylene buildup. Non-perforated film should not be used. Commonly, the desired relative humidity is obtained by placing the butts of asparagus on wet pads.



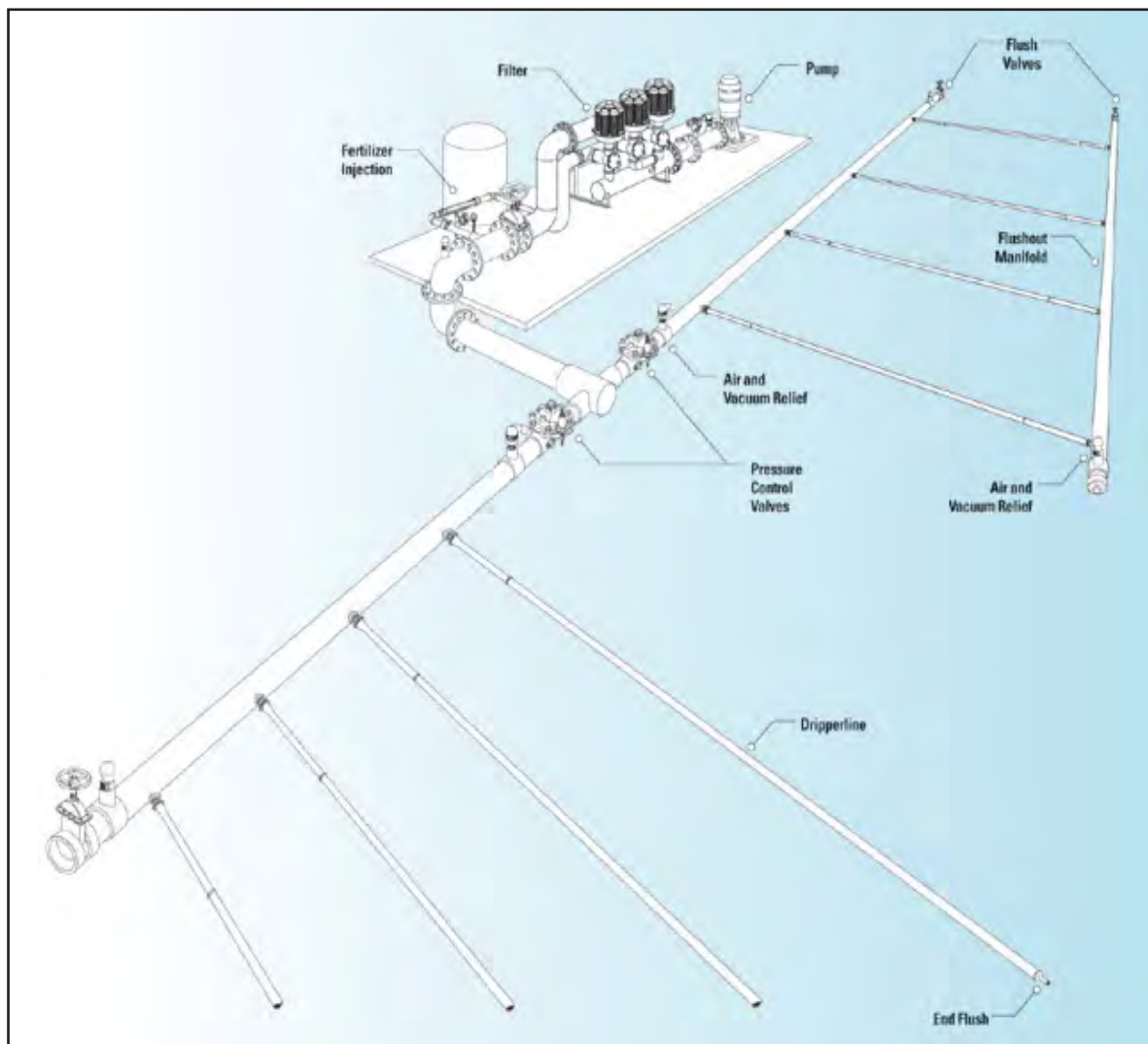
# DRIP SYSTEM COMPONENTS

## OVERVIEW

This section of the manual reviews the layout and function of the components required for a typical Drip Irrigation system. Drip systems may be installed on or just below the surface often referred to as surface systems or permanently buried 8 to 16 inches deep referred to as Subsurface Drip Irrigation Systems (SDI).

## WATER

Water sources currently used for flood or mechanized irrigation are generally suitable for drip irrigation of asparagus. However, there are some special considerations that are required to ensure the longevity of your drip irrigation system. When utilizing a new water source or if you have known conditions such as high salts, iron or manganese it is a good idea to have the source water analyzed before system design begins. Water quality issues can be addressed through proper system design and water treatment but it is most cost effective to do this before the system is installed. Maintenance procedures may also need to be adjusted for specific water conditions. Specific water quality issues are discussed in more detail in the operations and maintenance section of this manual.



**Figure 2.1.** Schematic diagram of the components which comprise a drip irrigation system.

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## BASIC SYSTEM LAYOUT

Figure 1 is a schematic layout of the components which make up a drip irrigation system. The heart of the system is the dripperline. For asparagus production this may employ pressure compensating or non-pressure compensating emitters depending upon row length and field topography. As the name suggests pressure compensating emitters produce the same flow rate over a wide range of pressures while non-compensating emitters the flow rate is a function of the inlet pressure. Pressure compensating emitters are generally more complex and hence more expensive than non-compensating emitters. On sloping terrain pressure compensating emitters allow uniform water distribution even though the slope will result in large pressure gradients. This can result in significant water savings and improved yield by producing a more uniform crop.

To protect the dripperline you must employ a high quality filtration system. This is typically a disc or media filtration system. Both of these systems filter across a depth of material making for a more robust protection of your investment in drip irrigation. Because asparagus is a multiyear crop and you expect your drip system to last for up to 15 years it is important not to skimp on filtration. For this reason we do not recommend screen filters. This two dimensional filter may work fine for short term drip applications of one to three years but are not robust enough to protect long term subsurface drip systems. It is best to employ an automatic backflush system to clean your filters. This system uses pressure drop across the filter to determine the extent of buildup on the filter elements and then automatically triggers a backflush to clean the filters. In this way irrigation cycles are not interrupted due to clogged filters and you maintain a consistent water application to the crop.

To maintain your dripperline over the long term requires a system for injecting chemicals. Some of these chemicals such as acid will keep your system clean. It is also possible to use this injection system to supply fertilizers directly to the crop roots. Supplying fertilizer directly to the roots is the most efficient and effective way to fertilize your crop. Pipeline headers, control and air release valve round out the rest of the system. Our intent is not to describe the process of system design in detail. Your Netafim dealer is trained to design and install quality SDI systems. Still it is important to understand how the system is put together and why certain design elements are specified.

## DRIPPERLINE LOCATION

The following dripperline recommendations are meant as guidelines. Soil type, topography and water quality will affect the final design. Your Netafim dealer is familiar with the local conditions and will recommend dripperline that is appropriate for your area. Dripperline should be installed with GPS where possible so that their position can be determined as necessary. SDI systems always employ dripperline with integral drippers. Depending upon local conditions this dripperline can employ either pressure compensating, DripNet PC or Uniram drippers or non-compensating Typhoon drippers. Factors such as length of run, topography and zone size in addition to water quality all come into play in choosing the right dripper. Regardless of the emitter employed there are several basic guidelines to follow.

- 1) When starting a new planting the dripperline should be shanked in just below the crowns in the center of the bed or furrow. The trend today for many crops is to use higher density plantings which can be accomplished by planting two rows close together in a staggered or off set pattern. In an existing field which will be converted to drip it is best to install the dripperline at the level of the crown to minimize root damage, and as close to the center of the bed as possible.
- 2) Dripperlines are generally buried at a depth of 12 inches but may be found 8 to 18 inches deep. Soil texture, germination and rodent pressure are the main considerations for dripperline depth. Sandy soils generally demand a shallower burial to expose the plant roots to the largest possible wetted zone. At a depth of 14" or deeper it is difficult to move water to the surface to germinate seed. This is mostly an issue in the arid west where there is little stored moisture in the soil prior to planting. In areas with strong rodent pressure a deeper dripperline is less likely to cross paths with rodent's teeth. In general rodents are not fond of sandy soil so the shallower depth is not a concern.
- 3) The distance between drippers is usually 18 inches. This may be adjusted to achieve the appropriate application rate.
- 4) Dripper flow rates of 0.16 to 1.0 gph may be employed depending upon the soil infiltration rate and the application rate desired. Typically 0.26 gph emitters are used.
- 5) Dripperline wall thickness of 13 to 35 mil is usually employed, with 15 mil being most common.

## PUMP REQUIREMENTS

The pumping requirements for a given drip field can be easily calculated from the dripper flow rate, row spacing and dripper spacing using the following formula.

$$\text{GPH (each emitter)} * 1.6 \text{ (conversion factor)} / \text{Row Spacing (ft)} * \text{Dripper Spacing (ft)} = \text{inches/hour}$$

For example a 0.26gph emitter with 18 inch spacing between each emitter and 4 ft rows becomes:

$$0.26 * 1.6 / 4.0 * 1.5 = 0.07 \text{ inches/hour, application rate}$$

To apply 0.21 inches per day would require 3 hours of irrigation. In a single day 6 to 7 irrigation sets (18 to 21 hours) can be accomplished.

To calculate the GPM required per acre the following formula is used.

$$\text{GPM/acre} = 43560 \text{ (sq ft/acre)} * 0.26 \text{ (GPH/emitter)} / 4.0 \text{ ft (row)} * 1.5 \text{ ft (dripper spacing)} * 60 \text{ min/hour} \\ = 32 \text{ gpm/acre}$$

On flat land the pressure output required of the pump stations is mainly dictated by the requirements to flush debris out of the filters and pipes. On hilly terrain the pressure required to lift water to the highest point must also be considered. Most automatic filters require a minimum of 30 PSI to self-clean properly. This is generally the minimum operating pressure of the pump to operate a drip system.

## FILTRATION

The filter system protects the drip system from sand and other small particles which can plug the drippers. A well conceived filter system allows for maximum operating life of your SDI system to be realized. Two types of filter methods are recommended:

1. Netafim disc filters
2. Sand media filters

Disc filters employ plastic discs with grooves molded into them such that they form layers of filter points along the depth of the discs similar to the depth filtration of media filters. The main advantage of disc filters in protecting your drip system is that they cannot form channels that allow debris to pass as sand media filters can when improperly maintained. As disc filters fill with debris they actually exert more pressure on the discs which prevents debris from passing through. This gives added protection to you investment in your drip system.

Sand media and disc filters utilize depth filtration which is most effective at removing suspended particles from the water. The filter system should be set up to clean automatically when the pressure differential across the media is too large. A pressure differential switch in combination with a flushing controller is a common approach for automation of filter cleaning.

## PRESSURE REGULATING VALVES

If the recommended dripper line is not compensated, pressure control valves are recommended to achieve the correct working pressure in the drip system. Pressure regulating valves must be adjustable to accommodate higher pressures during flushing.



Figure 2.2. An example of a Netafim Apollo Disc-Kleen Filter.

## AIR VALVES

The sucking in of soil just after shutting down the system can give problems if vacuum release valves are not used. For every 50 laterals there should be one anti-vacuum valve on the highest elevation. It is further recommended that an anti-vacuum valve be mounted on the flushing manifold's highest elevation. A double purpose automatic air valve must be installed at the pump.

## FERTILIZER INJECTION SYSTEM

The system must be designed to supply fertilizer to all irrigation blocks. This can be a completely automated system or a simple injection pump. Please consult your Netafim dealer to determine which fertilizers may be safely applied through the drip system.



**Figure 2.3.** An example of a field installation of pressure regulating and air release valves.



**Figure 2.4.** A Netafim fertilizer injection and irrigation control system. Flow meters are located on the right a pressure gauge is visible on the left.

## FLOW METER

It is essential to monitor flow in order to monitor the operation of your system and crop water use. Your SDI system is designed to produce a specific flow rate at a given pressure. Changes in the flow rate may indicate leaks in the system, improperly set pressure regulating valves or even changes in the well and pumping plant. The use of flow and pressure to diagnose your system is given in the operation and maintenance section

## PRESSURE GAUGES

Use pressure gauges to ensure that the drip system, filter system and pump operate at the correct pressure. Pressure gauges are also critical to assess potential problems with the system.

## FLUSH MANIFOLDS

Most permanent SDI systems employ flush manifolds so that entire zones can be flushed at a single time (see Figure 2.1). A manifold at the end of the field also improves system uniformity. The use of flush manifolds is highly recommended to reduce the labor required to properly maintain the system.



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# DRIP SYSTEM LAYOUT AND DESIGN FOR ASPARAGUS

## OVERVIEW

Spacing between rows of dripperline, depth of placement, dripper spacing and dripper flow rate are the four variables which define your Drip Irrigation system. These must be matched with soil type, water availability, pump capacity and crop water use to complete your system design. With your input, your local Netafim Dealer provides a customized drip system design and layout. Trained designers familiar with local conditions will ensure that you receive a system that will last for years. Consideration of the cropping system, crop rotation and soil conditions is an important part of the design process. This section is not meant as a treatise on the hydraulic design of the drip system but more of description of Drip System parameters as they apply to asparagus production.

## TYPICAL SYSTEM LAYOUT

In the United States the typical drip system used on asparagus employs drip tape or tubing buried 8" - 12" deep with one line in the center of the bed. This is often referred to as a subsurface drip irrigation (SDI) system. SDI systems have been in constant use at Kansas State research station in Colby Kansas for 20 years. Therefore it is reasonable to expect a properly maintained asparagus irrigation system to last at least for the life of the crop, up to 15 years. All tractor work including cultivation and harvesting is done with the dripperline in place. The SDI system is typically installed using a GPS equipped tractor so that the exact position of the dripperline is known for the life of the crop. This type of "permanent" drip installation requires a large upfront investment but is the most economical of drip systems when amortized over the life of the crop. It also the most economical to operate from a labor standpoint as all the installation labor is upfront and only maintenance labor is required year to year.

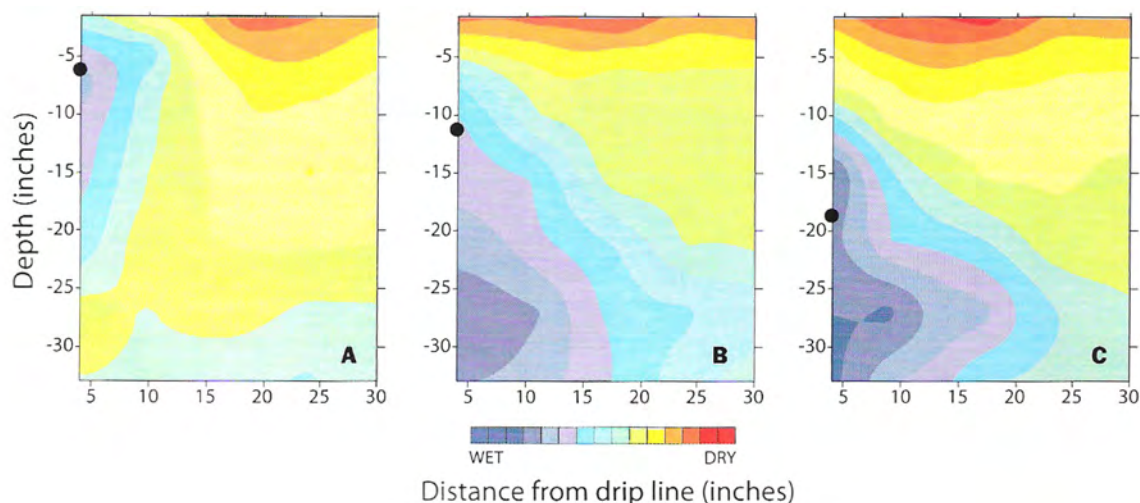
In developing countries with low labor costs sometimes a "surface" drip system is employed for asparagus production. In this system the dripperline is placed on the surface or just below the surface of the soil between two rows of crowns. The dripperline is commonly placed right before stalks appear in the spring and removed before burning in the fall. In this type of system the dripperline typically must be replaced every 3 to 4 years. A thinner walled dripperline may be employed and a less stringent maintenance program is required. In general an SDI system requires less labor but a higher level of skill and chemical inputs to maintain for a minimum 15 year period. A surface system requires more labor to lay out and retrieve but because it is not expected to last as long requires less maintenance. For some high value crops such as melons and onions surface systems are replaced every year.

The bulk of this guide will focus on SDI systems as they are the most common for asparagus production in the United States. As the basic design and operation of surface and subsurface drip systems are similar most of the principles apply to both.

At a given row spacing, the flow out of each dripper and the spacing between drippers will determine the application rate. The application rate desired is dependent on the water requirements, water availability and cultural practices. A common system may use 0.26 gph Typhoon emitters spaced at 18 inches. This will give an application rate of 0.07 inches/hour or 1.4 inches in a 24 hour period. To take advantage of existing pumps and to maximize the efficiency of your water supply your SDI system is typically divided into zones or blocks. In the above example the system could be divided into 8 blocks each operating for 3 hours. This results in an application rate of 0.21 inches per block which is close to the ET for many regions of the country. Your Netafim dealer will design systems that supply the appropriate amount of water for your region taking into account weather, soil type, cropping system and crop rotation.

Research done by Hansen et al (2008) demonstrates the extent of lateral water movement for subsurface drip irrigation. This work was done on tomatoes but applies to asparagus fields as well. Figure 1 shows the wetting pattern for a clay loam for dripperlines placed at varied depths. At a dripperline depth of 6 inches some moisture reaches the soil surface with horizontal wetting occurring out to about 12 inches. At depths of 12 and 18 inches the soil surface remained dry and maximum horizontal wetting of 25 to 30 inches was obtained. For most asparagus cropping systems this lateral pattern is sufficient to irrigate two rows of crowns.





**Figure 3.2.** Wetting patterns for subsurface drip irrigation for different drip line depths. (A) 6 inches deep, (B) 12 inches deep and (C) 18 inches deep. Soil Type was clay loam. The black dots are the locations of the dripperlines.

## DRIPPERLINE DEPTH

It is possible to place the dripperline in a asparagus field at any depth but there is little reason to place it shallower than 8 inches. Dripperline placed at 12 inches or deeper results in little moisture reaching the soil surface potentially reducing weed pressure on your crop. The advantage of a dry soil surface may be a disadvantage when it comes to starting your crop particularly in very arid regions. In dryer regions in the far west sprinklers may be required for starting your asparagus crop. In areas with severe rodent pressure dripperline placement at a depth of 15 to 18 inches or may help reduce rodent damage. This is below the depth of the majority of gopher activity.

Subsurface Drip Irrigation SDI is well adapted to a permanent planting of asparagus for several reasons.

- 1) A properly operated SDI system does not wet the soil surface reducing weed pressure and reducing herbicide application.
- 2) Water movement from the buried dripperline move primarily through capillary action not via mass flow in the soil. This gentle movement helps maintain and even improves soil structure for the entire life of the crop.
- 3) The application of water and fertilizer directly to the root zone via SDI is much more effective compared to surface applications.

## DRIPPER SPACING AND FLOW RATE

Dripper spacing and flow rate along with row spacing determine the water application rate. These are designed to supply adequate water to satisfy the peak water use for your crop (Etc) usually expressed as inches/day. In the U.S. peak ETc usually occurs in July and ranges from 0.15 inches/day to over 0.5 inches per day in the U.S. The precise peak water use depends upon the climate in your specific area and can be obtained from your local extension service. If you have poor quality water or soil, a leaching factor needs to be added to the system so that the additional water is available as needed. The section on irrigation and scheduling include more information on ET.



**Figure 3.3.** Buried dripperline 14" deep

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## FIELD PREPARATION

Your drip system is expected to last 20 years or more. As a result ground preparation is critical. Your SDI system is not just a watering tool but allows for fertilization over the course of the crop. This is critical to maintaining economic yields over an extended period of time. Still the soil should be properly amended at the time of initial land preparation. Soil samples should be taken and analyzed before establishment to determine what chemical ameliorations are required.

Asparagus performs best when the soil is in a pH range from 6.5 to 7.5. Soils with a pH of 6.0 or lower must be limed. Soils with a pH above 8.2 indicate excess sodium and must be reclaimed. Excess salts in your soil or water can significantly reduce yield. . In high salinity areas it is necessary to design the drip system so it can provide adequate leaching. Consult your local extension service for more information on problematic soils in your area. When dealing with problematic soils it is necessary to allow sufficient time for the reclamation process to take effect before planting. Your local Netafim dealer can give you guidance as to the proper field preparation prior to installation which will make installation go smoothly.

## SOIL FERTILITY

Fertile soil is fundamental to crop establishment. Even though SDI allows for the application of fertilizers directly to the root zone while the crop is growing it is important to start out with the right fertility in the bed. Have a soil sample analyzed prior to planting. Follow the recommendations of your local laboratory or extension service to prepare you field for planting. Of particular concern is phosphorous. This nutrient is quite immobile in the soil and an effective pre-plant will start your crop out right. This fertilizer can be broadcast and disked or harrowed. See the section on fertilization for more information on the fertilizer needs of asparagus.

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# DRIP SYSTEM STARTUP

## OVERVIEW

This section offers guidelines for the successful startup and operational testing of your drip system. Many times your Netafim dealer will conduct initial start-up and testing of your system. However, during the course of operation there may come times when the system needs to be started after a shutdown such as the off-season or following repairs. These procedures should be followed after any extended shutdown of your system. All drip system owners should make themselves familiar with the process of start-up and testing of their drip system.

## SYSTEM STARTUP

Your drip system should be operated as soon after installation as possible. Installation planning should include well operation and hook-up to the header system so dripperlines can be charged as soon as possible after installation. Filling the system with water inhibits insects as the inflated diameter of the dripperline is too big for their mandibles. The wet soils created by operating the system are a slight deterrent to rodents looking for a chew.

Whether you have just installed a new system or are starting your system up after sitting through the off season, a few simple steps taken before you begin irrigating will help to ensure optimum system performance

- 1) Flush the well before operation through the filter. New wells, may discharge sand on startup. This “plug” of sand can overwhelm the filtration system. Under these conditions the filtration system will backflush repeatedly without cleaning the system. This occurs because the clean water flow used to flush the filters is so reduced it does not sufficiently clean the dirty filter. In this case the unit must be disassembled and cleaned by hand. If the well discharges sand on a regular basis it may be necessary to install a sand separator before your regular filtration system. A sand separator continuously removes sand from you system as it is operating. Consult your Netafim Dealer for more information on sand separators.
- 2) Thorough flushing of the laterals and mains before system operation. In new systems, chances are good that during installation some dirt and PVC pieces accumulated in the system. These need to be flushed out properly. A properly designed drip system should have valves installed for flushing mains submains and dripperlines. Your Netafim dealer will review their operation prior to turning on the system. Your drip system needs to be flushed on a regular basis. Filters do not exclude 100% of particles in your water, often letting through fine silt. This will settle in lines and can clog your system. Debris also can get into the lines after a break has occurred and your system should be flushed after any repairs. Depending upon the condition of your water this flushing may need to be done as often as once a month or as little as once a year.
- 3) Check for leaks in dripperline laterals. Laterals are occasionally damaged during installation. System start-up is the right time to check for leaks, before the crop canopy expands making repairs difficult. Leaks in the dripperlines usually appear as isolated wet spots on the surface of the field

## STARTUP PROCEDURE

- 1) Disconnect all dripperlines from the Sub-header.
- 2) If possible, run your pump station for a few minutes with the discharge to waste, not through irrigation system, to flush out any sand.
- 3) Open mainline flush valves with any sub-main valves closed and operate your system until discharge water runs clear for 5 minutes. Pay attention to the flow rate and whether and how often the filter system back-flushed during this operation.
- 4) Open submain valves with dripperlines still disconnected to clear the submains of debris. Make sure that you are not pushing muddy water into the laterals during this operation
- 5) Connect laterals to the submains, without terminating the ends.
- 6) For each submain, open the control valve until discharge water at the end of the lateral runs clear. If the capacity of your water supply is insufficient to flush all laterals simultaneously, it may be necessary to terminate some laterals flushing only a few at a time. Close the submain valve.

- 7) Close the lateral ends
- 8) Operate the system until it is fully pressurized and all air is discharged.
- 9) Check system for leaks and repair
- 10) Re-flush the lines after leaks are repaired
- 11) Check pressure gauges and adjust all pressure regulators, or regulating valves as necessary.
- 12) Check for proper operation of all system components; pumps, controllers, valves, air vents, pressure regulators, gauges, flow meters, filter system and chemical injectors.
- 13) Record readings from all pressure gauges and flow meters and check on the frequency of backflush cycle of your filters. If backflushing is frequent, several times an hour, consult your Netafim dealer.

## SYSTEM PRESSURE AND FLOW TESTS

Upon initial startup it is best to evaluate the uniformity of your drip system. This is accomplished by:

- 1) Measuring the pressure in the system at various points and comparing this to the design pressure.
- 2) Reading from your water meter or calculating the system flow and comparing the result to the design flow rate

These evaluations should be conducted as part of system startup and as an ongoing part of system maintenance. Consult the maintenance section of this manual for a complete program for system care.

## SYSTEM PRESSURE EVALUATION

Drip systems are typically designed to operate between 8 and 25 PSI. Measuring the pressure at several points in your drip system is the simplest way to evaluate the performance. A good evaluation will include pressure measurements at a minimum of 3 points along the header end of the field and 3 points at the far end of the field. Pressure measurements at more points in the field including along the length of the laterals will give a more complete picture of system uniformity but are usually not necessary if the end pressures are within several PSI of the header pressure. Please note that if your system employs pressure compensating drippers the pressure drop across your system could be 10 or more PSI and still be highly uniform. Check with your Netafim dealer to determine what pressure measurements are reasonable.

## SYSTEM FLOW RATE:

A flow meter is an important component of every drip system. It gives a quick indication of the operational performance their system and is used to determine proper water application rates. Every new system should be designed with a flow meter. Older systems without flow-meters should be retrofitted with one. The system design should include an estimated system flow rate and the measured flow rate should be within +/- 5% of the designed rate. To calculate the flow rate expected for each zone use the following formula

$$\text{Flow rate (gpm)} = (0.26) \times \text{length of dripperline (ft)} \times \text{drinker flow rate (gph)} / \text{drinker spacing (in)}$$

## CONVERTING SYSTEM FLOW RATE TO INCHES OF APPLIED WATER:

Irrigation schedules are usually based on evapotranspiration (ET) rates which are expressed in inches of water evaporated over a given time period, usually a day or week. It is simple to convert a flow rate in gpm, either one read from a meter or calculated as outlined above, to inches of water applied per hour by using the following formula.

$$\text{Inches of water applied per hour} = (0.00221) \times (\text{flow rate, in gpm}) / (\# \text{ acres})$$

For example, a typical DRIP system on asparagus will have 48" spacing between dripperline rows with 0.26 gph drippers spaced at 18 inches. One acre of the above system has 52 rows each 208 feet long for a total of 10816 ft. This gives a flow rate 31.2 gpm.

$$(0.00221) \times 31.2 / 1 = .069 \text{ inches per hour which equals } 0.207 \text{ inches in 3 hours}$$

## MONITORING YOUR DRIP SYSTEM

To achieve the high yields and water savings possible with drip irrigation, it is necessary to monitor your system and make adjustments. In addition, regular system monitoring may give advance warning of potential problems.

### MONITORING SYSTEM PRESSURE AND FLOW RATES

As presented earlier measurements of system flow and pressure give a good picture of your system's performance. Because of the large number of variables at play in an irrigation system the measured water application rate can not be expected to exactly match the predicted rate. Still, large differences in calculated versus measured values, may indicate a problem with your calculations or a physical system problem such as a broken or clogged line. Over the growing season changes in the flow rate or pressure in your system can be used to diagnose problems with the system. Table 2, details some of the problems that can be diagnosed by monitoring system pressure and flow rate. This is by no means a comprehensive list but is a good place to start.

INDICATION	POSSIBLE PROBLEM
Gradual decrease in flow rate	Emitter plugging Possible pump wear (check pressure)
Sudden decrease in flow rate	Stuck control valve Water supply failure
Gradual increase in flow rate	Incremental damage to dripperline by pests
Sudden increase in flow rate	Broken lateral, submain, main line Pressure regulator failure
Large pressure drop across filters	Debris buildup in filters Inadequate flushing of filters
Gradual pressure decrease at filter inlet	Pump wear or water supply problems
Sudden pressure decrease at filter outlet	Broken lateral, submain, main line Pressure regulator or water supply failure
Gradual pressure increase at filter outlet	Emitter plugging
Sudden pressure increase at filter outlet	Stuck control valve Other flow restrictions
Sudden pressure decrease at submain	Damaged or broken lateral

**Table 2.** Problems diagnosed from system flow rates and pressures

With proper care your drip system will last many years. K-State in Colby KS has had a drip system with older technology continuously operating for 20 years. There is no reason to believe that another 10 to 20 years is possible. As with all of your farm equipment it all starts with good maintenance.



# IRRIGATION SCHEDULING

## INTRODUCTION

Drip irrigation keeps the soil closer to the optimum water content which can result in healthier ferns and higher yields than sprinkler or flood irrigation. Irrigation management has probably the greatest impact on yields than any other input. In addition proper irrigation practices will maximize the benefits of other crop inputs such as fertilizer and pest control. No irrigation system gives as much control over water and fertilizer management as drip irrigation.

## SOIL FACTORS AND IRRIGATION SCHEDULING

Soil is the storage from which plants extract water (Fig 6.1) If too much water is applied the storage reservoir will overflow and water will runoff or percolate below the active root zone of the crop. If the storage reservoir gets too low, the plants will be stressed and yield reduced. The science of irrigation management is to keep the storage reservoir at the correct level so stress and runoff is avoided. Your SDI system is the tool to manage water application.

Soil type determines the capacity of the soil reservoir. Soil is composed of particles of varied size, organic matter and pore spaces. Water occupies the smaller pore spaces and is held as a film around the soil particles. Sandy soils with large particles have few small pore spaces and have relatively low water holding capacity. Fine textured soils have many smaller pore spaces and a relatively large water holding capacity.

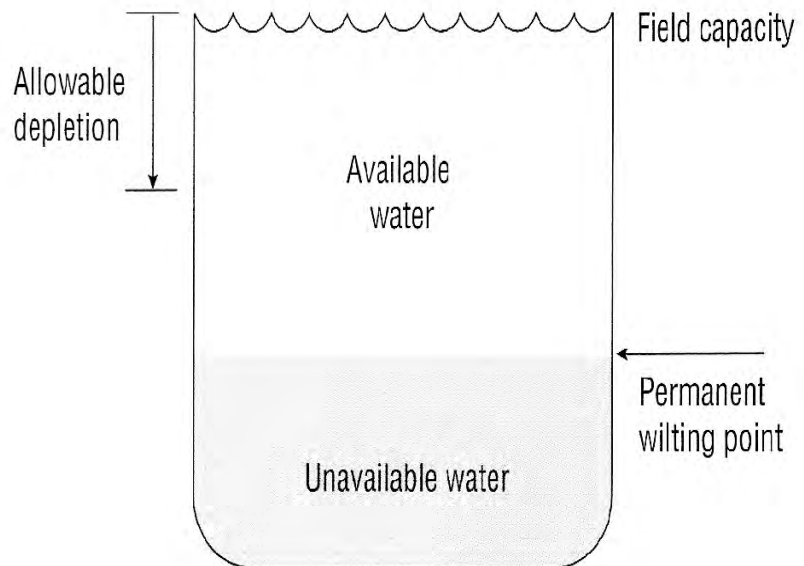
Plant roots also need air (oxygen) to uptake water and nutrients. The root requirement for oxygen for water uptake is a common observation when plants are over-watered. Flooded plants often wilt even though there is plenty of water around. That is because the roots are starved for air. The amount of air held in the soil is inversely proportional to amount of water held. Thus sandy soils hold relatively more air than water compared to fine soils. The real key to irrigation management is to maintain the balance of water to air.

The water status of the soil can be described in the following manner.

**Saturation** – The soil is essentially flooded. All pores in the soil contain water. This situation takes place when the rate of water applied exceeds the rate of gravity influenced movement in the soil. This usually occurs immediately after heavy rain or when irrigating using flood and sprinkler systems. The water flow in saturated soil is through the large pores under the influence of gravity.

**Field capacity** – Gravity has pulled all the water from the largest pores. The smallest pores hold the water against gravity, while the larger pores are filled with air. This is the optimal condition for crop development; the water is held at a force that is easily overcome by the uptake power of the roots, whereas at the same time the soil is sufficiently ventilated to enable the roots to breathe.

**Wilting point** – Not all the water in the soil is available to the plants. The water held in the film around soil particle or in very small pores is held too tight for the plants to remove it. Plants can be observed to wilt even if the soil feels damp. The wilting



**Figure 6.1.** The soil-water reservoir can be thought of as a storage tank with easily available water and water that is bound to the soil and is unavailable for plants to use

point is where the water absorption power of the crop cannot overcome the holding power of the soil. Unlike saturation and field capacity which are primarily influenced by the soil, the wilting point is crop dependent as some crops wilt much more easily than others.

**Available Water** – The amount of available water is the difference between field capacity, and the wilting point. In a theoretical sense all of this water is available. However, the available water and allowable depletion are gross large scale descriptions of soil water holding capacity. Soils are not uniform and more importantly crop water extraction will not occur uniformly across the field. Thus, it is not good practice to schedule irrigations to the wilting point. To provide a safety factor, crop irrigation scheduling is designed around “easily available water” which, as a rule of thumb, is assumed to be about 50% of the total available water. This is referred to as the limit of allowable depletion before an irrigation event must be triggered. Soil properties determine the limits of when to irrigate and how much to apply. Asparagus must be irrigated when no more than 50% of the available water has been depleted. The amount of water to apply is the amount required to fill the soil reservoir to field capacity. Table 6.1 summarizes typical quantities of available water and allowable depletion for various soil types and for a rooting depth of 4 feet.

SOIL TYPE	AVAILABLE WATER (IN./FT)	ALLOWABLE DEPLETION (IN./FT)	AVAILABLE WATER IN 4FT ROOT ZONE (IN.)	ALLOWABLE DEPLETION IN 4FT ROOT ZONE (IN.)
COARSE SAND	0.5	0.25	2.0	1.0
LOAMY SAND	1.0	0.50	4.0	2.0
SAND LOAM	1.5	0.75	6.0	3.0
FINE SANDY LOAM	2.0	1.00	8.0	4.0
CLAY LOAM	2.2	1.10	8.8	4.4
CLAY	2.3	1.15	9.2	4.6
ORGANIC CLAY LOAMS	4.0	2.00	16.0	8.0

Table 6.1. Estimates of available water content and allowable depletion for various soil types.

An allowable depletion of 50% is the maximum limit before an irrigation event must be triggered or there may be loss of yield. Subsurface drip irrigation will allow you to irrigate more precisely so that the soil is kept in a narrow, more productive zone of water content.

## IRRIGATION MANAGEMENT

Irrigation management is the scheduling and adjustment of an irrigation program based on the influences of climate and the crop. Irrigation scheduling requires knowledge of the water holding capacity of the soil, as discussed above, in combination with the water needs of your crop as determined by the crop and its environment. Irrigation and fertigation management is a major factor in maximizing crop productivity and economic returns.

## IRRIGATION SCHEDULING

The goal of irrigation scheduling is to determine an irrigation duration and frequency that keeps the root zone below field capacity and above the allowable depletion. At this point the crops roots are exposed to an ample supply of easily available water with sufficient oxygen to promote healthy root growth.

Because drip systems apply water directly to the roots with thousands of water sources throughout the field they are forgiving of poor irrigation scheduling, however, a little time taken to develop and apply an appropriate irrigation schedule will allow your drip system to operate at maximum efficiency.

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Two principle methods are used to schedule irrigations in asparagus fields. One method is called water budgeting and it involves estimating crop water needs based on the evaporative demand of the environment; the other technique relies on soil-based measurements. Both methods have there limitations. The water budgeting method looks at gross water demand and does not specifically look at your crop or soil. Factors are used to adjust for your specific growing conditions. The measurement of soil moisture is limited to the specific areas where measurement devices are placed. If the location of the devise is not representative of the entire field the information can be misleading. The best approach is use a combination of both techniques. Most commonly irrigations are scheduled using water budgeting and verified by measuring soil moisture at select points in the field.

## **WATER BUDGETING**

Water budgeting involves tracking additions and losses and balancing them The losses are due to crop water use, any leach requirements and inefficiencies in the irrigation system. The additions are due to irrigation and rainfall. The objective of the water budget method is to maintain soil moisture near the optimum level by keeping track of crop water use and then irrigating to replace the water used. Knowledge of crop water use is essential to using the water budget approach.

Crop water use is also called the evapotranspiration rate (ET). The term evapotranspiration refers to the combined loss of water through evaporation from the soil and from water taken up and evaporated from the plants (transpiration). The rate at which plants use water is determined by the growth stage of the plant and the weather. Small plants use less water than large plants and plants generally use more water the hotter or dryer the conditions are. Wind and clouds also affect the evaporation rate.

The reference evapotranspiration rate (ET<sub>o</sub>) can be calculated from weather data or measured as evaporation from a calibrated pan of water. Both methods give a close approximation of the environmentally induced evaporation rate from a given area of soil. Real pan evaporators are still used in many parts of the country and it is simple to construct your own pan evaporator (see the end of this section). However, more frequently the ET<sub>o</sub> is estimated from weather data which includes, temperature, relative humidity, wind velocity and solar radiation using a modified version of the Penman equation which relates these variables to evaporation rate. A discussion of the Penman equation is beyond the scope of this manual. Suffice it to say that the ET<sub>o</sub> for your area is commonly available from a variety of local sources.

Actual crop water usage is usually not exactly the same as the reference evaporation rate (ET<sub>o</sub>). First, plants regulate how much water they require by closing or opening stomata (small pores in their leaves used to maintain appropriate water levels in the plant). The difference between the actual peak crop water use and the pan evaporation rate is referred to as the crop factor (K<sub>c</sub>). The ET of your crop expressed as E<sub>Tc</sub> can be calculated from the ET<sub>o</sub> using the following formula

The following is an example of the calculation of the required irrigation time according to reference evaporation:

$$E_{Tc} = E_{To} \times K_c$$

The crop coefficient (K<sub>c</sub>) for fully leafed out asparagus is 1.0 . If the ET<sub>o</sub> either measured from a pan or calculated is 0.3 inches/day then your asparagus crop will be using

$$E_{Tc} = 0.3 \times 1.0 = 0.3 \text{ inches/day (2.1 inches/week) for a fully leafed out crop}$$

The water budget system for irrigation is relatively straightforward, but must be adjusted for crop growth stage and environmental conditions such as rain.

## **SPECIFIC IRRIGATION RECOMMENDATIONS FOR ASPARAGUS**

Most asparagus fields will benefit from applied irrigation. Irrigation is of course required in the arid west but even in wetter climates of the eastern US yields can be reduced by relatively short periods of drought. In addition irrigation is almost always required in sandy soils or where there are shallow root restrictions. Inadequate soil moisture during fern development can cause significant reduction in next spring's spear production. Dry soil conditions during spear growth can also affect quality and yield.

Adequate soil moisture is especially necessary for newly planted crowns to establish good root development and fern growth.

Asparagus roots can penetrate up to 10 feet to obtain soil water if not restricted but their greatest water uptake occurs from the

top 6 to 24 inches of rooting zone. Maintaining adequate soil moisture in this zone during the fern stage especially should be the goal of an irrigating producer. Asparagus plants will use .10 to .20 inches of soil water per day during fern growth depending on climatic conditions.

It is always best to start the growing season with a full soil profile. This can be from rainfall or pre-irrigation. This makes it easier for the grower to maintain optimum growing moisture with less stress of either over irrigating or under irrigating. It's always best to establish the plants water needs by stages of growth and or water sensing devices such as tensiometers or other similar equipment. You can also get access to Pan Evaporation and Potential Evapotranspiration (PET) from local universities or county web sites. The asparagus's water requirements will increase as it accumulates biomass, (taller plants demand more water). To maintain healthy fern development, soil moisture during this period should not be allowed to deplete more than 50 to 60% of the soil's water holding capacity in the active rooting zone or go beyond a soil tension of 70 centibars before another irrigation. Asparagus plants do not generally show visual signs of wilting when moisture-stressed, so soil moisture measurement technology should be employed where feasible to ensure there is adequate soil moisture throughout the growing season.



Several soil moisture monitoring methods are available to assist the grower in proper timing of irrigation water to maintain healthy plant growth.

Water scheduling is an essential management practice for irrigated asparagus production. Utilization of any of the available soil moisture monitoring tools requires only about 30 minutes a couple times a week to provide an operator with valuable information for scheduling the next irrigation.

Frequency of irrigation can vary from once or twice a week early in the season to daily during times of peak water demand.

## **INFLUENCE OF RAINFALL ON IRRIGATION**

In many regions there is rainfall during the irrigation season. It is necessary to consider the quantity of water provided by the rainfall based on the soil condition and crop. The agronomical term "Effective Rainfall" refers to that part of rainfall that is considered as available water.

If the rainfall provides less than ¼ inch and is the first rain, there is no need to consider this amount as a water contribution to the soil. Stronger rainfall providing ½ inch or more must be taken in account according to the specific circumstances.

It is difficult to predict which part of rainfall is the effective rain. However, in the case of strong rainfall providing up to 2 inches, the effective rain may be no more than 60% of the total quantity. If a rainfall provides 2 inches or more, only 1 1/2 inch will be considered as effective rain and the rest will be runoff.

It is obvious that these calculations require a certain amount of interpretation. Hence, it is highly recommended to check the status of the water in the soil in the active root zone using the hands, soil drill or tensiometers before resuming irrigation. The use of a tensiometer or soil moisture block may provide valuable information, since the readings will indicate the presence of water in the root zone.

## **MONITORING SOIL MOISTURE**

Measuring the soil moisture content is a good way to check and make adjustments to your irrigation schedule. In areas that receive significant rainfall soil moisture measurements are critical in assessing the amount of useful water received in a rain event.

There are several practical ways to assess soil moisture content. Experienced irrigation specialists can use the "look and feel" method where the moisture level is determined by handling a soil sample. This is an excellent way to confirm the measurements given by more sophisticated equipment

Tensiometers measure the strength which the soil is holding onto the water (soil matric potential). Tension is a measure of the work a plant must do to remove water from the soil. The higher the tension the harder the plant must work to remove water from the soil. Tension is usually expressed in bar or centibar (1bar = 100 centibar). The drier the soil, the more tightly the soil holds onto the water and the higher the tension measurement. The main drawback to tensiometers is that they require a certain skill to set-up and operate properly.

There are numerous sensors that measure the moisture content of the soil. The most common are moisture blocks but new sensors such as capacitance and resistance sensors are being developed all the time. Moisture content is a measurement of the water contained in the soil as a percentage of the volume of the entire soil solution. In general, sensors do not measure the moisture content directly but use an electronic calculation to infer the water content of the soil. Measurements expressed as moisture content can directly indicate how much water you need to apply to bring the soil to field capacity. The main drawback to these sensors is that they are sensitive to salts in the soil and water. Newer models do a good job of correcting for salt concentration but they may need to be calibrated more often than you think.

To get a complete picture of the water status of your soil it is best to take soil moisture measurements at several depths. Portable sensors can simply be inserted at different depths while inexpensive sensors can be buried permanently at the desired depth. Select a minimum of 2 sites to verify conditions across the field.

DEPTH BELOW SURFACE*	RESULT
6 inches	Reflects moisture content in the root zone in young or shallow rooted crops
12 inches	Monitors the root zone as plants mature and their root systems enlarge. This is the most active root zone.
24 inches	Monitors the degree of leaching below the root zone. The moisture level here should change little during drip irrigation.

## MONITORING SOIL SALINITY

Even with low salinity water, salt can accumulate in the soil unless some leaching occurs. In addition to the salts that are in the soil and are a part of almost all irrigation water, fertilizers can add to the salt content. It is best practice to send irrigation water and soil samples to a lab for analysis. In problem areas consider purchasing an EC sensor which will give instantaneous readouts of water and soil salt conditions. If salt levels are found to be increasing over time it is necessary to include a leach factor to your irrigation system.



# ASPARAGUS SOIL FERTILITY REQUIREMENTS

THE FOLLOWING SECTION OFFERS GENERAL GUIDELINES ON THE FERTILIZER REQUIREMENTS OF ASPARAGUS. PLEASE CONSULT YOUR LOCAL EXTENSION FOR SPECIFIC REQUIREMENTS FOR YOUR REGION AND GROWING CONDITIONS

Asparagus responds favourably to a well executed fertility regime. Consistent yields over 4000 lbs per acre are possible for properly watered and fertilized asparagus. Subsurface Drip Irrigation is uniquely suited to providing nutrients directly to the roots of a long term crop such as asparagus. Soil information is critical. Residual nutrients, nematode counts, root rot pressure, soil type, depth of soil, pH, and crop yield data all need to be evaluated. Netafim recommends soil samples pulled in 12 inch increments from one to three feet. This is especially recommended when asparagus is following heavily fertilized vegetable crops. This lets the grower make fertility decisions from preplant to first injected fertigation.

Field preparation should take place the year prior to planting. Soil tests (0–12”) can be used to determine needs for lime, phosphorus, and potassium. Asparagus will not tolerate extreme acid soil conditions and grows best at a pH of 6.5–7.0. The objective during the first 3 years after planting is to encourage maximum fern growth so that plants build extensive storage root systems.

Plow down soil amendments before furrow construction or bed shaping. All furrows should be 6 to 8 inches below the normal soil surface. Rates of fertilizer for asparagus are dependent on soil test values and relative organic matter levels. Refer to Tables 1, 2 and 3 for suggested rates of fertilizer. For nitrogen, (N) approximately 1/3 to 1/2 of the recommended rate should be broadcast after planting. The remainder of the N should be sidedressed at the first cultivation. Most of the phosphorus (P) and all of the potassium (K) should be broadcast and incorporated prior to furrow construction or bed shaping. Apply 25–30 lb/A P205 in the trench before crown setting. If soil test P is high, omit the broadcast application and apply only that recommended for the trench.

## NITROGEN RECOMMENDATIONS FOR ASPARAGUS

ASPARAGUS	ORGANIC MATTER LEVEL			HOW TO APPLY
	LOW	MED	HIGH	
	N to apply lb/A			
New Planting	120	100	80	½ broadcast, ½ sidedress during cultivation
Established Planting	80	60	40	Topdress after harvest

## PHOSPHORUS RECOMMENDATIONS FOR ASPARAGUS

PHOSPHORUS (P) SOIL TEST	AMOUNT OF PHOSPHATE (P <sub>2</sub> O <sub>5</sub> ) TO APPLY (lb/A)	
PPM	NEW	ESTABLISHED
0-10	250	100
11-20	200	75
21-30	150	50
31-40	100	25
41+	50	0

## POTASSIUM RECOMMENDATIONS FOR ASPARAGUS

POTASSIUM (K) SOIL TEST	AMOUNT OF POTASH (K <sub>2</sub> O) TO APPLY (lb/A)	
lb/A	NEW	ESTABLISHED
0-50	250	100
51-75	200	75
76-100	150	50
101-150	100	25
151-200	50	0
201+	0	0

For the second and third year following crown setting, nitrogen can be applied through the drip system at the following rates; during the spring prior to spear development (30–40 lbs. N/A and recommended rate of P and K according to a soil test). An additional 40–60 lbs. N/A should be applied as the soil warms up.

## SOIL FERTILITY REQUIREMENTS — ESTABLISHED PLANTINGS

Once the plants are established, the primary objective is to maintain plant vigor. Asparagus has a very fleshy root system which is capable of storing a large quantity of nutrients. It has been estimated that the roots can store 150 lbs. N/A, 37 lbs. P/A and 170 lbs. K/A. These stored nutrients, in part, can be used for the development of spears in the early spring. The actual amount of nutrients removed by a 2.5 T/A harvest is 23 lbs. N/A, 3 lbs. P/A and 20 lbs. K/A. Generally, it is not necessary to apply fertilizer for an asparagus crop until after harvest. Delaying fertilization until after harvest can reduce early weed growth. For sandy coarse-textured soils, 20–25 lbs. N/A in the spring may be beneficial for spear development. Tables 1, 2 and 3 present fertilizer recommendations for established plantings. All fertilizers should be applied through the drip system in small quantities “spoon feeding” over the growing season. The exact timing of application should correspond to periods on maximum growth. Care must be taken when applying phosphorous through the drip system many phosphorous products are insoluble or easily precipitate in the drip system resulting in clogged emitters. See the section below on appropriate fertilizers safe for use in your drip system.

**NUTRIENT CONCENTRATION RANGES IN HEALTHY ASPARAGUS FERNS**

STAGE OF GROWTH	PART SAMPLED	% PPM									
		N	P	K	Ca	Mg	Fe	B	Cu	Zn	Mn
Mature Fern	Fern from 18" - 36" up	2.4	0.3	1.5	0.4	0.15	-	50	6	20	20
		3.8	0.4	2.4	0.5	0.20	-	100	11	60	160

## SECONDARY AND MICRONUTRIENTS

Asparagus response to application of secondary and micronutrients is not well documented. Most soils low in calcium (Ca) and magnesium (Mg) are acid and should be limed with dolomitic lime prior to planting. Sulfur may be limiting on sandy soils with low organic matter. In general, asparagus response to micronutrients is low. Nutrient ranges from healthy mature asparagus ferns are presented in Table 4. Suspected nutrient deficiencies should be confirmed with soil tests and/or tissue analysis.

## FERTIGATION THROUGH YOUR DRIP SYSTEM

Subsurface drip irrigation applies fertilizer directly to the root zone (Nutrigration). This is the most efficient method to deliver fertilizer, water, and chemicals to irrigated crops such as asparagus. This ability to use the SDI system for delivering these inputs means more effective timing and utilization of fertilizers without the additional cost of traditional application practices thereby reducing both labor and energy. As a result it is possible to maintain a near optimum level of nutrients in the soil solution, available to the plants, helping promote plant health, production, and return per unit applied.

This guide is not meant as a complete treatise on asparagus nutrition. It is meant as a guide to properly feed your crop using your SDI system.

## BENEFITS OF FERTIGATION

- |                                  |                                                 |
|----------------------------------|-------------------------------------------------|
| Apply nutrients when needed      | Less exposure to elements                       |
| Friendlier to environment        | More control of plant growth and response       |
| Lower finance cost of fertilizer | No mechanical root pruning                      |
| Less equipment across the field  | Manage pH and EC                                |
| More uniform delivery            | Apply systemic chemicals for early pest control |

Fourteen mineral elements are needed in varying amounts for plant growth. (Table 7.1).The nutrients most often required by asparagus are nitrogen, phosphorous, potassium, calcium, and magnesium and zinc. The remaining elements are also important but vary in amounts and frequencies which may vary by region.

Evaluating the nutrient status of your crop and soil is a key aspect of designing a fertility program for your asparagus crop. This evaluation can be done by visual observation of previous crops, soil analysis and plant tissue testing. Using all three provides the best results. Always examine your crop looking for nutrient deficiencies that might exhibit symptoms. Consult you local extension for visual guides for each of the nutrient deficiencies that are common in your region. Unfortunately visual symptoms can often be confused with insect injury, diseases and restricted root growth. In addition, once a deficiency results in a visual symptom there has already been a yield reduction. Therefore it is good to be familiar with deficiency symptoms in the odd case they are manifested during growth but more emphasis should be placed on soil and tissue samples.

Soils tests provide an estimate of nutrient availability for uptake by plants. Soil tests must be taken prior to planting and the soil amended based on the laboratories recommendations for asparagus. . If possible soil samples should be taken at a depth of 8 inches, 24” and sometimes 36 inches. This will give an indication about nutrient movement in the soil and uptake by the plants

Taking soil samples from a drip irrigated field is slightly different than sprinkler or flood irrigated fields. The drip system creates a wetted area in the soil profile. Nutrients injected through the drip system are only found in this wetted area. It is important to sample within this wetted area to get a good assessment of the fertility of the soil. The goal is to test near the dripperline but not to hit it. This can be tricky. It is a good idea to develop some type of marker system so you can find an appropriate spot. Some growers rely solely on soil testing to determine their fertilizer regime during the life of the crop. However, it is more common to use tissue tests for this purpose. The objective of soil testing is to get a fertility map of the field. Samples should be taken from areas that are troublesome as well as productive regions often referred to as benchmark areas. The benchmark areas should be chosen so that they can be located year after year.

Plant tissue testing is by far the most precise method of determining the nutrient needs of asparagus. Such tests are the best reflection of what nutrients the plant has taken up and are far more accurate than soil tests. Plant tissue tests give rapid feedback on the current fertility status of the plants and the effectiveness of fertilization. Table 4 lists appropriate nutrient levels expected in healthy ferns.

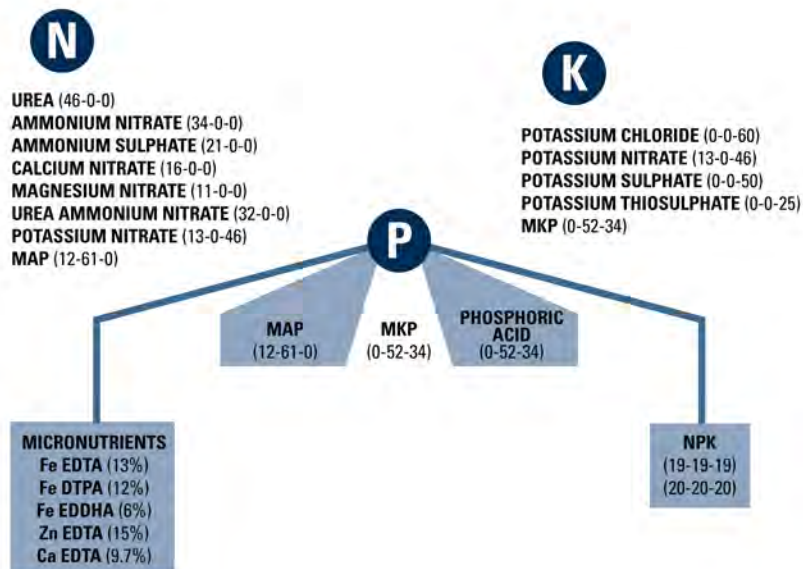
Not all fertilizer formulations are suitable for injecting through your SDI system. The fertilizers must be soluble and have a low propensity for reacting with your water and forming precipitates. Table 7.4 lists many common fertilizers that are compatible with your drip system. Your local Netafim dealer will steer you in the right direction regarding fertilizers which are incompatible with your drip system.

In areas where drip irrigation is prevalent fertilizer formulators can be found to produce the desired nutrient mix. In areas where fertilizer dealers are not familiar with fertilizers compatible with drip irrigation consult your local Netafim dealer or representative.

When choosing the right fertilizer to put through your drip system of particular concern is elements that may react with each other or with your water and form precipitates which may clog your drip system. Polyphosphates (10-34-0 and 11-37-0 can not be used to inject into SDI systems as they are highly reactive with Calcium and Magnesium in your water. Sulfates can also react with Ca and Mg to form gypsum in your dripperline. In most cases Micronutrients are supplied as chelates which are highly soluble and available to the plant.

ESSENTIAL ELEMENTS	SYMBOL	APPLICATION
Nitrogen	N	Seldom
Phosphorous	P	Frequently
Potassium	K	Less Frequently
Calcium	Ca	Seldom
Magnesium	Mg	Seldom
Sulfur	S	Frequently
Iron	Fe	Seldom
Manganese	Mn	Seldom
Chlorine	Cl	Seldom
Boron	B	Less Frequently
Zinc	Zn	Seldom
Copper	Cu	Seldom
Molybdenum	Mo	Less Frequently
Nickel	Ni	Seldom

**Table 6.1.** Essential Plant Nutrients



**Table 6.2.** Common fertilizers compatible with drip irrigation.

## NITROGEN

Nitrogen is one of the major plant nutrients required with asparagus production. Paying close attention to application rates and timing will greatly affect return on investment. Nitrogen is also one of the most mobile nutrients that can be leached readily with excess water from rain or irrigations. The asparagus plant doesn't require significant amounts of N until 3 weeks after germination. SDI eliminates the early preplant applications of large amounts of N that is common in growing furrow or sprinkler irrigated asparagus.

## PHOSPHOROUS

Phosphorous is also one of the major nutrients required for asparagus, Starting off your field at appropriate phosphorous levels is critical to a good stand. Any good quality source of phosphorous can be incorporated in the field as a preplant. Asparagus responds very well to liquid P starter fertilizers sprayed into the seed drill. In high pH soils it is not recommended to mix zinc with your P because it tends to tie up quickly in the soils and become unavailable to the plant. Phosphorous sources appropriate for application through the drip system include, Mono Ammonium Phosphate (MAP), Mono Potassium Phosphate (MKP) and phosphoric acid. MKP is expensive but it is highly soluble and is an excellent source of Potassium as well as Phosphorous. Again in high pH water it might be necessary to amend the water with sulphuric acid to lower the pH and keep the P in solution. Dry sources of P may also be used if placed in an area where the early root development will find it.

Phosphoric acid is good if the pH of the soil or water is a little high, but it is also expensive. When using Phosphoric acid be aware of high Ca and Mg levels in the water as they may react.

## POTASSIUM

Potassium is the forgotten nutrient. It is often available in adequate amount but your crop will still respond to added potassium. There are several good choices for adding potassium through the drip system. Potassium chloride is generally the cheapest but Potassium sulfate, Ammonium thiosulfate, and Potassium thiosulfate are good choices if you need added sulphur. Mono Potassium Phosphate is an expensive but excellent source of Potassium and Phosphorous. Don't forget that asparagus uses one unit of K for every unit of N applied. Keep a close watch on K levels in the tissue tests.

## SULPHUR

It is important to have an adequate level of sulphur in the soil prior to planting. However, soil tests are not a reliable method for predicting sulphur deficiency in a growing crop. The best approach is to determine if there is a history of sulphur deficiency in your area. If Sulphur is needed, the most economical practice is to broadcast apply and incorporate elemental sulphur at 200 to

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300 pounds per acre. At this rate elemental sulphur can last 4 to 7 years. The elemental sulphur will be gradually converted to the phytoactive sulphate form. To ensure a long slow release the particle size of the sulphur should range from 10 percent 100 mesh to 60 percent 6 mesh. The finer 100 mesh particles will convert to sulphate faster than the larger particles. A good source of S, K, and Mg is KMAG, a mined dry fertilizer Potassium Magnesium Sulfate. For injecting Sulphur through a SDI system KTS is a good source. This should be discussed.

## **ZINC**

## **IRON**

Iron deficiency must be confirmed with a tissue test. Chelated Iron is the best choice for application through the drip system

## **BORON**

Asparagus needs this nutrient early from germination to V5 and late in pollination to maturity. Watch tissue levels and apply when necessary. It is only required in very small amounts and is usually one of the minors supplied in common micro element packages added to liquid fertilizers.

## **CALCIUM AND MAGNESIUM**

Calcium and Magnesium are important in the pollination production and pollination of the ear. The levels of these nutrients in the soil should be adjusted prior to planting. Alkaline water or soil can contain a lot of calcium and magnesium in comparison to potassium, which makes it important to apply maintenance potassium even if the soil analyses show adequate potassium levels. Gypsum and magnesium sulphate are good sources for these nutrients.



## DRIP SYSTEM MAINTENANCE

The maintenance of your drip system centers on identification of the factors which can lead to reduction of the performance of your drip system and procedures to mitigate these negative impacts. Factors that can slow or stop flow through the drip system include, suspended material, chemical precipitation, biological growth, root intrusion, soil ingestion and crimping of the dripperline. To ensure maximum system life requires that you reduce or eliminate the impact of the negative factors. This may require water treatment and a systematic program for regular maintenance. In this section we outline the various potential issues that can adversely affect your drip system and offer procedures to mitigate the potential damage.

## WATER QUALITY

The type of emitter plugging problems will vary with the source of the irrigation water, either surface or ground water. In general, algal and bacterial growth are usually associated with the use of surface water. Whole algae cells and organic residues of algae are often small enough to pass through the filters of an irrigation system. These algal cells can then form aggregates that plug emitters. Residues of decomposing algae can accumulate in pipes and emitters to support the growth of slime-forming bacteria. Surface water can also contain larger organisms such as moss, fish, snail, seeds, and other organic debris that must be adequately filtered to avoid plugging problems. Groundwater, on the other hand, may contain high levels minerals that can challenge emitter function. Water from shallow wells (less than 100 ft) often will produce plugging problems associated with bacteria. Chemical precipitation is more common with deep wells.

A water quality analysis can give the grower a “heads up” on potential trouble areas for his drip system. This test should be accomplished before the final design of the system to ensure that proper components are installed to address any problem areas. Many laboratories around the United States have Water Quality Analysis services available which are able to conduct a “Drip Irrigation Suitability Test”. The analysis should include testing for pH, dissolved solids, manganese, iron, hydrogen sulfide, carbonate, and bicarbonates. Table 3 lists the more common water quality issues with drip irrigation. Having a water analysis in the moderate or even severe category does not mean drip irrigation cannot be used but only that special precautions must be applied to prevent problems. Consult your local Netafim dealer for more information on water quality and drip irrigation.

TYPE OF FACTOR	MINOR	MODERATE	SEVERE
SUSPENDED SOLIDS (ppm)			
INORGANIC	<10	10 - 100	>100
ORGANIC	<10		>10
CLOGGING			
IRON (ppm)	0.0 - 0.1	0.1 - 0.4	0.4+
MANGANESE (ppm)	0.0 - 0.2	0.2 - 0.4	0.4+
SULFIDES (ppm)	0.0 - 0.1	0.1 - 0.02	0.2+
CALCIUM CARBONATE	0.0 - 50.0	50.0 - 100.0	150.0+
BIOLOGICAL			
BACTERIA POPULATIONS	10,000	10,000 - 50,000	50,000+

**Table 7.1.** Water quality factors and their influence on your crop and drip system.

## SUSPENDED SOLIDS

Suspended solids in the incoming water are the most common stress impinging upon your drip system and the easiest to control. Each and every Netafim dripper has a large filter built into the unit to keep suspended particle from being trapped in the labyrinth. This filter is located toward the center of the drip pipe so that it can be cleaned by flushing the dripperline. This built in filter plays an important role in the longevity of your drip system. Thus, most water used for drip irrigation must be filtered to remove suspended solid particles that can lodge in the emitters and reduce or even stop the flow. These particles can be either organic such as algae or inorganic such as sand. Each manufacturer recommends a filtration level based on the technology of the emission device. The Netafim emitters commonly used for alfalfa production require 120 mesh filtration. This is the lowest filtration requirement of any commercial drip irrigation product. That means that the drippers are more reliable ensuring long

service even under harsh conditions.

Surface water generally contains a combination of organic and inorganic suspended particles. These include algae, moss, aquatic animals as well as suspended sand, silt and clay particles. Filtering this mix of material is a challenge that is best accomplished using three-dimensional filtration, such as disc or sand media. Well water generally has lower levels of suspended solids which can be handled using disc filtration or in cases of very low contaminant levels screen filters. If large quantities of sand are being generated by the well the a sand separator may be installed before other filters. Filters for your drip system should automatically clean (backflush) during operation when the contaminant levels get high enough (see Drip System Components for more information).

## CHEMICAL PRECIPITATION

Chemical plugging usually results from precipitation of one or more of the following minerals: calcium, magnesium, iron, or manganese. The minerals precipitate from solution and form encrustations (scale) that may partially or completely block the flow of water through the emitter. Water containing significant amounts of these minerals and having a pH greater than 7 has the potential to plug emitters. Particularly common is the precipitation of calcium carbonates, which is temperature and pH dependent. An increase in either pH or temperature reduces the solubility of calcium in water, and results in precipitation of the mineral.

When groundwater is pumped to the surface and discharged through a microirrigation system, the temperature, pressure, and pH of the water often changes. This can result in the precipitation of calcium carbonates or other minerals to form scale on the inside surfaces of the irrigation system components. A simple test for identifying calcium scale is to dissolve it with vinegar. Carbonate minerals dissolve and release carbon dioxide gas with a fizzing, hissing effervescence.



**Figure 7.1.** Dripper with calcium precipitate. The black pieces in the picture are pieces of the cut-away plastic dripperline and not contaminants.

Iron is another potential source of mineral deposit that can plug emitters. Iron is encountered in practically all soils in the form of oxides, and it is often dissolved in groundwater as ferrous bicarbonate. When exposed to air, soluble ferrous bicarbonate oxidizes to the insoluble or colloidal ferric hydroxides and precipitates. The result is commonly referred to as 'red water,' which is sometimes encountered in farm irrigation wells. Manganese will sometimes accompany iron, but usually in lower concentrations.

Hydrogen sulfide is present in many wells. Precipitation problems will generally not occur when hard water, which contains large amounts of hydrogen sulfide, is used. Hydrogen sulfide will minimize the precipitation of calcium carbonate ( $\text{CaCO}_3$ ) because of its acidity.

Fertilizers injected into a drip system may contribute to plugging. This may be the result a chemical reaction that occurs when different fertilizers are mixed or because the fertilizer in question is not completely soluble. This type of plugging is completely preventable. To determine the potential for plugging problems from fertilizer injection, the following test can be performed:

1. Add drops of the liquid fertilizer to a sample of the irrigation water so that the concentration is equivalent to the diluted fertilizer that would be flowing in the lateral lines.
2. Cover and place the mixture in a dark environment for 12 hours.
3. Direct a light beam at the bottom of the sample container to determine if precipitates have formed. If no apparent precipitation has occurred, the fertilizer source will normally be safe to use in that specific water source.

## BIOLOGICAL GROWTH

A microirrigation system can provide a favorable environment for bacterial growth, resulting in slime buildup. This slime can combine with mineral particles in the water and form aggregates large enough to plug emitters. Certain bacteria can cause enough precipitation of manganese, sulfur, and iron compounds to cause emitter plugging. In addition, algae can be transported into the irrigation system from the water source and create conditions that may promote the formation of aggregates.

Emitter plugging problems are common when using water that has high biological activity and high levels of iron and hydrogen sulfide. Soluble ferrous iron is a primary energy source for certain iron-precipitating bacteria. These bacteria can attach to surfaces and oxidize ferrous iron to its insoluble ferric iron form. In this process, the bacteria create a slime that can form aggregates called ochre, which may combine with other materials in the microirrigation tubing and cause emitter plugging). Ochre deposits and associated slimes are usually red, yellow, or tan.

Sulfur slime is a yellow to white stringy deposit formed by the oxidation of hydrogen sulfide. Hydrogen sulfide (H<sub>2</sub>S) accumulation in groundwater is a process typically associated with reduced conditions in anaerobic environments. Sulfide production is common in lakes and marine sediments, flooded soils, and ditches; it can be recognized by the rotten egg odor. Sulfur slime is produced by certain filamentous bacteria that can oxidize hydrogen sulfide and produce insoluble elemental sulfur.

The sulfur bacteria problem can be minimized if there is not air-water contact until water is discharged from the system. Defective valves or pipe fittings on the suction side of the irrigation pump are common causes of sulfur bacteria problems. If a pressure tank is used, the air-water contact in the pressure tank can lead to bacterial growth in the tank, clogging the emitter. The use of an air bladder or diaphragm to separate the air from the water should minimize this problem.

## ROOT INTRUSION

Plant roots tend to grow toward soil areas with the highest water content. Because of this tendency, roots can clog subsurface drip systems by growing into the emitter openings. Plant roots tend to “hunt” for water when it is in short supply thus, the problem seems to be more acute in when irrigation is not sufficient for the plant needs. This is a particular problem in systems that are left unused for part of the season. Several strategies can be employed to reduce the possibility of root intrusion.

1. Short frequent irrigations keep adequate water in the root zone so the roots have no need to look for water.
2. Acid injection that lowers the pH to less than 4 will discourage root growth and can be used to clean roots out of emitters with small amounts of root intrusion. High concentrations of chlorine (100 to 400 ppm), N-pHURIC, phosphoric or metam sodium (Vapam) will also destroy roots in the emitters.
3. In areas where it is allowed, trifluralin is an effective inhibitor of root growth and can be used to prevent root intrusion.
4. Seamed tape encourages roots to grow along the seam and into the emitter. Netafim Products are designed without a seam to discourage this intrusion.



**Figure 7.2.** Filamentous sulfur slime completely clogging a small water meter.

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## SOIL INGESTION

Soil ingestion is not a problem in properly designed drip systems. Soil injection occurs when soil is sucked into the drip tape. When a drip system is shut off the water continues to flow to the low end of the field creating a vacuum at the higher end, sucking saturated soil into the line. A properly designed drip system will minimize this potential problem. Netafim drippers and dripperline offer protection against soil ingestion because DripNet PC and UniRam have an anti-siphon feature built into the dripper. The 15 mil dripperline products like Typhoon have a “flap” outlet which prevents the outlet hole from sealing by wet soil. Supply manifold must be equipped with vacuum relief valves. These valves allow air to flow into the dripperlines when the system is shut off. Use high quality Netafim/ARI valves that will allow sufficient air into the system. Insufficient air will create a vacuum the same as no valve. This is not a good place to skimp.

## MAINTENANCE PROCEDURES

### FILTER MAINTENANCE

Follow the standard instructions for the maintenance of your filter system. Filters are the first line of protection for your drip system and they need regular maintenance to operate at a high level. On a biweekly basis observe the system as it completes a backflush cycle. Make sure all pressures are within the system limits before and after backflushing. Check the operation of backflush valves, pressure differential switches and controller. Make sure you clean the command filter! At the end of the season check the media level in media tanks. Scum can build up on disc filters and the discs may need to be cleaned with acid. In areas that experience a freeze drain all water from the filter, valves and command system!

### DRIPPERLINE FLUSHING

To minimize sediment build up, regular flushing of drip irrigation pipelines is recommended. The system design should be such that a minimum flush rate of 1.5 ft/sec can be obtained in the lines. Valves large enough to allow sufficient velocity of flow should be installed at the ends of mains, submains, and manifolds. Also, allowances for flushing should be made at the ends of lateral lines. Begin the flushing procedure with the mains, then proceed to submains, manifolds, and finally to the laterals. Flushing should continue until clean water runs from the flushed line for at least two minutes. A regular maintenance program of inspection and flushing will help significantly in preventing emitter plugging. Flushing is required both at system startup and shutdown. At shutdown it is best to flush all fertilizer from the lateral lines prior to shutting the irrigation system down.

## CHEMICAL TREATMENT

Chemical treatment is often required to prevent emitter plugging due to microbial growth and/or mineral precipitation. The attachment of inorganic particles to microbial slime is a significant source of emitter plugging. Chlorination is an effective measure against microbial activity. Use chlorine and all other chemicals only according to label directions. Acid injection can remove scale deposits, reduce or eliminate mineral precipitation, and create an environment unsuitable for microbial growth.

## CHLORINE INJECTION

### OVERVIEW

Chlorination is the most common method for treating organic contaminants. Active chlorine is a strong oxidizer and as such, is useful in achieving the following:

- A. Prevent clogging and sedimentation of organic substances.
- B. Destroy and decompose sulfur and iron bacteria, as well as accumulated bacterial slime in the system.
- C. Improve performance of filtration systems while reducing back flush water.
- D. Clean systems of organic sediments. (Chlorine has no effect on scale deposits.)

If the microirrigation system water source is not chlorinated, it is a good practice to equip the system to inject chlorine to suppress microbial growth. Since bacteria can grow within filters, chlorine injection should occur prior to filtration.

Liquid sodium hypochlorite (NaOCl)--laundry bleach--is available at several chlorine concentrations. The higher concentrations are often more economical. It is the easiest form of chlorine to handle and is most often used in drip irrigation systems. Powdered calcium hypochlorite (CaCOCl<sub>2</sub>), also called High Test Hypochlorite (HTH), is not recommended for injection into

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micro-irrigation systems since it can produce precipitates that can plug emitters, especially at high pH levels. The following are several possible chlorine injection schemes:

- Inject continuously at a low level to obtain 1 to 2 ppm of free chlorine at the ends of the laterals.
- Inject at intervals (once at the end of each irrigation cycle) at concentrations of 20 ppm and for a duration long enough to reach the last emitter in the system.
- Inject a slug treatment in high concentrations (50 ppm) weekly at the end of an irrigation cycle and for a duration sufficient to distribute the chlorine through the entire piping system.

The method used will depend on the growth potential of microbial organisms, the injection method and equipment, and the scheduling of injection of other chemicals.

When chlorine is injected, a test kit should be used to check to see that the injection rate is sufficient. Color test kits (D.P.D.) that measure 'free residual' chlorine, which is the primary bactericidal agent, should be used. The orthotolidine-type test kit, which is often used to measure total chlorine content in swimming pools, is not satisfactory for this purpose. D.P.D. test kits can be purchased from irrigation equipment dealers. Check the water at the outlet farthest from the injection pump. There should be a residual chlorine concentration of 1 to 2 ppm at that point. Irrigation system flow rates should be closely monitored, and action taken (chlorination) if flow rates decline.

Chlorination for bacterial control is relatively ineffective above pH 7.5, so acid additions may be necessary to lower the pH to increase the biocidal action of chlorine for more alkaline waters. Since sodium hypochlorite can react with emulsifiers, fertilizers, herbicides, and insecticides, bulk chemicals should be stored in a secure place according to label directions.

## RECIPE FOR CHLORINE INJECTION

**WARNING!** Active chlorine solutions are dangerous to human beings and animals. So, the manufacturers' instructions must be followed very carefully. When using chlorine, proper protection for the eyes, hands, and body parts must be worn, i.e. glasses, gloves, shoes, etc. Chlorine contact with the skin can cause serious burns, contact with the eyes can cause blindness, and swallowing may be fatal. Prior to filling any tank with chlorine solution, be sure it is absolutely clean of fertilizer residue. Direct contact between chlorine and fertilizer can create a thermo reaction, which can be explosive. This is extremely dangerous!! The direct contact of chlorine and fertilizer in the irrigation water after it has been injected into the system is not hazardous.

The contact of free chlorine in water and nitrogenous (ammonium and urea) fertilizer creates the combination of chlor amine which is called "combined chlorine". Hence, if possible, avoid any application of ammonium or urea fertilizers together with chlorination.

**In the case that chlorination is required, it is recommended to ask your local Farm Extension Service for assistance in the computation and application methods.**

Sodium hypochlorite is transported by tanks. It should be stored in a clean tank without any remnants of fertilizers. The tanks should be painted white and placed in a shaded area. In field storage should not exceed 20 days. In case of gas chlorine, transportation, storage and general handling should be carried out in accordance with the manufacturers' specific instructions under supervision of the relevant authorities.

## CONCENTRATION AND INJECTION POINT

It is important to remember that chlorine concentration decreases as time and distance from the injection point increases. The lowest concentration will always be found furthest from the injection point. The injection point should be as close as possible to the treated system.



The required concentration of active chlorine is a result of the chlorination objective.

CHLORINATION OBJECTIVE	APPLICATION METHOD	REQUIRED CONCENTRATION (PARTS PER MILLION)	
		SYSTEM HEAD	SYSTEM END
PREVENT SEDIMENTATION	CONTINUOUS CHLORINATION	3 - 5	0.5 - 1
	INTERMITTENT CHORINATION	10	1 - 2
SYSTEM CLEANING	CONTINUOUS CHLORINATION	5 - 10	1 - 2
	INTERMITTENT CHORINATION	15 - 50	4 - 5

When the purpose of chlorination is improving filtration performance, the injection point should be close to the filtration plant to assure even distribution throughout the filters. Chlorine concentration downstream of the filter battery should be no less than 12 p.p.m. for constant chlorination and three times more for intermittent chlorination.

For continuous chlorination, the injection should start after pressurizing the system. For intermittent chlorination, the procedure should be as follows:

- Start: By flushing the system.
- Injection: Inject required amount over time, preferably at the beginning of the cycle.
- Contact Time: Preferably one hour, but not less than thirty minutes.
- Flush: At the end of the process, open the end of the line, flush out and run fresh water for an hour.

## CALCULATIONS - LIQUID CHLORINE

Use the following worksheets to determine the proper injection rate of chlorine in terms of GPH for liquid and Lbs./hr. for gas.

1. Choose the proper chlorine solution factor:
  - 5% Chlorine Solution: The factor is = 2.00
  - 10% Chlorine Solution: The factor is = 1.00
  - 15% Chlorine Solution: The factor is = 0.67
2. Multiply the solution factor by the treated flow in terms of gpm.
3. Multiply by the desired chlorine concentration in terms of ppm.
4. Multiply by the factor of 0.0006.
5. The result will be the required injection rate of chlorine in terms of GPH

For example:

The chlorine solution is 10%.

The flow is 100 gpm.

The desired chlorine concentration is 10 ppm.

Chlorine	Flow	Desired Chlorine	Chlorine Injection
Solution Factor	x gpm	x concentration (ppm)	x 0.0006 = Rate GPH
10	x 100	x 10	x 0.0006 = 0.6

The injection rate of chlorine solution will be 0.6 gph

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## CALCULATIONS - CHLORINE GAS

1. Determine the flow of the treated zone in terms of gpm.
2. Multiply the flow by the desired chlorine concentration in terms of ppm.
3. Multiply it by the factor of 0.0005.
4. The result will be the injection rate of the gas in terms of lbs. per HOUR.

For example:

The flow is 100 gpm.

The desired chlorine concentration is 10 ppm.

Flow		Desired Chlorine		Chlorine Injection
gpm	x	Concentration (ppm)	x 0.0005	= Rate (lb/hr)
100	x	10	x 0.0005	= 0.5

The injection rate of the gas will be 0.5 Lb./hr.

## ACID INJECTION OVERVIEW

Acid can be used to lower the pH of irrigation water to reduce the potential for chemical precipitation and to enhance the effectiveness of the chlorine injection. Sulfuric, hydrochloric, and phosphoric acid are all used for this purpose. Acid can be injected in much the same way as fertilizer; however, extreme caution is required. The amount of acid to inject depends on how chemically base (the buffering capacity) the irrigation water is and the concentration of the acid to be injected. One milliequivalent of acid completely neutralizes one milliequivalent of bases.

If acid is injected on a continuous basis to prevent calcium and magnesium precipitates from forming, the injection rate should be adjusted until the pH of the irrigation water is just below 7.0. If the intent of the acid injection is to remove existing scale buildup within the microirrigation system, the pH will have to be lowered more. The release of water into the soil should be minimized during this process since plant root damage is possible. An acid slug should be injected into the irrigation system and allowed to remain in the system for several hours, after which the system should be flushed with irrigation water. Acid is most effective at preventing and dissolving alkaline scale. Avoid concentrations that may be harmful to emitters and other system components.

Phosphoric acid, which is also a fertilizer source, can be used for water treatment. Some microirrigation system operators use phosphoric acid in their fertilizer mixes. Care should be used with the injection of phosphoric acid into hard water since it may cause the precipitation of calcium carbonate.

For safety, dilute the concentrated acid in a non-metal, acid-resistant mixing tank prior to injection into the irrigation system. When diluting acid, always add acid to water, never water to acid. The acid injection point should be beyond any metal connections or filters to avoid corrosion. Flushing the injection system with water after the acid application is a good practice to avoid deterioration of components in direct contact with the acid.

Acids and chlorine compounds should be stored separately, preferably in epoxy-coated plastic or fiberglass storage tanks. Acid can react with hypochlorite to produce chlorine gas and heat; therefore, the injection of acid should be done at some distance (2 feet), prior to the injection of chlorine. This allows proper mixing of the acid with the irrigation water before the acid encounters the chlorine.

Hydrochloric, sulfuric, and phosphoric acids are all highly toxic. Always wear goggles and chemical-resistant clothing whenever handling these acids. Acid must be poured into water; never pour water into acid.

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## RECIPE FOR THE TREATMENT OF DRIP IRRIGATION SYSTEMS WITH ACID

**SAFETY PRECAUTIONS:** Contact of the acid with the skin can cause burns. Contact with the eyes could be extremely dangerous. During treatment, and especially when filling containers with acid, wear protective goggles, clothes and boots. Follow the instructions on the Material Safety Data Sheet (M.S.D.S.) attached to the delivered acid.

**PROBLEMS OF CORROSION:** Polyethylene and PVC tubes are resistant to acid. Aluminum, steel, (with or without inner concrete coating) and asbestos-cement pipes are damaged by corrosion. In every case, resume normal water flow through the system after completion of treatment for at least one hour in order to flush any remaining acid. The importance of flushing cannot be over emphasized when the pipes used are particularly sensitive to corrosion.

**METHOD OF OPERATION:** Acid can be applied through the drip-irrigation system by a fertilizer pump resistant to acids or by conventional control head with a fertilizer tank.

### APPLICATION OF ACID BY FERTILIZER PUMP

The goal of acid treatment is to lower the pH level of the water in the irrigation system to values between two to three for a short time (twelve - fifteen minutes). This is achieved by injection of a suitable quantity of acid into the system.

#### INSTRUCTIONS:

1. Clean the filters.
2. Flush the system with clean water as follows: flush the main pipes then the distribution pipes and finally the drip laterals. Use the highest pressure possible for flushing. Deactivate the pressure regulators and flush the laterals, a few at a time. Flushing with clean water will prevent blockages during treatment.
3. Ascertain the discharge of the water from the system through which the acid will be injected, and the discharge of the fertilizer pump.
4. Calculate the required amount of acid that should be injected into the system in order to get 0.6% of acid concentration in the irrigation water.
5. Inject the acid into the system within fifteen minutes only after the system has reached maximum operation pressure.

**NOTE:** Acids suitable to be injected in 0.6% concentrations are:

Nitric acid	60%
Phosphoric acid	75%- 85%
Sulfuric acid	90%- 96%
Hydrochloric acid	30%- 35%

In many cases the most economical acids are sulfuric acid (battery acid) and hydrochloric acid (swimming pool acid).

### CALCULATION METHOD:

The injection rate of the acid to the treated zone can be calculated as follows:

$$\text{Injection rate in GPH} = (\text{System flow in GPM}) \times (.36/\text{acid \% in decimal form})$$

For example:

Given the following-Sulfuric acid 90%, and system flow 100 g.p.m.

$$100 \times (0.36/.9) = 40 \text{ g.p.h.}$$

Because the acid is to be injected only 15 minutes the total acid required is 10 gallons

**NOTE:** Under certain conditions, i.e., hard water with a very high pH, there might be a need to raise the acid concentrate in the system to 1%. Please consult a Netafim Representative prior to such a treatment.

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# IRON CONTROL SYSTEM FOR DRIP IRRIGATION

## INTRODUCTION

Iron deposits create severe clogging problems in drip systems. Iron deposit is described as a filamentous amorphous gelatinous type of brown-reddish slime, that precipitates from water that contains iron. Iron deposits get stuck in drippers and cause complete plugging of the system.

The problem exists in well water areas where the groundwater aquifers are formed mainly of sandy soils or organic muck soils (very common in Florida) usually with a pH of below 7.0 and in the absence of dissolved oxygen. These waters contain ferrous iron (Fe+2) which is chemically reduced, 100% water soluble and serves as the primary raw material for slime formation.

Iron bacteria, mainly from the filamentous genuses like Gallionella Sp. Leptolhris and ,Sphaerotihus and less from the rod type like Pseudomonas and Enterobacter, when present in the water, react with the ferrous iron (Fe+2) through an oxidation process. This changes the iron form to ferric iron (Fe+3) which is insoluble. The insoluble Ferric iron is surrounded by the filamentous bacteria colonies that create the sticky iron slime gel that is responsible for clogging the dripper.

Concentrations of ferrous iron as low as 0.2 ppm are considered as a potential hazard to drip systems (H.W. Ford 1982). Between 0.2-1.5 ppm emitter clogging hazard is moderate. Concentrations above 1.5 ppm are described as severe (Bucks and Nakayama -1980). Practically any water that contains concentrations higher than 0.5 ppm of iron cannot be used in drip systems unless they are treated chemically or otherwise. Experiments in Florida indicate that chlorination successfully controls iron slime when iron concentrations were less than 3.5 ppm and the pH was below 6.5 (Nakayama and Bucks -1986). It is also stated that long term use of water with a high level of iron, may not be suitable for drip irrigation. The literature mentions that water containing more than 4.0 ppm cannot be efficiently chemically treated and it should undergo a pond sedimentation process before pumping it back to a drip system.

## IRON CONTROL METHODS

There are several ways to control iron slime problems. The common denominator of all treatments is prevention of the formation of slime. Basically there are two preventive treatments:

1. STABILIZATION (Precipitation Inhibitors)

Stabilization treatments keep the ferrous iron in solution by chelating it with sequestering agents. Such agents include various poly phosphates and phosphonate.

2. OXIDATION - SEDIMENTATION - FILTRATION

This type of treatment oxidizes the soluble "invisible" ferrous iron into the insoluble "visible" ferric iron, It then will precipitate, so it can be physically separated from the water by means of filtration.

The second procedure is generally the less expensive for the severe iron problems in supply water. The various means to oxidize iron include chlorination, and aeration. There are also other oxidizers but they are generally more expensive. Chlorine injection for iron control is normally handled in the same manner as continuous chlorine injection outlined above, with residual chlorine levels of 1 to 2 ppm. Aeration is most often applied to settling ponds using sprayers or agitators to react the Iron with the air. In this case the pond becomes a pre-filtration component.

## SEDIMENTATION - FILTRATION

A sand media filter is the most appropriate filter for settling down the oxidized iron and filtering it from the water. When designing a filtration system for iron removal it is good practice to oversize the filter units. Larger units with slower water velocity will allow oxidized iron to settle and the resultant water will be easier to filter. This is the same principle as exhibited in settling ponds.

## SCALE INHIBITORS

Scale inhibitors, such as chelating and sequestering agents, have long been used by other industries. A number of different chemicals are being marketed for use in microirrigation systems to prevent plugging. Many of these products contain some form of inorganic polyphosphate that can reduce or prevent precipitation of certain scale-forming minerals. These inorganic

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phosphates do not stop mineral precipitation, but keep it in the sub-microscopic range by inhibiting its growth. Probably the most commonly used of these materials is sodium hexametaphosphate -- as little as 2 ppm can hold as much as 200 ppm calcium bicarbonate in solution.

Sodium hexametaphosphate is not only effective against alkaline scale, but also forms complexes with iron and manganese and can prevent depositions of these materials. Although the amount of phosphate required to prevent iron deposits depends on several factors, a general recommendation is 2 to 4 ppm phosphate for each ppm of iron or manganese.

These phosphates are relatively inexpensive, readily soluble in water, nontoxic, and effective at low injection rates.

## **POND TREATMENT**

Algae problems which often occur with surface water sources such as a pond can be effectively treated with copper sulfate (CuSO<sub>4</sub>). Dosages of 1 to 2 ppm (1.4 to 2.7 pounds per acre foot) are sufficient and safe to treat algae growth. Copper sulfate should be applied when the pond water temperature is above 60°F. Treatments may be repeated at 2 to 4-week intervals, depending on the nutrient load in the pond. Copper sulfate should be mixed into the pond (i.e., sprinkled into the wake of a boat). The distribution of biocides into surface water must be in compliance with EPA regulations.

Copper sulfate can be harmful to fish if alkalinity, a measure of the water's capacity to neutralize acid, is low. Alkalinity is measured volumetrically by titration with H<sub>2</sub>SO<sub>4</sub> and is reported in terms of equivalent CaCO<sub>3</sub>. Repeated use of copper sulfate can result in the buildup to levels toxic for plants.



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## RODENT MANAGEMENT STRATEGIES

Unmanaged populations of rodents in agricultural fields cause significant damage and loss of productivity in a wide range of crops. Small rodents such as mice and voles damage young and older trees alike in nurseries and orchards by girdling the tender saplings and branches. Studies in New York have show up to a 66% reduction in apple yields as a result of girdling by an over-population of voles. In field crops these small mammals love to unearth and devour newly planted seeds and snack on the young seedlings that survive. Larger rodents such as pocket gophers damage field crops by eating the root system out from under the plant. Colorado State University Cooperative Extension Bulletin # 6.515 states, "pocket gophers reduce productivity of portions of alfalfa fields by 20 to 50%". Rodents can also cause damage to farm equipment and infrastructure. They may gnaw on small diameter cables and irrigation pipes. The mounds created by larger rodents can damage or disrupt harvesting equipment while the tunnels can cause leaks in irrigation channels and even small earthen dams.



There is no single, simple method for managing rodent overpopulation on agricultural lands. Control of these potential pests requires a well designed plan that is executed on a consistent basis. The formation of a systematic plan for managing rodents in subsurface drip irrigated fields requires research into the predominant species in your region and rules regulating how these populations may be managed. It is not the purpose of this fact sheet to be a comprehensive manual on rodent population control throughout North America. This document is meant to outline the components of a well thought out rodent control plan, and to guide growers to local resources to help them formulate such a plan. A reference list at the end of this guide will assist you in finding more information on your local conditions.

A wide variety of rodents may inhabit agricultural lands, from voles, mice and rats to ground squirrels and gophers. A comprehensive 2 volume set, *Prevention and Control of Wildlife Damage* edited by Hygnstrom, Timm and Larson is a comprehensive resource for all types of human animal interaction with special attention given to animal behavior. In general, rodents responsible for the majority of damage to agricultural crops and systems live underground for at least part of their lives. A physiological feature of rodents is that their teeth grow continuously. As a result these animals must chew to wear down their teeth so that they fit in the mouth else the animal will starve. Both the feeding and the need to gnaw effect damage on crops and equipment. In the following discussions general applications to all rodents will be presented and species specific actions included when appropriate.

Management of rodent populations on agricultural land generally falls into the following categories.

1. Habitat modification and exclusion to reduce population pressure
2. Trapping and removal
3. Use of repellants to deter invasion
4. Use of repellants to deter gnawing
5. Extermination

Each category will be discussed with respect to protecting crops and equipment.

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## HABITAT MODIFICATION TO REDUCE RODENT PRESSURES

Existing rodent pressures either from surrounding fields or within a newly planted field is the first source of conflict between rodents, your crop and equipment. A cultivated block surrounded by unkempt ground or by open fields infested with rodents represents a continuous battle. Thus, the first step in an integrated rodent management program is to reduce the pressure of high rodent populations in the entire area. First take a visual count of rodent presence in the surrounding fields. Large rodents such as pocket gophers will leave telltale mounds. Smaller animals such as mice and voles will not be as obvious. The presence of “runways” in grassy areas is one sign of small rodent activity. Assessing the rodent population in the general area will give you an indication of the intensity of the management required to protect your crop and irrigation system.

After assessing the situation establish a buffer zone around the field. Elimination of weeds, ground cover and litter around the field will reduce habitat suitability. Cultivating this area is a good deterrent for small rodents as it destroys runways and may kill them outright. Larger animals such as pocket gophers can borrow under it this area, but the lack of food may slow them down. If cultivation is not an option weed control is still imperative especially for pocket gopher management. Weeds often have large tap roots which are the preferred food for gophers while fibrous rooted grasses are less appealing. The opposite is true for smaller rodents which enjoy the cover that grasses provide. Thus, in plantings of corn which have a fibrous root structure, the main rodent pressure may be mice and other small rodents. The resources listed here as well as your local extension service can help you characterize the primary rodent pressures for your area and crop.

## TRAPPING AND REMOVAL

Trapping can be an effective method to reduce the population of large rodents such as pocket gophers on small to medium sized fields (<50 acres). Trapping is also effective to clean up remaining animals after a poison control program. In the case of smaller rodents such as mice, trapping is not usually cost effective because these animals have such rapid reproduction rates. Body-gripping traps work exceptionally well for capturing pocket gophers. Traps can be set in the main tunnel or in a lateral, preferably near the freshest mound. Consult some of the specific pocket gopher control guides listed at the end of this document for details on how and where to set these traps. Gophers usually visit traps within a few hours of setting so newly placed traps should be checked twice daily. If a trap has not been visited within 48 hours, move it to a new location. Trapping is usually most effective in the spring and fall when the gophers are actively building mounds. The information section at the end of this document lists several sources for traps.

## REPELLANTS

The rodent repellants can be divided into two large categories, those that affect the population at large and those that repel the rodent from gnawing on cables or small diameter tubing such as dripperline. Two repellants that have proven effective in reducing rodent populations over a large area are owl boxes and wet soil. Owl boxes are being employed in greater numbers as part of a rodent management program. The principle is simple, the higher the owl population the fewer the rodents. The application of owl boxes to deter rodents is becoming more prevalent. This technique works especially well for small bodied rodents such as mice but also affects larger rodents because owls prey on the young. Consult your local extension service for the design and placement of owl boxes appropriate for your area.

Wet soil, but not flooding, can be an effective deterrent for rodents that spend much of their time in tunnels. The repellent effect of wet soil seems to be the result of poor oxygen transfer through the wet soil. Rodents that live in tunnels depend upon the air traveling through the soil for oxygen. In wet soils the rate of oxygen diffusion is greatly reduced and produces an environment inhospitable to the rodents. Flooding the soil, to drown the rodents is not as effective. The rodents are mobile enough to avoid drowning and most have tunnels designed to avoid the wettest areas in the field in the case of heavy rains. The soil need not be saturated to effect the population. In practice the use of soil wetness to repel rodents is limited because many crops require soil drying before harvest and because the irrigation system is off for a period of time.

Other general repellants are not effective in rodent management over a large area. Sound or ultrasound generators have not been proven effective in driving out rodents. Taste repellants such as capsicum may affect some rodents such as voles but have less effect on pocket gophers.

Targeted repellants, those applied on or around the object you wish to protect, a sapling, cable or dripperline have not received much formal study but has promise when combined with a plan to reduce overall populations. Proper dripperline installation

practices can reduce rodent, specifically mouse damage. When plowing thin walled dripperline in deep installations the installation shank can leave cracks in the soil and a path down to the dripperline that mice love to follow chewing as they go. Best installation practices dictate that following installation cracks in the soil be sealed by running a tractor tire over cracks created by the plow. This will close the opening in the soil made by the plow and cut off easy access by mice or voles to the loose soil around the dripperline.

The following installation procedures can significantly reduce potential rodent damage to subsurface dripperlines. It is highly recommended that all these procedures be followed.

1. Prepare a buffer area around the field and apply rodenticides according to a plan drawn up with your local extension agent if rodent pressures are high.
2. Have the field as free of crop residue as possible. Field mice are especially found of plant residues.
3. Apply drip tube as deep as practical for the crop being grown. Installations of the drip tube at depths greater than 12" exhibit less rodent damage.
4. Apply a repellent or toxicant as you install the dripperline
5. Pack the shank slit with front tractor tires to reduce ready made paths for small rodents. The front tires should be narrow, single ribbed, cultivating tires (see photo) and the front of the tractor must be weighted. This operation must be completed the same day as installation
6. Run the system for 12 hours per zone as within two weeks of completing the installation. Installing the tube in the fall and running the first water in the spring is asking for problems.



Figure 8.1. Tractor on left installing TWD while tractor on right packs soils left open by shank.

Rodents, especially pocket gophers, are often most active in the fall and early spring. It is often at these times, when the irrigation system is not being used that most damage occurs. Experience has shown that rodent damage when the system is shut down can be reduced by properly applying an acid treatment. As acidification of the dripperline is standard practice for end of the season cleaning a slight modification of this process may also help to protect dripperlines from rodent damage.

1. Flush each zone at pressures recommended by your dealer
2. If the field is dry pre-water each zone for 6 hours
3. Inject N-pHuric at 200 ppm for 1 hour before shutdown of each zone. Shut down zones leaving N-pHuric in the lines.

Chemigating with properly labeled pesticide that has a strong odor or fumigation effect such as thiram (a fungicide) will cause many rodents to keep away from buried dripperlines. This may be an effective technique for early season deterrence. Under all conditions make sure the pesticide is properly labeled for use in your area.

## EXTERMINATION

Several rodenticides including toxicants and anticoagulants have been registered with the federal government and are in current use for managing rodent populations. Please check with your local extension service for those labeled for your area and always follow the application directions. In general placing approved baits around the perimeter of the field prior to irrigation system installation will reduce rodent pressures on a new field. For pocket gophers a mechanical "burrow builder" that releases bait is effective in perimeter applications (see Appendix for sources and plans). Hand baiting tunnels is time consuming but effective for the trained applicator. The usual treatment for gophers is bait plowed in every other furrow and around the perimeter of the field. Fumigants applied in the tunnels are usually not as effective as toxicants and trapping because they tend to diffuse which gives the gopher enough time to escape.

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## **RODENT MANAGEMENT ACTION PLAN**

An integrated approach must be taken to reduce rodent damage to crops and equipment. This plan must involve reducing acceptable habitats for rodents close to the field and may involve trapping or poisoning to control active populations. In addition, the dripperline itself can be protected using the repellent effect of some pesticides and slightly acidifying the soil around the lines.

Fall and spring are the most active time for rodents and these seem to be the worst seasons for damage. Thus any management program must focus on these seasons. Do not underestimate the wealth of reference materials and the help of local extension agents and pest control specialists. Many growers have implemented successful plans for rodent management on their fields protecting the investment in their irrigation system and improving yields. To be effective, any rodent control plan must be diligent and consistent in a time frame determined by the extent of the rodent pressure in the general area.





# POCKET GOPHER MANAGEMENT SUPPLIES

## TOXICANTS

### Anticoagulants (Chlorphacinone and Dipacinone)

B & G Chemicals and  
Equipment Co., Inc.  
10539 Maybank  
Dallas TX 75345-0428  
(214) 357-5741  
(800) 345-9387  
(214) 357-4541 Fax

J.T. Eaton & Co., Inc.  
1393 E. Highland Road  
Twinsburg, OH 44087  
(216) 425-7801  
(800) 321-3421  
(216) 425-8353

HACCO, Inc.  
PO Box 7190  
Madison, WI 53707  
(608) 221-6200  
(608) 221-6208 Fax

### Strychnine and Zinc Phosphide

B & G Chemicals and  
Equipment Co.  
10539 Maybank  
Dallas, TX 75345-0428  
214 357-5741  
800 345-9387  
214 357-4541 Fax

Pocatello Supply Depot USDA-  
APHIS Wildlife Services  
238 E. Dillion Street  
(208) 236-6920  
(208) 236-6922 Fax

RCO, Inc.  
PO Box 446  
Junction City, OR 97448  
(503) 995-8160  
(800) 214-2248

York Distributors  
120 Express Street  
Plainview, NY 11803  
(516) 932-0600  
(800) 645-6007  
(516) 932-4316

## FUMIGANTS

### Aluminum Phosphide

Douglas Products  
and Packaging Co.  
1500 E. Old 210 Hwy  
Liberty, MO 64068  
(800) 223-3684  
(816) 781-1043 Fax

Pestcon Systems, Inc.  
PO Box 339  
Wilson, NC 27894  
(800) 548-2778  
(919) 243-1832 Fax

Research Products Co.  
PO Box 1460  
Salina, KS 67402-1460  
(913) 825-2181  
(913) 825-8908 Fax

Van Waters and Rogers  
PO Box 24325  
Seattle, WA 98124-1325  
(206) 889-3400  
(206) 889-4100 Fax

### Gas Cartridges

Dexol Industries  
1450 W. 228th Street  
Torrance, CA 90501  
(310) 326-8373  
(800) 421-2934  
(310) 325-0120 Fax

Pocatello Supply Depot USDA-  
APHIS Wildlife Services  
238 E. Dillion Street  
Pocatello, ID 83201  
(208) 236-6920  
(208) 236-6922 Fax

South Dakota Dept. of  
Agriculture

Rodent Control Fund  
Anderson Bldg.  
Pierre, SD 57501  
(605) 773-3724 Fax

Van Waters and Rogers  
PO Box 24325  
Seattle, WA 98124-1325  
(206) 889-3400  
(206) 889-4100 Fax

## BAIT APPLICATION DEVICES & MATERIALS

### Burrow-Builder

Rue R. Elston Co.  
706 N. Weber  
Sioux Falls, SD 57103  
(605) 336-7716

The Perry Company  
PO Box 7187  
Waco, TX 76714  
(817) 756-2137  
(800) 792-3246

RCO, Inc.  
PO Box 446  
Junction City, OR 97448  
(503) 995-8160  
(800) 214-2248

Wilco Distributing, Inc.  
1215 W. Loral Ave.  
Lompoc, CA 93436  
(805) 735-2476

### Probes and Bait Dispensers

Eckroat Seed Co.  
1106 N. Eastern Ave.  
PO Box 17610  
Oklahoma City, OK 73117  
(405) 427-2484

Rue R. Elston Co.  
706 N. Weber  
Sioux Falls, SD 57103  
(605) 336-7716

Quinn Mfg Co.  
44201 Chapman Road  
Anaza, CA 92539  
(909) 763-4590

Wilco Distributing, Inc.  
1215 W. Loral Ave.  
Lompoc, CA 93436  
(805) 735-2476

## TRAPS

M&M Fur Co.  
PO Box 15  
Bridgerwater, SD 57319-0015  
(605) 729-2532  
(800) 658-5554

H.J. Spencer & Sons  
PO Box 131  
Grainsville, FL 32602  
(904) 372-4018

### Wildlife Management Supplies

Critter Control, Inc.  
640 Starkweather Road  
Plymouth, MI 48170  
(313) 435-6300  
(800) 451-6544

## EXTERMINATION EQUIPMENT

### Rodentator

Meyer Industries  
PO Box 39  
Midvale, ID 83645  
(800) 750-4553

### Pressurized Exhaust Rodent Control

H & M Gopher Control  
1979 Country Rd 106  
Tulelake, CA 96134  
(530) 667-5181