John Ogonowski and Doug Bereuter Farmer-to-Farmer Program

Seedless Water Melon Production Guideline for Kenyan Growers

By

Mark Arena

Horticulturist & Farmer-to-Famer Volunteer

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Before introducing the production guidelines it is important to make the grower aware of certain challenges that are associated with producing seedless watermelons. The reason being is that if the grower is not able to address and overcome a majority of these challenges production and profit levels with suffer. They following issues are based on past experiences from farmers[1] that have produced melons crop, university research[2], and first-hand observations[3] made while in Kenya. These issues are not meant to discourage growers but to provide them a realistic view of the challenges associated with growing such a specialized crop. When crop production guidelines are carried out at a successful level the economical return and sense of success/personal satisfaction are very rewarding!

Issues:

[123] Proper evaluation of soil nutrient levels and pH:

The only way to accurately manage soil fertility and pH is through proper soil testing and analysis that is representative of the area being planted. The information generated from this procedure allows the grower to properly address most nutritional and pH concerns. This procedure is highly recommended for the following reasons: 1) proper nutrient management leads to healthy plants and fruit development which in-turn generates a higher yield (profit) 2) typically reduces input costs and 3) is an environmental sound approach to growing. Preferred pH for melon production is between 6.0-6.5.

There are several companies on the internet that offer simple and affordable testing kits. Cost of the kits will reflect accuracy of results and parameters that can be tested. A basic kit that test N-P-K and pH should be sufficient for most situations. LaMotte Company in the USA offers a wide array of testing kits that are suitable for grower (www.lamotte.com).

[12] Pollination for seedless watermelons:

Basically, seedless watermelon plants do not produce enough viable pollen to pollinate themselves, therefore, successful pollination is dependent on a pollenizer. A pollenizer is a plant that provides additional pollen in order to achieve successful fruit set and enlargement of the melons. There are two types of plants currently been used as pollinizers: the first is the common seeded hybrid diploid watermelon. The other is a commercially available line of watermelons known as a “pollenizer.”
In addition, a sufficient bee population is required for successful pollination. The use of Honeybee hives located next to the field being planted is commonly practiced and recommended. The net result of inadequate pollination will be fruits that are irregular in shape and of inferior quality.

[123] Wind has the potential to damage young seedlings:

Kenya has frequent gust of wind that may be potentially damaging to freshly transplanted seedlings. The use of natural windbreaks is a common practice for areas where winds can be an issue. Plants such as wheat, grasses and cane are commonly used and should be planted at a distance from the watermelons that provides adequate protection. A standard rule is planting a wind-break every fifth or sixth row. Once the melons are harvested this material can then be tilled into the soil to enhance its physical properties.

[123]Providing an adequate and constant level of irrigation:

Water is essential for growth and development of all plants and seedless watermelon is no exception. In fact, a certain amount of water is required for the fruit to properly develop and reach optimal size. Improper watering can also play a role in diseases and physiological disorders of the melons. Drip irrigation is highly recommended for successful production. In general the crops should receive one-inch of water per week. Adjustments need to be made based on soil type, the size and stage of the plant and rainfall. Critical periods of water needs are at flowering and fruit development. Plastic mulch systems will require less irrigation as this prevents the soil from drying out as fast. Physically, checking the soil is the best method for determine moisture needs.

[123]Disease, Insect and Weed management:

Proper management of insects, diseases and weeds (IDWs) needs to be achieved in order to produces healthy productive plants. A certain level of IDWs known as the "threshold" of each is acceptable, however, when the population exceeds this limit it can and will impact growth and development of the plant and fruit. Therefore, proper management is critical which includes proper identification and treatment of the issue.

[3]Seed handling, storage and quality.

Seedless watermelon seeds are expensive; therefore, measures should be taken to ensure good quality seeds are purchased. Purchasing seed from a reputable and reliable source prior to planting is essential. Be sure seed is fresh, treated with an insecticide or fungicide and assayed for bacterial fruit blotch. If one needs to store seed a place that is cool and temperatures do not exceed 45F and a relative humidity of 50% is best. This will increase the longevity of the seeds life. A simple storage pit in the ground may be adequate. Care should be taken to protect the seeds form water and other potentially damaging elements. All seed that is over one-year in age should be test for germination percentage prior to planting.

The following guidelines are meant to serve as a reference point for the grower. Since each operation is unique in its own way the growers will be required to make the necessary corrections/adjustments to ensure production goals are meet.

Purchasing High Quality Transplants: The use of transplants is highly recommended practice in the production of seedless watermelons. It provides the grower a jump-start on production and the correct number of plants to reach production goals. Plants should be inspected prior to acceptance to be sure they are free of diseases, insects, have a good quality root system, similar in appearance, color and height. Seedlings should be grown in containers that provide a space of at least 1.5 inches by 1.5 inches for each plant. Smaller pots or cells will restrict root growth and provide less protection to the newly set transplant. Check seedlings for circling roots and being root bound. If either one is noticed root pruning is recommended to correct this condition. There should be one plant per pot. If not, cut one plants out using scissors or other similar tool. Don't try to physical remove the plant as this will cause root damage.

Note: Seed production of seedless watermelons is a specialized process and will be covered in a separate document.

Transplanting Seedlings to the Field*:* There are two systems available for field production: one is the open-field system where seedlings are grown in the rows without any type of mulch covering, the other, utilizes a plastic mulch covering. Either system is acceptable if properly managed. The use of plastic mulches does offer several benefits and is highly utilized by many farmers.

In Kenya growers need to be cautious of excessively high soil temperatures when transplanting. This condition can damage and at times kill young tender plants. Planting seedlings in moisten soil prior to sunset should be considered. Also the use of any type of mulch to reduce the sun's rays from directly coming in contact with the soil would be beneficial. Once plants are established soil temperature usually is not concern.

If plastic mulch is used it needs to be installed properly and checked for potential movement. Properly installed plastic doesn't move even during heavy winds. The reason the plastic shouldn't move is because it can damage the newly planted seedlings. As mentioned previously protecting plants from wind is critical until they are established.

POLLINATION AND PLANTING ARRANGEMENTWITH SEEDLESS WATERMELONS

Fruit set is dependent on pollination. Therefore, fields should be inter-planted with either pollenizer plants or diploid plants in order to provide sufficient, viable pollen. There are currently two methods being practices: *Method 1- use of a "dedicated pollenizer row" where* pollenizer plants are placed in single rows starting on the outside row and then every third or fourth row throughout the field. Growers should be aware that this method results in a reduction of seedless watermelons. The one benefit is that if can provide two marketable melons. When using this method, it is important to use a pollenizer variety that is marketable because up to one-third of all watermelons produced in the field will be from this seeded variety. The rind pattern and/or shape of the fruit from the pollenizer must be easily distinguished from that of the fruit from the seedless variety in order to reduce confusion at harvest.

Method 2: "Planting Pollenizer within Each Row" where pollenizer plants are planted between every third plant within each row without changing the plant spacing of the seedless watermelons. This arrangement results in a greater amount of seedless watermelon plants. The use of selected normal diploid/seeded watermelon as a pollenizer has produced favorable results. When selecting a diploid/seeded pollenizer variety that will also be harvested, growers must take into account market demand, plant vigor, pollen production, disease resistance, and environmental conditions.

Typical planting scheme for planting pollenizer within each row:

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SL ------ P -------- SL --------- SL --------SL --------SL ------P ----- SL ------SL ------ SL --- P --- SL --------SL
                        I<---3’-->I I<---3’-->I             I<1.5’>I<1.5’>I
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SL = seedless watermelon plant & P = pollenizer plant
Spacing is 1.5 feet between the P and SL, and 3 feet between SL on center
Spacing of 8’ on center is recommended between rows
-Plant all the seedless transplant first then the all pollenizers for efficient-

It is important that pollen from the seeded hybrid pollenizer variety be available when the female blossoms on the seedless plants are open and ready for pollination. As a general rule, the pollenizer variety should be seeded on the same day that the seedless seed is sown in the greenhouse. Smaller seeded, slower to germinate pollenizers such as SP-5; however, should be planted one week prior to planting triploid seed.

Growers should be aware that special “pollenizer” varieties have been developed solely for pollen production and most do not produce marketable fruit. The main purpose for using a special pollenizer is that it makes harvesting easier for crews who can more easily distinguish between fruit produced from the seeded, special pollenizer and fruit from the seedless watermelon varieties.

The following diploid hybrids have performed well as both a pollenizer and producing a harvestable fruit: 'Jenny', 'Mickylee', 'Minipol', 'Pinnacle', 'Patron', 'Sidekick', and 'SP-1.' A favorite among many growers is Mickylee as it is very affordable and easily distinguish from most seedless varieties.

Drip Fertilization and Mulching. Before mulching, adjust soil pH to 6.5, and in the absence of a soil test, apply enough fertilizer to supply 50 pounds per acre of N, P2O5 and K2O, (some soils will require 100 pounds per acre of K2O) then thoroughly incorporate into the soil. After mulching and installing the drip irrigation system, the soluble fertilizer program should then be initiated according to that described in the following table. On soils testing low to low-medium boron, also include 0.5 pound per acre of actual boron. The first soluble fertilizer application should be applied through the drip irrigation system within a week after field transplanting or direct-seeding the watermelons. Continue fertigating until the last harvest. More frequent applications of smaller amounts of fertilization are preferable and tend to produce more even and uniform growth.

Suggested Fertigation Schedule for Watermelons*

From Southeasterns U.S. 2012 Vegetable Crop Handbook

Growth Stage[1]	Days after planting	Daily nitrogen	Daily potash	Cumulative nitrogen	Cumulative potash
		(lb / A)			
Preplant				35.0	35.0
Planting to Vining	0 - 14	0.5	0.5	42.0	42.0
Vining to Flowering	15 - 28	1.0	1.0	56.0	56.0
Flowering to Fruit Set	29 - 49	1.5	1.5	86.0	86.0
Fruit Set to Initial	50 - 77	2.0	2.0	140.0	140.0
Ripening Harvest	78 - 91	1.0	1.0	153.0	153.0

* Adjust based on soil and tissue analysis

[1] Growth Stage can vary from season to season. For optimal results, fertigate watermelons based on their growth stage as opposed to days after planting.

The use of slow-release fertilizers are also an acceptable practice if fertigation is not available:

It is best to base fertilizer application on the results of a soil test. If a soil test has not been taken, apply 5-10-10 at 20 pounds per 1,000 square feet before planting. Melons should be side-dressed before the vines start to "run." Side-dress with ammonium nitrate at 1 pound per 100 feet of row or calcium nitrate at 2 pounds per 100 feet of row. Side-dress a second time after bloom when fruit is developing on the vine. Side-dressing should take place approximately 2’ away from the plant. Too much nitrogen fertilizer can encourage excess vine growth and reduce fruit growth. Boron is another nutrient that is

Cover Crops and Green Manure

Winter cover crops help protect the soil from excessive water and wind erosion. When incorporated into the soil as green manure, cover crops add organic matter (OM) to soils. Soil organic matter consists of plant and animal residues in various stages of decay. Adding OM improves soil structure, which, in turn, enhances soil tilth (helps to reduce compaction and crusting), increases water infiltration and decreases both water and wind erosion. Also of importance, OM serves as a storehouse of many plant nutrients. Furthermore, OM improves the efficiency of applied fertilizers by increasing the soil’s ability to retain plant nutrients under leaching conditions. Many growers frequently plant wheat, oats, rye or ryegrass as winter cover crops. Whenever these non-nitrogenfixing cover crops are to be incorporated as green manure, they should be provided with adequate nutrients (especially nitrogen) during their growth. This increases the quantity of OM produced and helps provide a carbon to nitrogen (C:N) ratio less likely to tie-up (immobilize) nitrogen during decomposition. As a general rule, when nonleguminous OM having a C:N ratio greater than 30 to one is incorporated into the soil, it is usually beneficial to broadcast supplemental nitrogen before incorporation. The amount of nitrogen to add varies, depending on the C:N ratio, soil type and amount of any residual nitrogen in the soil. Typically, green manure crops should be plowed under as deeply as possible with a moldboard plow so that large amounts of crop residue will not be in the immediate vicinity of germinating watermelon seed. Lush cover crops should be turned under at least two weeks prior to planting the succeeding crop. If small grains are grown as a cover crop, strips of grain (2 feet to 6 feet wide) left in spray or harvest lanes provide windbreaks that help reduce damage and sandblasting of small plants during early spring. To minimize the possibility of insect migration to the watermelon crop, grain strips should be turned under before the onset of senescence

INSECT MANAGEMENT

Cucumber Beetle: Watermelons are resistant to bacterial wilt; however, control may be needed to prevent feeding damage to seedlings. Treat when an average of two beetles per plant is found.

Aphids: Aphids can delay fruit maturation. Thorough spray coverage beneath leaves is important. For further information on aphid controls, see the preceding “Drip Fertilization and Mulching” section. Treat seedlings every 5 to 7 days or as needed.

Mites: Mite infestations generally begin around field margins and grassy areas. CAUTION: DO NOT mow or maintain these areas after midsummer because this forces mites into the crop. Localized infestations can be spot-treated. **Note:** Continuous use of Sevin or the pyrethroids may result in mite outbreaks.

Note: Honeybees are important for high fruit yields and quality. Populations of pollinating insects may be adversely affected by insecticides applied to flowers or weeds in bloom. Apply insecticides only in the evening hours or wait until bloom is completed before application.

FUNGAL DISEASE MANAGEMENT

***Fusarium* wilt** of watermelon is a widespread issue. Growers should choose resistant varieties whenever possible, including the pollenizers that they select for seedless watermelon production.

Watermelon Spray Guide for 2012

Prepared by ***Anthony P. Keinath****, Extension Plant Pathologist and* ***Gilbert A. Miller****, Area Vegetable Specialist Clemson University, SC*

Spray recommendations for watermelon are based on the fact that ‘‘It is easier to prevent disease than to cure it.’’

1) **Crop Rotation** is very important for a good start to controlling gummy stem blight and anthracnose. Growing watermelon, cantaloupe, or cucumber only once every 3 years in a field will minimize problems with these diseases. Never double-crop cucurbits on the same plastic.

2) **Spray Early.** The first spray should be put on when vines start to run or no later than when the first blooms (the male ones) open. This is the most important spray of the season!

3) **Rotate Systemic Fungicides.** Do not make more than three applications of fungicides from FRAC Group 3 per season to reduce the risk of resistance. For rates, see the fungicide labels.

4) **Choose the right fungicides based on disease pressure.**
Watermelon growers should watch for four common diseases and pick fungicides based on which disease will most likely appear.

Gummy stem blight often starts on old leaves near the crowns of plants inside the rows. Leaf spots are dark brown and start on leaf edges. The gummy stem blight fungus in South Carolina and other states is resistant to strobilurins (Group 11 fungicides), Topsin M, and Pristine. Growers should use tebuconazole (Group 3), Inspire Super (Groups 3 + 9), or Switch (Groups 9 + 12) to manage gummy stem blight. **However, do not make more than three applications of Group 3 fungicides per season to reduce the risk of resistance.**

GUMMY STEM BLIGHT

Powdery mildew appears during dry spells in June as yellow or white powdery spots on the top or bottom of leaves. Often, leaves may yellow from powdery mildew growing on the bottom side of the leaf. Cucurbit powdery mildew in some areas has become resistant to fungicides in Groups 1, 3, and 11. The recommended fungicides for powdery mildew are Quintec, Procure, or Switch. Quintec and Switch must be rotated after two applications.

POWDERY MILDEW

Leaf spots of **anthracnose** are smaller and more angular (pointed) than gummy stem blight spots. Look for ½ to 1-inch-long narrow, reddish brown spots on the vines. Anthracnose fruit rot starts as round, sunken spots that usually are found on the belly of the fruit. Cabrio is the best fungicide to spray for anthracnose; Topsin M also controls it.

LEAF SPOT ANTHRACNOSE

5) Spray Schedules. There are two basic types of fungicides: protectant or contact fungicides (such as chlorothalonil and mancozeb) and systemic fungicides that are absorbed by leaves (most new fungicides). Use a protectant for the first several sprays. Use systemic fungicides mid- to late season, when their ability to get into leaves is useful during rainy periods.

Spray Schedule #1 for Spring Watermelon to Control Gummy Stem Blight, Powdery Mildew, and Anthracnose

Spray	**Fungicide***
1 (vine run)	chlorothalonil or Catamaran
2	chlorothalonil or Catamaran**
3	**tebuconazole**
4	chlorothalonil or Catamaran

5	**Inspire Super**
6	mancozeb + **Cabrio**
7	**Switch** (or **tebuconazole**)
8	mancozeb + Quintec or **Procure**

* Systemic fungicides are in **bold** type. ** May use mancozeb + copper to protect against bacterial fruit blotch in week 2.

After the first protectant spray at vine run, match the spray schedule to fit general weather conditions.

- In spring, if it is dry, spray every 10 to 14 days.
- During a wet period, spray every 5 to 7 days. The chlorothalonil label limits the spray interval to 7 days for watermelon.
- If leaves stay wet for 48 hours, use a systemic fungicide for the next spray.
- In the fall, spray every 7 days, starting at vine run, and shorten the spray interval to 5 days during rainy periods.
- Apply fungicides before a predicted rain rather than after. As long as the fungicide dries on the leaves before rain starts, it will protect plants from new infections.

Spray Schedule #2 for Spring Watermelon to Control Powdery Mildew, Gummy Stem Blight, and Anthracnose

Spray	**Fungicide***
1 (vinerun)	Catamaran
2	**tebuconazole**
3	Catamaran
4	**Inspire Super**
5	mancozeb + Quintec
6	**Switch** or **tebuconazole**
7	mancozeb + **Cabrio**
8	mancozeb + **Procure**

* Systemic fungicides are in **bold** type.

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Bacterial fruit blotch often appears first as dark, greasy blotches on nearly ripe fruit. Leaf symptoms, if they are present, are small irregular spots. Fruit blotch often can beprevented with 3 sprays of copper hydroxide. These can be mixed with fungicides other than chlorothalonil and must be applied 2 weeks before female flowers open, at bloom, and 2 weeks after bloom. Applications later than this will be too late to protect early fruit. Additional applications can be made to protect late-season fruit.

 **BACTERIAL FRUIT BLOTCH**

Spray Schedule #3 for Spring Watermelon to Control Bacterial Fruit Blotch and Other Diseases

Spray	Fungicide*
1 (vine run)	mancozeb + copper**
2	mancozeb + copper
3	**tebuconazole** + copper
4	mancozeb + copper
5	**Inspire Super** + copper
6	mancozeb + **Cabrio** + copper
7	**Switch** or **tebuconazole**
8	mancozeb + Quintec or **Procure**

* Systemic fungicides are in **bold** type.
** Do not mix copper with chlorothalonil. When spraying copper weekly, use 1 pound per acre.

Downy mildew can infect watermelon in the fall. It spreads very quickly after infection on unsprayed crops. Chlorothalonil and mancozeb provide some protection from initial infection, but they are not enough to stop downy mildew once it starts in a field. Cucurbit downy mildew is resistant to Ridomil Gold and strobilurin (Group 11) fungicides. Ranman and Previcur Flex are included in Spray Schedule #4 to prevent downy mildew. If downy mildew is found, switch to Presidio rotated with Ranman on a weekly schedule. You must tank mix a protectant with Presidio and Ranman.

DOWNY MILDEW

Spray Schedule #4 for Fall Watermelon to Control Downy Mildew, Gummy Stem Blight, and Other Diseases

Week	Fungicide*
1 (vine run)	chlorothalonil or Catamaran
2	**tebuconazole**
3	chlorothalonil + **Ranman**
4	**Switch** or **Inspire Super**
5	mancozeb + **Previcur Flex**
6	**Inspire Super** or **tebuconazole**
7	mancozeb + **Ranman**
8	chlorothalonil or Catamaran

* Systemic fungicides are in **bold** type.

HANDLING PESTICIDES

Before opening a pesticide container, all applicators should carefully read the label, and accurately follow all directions and precautions specified on the labeling. In order to handle and apply pesticides safely, it is essential to use the proper personal protective equipment (PPE). Safety equipment should at least consist of unlined neoprene or rubber boots and gloves, waterproof hat, coat, and coveralls, an approved respirator, and proper measuring equipment.

APPLY THE CORRECT DOSAGE

- To avoid excessive residues on crops for feed and food
- To achieve optimum pest control and minimum danger to desirable organisms
- To avoid chemical damage to the crops
- To obtain the most economical control of pests.

PROTECT OUR ENVIRONMENT

- Do not burn pesticides. The smoke from burning pesticides is dangerous and can pollute air.
- Do not dump pesticides in sewage disposal or storm sewers because this will contaminate water.
- Avoid using excess quantities of pesticides. Calibrate sprayers to make sure of the output.
- Adjust equipment to keep spray on target. Chemicals off-target pollute and can do harm to fish, wildlife, honey bees, and other desirable organisms.
  - When cleaning or filling application equipment, **do not contaminate** streams, ponds, or other water supplies. Always keep a record of all pesticides

APPENDICES

APPENDIX: 1

INITIAL FERTILIZATION RATES FOR GREENHOUSE AND FIELD BEDS:

Drip Irrigation Fertilization:

When irrigating through an irrigation system, many different programs may be used. For example, some growers feed with every watering, some once a week, twice a week, every two weeks, etc. In each case the fertilizer concentration changes although the ratio between the various nutrients generally remains the same. However, during the cropping period the various levels of nutrients also need to change. For example …feeding with every watering:

During the vegetative stage (no flowers or fruit) which lasts only a couple of weeks, a concentration such as the following is used:

- Feed at 200 ppm N,P,K. Phosphorus has already been added to the soil, but roots are not as yet well developed. Therefore it is recommended to use a soluble P such as in 20-20-20 or 17-17-17 for the first week or two.

As fruit development begins, change the mixture and add more K.

- Feed at the rate of 200 ppm N, 0 ppm P and 300 ppm K.

After another 3-4 weeks change the mixture again and add more K.

- Feed 200 ppm N, 0 ppm P and 350 ppm K

At the end of the crop, reduce N and totally drop all N the last several weeks. Feed K at 350 ppm until the end.

After 5-6 irrigations using fertilizer in the water, use only plain water to flush out the lines and the soil. Continuous feeding without using plain water periodically will often cause a fertilizer buildup in the soil that can injure the crops. In short, wash out the excess fertilizers periodically.

TO DEVELOP 100 PPM (Same as 100 milligrams per liter) FROM EACH FERTILZER:

1:1,000,000 or 1 part per million or 1 ppm or 1 mg /liter

Divide the number of ppm desired by the percentage of the element in the fertilizer bag (% changed to a decimal….17% = 17/100 or 0.17

For a 17-17-17 fertilizer, to develop 100 ppm N, P, K.

100 ppm /.17 = 588 mg/l of water

TO DEVELOP 100 mg/l or PARTS PER MILLION (ppm)

Analysis	mg/liter	N	P	K in ppm or mg/l
17-17-17	588	100	100	100
20-20-20	500	100	100	100
46-0-0 (Urea)	217	100	0	0
34-0-0 (Ammonium Nitrate)	294	100	0	0
21-0-0 (Ammonium Sulfate)	476	100		
0-0-50 (Potassium Sulfate)	200	0	0	100
0-0-60 (Potassium Chloride)	167	0	0	100
15-0-0 (Calcium Nitrate)	667	100	0	0

588 mg of 17-17-17 dissolved in one liter of water will supply 100 ppm of N,P,and K.

If you are using a 300 liter tank: 588mg x 300 = 176400 mg or 176.4 grams will supply 100ppm of each (N,P,K).

APPENDIX: 2

CROP FERTILIZATION USING WEIGHT VS. VOLUME CALCULATIONS:

Many fertilizers weight very close to the weight of water. Because of this, growers can use volume measures and be quite close to actually weighed products.

For practical purposes consider 1gram = 1 ml = 1 cc. Therefore it is suggested that growers purchase several small plastic or glass measuring cups. These can be used to measure quite accurately. Likewise, missing a measurement by a few grams one way or the other will not cause any problems.

For every 10 sq.m of bed, apply the following as a dry fertilizer and then spade the materials into the soil. Initial Fertilization for Greenhouse Beds: (Based on 10 sq.m of bed)

Lime or dolomitic lime: 24 (250 ml cups) per bed (6 kg)

Single Super Phosphate (0-20-0) 12 cups per bed (3 kg)

Potassium Sulfate or Chloride (0-0-50 or 60) 3 cups (750 g)

Ammonium Nitrate (34-0-0) 2 cups (500 g) or Ammonium Sulfate (21-0-0) 3 cups (750 g).

Completely spade the bed to a depth of 25-30 cm

Level and irrigate carefully not to compact the soil. Continue to irrigate a small amount daily until the entire bed is moist. This will allow the soluble materials to begin dissolving and become attached to soil and organic matter particles.

The above materials were selected because they are by far the least expensive forms of these fertilizers (Calcium, Magnesium from Dolomite, Phosphorus, Calcium and Sulfur from Super Phosphate, and Nitrogen).

Plant by opening a small hole, set the root ball and cover lightly with soil. Do not pack the soil! Irrigate the first few days using a sprinkler type watering can with SMALL holes. Large holes will only tend to pack the soil and reduce soil oxygen which is very essential following root injury during transplanting.

Some fertilizers supply two nutrients. When using these, one usually calculates the portion with the highest percentage first. Calculate looking for 100 ppm of the phosphate portion and calculate again looking for the nitrogen portion.

For example if we want 100 ppm N and 100 ppm P from Di-ammonium Phosphate and Ammonium Sulfate:

18-46-0 (Di-ammonium Phosphate) (100/.46 = 217 mg/l (all of the P)

18-46-0 (Di-ammonium Phosphate) (100/.18 = 556 mg/l (a portion of the N)

But since we are only going to use 217 mg then use a proportion formula and determine the amount of N in 217 mg. of DAP.

If	556 mg is to 100 ppm of nitrogen
As	217 mg is to X ppm of nitrogen

Cross multiply and divide as follows: 217 x 100 = 21700 then divide by 556 = X = 39mg

So by using 217 mg/liter of DAP we will get 100 ppm P and 39 ppm of N.

We need a total of 100 ppm of N so 100 – 39 = 61 ppm needed from another fertilizer.

Using the same technique you can pick up the remaining N from Ammonium Nitrate or Ammonium Sulfate, etc.

If we used Ammonium Sulfate: (100/.21 = 476 mg of N) We need only 61 ppm so

If 476 mg will give us 100 ppm N then

X   will give us 61 ppm   cross multiply….

476 x 61 = 3713 (x)   3713/100 = 37 mg/liter.

Therefore we need 217 mg of DAP + 37 mg of Ammonium Sulfate to give us 100 ppm of P and N.

Fertilizing the crop:

During the vegetative stage: The following would be used to feed at every watering. However, about every 4-6 irrigations the grower should use only plain water with no fertilizer (mentioned above).

To feed at 200 ppm N, P and K using 17-17-17 =

100 ppm x .17 = (588 mg/l = 100 ppm) so 588 x 2 = 1176 x 300 liter tank = 352800 mg or 353 g/tank

During early fruit development:

Feed 200 ppm N and 300 ppm K.

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 2 = 588 mg/l x 300 liter tank = 176400 mg or 176.4 grams

plus

100 ppm K from Potassium Chloride = (167 mg/l = 100 ppm) so 167 x 3 = 501 mg/l x 300 liter tank = 150300 mg or 150.3 grams

These are both dissolved and placed in the tank of 300 liters of water.

Maximum fruit development:

To feed at 200 ppm N and 350 ppm K the grower would need the following:

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 2 = 588 mg/l x 300 liter tank = 176400 mg or 176.4 grams

plus

350 ppm K from Potassium Chloride + (167mg = 100ppm) so 167 x 3.5 = 584.5 mg x 300 liter tank = 175350 mg or 175.35 grams.

These are both dissolved and placed in the 300 liter tank.

Late fruit development…end of crop:

To feed at 150 ppm N plus 350 ppm K

100 ppm from Ammonium Nitrate = (294 mg/l = 100 ppm) so 294 x 1.5 = 441 mg/liter x 300 liter tank = 132300 mg or 132.3 grams

plus

100 ppm K from Potassium Chloride = (167mg = 100ppm) so 167 x 3.5 = 584.5 mg x 300 liter tank = 175350 mg or 175.35 grams.

These are both dissolved and placed in the 300 liter tank. During the last 3 weeks of crops totally stop feeding N.

If the tank holds 300 liters and you wish to give each plant 250 ml or ¼ of a liter then the 300 liters will irrigate 1200 plants. This is probably sufficient for small plants. As they get larger a tank may only irrigate half this many….500 ml per plant with each irrigation. Each grower will have to determine how much water is sufficient considering plant size, temperature, soil, etc.

When dissolving fertilizer for injectors or drip systems, always dissolve the materials in a second container and then pour the dissolved portion into the main holding tank. Some fertilizers may contain impurities, others may be wax coated to prevent sticking together in the fertilizer bags. Always run everything through a filter prior to the drip system.

APPENDIX: 3

DRY FERTILIZER RATES AND APPROXIMATE EQUIVALENTS: (values rounded)

200 lbs per acre or 5 lbs per 1000 sq.ft. or 1 dry cup/100 sq.ft. (1 cup = 8 oz or nearly 250 cc) or 250 ml or cc per 1 square meter.

Very light field fertilization = 200 lbs / acre or 225 kg/hectare

Moderate field fertilization = 350-450 lbs./acre or 400-500 kg/hectare

High rate field fertilization = 600-700 lbs./acre or 675-800 kg/hectare

200 lbs/acre = 224 kg/hectare or one 250cc (dry fertilizer) cups /1 sq.meters)

400 lbs/acre = 448 kg/hectare or two 250 cc (dry fertilizer) cups /1 sq.meters

APPENDIX: 4

FERTILIZER MIXTURE FOR FIELD USE:

Although there are exceptions, most dry fertilizers weigh about the same as water. Exceptions are materials such as Potassium Chloride, Lime (CaCO3) and Dolomitic Lime (CaCO3 + MgCO3) which are heavier than most. When using Potassium Chloride in a mix reduce the volume to about 2/3 to make up for its added weight. For this reason, fertilizers for field use can be measured on a volume basis and likewise mixed on a volume basis to obtain specific percentage mixes.

For example, one can mix the following and the percentages will not be scientifically accurate but will be sufficiently close for field use.

Using equal parts (cups, pounds, kg or any other value), make the following mixture.

3 parts Ammonium Sulfate	21-0-0	
	21-0-0	
	21-0-0	
1 part Treble Super Phosphate	0-45-0	
1 part Potassium Sulfate	0- 0-60	
Total	63-45-60	now divide by the number of parts (not fertilizers)

63-45-60 / 5 = approximately 13-9-12

A grower may want to make a relatively balance material such as a 12-12-12 or 15-15-15.

Mix the following:

2 Parts of Ammonium Nitrate	34-0-0
	34-0-0
3 Parts Super Phosphate	0-18-0
	0-18-0
	0-18-0
1Part Potassium Chloride	0-0-60

Total and divide by the number of parts: 68-54-60 divided by 6 = 11-9-10

One can therefore make up nearly any percentage mixture by blending base materials such as Ammonium Nitrate, Ammonium Sulfate, Urea, any Phosphate material and Potash materials such as Potassium Chloride, Potassium Sulfate or Magnesium Potassium Sulfate, etc.

Caution, since the particle sizes may differ considerably, the mixtures may tend to separate if much vibration is experienced during handling or in a mechanical spreader.

Also when using Potassium Chloride, reduce it volume to about 2/3 to account for its greater weight.

APPENDIX: 5

ANOTHER METHOD OF FERTILIZER CALCULATION:

When using part per million (ppm) one can use the following formula.

75 (a constant) x percent of the fertilizer expressed as a decimal (for example, ammonium nitrate 34% or 0.34) = the ppm of 1 oz. of this fertilizer dissolved in 100 gallons of water.

$75 \times 0.34 = 25.5$ ppm of N when 1 oz of ammonium nitrate is dissolved in 100 gal.

APPENDIX: 6

FERTILIZER CALCULATIONS (FERTCALC):

Now after all these calculations, if you have access to the internet, go to FERTCALC. You will find this program developed by the University of North Carolina, Horticulture Department staff, USA. This program can be downloaded and do basically all these calculations for you.

APPENDIX: 7

WATER QUALITY: ADJUSTING pH OF IRRIGATION WATER

Info. source: Dr. Hannah Mathers and Vaughn's Seed Co publications.

The total carbonates plus bicarbonates (CO2)-2 + (HCO3)- equals the alkalinity of the water.

The alkalinity of the water also determines its buffering capacity. The higher the buffering, the more difficult it is to change pH.

Water containing less than 50 meq/l of alkalinity usually pose little problem.

Acid injection into irrigation water.

Formula: A x B x C= ounces of acid/1000 gal of water to adjust pH to approximately 6.4.

A is a factor determined by water pH

Water pH	A	Water pH	A
6.7	0.249	7.7	0.475
6.9	0.342	7.9	0.484
7.1	0.400	8.1	0.490
7.3	0.437	8.3	0.494
7.5	0.460	8.5	0.496

B = the sum of bicarbonate and carbonate expressed as milliequivalents/liter of water (meq).

This information will come from a water test.

C = A factor determined by the type of acid used.

Acid: 75% Phosphoric = 10.6

85% Phosphoric = 8.74

93% Sulfuric= 3.72

61.4% Nitric = 15.6

Example: (A) Water pH = 7.5 x (B) (carbonates + bicarbonates) value 3.4 meq/l x C (75% Phosphoric Acid) =

A x B x C = ounces of acid/1000 gal of water to bring the water to pH 6.4

0.460 x 3.4 x 10.6 = 16.5 oz. of 75% Phosphoric acid /1000 gal of water.

Nutrients added to irrigation water using the above acids.

1 oz 75% Phosphoric acid /1000 gal of water delivers 2.8 ppm of P

1 oz 85% Phosphoric acid /1000 gal of water delivers 3.4 ppm of P

1 oz 93% Sulfuric acid / 1000 gal of water delivers 4.2 ppm of S

APPENDIX: 8

SALINITY OF IRRIGATION WATER: DESIRABLE RANGES

Electrical conductivity: EC

Usually measured as millimhos per centimerter: (mmhos/cm) which is equal to millisiemen (mS).

Millimhos per centimeter (mmhos/cm) has been renamed recently to decisiemens per meter (dS/m).

The values of the two units are equal; only the name was changed.

Total dissolved salts (TDS) is measured in parts per million (ppm).

The relationship between water's electrical conductivity (Ecw) and its total dissolved salts (TDS) is:

Ecw (in dS/m) x 640 = TDS (in ppm or mg/l)

Desirable Ranges for Specific Elements in Irrigation Water:

Set 1:

	Upper Limit	Optimum Range
pH		5-7
EC general production,	1.25 dS/m	near 0
plugs and seedlings	0.75 dS/m	near 0
Phosphorus (P)	0.005-5 mg/l*	< 1 mg/l
Calcium (Ca)	120. mg/l	40-120 mg/l
Sulfate (SO4)	240 mg/l	24-240 mg/l
Alkalinity	240 mg/l	0-100 mg/l
Sodium (Na)	50 mg/l	0-30 mg/l
Boron (B)	0.8 mg/l	0.2-0.5 mg/l
Fluoride (F)	1.0 mg/l	0 (especially for sensitive crops such as lilies, freesia and some foliage items.)
Magnesium (Mg)	24 mg/l	6-24 mg/l
Chloride (Cl)	140 mg/l	0-50 mg/l
Bicarbonate Equivalent	150 mg/l **	30-50 mg/l

Set 2:

Nitrates (NO3)	5 mg/l	0-5 mg/l
Potassium (K)	10 mg/l	0.5-10 mg/l
Zinc (Zn)	2 mg/l	0.1-0.2 mg/l
Molybdenum (Mo)	0.07 mg/l	0.02-0.05 mg/l

Iron (Fe)	5	mg/l	1-2 mg/l
Copper (Cu)	0.2	mg/l	0.8-0.15 mg/l
Aluminum (Al)	5	mg/l	0-5.0 mg/l
Sodium Absorption Ratio (SAR)	4	mg/l	0-4 mg/l

* 1 mg/l = 1 ppm

** Acidification is usually required to correct pH if bicarbonate equivalent is above 50 mg/l.

APPENDIX: 9

INTERPRETATION OF SOLUBLE SALT LEVELS *

DILUTIONS **					
1:2		1:5	Saturated Paste Extract	Pour Thru	
Soil	Soilless	Soil	Soil & Soilless	& Press	Interpretation
0-0.25	0-?	0-0.10	0-0.75	0-1.0	Crops hungry
0.26-0.50	?-1.0 0	0.11-0.25	0.75-2	1.0-2.6	Low value, unless applied with every watering
1.00		.50			Maximum for planting seedlings and rooted cuttings
0.51-1.25	1.00-1.75	0.26-0.60	2-4	2.6-5.3	Good for most crops
1.26-1.75	1.76-2.25	0.61-0.80	----	----	Good for established crops
1.76-2.00	2.25-3.50	0.81-1.00	4-8	5.3-10	Dangerous to most crops
2.00+	3.50+	1.00+	8+	10+	Usually injurious or lethal

* Electrical Conductivity (EC) levels are expressed as mmho/cm, which is equivalent to mS/cm and to dS/m.

**Some labs will report these values as mho x 10 (to the minus 5)/cm. (1mmho/cm = 100 mho x 10 to the minus 5/cm).

APPENDIX: 10

EFFECTS OF WATER pH ON PESTICIDES

GENERAL: Pesticides are decomposed or broken down by many things in the environment. Fungi, bacteria, sun light, oxygen, high temperature, water and the pH of water plays a very important role.

Alkaline spray water often results in the rapid decomposition of many pesticides. Usually water over pH 7 is quite detrimental to many pesticides. Buffer solutions are marketed in many countries that must be mixed with the spray solution prior to adding the pesticide. These materials generally lower pH to 6 or below and thus make the pesticide last longer and do a more complete job.

Following are just a few examples:

Common or Trade Name	Chemical or Technical Name	Comments/Rate of Hydrolysis Time for 50% to Decompose
Ambush/Pounce	Permethrin	Stable at pH 6 - 8
Aeracide	Aramite	Slow breakdown under alkaline conditions, rapid if lime is present.
Baytex	Fenthion	Incompatible with alkaline conditions.
Cygon	Dimethoate	pH 2=21 hrs, pH 6=12 hrs., pH 9=48min. Iron increases breakdown speed

Cythion	Malathion	pH 6=7.8 days, pH 7=3 days, pH 8=19 hrs. pH 10=2.4 hrs.
Diazinon	Diazinon	pH 5=31 days, pH 7.5=185 days, pH 9=136 days, stable near 7, avoid acid conditions.
Dursban	Chloropyrifos	pH 4.7=63 days, pH 6.9=35 days, pH 8.1=22 days, pH 10=7 days.
Orthene	Acephate	pH 3=65 days, pH 9=16 days
Sevin	Carbaryl	pH 6=100-150 days, pH 7=24 to 30 days, pH 8=2 to 3 days, pH 9=1 day
Vapona	Dichlorvos	pH 7=8 hrs.
Captan (fungicide)	Captan	pH 4=32 hrs, pH 7=8.3 hrs, pH 10= 2 min.
Roundup (herbicide)	Glyphosate	Avoid alkaline conditions, best at pH 2.5

APPENDIX: 11

MAINTAINING CLEAN DRIP IRRIGATION WATER

WATER QUALITY & TREATMENT

1. **Because of small orifice size, slow flow rates and lower system pressures; drip lines are susceptible to clogging.**

2. **Algae, Ferrous Iron (called Iron) and Hydrogen Sulfide (called Sulfur) are among the most common clogging enemies.**

3. **A commercial water test should be performed for the three problems above as well as suspended solids and water pH. This commercial test is a small price to pay for protecting $200-$500 per acre investment.**

4. **The most successful agent for treating various clogging problems in drip lines is chlorine. It is generally used in one of three forms: liquid or gas chlorine, or sodium hypochlorite. Liquid chlorine and sodium hypochlorite are recommended because they are much safer to use.**

5. **No matter what form of chlorine is used; always inject it before the filters. This helps keep the filters cleaner as well as gives the filters a chance to remove any dead, suspended or precipitated materials in the water.**

6. **When using chlorine, there should be a free residual chlorine level of 1 to 2 ppm at the farthest end of the drip lines. Free chlorine is that chlorine which is left unused after it has finished interacting with the chemical and biological compounds in the water.**

7. Chlorination is generally done at the end of the irrigation cycle. This is done to ensure that there will be free chlorine available in the drip lines to fight chemical or biological enemies that might arise between irrigations.

8. Free chlorine can be tested for with a Hach Chemical DPD Test Kit. It has been found to be an effective means for testing for free chlorine. Hach Chemical is located in Loveland, Colorado. Other chlorine test strips are also available.

9. The slide trap is another method that is used in conjunction with the DPD Test Kit. A slide trap is a piece of black polyethylene pipe (PE) or a piece of PVC pipe pained black with a slide mounted inside it.

10. Irrigate and chlorinate, then check the slide inside the trap 48 hours later for any growths. If there is an ochre color, iron is present, a clear slime would be sulfur and a dull green or brown growths would be algae.

11. If there is no slime or growths present, chlorination is adequate. Also, if there has been no irrigation in a while and these growths appear, then it is time to chlorinate again.

12. Algae == For algae, enough chlorine should be injected to arrive at a free chlorine count of 1-2 ppm in the first part of the irrigation cycle. Generally, 30-60 minute chloroination at these free chlorine levels once every 4-6 irrigation hours is sufficient to keep lines free from clogging. Sand filters are usually used with algae present in the water. You should always assume the presence of algae in any pond, stream or canal.

13. Iron == For treatment of iron, 1 ppm of chlorine is used for every 1 ppm of iron in the water. The chlorine oxidizes and precipitates the iron as well as kills the iron bacteria. It is actually the bacteria that create the iron-clogging problem. It acts upon the iron in such a way that forms a slime that can live on the oxygen in the water. It clogs the holes because of the size of the slime. Again, injection of chlorine should be enough so as to have 1-2 ppm free chlorine count. The same 40-60 minute chlorination at free chlorine levels every 4-6 irrigation hours also applies. A sand filter is used above 2.5 ppm iron, below this a screen filter is sufficient.

14. Sulfur == For treatment of sulfur, 9 ppm of chlorine is needed for every 1 ppm of sulfur in the water. The chlorine kills the sulfur bacteria and thus prevents slime growths. Injection should be enough so as to have 1-2 ppm free chlorine. Once the real chlorine level is reached, injections should be maintained for 40-60 minutes. This should be done every 4-6 irrigation hours. Screen filters are all that is needed for sulfur.

15. The reason for determining water pH, is that when pH is 7.5 or above, it takes nearly twice as much chlorine to do the job than if it were below 7.5.

16. To lower the pH of water, add some form of acid to the water. A consultation with the person or lab who did the water test could probably determine how much it would take to lower the water pH to the desired level.

17. Generally, muriatic acid (hydrochloric acid) or Sulfuric acid are used to lower pH. They are easier to use that phosphoric acid. The water should always be tested if Phosphoric acid is used in the drip system. Phosphoric acid, unless injected in the exact amount needed, will precipitate almost everything present in the water and cause clogging of the drip lines.

18. PVC and Lay-Flay should be cleaned and flushed every year before using again; one-half gallon of 68.6 % murataic acid per three acre block will clean out mains and sub mains. The reason for cleaning and flushing is that they often become coated with oil from the pump and protective coatings on fertilizers. If the lines are not cleaned, flakes will fall off and clog drip lines.

START UP PROCEDURE

Flushing Mains:

1. Flush your main lines first.

2. Flush the main lines for about 20 minutes with all valves to the submains closed at this time.

3. After flushing is completed, close the end and install at least a 1" valve for future flushing operations.

Flushing Submains:

1. Flush submains one at a time for 5-10 minutes.

2. This should be done without the supply tubes hooked into the Twinwall.

3. Now close the ends. PVC can be capped. Lay-Flay can e closed by folding the end 3 or 4 times and then in half. Next take an 8" sleeve of the same size Lay-Flat and slide it over the folded Lay-Flat. This will seal water tight when filled with water. This also makes it convenient for future flushing.

4. Lay-Flat ends can also be closed off by folding it once and putting one piece of short 2 x 4 on either side and squeezing the Lay-Flay shut with bolts and wing nuts.

Flushing The Drip Lines:

1. Flush the drip lines themselves until the water shows clear in each line.

2. This will help determine if there are any problem rows by showing whether the water is getting through all the lines or not.

Checking Pressures:

1. Once a system is turned on, let it run for about 20 minutes sod that any air in the system has a chance to work its way out.

2. After 20 minutes start checking your pressure gauges.

3. Start at the filter and check your pressure differential.

4. Proceed to the pressure gauges on your submains. These gauges should be located on the field side of your gate valve.

5. These gauges should be checked every time the system is turned on. First to check and see if they are even working, and second to see if the pressure is OK.

6. Pressure in the Twin-Wall can be checked with a pressure Gauge with probe. A small hole is pierced in the Twin-Wall and the probe is inserted. The Twin-Wall should be adjusted by installing the correct supply tube.

7. Walk through each block checking wetting patterns. Any kind of tears or leaks will appear after 30 minutes of operation time. The appropriate splices should then be made. If pressures in the drip line are still too high or low while pressure is the submains is correct, then the drip line pressure should be adjusted by installing the correct supply tube.

OPERATION

1. Always run the drip line after it is first set up. This will open a "mole hole" for the buried drip line and allow the system to work faster 2-3 months in the future when it is started up. It is also a good time to check for leaks and other problems that could have occurred during installation.

2. Some growers use their start up operation to germinate weeds in the soil, after which they come through and kill them.

3. You're newly established "mole hole" can collapse too. You will have to use you judgment as to what a heavy rain is, but in any case you should turn your system on shortly after a heavy rain.

4. Turning our system on during a heavy rain will accomplish two things. One, it will keep the "mole hole" open and prevent the soil from drying like concrete around the tubing. Two, it will keep the rain from driving the accumulated salts at the root's edge back into the root zone. It will cause the salts to leach out of the root zone and thus prevent plant damage.

5. Although most drip systems are designed to apply a given amount of water per acre per day, most growers do not water on a daily basis. They usually water every second or third day. So if acre inches per day call for the field to be irrigated two hours a day, it would have to be irrigated for 4 hours every second day or for 6 hours every third day. Obviously, earlier in the season you would water for shorter periods of time. If you irrigated every day, you would be keeping the soil moisture at maximum levels. In the event of any rain, your crop could be hurt by too much moisture. That is why most people use a 2-3 day watering schedule.

6. At the time transplants are placed, the drip line is usually run long enough to moisten the entire bed. This takes 6-8 hrs, though in some sandier soils it takes 10-12 hrs.

7. Do not rely on surface moisture on the bed to determine whether the crop is watered enough. If this is done, there is a good possibility the crop will be overwatered. Either take core samples or use soil tensiometers to determine if there is enough water.

CHOOSING COMPONENTS

Screen Filters:

1. 200 mesh screen filters are used as a primary filter when there are only small quantities of contaminants in the water.

2. If the water is really clean, the filter can be used at its rated capacity.

3. If the water is dirty and a screen filter can still be used, use the filter at 1/2 its rated capacity. This is done to help the screen filter do a lore effective job as well as to keep it from plugging up as quickly with contaminants.

4. Screen filters are normally backflushed or cleaned at 5-7 psi differential.

5. A clean screen filter will normally register 1-2 psi friction loss.

Sand Filters & Separators.

1. Sand filters are used when fine particulate and/or organic matter starts to show up (ie. fine sand, algae, silt, clay and iron).

2. Sand filters should be followed by enough screen filters to handle the GPM going through the sand filters. This is a safety precaution that should always be taken. It is done to prevent accidentally

discharge sand from the sand filter getting into the drip lines during backflushing or other operations on the sand filter.

3. #16 Silica sand (.66 mm, 1.51 uniformity coefficient) will remove particles down to 75 microns in size. This has usually been sufficient to prevent clogging in Twin-Wall.

4. Sand filters should be backflushed at 10 PSI differential.

5. When the season is over, the sand filters should be drained.

6. If a sand filter was not drained when put away during the off season, algae or other biological build-up can clog the filter. To unclog the filter, pour 2-3 quarts of chlorine into the filter, fill it with water and let sit for 24 hrs. After this is done, backflush the filter until the water runs clean.

7. Sand separators are used when large amounts of sand and small stones are being pumped from the well.

Injectors:

1. Positive Displacement Pumps meter out materials by forcing it into the line. This provides a very accurate method of injection.

2. When corrosive materials will be used, corrosive resistant injectors should be chosen. Most corrosive resistant injectors are made of stainless steel, porcelain or PVC.

3. Whatever injector you choose, always choose the simplest. The simpler it is the less chance of breakdown there is and the cheaper repairs will be.

Gate Valves:

1. Use gate valves but do not use quick closing valves (i.e. ball valves or butterfly valves). A quick closing valve can cause a sudden surge in submains and drip lines that can damage the system.

Pressure Regulating Valves:

1. These are sometimes used for two reasons: a). They are used when pressure at the source is know to fluctuate widely, and b). They are used on submains to maintain a uniform pressure.

Fertilizer Injection:

1. Only 100 % water-soluble fertilizers should be used. Any other materials could clog the system.

2. The fertilizer should always be injected before the filters so that any undissolved particles can be filtered out.

3. Drip irrigation has a greater leaching affect on fertilizer than furrow irrigation. Phosphates and potash move much more with drip, necessitating the addition of these elements as well as nitrogen on a frequent basis.

4. The drip, however, places the fertilizer accurately and evenly in relation to the root zone of the plant. These frequent, accurate applications of water and fertilizer lead to a healthier plant because it is not stressed as much.

From: Chapin Watermatics, Inc., USA

APPENDIX: 12

CHANGING pH:

Because of a soils ability to hold nutrients as opposed to allowing them to wash away, changing pH in soils is highly dependent on soil type.

Pounds of limestone needed per acre as affected by soil type.

pH CHANGE DESIRED	SAND	SANDY LOAM	LOAM	SILT LOAM	CLAY LOAM
4.0-6.5	2,600	5,000	7,000	8,400	10,000
4.5-6.5	2,200	4,200	5,800	7,000	8,400
5.0-6.5	1,800	3,400	4,600	5,600	6,600
5.5-6.5	1,200	2,600	3,400	4,000	4,600
6.0-6.5	600	1,400	1,800	2,200	2,400

These changes may take several months to complete. When dealing with greenhouse crops in containers, KOH can be used to raise pH and most any acids can be used to reduce it quickly (H3PO4, HNO3, are the most common). Applied

APPENDIX: 13

BLOSSOM END ROT III

BLOSSOM END ROT OF TOMATO, PEPPER, EGGPLANT AND OTHER RELATED VEGETABLES

SYMPTOMS:

BER is characterized by a shriveling, browning and drying of fruit tissue primarily at the blossom end. Symptoms may be in multiple spots as in the case of peppers and eggplant but are usually found at a single site on tomato. Following the browning etc, various fungi or bacteria may enter the dead tissue and spread throughout the fruit.

CAUSES:

BER is caused by a deficiency of CALCIUM in the fruit; however, this is often made more sever by several other factors.

1. **Low calcium level in the soil.**

2. **Low soil pH associated with low soil calcium.**

3. High levels of soil magnesium often results in lower calcium uptake. These two elements are extremely similar in atomic size and weight. For this reason, plants apparently have difficulty telling the two apart. The calcium: magnesium ratio is often maintained between 6:1 to 3:1 and sometimes as high as 10:1 depending on the crops in question. Absolute ratios will differ from one crop to another as well as being influenced by environmental conditions.

If the ratios are far out of balance, one element can cause a reduced uptake of the other. In other words, very high calcium can cause a magnesium deficiency and vice versa. In tomato, peppers, and eggplant, it is recommended to keep the balance in the 6:1 to 3:1 ratio range.

4. High levels of other cations (+ changed elements such as ammonia {NH4+}, potassium (K+} and magnesium {Mg++}) can also promote lower uptake of calcium.

5. Extremely rapid growth rates as encountered in mid-summer often appear to bring on BER. When plants are growing very rapidly, the need for calcium throughout the plants' foliage as well as fruit is high. Unlike several other elements such as nitrogen, phosphorus and potassium, calcium, once used by the plants' foliage, stems or fruit cannot be moved to another site and used over again. For this reason, BER normally is exhibited in the newly developing fruit. The blossom end is the most rapidly developing area of the fruit and therefore it is the site of the deficiency.

6. During extremely hot weather, excessive irrigation is often used. If media particle size is too small, media remains saturated from one irrigation to the next. This in turn brings about low oxygen levels in the soil or artificial media in which the plants are growing.

(Hydroponic Culture) Polyethylene wrapped media blocks, planks or other named products often have sufficient air space under normal growing conditions. However, because of their shallow (7-10cm) depth, frequent irrigation can result in near saturated conditions.

Studies have shown that low oxygen levels greatly inhibit growth of root tips. Other studies indicate that calcium is taken up primarily at the root tip whereas other elements may be taken up further back along the root. Again, a combination of environmental and physical conditions brings about a low oxygen situation in which calcium uptake is less than needed and thus promotes BER.

7. In the case of hydroponic production, increased temperature of the nutrient solution reduces its ability to carry oxygen. Damming or ponding of the nutrient solution within the hydroponic system greatly reduces nutrient flow as well as its oxygen content and availability to the roots.

In short, almost any condition that puts plants into a stressful situation appears to promote BER; i.e. low Ca, high NH4, Mg or K, extremes of heat, excessive growth rates, excessive EC values, excessive wet or dry conditions, low oxygen content of soil or nutrient solution.

POTENTIAL CORRECTIONS:

Correction of BER can usually be accomplished by spraying a soluble calcium directly on the plant foliage (primarily upper or newly developing fruit and foliage). Products such as calcium nitrate, calcium chloride or calcium hydroxide can be used.

1. Calcium Nitrate: This is usually the first choice of most growers because of its availability. However, in many cases, the added nitrogen is not needed in that it also promotes excessive foliage development and further complicates the issue.

Apply as a foliage spray of 1 lb/100 gals. of water (0.5 kg/500 liters). Use lower rates during extremely hot weather. Always apply early in the morning or very late in the day to avoid burning. Where extreme environmental conditions persist and plants are large and carrying large quantities of fruit, spray applications may be necessary two to three times each week and continue until cooler growing condition return.

2. Calcium Chloride: This material is used except where excessive chlorine exists in the native soil or in water supplies. Calcium Chloride is usually the preferred material for BER correction. Application rates should be one half that of calcium nitrate. Frequencies are similar to calcium nitrate.

3. Calcium Hydroxide: This is usually a grower's last choice because it is very caustic and difficult to handle. Apply only one half as much per application as the above materials, i.e. 0.5 lbs/100 gal or 0.25 kg/500 liters.

Lime (calcium carbonate) or Dolomitic Lime (calcium carbonate + magnesium carbonate) or Gypsum (calcium sulfate) may be applied to the soil. These products dissolve very slowly thus any affects on the crop may take weeks or even months. These materials should be applied to the soil and thoroughly mixed prior to planting. Lime and Dolomitic Lime will increase soil pH whereas Gypsum will have little or no effect on pH.

APPENDIX: 14

BASIC NUTRIENT SOURCES:

NITROGEN CONTAINING MATERIALS:

*	Analysis	Product	Other Ingredients
*	46-0-0	Urea	
*	36-0-0	Urea-Sul	20% S
*	34-0-0	Ammonium Nitrate	
*	30-0-0	Ammonium Nitrate Sulfate	6% S
*	21-0-0	Ammonium Sulfate	24% S
*	15-0-0	Calcium Nitrate	20% Ca
*	13-0-44	Potassium Nitrate	
*	12-0-0	Ammonium Thio Sulfate (liquid)	26% S
*	32-0-0	Solution 32 (liquid, ll.25 lbs/gal, 3.58 lbs. N/gal)	
	18-46-0	Diammonium Phosphate	
	16-20-0	Monoammonium Phosphate	12% S
	13-39-0	“ “	6% S
	11-48-0	“ “	3% S
	11-52-0	“ “	3% S
*	12-61-0	Monoammonium Phosphate (technical grade)	
*	21-53-0	Diammonium Phosphate (technical grade)	

PHOSPHATE CONTAINING MATERIALS:

Analysis	Product	Other Ingredients
0-18-0	Single Superphosphate	12% S
0-20-0	“ “	10% S
0-25-0	“ “	6% S
16-20-0	Monoammonium Phosphate	12% S

- 13-39-0 “ “ 6% S
- 11-48-0 “ “ 3% S
- 11-52-0 “ “ 3% S
- 0-45-0 Treble Superphosphate 3% S, 10% Ca
- * 0-75-0 Phosphoric Acid (75%, 13.3 lbs/gal, 10 lbs P/gal)
- * 12-61-0 Monoammonium Phosphate (technical grade)
- * 21-53-0 Diammonium Phosphate (technical grade)

see also the Phosphate containing materials in the Nitrogen section above)

POTASSIUM CONTAINING MATERIALS:

- * 0-0-60 Potasium Chloride (Muriate of Potash)
- 0-0-50 Potassium Sulfate 18% S
- * 13-0-44 Potassium Nitrate
- 0-0-20 Potassium/Magnesium Sulfate (Sul-Po-Mag) 22% S, 11% Mg
- 0-0-18 Kelp Meal

(*) GENERALLY SOLUBLE IN WATER

BASIC NUTRIENT SOURCES

SULFATE OR SULFUR CONTAINING MATERIALS:

*	Analysis	Product	Other Ingredients
*	36-0-0	Urea-Sul	20% S
*	30-0-0	Ammonium Nitrate Sulfate	6% S
*	21-0-0	Ammonium Sulfate	24% S
*	12-0-0	Ammonium Thio Sulfate (liquid)	26% S
*	32-0-0	Solution 32 (liquid, ll.25 lbs/gal, 3.58 lbs. N/gal)	
	16-20-0	Monoammonium Phosphate	12% S

- 13-39-0 “ “ 6% S
- 11-48-0 “ “ 3% S
- 11-52-0 “ “ 3% S
- 0-18-0 Single Superphosphate 12% S
- 0-20-0 “ “ 10% S
- 0-25-0 “ “ 6% S
- 0-45-0 Treble Superphosphate 3% S, 10% Ca
- 0-0-50 Potassium Sulfate 18% S
- 0-0-20 Potassium/Magnesium Sulfate (Sul-Po-Mag) 22% S, 11% Mg
- Calcium Sulfate (gypsum) 12-15% S
- Magnesium Sulfate (Epsom Salts) 13% S
- * Iron Sulfate 19% S, 20% Fe
- * Manganese Sulfate 14% S, 24-65% Mn
- * Copper Sulfate 13% S, 25% Cu
- * Aluminum Sulfate 14% S
- Flowable Sulfur (6 lbs S/gal) 51% S
- Lime Sulfur 24% S
- Yellow Elemental Sulfur 30-100% S
- Sulfuric Acid 75% 75% S

CALCIUM AND/OR MAGNESIUM CONTAINING MATERIALS:

*	Analysis	Product	Other Ingredients	Neutralizing Value
*	20% Ca, 15%	Calcium Nitrate		
*	29% Ca	Calcium Chloride		
	32% Ca	Ag Lime, Calcium Carbonate, Limestone		75-90
*	60-80% Ca	Calcium Hydroxide, Slacked or Hydrated Lime		115-136
	43% Ca	Calcium Oxide, Unslacked, Burned or Quick Lime		173-179
	30% Ca	Cottrell Lime (Stack dust from Concrete Plant)		85
	30% Ca	Sugar Lime (contains much water)	(< 0.5% N, <1.0% P)	85
	36% Mg	Magnesium Oxide		
	24% Ca, 11% Mg	Dolomite (mix of Ca & Mg Carbonates)		100-105
	11% Mg	Magnesium Sulfate	13% S	
	11% Mg	Potassium Magnesium Sulfate (SulPoMag)	20% K, 22% S	

(* GENERALLY SOLUBLE IN WATER)

MINOR ELEMENTS: **Suggested Rates:**

*	20% Fe	Iron Sulfate	0.5-1 lb/100 sq.ft or 0.25-0.5 g/ 10 sq. m.
*	24-65% Mn	Manganese Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g / 10 sq. m.
*	25% Cu	Copper Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g / 10 sq. m.
*	22-35% Zn	Zinc Sulfate	1/4-1/2 oz/100 sq.ft. or 7 - 15 g /10 sq. m.
*	22% Mo	Sodium Molybdate	0.05 oz/100 sq.ft. or 1.5 g / 10 sq. m.
*	11% B	Borax or Boric Acid	0.5-1 oz/100 sq.ft. or 14 - 28 g / 10 sq. m.
*	20% B	Solubor	0.5 oz/100 sq.ft. or 14 g / 10 sq. m.

(* GENERALLY SOLUBLE IN WATER)

All Minor Elements must be applied in very small quantities. Larger quantities or frequent applications can result in crop death.

Chelated minor elements: see manufacturer's directions

Fritted minor elements are available for most elements. These elements are dissolved in molten glass, ground and then applied as a very fine powder. The glass dissolves slowly thus giving a slow-release effect.

Since most or the above listed minor elements are soluble in water, they can be applied as a foliar spray. These are usually applied no more than every 6-8 weeks apart.

SLOW-RELEASE FERTILIZERS:

Slow-release fertilizers are produced in many ways. Many factors affect their release rate and this must be known by the grower or production disasters will occur. Following are just a few products.

Plastic Coated Materials: There are several types of plastic coated materials on the market. The release rate of some plastic coated materials is highly dependent on temperature. Microscopic holes in the plastic coating become larger as temperatures increase. Growers using these products inside of greenhouses, in tropical areas or during the hottest periods of the year must take into account faster release rates than are usually advertised.

Other plastic coated materials may not be as adversely affected by temperature. In order to have relatively even release rates over an extended period of time, some companies will use different plastics for their short term materials as opposed to their longer life materials.

Plastic coated granules of different sizes are sometimes used. Formulas using many small particles give a greater surface area than if the material was formulated with fewer large particles. Thus, the greater the surface area, the faster the release rate.

Some products are coated with sulfur to slow down their release, others merely dissolve very slowly. The bottom line is that a grower must understand how a product releases its fertilizers prior to their use! Once the product is applied, it is nearly impossible to remove. When starting to use a new product, apply it at several different rates on small areas and under different production circumstances (different times of the year, inside a greenhouse as opposed to outside use). From these trials, develop your own use rates.

APPENDIX: 15

SOLARIZATION: USING THE SUN FOR SOIL STERILIZATION

Heat is used in many commercial businesses for the purpose of pasteurizing or sterilizing objects, media, etc. Likewise, media used for starting seedlings is often pasteurized to eliminate disease as well as other unwanted seeds and insects.

Pasteurization of sowing media can be done either by placing media in an oven or by using the heat of the sun during mid- to late-summer.

Requirements:

- Media must be wet or moist for 1-2 weeks prior to heat treatment. This allows the resting stages of fungi and bacteria to begin growing. Resting stages are very resistant to heating.
- Media temperature must be raised to about 75 C - 165 F for 30 minutes. Using higher temperatures will often change the organic matter in the media to black carbon and this defeats the purpose of having it in the mixture.
- Following pasteurization cover the media so that no new weed seed can contaminate it.
- Make sure that "clean" tools (shovels, etc.) are used to handle newly pasteurized media.

Oven Pasteurization:

- Heat oven to about 100 C
- Place moist media in a shallow pan such as a cookie sheet. (3-5 cm in depth) Use of a shallow pan allows the media to heat rapidly.
- Use a cooking thermometer and periodically check media temperature. When the center of the media reaches 75 C- 165 F reduce oven temperature and hold at this temperature for 30 minutes.

Solar Pasteurization:

- For container media, place media on a sheet of plastic or a concrete area. Place no more than about 10 - 15 cm deep. The quicker it heats the easier it is to handle large amounts.
- For field soils, till several times to eliminate major weeds and large clods.
- Make sure the soil remains moist for 1 - 2 weeks prior to heating.
- Cover soil with either clear or black polyethylene, clear usually works best. This acts to hold the heat in and allows heat to reach pasteurization temperatures.
- Check periodically to determine the depth to which the required heating has occurred. In field situations, pasteurization may only occur to a depth of 5-10 cm. Since turning the soil with a tiller will bring new living weed seed to the surface, sow new seed without doing any tillage other than just breaking the surface.
- Following the required heating and time period, remove the treated soil and store in containers or under a cover so that new weed seed will not contaminate it.
- Use clean tools and do not allow individuals to walk on the clean soil. Use all precautions to keep it clear of contaminated tools, hands, boots, etc.

Many beneficial fungi and bacteria are not killed at the 70 C level and thus will continue to inoculate the media. If they are killed they normally return relatively quickly on their own.

APPENDIX: 16

SOIL AND MEDIA STERILIZATION:

As methyl bromide is being phased out around the world as a soil fumigant, many products are being investigated. Metam Sodium, chloropicrin or teargas is one of the primary materials currently in use. Another is the old practice of using steam.

For many years the practice involved injecting steam through downspout pipes with holes drilled in the sides for the steam to escape. The pipes were laid in beds of soil and covered by about 12-15 cm of soil. The entire bed was then covered with some type of tarp to help hold the steam. Bed temperatures were raised to 180F (82C) and held there for 30 minutes. Later, it was found that raising the temperature to only 165F (74C) was sufficient to kill pathogenic fungi and bacteria but allow many of the non-pathogenic fungi to remain. The current practice is to use the 165F (74C) for 30 minutes.

Using the higher temperature often created problems because of the release of manganese in the media which was then toxic to immediately planted crops. Using the lower temperature has greatly reduced this problem.

APPENDIX: 17

GROWING GREENHOUSE TOMATOES AND OTHER VEGETABLES IN CONTAINERS:

Growing crops in containers is an entirely different situation than in-ground or field production. The above ground environment remains the same but everything from the soil surface down changes drastically.

As mentioned in other aspects of this report, roots need oxygen just as all above ground growing parts. The major changes are brought about by putting media in a container. When growing in the ground, the water table may be only 2-3 meters or 100 meters below the soil surface. The container, on the other hand, makes an artificial water table often referred to as a “perched” water table (perched….as a bird perches on a limb).

This means that the media’s water content at the base of the container is just as wet as if it were sitting immediately on top of the soil water table many meters down. If one measures the quantity of water held at various levels above a water table you would find total saturation at the table. It would gradually hold less and less water with increased height. You can easily test this for yourself. Fill a kitchen sponge with water and lay it flat in your hand until it stops dripping. Next, turn the sponge on its side and you will see more water drain out. Next, turn the sponge on end so that the length of the water column is again increased. More water drains out!

You have not squeezed the sponge, merely changed the vertical length of the water column and each time drainage increased. The same thing occurs when media is placed in a container. The taller the container the dryer the media as you move above the base.

For example, if we had three containers, one 20 cm deep, one 40 cm and a third at 60 cm. All three could have the same volume. Irrigate the containers and allow them time to drain (nothing dripping out) then if we could measure the amount of water in all three this is what we would find.

- Wetness at the base of all three would be exactly the same.

- Wetness at the 20cm level of all three would be the same but less that at the bottom.
- Wetness at the 40 cm level of the last two would be the same but less than the moisture level at the 20 cm level.
- The wetness at the 60 cm level of the third container would be much less than that of the top of the 20 cm container.

Again, you can test this for yourself. Totally wet 4 or 5 new kitchen sponges and quickly stack them on top of each other. Pour some more water on the top sponge. Let the stack drain for a minute or so. Starting at the top, squeeze each sponge into a glass and collect the water. You will see that as you get closer to the bottom sponge the amount of water held increases greatly.

Now what does all of this have to do with growing a tomato or anything else in a container?

When any media is irrigated, each particle becomes surrounded by a tiny film of water. Soil particles, sand, silt and clay are so small that when they are close to a water table, there is essentially no space left for air. No air no root growth no plant!

All commercial container production world-wide is done in various mixtures usually containing a large percentage of organic waste products. Organic waste is used because it has many characteristic needed for good culture as well as being low in cost. An Appendix is included which shows what the air and water relationship is in many individual products as well as many 1:1 mixtures. The last item in the Appendix is one of the most costly mixes but it shows what all other mixtures try to duplicate.

1:1 peat and perlite……….Water Space (53%) and Air Space (23%)

A technique is shown how one can mix different media and actually measure the Water and Air Space in a container.

If you are contemplating growing in containers, choose a container of the same vertical height for doing the testing. The volume plays only a small role in this type of testing. Tomatoes, for example are often grown in rigid containers or black plastic bags. Approximately 8-10 liter bags work nicely (media depth about 25cm) Again, a grower located in an extremely hot country should use a taller container because they will usually tend to overwater during high temperature extremes. Growers in The Netherlands, Western Europe and North America often used artificial media in the form of plastic wrapped blocks about 5 cm high, 15 cm wide and 100 cm long. I have seen extremely poor root development during excessively hot weather just because they watered too often and kept the media totally saturated.

One should try to make a mixture that has the following characteristics:

- Since particle size of an organic waste product continues to get smaller as it decomposes, try to find something that decomposes slowly or not at all. Screened volcanic stone, sawdust, ground tree bark, sugar cane waste, rice hulls, chopped wheat straw. Each of these should be tested for a season before making a large planting.
- Add a small size organic waste to increase the water holding capacity. Shredded or composted manure, peat, etc.
- Do not add sand as this only increases weight.
- Perlite
- I don’t suggest vermiculite because it breaks down into much smaller pieces with time and also if it used over again.

When a mix is completed and ready for testing, try to come close to the following values:

Water holding capacity: 35-50%, Air space: 15-20+ %

Also, keep the following in mind. Organic materials generally hold a great deal of water and nutrients. As they decompose their CEC or nutrient holding ability increases as well as the water holding ability. The air space begins to decrease as decomposition continues and particles get smaller.

Media temperature also increases well above what is found in the soil. Growers in extremely hot regions use plastic bags that are white on the outside and black on the inside.

Crop nutrition is very similar to soil application. Nutrient rich water can be used a single time and then discarded or reused and nutrients added every few days. This will not be discussed at this time. The above information on media is mentioned only to get growers to begin thinking about alternatives to soil culture. Several fungal root rots and various bacterial diseases are very common in this area and will increase with time. Many growers around the world have moved to soilless culture because of these problems that you are now facing.

One of the first media I would suggest looking at is a mixture of screened volcanic stone (2-6mm) mixed with peat or composted manure. This mixture could be used over several times and could also be chemically sterilized. The composted manure would gradually decompose to almost nothing.

APPENDIX: 18

DETERMINATION OF AIR AND WATER VOLUME PERCENTAGE

FOR CONTAINER MEDIA

GENERAL OBSERVATIONS:

- **Roots need oxygen to function normally. For this reason mixtures of various media are used when growing in any type of container.**
- **When media is placed in a container, a "perched" water table forms at the bottom of the container. Media in this area remains totally saturated following irrigation. This total saturation greatly inhibits root development.**
- **Selection of ingredients used in a particular mix should be based on several factors.**

The media performs several functions;

- **coarse products promote rapid drainage and increase air space;**
- **fine textured products increases water holding capacity;**
- **mineral products are usually heavy and add a great deal of weight to the final mix;**
- **organic products are usually lighter than mineral products and like sponges hold a great deal of water not only on their surfaces but also internally. They usually have a great capacity to hold on to positively charge (+) nutrients called cations. Cations are nutrients such as the following: Ammonium, Potassium, Calcium, Magnesium, Iron, Manganese, Copper, and Zinc. Most mineral products other than clay have very little or no nutrient holding ability.**
- **Mineral products generally do not change in size, nutrient holding ability or water holding ability with time.**
- **Organic products continue to decompose with time and thus particles get smaller. Water holding capacity increases, nutrient-holding capacity increases but due to the decrease in particle size, air space decreases also.**
- **Some organics such as peat moss decompose more quickly than others, bark and wood containing materials, generally decompose quite slowly.**
- **Drainage in any mixture is controlled to a great degree by the texture or particle size of the various components of the mix. However, the vertical length of the water column in the container also plays a major role.**

For example, fill a sponge with water and lay it flat in your hand. When the dripping has stopped, turn the sponge on edge and more water will drain out. Finally, turn the sponge on end and you'll

find that even more water comes out. Hole sizes in the sponge have not changed; no additional pressure was place on it; only the vertical length of the water column was increased.

Next, make a stack of four or five sponges and thoroughly wet them. Allow them to drain for five to ten minutes. Starting with the top sponge, squeeze the water into individual cups. The top sponge yields a small amount of water and each succeeding sponge will yield more water until the last, which appears to be nearly totally saturated.

The above examples illustrate the importance of the length of the final water column.

- **Soil scientists tell us that any media that has an air volume of 8% or less will produce only grass.**
- **One of the most productive container media used worldwide is a 1:1 mixture of peat and coarse perlite. The peat acts to hold a great deal of water and nutrients; the perlite maintains good drainage and air space. Air space is usually around 25% and water space can be as high as 30-50%.**

The following will show how to quickly and easily measure the air and water space of any mixture of materials.

First, a few general rules:

- **The finest textured material (smallest particles) usually has the greatest overall effect on the mixture.**
- **When measuring, slight differences will occur between small diameter and very large diameter containers. For this reason, use small containers when checking mixture for use in small pots and large ones for large pots and bag culture.**
- **If you attempt to measure a material a second time while the media is still extremely wet, then the only reading will be the Air Space.**
- **Measurements such as these can be used to measure media after crops have been growing in them for a period of time. If this is done, try to use the existing growing container so as not to disturb the existing media structure and root system.**

PROCEEDURES FOR TESTING AIR AND WATER VOLUME PERCENTAGES

1. Select container(s) for testing.

2. Seal drainage holes with electrical tape.

3. Fill containers with water in order to measure their total volume. In the following example, we'll use 5000 ml for the total volume.

4. Empty container and fill with media mixture to be tested.

5. Compress slightly as you would if you were potting a new plant.

6. Using a measured amount of water, slowly add water down one side of the container until the water is level with the surface of the media. By adding to the side, air bubbles will be forced out as the water level rises. Pouring water in the center often traps air below.

7. Allow to sit for 5 minutes in order to thoroughly saturate all of the media.

8. A narrow knife or wire is often pushed into the mix to insure that all air bubble have risen to the surface.

9. Add water if necessary to bring water level back to the media surface.

10. The amount of water added is equal to the media's Total Porosity. This is the total of both the Water Space and the Air Space.

11. Remove a piece of tape from the bottom of the container and catch the water that drains out.

12. The volume of drainage water equals the Air Space or Air Volume since air moves into the media as the water drains away.

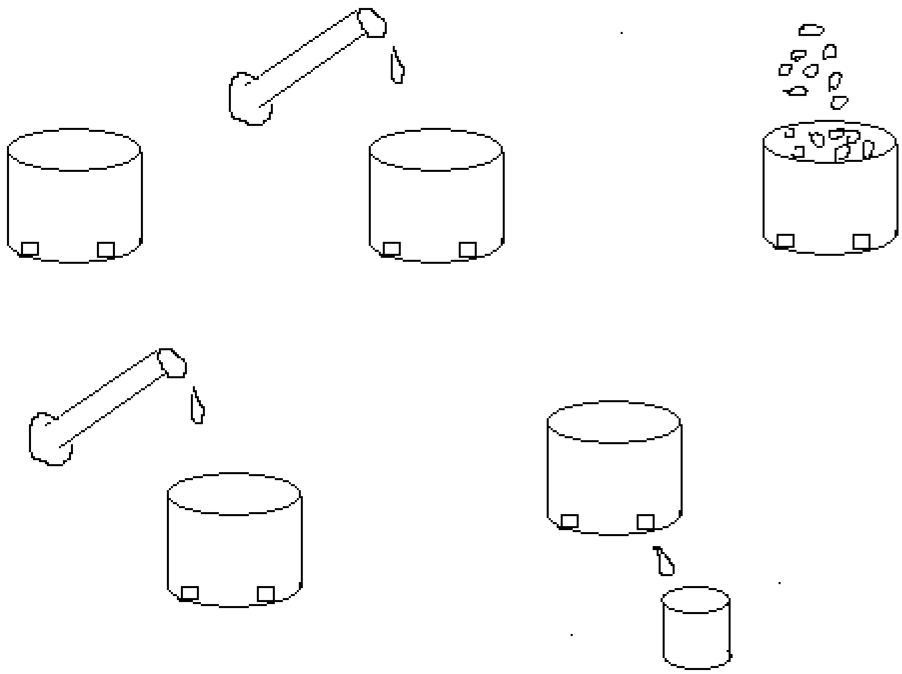
13. Subtract the drained water from the total water added. This gives the water retained in the mix or is the Water Space or Water Volume.

14. All readings are on a volume basis and in (ml).

Tape Holes

Determine **TOTAL VOLUME** volume (ml)
(Example: **5000 ml**)

Drain and fill with media, compress slightly



Add water slowly to media surface.
This volume equals **Total Porosity**
(Example: **3000**)

Drain water =
Air Volume
(Example: **1000 ml**)

Total Porosity minus
Air Volume =
Water Volume
(Example: **2000 ml**)

Develop all values into percentages (%).

$$\frac{3000 \times 100}{5000} = 60\% \text{ Total Volume}$$

$\frac{1000}{5000} \times 100$ = 20% Air Volume

Total Porosity – Air Volume = Water Volume

60% - 20% = 40%

SUGGESTED VALUS: AIR SPACE = 20-30%

WATER SPACE = 30% +

INFORMATION FROM "HORTICULTURAL AND AGRICULTURAL USES OF SAWDUST AND SOIL AMMENDMENTS, TECHNICAL BULLETIN 1968, PAUL JOHNSON

PHYSICAL PROPERTIES OF AMENDMENTS, SOILS AND MIXTURES.

TEST MATERIAL	WATER RETENTION CAPACITIES		AIR RELATIONSHIPS (VOLUME PERCENT)
100%	Volume Percent	Total Porosity	Air Space After Drainage (1/8 " = 3 mm) (3/16" = 5 mm) (1/4" = 6 mm) (3/8" = 9 cm) (½" = 12 mm) (5/8" = 16 mm)
Bark, fir 0-1/8"	38	69.5	31.5
Bark, fir 1/8-5/8"	15	69.7	54.7
Bark, redwood 3/8"	30.8	80.3	49.5
Loam, clay	54.9	59.6	4.7
Loam, sandy	35.7	37.5	1.8
Peat, sedge, AP	52.3	69.3	17
Peat, sedge, BD	68.6	77	8.4

Peat, sedge BP	47.6	68.1	20.5
Peat, sedge MP	53.7	73.5	19.8
Peat moss, hypnum	59.3	71.7	12.4
Peat moss, sphagnum	58.8	84.2	25.4
Perlite, 1/50 - 1/16”	42.6	75.8	33.2
Perlite, 1/16 - 3/16”	47.3	77.1	29.8
Perlite, 3/16 - ¼”	19.0	75.3	56.3
Perlite, ¼ - 5/16”	19.5	73.6	53.9
Pumice, 1/50 - 1/16”	40.5	62.2	21.7
Pumice, 1/16 - 1/8”	33.0	65.2	32.2
Pumice, 1/8 - 5/16”	25.9	60.3	34.4
Pumice, 5/16 - 5/8”	25.5	70.5	45.0
Rice hulls	12.3	81.0	68.7

Sand, builders	26.6	36.0	9.4
Sand, fine A	33.7	36.2	2.5
Sand, fine, B	38.7	44.6	5.9
Sawdust, cedar	38.2	80.8	42.6
Sawdust, redwood	49.3	77.2	27.9
Vermiculite, 0 - 3/16”	53.0	80.5	27.5
Manure, dairy	66.7	74.3	7.6

50/50 (volume/volume) Mixtures using:

Clay loam with the following materials:

Peat, sedge	56.5	61.8	5.3
Peat moss, hypnum	59.9	66.2	6.3
Peat moss, sphagnum	61.0	71.0	10.0
Sand, builders	40.8	47.0	6.2
Sand, fine	41.5	47.4	6.9
Sawdust, redwood	57.6	72.0	14.4

Sandy loam with the following materials:

Peat moss, hypnum	49.8	54.2	4.4
Peat moss, sphagnum	52.8	59.1	6.3
Sawdust, redwood	52.7	62.8	10.1

Fine sand with the following materials:

Bark, fir, 0 - 1/8”	37.4	54.6	15.2
Bark, fir, 1/8 - 5/8”	36.0	44.3	8.3
Bark, redwood 3/8”	43.5	56.8	13.3
Peat moss, hypnum	49	55.5	6.5
Peat moss, sphag.	47.3	56.7	9.4
Perlite, 1/16 - 3/16”	42.6	52.0	7.6
Perlite, 3/16 - ¼”	38.5	43.2	4.7
Perlite, ¼ - 5/16	34.6	41.5	6.9
Pumice, 1/16 - 1/8”	37.5	42.3	4.8
Pumice, 1/8 - 5/16”	33.5	37.3	3.8
Pumice 5/16 - 5/8”	35.2	37.3	2.1

Sawdust, redwood	40.5	52.6	12.1

Peat moss with the following material:

Perlite, 3/16 - ¼"	51.3	74.9	23.6

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INFORMATION FROM "HORTICULTURAL AND AGRICULTURAL USES OF SAWDUST AND SOIL AMMENDMENTS, TECHNICAL BULLETIN 1968, PAUL JOHNSON

PHYSICAL PROPERTIES OF AMENDMENTS, SOILS AND MIXTURES.

TEST MATERIAL	WATER RETENTION CAPACITIES	AIR RELATIONSHIPS (VOLUME PERCENT)	
100%	Volume Percent	Total Porosity	Air Space After Drainage
Peat moss, sphagnum	58.8	84.2	25.4
Rice hulls	12.3	81.0	68.7

Sand, builders	26.6	36.0	9.4
Sand, fine A	33.7	36.2	2.5
Sand, fine, B	38.7	44.6	5.9
Sawdust, cedar	38.2	80.8	42.6
Sawdust, redwood	49.3	77.2	27.9
Manure, dairy	66.7	74.3	7.6

50/50 (volume/volume) Mixtures using:

Clay loam with the following materials:

Peat moss, sphagnum	61.0	71.0	10.0
Sand, builders	40.8	47.0	6.2
Sand, fine	41.5	47.4	6.9
Sawdust, redwood	57.6	72.0	14.4

Fine sand with the following materials:

Peat moss, sphag.	47.3	56.7	9.4
Perlite, 1/16 - 3/16”	42.6	52.0	7.6
Sawdust, redwood	40.5	52.6	12.1

Peat moss with the following material:

Perlite, 3/16 - ¼”	51.3	74.9	23.6

APPENDIX: 19

SOIL PARTICLE SIZE AND CONSTITUENTS

GENERAL: Soil plays two major roles; one is to hold the plant in an upright position and second, it acts as a bank to hold nutrients, oxygen and water. Needless to say, it also contains many other items…some useful and others that may cause problems: i.e. bacteria, fungi, viruses and a number of other non-essential products.

BASIC SOIL INGREDIENTS: Organic materials, sand, silt and clay. Each of these materials plays a role in crop growth. Their influence is related both to their physical size and chemistry. The ingredient with the smallest size usually has the greatest effect on the total media. For the scientists among us, the following are used to identify these particles.

a. Organic materials: made primarily of carbon, oxygen and hydrogen. As they decompose (rot) many electrical charged sites develop on their surfaces…primarily negatively charged like the negative end of a magnet (-).

b. Sand: 1.0-0.05 mm

Particles in 1 gram of fine sand = 46,213

Total surface area of one gram = 90.7 sq.cm.

The mineral base can be of almost anything.

Feels gritty to the touch.

Essentially no electrically charged sites.

c. Silt: 0.05-0.002 mm

Particles in 1 gram = 5,776,674

Total surface area of one gram = 453.7 sq.cm.

Mineral base

Feels “slippery” to the touch without being “sticky”

Few electrically charged sites….(negative (-).

d. Clay: 0.002-0.0002mm, 0,0002 and small – colloidal clay = gluelike

Particles in 1 gram = 90,260,853,860

Total surface area of one gram = 11,342 sq.cm. (12 sq.ft.)

Mineral base

Feels “sticky” to the touch, almost like glue.

Contains many electrically charged sites….negative (-).

A typical soil is a combination of all of the above. Likewise, because some soils have more of one ingredient that another, they are classified by different names. In short, some soils produce good crops and others, very poor crops. Other than the crop’s nutrient needs, there is a great need for oxygen since these are living organisms like us.

When a soil is watered, each soil particle becomes surrounded by a microscopic film of water. If the soil particles are extremely small, there is essentially no space left for air (oxygen) and plant growth is very poor. On the other hand, if the soil particles are very large, (gravel), the crop must be watered several times each day to prevent wilting and death. This latter method is used to a great advantage in hydroponic production.

ROOTS NEED OXYGEN: any part of a plant that is growing rapidly needs a great deal of oxygen. One of the roles of the expert gardener is to evaluate their soil and its ability to supply oxygen. The gardener can always add nutrients and water but it is near impossible to “add” oxygen. Forget the peroxide pills!!!

SOIL NUTRIENTS: Let’s look next at the ability of a soil to supply nutrients. Remember, one of the tasks of a soil is that it acts like a nutrient bank.

Nutrients come in many forms, manure, green leaves and elemental fertilizers in either a dry or liquid form. In all cases, the nutrient as it is taken in by the plant is usually in a very simple elemental complex, such as nitrate, ammonium, potassium, iron, calcium etc. When elemental fertilizers are dissolved in water, they come apart into two pieces. One piece carries a (+) charge and the other a (-) charge…again, just like magnets. Remember that some soils have lots of (-) charge sites….those with lots of clay and organic matter. These will hold the (+) fertilizers and will trade them for hydrogen (+) which is given off by the plant root. In short, the soil's ability to "trade" nutrients for hydrogen is refer to as Cation Exchange Capacity or CEC. A "cation" is a positively charge element and the negatively charged elements are called "anions".

Evaluate soils: water bottle test…how much sand, silt, clay and organic matter?

- Canby Sand: sand settles out in only a few seconds
- Silt Loam: silt settles out usually in an hour at the most
- Clay: a clay layer may not be seen for 24 hours and much will remain suspended in the water.

Compare the thickness of each layer as a percentage of the total.

- Soils high in clay usually contain little air space. The clay particle is usually in layers and water and nutrients can be held between the layers. Cracking often occurs as the soil dries due to the shrinkage of these layers.
- Soils high in silt usually hold only a small amount of water and are very prone to cracking as they dry out…root breakage.
- Soils high in sand hold very little water and can also hold very little air immediately following an irrigation particularly if the sand particles are round and small. (Columbia River sand…often sold locally as "top soil"…don't buy it!!).
- Soils high in organic matter are often black in color, hold lots of nutrients and water but also are very prone to shrinkage with time… Organic matter decomposes to carbon dioxide and water. Highly organic soils are often referred to as "muck soils" such as in Lake Labish just north of Salem. As the organic materials decompose, the surface level of the field slowly recedes.

HOW TO IMPROVE MOST SOILS - ADDITION OF ORGANIC MATERIALS:

- Peat Moss, Manures, Decayed Leaves, Green Leaves: The addition of almost any kind of organic matter will improve oxygen levels because of the coarse texture of the materials. Keep in mind that different kinds of organic matter decompose at different rates. Peat decomposes very fast, bark is extremely slow. Similarly, nutrient levels are totally dependent on the type of organic material used…manure vs. bark dust.
- Poultry Manures: Excessively fine organic matter (poultry manure) should be added in small amounts because it can reduce the oxygen content. Poultry manure also contains a great deal of soluble nutrients. If too much is added at one time, fertilizer burn will occur. Apply no more than 1 inch if it is to be tilled into the soil. A half an inch is sufficient if it is to be left on the surface.

- Cattle and Horse Manure: Fresh or nearly fresh cow and horse manures and leaves are all good. Use probably no more than 2 inches on the soil surface and then work it into the soil. Older or aged materials can be used in larger amounts.
- Bark and Sawdust: The use of sawdust or bark often causes nutrient deficiency problems. Soil bacteria and fungi need lots of nitrogen in their diet to attack woody materials such as old dry leaves, sawdust and bark dust. If these materials are added to your soil without adding extra nitrogen, crops will suffer. In short, bacteria and fungi are much more efficient at taking nitrogen out of the ground than the plant. Nitrogen depletion when using bark or sawdust (mixed into the soil): Add 2-3 cups of ammonium nitrate or ammonium sulfate per 10 x 10 foot area (3 x 3 meters) for each one inch of sawdust/bark dust added prior to working the soil. Watch the plants color. A light green plant usually indicates low nitrogen levels in the soil. When bark or sawdust is used as mulch on the soil surface, addition of extra nitrogen is generally not needed.

OXYGEN in the key…roots need lots…anything you can do to increase water drainage and air movement into and out of the soil will promote better growth. HOWEVER, SAND AND CLAY MAKES SUPER CONCRETE….DON'T ADD SAND TO SOIL…USE ORGANIC MATTER OF SOME TYPE.