NC STATE UNIVERSITY

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Monitoring and Managing pH and EC Using the PourThru Extraction Method

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Providing a proper nutritional program is essential for growing top quality plants. Sampling the root substrate for pH and electrical conductivity (EC) with the PourThru extraction method is a quick and simple check of the nutritional status of a crop. The PourThru extraction method allows rapid on-site determination of pH and EC values. The values provide clues about a crop's performance before deficiency or toxicity symptoms appear.

Sampling Procedures

Sampling results are only valid if they represent the whole crop. How to set up a sampling program, which crops, and the number of samples to collect are all factors to consider. Below are guidelines for taking representative PourThru samples for in-house testing.

Collecting Samples. The PourThru extraction method is a quick and simple way to monitor a crop's nutritional status. For routine analysis, collect and analyze a minimum of 5 individual pots (or for bedding plants a minimum of 5 cell packs). Results from each of the 5 samples can then be averaged for a single "interpretation value". (Do not combine the 5 samples for a single test. A sampling form is provided.) If the 5 values vary widely in pH or EC you may need to increase your sample size.

Frequency of Testing. The speed of this method makes routine sampling possible. Ideally sampling should be done weekly on all crops, but this may not be practical. Since time availability is a concern, consider selecting the "Top 10 Crops of Concern", based on economic value or nutritional problems. Divide the 10 crops into 2 groups and test each group every other week.

The recommended frequency of testing depends on the container size, as smaller substrate volumes are more susceptible to rapid changes in pH than larger, more buffered substrate volumes. For plugs, test pH and EC 2 to 3 times per week. Weekly testing should be sufficient for crops such as flats of bedding plants or 4" pots. For crops grown in large containers (such as 6" pots), monitoring every two weeks should be sufficient.

Crop Factors. Consider taking separate samples within a crop if there are large variations in the substrate type (different manufacturers or ingredients), the fertilizer type or rates (acidic or basic types), or planting dates.

Other Tips. If steps to correct pH or EC problem have been taken, then resample the plants weekly. If needed, sample as

frequently as every two days.
• If results seem atypical, consider resampling before making drastic changes, especially to the substrate pH.
• For more information on PourThru techniques, extra charts, graphs, and general guidelines check out our WEB sites:
http://www.ces.ncsu.edu/floriculture/
http://www2.ncsu.edu/hortsublab/

How to Collect the Leachate

1. Irrigate the crop one hour before testing. Make sure the substrate is saturated (**Figure 1a**). If the water supplied by your automatic irrigation system varies, then water the pots/flats by hand. If using constant liquid feed, irrigate with fertilizer solution as usual. If using periodic feeding: a) irrigate with clear water, b) test a day or two before fertilizing, and/or c) test on the same day in the fertilizing cycle each time.

2. Place saucer under container. After the container has drained for 30 to 60 minutes, place a plastic saucer under the containers to be sampled (**Figure 1b**). If you are testing seedlings in bedding plant flats, place cell packs in saucers (**Figure 1c**).

3. Pour enough distilled water on the surface of the substrate to get 50 ml (1.5 oz) of leachate in the saucer (**Figure d**). The amount of water needed will vary with container size, crop, and environmental conditions. Use the values in the **Table 1** as a guide.

Figure 1a. Irrigate containers thoroughly.

Figure 1b. Saucer for pots.

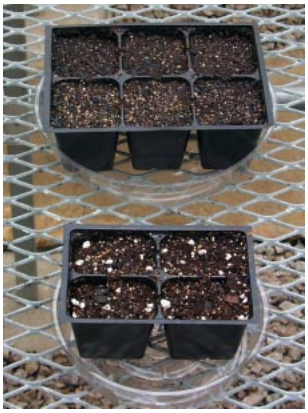


Figure 1c. Saucers for cell packs.

Figure 1d. Applying water for extraction.

Figure 1e. Collected leachate for testing.

Figure 1f. Collect 50 ml (1.5 ounces) for testing.

Figure 1g. Calibration standards for testing.

Figure 1h. Testing leachate samples.

Table 1. Amount of water to apply to various containers to obtain 50 ml (1.5 ounces) of extract*.

Container Size	Water to add**	
	milliliters	*ounces*
4 inch 5 inch 6 inch	75	2.5
6.5 inch azalea	100	3.5
1 quart	75	2.5
4 quart	150	5.0
12 quart	350	12.0
Flats 606 (36 plants) 1203 (36 plants) 1204 (48 plants)	50	2.0

**Containers should be brought to container capacity 30 to 60 minutes before applying these amounts.*
***These amounts are estimates. Actual amounts will vary depending on crop, substrate type, and environmental conditions.*

4. Collect leachate for pH and EC (Figure 1e). Make sure you get about 50 ml (1.5 oz) of leachate each time you test (**Figure 1f**). Leachate volumes over 60 ml will begin to dilute the sample and give you lower EC readings.

5. Calibrate your pH and EC meters prior to testing (Figure 1g). The test results are only as good as the last calibrations. Calibrate the instruments every day they are used. Always use fresh standard solutions and never pour used solution back in the original bottle.

6. Test your samples for pH and EC (Figure 1h). Test the leachate as soon as possible. Electrical conductivity will not vary much over time if there is no evaporation of the sample. However, the pH can change within two hours. Record the values on the chart specific to each crop.

TESTING, INTERPRETING, AND MANAGING SUBSTRATE pH

Substrate pH is very important to plant nutrition because it directly affects the availability of many nutrients, especially micronutrients. Low pH (below 5.8) can increase micronutrient availability, such as iron and manganese, that can lead to phytotoxic responses. In contrast, a pH above 6.8 can lead to micronutrient deficiency problems, especially with iron. Both excessively low and high pH's should be avoided. Optimal pH ranges for many crops are listed in **Figure 2**.

Testing and Interpreting Substrate pH

Test substrate pH substrate prior to use and on a routine basis to assure proper levels. Charts for recording pH has been included. The target pH range, high, and low decision ranges should be established. If the substrate pH climbs into or above the high pH decision range, action should be taken to lower pH. If the substrate pH drops into or below the lower pH decision range, action should be taken to raise pH.

Adjusting Substrate pH

Substrate pH changes over time due to many factors. The four main factors affecting substrate pH are ❶ the initial components and amendments in the substrate, including the liming charge; ❷ the alkalinity of the irrigation water; ❸ the fertilizer(s); and ❹ the species being grown. Obviously, during production, the species being grown or the substrate cannot change, but adjustments to the watering and fertilization can.

Lowering Substrate pH. Listed below (in preferred order) are immediate steps to take to lower substrate pH:

❶ Switch from a basic (nitrate-based) to acidic (ammonium-based) fertilizer..
❷ Acidify the irrigation water to an endpoint pH of 5.8[z]
❸ Apply an iron sulfate ($FeSO_4 \cdot 7H_2O$) drench using 3 lb per 100 gallons of water. Mist off the foliage after application.
❹ Acidify the irrigation water to a pH of 5.1[z].

If the substrate pH frequently increases, employ the following steps (listed in preferred order):

❶ Use an acidic (ammonium-based) fertilizer throughout the cropping period.
❷ Acidify your irrigation water to pH 5.1.
❸ Reduce the initial lime charge or change substrates.

Increasing Substrate pH. Listed below (in preferred order) are immediate steps to take to increase substrate pH:

❶ Stop neutralizing the alkalinity of the irrigation water (if currently acidifying your water).
❷ Switch from acidic (ammonium-based) to basic (nitrate-based) fertilizers.
❸ Apply a flowable limestone drench. Start with a 1 quart per 100 gallons rate. Lightly mist off any solution on the foliage after application.

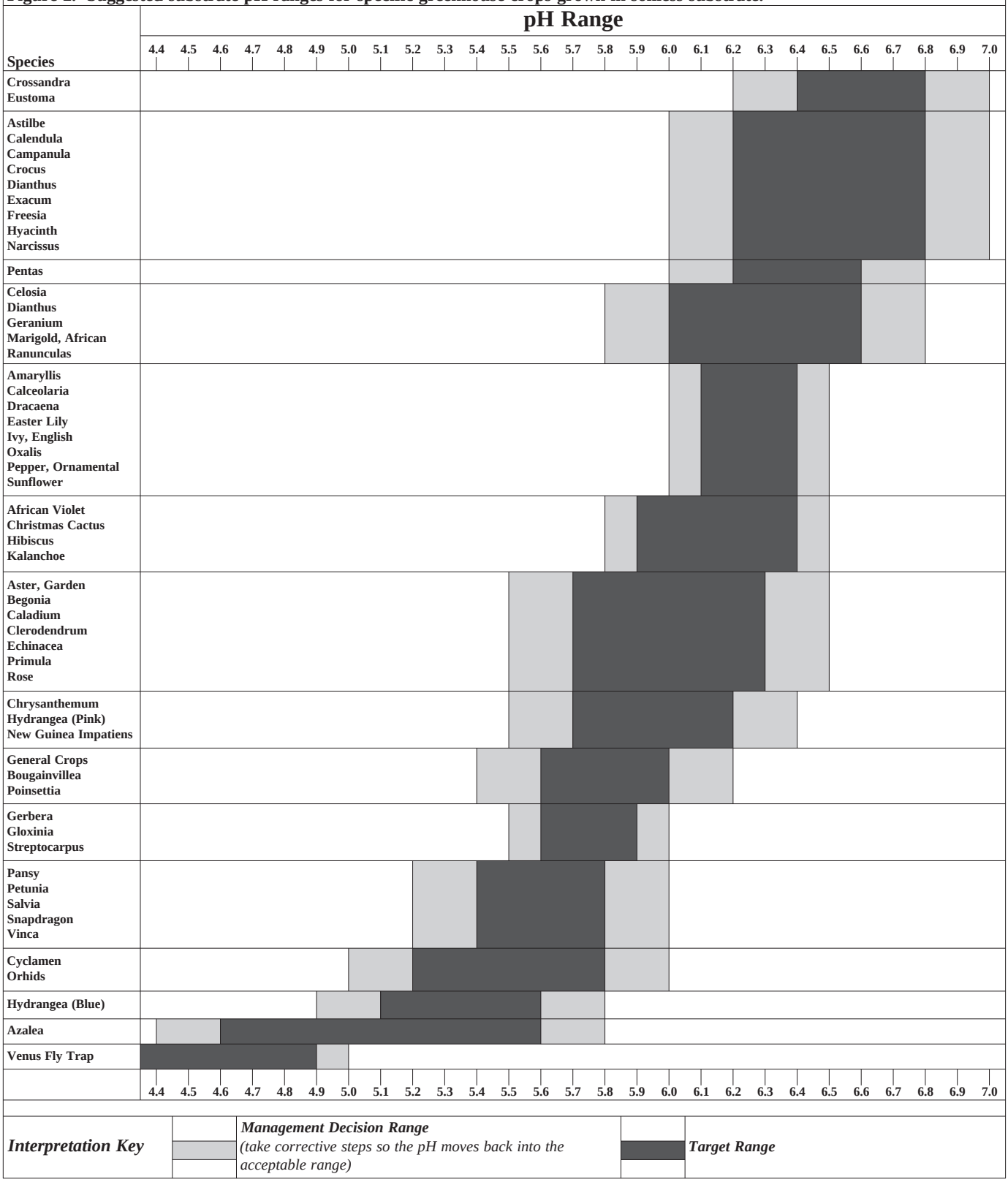
If the substrate pH frequently decrease, employ the following steps (listed in preferred order):

❶ Use a basic (nitrate-based) fertilizer throughout the cropping period.
❷ Inject potassium bicarbonate ($KHCO_3$) into the irrigation water. Start with 13.4 oz per 100 gallons. This supplies 1 meq/L of alkalinity and 39 ppm K with every watering (reduce potassium feed accordingly).
❸ Increase the initial lime charge or change substrates.

TESTING, INTERPRETING, AND MANAGING SUBSTRATE EC

Soluble salts are the total dissolved salts in the root substrate (medium) and are measured in by electrical conductivity (EC). A conductivity

Figure 2. Suggested substrate pH ranges for specific greenhouse crops grown in soilless substrate.



meter measures the passage of electrical current through a solution. The higher the EC, the easier it is for electric current to move through the solution. The EC of the substrate provides insight to the nutrient status of the crop. Keep in mind that not all of the salts measured by an EC meter are fertilizer salts. An EC meter measures all salts in a solution, but does not provide details on the type or amount of each salt present.

High EC. Be aware of substrate EC levels because excess salts can accumulate when: ❶ leaching during irrigation is insufficient, ❷ the amount of fertilizer applied is greater than what is required by the plant, or ❸ the irrigation water contains a high amount of dissolved elements.

Excessively high EC values are associated with poor shoot and root growth. Symptoms often begin on the lower leaves as chlorosis and progress to necrotic tips and margins. As the root substrate dries to the point of irrigation, plants may exhibit wilting symptoms because of die-back of the root tips, which further inhibits water and nutrient uptake. High EC has also been linked with the increased incidence of *Pythium* root rot.

Low EC. In contrast, when the EC values are too low, plant growth can be stunted or leaf discoloration can result from the lack of nutrients. Usually nitrogen is the most typical nutrient deficiency symptom, manifesting itself as lower leaf yellowing.

Factors Affecting EC

Fertilizers. Substrate EC levels can be used to estimate the nutrient status of the crop. Substrate EC levels are more consistent with the constant liquid feed (CLF) irrigation method than with a periodic fertilization. Substrate EC levels with a periodic fertilization regime can vary due to: ❶ when a sample was taken after fertilization and ❷ the number of clear irrigations applied between the fertilizer applications.

The nutrient contribution of slow release fertilizers can also be monitored with regular substrate testing. Most fertilizer materials contribute to the EC content of the substrate. The most common contributors are nitrates (NO_3), potassium (K), calcium (Ca), magnesium (Mg), and sulfates (SO_4). Organic materials also contribute to the EC content after they have been changed from an insoluble to soluble form. Electrical conductivity can also monitor the accuracy of a fertilizer injector. Consult the fertilizer fact sheet for the appropriate EC values to ensure the fertilizer application rate is correct.

Irrigation Water. Elevated substrate EC levels can be caused by naturally high concentrations of bicarbonate (HCO_3), calcium (Ca), chloride (Cl), magnesium (Mg), sodium (Na), or sulfates (SO_4) in the irrigation water.

Irrigation Method. Different irrigation methods provide different amounts of leaching. Leaching prevents excess soluble salts from building up in the root substrate. Excessive leaching or excessive rainfall with outdoor production can lead to low EC problems.

The negative effects of high EC are more pronounced for growers who grow on the "dry side". If the root substrate is allowed to dry, plants may exhibit wilting symptoms because of die-back of the root tips, which further inhibits water and nutrient uptake. It is important for "dry" growers to monitor EC to avoid root damage. If EC levels are too high, be sure to maintain adequate moisture levels within the substrate.

Substrate Type. The substrate components can influence the substrate EC. Sphagnum peat has a low EC, while composted pine bark and coir usually have a slightly higher EC. It is a good idea to test any new substrate mix to ensure it meets specifications.

Crop Factors. When establishing an EC monitoring and management program, match the fertilizer rate with the nutrient demands of the crop. There are two main parameters which should be considered:

❶ **Nutrient Demands.** Crops vary in their fertility requirements for optimal growth. Some crops such as poinsettias and chrysanthemums are "heavy feeders" and require high fertilizer rates. Others like geraniums are "moderate feeders", while "light feeders" like pansies and New Guinea impatiens require low nutrient levels. Optimal EC levels are listed for many crops in **Table 2**.

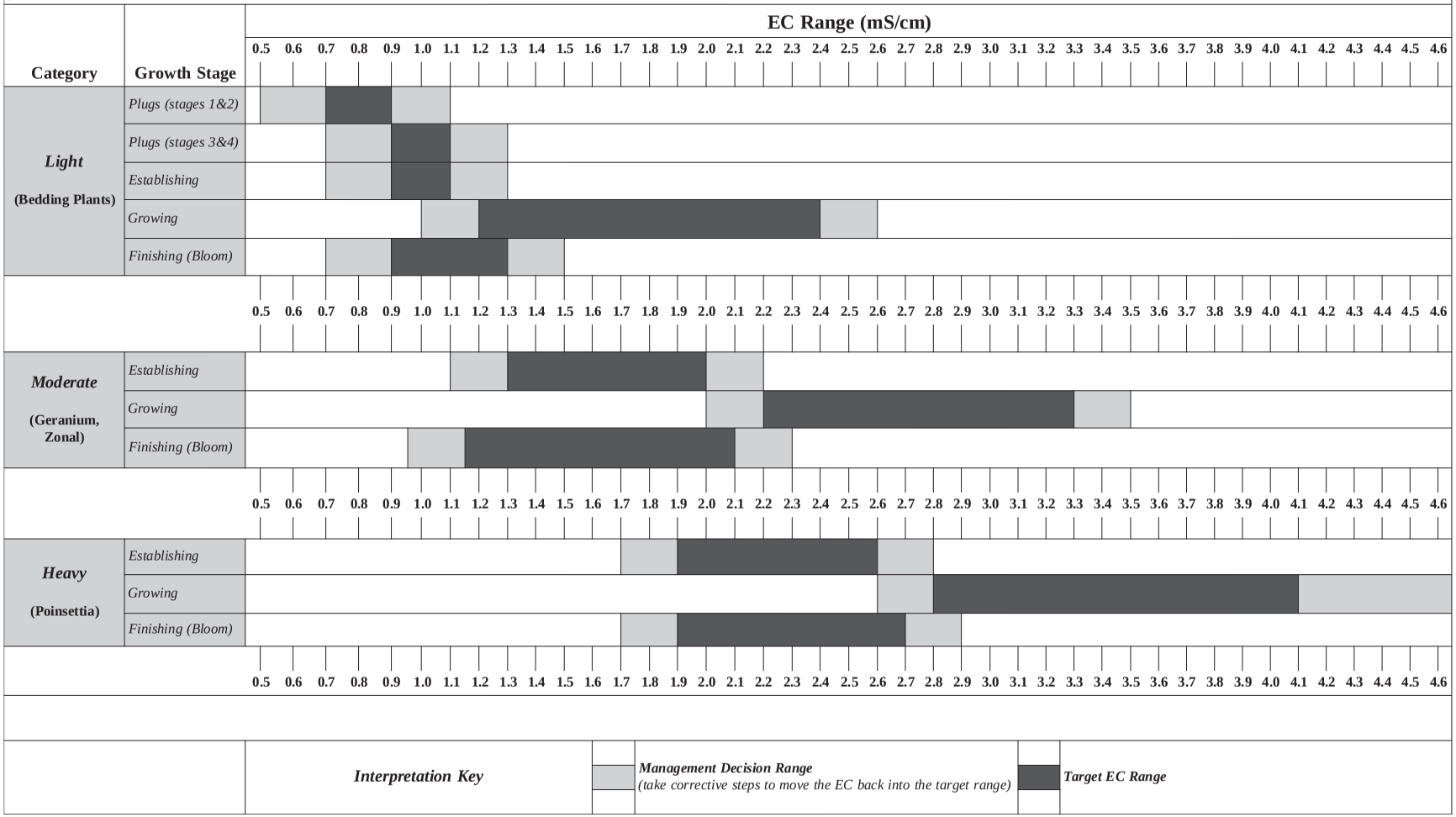
❷ **Crop Development Stage.** The nutrient demands of a crop vary by development stage. Plugs and rooting cuttings require low levels of fertility and nutrient demands increase as plants

Table 2. The relative nutrient requirements of actively growing greenhouse crops, with EC ranges for both the SME and PourThru methods. Use this classification system and the examples provided in Figure 3 for the PourThru method to determine the suggested target EC ranges for the entire crop production cycle.

No Additional Fertilizer Required		Medium (SME EC of 1.5 to 3.0 mS/cm) (PourThru EC of 2.0 to 3.5 mS/cm)	
Amaryllis Crocus *Narcissus*		Alstroemeria Alyssum *Bougainvillea* Calendula *Campanula* Cactus, Christmas Carnation Cauliflower Centaurea Cleome Clerodendrum *Crossandra* Dahlia Dianthus Dusty Miller Exacum Geranium (cutting) Hibiscus Hydrangea Jerusalem Cherry	Kalanchoe Larkspur Lily, Asiatic & Oriental Lily, Easter Lobelia Morning Glory Onion Ornamental Kale Ornamental Pepper Oxalis Pepper Petunia Phlox *Platycodon* Portulaca Ranunculus Rose Sunflower (potted) Tomato Verbena
Light (SME EC of 0.76 to 2.0 mS/cm) (PourThru EC of 1.0 to 2.6 mS/cm)		**Heavy (SME EC of 2.0 to 3.5 mS/cm) (Pourthru EC of 2.6 to 4.6 mS/cm)**	
Aconitum African Violet Ageratum Anemone *Anigozanthos* *Asclepias* Aster Astilbe Azalea Balsam Begonia (fibrous) Begonia (Hiemalis) Begonia (Rex) Begonia (Tuberous) Caladium Calceolaria Calla Lily Celosia Cineraria	Coleus Cosmos Cuttings (during rooting) Cyclamen Freesia Geranium (seed) Gerbera Gloxinia Impatiens Marigold New Guinea Impatiens Orchids Pansy Plugs Primula Salvia Streptocarpus Snapdragon Zinnia	Chrysanthemum Poinsettia	

Adapted from:
Bunt, A.C. 1988. Media and mixes for container-grown plants. Unwin Hyman Press. pp. 309.
Devitt, D.A. and R.L. Morris. 1987. Morphological response of flowering annuals to salinity. J. Amer. Soc. Hort. Sci. 112:951-955.
Dole, J. and H. Wilkins. 1999. Floriculture principles and species. Prentice Hall.
Hofstra, G. and R. Wukasch. 1987. Are you pickling your pansies? Greenhouse Grower. Sept: 14-17.
Nelson, P.V. 1996. Macronutrient fertilizer programs, p. 141-170. In: D.W. Reed. Water, media, and nutrition for greenhouse crops. Ball Publ., Batavia, IL.
Wilkeraon, D.C. Soilless growing media and pH. Texas Greenhouse Management Handbook. p.30-34, 45-47.

Figure 3. Suggested substrate PourThru EC ranges for floricultural crops grown in soilless substrate. These values are guidelines and adjustments should be made based on your growing practices.



become established. Actively growing plants have the highest nutrient demands, but demands decrease as a plants sets buds and flowers. In fact, research has shown that flower longevity is increased when fertilizer rates are decreased or terminated at visible bud or just prior to flowering for most crops.

An EC monitoring and managing plan should be adapted to account for the crop's nutrient demands and stage of development. **Figure 3** contains the target EC levels for establishment, active growth, and bloom stages of growth for plants using the PourThru extraction method. **Table 3** contains interpretative EC values for the 1:5, 1:2, saturated media extract (SME), and PourThru extraction procedures.

Testing and Interpreting Substrate EC

Electrical conductivity charts have been developed for recording values obtained with the PourThru extraction method. The target EC range for the active growth phase of the crop has been added. During the first 2 weeks after transplanting, gradually increase the substrate EC to the target level. Use the EC values listed in **Figure 2** during the plant establishment phase as a guideline. Also as the crop blooms, gradually decrease the EC levels. EC values for the finishing stage are also listed in **Figure 3**.

If the substrate EC rises into or above the upper EC decision range, action should be taken to reduce EC. If the substrate EC drops into or below the lower EC decision range, action should be taken to increase EC.

Adjusting Substrate EC

The substrate EC changes over time due to many factors. The four main factors are: ❶ the initial components and amendments in the substrate, including the substrate type and initial nutrient charge, ❷ fertility regime, ❸ the crop's nutrient demands, and ❹ the crop's development stage. During production the species being grown or the substrate composition cannot change, but adjustments to the fertilization program can.

Steps to Lower EC. Listed below (in preferred order) are immediate steps to take to lower substrate EC:

Table 3. EC interpretation values (mS/cm) for various extraction methods[1].

1 : 5	1 : 2	SME	PourThru[2]	Indication
0 to 0.11	0 to 0.25	0 to 0.75	0 to 1.0	**Very Low.** Nutrient levels may not be sufficient to sustain rapid growth.
0.12 to 0.35	0.26 to 0.75	0.76 to 2.0	1.0 to 2.6	**Low.** Suitable for seedlings, bedding plants and salt sensitive plants.
0.36 to 0.65	0.76 to 1.25	2.0 to 3.5	2.6 to 4.6	**Normal.** Standard root zone range for most established plants. Upper range for salt sensitive plants.
0.66 to 0.89	1.26 to 1.75	3.5 to 5.0	4.6 to 6.5	**High.** Reduced vigor and growth may result, particularly during hot weather.
0.9 to 1.10	1.76 to 2.25	5.0 to 6.0	6.6 to 7.8	**Very High.** May result in salt injury due to reduced water uptake. Reduced growth rates likely. Symptoms include marginal leaf burn and wilting.
>1.1	>2.25	>6.0	>7.8	**Extreme.** Most crops will suffer salt injury at these levels. Immediate leaching required.

[1]Adapted from: On-site testing of growing media and irrigation water. 1996. British Columbia Ministry of Agriculture.
[2]Due to the variability of the PourThru technique results, growers should always compare their results to the SME method to establish acceptable ranges.

❶ Decrease the fertilization rate or decrease the frequency of fertilization (irrigate with clear water).

❷ Leach with clear water to reduce the salts level. The root substrate should be irrigated allowing for 20% leaching, then followed immediately with another irrigation. The root substrate should then be allowed to dry to the usual stage. If further leaching is required, the double-irrigation treatment can be repeated. Recheck the EC values to make sure they are within the acceptable range.

Steps to Increase EC. Listed below (in preferred order) are immediate steps to take to raise substrate EC:

❶ Increase the fertilization rate. A corrective N fertilization will return the lower leaves to the normal green color within 1 to 2 weeks. Do not over apply. It is important to correct nutrient deficiency when symptoms first appear because lower leaf drop or necrosis cannot be reversed.

❷ Increase the fertilization frequency. Use constant fertilization and discontinue any clear water irrigations until the EC levels are within the acceptable range.

Points to Remember.

- If using calcium nitrate ($Ca(NO_3)_2$) + potassium nitrate (KNO_3), remember to supply P, Mg, and micro-nutrients to the plants.
- If using 20-10-20 or 20-20-20, remember to supply Ca and Mg to the plants.

Conclusion

The PourThru Monitoring and Managing program is designed for growers to monitor and maintain their crops. It is a simple program for rapidly determining a crop's pH and EC. It is a program that allows growers to change their focus to prevention instead of cure, and action instead of reaction. If adopted, this proactive program can virtually eliminate nutritional problems.

We would like to thank the Fred C. Gloeckner Foundation and the Ohio Florists' Foundation for funding support of this research project.

[z] See North Carolina State University Horticulture Information Leaflet 558 for more details. Available at: http://www.ces.ncsu.edu/floriculture/

Crop _____

Starting Date (week 0) _____

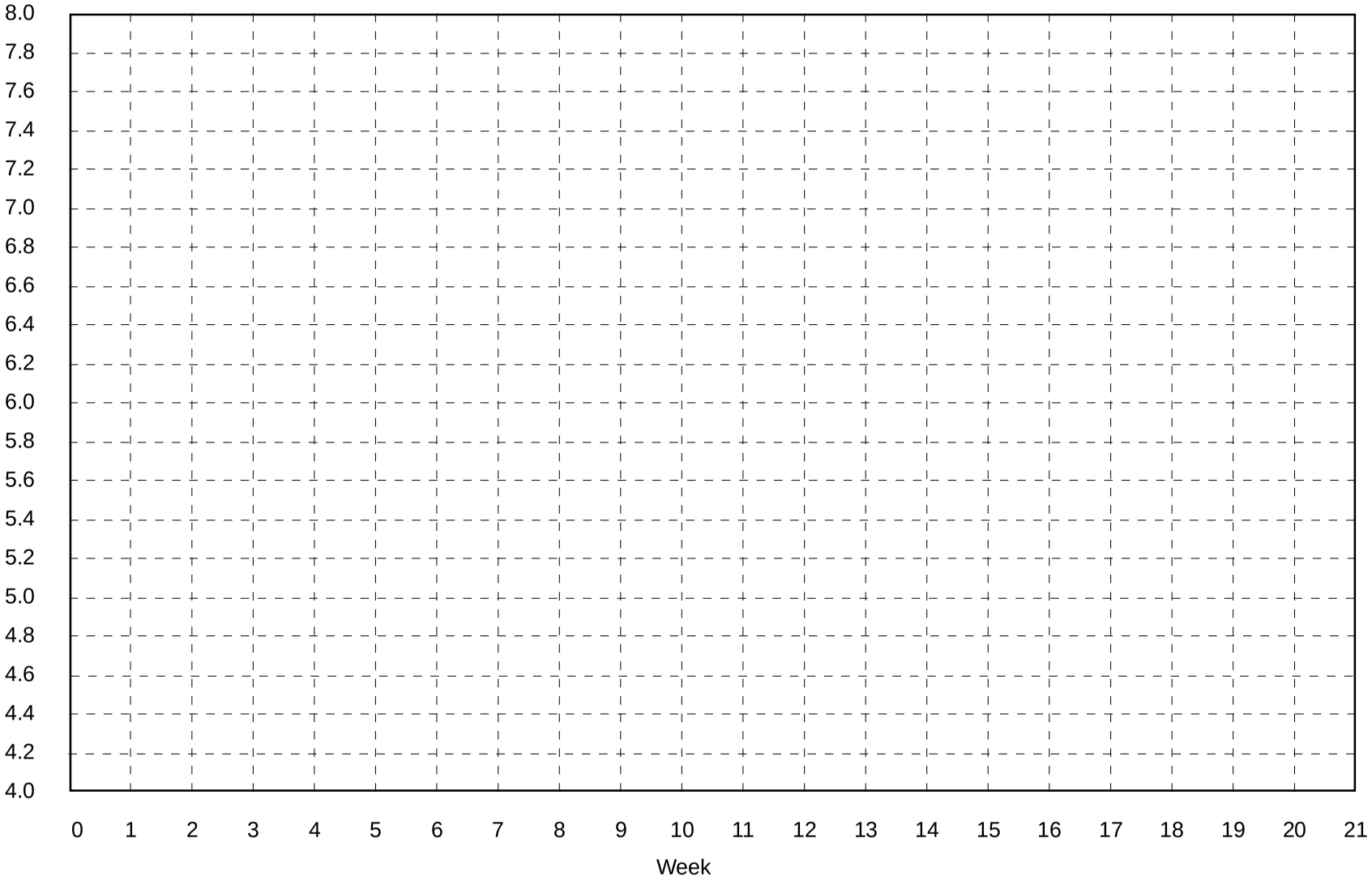
Ending Date _____

Target pH Range _____

Upper pH Decision Range_____

Lower pH Decision Range_____

PourThru pH Chart (21 Weeks)



PourThru pH Chart (10 Weeks)

Crop _____

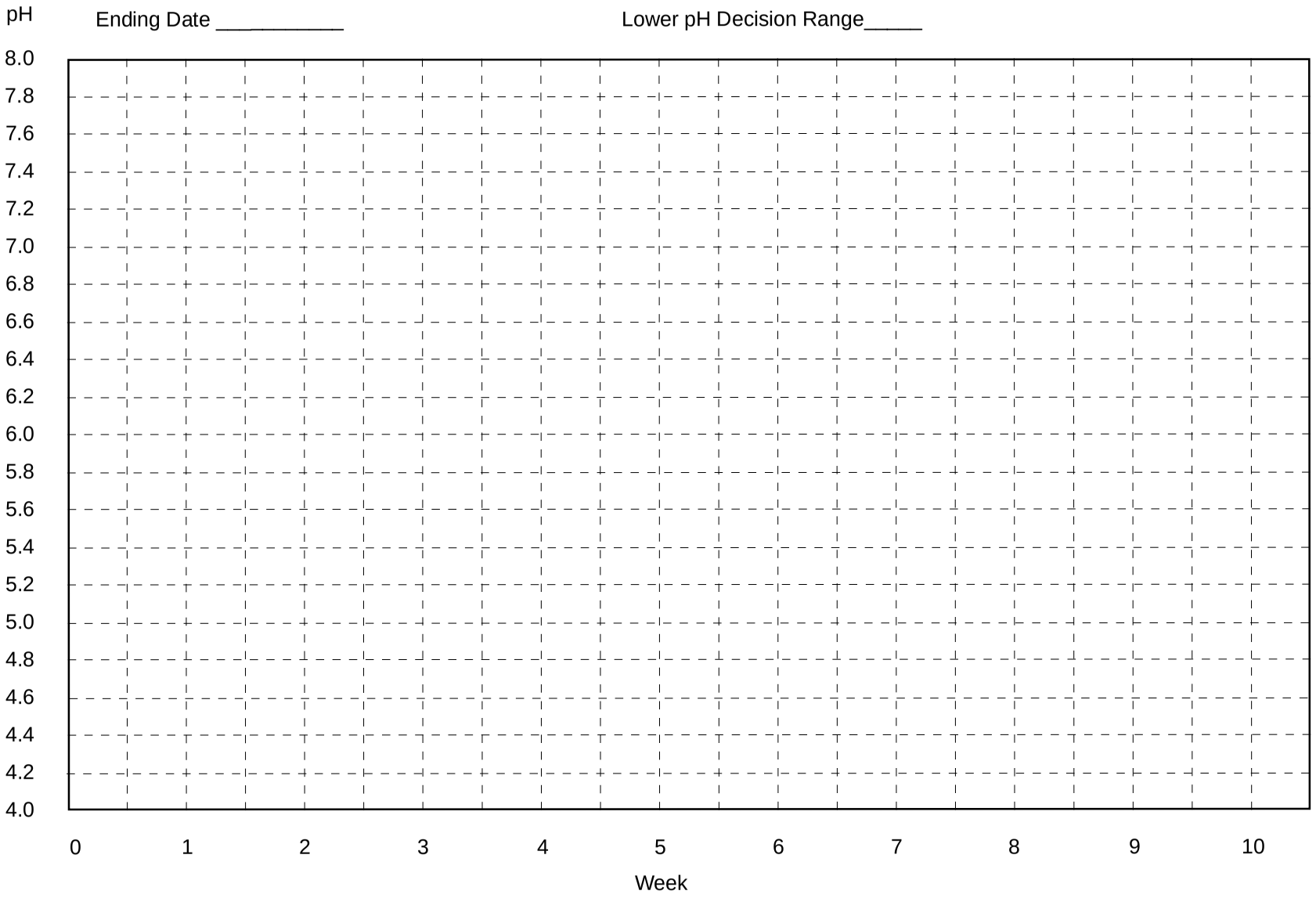
Starting Date (week 0) _____

Ending Date _____

Target pH Range _____

Upper pH Decision Range_____

Lower pH Decision Range_____



Crop _____

Starting Date (week 0) _____

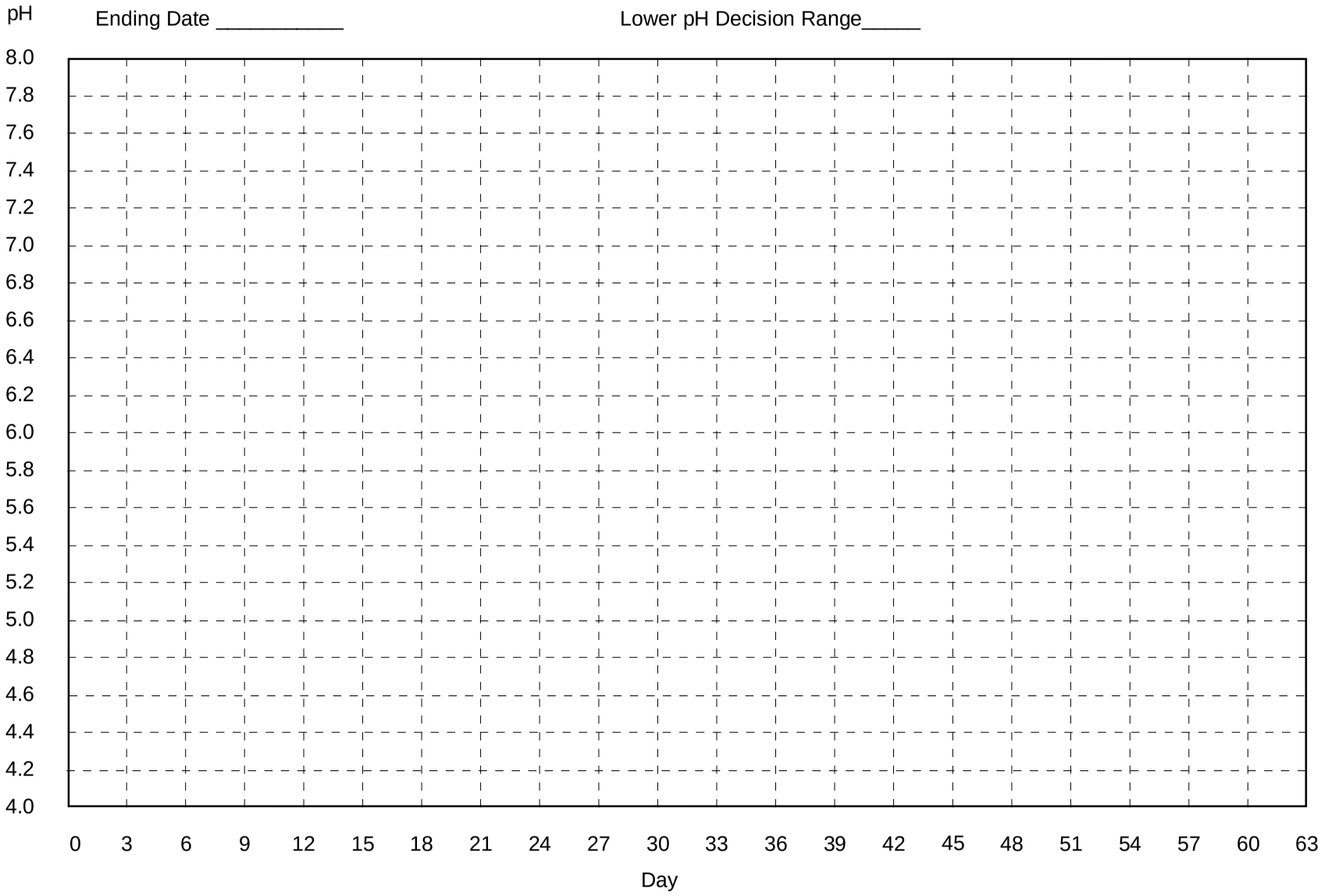
Ending Date _____

Target pH Range _____

Upper pH Decision Range_____

Lower pH Decision Range_____

PourThru pH Chart (63 Days)



Crop _____

Starting Date (week 0) _____

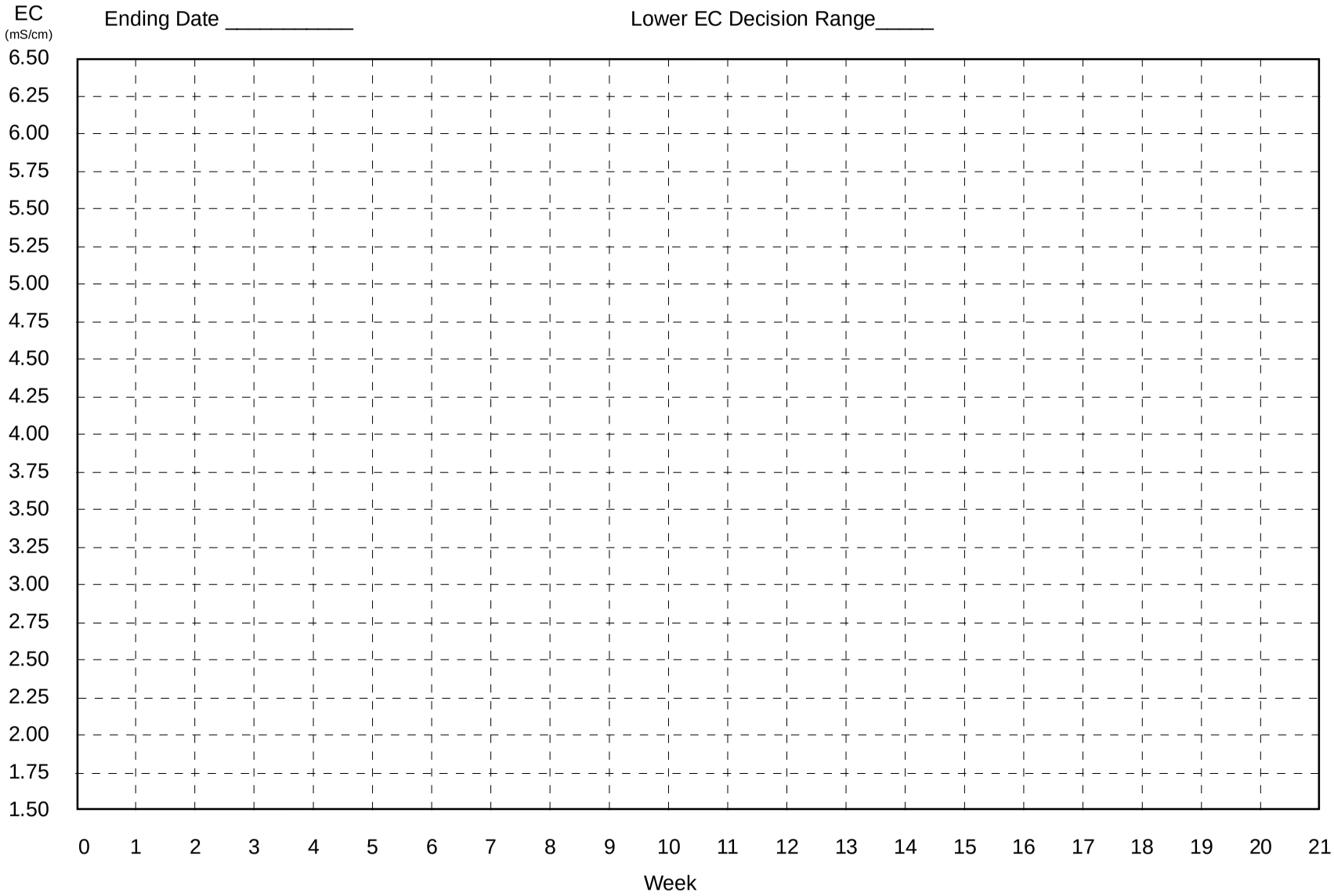
Ending Date _____

Target EC Range _____

Upper EC Decision Range_____

Lower EC Decision Range_____

PourThru EC Chart (21 Weeks)



Crop _____

Starting Date (week 0) _____

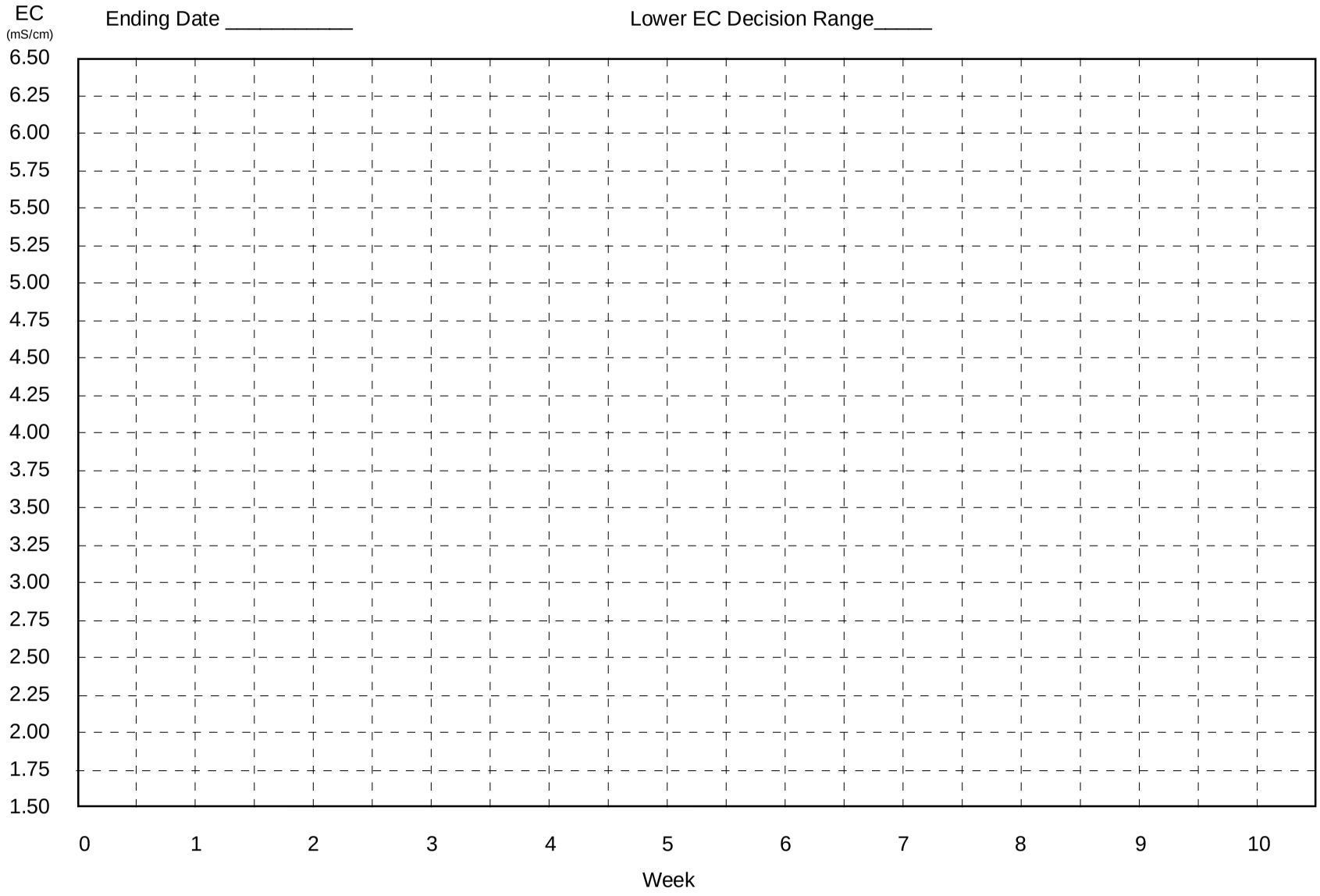
Ending Date _____

Target EC Range _____

Upper EC Decision Range_____

Lower EC Decision Range_____

PourThru EC Chart (10 Weeks)



Crop _____

Starting Date (week 0) _____

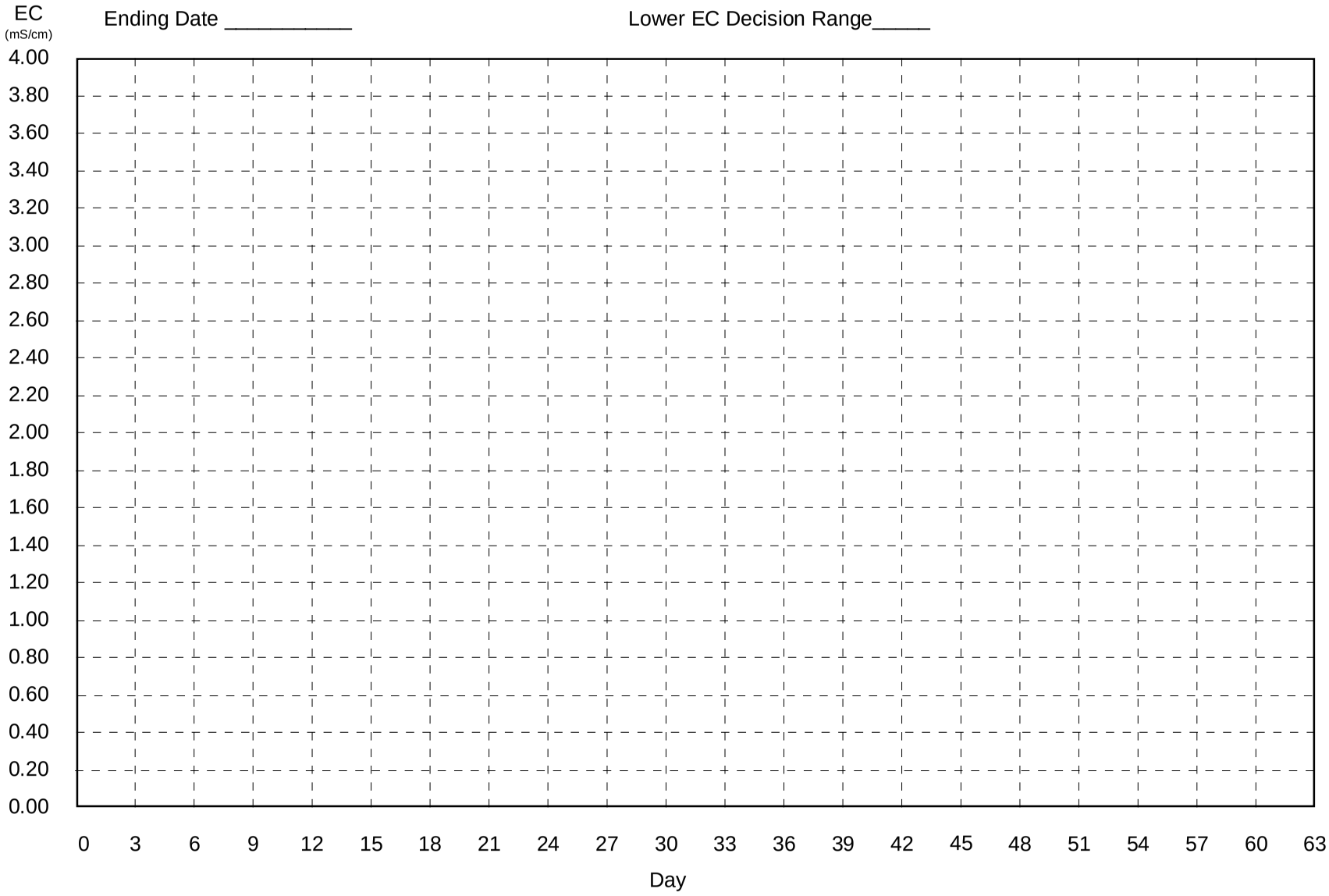
Ending Date _____

Target EC Range _____

Upper EC Decision Range_____

Lower EC Decision Range_____

PourThru EC Chart (63 Days)



Sampling Form

Crop: _____

Date: _____

Location: _____

Samples	ml added	ml out	pH	EC	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					

Crop: _____

Date: _____

Location: _____

Samples	ml added	ml out	pH	EC	Comments
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					