# A comparison of calcium and magnesium ratios in soilless media for optimum vegetable production irrigated with alkaline pH water

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# A COMPARISON OF CALCIUM AND MAGNESIUM RATIOS IN SOILLESS MEDIA FOR OPTIMUM VEGETABLE PRODUCTION IRRIGATED WITH ALKALINE pH WATER

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I would like to dedicate this thesis, first, to my parents, Patricia and Gary, because without their support graduate school would have remained only a dream for me. Second, I would like to dedicate this to my beautiful daughter, Madeline, who has been a constant motivation for me to complete my education.

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# ABSTRACT

Home gardeners in areas with alkaline water sources do not have means of acidifying water for vegetable production. A solution to achieving optimal yields with alkaline irrigation water is to use specialized media; however, current media available does not meet these needs. New media recipes with varied levels (0 to 8 lbs/$yd^3$) and sources of Ca (dolomitic lime, calcium sulfate) and Mg (dolomitic lime, magnesium sulfate) were tested using alkaline irrigation on lettuce, cabbage, and cauliflower crops under high tunnel and on nursery yard sites. Media treatments with an 80:20 bark:peat and 7.1 kg/$m^3$ slow release 15-9-11 base mix and the following fertilizer levels: 2.4 kg/$yd^3$ calcium sulfate and 2.4 kg/$yd^3$ magnesium sulfate (Ca/Mg); 2.4 kg/$yd^3$ dolomitic lime (4L); 2.4 kg/$yd^3$ dolomitic lime, 2.4 kg/$yd^3$ calcium sulfate, and 2.4 kg/$yd^3$ magnesium sulfate (4L+Ca/Mg); 4.7 kg/$yd^3$ dolomitic lime (8L), outperformed a commercially available (IS) and control (C) (no Ca or Mg fertilizer) media in nearly all crops. All crops grown on the nursery yard and cabbage grown under the high tunnel had significantly greater yields when grown in medium 4L+Ca/Mg, compared to the IS and C media ($p \leq 0.05$). Media treatment 4L produced significantly greater yields and plant growth of all tested crops on the nursery yard compared to the IS and C media ($p \leq 0.05$). Media longevity was tested by planting cucumber, tomato, and bell pepper into the same pots, at the same sites, during the spring with no additional pre-plant amendments added to the media. All crops grown on the nursery yard, and cucumber and bell pepper grown under the high tunnel, had significantly greater yields when grown in media 4L+Ca/Mg and 8L, compared to the IS ($p \leq 0.05$). Tomatoes and bell peppers grown on the nursery yard and under the high tunnel had significantly greater growth and yield when grown in 4L+Ca/Mg and 8L, compared to the C medium ($p \leq 0.05$).

# CHAPTER 1: INTRODUCTION

## Global Fruit and Vegetable Production

Humans have been farming for centuries to create a dependable food supply. Globally, fruit and vegetable production increased 3% between 2001 and 2011; over 1 billion tons of vegetables were produced worldwide in 2011. Much of this increase is attributed to expansion of land dedicated to agriculture in Asia, particularly China. China has become the leading producer of vegetable crops worldwide, with 50% of global output shares for vegetables. In southern Asia and impoverished areas, such as sub-Saharan Africa, fruit and vegetable production has also increased over the last decade. Increasing specialty crop production is important to developing economies and small farmers, because the economic returns per unit of land are much higher than field crops (FAO, 2013). Vegetable crops were less than 2% of the harvested acres in the United States from 2000 to 2008 but generated 14% of crop cash receipts (USDA-ERS, 2013).

## United States Farming History

In the United States, vegetables have been produced since the beginning of colonization. During the 16$^{th}$ century, American colonists were given small land grants to establish residence and begin farming (National, 2011). Early settlers brought their knowledge of gardening and depended on it for survival. Many colonial settlers adopted gardening techniques used by Native Americans, such as the three sisters technique of growing corn, beans, and squash together to provide enough food for survival (Schupp and Sharp, 2012). In 1790, farmers constituted 90% of the United States' workforce (National, 2011). However, the number of people living in rural communities and having involvement in farm related activities has decreased over time. By the end of the industrial revolution, the rural population in the US decreased to 35% of the total population, with farmers comprising 31% of the labor force. In 1910, there were over 6 million farms, and the average farm size was 138 acres (National, 2011). In the years following the industrial revolution, agriculture became industrialized

and revolutionized. Factory jobs and the number of goods available to the general public were increasing. There was a need for fewer farmers to produce more food at a cheaper cost. Farms became "factories" with inputs and outputs, and efficiency increased (Ikerd, 1996). The number of farms decreased to just over 5 million by 1950, and the average number of acres per farm increased by 78 acres. By 1950 farmers were only 12.2% of the labor force. In 1990, there were just over 2 million farms with an average farm size of 461 acres, and farmers made up only 2.6% of the labor force (National, 2011). At the end of the 1900s, Americans spent an average of only 10% of their disposable income on food (Ikerd, 1996). Through the end of the 1900s, the number of farms and farmer percent of labor force decreased dramatically, while farm size increased. This was likely due to an increase in education and non-agricultural employment opportunities, as well as increased mechanization on the farm, allowing fewer farmers to farm more land.

## United States Fruit and Vegetable Production

In 2007, 69,172 farms produced vegetables, and 75% of those farms harvested less than 15 acres each (USDA-ERS, 2013). Within the United States, the rate of vegetable production has maintained small, but steady, growth of approximately 1% per year (FAO, 2013). The top fresh vegetable-producing states are California, Florida, Arizona, Georgia, New York, and Washington. In 2011, there were almost 6 million acres of edible horticultural crops harvested in the United States (USDA-ERS, 2012). Production of fresh market vegetables and melons increased by 1% from 2011 to 2012 within the United States (USDA-NASS, 2013).

## Louisiana Fruit and Vegetable Production

Louisiana, although not a top producer of vegetables in the United States, has a diverse and valuable vegetable industry. In 2013, Louisiana had approximately 344 commercial producers growing 33 different vegetable species on 9,149 acres (Fontenot, personal communication). The gross vegetable farm value was $51.4 million in 2012. The majority of vegetable crops grown are sold

through direct marketing such as farmer's markets and roadside stands. In 2012, the most valuable crops in Louisiana were tomatoes, watermelons, okra, summer squash, and winter squash (LSU AgCenter, 2012).

**United States Home Gardening History**

Vegetable gardening has been defined as a federal initiative throughout US history, with war gardens being the most notable. During WWI and WWII, War Gardens and Victory Gardens were promoted by the United States government to avoid a food crisis. The gardens served as a symbol of patriotism, helped families provide for themselves during an economically challenging time, and allowed acreage-grown produce to be sent to soldiers and allies overseas (Schupp and Sharp, 2012). In addition to promoting home gardening during WWI, the US Bureau of Education created a Division of Home and School Gardening that was later re-named the US School Garden Army. This program encouraged schools to adopt gardening as part of their curriculum (Francis, 1919). Federal funding of vegetable gardens has continued through different programs. Currently, the United States Department of Agriculture's People's Garden Grant Program provides start-up funds for school and community gardens in areas identified as food insecure or food deserts (USDA, 2012). Federal nutritional programs, such as the USDA MyPlate program, encourage healthy eating, exercise and local food (USDA, 2014), and hope to encourage, not only wellness, but also gardening. No matter the reason people garden - need, hobby, or health - it remains a popular past time for people of all ages and physical fitness levels.

**Recent United States Home Gardening Statistics**

Approximately 41% of Americans participate in some form of gardening (US Census Bureau, 2012). In the 2012, the US Census Bureau reported 33.6% of males and 48.9% of females reported participation in gardening. Participation by age increased from 15.1% in the 18 to 24 years category to 34.8% in 25 to 34 years and 43.9% between 35 to 44 years. Participation continued to increase to

49.1% between 45 and 54 years, 52.4% 55 to 64 years, and it peaked at 54.5% between 65 to 74 years, with a decrease to 41% in the age group 75 years and over. Percent participation also increased with education and income level. Thirty percent of people with a grade school education participate in gardening, increasing to 37.7% with a high school diploma garden, 49% of college graduates garden, and 53.3% people with graduate-level education actively garden. Although there is some variability in percent participation in gardening by income level, the general trend is increased participation with increased income. This may be due to greater funds for initial garden inputs, increased education leading to increased health consciousness and nutritional education, and possibly increased leisure time with increased income. Approximately 25% of people with incomes less than $10,000 garden. Garden participation increases to roughly 38% when income levels rise to $30-39,999, while 43% of those with income levels of $50-74,999 garden and 54% of those with incomes between $100,000 to 149,999 garden. Percentage decreases were observed between income levels at the $40 to 49,999 range and $50 to 59,999 range (44.9% to 42.8%) and again at the $100,000 to 149,999 range to over $150,000 range (54.0% to 50.9%) (USCB, 2012).

The US Census Bureau reported a decrease in percent participation in gardening and retail gardening sales between 2005 and 2010 (2005: 83% participation, $35,208,000,000; 2010: 68% participation and $28,409,000,000 in retail sales). In this same time period, the percent of households engaged in vegetable gardening increased from 25% in 2005 to 27% in 2009 and decreased to 26% in 2010. The decrease in total gardening retail sales over this period was potentially due to the decrease in ornamental gardening. Retail sales for vegetable gardening fluctuated yearly during but increased from $1,154,000,000 in 2005 to $1,701,000,000 in 2010. From 2005 to 2010, between 17 and 26% of households participated in container gardening (numbers varied by year but decreased from 2005-2010 – 26%, 18%, 19%, 19%, 17% respectively). In 2005, 12% of households reported participating in ornamental gardening, and only 6% of households participated between 2007 and 2010 (USCB, 2012).

Since 17% of American households participated in container gardening in 2010 and only 6% participated in ornamental gardening, the minimum percentage of households participating in container gardening of edible crops was assumed to be 11%. According to the US Census Bureau, there were 116.7 million households in the United States. Eleven percent participation in edible crop container gardening was an assumed 12.8 million households. The large number of gardeners using containers for vegetable production warrants research into soilless media specific to vegetable crops. Currently there is a lack of such media types on the market.

In 2011, 92% of American households were in urban settings (USDL, 2013). The United States consists of 17.7 million acres of residential lawns; and 80% of US households have a private lawn (USEPA, 2012). The average Amerinursery yard size was 0.225 acres, and the average American vegetable garden was 0.014 acres in 2011 (Cornell, 2011). Americans with below average yard sizes and the 20% of Americans who do not have garden space would benefit from improved vegetable media (USEPA, 2012).

**Louisiana Home Gardening Statistics**

The LSU AgCenter estimated 475,337 home gardeners in Louisiana with an estimated gross farm value of $249.5 million in 2012. A 2008 survey of Louisiana home gardeners concluded that the average age of the primary gardener was 62 years, and the median age was 67 years. The 2008 average home garden size was 800 square feet and yielded approximately $525 of produce annually (LSU AgCenter, 2012). Home gardeners growing vegetables in soilless media have reported less than desirable vegetable quality. Nutrient deficiencies have been noticed and may be due to inappropriate media for the alkaline irrigation water used by homeowners. The objective of this study is to develop a soilless medium that will produce high-quality vegetables for homeowners irrigating with alkaline pH water.

# CHAPTER 2: LITERATURE REVIEW

## **Soilless Media History**

The first records of growing plants in containers dates back 4,000 years ago in Egypt, recorded on temple walls (Raviv and Ledith, 2008). During the 17th century, people transported plants in containers from the Middle East to orangeries in Europe. This required the use of soil as a potting medium to grow exotic plants in containers. During the 19th and 20th centuries, in-depth study of plant nutrition led to the eventual creation of modern organic media that no longer contained soil (Raviv and Ledith, 2008). Today, greenhouse production, urban agriculture, and the nursery industry are the largest consumers of soilless media. Soilless media is desirable in container production because the physical and chemical properties of the growing media, as well as pathogens, are more easily Cled. Organic media is also lighter than soil and is easier and more economical to ship (Raviv and Ledith, 2008). Since the creation of the first soilless media, various materials and mixtures have been studied in an attempt to create media with optimal physical and chemical properties at the most economical cost. Researchers continue to study media, often focusing on the use of regional materials that can be combined with specific regional crops.

## **Soilless Media Components**

The materials that comprise a growing media, along with their combined physical and chemical properties, are crucial to successful container vegetable production (Baevre, 1982). Depending on the particular growing location, media components may vary. For instance, in production of Sandalwood, the traditional media components in India are sand, soil, and farmyard manure (Rai, 1990). In China, burnt soil, peat, and coconut dust have been used to create a successful media for sandalwood (Xiao-jin et al., 2009). Other materials have also been successful for sandalwood, including sand/peat/perlite, compost, burnt rice husk, and charcoal (Annapurna, 2005). This is an example of a variety of materials that have been effective for one species and how much media components may vary based on

what is available and most cost-effective in a region. Another example of plant specific media include impatiens successfully growing in peat (Argo, 1996), composted biosolids and yard trimmings (Klok, 1997), and sawdust/clay (Ehret et al., 1998). Ehret et al. (1998) found that the sawdust amended with clay media was successful with greenhouse cucumbers as well, but little research exists describing optimum vegetable media mixes, especially in the presence of alkaline irrigation water.

Sphagnum peat has been a successful base media component for many years (Richard, 2006; Puustjarvi and Robertson, 1975). In 1969, Pustjarvi described fertilized sphagnum peat used alone as a growing media. Sphagnum peat has been used more often than other sources of peat because of its physical properties (Puustjarvi, 1969), chemical properties, and consistency (Rippy and Nelson, 2007). Sphagnum peat is light weight but has high water holding capacity (Raviv et al., 2002) and high cation exchance capacity (CEC) (Argo and Biernbaum, 1997b). According to Biernbaum (1992), a peat:vermiculite media holds up to seven times the amount of nutrients as an equal weight of mineral soil, but only half as much as an equal volume of mineral soil. Peat, however, is often considered a non-renewable resource because it takes many years to form, and it can be expensive to ship, as it is not produced in many areas of the world (Richard, 2006). Many regional alternatives to sphagnum peat have been suggested, including municipal solid waste (Cai et al., 2010), biological waste (Annapurna, 2005; Adediran, 2005), coconut coir dust (Evans and Stamps, 1996), composted pine bark (Yu and Zinati, 2006), and other materials.

In the southeastern United States, pine bark is a commonly combined with peat in organic media. Once a waste product from the timber industry, pine bark has served as an effective media substrate for many crops (Richard, 2006). When combined with peat, media aeration, water holding capacity, and CEC increase (Argo and Biernbaum, 1997b). Pine bark has also been reported to have anti-pathogenic effects (Hoitink, 1982; Kokalis-Burelle and Rodriguez-Kabana, 1994).

Inert components are commonly added to media recipes to make small changes to properties of the base mix. Sand is used to increase air space, drainage, and bulk density of the media (Hoitink, 1982; Yu and Zinati, 2006; Biernbaum, 1992). Pumice and expanded shale can provide similar results (Hoitink, 1982). Perlite, polystyrene, or rockwool are added to increase aeration and water holding capacity. Vermiculite increases aeration, water holding capacity, and CEC of the media (Argo and Biernbaum, 1997b; Biernbaum, 1992). Inert ingredients are not used in every media, but have useful roles.

It is becoming industry standard to incorporate a slow-release, complete fertilizer into media (Argo et al. 1995). At one time, heavy amounts of water soluble fertilizers were used to supply nutrition to container-grown plants. This practice is no longer acceptable as it attributed to high rates of runoff and nutrient leaching (Argo and Biernbaum, 1997b; Beirnbaum, 1992). Although bark contains some micronutrients, an incorporated slow-release fertilizer can increase micronutrient availability to the plant roots (Niemiera, 1992, Wright et al., 1999a). Multiple studies document that the release rate of nutrients increases with increased temperature (Allen et al., 1971; Oertli and Lunt, 1962). The longevity of fertilization and nutrient availability at a given time may vary depending on climatic conditions. This, combined with changes in medium pH and the settling, shrinkage, and breakdown of the organic components determines the life-span of media.

Countless media recipes exist that have shown superior production in research studies (Banko and Stephani, 1991). Ideally, physical properties of media after irrigation and drainage should be 10 to 30% air space, 45 to 65% container capacity, 25 to 35% available water, 25 to 35% unavailable water, 50 to 85% total porosity, and 0.19 to 0.70 g/cm$^3$ bulk density (Yeager et al., 2007). A more precise recommendation by Handreck and Black (2002) suggests 50 to 65% water holding capacity, 60 to 75% total porosity, and 10 to 20% air space as ideal physical properties for container nursery crops. Pine bark, supplemented with micronutrients, has been successful as the sole media component for a

number of nursery plants (Pomper et al., 2002; Svensen and Witte, 1992). In a study by Yu and Zinati (2006), three bark:peat:sand combinations met the Handreck and Black (2005) guidelines for physical properties. Those were (70:20:10), (80:10:10), and (70:10:20). Although sand is a common media component used to increase air space and bulk density, when combined with pine bark sand reduces air space and total porosity (Yu and Zinati, 2006). Martin and Ingram (1991) found that combining sand with pine bark increased the overall media temperature, which may lead to adverse growth effects in warm climates.

**Media pH and Alkalinity**

Un-amended, pine bark and peat-based media are too acidic for many container crops. According to Wright et al. (1999b), the initial pH of pine bark ranges from 4.0 to 5.5, depending on age, source, and other factors. Pokorny (1979) reported the initial pH of pine bark to be between 3.5 and 4.8. The addition of dolomitic lime to most bark/peat media is a common practice in container production (Kraus and Warren, 2006), as it neutralizes acidity, increases the pH, and provides Ca and Mg (Argo and Biernbaum, 1997ab; Wright et al., 1999b). Liming rates vary based on plant species, media components, and lime particle size, and should be incorporated to increase the media pH to between 5.5 and 6.4 (Argo, 1996a) for most crops. Cobb (1983) reports that growers often incorporate 8 to 12 $lbs/yd^3$ of dolomitic lime. However, in his study growing *Juniperus virginiana*, in pine bark-based medium amended with calcium sulfate, superphosphate, Micromax®, and Osmocote®, plant tissue concentrations of Ca were not affected by increasing liming rate. However, increased lime caused Mg concentrations to increase, and potassium levels to decrease. Countless liming rates exist for nursery crops. A few of the recommended liming rates include 5$lbs/yd^3$ for pecan trees in pine bark/sand (Keever et al., 1991), 2.4 $kg/yd^3$ for butterfly bush (*B. davidii*) grown in pine bark (Gillman, 1998), and 3$lbs/yd^3$ for Lenten rose (*Helleborus* x *hybridus*) grown in pine bark (Kraus and Warren, 2006). Some studies with nursery crops have found ideal plant growth in pine bark media when no

lime was added to holly, azalea, juniper (Chrustic and Wright, 1983), and in nine landscape tree species with two pine bark media (Wright et al., 1999b). It is important to maintain proper media pH so that water-soluble nutrients will remain consistent and at ideal availability (Argo, 1996b). However, no studies have reported liming rates for vegetable crops produced in containers.

In addition to lime, alkalinity in irrigation water can cause increased media pH and decreased nutrient availability (Wickerson, 1996), as well as other growth problems for the crop. Alkali salts are the product of a weak acid combined with a strong base (Wickerson et al., 1996). When dissolved in water, they react with the water and form a basic solution. Alkalinity differs from alkaline pH because it is primarily caused by carbonates and bicarbonates (Handreck and Black, 2002). Thus, high pH may be an indicator of alkalinity, but it does not give conclusive evidence of the presence of alkalis. The hydroxide anion does not become a major source of alkalinity in the presence of carbonates and bicarbonates until the pH is above 11 (Valdez-Aguilar, 2004). The most important ions that cause alkalinity are carbonate ($CO_3^{2-}$) and bicarbonate ($HCO_3^-$), but hydroxide, borate, ammonia, organic bases, phosphates, and silicates can be minor contributors as well (Petersen, 1996). Bicarbonates form as a result of carbon dioxide and water and are of the most concern because they are more common; carbonates are only major contributors to alkalinity above pH 9.5 (Gregory, 2001). Carbonates and bicarbonates remove hydrogen ions from solution, acting as buffers against pH fluctuations (Greenlee et al., 2009); therefore, low levels of alkalinity should be present to protect the growing media solution from rapid pH changes (Valdez-aguilar, 2004; Greenlee et al., 2009). Research-based recommendations for ideal bicarbonate in irrigation water vary from 0 to 75mg/L to 61 to 122mg/L (Nelson, 1988; Peterson and Kramer, 1991; Bierbaum, 1994; Dole 1994). Bicarbonate concentrations have been reported to have negative effects between 244-1220mg/L depending on the plant species and other conditions (Valdez-Aguilar, 2004). In addition to causing micronutrient deficiencies by increasing the media pH, bicarbonates may have direct adverse effects on plant growth (Lee and

Woolhouse, 1969). Alhendwi et al. (1997) observed iron deficiency symptoms as well as decreased root growth in the presence of bicarbonates for barley, sorghum, and maize. Decreased plant tissue nutrients have also been reported in tobacco (Pearce et al., 1999).

Ca and Mg carbonates are common forms of alkali salts, and above pH 8.4, sodium carbonate is likely present (Handreck and Black, 2002). When using an acid injection system, bicarbonate is eliminated at pH 4.5 (Gregory, 2001).

Methods that may decrease the negative effects of alkaline water include growing in larger pots, leaching, acidifying fertilizer, or acidifying the irrigation water. When growing in a larger pot, it will take longer for alkalinity to increase the pH of the increased amount of media (Biernbaum and Versluys, 1998). Periodic leaching may decrease the presence of alkalinity in the soil solution, but it will also leach nutrients from the media and is not an environmentally conscious practice (Biernbaum, 1992). In addition, Biernbaum (1992) reported that it takes between 40% and 60% leaching to maintain a constant electrical conductivity when using liquid feed. Fertilizers that are high in ammonium ($NH_4^+$) will bind the negatively charged, alkaline ions to acidify the pH of the soil solution (Biernbaum and Versluys, 1998) and can be a helpful tool in areas with alkaline water. Injecting a strong acid, for example sulfuric acid, reduces the concentration of bicarbonates and other alkaline ions and decreases the pH of the water to suitable levels for irrigation (Bauder et al., 2008; Gregory, 2001; Argo, 1996b), but this is too expensive for a home gardener. Of the solutions to alkaline irrigation water, it is possible for home vegetable gardeners to choose larger pots, leach, and possibly to purchase acidifying fertilizers if the home gardener is knowledgeable enough to understand these practices. Specialized media for vegetable container production targeting home gardeners in areas of alkaline irrigation water that were economically reasonable would serve as a reasonable solution.

**Media Electrical Conductivity (EC) and Salinity**

In addition to alkali salts, other salts may be present in the original media, irrigation water, or fertilizers that affect its quality. A salt is any water-soluble compound formed by the combination of an acid and a metal, and soluble salts affect crops (Bauder et al., 2008). Salts present in the plant's root zone impair the plants ability to absorb water and nutrients if they increase the osmotic potential of the soil solution above that of the plant's internal salinity level. Yield losses and plant-toxic concentrations of some elements may occur (Bauder et al., 2008). In a study by Cai et al. (2010), soluble salts at 1.1% did not show significant damage to tomato, pepper, and cucumber seedlings grown in composted sewer sludge, but soluble salt levels at 1.45% inhibited growth of all seedlings. Campbell et al. (1976) reported decreased mitochondrial activity in potato tubers with 125mM potassium chloride or sodium chloride, as well as similar results for mitochondria of cauliflower, beet root, cucumber, rock melon, and watermelon (some species more sensitive than others). Soluble salts in irrigation water are made up of cations and anions, generally Ca, Mg, Na, and K as cations and chloride, sulfate, nitrate, bicarbonate, and carbonate as anions (Gregory, 2001). Because these salts are soluble, dissociating in water, they cause the water to conduct electricity (Bauder et al., 2008).

Because soluble salts produce electrical conductivity in water, the total soluble salt content (alkali salts and other soluble salts) is most commonly estimated using an electrical conductivity (EC) meter (Bauder et al., 2008). High EC, like pH, is an indicator of alkalinity because alkali salts are measured within the EC value; however, it is not conclusive evidence because non-alkali salts may be present and would also conduct electricity. A high pH, combined with a high EC, is a strong indication that alkali salts are present in the water. Bauder et al. (2008) suggested that a moderate EC for irrigation water is between 0.75 and 3 ds/M and that water should not be used above 3 ds/M. In 1984, Ludwig and Peterson reported that 80.8% of water samples tested from around the United States

exceeded desirable alkalinity.  This would suggest that research on alkalinity and vegetable media is beneficial for areas with sub-optimal irrigation water alkalinity.

**Media EC and pH Measurement**

The Virginia Tech Extraction Method (VETM) is a common method used by nurseries to determine the pH, EC, and nutrient availability of the media solution (Wright et al., 1990; Blythe and Merhaut, 2007).  Unlike other methods, it does not disturb the plant roots, so it is able to be used throughout the growing season (Bilderback, 2001).  The procedure is performed between 30 minutes and 2 hours after irrigation by pouring a known amount of distilled water into the container media and catching the leachate (Wright et al., 1990; Blythe and Merhaut, 2007; Bilderback, 2001).  The pH and EC of the leachate will provide an estimate of the soluble salts and acidity/alkalinity of the media solution. The leachate may then be sent to a laboratory to determine specific nutrient levels. Bilderback (2001) states maximum EC for pine bark based media should be 2 dS/m.

There are many combinations of media components that can meet the specific physical and chemical property needs of a crop, and there have been many combinations identified for ornamental crop production in containers.  Less research exists, however, for vegetable production in containers. It is important to find a reproducible organic media made from available sources that meets the needs of vegetable crops.

## CHAPER 3: THE EFFECT OF SOILLESS ORGANIC MEDIA TREATMENTS ON THREE FALL CROPS

**Abstract**

Home gardeners residing in areas with alkaline water sources do not have means of acidifying water for optimal vegetable production. A solution to achieving optimal yields with alkaline water is to use a specialized media; however, current media available does not meet these needs, leaving home gardeners with plant nutrient deficiencies and poor quality vegetables. New media recipes with varied levels (0 to 8 lbs/yd$^3$) and sources of Ca (dolomitic lime, calcium sulfate) and Mg (dolomitic lime, magnesium sulfate) were tested using alkaline irrigation water for lettuce, cabbage, and cauliflower production under high tunnel and on nursery yard sites. All treatments outperformed the commercially available (IS) and control (C) (no Ca or Mg fertilizer) media in nearly all treatments with all crops. All crops grown on the nursery yard and cabbage grown under the high tunnel had significantly greater yields when grown in medium 4L+Ca/Mg (80:20 bark:peat with 12 lbs/yd$^3$ Osmocote® Plus, 2.4 kg/yd$^3$ dolomitic lime, 2.4 kg/yd$^3$ calcium sulfate, and 2.4 kg/yd$^3$ magnesium sulfate) compared to the IS and C media ($p \leq 0.05$). Media treatment 4L (80:20 bark:peat with 12 lbs/yd$^3$ Osmocote® Plus and 2.4 kg/yd$^3$ dolomitic lime) also produced significantly greater yields and plant growth of all tested crops on the nursery yard when compared to the IS and C media ($p \leq 0.05$).

**Introduction**

Approximately 41% of Americans participate in some form of gardening (US Census Bureau, 2012). From 2005 to 2010, between 17 and 26% of households participated in container gardening (numbers varied by year but decreased from 2005-2010 – 26%, 18%, 19%, 19%, 17% respectively). In 2005, 12% of households reported participating in ornamental gardening, but only 6% of households participated in ornamental gardening between 2007 and 2010 (USCB, 2012). Since 17% of American households participated in container gardening in 2010 and only 6% participated in ornamental gardening, the minimum percentage of households participating in container gardening of edible crops

was assumed to be 11%. According to the US Census Bureau, there were 116.7 million households in the United States. Eleven percent participation in edible crop container gardening was an assumed 12.8 million households. The large number of gardeners using containers for vegetable production warrants research into soilless media specific to vegetable crops. Currently there is a lack of such media types on the market.

Media components may vary based on what is available and most cost-effective in a region. Sphagnum peat has been a successful base media component for many years (Richard, 2006; Puustjarvi and Robertson, 1975). Many regional alternatives to sphagnum peat have been suggested, including municipal solid waste (Cai et al., 2010), biological waste (Annapurna, 2005; Adediran, 2005), coconut coir dust (Evans and Stamps, 1996), composted pine bark (Yu and Zinati, 2006), and other materials. In the southeastern United States, pine bark is commonly combined with peat in organic media. When combined with peat, media aeration, water holding capacity, and CEC increase (Argo and Biernbaum, 1997b).

Un-amended, pine bark and peat-based media are too acidic for many container crops. According to Wright et al. (1999b), the initial pH of pine bark ranges from 4.0-5.5, depending on age, source, and other factors. Liming rates vary based on plant species, media components, and lime particle size, and should be incorporated to increase the media pH to between 5.5 and 6.4 (Argo, 1996a) for most crops. However, studies have not reported liming rates for vegetable crops produced in containers.

Alkalinity, caused by carbonates and bicarbonates (Handreck and Black, 2002), in irrigation water can cause increased media pH and decreased nutrient availability (Wickerson, 1996). However, low levels of alkalinity should be present to buffer growing medium solution from rapid pH changes (Valdez-aguilar, 2004; Greenlee et al., 2009). Research-based recommendations for ideal bicarbonate in irrigation water vary from 0-75mg/L to 61 to 122mg/L (Nelson, 1988; Peterson and Kramer, 1991;

Bierbaum, 1994; Dole 1994), but alkalinity problems exist when levels are too high. Bauder et al. (2008) suggested that a moderate electrical conductivity (Ec – measures soluble salts) for irrigation water is between 0.75 and 3 ds/M and that water should not be used above 3 ds/M. In 1984, Ludwig and Peterson reported that 80.8% of water samples tested from around the United States exceeded desireable alkalinity.

Specialized media for vegetable container production, targeting homeowners in areas of alkaline irrigation water, would allow homeowners to produce high-quality vegetables despite pH and alkalinity issues with their irrigation water. The objective of this study was to find a suitable organic media recipe for container production of lettuce, cabbage, and cauliflower irrigated with alkaline water.

## Materials and Methods

### Experimental Design

This experiment was conducted at the LSU AgCenter's Burden Ornamental and Turfgrass Research Farm in Baton Rouge, Louisiana. Two experimental sites included a nursery yard arranged in a randomized block design with overhead irrigation (2.5 gal/min), exposed to rain water, and a high tunnel arranged in a randomized block design with drip irrigation (2 gal/h) and not exposed to rain water. Fall crops including lettuce (*Lactuca sativa* 'Oakleaf'), cabbage (*Brassica oleracea* var. capitata 'Earliana'. The second cabbage planting was 'Salad Delight' cultivar.), and cauliflower (*Brassica oleracea* var. botrytis 'SnowCrown'), and spring crops including cucumber (*Cucumis sativus* 'Dasher II'), tomato (*Solanum lycopersicum* 'Patio Princess'), and bell pepper (*Capsicum annuum* 'Stiletto') were grown in six media treatments. Each medium treatment/crop combination was replicated ten times per experimental site, and each planting was replicated over two planting dates, approximately two months apart.

## Media Treatments

Six media treatments were used in this study containing 0, half (2.4 kg/$m^3$), or full (4.7 kg/$m^3$) rates of dolomitic lime and 0 or half (2.4 kg/$m^3$) rates of calcium sulfate and magnesium sulfate (Table 3.1). Treatment 1 was a commercially available media selected as the industry standard (IS) because of its notoriety among home gardeners, and its contents can be found in Figure A.1. Treatments 2 to 6 were mixed at LSU and contained 80% bark (1.59 cm ($^5/_8$") screened, partially composted, Phillip's Bark, Brookhaven, MS) and 20% peat (Fertilome Pure Canadian Sphagnum Peat Moss) with 7.1 kg/$m^3$ (12 lbs/$yd^3$) slow release (15-9-11) complete fertilizer. No additional components were added to treatment 2, so it was considered the control (C). Treatment 3 (Ca/Mg) contained an additional 2.4 kg/$m^3$ (4 lbs/$yd^3$) calcium sulfate (MK Minerals Inc. Soft Pelletized Gypsum, 23% Ca) and 2.4 kg/$m^3$ (4 lbs/$yd^3$) magnesium sulfate (Graco Fertilizer Company, Product 24592, 13.7% Mg). Treatment 4 (4L) contained an additional 2.4 kg/$m^3$ (4 lbs/$yd^3$) dolomitic lime (MK Minerals Inc. Pelletized Dolomitic Limestone, 17.5% Ca, 10.1% Mg). Treatment 5 (4L+Ca/Mg) contained an additional 2.4 kg/$m^3$ (4 lbs/$yd^3$) dolomitic lime, 2.4 kg/$m^3$ (4 lbs/$yd^3$) calcium sulfate, and 2.4 kg/$m^3$ (4 lbs/$yd^3$) magnesium sulfate. Treatment 6 (8L) contained an additional 4.7 kg/$m^3$ (8 lbs/$yd^3$) dolomitic lime.

Table 3.1. Media treatments, abbreviations, and ingredients (per $m^3$).

| Trt | Abbrev. | Base Mix | Fertilizer Added |
|---|---|---|---|
| 1 | IS | Popular home gardener potting mix | None |
| 2 | C | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | None |
| 3 | Ca/Mg | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg calcium sulfate + 2.4 kg magnesium sulfate |
| 4 | 4L | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg dolomitic lime |
| 5 | 4L+Ca/Mg | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg dolomitic lime + 2.4kg calcium sulfate + 2.4 kg magnesium sulfate |
| 6 | 8L | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 4.7 kg dolomitic lime |

Media was mixed in 0.91 $m^3$ (1 $yd^3$) batches. One batch of media per treatment was prepared. Standard three gallon, blow molded black pots were filled with 0.013$m^3$ (0.45 $ft^3$) of media. Pots were placed on 0.46 m (18-inch) centers under the high tunnel and on the nursery yard and watered to

saturate media prior to planting transplants of fall vegetables. No additional media was added after settling. Three of the 10 containers of each media treatment were used to measure initial pH and Ec according to the Virginia Tech Extraction Method (VTEM). Pots were saturated, and after 30 minutes leachate was collected. The pH and EC of the leachate were recorded on the day of mixing and again 2 weeks later to allow time for the fertilizer amendments to react.

**Crops**

The three fall crops included lettuce (*Lactuca sativa* 'Oakleaf'), cabbage (*Brassica oleracea* var. capitata 'Earliana'. The second cabbage planting was 'Salad Delight' cultivar.), and cauliflower (*Brassica oleracea* var. botrytis 'Snow Crown'). The second cabbage planting consisted of a different cultivar because the seeds planted were mis-labeled, and it was too late in the season to replant cabbage seed. Seeds were planted mid-November (1$^{st}$ planting replication) and again in mid-February (2$^{nd}$ planting replication) into Sunshine Professional Growing Mix 3 in 98-count plug trays and grown in a greenhouse for 39 days. Seedlings were fertilized weekly after the first true leaf emerged with liquid fertilizer (24-8-16) according to package directions (1 tablespoon per gallon of water). Once the root balls developed in the plug trays (39d after seeding), plants were transplanted into pre-filled pots, one per pot. Plants that did not survive transplant due to cold weather conditions were replaced for only one week after planting. Fewer than 10 plants were replaced per planting date.

Containers were watered twice daily at 10 minute increments and fertilized with liquid fertilizer (24-8-16) once during the season (1 tablespoon per gallon per container), timed according to the LSU AgCenter's Louisiana Commercial Vegetable Production Recommendations. Pesticides were used as needed and included malathion, 1.5oz/A; metaldehyde (4%) mini pellets, 30 kg/A; *Bacillus thuringiensis* (15%), 65oz/A. Days to harvest after transplanting for each crop is in Table 3.2.

Table 3.2. Days from transplant to harvest for fall crops.

| Crop | Nursery yard 1st Replication | High Tunnel 1st Replication | Nursery yard 2nd Replication | High Tunnel 2nd Replication |
|---|---|---|---|---|
| Lettuce | 47 | 40 | 44 | 35 |
| Cabbage | 80 | 78 | 70 | 68 |
| Cauliflower | 87 | 87 | 62 | 66 |

**Data Collection**

Weekly heights (cm) of each plant were collected measuring from the soil level to the tallest growing point on the plant. Vigor on a 1 to 5 scale was rated for each plant bi-weekly. Growth rates, pest damage, and color were judged as compared to all other plants of the same species, planting date, and planting site. The vigor scale was calculated as follows: 1 – very poor, no growth, disease covering over half of the plant, chlorosis covering the entire plant, damaged such that the plant is not likely to survive; 2 – below average growth rate, above average pest damage, coloration problems, may have some disease; 3 – average growth rate, pest damage, color, no disease; 4 – above average growth, below average pest damage, ideal color, no disease; 5- excellent growth, excellent color, no pest damage, no disease. Precipitation (mm), relative humidity (%), and temperature (°C) were recorded hourly and reported on a monthly basis (See figure 2.1).

At harvest, two widths (cm) were collected of the foliage and two widths (cm) were collected of the crown (cauliflower and cabbage only). Whole plants were harvested, cut even with the soil line, and a fresh weight (g) was measured. Cabbage and cauliflower heads were harvested and a separate fresh weight (g) was measured. The above-ground plant material was dried in a 220V forced air oven (Shel Lab, SM028-2) for 3 weeks. Dry head and foliage weights were recorded. Five foliage samples per treatment and 3 head samples per treatment were ground (Thomas Scientific, 383-L10) to a fine powder using a 30-mesh filter and were prepared for Inductively Coupled Plasma (ICP) nutrient analysis to analyze nutrient levels. The foliage samples to be ground were taken by grinding half of the leaves from the plant and selecting a sub-sample of the ground tissue for ICP.

**ICP Nutrient Analysis**

Ground plant material was transferred to a 20ml scintillation vial and placed in an oven at 50°C for 1h to remove moisture. Vials were transferred to a desiccator for 1h to further remove moisture and cool the sample to room temperature. The caps of each sample were tightened upon removal from the desiccator to prevent moisture from re-entering. One-half of a gram was placed into a 50ml tube (SCP Scientific digiTUBE). Funnels were placed in each tube, and samples were placed into an automatic digester (Thomas Cain, DEENA) for digestion using nitric acid. During the digestion, the samples are heated for 6s at 60°C and 2.2ml of distilled water is added. After 2m, 5mL nitric acid (SCP Science, 67% to 70% $HNO_3$, reagent grade) was dispensed into each tube, and the temperature was increased 10°C every 10m from 60°C to 110°C. The temperature was increased to 125°C and held for 45m, and then held for 50m at 128°C, and cooled for 2m. One ml hydrogen peroxide (Macron Fine chemicals, 30% solution) was dispensed into each tube. The samples were cooled for 5m and reheated for 5m to 128°C. One ml of hydrogen peroxide was dispensed, and another 1ml of hydrogen peroxide was dispensed into each tube. Samples were cooled for 5 minutes and heated for 30 minutes at 122°C, cooled for 6 seconds to 20°C and cooled for 1 more minute. The volume of each sample was brought to 20ml using distilled water.

Samples were removed from the digester and vacuum filtered using a 1.0 micron Teflon membrane filter (SCP Science) into another 20ml tube. ICP was performed for the elements P, K, Ca, Mg, S, Al, B, Cu, Fe, Mn, Mo, Na, and Zn using a Spectro Arcos according to the LSU Soil Testing and Plant Analysis Lab's AgMetals procedure. The instrument was calibrated using 1 blank and 6 standards. Samples were run in sets of 60 (2 blanks included) with two National Institute of Standards and Technology (NIST) peach samples and an internal standard every 20 samples. The data was verified to ensure it was within the tolerant ranges of the NIST and internal standards. Nutrient levels were reported as % for macronutrients and ppm for micronutrients.

### Nitrogen

Cauliflower tissue samples (0.15g/sample) were measured into tin foil cups and nitrogen (%) was tested using a LECO TruSpec C/N Analyzer. The machine was calibrated using 5 NIST apple tissue samples and 5 blank samples.

### Data Analysis

Data was analyzed with SAS 9.3 software at a p = 0.05% error rate. Proc glm was used to compare continuous variables based on arithmetic means and standard deviations. A Duncan's Multiple Range Test was performed on all variables of interest for each crop.

## Results and Discussion

### Environmental Conditions

Throughout this study, precipitation, average relative humidity, and average temperature were monitored. The relative humidity and average temperature remained relatively constant between December and April. Precipitation decreased from December to February and increased in March and April (Figure 3.1).

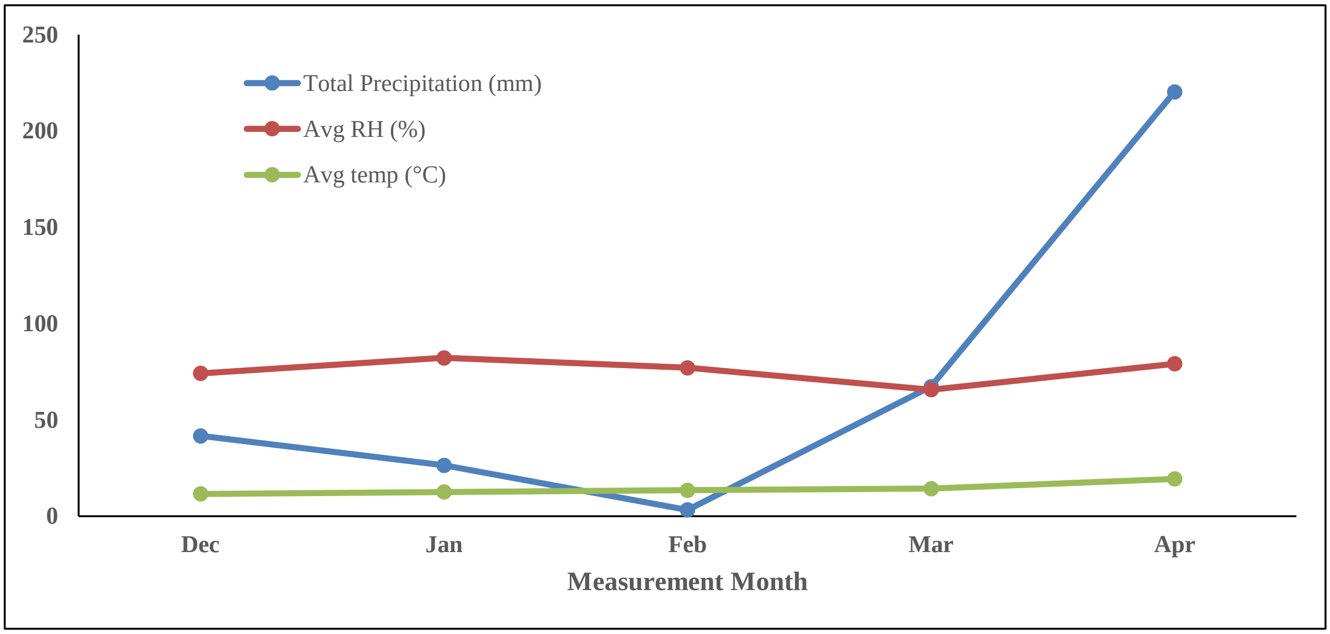


Figure 3.1. Monthly total precipitation, average relative humidity, and average temperature

**Nursery Yard**

Lettuce Growth and Yield

Final lettuce height, vigor, and two head diameter measurements were collected the week of harvest. At harvest, head fresh weight was measured, and head dry weight was later recorded. Leaf tissue was analyzed for plant nutrient content.

First Planting Date

There were no differences between treatments for lettuce height, head diameter, or dry weight on the nursery yard. Plant vigor rates in medium 4L was higher than the IS, C, and medium 4L+Ca/Mg. Head fresh weights of Ca/Mg, 4L, 4L+Ca/Mg, and 8L were at least 39% and significantly greater than the IS and C (Table 3.3). This is important because growers market lettuce based on fresh weight and consumers eat it in the fresh form.

Second Planting Date

Plants growing in the IS, 4L, 4L+Ca/Mg, and 8L were the tallest and had the heaviest head dry weight for lettuce planted on the nursery yard. The C was the least vigorous of all treatments. All treatments had a larger head diameter than the C. The head fresh weight of 4L and 4L+Ca/Mg was 18% heavier than the IS, 139% heavier than the C, and 48% heavier than Ca/Mg (Table 3.3). Treatment Ca/Mg did not perform as well in the second planting date as it had during the first planting date, and this may be due to changes in environmental conditions between planting dates, namely an increase in total precipitation with a slight increase in temperature. Media 4L and 4L+Ca/Mg produced lettuce with the heaviest fresh weight, and these treatments each contained 2.4 kg of dolomitic lime. Treatment 4L+Ca/Mg contained an additional 2.4 kg of calcium sulfate and 2.4 kg of magnesium sulfate, but did not appear to affect lettuce for any of the parameters measured on the nursery yard, for either planting date.

Table 3.3. Growth characteristics of lettuce at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Head Fresh Weight | Head Dry Weight |
|---|---|---|---|---|---|
| Planting Date 1 (12/18/2013 – 2/7/2013) | | | | | |
| | ▪▪cm▪▪ | ▪▪▪ (1-5) ▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 15.7 a[W] | 3.3 c | 25.1 a | 137 b | 6.4 a |
| C | 15.4 a | 3.3 c | 24.5 a | 140 b | 6.6 a |
| Ca/Mg | 16.8 a | 4.2 ab | 23.6 a | 191 a | 7.9 a |
| 4L | 17.0 a | 4.4 a | 26.7 a | 206 a | 8.8 a |
| 4L+Ca/Mg | 17.0 a | 3.7 bc | 26.6 a | 220 a | 8.5 a |
| 8L | 16.5 a | 3.8 abc | 26.5 a | 199 a | 8.3 a |
| Planting Date 2 (2/18/2013 – 4/3/2013) | | | | | |
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Head Fresh Weight | Head Dry Weight |
| | ▪▪cm▪▪ | ▪▪▪ (1-5) ▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 19.3 a | 3.4 ab | 30.9 a | 316 b | 12.4 a |
| C | 14.1 c | 2.3 c | 26.5 b | 155 d | 8.0 b |
| Ca/Mg | 16.9 b | 3.0 b | 29.8 a | 251 c | 8.9 b |
| 4L | 18.8 a | 3.7 a | 31.7 a | 371 a | 13.5 a |
| 4L+Ca/Mg | 19.7 a | 3.7 a | 31.6 a | 374 a | 12.6 a |
| 8L | 19.2 a | 3.8 a | 30.9 a | 364 ab | 11.9 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.
[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Lettuce Nutrition

First Planting Date

There were no significant differences in the leaf tissue for elements P, S, Al, Cu, Fe, Na, and Zn for the first planting date, however 8L had the highest levels of leaf K. Plants growing in the IS accumulated more K than plants in the C and 4L media. Plants in the C medium had the lowest levels of K. The C had the least Ca, but all other treatments were equal. Plants in 4L+Ca/Mg and 8L had greater Mg than those growing in the C medium, and that is expected because media 4L+Ca/Mg and 8L contained the highest Ca and Mg fertilizer levels. Cobb (1983) found that increasing lime levels

did not increase foliar Ca levels, but it did increase foliar Mg while decreasing foliar K. The findings from this planting date support Cobb (1983) in that there was no significant difference in foliar Ca levels when lime was increased from 2.4 kg/yd$^3$ to 4.7 kg/yd$^3$ (there was a significant difference between 0 kg/yd$^3$ and 2.4 kg/yd$^3$ dolomitic lime). However, there was no increase in Mg levels from 2.4 kg/yd$^3$ to 4.7 kg/yd$^3$ (there was a significant difference between 0 kg/yd$^3$ and 2.4 kg/yd$^3$ dolomitic lime). Decreased K with increased lime was also not observed. Plants in the C and 4L treatments had more B than the plants growing in the IS and 4L+Ca/Mg. Plants in the IS had more Mn than plants in 4L, 4:+Ca/Mg, and 8L, and the plants in the C medium had more Mn than plants in 4L and 4L+Ca/Mg. Plants in the IS and C had greater Mo levels than those plants growing in 4L+Ca/Mg and 8L, which was less than 1ppm (Table 3.4).

Second Planting Date

During the second planting date, plants in 4L+Ca/Mg had greater P in the leaf tissue than the plants in the IS. Plants in all treatments contained more tissue K than the plants growing in the C medium. Plants in medium 4L had 3.5 times more Ca than the plants in the C and approximately 20% more Ca than plants growing in media 4L+Ca/Mg and 8L. Lettuce grown in the IS and medium Ca/Mg had more leaf tissue Ca than lettuce in 8L. Media Ca/Mg and 4L were not expected to have more Ca than 4L+Ca/Mg or 8L, because the media in 4L+Ca/Mg and 8L contained additional Ca fertilizer. The difference between media Ca/Mg and 8L, is the source of Ca fertilization, and the difference between media 4L and 4L+Ca/Mg and 8L is both the source and amount of fertilizer. Medium Ca/Mg contains Ca as calcium sulfate, whereas medium 8L contains Ca as dolomitic lime. Media 4L, 4L+Ca/Mg, and 8L all contain 4 to 8 lbs dolomitic lime, and 4L+Ca/Mg also contains calcium sulfate. There were no significant differences between Ca/Mg, 4L, 4L+Ca/Mg, or 8L for Ca during the first planting date. Further testing is warranted to determine the availability of Ca as calcium sulfate versus dolomitic lime under various fertilizer levels and environmental conditions in

lettuce. Plants in the C medium had the least Ca, which was expected because it had no Ca fertilizer from dolomitic lime or calcium sulfate. Ca/Mg produced plants with more Mg than the IS, C, 4L+Ca/Mg, or 8L, and plants in medium 4L had more Mg than the plants grown in the IS medium. Like Ca, this was not the expected outcome, as Ca/Mg and 4L contain lower levels of Mg fertilizer than 4L+Ca/Mg and 8L. According to Cobb (1983), there should be no significant differences between Ca levels, and Mg levels should be highest in medium 8L. Ca/Mg and 4L were expected to outperform the C medium; however Ca/Mg contained half the amount of Mg in the media compared to 4L+Ca/Mg and 8L. Based on the Ca and Mg levels during the second lettuce planting date, the dolomitic lime may have had a different release pattern during the first planting date than it did during the second planting date when there were slightly higher temperatures and increased precipitation. Lettuce from 4L+Ca/Mg had greater S than the IS, Ca/Mg, 4L, and 8L. The C and 8L media had more S in the plant tissues than the IS. There were no significant differences between media treatments for Al. Medium 4L+Ca/Mg had greater leaf B levels than Ca/Mg. Plants grown in media Ca/Mg and 4L had more Cu than the C, and the C plants had more Fe than all other treatments. The C and 4L+Ca/Mg media produced lettuce with more Mn than Ca/Mg and 4L. Plants from the C medium had the most Mo of all treatments, and they had more Na than the IS, Ca/Mg, and 4L. The C may have taken up more $Na^{+}$ ions in the absence of $Ca^{2+}$ and $Mg^{2+}$. Plants grown in 4L+Ca/Mg had more Zn leaf tissue content than the IS and media Ca/Mg and 4L, and the C plants had more Zn than Ca/Mg (Table 3.4).

<u>Summary</u>

Media 4L and 4L+Ca/Mg produced significantly more edible biomass compared to the C and IS medium. These would be the recommended treatments for container production when growing ‘Oakleaf’ lettuce on a nursery yard, exposed to rain water and, twice daily, to alkaline water.

Lettuce leaf tissue contained the least amount of Ca in the C medium, and it was the only treatment below the Ca sufficiency range of 0.80 to 1.20% as described by Mills and Jones (1996).

Table 3.4. Mean lettuce leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012 – 2/7/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.9 a[Y] | 7.0 b | 0.91 a | 0.43 ab | 0.4 a | 96 a | 34 b | 15 a | 200 a | 383 a | 1.7 a | 21367 a | 144 a |
| C | 0.9 a | 3.4 d | 0.35 b | 0.32 b | 0.6 a | 94 a | 44 a | 13 a | 251 a | 354 ab | 2.0 a | 20133 a | 132 a |
| Ca/Mg | Missing values | | | | | | | | | | | | |
| 4L | 1.0 a | 6.0 c | 0.96 a | 0.48 ab | 0.5 a | 100 a | 45 a | 15 a | 285 a | 163 c | 0.8 ab | 16834 a | 118 a |
| 4L+Ca/Mg | 0.9 a | 6.2 bc | 0.96 a | 0.55 a | 0.4 a | 86 a | 34 b | 14 a | 224 a | 117 c | 0.0 b | 16879 a | 97 a |
| 8L | 0.8 a | 8.1 a | 1.10 a | 0.53 a | 0.4 a | 116 a | 37 ab | 14 a | 206 a | 194 bc | 0.0 b | 17240 a | 118 a |
| **Planting Date 2 (2/18/2013 – 4/3/2013)** | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.72 b | 5.7 a | 1.1 ab | 0.30 c | 0.41 c | 60 a | 36 ab | 13 ab | 161 b | 261 ab | 0.3 b | 11291 bcd | 93 bc |
| C | 0.78 ab | 3.4 b | 0.27 d | 0.33 bc | 0.47 ab | 64 a | 35 ab | 10 b | 293 a | 301 a | 4.0 a | 16637 a | 110 ab |
| Ca/Mg | 0.74 ab | 5.7 a | 1.1 ab | 0.41 a | 0.42 bc | 55 a | 30 b | 15 a | 150 b | 125 bc | 0.0 b | 10478 cd | 89 cd |
| 4L | 0.77 ab | 5.7 a | 1.2 a | 0.38 ab | 0.42 bc | 59 a | 31 ab | 15 a | 191 b | 103 c | 0.0 b | 9327 d | 73 d |
| 4L+Ca/Mg | 0.88 a | 6.4 a | 1.0 b | 0.34 bc | 0.52 a | 39 a | 41 a | 13 ab | 202 b | 279 a | 0.9 b | 13658 abc | 114 a |
| 8L | 0.80 ab | 5.4 a | 0.8 c | 0.33 bc | 0.46 b | 37 a | 36 ab | 13 ab | 167 b | 169 abc | 0.8 b | 14217 ab | 103 abc |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

The C media was expected to have the least amount of growth, as this treatment did not contain supplemental Ca. The addition of calcium sulfate or lime increased Ca levels in the plant tissue; however, addition of dolomitic lime or magnesium sulfate did not produce consistent increases in plant tissue Mg levels.

**High Tunnel**

Lettuce Growth and Yield

First Planting Date

Lettuce grown in 4L+Ca/Mg was taller than lettuce grown in 4L, but there were no other significant height differences. In addition, 4L+Ca/Mg produced more vigorous lettuce heads than the C and medium 4L. Significant differences were not found for mean lettuce head diameter. Lettuce heads growing in medium Ca/Mg had a 30% heavier fresh weight than the IS and a 73% heavier fresh weight than the C, similar to the results found on the nursery yard for the first planting date of lettuce. Ca/Mg medium produced greater dry head weight than the IS or C, but the C and IS plant dry weights were not significantly different from any other treatments (Table 3.5).

Second Planting Date

Lettuce grown under the high tunnel in the C medium had the lowest growth for all parameters measured. Plants grown in media 8L were the tallest, and plants in 4L and 6 were more vigorous than the IS, C, and Ca/Mg. Plants grown in media 4L and 8L had a larger head diameter than the IS and C. Lettuce from medium 8L had a 38% heavier head fresh weight than the IS medium and was also heavier than the C and media Ca/Mg and 4L+Ca/Mg. Plants produced in medium 8L had a greater dry weight than the IS, C, and Ca/Mg. (Table 3.5). Ca/Mg, again, did not perform as well during a later planting date. Rain did not affect plants under the high tunnel, as plants were arranged to compensate for slanted downpours. Ambient temperatures increased slightly from the first planting date to the second planting date, potentially influencing lettuce growth under the high tunnel.

Table 3.5. Growth characteristics of lettuce at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Head Fresh Weight | Head Dry Weight |
|---|---|---|---|---|---|
| Plant Date 1 (12/18/2013 – 1/30/2013) | | | | | |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 20.4 ab[W] | 4.0 ab | 32.8 a | 204 b | 8.6 b |
| C | 20.4 ab | 3.9 b | 34.2 a | 153 c | 8.1 b |
| Ca/Mg | 19.1 ab | 4.5 ab | 37.4 a | 265 a | 11.3 a |
| 4L | 17.5 b | 3.9 b | 36.3 a | 215 ab | 9.3 ab |
| 4L+Ca/Mg | 21.8 a | 4.6 a | 34.9 a | 228 ab | 10.4 ab |
| 8L | 21.0 ab | 4.3 ab | 36.1 a | 234 ab | 10.1 ab |
| Plant Date 2 (2/18/2013 – 3/25/2013) | | | | | |
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Head Fresh Weight | Head Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 18.4 bc | 4.0 c | 28.8 b | 200 c | 8.7 bc |
| C | 15.3 d | 3.1 d | 25.5 c | 106 d | 5.3 d |
| Ca/Mg | 17.5 c | 4.2 bc | 30.0 ab | 196 c | 7.9 c |
| 4L | 18.9 b | 4.7 a | 32.7 a | 251 ab | 10.0 ab |
| 4L+Ca/Mg | 19.5 b | 4.5 ab | 31.2 ab | 226 bc | 10.1 ab |
| 8L | 20.9 a | 4.7 a | 33.2 a | 276 a | 10.7 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.
[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Lettuce Nutrition

First Planting Date

There were no significant differences among treatments for lettuce Al, B, and Cu leaf content for the first planting date. The IS had greater foliar P than the C, Ca/Mg and 4L+Ca/Mg media. Plants grown in 8L had greater K content than the C and Ca/Mg treatments. Lettuce grown in medium 4L+Ca/Mg had more Ca than lettuce from the IS, C, Ca/Mg, and 4L media treatments. This was the expected outcome because medium 4L+Ca/Mg has more Ca fertilizer (2.4 kg dolomitic lime, plus 2.4 kg calcium sulfate) than the C and media Ca/Mg and 4L. The C plants had the lowest Ca leaf tissue

content. Treatments Ca/Mg, 4L, and 4L+Ca/Mg had more Mg leaf tissue content than all other treatments, which may suggest more Mg uptake from magnesium sulfate than dolomitic lime, as all three of these treatments contain magnesium sulfate, but the equivalent of less Mg than is present in 8L as dolomitic lime. Plants produced in the C and medium Ca/Mg had more foliar S than all other treatments. The IS and 8L plants had the lowest Fe, whereas plants produced in media Ca/Mg and 4L had more Fe than 4L+Ca/Mg. Lettuce produced in media 4L, 4L+Ca/Mg, and 8L had the lowest foliar Mn levels, and the C medium had the highest foliar Mn levels. The IS plants had the highest Mo; Mo in plants from media Ca/Mg, 4L, 4L+Ca/Mg, and 8L was below detection limits. The IS and C plants had the highest Na, and plants from the IS had the highest Zn foliar levels (Table 3.6).

Second Planting Date

At the end of the second planting date, lettuce from 4L+Ca/Mg had more P than 8L. For K and Ca, medium C had the lowest tissue levels, and all other treatments were equal. Plants produced in media Ca/Mg and 4L+Ca/Mg had the highest Mg levels, echoing findings from the first planting date where treatments with magnesium sulfate contained more Mg than 8L, which had higher levels of Mg present as dolomitic lime. The C and 8L plants had more Mg than plants grown in the IS medium. It was expected that 8L should have more Mg, as more Mg fertilization is present in the media and Cobb (1983) noted increased Mg with increased lime, but the C should not have had more Mg than the IS. The C medium and 4L+Ca/Mg had lettuce with the highest S, and all other treatments were equal. There were no significant differences for Al. Lettuce grown in the C medium had more B than the IS and medium 4L, and 4L+Ca/Mg plants also had more B than 4L. 4L+Ca/Mg plants had more Cu than the IS, C, and medium 8L plants. The C plants had greater tissue Fe than plants grown in the IS and media 4L and 8L. Plants from Ca/Mg and 4L had the least Mn. Lettuce grown in the IS medium had the highest Mo content and had more Na than the C, Ca/Mg, and 4L. Similar to the C pattern

Table 3.6. Mean lettuce leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012 – 1/30/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 1.05 a[Y] | 6.5 ab | 0.85 c | 0.41 b | 0.53 b | 60 a | 63 a | 13 a | 169 c | 428 b | 1.2 a | 15692 a | 133 a |
| C | 0.85 b | 5.4 b | 0.52 d | 0.40 b | 0.68 a | 60 a | 84 a | 12 a | 235 ab | 506 a | 1.3 b | 15323 a | 103 b |
| Ca/Mg | 0.89 b | 6.1 b | 0.83 c | 0.62 a | 0.64 a | 55 a | 48 a | 13 a | 248 a | 317 c | 0.0 c | 9728 b | 103 b |
| 4L | 0.94 ab | 6.6 ab | 1.04 bc | 0.59 a | 0.51 b | 72 a | 70 a | 12 a | 272 a | 149 d | 0.0 c | 9433 b | 96 b |
| 4L+Ca/Mg | 0.84 b | 6.3 ab | 1.29 a | 0.65 a | 0.44 b | 64 a | 51 a | 13 a | 187 bc | 106 d | 0.0 c | 8543 b | 111 b |
| 8L | 0.94 ab | 7.7 a | 1.21 ab | 0.58 b | 0.44 b | 65 a | 46 a | 13 a | 155 c | 151 d | 0.0 c | 9518 b | 112 b |
| Planting Date 2 (2/18/2013 - 3/25/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.79 ab | 7.3 a | 1.1 a | 0.29 c | 0.46 b | 67 a | 40 bc | 11 c | 190 c | 376 a | 1.1 a | 11777 a | 102 bc |
| C | 0.85 ab | 4.4 b | 0.5 b | 0.51 b | 0.66 a | 52 a | 50 a | 13 bc | 416 a | 393 a | 0.2 b | 9401 bc | 126 ab |
| Ca/Mg | 0.82 ab | 7.3 a | 1.3 a | 0.65 a | 0.53 b | 52 a | 42 abc | 16 ab | 254 bc | 107 b | 0.0 b | 7786 c | 114 bc |
| 4L | 0.80 ab | 6.3 a | 1.1 a | 0.37 bc | 0.49 b | 71 a | 34 c | 15 abc | 218 c | 151 b | 0.2 b | 8428 bc | 100 bc |
| 4L+Ca/Mg | 0.89 a | 6.5 a | 1.2 a | 0.70 a | 0.75 a | 53 a | 46 ab | 19 a | 365 ab | 331 a | 0.0 b | 9840 abc | 143 a |
| 8L | 0.72 b | 6.2 a | 1.1 a | 0.47 b | 0.51 b | 62 a | 40 bc | 13 bc | 280 bc | 194 a | 0.0 b | 10385 ab | 97 c |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

observed previously, the IS had the lower $Mg^{2+}$ levels, contrasted with higher $Na^{+}$. Medium treatment 4L+Ca/Mg plants had more Zn than all other treatments, except the C (Table 3.6).

Summary

There was a lack of consistency in lettuce growth both under the high tunnel and in open conditions among the media treatments, making it difficult to suggest a clearly superior media. However, according to fresh weight (yield), Ca/Mg, 4L+Ca/Mg, and 8L had greater production overall than the C, and they were similar to or better than the IS.

Nutritionally, the same results were seen for leaf tissue Ca under the high tunnel as on the nursery yard. The C medium produced lettuce with the least leaf tissue Ca, and it was the only treatment below the Ca sufficiency range of 0.80 to 1.20% that was described by Mills and Jones (1996). Media treatments Ca/Mg and 4L+Ca/Mg produced lettuce with more Mg than the C and IS for both planting dates, but all treatments were within the sufficiency range of 0.24 to 0.73% (Mills and Jones, 1996).

**Nursery Yard**

Cabbage Growth and Yield

First Planting Date

Cabbage from medium 8L was taller than the IS, C, and 4L. Treatment Ca/Mg and 8L produced more vigorous cabbage than the IS and C, and cabbage from 8L had a larger head diameter than plants grown in the IS and C media. The leaf diameter of plants in 4L+Ca/Mg and 8L were larger than those in the IS and C. Cabbage heads from 4L, 4L+Ca/Mg, and 8L had a 115% to 151% larger fresh weight than the IS, and heads from Ca/Mg, 4L, 4L+Ca/Mg, and 8L had a 123% to 157% larger fresh weight than the C. Suggesting that cabbage performs best when planted in an 80:20 bark:peat medium with 4 to 8 lbs/$yd^3$ of dolomitic lime added. The head dry weight of plants grown in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L was larger than the C medium. The leaf fresh weight of cabbage from

8L was 18% to 59% greater than cabbage from all other treatments. Media treatment 8L also produced a heavier leaf dry weight than all other treatments, with the exception of 4L+Ca/Mg (Table 3.7). Media 8L out-performed the IS and C for nearly all of the parameters measured, and 4L+Ca/Mg out-performed them for many as well. This may be due to the Ca and Mg present in these media.

Second Planting Date

Similar to the first planting date, yields during the second planting date were the greatest when cabbage was grown in media treatments 4L, 4L+Ca/Mg, and 8L. Additionally, cabbage grown on the nursery yard in medium 4L+Ca/Mg had the highest vigor, leaf diameter, and leaf fresh weight for the second planting date, suggesting that it is the best medium during this planting date. Although the second planting date of cabbage was a different cultivar, results were similar to the first planting date. The C plants had the lowest vigor, leaf diameter, head fresh weight, head dry weight, leaf fresh weight, and leaf dry weight. Cabbage from all treatments had larger head diameters and greater leaf fresh weights than the IS and C (Table 3.7).

<u>Cabbage Nutrition</u>

First Planting Date

Cabbage grown in the C medium on the nursery yard had the highest P, K, Cu, Na, and Zn tissue levels, and it had the lowest Ca for the first planting date. P levels for plants in the IS and all other treatments were not significantly different. Treatment 4L+Ca/Mg cabbage had greater K leaf content than 8L. The IS cabbage plants had 62% more Ca than cabbage from medium 4L+Ca/Mg and 28% more Ca than 8L, which is a much larger difference than was seen in lettuce on the nursery yard. This demonstrates the crop-specific response to media fertilization. Medium Ca/Mg had greater S leaf tissue levels than all others, and cabbage from Ca/Mg, 4L, and 4L+Ca/Mg had more S than the IS and C. There were no differences among treatments for leaf tissue Al and Fe. For B, plants grown in the C medium had higher levels than Ca/Mg, 4L, 4L+Ca/Mg, and 8L. Plants in the IS medium had the

Table 3.7. Growth characteristics of cabbage at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
|---|---|---|---|---|---|---|---|---|
| Plant Date 1 (12/18/2013 – 3/8/2013) | | | | | | | | |
| | ▪▪▪cm▪▪▪ | ▪▪▪(1-5)▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 17.1 bc[W] | 3.4 bc | 7.6 b | 35.3 bc | 243.9 bc | 20.3 ab | 277.6 c | 29.6 bc |
| C | 16.3 c | 3.4 bc | 7.2 b | 32.3 c | 204.2 c | 12.1 b | 268.5 c | 21.9 c |
| Ca/Mg | 18.6 ab | 3.9 a | 9.5 ab | 38.5 ab | 456.1 ab | 30.1 a | 333.5 bc | 30.0 bc |
| 4L | 17.3 bc | 3.8 ab | 9.9 ab | 37.1 ab | 530.4 a | 32.1 a | 322.3 bc | 29.5 bc |
| 4L+Ca/Mg | 18.5 ab | 3.8 ab | 9.6 ab | 38.8 a | 524.9 a | 30.2 a | 373.3 b | 36.1 ab |
| 8L | 20.4 a | 4.1 a | 10.7 a | 40.1 a | 613.4 a | 31.5 a | 440.2 a | 39.4 a |
| Plant Date 2 (2/27/2013 – 5/8/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪▪(1-5)▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 19.2 bc | 2.7 c | 5.8 b | 37.6 c | 277.6 c | 25.6 c | 267.0 c | 13.0 c |
| C | 17.6 c | 2.0 d | 3.5 b | 26.7 d | 106.1 d | 13.0 d | 158.8 d | 4.7 d |
| Ca/Mg | 22.9 a | 3.0 bc | 8.9 a | 38.9 bc | 414.3 bc | 27.1 c | 333.9 b | 20.2 bc |
| 4L | 18.9 bc | 3.2 bc | 8.6 a | 41.7 b | 455.9 ab | 34.9 ab | 369.8 b | 28.6 a |
| 4L+Ca/Mg | 23.9 a | 4.0 a | 10.0 a | 45.3 a | 609.5 a | 38.8 a | 497.4 a | 32.5 a |
| 8L | 21.7 ab | 3.3 bc | 9.1 a | 40.7 b | 529.9 ab | 30.4 bc | 355.8 b | 26.3 ab |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

highest Mn, and those in Ca/Mg and 4L had the lowest. The C plants had more Mn than Ca/Mg, 4L, 4L+Ca.Mg, and 8L. Cabbage grown in the IS, Ca/Mg, and 4L media had the lowest Na. These were treatments that contained among the highest $Ca^{2+}$ leaf tissue contents. Plants in media 4L+Ca/Mg and 8L were not significantly different for leaf tissue Na. The IS and 8L plants had more Zn than Ca/Mg and 4L plants (Table 3.8).

Second Planting Date

Cabbage grown in the C medium had the highest P, Cu, and Na for the second planting date. All other treatments were statistically similar for leaf tissue P. The C plants had more K than the IS, 4L, and 8L; medium Ca/Mg plants had more K than 4L. The IS, 4L, 4L+Ca/Mg, and 8L produced cabbage with the highest Ca and Mg tissue levels by at least 127% for both elements. In lettuce, crops, calcium sulfate and magnesium sulfate may have been more readily available to plant roots; however, the treatments containing Ca and Mg in the form of dolomitic lime out-performed Ca/Mg which contained Ca and Mg in the form of calcium sulfate and magnesium sulfate. In addition, there was no increase in Mg or a decrease in K as dolomitic lime increased from 4 to 8 lbs/$yd^3$ as Cobb (1983) would have predicted. Plants in Ca/Mg and 4L+Ca/Mg had the highest S levels, and medium 8L had higher S than the IS and C media. Treatment 8L cabbage had more Al than the IS. Plants from Ca/Mg had more B than those from IS, C, 4L+Ca/Mg, and 8L. Medium 4L cabbage had more B than the IS. Plants grown in Ca/Mg and 4L had more Cu, and those grown in 4L+Ca/Mg had more Fe, than the IS. The IS plants had more Mn than all other media treatments, except 4L. Cabbage grown in 4L had more Mn than the C, 4L+Ca/Mg, and 8L media; the C plants had more Mn than 8L. The IS and 8L had the highest leaf tissue Mo, while Ca/Mg and 4L+Ca/Mg had the lowest. Cabbage leaves from 4L, 4L+Ca/Mg, and 8L had the lowest Na, and not surprisingly contained the most Ca and Mg cations. Treatment 4L plants had more Zn than the C, 4L+Ca/Mg, and 8L plants, and plants grown in the IS had greater Zn than media 4L+Ca/Mg and 8L (Table 3.8).

Table 3.8. Mean cabbage leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012 – 3/8/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.34 b[Y] | 1.9 bc | 5.5 a | 0.20 d | 1.08 d | 35 a | 62 ab | 2.8 c | 77 a | 434 a | 15 bc | 9211 c | 51 b |
| C | 0.55 a | 3.7 a | 0.7 d | 0.15 d | 1.12 d | 60 a | 78 a | 6.7 a | 114 a | 305 b | 21 ab | 28640 a | 86 a |
| Ca/Mg | 0.34 b | 2.3 bc | 5.2 ab | 0.62 a | 2.61 a | 52 a | 56 b | 3.7 bc | 82 a | 104 d | 14 c | 9147 c | 27 c |
| 4L | 0.38 b | 2.2 bc | 5.4 ab | 0.39 c | 1.75 bc | 68 a | 45 b | 4.5 b | 96 a | 110 d | 27 a | 9717 c | 31 c |
| 4L+Ca/Mg | 0.32 b | 2.6 b | 3.4 c | 0.56 ab | 2.15 b | 63 a | 54 b | 3.5 bc | 94 a | 191 c | 10 c | 15141 b | 39 bc |
| 8L | 0.29 b | 1.8 c | 4.3 bc | 0.50 b | 1.34 cd | 58 a | 57 b | 3.9 bc | 101 a | 209 c | 22 ab | 14535 b | 50 b |
| Planting Date 2 (2/18/2013 – 5/8/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.41 b | 1.6 c | 2.9 a | 0.58 a | 1.18 c | 12 b | 42 cd | 3.7 d | 49 b | 314 a | 23 a | 17666 bc | 142 ab |
| C | 0.60 a | 2.5 a | 0.5 b | 0.12 c | 1.17 c | 15 ab | 46 bc | 9.3 a | 67 ab | 161 cd | 12 b | 33038 a | 107 bc |
| Ca/Mg | 0.46 b | 2.3 ab | 1.1 b | 0.28 b | 2.02 a | 24 ab | 55 a | 7.2 b | 80 ab | 191 bc | 6 c | 21737 b | 121 abc |
| 4L | 0.36 b | 1.5 c | 2.6 a | 0.52 a | 1.40 bc | 22 ab | 51 ab | 5.9 bc | 54 ab | 261 ab | 18 ab | 16623 c | 151 a |
| 4L+Ca/Mg | 0.43 b | 1.8 abc | 2.5 a | 0.51 a | 2.02 a | 25 ab | 47 bc | 4.0 cd | 88 a | 100 de | 6 c | 14331 c | 85 cd |
| 8L | 0.43 b | 1.7 bc | 2.8 a | 0.55 a | 1.63 b | 27 a | 38 d | 3.8 cd | 75 ab | 76 e | 18 a | 13703 c | 52 d |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Summary

Treatments 4L, 4L+Ca/Mg, and 8L produced among the top yields for both planting dates, and Ca/Mg, 4L, 4L+Ca/Mg, and 8L had among the largest head diameters. This indicates that media 4L, 4L+Ca/Mg, and 8L are suitable for cabbage production on a nursery yard irrigated with alkaline water.

As observed in the lettuce, the C media had the lowest foliar Ca levels, but in the second planting date of cabbage, Ca/Mg had a lower level of Ca than all other treatments. The sufficiency range for Ca in Cabbage leaves is 1.30 to 3.50% (Mills and Jones, 1996). The C is below this range for both planting dates, and Ca/Mg is below this range for the second planting date. The difference in leaf tissue Ca levels for Ca/Mg may be cultivar related, as the first planting date was a green cabbage and the second planting date was a red cabbage. For the second planting date, all treatments are within or below the sufficiency range for Ca, but for the first planting date, the IS as well as Ca/Mg, 4L, and 8L were above the Mills and Jones (1996) sufficiency range. The Mg sufficiency range is 0.25% to 0.80% for cabbage foliage (Mills and Jones, 1996), and for the first planting date, foliage grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L were within this range. The IS and C had significantly lower Mg and were below the sufficiency range. For red cabbage in the second planting date, the C had the lowest leaf tissue Mg levels, and they were below the sufficiency range. Like Ca, the C did not have any magnesium sulfate added and was expected to have the lowest Mg in its leaf tissues. Nutritionally, it appears that Ca/Mg performed the best for green cabbage, and all treatments except the C and Ca/Mg performed the best for red cabbage on the nursery yard.

**High Tunnel**

Cabbage Growth and Yield

First Planting Date

Plants in the C media had the lowest vigor, head diameter, leaf diameter, head fresh weight, and head dry weight of all cabbage planted under the high tunnel during the first planting date. Plants

grown in 4L+Ca/Mg medium were taller than plants in the C and IS media at the final data collection. Media treatments Ca/Mg, 4L+Ca/Mg, and 8L grew plants with larger head diameters than plants in the C and IS media. Plants in all treatments had a larger leaf diameter than the C and IS, which indicates that Ca/Mg, 4L, 4L+Ca/Mg, and 8L may have had more leaf surface area available for photosynthesis. Medium 4L+Ca/Mg yielded the largest cabbage heads by fresh weight, 68% heavier than the IS and 139% heavier than the C. Plants from Ca/Mg, 4L, and 4L+Ca/Mg had heavier head dry weights than those from the IS. All treatments produced plants with greater leaf fresh weight than the IS and C. Cabbage grown in medium Ca/Mg had a greater leaf dry weight than cabbage from the IS, C, and 8L treatments (Table 3.9). Cabbage planted during the first planting date yielded the highest (head fresh weight) when grown in 4L+Ca/Mg, and the dry weight of heads and fresh weight of leaves (biomass production) was the highest in media 4L, 4L+Ca/Mg, and 8L. This suggests that any of the media, 4L, 4L+Ca/Mg, or 8L, may perform better than the C and IS, but 4L+Ca/Mg performed the best for green cabbage grown under the high tunnel.

Second Planting Date

When red cabbage was planted under the high tunnel, head fresh weights were lower for all treatments, as compared to the first planting date. This is expected, because red cabbages tend to produce smaller heads than green cabbage varieties. Cabbage grown in the IS and C media were lower than all other treatments for vigor, head fresh weight, and head dry weight. Treatments Ca/Mg, 4L+Ca/Mg, and 8L grew taller plants than the C. Cabbage from 4L and 4L+Ca/Mg had a larger head diameter than the C and the IS. This is good because a cabbage head that looks larger may increase the visual appeal of the cabbage to consumers. Cabbage plants grown in 4L, 4L+Ca/Mg, and 8L had larger leaf diameters than all other treatments. Medium 4L produced plants with the greatest leaf fresh weight, and cabbage from the IS and C media had the lowest leaf fresh weight. Treatment 4L plants had a greater leaf dry weight than the IS and C (Table 3.9). Treatments Ca/Mg, 4L, 4L+Ca/Mg, and

8L yielded better than the IS and C for fresh weight and dry weight, so any of these treatments may be better than the IS and C for red cabbage under the high tunnel. This data suggests that 4L and 4L+Ca/Mg are the best for producing red cabbage under the high tunnel, which is similar to the first planting date.

Cabbage Nutrition

First Planting Date

There were no significant differences in Al, Cu, Fe, and Zn content of cabbage foliage grown in any of the media treatments. The C media plants had the most P, K, and Na and the least Ca foliar content during the first planting date of cabbage under the high tunnel. The elements P, K, and Na being highest in the C media is consistent with results found during the first planting date on the nursery yard, and increased Na with decreased Ca or Mg leaf content was also observed in this cabbage planting. Cabbage from 8L had less P and K than the C medium cabbage but more than all other treatments. The IS plants had more leaf tissue Ca than the C, 4L+Ca/Mg, and 8L, the same results found on the nursery yard for the first planting date. Ca/Mg and 4L had more leaf tissue Ca than the C and 8L. Plants from Ca/Mg and 4L+Ca/Mg had the most Mg. These are the two treatments that contained magnesium sulfate, versus (or in addition to) dolomitic lime. Treatment 8L plants had more Mg than the IS and C. Medium 4L+Ca/Mg cabbage had the most S, and Ca/Mg cabbage had more S than all media treatments, except 4L+Ca/Mg. Plants grown in the C and 8L had more B than the IS and plants from Ca/Mg and 4L. Medium treatment 4L+Ca/Mg plants had more B than plants from Ca/Mg and 4L. Cabbage grown in the IS medium had more Mn than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and the C plants had more Mn than those grown in media Ca/Mg, 4L, and 8L. Plants in medium 4L had more Mo than those in the C, Ca/Mg, 4L+Ca/Mg, and 8L media treatments. The IS cabbage had more Mo than cabbage in Ca/Mg and 4L+Ca/Mg. Medium 4L had the least cabbage leaf tissue Na content, and the IS cabbage leaves had the second to least leaf tissue Na content (Table 3.10).

Table 3.9. Growth characteristics of cabbage at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (12/18/2013 – 3/6/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪ (1-5) ▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 20.9 bc[W] | 3.5 a | 12.0 c | 42.9 b | 697.4 c | 33.8 b | 328.0 b | 25.3 bc |
| C | 19.1 c | 2.9 b | 9.9 d | 37.0 c | 490.2 d | 23.2 c | 272.9 b | 20.8 c |
| Ca/Mg | 22.6 ab | 3.8 a | 13.7 ab | 48.6 a | 951.5 b | 47.4 a | 499.3 a | 36.4 a |
| 4L | 22.2 ab | 3.7 a | 12.9 bc | 48.0 a | 833.5 bc | 43.0 a | 437.0 a | 32.0 ab |
| 4L+Ca/Mg | 23.7 a | 4.0 a | 14.6 a | 48.4 a | 1173.6 a | 48.1 a | 447.1 a | 30.9 ab |
| 8L | 22.6 ab | 3.6 a | 13.5 ab | 48.1 a | 882.8 bc | 41.9 ab | 421.9 a | 27.2 bc |

| Plant Date 2 (2/18/2013 – 5/6/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪ (1-5) ▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 24.8 ab | 2.7 b | 6.8 c | 42.7 bc | 320.4 b | 20.3 b | 347.1 c | 25.1 c |
| C | 22.2 b | 2.4 b | 8.1 bc | 40.2 c | 258.7 b | 19.9 b | 345.9 c | 31.0 bc |
| Ca/Mg | 26.0 a | 3.4 a | 9.6 ab | 44.8 b | 544.8 a | 35.7 a | 538.0 b | 36.2 abc |
| 4L | 24.6 ab | 3.8 a | 10.2 a | 49.5 a | 642.4 a | 36.5 a | 643.5 a | 46.3 a |
| 4L+Ca/Mg | 28.0 a | 4.0 a | 10.3 a | 49.4 a | 647.9 a | 36.8 a | 571.0 b | 40.8 ab |
| 8L | 28.0 a | 3.4 a | 9.7 ab | 47.6 a | 574.3 a | 36.2 a | 532.3 b | 36.0 abc |

[Z]Treatments (Tmt) are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Second Planting Date

There were no significant differences for K, B, Cu, Fe, and Zn leaf content for the second planting date. Identical to nursery yard results, the C media had greater leaf P than the IS, 4L+Ca/Mg, and 8L. Cabbage grown in 4L+Ca/Mg had greater Ca levels than cabbage grown in the C and medium Ca/Mg. The C medium plants had the least Ca of all treatments. Plants from all treatments had more Mg leaf levels than the C media plants. Cabbage grown in medium 8L had more Mg than the IS and Ca/Mg. Treatment 4L+Ca/Mg cabbage had more S than the IS and C, and the C plants had higher Al leaf content than plants from media Ca/Mg and 4L+Ca/Mg. Medium Ca/Mg plants had more Mn than 8L, and the IS had more Mo than medium 4L+Ca/Mg (Table 3.10).

Summary

Overall, 4L+Ca/Mg had consistently high performance with both red and green cabbage under the high tunnel and could be suggested as a suitable medium for growing this crop. It performed the highest for green cabbage and was among the highest performing media treatments for red cabbage as well. The C had the lowest leaf tissue Ca levels, below the cabbage sufficiency range for both planting dates. The C cabbage leaves were also below the sufficiency range for Mg during both planting dates, as was the IS for the first planting date. Leaf tissue Ca levels in the IS and Ca/Mg, 4L, and 4L+Ca/Mg were above the sufficiency range for the first planting date, but they were all within range for the second planting date. As noticed in the nursery yard cabbage, Ca levels were again lower in the red cabbage planted under the high tunnel than in the green cabbage.

**Nursery Yard**

Cauliflower Growth and Yield

First Planting Date

Cauliflower grown in medium 8L was taller and had a larger leaf diameter than the IS, C, and Ca/Mg media. Plants from all treatments were more vigorous, with larger head diameters, than the C medium

Table 3.10. Mean cabbage leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting Date 1 (12/18/2012 – 3/6/2013) | | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| IS | 0.47 cd[Y] | 2.9 c | 4.93 a | 0.17 c | 1.26 c | 58 a | 56 bc | 3.3 a | 94 a | 361 a | 12 ab | 10383 d | 56 a |
| C | 0.88 a | 5.3 a | 0.71 d | 0.18 c | 1.46 c | 66 a | 72 a | 5.0 a | 143 a | 323 ab | 11 bc | 22716 a | 62 a |
| Ca/Mg | 0.48 cd | 3.3 c | 4.63 ab | 0.67 a | 2.64 b | 37 a | 49 cd | 4.7 a | 95 a | 106 cd | 8 cd | 8717 de | 49 a |
| 4L | 0.43 d | 3.2 c | 4.24 ab | 0.30 bc | 1.22 c | 43 a | 40 d | 3.0 a | 98 a | 88 d | 15 a | 7652 e | 48 a |
| 4L+Ca/Mg | 0.51 c | 3.6 c | 3.84 bc | 0.76 a | 3.57 a | 50 a | 63 ab | 4.5 a | 124 a | 277 b | 6 d | 18111 b | 64 a |
| 8L | 0.61 b | 4.5 b | 3.31 c | 0.42 b | 1.67 c | 49 a | 67 a | 4.5 a | 126 a | 174 c | 10 bc | 15189 c | 64 a |
| Planting Date 2 (2/18/2013 – 5/6/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.47 b | 2.4 a | 2.13 ab | 0.56 bc | 1.08 c | 23 ab | 45 a | 4.7 a | 67 a | 201 ab | 13 a | 19142 a | 126 a |
| C | 0.92 a | 4.0 a | 0.54 c | 0.15 d | 1.25 bc | 30 a | 62 a | 7.9 a | 92 a | 190 ab | 4 ab | 21622 a | 95 a |
| Ca/Mg | 0.65 ab | 2.7 a | 1.87 b | 0.46 c | 1.49 abc | 20 b | 53 a | 7.2 a | 78 a | 213 a | 6 ab | 17549 a | 124 a |
| 4L | 0.69 ab | 3.7 a | 2.54 ab | 0.70 ab | 1.84 ab | 22 ab | 67 a | 7.3 a | 82 a | 135 ab | 5 ab | 19164 a | 151 a |
| 4L+Ca/Mg | 0.54 b | 2.7 a | 3.02 a | 0.65 abc | 2.08 a | 20 b | 54 a | 6.9 a | 94 a | 125 ab | 1 b | 13788 a | 136 a |
| 8L | 0.54 b | 3.8 a | 2.88 ab | 0.78 a | 1.64 abc | 22 ab | 44 a | 5.7 a | 79 a | 115 b | 3 ab | 14251 a | 137 a |

[Z]Treatments (Tmt) are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

plants. Cauliflower from 4L, 4L+Ca/Mg, and 8L had a greater head fresh and dry weight, as well as leaf fresh weight, than plants from the IS and C media. These treatments all contained some amount of lime which may increase performance, and 4L+Ca/Mg had calcium sulfate and magnesium sulfate added. Cauliflower from 8L had a heavier leaf dry weight than the IS, C, and Ca/Mg, and plants from all treatments had a heavier dry weight than the C medium treatment (Table 3.11).

Second Planting Date

Cauliflower plants grown in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L were taller than those grown in the IS. All treatments grew more vigorous cauliflower than the C, but 4L+Ca/Mg cauliflower was also more vigorous than the IS. The C plants had the smallest head diameter. Plants grown in medium 4L+Ca/Mg had a larger leaf diameter than Ca/Mg and 8L, as well as the IS and C. Medium 4L+Ca/Mg plants had a greater head fresh weight than the plants grown in media IS, C, Ca/Mg and 4L by 51% to 367%. Heads grown in 4L+Ca/Mg had the heaviest dry weight, followed by Ca/Mg, 4L, and 8L, which were all larger than the IS and the C. The leaf fresh and dry weights were the largest for 4L and 4L+Ca/Mg (Table 3.11). Media Ca/Mg, 4L, 4L+Ca/Mg, or 8L produced greater yields over the commercially available medium (IS); however, based on head fresh and dry weight, 4L+Ca/Mg performed the best for the second planting date on the nursery yard.

Cauliflower Nutrition

First Planting Date

Cauliflower grown in the IS and C media had more P leaf content than 4L+Ca/Mg. The C plants also had more K than Ca/Mg, 4L, and 4L+Ca/Mg, and it had less Ca than all other treatments for cauliflower planted on the nursery yard. Leaves collected from plants grown in 8L had 52% to 327% more Mg than all other media treatments, except 4L. Treatments Ca/Mg and 4L+Ca/Mg produced cauliflower leaves with more S than 4L, and plants from all treatments had more S than the IS. For micronutrients, 4L+Ca/Mg had more leaf tissue Al than all other treatments. The C plants had more

Table 3.11. Growth characteristics of cauliflower at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (12/18/2013 – 3/15/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪ (1-5) ▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 28.8 bc[W] | 4.2 a | 9.1 a | 52.0 cd | 209.7 c | 22.2 b | 361.0 bc | 57.9 b |
| C | 26.6 c | 2.3 b | 6.2 b | 43.5 d | 73.9 d | 6.4 c | 280.4 c | 34.1 c |
| Ca/Mg | 29.5 bc | 4.4 a | 9.6 a | 54.3 bc | 277.3 bc | 24.8 b | 482.2 ab | 56.6 b |
| 4L | 32.9 ab | 4.8 a | 9.7 a | 61.4 ab | 358.7 ab | 28.1 ab | 507.7 a | 72.8 ab |
| 4L+Ca/Mg | 32.1 ab | 4.4 a | 11.5 a | 62.3 ab | 380.3 ab | 36.1 a | 513.8 a | 72.0 ab |
| 8L | 34.8 a | 4.7 a | 11.2 a | 67.2 a | 412.8 a | 35.1 a | 608.7 a | 81.1 a |
| Plant Date 2 (2/27/2013 – 5/3/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪ (1-5) ▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 30.8 c | 2.9 b | 9.7 a | 51.0 c | 173.5 c | 14.4 c | 420.3 b | 57.1 b |
| C | 32.8 bc | 2.0 c | 5.8 b | 47.0 c | 93.6 c | 7.3 c | 275.6 c | 28.1 c |
| Ca/Mg | 39.4 a | 3.2 ab | 9.1 a | 56.6 b | 276.8 b | 24.3 b | 503.4 b | 62.3 b |
| 4L | 36.9 ab | 3.3 ab | 9.3 a | 61.1 ab | 289.0 b | 23.5 b | 507.7 a | 80.8 a |
| 4L+Ca/Mg | 39.8 a | 3.5 a | 11.0 a | 63.4 a | 437.2 a | 32.3 a | 640.8 a | 80.3 a |
| 8L | 39.1 a | 3.3 ab | 10.3 a | 56.3 b | 355.2 ab | 22.8 b | 482.0 b | 67.2 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

B than all media treatments, except 4L+Ca/Mg. Ca/Mg, 4L, and 4L+Ca/Mg had more foliar B than foliage produced in the IS. The C plants had more Cu, Fe, and Na than all other treatments. Cauliflower grown in 4L+Ca/Mg also had more Fe than the IS, 4L and 4L+Ca/Mg treatments. The IS plants had the most Mn. Media 4L+Ca/Mg and 8L cauliflower had the most Mo. Plants grown in Ca/Mg and 4L+Ca/Mg had more leaf tissue Na than the IS. The C cauliflower leaves had more Zn than the IS, Ca/Mg, and 4L+Ca/Mg (Table 3.12).

Second Planting Date

Plants grown in the C medium treatment had the most P, K, Cu, Fe, and Na, and the least Ca, leaf content of all treatments, similar results as those noted for other crops. The IS plants had more P than Ca/Mg, 4L, 4L+Ca/Mg, and 8L for the second planting date. There were no significant differences between the IS and Ca/Mg, 4L, 4L+Ca/Mg, and 8L for K, Ca, or Fe leaf content. Cauliflower grown in the IS medium and 4L+Ca/Mg had 3 times more Mg than the C and 69% more Mg than cauliflower grown in Ca/Mg and 4L. Treatment 4L+Ca/Mg plants had more S than all other treatments. Plants grown in the C and Ca/Mg media had more S than the IS, 4L, and 8L media, and the IS cauliflower had the least S. There were no significant differences among treatments for Al leaf tissue content. Plants grown in the C medium had more B than the IS and media Ca/Mg, 4L, and 8L. Plants from medium Ca/Mg had more Cu than the plants grown in the IS medium. Manganese levels were highest in the cauliflower grown in the IS medium. Plants from 8L had more Mo than the C, Ca/Mg, 4L, and 4L+Ca/Mg. The IS cauliflower leaves had more Mo than the C and Ca/Mg cauliflower. Media Ca/Mg plants had more Na than the IS. Both the IS and C had more leaf tissue Zn content than all other treatments (Table 3.12).

Nitrogen

Percent N leaf content analysis indicated that the C media plants had greater N tissue content than the IS for cauliflower grown on the nursery yard. This could be due to higher concentration of N

in the leaf tissues, given that the C had the same level of N fertilizer as Ca/Mg, 4L, 4L+Ca/Mg, and 8L, but it grew smaller plants. The IS may have less N fertilizer included in the base mix. There was no significant difference between cauliflower grown in the IS medium and all other media treatments (Table 3.13).

Summary

Overall, cauliflower grown on the nursery yard in medium 4L+Ca/Mg is recommended as the optimum growing medium because it was among the top yielding during the first planting date and second planting date.

Leaves sampled from cauliflower growing in the C medium treatment had significantly less tissue Ca than any other treatments, and lower levels than prescribed by Mills and Jones (1996) for a sufficient range. The Mills and Jones (1996) sufficiency range for cauliflower leaf tissue is 2.0 to 3.5% for Ca and 0.24 to 0.5% for Mg. All treatments, except the C, fell in this range for the first planting date. The IS, C, and Ca/Mg cauliflower did not meet these requirements for the second planting date. Mg tissue levels were below sufficiency range for the IS, C, and 4L+Ca/Mg from the first planting date, and for the C during the second planting date. The reason for many treatments being below sufficiency level for cauliflower Ca and Mg may be that the levels determined by Mills and Jones (1996) were for cauliflower at heading, and our cauliflower leaves were sampled at harvest.

**High Tunnel**

Cauliflower Growth and Yield

First Planting Date

Cauliflower produced in the C medium treatment had the lowest final height, vigor, head diameter, leaf diameter, head fresh weight, head dry weight, and leaf fresh weight for cauliflower planted on the nursery yard during the first planting date. Medium 4L+Ca/Mg plants were taller than

Table 3.12. Mean cauliflower leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012 – 3/15/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.54 a[Y] | 1.5 ab | 2.10 a | 0.14 bc | 0.35 c | 16 b | 32 d | 1.7 b | 62 c | 198 a | 9.9 b | 6434 c | 26 b |
| C | 0.58 a | 2.1 a | 0.30 b | 0.11 c | 0.85 ab | 12 b | 56 a | 4.8 a | 108 a | 118 b | 10.4 b | 18972 a | 62 a |
| Ca/Mg | 0.38 ab | 1.2 b | 2.23 a | 0.28 bc | 1.10 a | 11 b | 46 b | 2.6 b | 61 c | 98 b | 6.2 c | 11080 b | 31 b |
| 4L | 0.37 ab | 1.2 b | 2.53 a | 0.31 ab | 0.69 b | 9 b | 45 bc | 2.2 b | 61 c | 102 b | 14.5 a | 10027 bc | 36 ab |
| 4L+Ca/Mg | 0.23 b | 1.1 b | 2.35 a | 0.21 bc | 1.00 a | 35 a | 55 ab | 1.8 b | 82 b | 119 b | 8.1 bc | 13754 b | 19 b |
| 8L | 0.48 ab | 1.6 ab | 2.29 a | 0.47 a | 0.95 ab | 7 b | 35 cd | 2.4 b | 63 bc | 79 b | 13.8 a | 9771 bc | 36 ab |
| Planting Date 2 (2/27/2013 – 5/3/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.64 b | 1.6 b | 1.82 a | 0.44 a | 0.38 e | 12 a | 38 b | 1.9 c | 50 b | 314 a | 11.0 ab | 6408 c | 66 a |
| C | 0.94 a | 2.3 a | 0.35 b | 0.11 c | 1.05 b | 20 a | 61 a | 5.9 a | 115 a | 127 b | 6.2 cd | 18124 a | 64 a |
| Ca/Mg | 0.35 c | 1.3 b | 1.64 a | 0.26 bc | 1.12 b | 24 a | 44 b | 3.1 b | 65 b | 138 b | 4.5 d | 12825 b | 44 b |
| 4L | 0.33 c | 1.4 b | 2.01 a | 0.26 bc | 0.59 d | 19 a | 44 b | 2.2 bc | 64 b | 108 b | 9.6 bc | 9567 bc | 37 b |
| 4L+Ca/Mg | 0.46 c | 1.4 b | 2.00 a | 0.44 a | 1.47 a | 10 a | 47 ab | 2.5 bc | 69 b | 72 b | 8.6 bcd | 10372 bc | 38 b |
| 8L | 0.37 c | 1.5 b | 2.28 a | 0.36 ab | 0.81 c | 29 a | 45 b | 2.2 bc | 72 b | 91 b | 15.0 a | 9532 bc | 26 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Table 3.13. Cauliflower and tomato leaf tissue nitrogen for 1st planting date when produced on a nursery yard and under a high tunnel in Ca and Mg amended organic media with alkaline irrigation.

| Treatment[Z] | Cauliflower | | Tomato | |
|---|---|---|---|---|
| | Nursery yard | High Tunnel | Nursery yard | High Tunnel |
| | % | | | |
| IS | 1.85 b[Y] | 3.01 ab | 2.01 d | 2.26 c |
| C | 5.28 a | 4.63 a | 3.62 a | 4.92 a |
| Ca/Mg | 2.83 ab | 4.50 a | 2.45 cd | 2.18 b |
| 4L | 3.27 ab | 2.58 b | 2.67 bc | 3.06 b |
| 4L+Ca/Mg | 2.87 ab | 3.96 ab | 2.92 b | 3.42 b |
| 8L | 3.60 ab | 3.81 ab | 3.61 a | 3.49 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

the IS and Ca/Mg plants, and 4L+Ca/Mg produced plants with greater vigor ratings than the IS and medium 4L. Treatment 4L+Ca/Mg plants had the greatest leaf diameter, and cauliflower grown in medium 4L+Ca/Mg had a 40% heavier head fresh weight than the IS and was 9 times heavier than the C. The head dry weight of 4L+Ca/Mg was heavier than the C and Ca/Mg and 8L. The leaf fresh weight for 4L+Ca/Mg was greater than all treatments, except 8L. The leaf dry weight of 4L, 4L+Ca/Mg, and 8L was equal to or greater than the weight of cauliflower produced in all other treatments (Table 3.14).

Second Planting Date

Cauliflower height, vigor, leaf diameter, and leaf fresh and dry weight, when grown in the C medium treatment, were lower than all other media treatments. There were no other significant differences for vigor or head diameter. Plants grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L were taller than the IS, and plants in Ca/Mg, 4L, and 8L had a larger leaf diameter, head fresh weight, and head dry weight than the IS plants. Medium treatment 4L+Ca/Mg was not heavier than the IS. This may be due to increased temperature and pest pressure, especially towards the end of the growing season. The

leaf fresh weights for Ca/Mg, 4L, 4L+Ca/Mg, and 8L were heavier than the IS, and Ca/Mg, 4L, and 8L had a heavier leaf dry weight than the IS (Table 3.14).

Cauliflower Nutrition

First Planting Date

Cauliflower leaves grown in the IS, C, and Ca/Mg media had more P than 4L for the first planting date. The C and Ca/Mg also had more K than 4L. The IS and 4L leaf tissue had more Ca than the C and Ca/Mg, and cauliflower leaves of Ca/Mg, 4L+Ca/Mg, and 8L had more Ca than the C. Cauliflower leaves from Ca/Mg, 4L+Ca/Mg, and 8L had at least double the Mg of the IS, C, and 4L, suggesting that the addition of only 2.4 kg of dolomitic lime with no supplementation of magnesium sulfate decreases leaf tissue Mg content. Plants grown in Ca/Mg and 4L+Ca/Mg had more S than all other treatments. There were no significant differences for Al. The C had more B leaf content than 4L, 4L+Ca/Mg, and 8L, and leaves from all treatments had more B than 4L. For Cu, plants from Ca/Mg had more than the IS, 4L, and 4L+Ca/Mg plants. The C and 8L plants had more Cu than 4L. Plants grown in the C medium had more Fe than those grown in medium 4L, but there were no other significant differences for Fe. The IS cauliflower plants had more Mn than all other treatments. Treatment 8L foliage had more Mo than Ca/Mg, and the C medium produced plants with more Na than the IS and 4L. Plants from the C treatment, as well as from media Ca/Mg and 4L+Ca/Mg had more Zn than those from 4L (Table 3.15).

Second Planting Date

There were no significant differences in Al, B, and Fe leaf tissue content. Cauliflower leaves grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L had more P than plants grown in the IS and C. The C medium treatment produced cauliflower with more K than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and with the lowest Ca leaf content. Plants produced in 4L and 4L+Ca/Mg had more Mg than the C, but there

Table 3.14. Growth characteristics of cauliflower at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (12/18/2013 – 3/11/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪ (1-5) ▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 44.8 b[W] | 3.9 b | 10.4 a | 63.2 b | 382.0 b | 29.7 ab | 512.8 c | 42.0 bc |
| C | 35.1 c | 2.0 c | 4.4 b | 47.3 c | 53.3 c | 4.4 c | 352.6 d | 35.6 c |
| Ca/Mg | 46.2 ab | 4.6 a | 9.7 a | 63.4 b | 416.8 ab | 28.3 b | 624.4 bc | 53.0 b |
| 4L | 45.7 ab | 4.0 b | 10.1 a | 64.4 b | 426.2 ab | 32.4 ab | 561.7 c | 69.7 a |
| 4L+Ca/Mg | 50.1 a | 4.6 a | 10.7 a | 73.6 a | 534.0 a | 38.5 a | 786.3 a | 67.3 a |
| 8L | 48.5 ab | 4.2 ab | 9.7 a | 65.1 b | 420.3 ab | 28.7 b | 726.1 ab | 67.7 a |
| Plant Date 2 (2/27/2013 – 5/3/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Mean Head Diameter | Mean Leaf Diameter | Head Fresh Weight | Head Dry Weight | Leaf Fresh Weight | Leaf Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪▪ (1-5) ▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪cm▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 45.1 b | 2.9 a | 10.2 ab | 56.1 b | 205.4 bc | 13.7 bc | 525.6 b | 46.5 b |
| C | 38.0 c | 1.9 b | 7.4 b | 42.8 c | 93.8 c | 5.8 c | 288.6 c | 24.4 c |
| Ca/Mg | 52.3 a | 3.2 a | 12.6 a | 67.2 a | 352.7 a | 22.7 a | 811.2 a | 66.1 a |
| 4L | 51.3 a | 3.2 a | 12.3 a | 70.7 a | 358.9 a | 24.2 a | 809.0 a | 70.6 a |
| 4L+Ca/Mg | 49.9 a | 3.4 a | 11.7 a | 63.6 ab | 299.6 ab | 17.4 ab | 706.8 a | 55.2 b |
| 8L | 50.9 a | 3.3 a | 12.5 a | 70.6 a | 371.8 a | 23.3 a | 805.3 a | 70.5 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

were no other significant differences for that element. This is inconsistent with Mg results from the first planting date and will require additional testing for a conclusive explanation. Medium 4L+Ca/Mg plants had more S than all other media treatments, except Ca/Mg, and Ca/Mg plants had more S than plants grown in the IS and 4L. The C media cauliflower leaves had the most Cu and Na, and the IS had the most Mn leaf content. Plants grown in the C, IS, 4L, and 8L had more Mo than Ca/Mg and 4L+Ca/Mg. The IS cauliflower leaves had more Zn than leaves grown in 8L (Table 3.15).

Nitrogen

The C and Ca/Mg had higher % N leaf content than 4L for cauliflower under the high tunnel (Table 3.13). Further research should be conducted to determine why media Ca/Mg would result in greater levels in cauliflower under the high tunnel.

Summary

Under high tunnel conditions, cauliflower produced in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L performed similar or better than the IS and C in both planting dates. Medium 4L+Ca/Mg has been fairly consistent across the fall crops for high yield performances, indicating that the reduction of dolomitic lime, supplemented with calcium sulfate and magnesium sulfate may be the best medium combination under these particular conditions.

Cauliflower leaf tissue Ca content was lowest in the C medium. Cauliflower in Ca/Mg had more Ca than the C, yet remained below the sufficient range in the first planting date. Foliar Mg was below the sufficiency range for both planting dates in the C, IS, and medium 4L in the first planting date. The lower nutritional levels during the first planting date may be a result of growing through a longer growing season, 87 d, for the first planting date, versus the second planting date of 62 d. The longer season during the first planting date is likely temperature-related.

Table 3.15. Mean cauliflower leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012 – 3/11/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.59 a[Y] | 1.6 ab | 2.88 a | 0.10 b | 0.74 b | 49 a | 54 ab | 2.6 bc | 102 ab | 276 a | 8.3 ab | 9940 b | 32 ab |
| C | 0.56 a | 1.9 a | 0.28 c | 0.09 b | 0.74 b | 60 a | 58 a | 3.6 ab | 124 a | 206 b | 10.5 ab | 21688 a | 46 a |
| Ca/Mg | 0.63 a | 2.2 a | 1.72 b | 0.32 a | 1.50 a | 30 a | 52 ab | 3.9 a | 103 ab | 115 b | 6.0 b | 16790 ab | 48 a |
| 4L | 0.28 b | 1.1 b | 3.04 a | 0.14 b | 0.71 b | 42 a | 33 c | 1.7 c | 74 b | 73 b | 12.6 ab | 10265 b | 20 b |
| 4L+Ca/Mg | 0.47 ab | 1.6 ab | 2.41 ab | 0.41 a | 1.72 a | 53 a | 48 b | 2.7 bc | 106 ab | 78 b | 9.4 ab | 16369 ab | 47 a |
| 8L | 0.45 ab | 1.8 ab | 2.31 ab | 0.33 a | 1.00 b | 30 a | 46 b | 2.9 ab | 86 ab | 83 b | 14.4 a | 15709 ab | 36 ab |
| Planting Date 2 (2/27/2013 – 5/3/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.90 a | 1.9 ab | 2.78 a | 0.35 ab | 0.97 c | 32 a | 61 a | 3.0 b | 95 a | 269 a | 13.1 a | 11140 b | 63 a |
| C | 1.04 a | 2.5 a | 0.40 b | 0.15 b | 1.35 bc | 18 a | 66 a | 5.6 a | 108 a | 144 b | 12.9 a | 26371 a | 60 ab |
| Ca/Mg | 0.50 b | 1.4 b | 2.30 a | 0.38 ab | 1.69 ab | 32 a | 56 a | 3.6 b | 108 a | 142 b | 5.0 b | 15950 b | 42 ab |
| 4L | 0.55 b | 1.6 b | 2.07 a | 0.49 a | 0.99 c | 24 a | 66 a | 4.0 b | 100 a | 154 b | 14.4 a | 12341 b | 54 ab |
| 4L+Ca/Mg | 0.64 b | 1.7 b | 2.43 a | 0.50 a | 1.89 a | 27 a | 55 a | 3.8 b | 97 a | 88 b | 7.0 b | 12570 b | 42 ab |
| 8L | 0.48 b | 1.7 b | 2.75 a | 0.36 ab | 1.28 bc | 37 a | 59 a | 3.4 b | 102 a | 103 b | 12.3 a | 15861 b | 31 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

# CHAPTER 4: LONGEVITY OF SOILLESS ORGANIC MEDIA TREATMENTS TESTED ON THREE SPRING CROPS


## Abstract

Home gardeners residing in areas with alkaline water sources do not have means of acidifying water for optimal vegetable production. A solution to achieving optimal yields with alkaline water is to use a specialized media; however, current media available does not meet these needs, leaving home gardeners with plant nutrient deficiencies and poor quality vegetables. New media recipes with varied levels (0 to 8 lbs/yd$^3$) and sources of Ca (dolomitic lime, calcium sulfate) and Mg (dolomitic lime, magnesium sulfate) were used for the production of lettuce, cabbage, and cauliflower on high tunnel and nursery yard sites. The longevity of this media was determined by planting cucumber, tomato, and bell pepper crops into the same pots, at the same sites, during the spring with no pre-plant amendments to the media. All crops grown on the nursery yard and cucumber and pepper crops grown under the high tunnel had significantly greater yields when grown in media 4L+Ca/Mg (80:20 bark:peat with 12 lbs/yd$^3$ Osmocote® Plus, 2.4 kg/yd$^3$ dolomitic lime, 2.4 kg/yd$^3$ calcium sulfate, and 2.4 kg/yd$^3$ magnesium sulfate) or 8L (80:20 bark:peat with 12 lbs/yd$^3$ Osmocote® Plus and 8 lbs/yd$^3$ dolomitic lime) compared to the IS ($p \leq 0.05$). Tomatoes and peppers grown on the nursery yard and under the high tunnel had significantly greater growth than the C media when grown in 4L+Ca/Mg or 8L ($p \leq 0.05$).


## Introduction

Approximately 41% of Americans participate in some form of gardening (US Census Bureau, 2012). From 2005 to 2010, between 17 and 26% of households participated in container gardening (numbers varied by year but decreased from 26% to 17% between 2005 and 2010). In 2005, 12% of households reported participating in ornamental gardening, whereas only 6% of households participated in ornamental gardening between 2007 and 2010 (USCB, 2012). Seventeen percent of American households participated in container gardening in 2010 with 6% reported participation in

ornamental gardening. Therefore we are assuming that the minimum percentage of households participating in container gardening of edible crops was 11%. According to the US Census Bureau, there were 116.7 million households in the United States. Eleven percent participation in edible crop container gardening was an assumed 12.8 million households. The large number of gardeners using containers for vegetable production warrants research into soilless media specific to vegetable crops. Currently there is a lack of such media types on the market.

Media components vary based on what is regionally available and the most cost-effective material. Sphagnum peat has been a successful base media component for many years (Richard, 2006; Puustjarvi and Robertson, 1975). Many regional alternatives to sphagnum peat have been suggested, including municipal solid waste (Cai et al., 2010), biological waste (Annapurna, 2005; Adediran, 2005), coconut coir dust (Evans and Stamps, 1996), composted pine bark (Yu and Zinati, 2006), and other materials. In the southeastern United States, pine bark is commonly combined with peat in organic media. When combined with peat, aeration, water holding capacity, and CEC increase (Argo and Biernbaum, 1997b).

Un-amended, pine bark and peat-based media are too acidic for many container crops. According to Wright et al. (1999b), the initial pH of pine bark ranges from 4.0-5.5, depending on age, source, and other factors. Liming rates vary based on plant species, media components, and lime particle size, and should be incorporated to increase the media pH to between 5.5 and 6.4 (Argo, 1996a) for most crops. However, studies have not reported liming rates for vegetable crops produced in containers.

Alkalinity, caused by carbonates and bicarbonates (Handreck and Black, 2002), in irrigation water can cause increased media pH and decreased nutrient availability (Wickerson, 1996). However, low levels of alkalinity are necessary to buffer the media from rapid pH changes (Valdez-aguilar, 2004; Greenlee et al., 2009). Research-based recommendations for ideal bicarbonate in irrigation

water vary from 0 to 75mg/L to 61 to 122mg/L (Nelson, 1988; Peterson and Kramer, 1991; Bierbaum, 1994; Dole 1994), but problems exist when there is too much alkalinity in irrigation water.

Fertilizer lifespan, combined with changes in media pH and the settling, shrinkage, and breakdown of the organic components determines the life-span of media. In addition, build-up of soluble salts from alkaline irrigation water decreased the media's usable lifespan. Multiple studies document that the release rate of nutrients increases with increased temperature (Allen et al., 1971; Oertli and Lunt, 1962). The longevity of fertilization and nutrient availability at a given time may vary depending on climatic conditions. Countless media recipes exist that have shown superior production in research studies (Banko and Stephani, 1991), but the longevity of this media has seldom been studied.

Specialized media for vegetable container production, targeting homeowners in areas of alkaline irrigation water, would allow homeowners to produce high-quality vegetables despite alkalinity issues. The objective of this study was to create a media recipe that would perform well for container production of tomato, cucumber, and bell pepper during a second growing season irrigated with alkaline water.

## Materials and Methods

### Experimental Design

This experiment was conducted at the LSU AgCenter's Burden Ornamental and Turfgrass Research Farm in Baton Rouge, Louisiana. Two experimental sites included a nursery yard arranged in a randomized block design with overhead irrigation (2.5gal/min), exposed to rain water, and a high tunnel arranged in a randomized block design with drip irrigation (2 gal/h) and not exposed to rain water. Spring crops [cucumber (*Cucumis sativus* 'Dasher II'), tomato (*Solanum lycopersicum* 'Patio Princess'), and pepper (*Capsicum annuum* 'Stiletto')] were grown in six media treatments. The spring crops were planted into the same media used for fall crops, with no additional pre-plant amendments,

to test media longevity. Each media treatment/crop combination was replicated ten times per experimental site, and each planting was replicated over two planting dates, approximately two months apart.

**Media treatments**

Six media treatments were used in this study containing 0, half (2.4 kg/$m^3$), or full (4.7 kg/$m^3$) rates of dolomitic lime and 0 or half (2.4 kg/$m^3$) rates of calcium sulfate and magnesium sulfate (Table 4.1). Treatment 1 was a commercially available media selected as the industry standard (IS) because of its notoriety among home gardeners, and its contents can be found in Figure A.1. Treatments 2-6 were mixed at LSU and contained 80% bark (1.59 cm ($^5/_8$") screened, partially composted, Phillip's Bark, Brookhaven, MS) and 20% peat (Fertilome Pure Canadian Sphagnum Peat Moss) with 12 lbs slow release (15-9-11) complete fertilizer. Treatment 2 included no additional components and was considered the control (C). Treatment 3 (Ca/Mg) contained an additional 2.4 kg/$m^3$ (4 lbs/$yd^3$) calcium sulfate (MK Minerals Inc. Soft Pelletized Gypsum, 23% Ca) and 2.4 kg/$m^3$ (4 lbs/$yd^3$) magnesium sulfate (Graco Fertilizer Company, Product 24592, 13.7% Mg). Treatment 4 (4L) contained 2.4 kg/$m^3$ (4 lbs/$yd^3$) dolomitic lime (MK Minerals Inc. Pelletized Dolomitic Limestone, 17.5% Ca, 10.1% Mg). Treatment 5 (4L+Ca/Mg) contained 2.4 kg/$m^3$ (4 lbs/$yd^3$) dolomitic lime, 2.4 kg/$m^3$ (4 lbs/$yd^3$) calcium sulfate, and 2.4 kg/$m^3$ (4 lbs/$yd^3$) magnesium sulfate. Treatment 6 (8L) contained 4.7 kg/$m^3$ (8 lbs/$yd^3$) dolomitic lime.

Table 4.1. Media treatments with abbreviations and ingredients (per $m^3$).

| Trt | Abbrev. | Base Mix | Fertilizer Added |
|---|---|---|---|
| 1 | IS | Scott's® Miracle-Gro® All Purpose Potting Mix | None |
| 2 | C | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | None |
| 3 | Ca/Mg | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg calcium sulfate + 2.4 kg magnesium sulfate |
| 4 | 4L | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg dolomitic lime |
| 5 | 4L+Ca/Mg | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 2.4 kg dolomitic lime +2.4 kg calcium sulfate + 2.4 kg magnesium sulfate |
| 6 | 8L | 80:20 bark:peat + 7.1 kg slow release (15-9-11) | 4.7 kg dolomitic lime |

Media was mixed in 0.91 $m^3$ (1 $yd^3$) batches.  Standard three gallon, blow molded black pots were filled with 0.013 $m^3$ (0.45 $ft^3$) of medium.  Pots were placed on 0.46 m (18-inch) centers under the high tunnel and on the nursery yard and watered to saturate media prior to planting transplants of fall vegetables. No additional media was added after settling.  Three pots of each media treatment were used to measure initial pH and EC according to the Virginia Tech Extraction Method (VTEM).  Pots were saturated, and after 30 minutes leachate was collected.  The pH and EC of the leachate were recorded on the day of mixing and again 2 weeks later to allow time for the dolomitic lime to react. Three fall crops [lettuce (*Lactuca sativa* 'Oakleaf'), cabbage (*Brassica oleracea* var. capitata 'Earliana'.  The second cabbage planting was 'Salad Delight' cultivar.), and cauliflower (*Brassica oleracea* var. botrytis 'Snow Crown')] were grown in the pots.  The three spring crops followed the fall crops.  Cabbage pots were replaced with cucumber, lettuce pots were replaced with tomato, and cauliflower pots were replaced with bell pepper.

**Crops**

Seeds of all species were planted in late March (1$^{st}$ planting replication) and again in late May/early June (2$^{nd}$ planting replication) into Sunshine Professional Growing Mix 3 in 98-count plug trays and grown in a greenhouse for 21 days (cucumber) and 60 days (tomato and bell pepper). Seedlings were fertilized weekly after the first true leaf emerged with liquid fertilizer (24-8-16) according to package directions (1 tablespoon per gallon of water).  Once the root balls developed in the plug trays (21 to 60 d after seeding), the plants were transplanted into the pre-filled pots, one per pot.  Plants that did not survive transplant due to windy conditions within the first week after planting. Fewer than 10 plants per species were replaced for the first planting date.  The majority of the tomato plants were replaced during the second planting date because of damage from a storm.  Containers were watered twice daily at twenty minute increments using overhead irrigation (2.5 gal/min) on the nursery yard and drip irrigation (2 gal/h) under the high tunnel, and fertilized with liquid fertilizer (24-

8-16) once during the season (1 tablespoon per gallon per container), timed according to the LSU AgCenter's Louisiana Commercial Vegetable Production Recommendations. Pesticides were used as needed and included bifenthrin (10%), 5.2oz/A; imidacloprid (21.4%), 24oz/A; chlorothalonil (6lbs/gal), 2 pints/A; esfenvalerate (8.4%), 8 oz/A; azoxystrobin (22.9%), 15.4 oz/A; dinotefuan (70%), 3 oz/A. Days to first harvest after transplanting for each crop is in Table 4.2.

Table 4.2. Days from transplant to first harvest for spring crops.

| Crop | Nursery yard 1st Replication | High Tunnel 1st Replication | Nursery yard 2nd Replication | High Tunnel 2nd Replication |
|---|---|---|---|---|
| Cucumber | 55 | 55 | 47 | 47 |
| Tomato | 68 | 61 | 50 | 50 |
| Bell Pepper | 73 | 69 | 46 | 46 |

**Data Collection**

Weekly heights (cm) of each plant were collected measuring from the soil level to the tallest point on the plant, until harvest began. Vigor on a 1 to 5 scale was rated for each plant bi-weekly, until harvest began. Average growth rates, pest damage, and color were judged as compared to all other plants of the same species, planting date, and planting site. The vigor scale was calculated as: 1 – very poor, no growth, disease occurring on greater than 50% of the foliage, 100% foliage chlorosis, damaged such that the plant was not likely to survive; 2 – below average growth rate, above average pest damage, coloration problems, may have some disease; 3 – average growth rate, pest damage, and color, with no disease; 4 – above average growth, below average pest damage, ideal color, no disease; 5- excellent growth, excellent color, no pest damage, no disease. Precipitation (mm), relative humidity (%), and temperature (°C) were recorded hourly and reported on a monthly basis (Figure 2.1).

Crops were harvested bi-weekly for 4 weeks. Fruit was classified as marketable or unmarketable based on the USDA standards for grades of each crop. USDA grades 1 and 2 were considered marketable, and all others were considered unmarketable.

After the final fruit harvest, immature fruit was removed. Whole plants were harvested, cut even with the soil line, and a fresh weight (g) was collected. Five foliage samples per treatment were

collected. The above-ground plant material was dried in a 220V forced air oven (Shel Lab, SM028-2) for 3 weeks. Dry plant and leaf sample weights were recorded. Leaf samples were ground (Thomas Scientific, 383-L10) to a fine powder using a 30-mesh filter and were prepared for Inductively Coupled Plasma (ICP) nutrient analysis to analyze nutrient levels.

Analysis of the leachate of 5 pots per treatment on the nursery yard and 5 pots per treatment under the high tunnel was performed according to the Virginia Tech Extraction Method at the end of the study to determine the final Ec and pH of each treatment.

**ICP Nutrient Analysis**

Ground plant material was transferred to a 20ml scintillation vial and placed in an oven at 50°C for 1h to remove moisture. Vials were transferred to a desiccator for 1h to further remove moisture and cool the sample to room temperature. The caps of each sample were tightened upon removal from the desiccator to prevent moisture from re-entering. One-half gram of ground tissue was placed into a 50ml tube (SCP Scientific digiTUBE). Samples were placed into an automatic digester (Thomas Cain, DEENA) for digestion using nitric acid. During the digestion, the samples were heated for 6s at 60°C and 2.2ml of distilled water was added. After 2m, 5mL nitric acid (SCP Science, 67 to 70% $HNO_3$, reagent grade) was dispensed into each tube, and the temperature was increased 10°C every 10m from 60°C to 110°C. The temperature was increased to 125°C and held for 45m, and then held for 50m at 128°C, and cooled for 2m. One ml hydrogen peroxide (Macron Fine chemicals, 30% solution) was dispensed from the digester into each tube. The samples were cooled for 5m and reheated for 5m to 128°C. One ml of hydrogen peroxide was dispensed, and another 1ml of hydrogen peroxide was dispensed into each tube. Samples were cooled for 5 minutes and heated for 30 minutes at 122°C, cooled for 6 seconds to 20°C and cooled for 1 more minute. The volume of each sample was brought to 20ml using distilled water.

Samples were removed from the digester and vacuum filtered using a 1.0micron Teflon membrane filter (SCP Science) into a 20ml tube. ICP was performed for the elements P, K, Ca, Mg, S, Al, B, Cu, Fe, Mn, Mo, Na, and Zn using a Spectro Arcos according to the LSU Soil Testing and Plant Analysis Lab's AgMetals procedure. The instrument was calibrated using 1 blank and 6 standards. Samples were run in sets of 60 (2 blanks included) with two National Institute of Standards and Technology (NIST) peach samples and an internal standard every 20 samples. The data was verified to ensure it was within the tolerant ranges of the NIST and internal standards. Nutrient levels were reported as percentages for macronutrients and ppm for micronutrients.

**Nitrogen**

Tomato tissue samples (0.15g/sample) were measured into tin foil cups and N (%) was determined using a LECO TruSpec CN Analyzer. The instrument was calibrated using 5 NIST apple tissue samples and 5 blank samples.

**Data Analysis**

Data was analyzed with SAS 9.3 software at a 0.05% error rate. Proc glm was used to compare continuous variables based on arithmetic means and standard deviations. A Duncan's Multiple Range Test was performed on all variables of interest for each crop.

## Results and Discussion

**Environmental Conditions**

Throughout this study, precipitation, average relative humidity, and average temperature were monitored. The average relative humidity remained between 50% and 100% throughout the growing season. The average temperature increased slowly from March to June and increased rapidly from June to July. Precipitation was variable throughout the season, ranging from just over 50 mm to 200 mm throughout the study (Figure 4.1). This may have affected growth and quality of the plants.

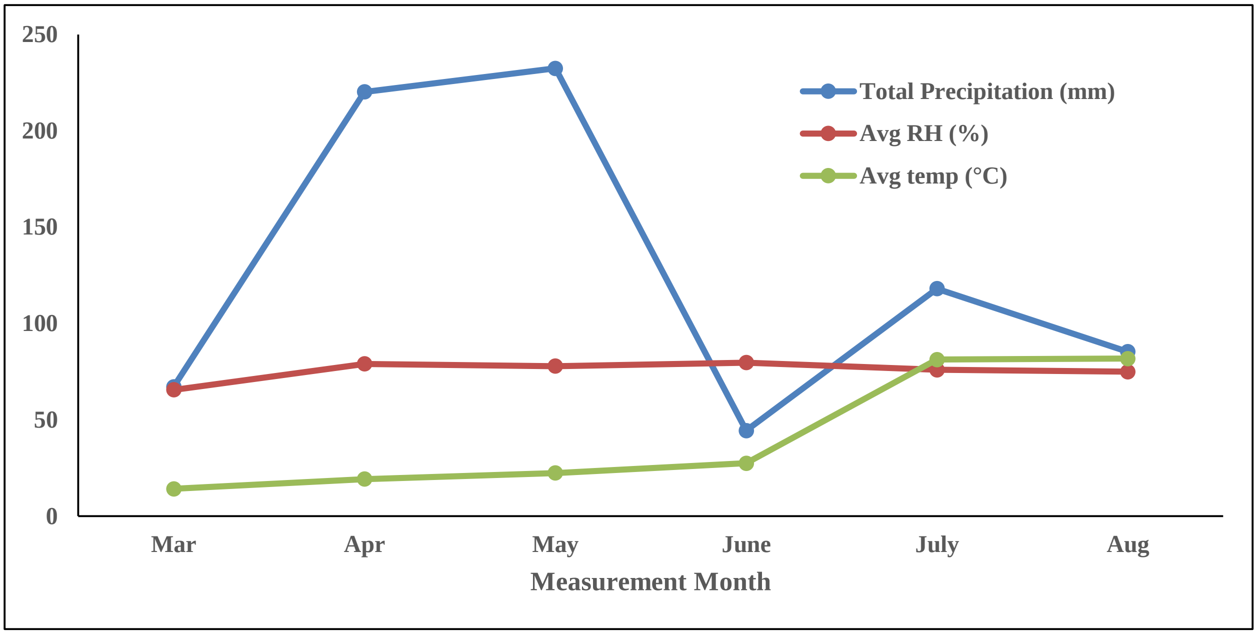

Figure 4.1. Monthly total precipitation, average relative humidity, and average temperature

**Nursery Yard**

Cucumber Growth and Yield

First Planting Date

Cucumbers grown in the IS medium had significantly lower measurements and ratings when compared to all other tested medias. Media 8L appears to be the optimal media for growing cucumbers in an open environment or nursery yard setting. Plants grown in 8L were significantly taller than those plants grown in media 4L, C, and IS. Media 8L plants had significantly higher vigor ratings than plants grown in IS, C, Ca/Mg, and 4L media treatments. Significantly more fruit (total number harvested), the number of marketable fruit and marketable weight of cucumbers were harvested from those plants growing in media 8L as compared to plants in media treatments IS, C, Ca/Mg, and 4L. Plants in media 8L also produced more fruit than plants growing in any of the other tested media. As expected, total fresh weight of plants growing in media 8L were significantly greater than weights of plants in all other media treatments. After total plant weight was dried, media 8L plants were significantly greater than media IS, C, Ca/Mg, and 4L+Ca/Mg plants. In all tested

parameters, plants in media six were equal to or significantly greater than plants produced in media 4L+Ca/Mg (Table 4.3).

Second Planting Date

Approximatly two months after the first planting, a second set of cucumbers were planted into the fall media pots. Cucumbers in the second planting performed similar to those planted on the first date, with a few exceptions. The media treatments Ca/Mg, 4L, 4L+Ca/Mg, and 8L all produced significantly taller plants and significantly more vigorous plants than those grown in media IS and C. Media 8L plants had significantly greater total fruit number, total fruit weight, number of marketable fruit, and total weight of marketable fruit than the IS medium, but there were no significant differences between media 8L and media C, Ca/Mg, 4L, or 4L+Ca/Mg. The toal fresh weight of the entire plant was greatest in media 8L, but dry weight of 8L plants were only greater than treatments IS, C, Ca/Mg, and 4L+Ca/Mg (Table 4.3).

<u>Cucumber Nutrition</u>

First Planting Date

Cucumber leaves sampled from plants grown in the IS and C media had more P than leaves from plants grown in medium 8L, and leaves from the C had the most K of the cucumber plants grown on the nursery yard during the first planting date. The C, as expected, had the least leaf tissue Ca, and the IS had 43% more leaf tissue Ca than leaves from 4L+Ca/Mg. Plants in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L had more Mg than the IS and C. Foliage grown in the IS had the least S, Al, and Fe leaf content, and there were no other significant differences for S and Al. The IS plants from Ca/Mg, 4L+Ca/Mg, and 8L had more B than the C, but the C plants had more Cu than all other treatments. Plants grown in the C medium had more Fe than media Ca/Mg and 8L. The IS plants had the most Mn. For Mo, vines from 8L had more than all other treatments. The C and Ca/Mg, 4L, 4L+Ca/Mg, and 8L all had significantly more Na than the IS. The IS cucumber plants had more Zn than 4L (Table

Table 4.3. Growth and yield characteristics of cucumber when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (3/20/2013 – 6/19/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 25.4 d[W] | 2.0 d | 2.3 c[V] | 438 d | 1.0 c | 232 c | 84 d | 14.6 d |
| C | 47.3 c | 3.0 c | 7.5 b | 1691 c | 5.2 b | 1243 b | 192 c | 25.4 c |
| Ca/Mg | 59.0 ab | 3.4 bc | 7.6 b | 1828 bc | 5.6 b | 1311 b | 240 bc | 37.1 b |
| 4L | 57.6 b | 3.7 b | 7.2 b | 1875 bc | 5.6 b | 1400 b | 261 b | 41.7 ab |
| 4L+Ca/Mg | 64.3 ab | 3.8 ab | 8.1 ab | 2125 b | 6.0 ab | 1579 ab | 257 b | 38.1 b |
| 8L | 68.5 a | 4.2 a | 9.4 a | 2538 a | 7.2 a | 1863 a | 334 a | 46.8 a |
| Plant Date 2 (5/22//2013 – 8/1/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 47.5 b | 2.1 c | 3.1 b | 604 b | 1.1 b | 262 b | 166 b | 27.8 cd |
| C | 56.9 b | 2.4 bc | 4.7 ab | 990 ab | 3.0 ab | 701 ab | 141 b | 18.8 d |
| Ca/Mg | 79.2 a | 3.1 ab | 5.9 ab | 1369 a | 3.7 a | 871 a | 203 b | 34.8 bc |
| 4L | 81.9 a | 3.9 a | 5.3 ab | 1363 a | 2.5 ab | 606 ab | 326 a | 46.7 ab |
| 4L+Ca/Mg | 87.0 a | 3.7 a | 6.3 a | 1429 a | 3.4 a | 847 a | 378 a | 54.0 a |
| 8L | 85.4 a | 3.9 a | 6.7 a | 1390 a | 3.9 a | 992 a | 347 a | 52.1 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

4.4). In the first planting date there was no consistently better media than any other for optimal plant tissue nutritional analysis.

Second Planting Date

There were no significant differences in cucumber leaf tissue amounts of Ca, S, Al, B, Cu, Fe, and Mn during the second planting date. Cucumber vines grown in the C medium had more P than those grown in Ca/Mg, and the C media treatment had greater amounts of K than the IS and 4L+Ca/Mg and 8L. Plants grown in 4L+Ca/Mg and 8L had more Mg than the IS, C, and Ca/Mg plants. The C plants had more Mo than Ca/Mg, 4L+Ca/Mg, and 8L, and cucumbers grown in the C medium also had more Na and Zn than all other treatments. Again, this information is not conclusive as to which media produced plants with optimal foliar nutrition (Table 4.4).

Summary

Based on yield, medium 8L would be recommended for growing 'Dasher II' cucumbers as a spring crop following a cabbage fall crop. Medium 8L retained nutrients well, based on leaf tissue samples. It had the highest marketable fruit production for the first planting date and was among the highest producers for the second planting date.

Tissue samples taken at the end of the first planting date showed the least amount of Ca in the C, but there were no significant differences in Ca for the second planting date. This could be because of disease that caused high mortality for cucumber vines, decreasing the power of our statistics such that differences could not as easily be detected. According to Miller and Jones (1996), the sufficiency range for Ca is 1.50 to 5.50%, and the sufficiency range for Mg in cucumbers is 1.50 to 4.00%. All cucumbers were within this range for the first planting date, except the IS was slightly above it. During the second planting date, the C and medium Ca/Mg were below the Ca sufficiency range. This may also have been due to disease causing plant collapse. All leaf tissue samples were below the sufficiency range for Mg for both planting dates. Leaves from media treatments Ca/Mg, 4L,

Table 4.4. Mean cucumber leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (3/20/2013 – 6/19/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.28 a[Y] | 0.76 b | 5.7 a | 0.55 b | 0.79 b | 9 b | 66 a | 4.5 b | 32 c | 263 a | 8.7 b | 562 d | 69 a |
| C | 0.27 a | 1.79 a | 1.7 c | 0.30 b | 1.25 a | 41 a | 49 b | 7.2 a | 88 a | 168 b | 8.6 b | 3903 a | 59 ab |
| Ca/Mg | 0.24 ab | 0.67 b | 5.2 ab | 1.36 a | 1.25 a | 35 a | 68 a | 5.7 b | 64 b | 51 c | 10.0 b | 1593 cd | 57 ab |
| 4L | 0.23 ab | 0.64 b | 5.4 ab | 1.20 a | 1.29 a | 31 a | 60 ab | 5.0 b | 69 ab | 57 c | 10.2 b | 2507 bc | 44 b |
| 4L+Ca/Mg | 0.22 ab | 0.75 b | 4.0 b | 1.23 a | 1.28 a | 30 a | 66 a | 5.5 b | 75 ab | 124 b | 10.3 b | 2329 bc | 63 ab |
| 8L | 0.20 b | 0.62 b | 4.7 ab | 1.07 a | 1.41 a | 32 a | 70 a | 5.4 b | 67 b | 135 b | 15.2 a | 3014 ab | 53 ab |
| Planting Date 2 (5/22/2013 – 8/1/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.29 ab | 1.0 b | 3.5 a | 0.96 b | 0.85 a | 32 a | 56 a | 3.9 a | 49 a | 106 a | 8.4 ab | 999 b | 49 b |
| C | 0.33 a | 4.5 a | 1.0 a | 0.23 c | 2.06 a | 99 a | 42 a | 11.7 a | 166 a | 244 a | 21.8 a | 8202 a | 79 a |
| Ca/Mg | 0.18 b | 1.7 ab | 0.5 a | 0.39 c | 0.73 a | 45 a | 33 a | 5.7 a | 289 a | 90 a | 4.2 b | 1838 b | 37 c |
| 4L | Missing values | | | | | | | | | | | | |
| 4L+Ca/Mg | 0.22 ab | 0.7 b | 2.1 a | 1.12 ab | 1.04 a | 108 a | 51 a | 6.4 a | 493 a | 235 a | 6.3 b | 2051 b | 39 c |
| 8L | 0.20 ab | 0.5 b | 3.6 a | 1.38 a | 0.86 a | 139 a | 56 a | 6.6 a | 297 a | 145 a | 7.8 b | 1472 b | 41 c |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

4L+Ca/Mg, and 8L had more Mg than the IS and C for the first planting date, and 8L had more Mg than the IS and C for the second planting date. These results suggest the need for additional Mg fertilization if a second crop is to be grown; however media 4L+Ca/Mg and 8L retained the highest Mg levels. Media 4L+Ca/Mg and 8L were provided with the highest levels of Mg in the media at the beginning of the study. Our results did not support Cobb (1983) who found that increasing lime increased Mg and decreased K.

**High Tunnel**

Cucumber Growth and Yield

First Planting Date

Cucumber vines grown in the IS medium had significantly lower recorded height, vigor, marketable fruit number and vine fresh weight measurements compared to plants grown in all other media treatments under the high tunnel during the first planting date. All other treatments were equal for these parameters. Plants grown in media 4L, 4L+Ca/Mg, and 8L produced more fruit than the IS. Plants grown in the C, 4L, 4L+Ca/Mg, and 8L had a greater marketable fruit weight than the IS. Cucumber plants grown in media Ca/Mg, 4L, and 8L had significantly greater vine dry weights than the C and IS (Table 4.5). This suggests that growing conditions were optimum under the high tunnel for the 80:20 bark:peat medium, regardless of Ca and Mg fertilization

Second Planting Date

The second planting date produced similar results under the high tunnel. Plants grown in the IS and C medias had significantly lower measurements and ratings for final height and final vigor as compared to plants growing in media Ca/Mg, 4L, 4L+Ca/Mg and 8L. Plants in media Ca/Mg, 4L, 4L+Ca/Mg and 8L also produced significantly more total fruit than treatment 1 plants. Total fruit weight harvested was greatest from plants grown in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L as compared to the IS and marketable fruit number and weight were both significantly greatest in plants

grown in media treatments C, Ca/Mg, 4L, 4L+Ca/Mg, and 8L as compared to the IS. Vine fresh and dry weights were greatest in plants grown in media 4L, 4L+Ca/Mg and 8L as compared to media treatments IS, C, and Ca/Mg (Table 4.5).

Cucumber Nutrition

First Planting Date

There were no significant differences in foliage levels of P and Fe for the first planting date. The C had more K leaf content than all other treatments, and 4L+Ca/Mg had more K than the IS. Leaves sampled from plants grown in the IS medium had more Ca than those from the C and Ca/Mg and 4L+Ca/Mg. Plants from 4L had more Ca than the C and 4L+Ca/Mg. While plants from 4L would be expected to have more Ca than the C based on media fertilizer levels, 4L would not be expected to have more Ca than 4L+Ca/Mg. Medium 4L+Ca/Mg contained the same amount of lime as 4L, but it also contains calcium sulfate, suggesting that the calcium sulfate did not increase Ca fertilization for this planting date. Medium Ca/Mg also contained calcium sulfate (without dolomitic lime), and it had among the lowest leaf tissue Ca levels for this planting date. The C plants had the least Ca and Mg. Cucumber vines grown in Ca/Mg had the most Mg, and 4L, 4L+Ca/Mg, and 8L had 71 to 100% more Mg than the IS. In contrast to Ca, plants in the media that contained magnesium sulfate but no dolomitic lime (Ca/Mg) outperformed plants from media treatments that should have had more Mg fertilizer in the media. Plants in 4L+Ca/Mg had more S than all media treatments, except Ca/Mg, and Ca/Mg vines had more than the IS, C, and medium 4L. Vines from the IS had the least S. The C foliage had more Al than all treatments, except Ca/Mg, which had more Al than the IS foliage. Cucumber plants grown in 4L+Ca/Mg had more Cu than the IS and 8L. Plants from 8L had more Mn than all media treatments, except 4L+Ca/Mg, which had more Mn than 4L. Media 4L and 8L had more leaf tissue Mo content than Ca/Mg. For Na, plants grown in 4L+Ca/Mg had more than those

Table 4.5. Growth and yield characteristics of cucumber when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Plant Date 1 (3/20/2013 – 6/19/2013) | | | | | | | | |
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 62.3 b[W] | 2.6 b | 5.5 b[V] | 1351 b | 3.2 b | 823 b | 228 b | 48.5 c |
| C | 82.9 a | 3.6 a | 7.3 ab | 1825 ab | 5.7 a | 1414 a | 449 a | 54.1 bc |
| Ca/Mg | 89.4 a | 4.0 a | 7.1 ab | 1708 ab | 5.2 a | 1285 ab | 466 a | 65.4 a |
| 4L | 79.4 a | 3.3 a | 7.7 a | 1925 a | 5.8 a | 1420 a | 473 a | 66.3 a |
| 4L+Ca/Mg | 85.5 a | 3.6 a | 8.8 a | 2089 a | 7.2 a | 1750 a | 506 a | 61.6 ab |
| 8L | 85.8 a | 3.8 a | 8.1 a | 2077 a | 6.9 a | 1735 a | 473 a | 66.4 a |
| Plant Date 2 (5/22//2013 – 8/1/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 82.0 c | 1.4 c | 4.2 c | 780 b | 1.8 b | 370 b | 155 c | 22.3 c |
| C | 104.7 b | 2.8 b | 6.8 ab | 1266 ab | 4.5 a | 992 a | 283 b | 36.3 b |
| Ca/Mg | 118.7 a | 4.1 a | 9.0 a | 1835 a | 5.8 a | 1269 a | 359 b | 45.4 b |
| 4L | 128.2 a | 4.6 a | 5.5 bc | 1370 a | 4.4 a | 1119 a | 441 a | 61.0 a |
| 4L+Ca/Mg | 125.4 a | 4.5 a | 7.3 ab | 1609 a | 4.8 a | 1047 a | 455 a | 62.2 a |
| 8L | 127.7 a | 4.3 a | 7.6 ab | 1603 a | 5.5 a | 1232 a | 462 a | 65.1 a |

[Z]Treatments (Tmt) are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

[U]Results for Plant Date 2 (5/22/2013) may be skewed. Disease caused many plant deaths.

grown in media Ca/Mg, 4L and 8L, and 8L had more than Ca/Mg. The IS cucumber vines had more Zn than Ca/Mg and 4L (Table 4.6).

Second Planting Date

There were no significant differences for P, K, S, Al, B, Fe, Mn, Mo, and Zn leaf tissue content for the second planting date. Plants grown in the IS medium and 4L+Ca/Mg and 8L had more Mg than Ca/Mg, which was opposite from results during the first planting date and may be due to disease and high mortality. Plants from 4L+Ca/Mg had more Mg than plants from the IS medium and Ca/Mg. Ca/Mg plants had a higher Cu leaf tissue content than the IS, and Ca/Mg also had the most leaf tissue Na. There were no plants that survived from the C which has consistently contained the most Na, so Ca/Mg, which had low Mg levels contained the highest Na (Table 4.6).

Summary

Overall, 'Dasher II' grown in a greenhouse situation after cabbage performed best when grown in media 4L, 4L+Ca/Mg, or 8L. These produced the most yield and biomass, even during the second planting date when disease was a problem.

The C medium produced plants with the least Ca and Mg in the leaf tissues, both below the sufficient range. This suggests that the presence of Ca and Mg may have a lesser effect on growth of cucumbers than on other crops. All other treatments were within the Mills and Jones (1996) sufficiency range for Ca, but many were below Mg thresholds. The IS contained less Mg than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, so that may have had some effect on plant growth and yield. Statistics for the second planting date are difficult to decipher due to many dead and diseased plants at the time of last harvest; however 4L+Ca/Mg appears to have more Mg than the IS and Ca/Mg as was seen on the nursery yard.

Table 4.6. Mean cucumber leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting Date 1 (3/20/2013 – 6/19/2013) | | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| IS | 0.33 a[Y] | 0.48 c | 5.0 a | 0.66 c | 0.44 d | 20 c | 65 ab | 3.6 b | 38 a | 82 bc | 5.9 ab | 447 abc | 77 a |
| C | 0.28 a | 1.99 a | 0.9 d | 0.29 d | 0.76 c | 55 a | 49 b | 5.3 ab | 79 a | 102 b | 6.4 ab | 628 abc | 66 ab |
| Ca/Mg | 0.23 a | 0.78 bc | 3.3 bc | 1.67 a | 1.10 ab | 46 ab | 62 b | 4.6 ab | 74 a | 73 bc | 4.7 b | 180 c | 46 bc |
| 4L | 0.27 a | 0.82 bc | 4.6 ab | 1.13 b | 0.86 c | 31 bc | 56 b | 4.7 ab | 56 a | 42 c | 7.6 a | 259 bc | 41 c |
| 4L+Ca/Mg | 0.29 a | 1.00 b | 2.9 c | 1.32 b | 1.24 a | 36 bc | 66 ab | 6.0 a | 68 a | 116 ab | 7.2 ab | 908 a | 55 abc |
| 8L | 0.24 a | 0.59 bc | 3.8 abc | 1.30 b | 0.97 bc | 33 bc | 80 a | 4.1 b | 158 a | 162 a | 7.9 a | 770 ab | 58 abc |
| Planting Date 2 (5/22/2013 – 8/1/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.27 a | 0.89 a | 3.4 a | 1.01 b | 0.47 a | 25 a | 57 a | 2.6 b | 42 a | 132 a | 5.0 a | 278 b | 50 a |
| C | Missing values | | | | | | | | | | | | |
| Ca/Mg | 0.26 a | 1.00 a | 2.2 b | 0.94 b | 1.08 a | 40 a | 56 a | 4.7 a | 452 a | 166 a | 7.1 a | 1987 a | 57 a |
| 4L | Missing values | | | | | | | | | | | | |
| 4L+Ca/Mg | 0.23 a | 0.52 a | 3.6 a | 1.40 a | 0.76 a | 34 a | 64 a | 3.2 ab | 367 a | 260 a | 5.9 a | 180 b | 43 a |
| 8L | 0.25 a | 0.98 a | 3.3 a | 1.28 ab | 0.86 a | 35 a | 62 a | 4.0 ab | 250 a | 128 a | 6.0 a | 941 b | 46 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

## Nursery Yard

Tomato Growth and Yield

First Planting Date

Plants in the IS had the lowest value for final height, total fruit number and weight, and vine fresh and dry weight for the tomato plants grown on the nursery yard during the first planting date. Plants in 8L had the highest vigor ratings of all plants grown in all media types. All plants grown in all media treatments produced more total marketable fruit and weight of marketable fruit than the IS and C media. The C medium fruit had significantly more incidences of blossom end rot than any of the fruit produced in other tested media. This suggests that the 80:20 bark:peat mix with fertilizer added has additional longevity when compared to the IS or the mix with no fertilizer added (Table 4.7).

Second Planting Date

Tomato plants grown in the C medium and medium 4L were taller than plants produced in the IS. Plants growing in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L had greater vigor ratings than plants produced in the IS and C. Media 4L, 4L+Ca/Mg and 8L produced vines with more fruit than the IS and C media, but total fruit weight and marketable fruit, by number and weight were only greater in plants produced in media 4L+Ca/Mg and 8L as compared to the IS, C, and medium Ca/Mg. Medium Ca/Mg did not perform as well as in the first planting date, so it may not be as tolerant to high heat and increased rain that occurred during the second planting date. Tomato vines grown in medium 4L produced more fruit than the IS and C, and they had a heavier total fruit weight, marketable fruit number, and marketable fruit weight than the C. Those grown in medium 4L+Ca/Mg had more blossom end rot, by number, than the IS, but the fruit produced in 4L+Ca/Mg still out produced marketable fruit as compared to the IS. Media Ca/Mg, 4L, 4L+Ca/Mg, and 8L produced vines with a heavier vine fresh weight than the C and IS. Plants grown in media 4L+Ca/Mg and 8L had heavier vine dry weights than plants produced in the IS, C, and medium Ca/Mg (Table 4.7).

Table 4.7. Growth and yield characteristics of tomato when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| | Plant Date 1 (3/20/2013 – 6/27/2013) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 29.5 b[W] | 1.8 c | 7.3 c[V] | 380 d | 5.9 b | 325 c | 0.0 c[U] | 74 d | 13.2 d |
| C | 42.9 a | 2.1 c | 29.0 a | 748 c | 11.5 b | 560 c | 16.4 a | 200 c | 35.8 c |
| Ca/Mg | 38.3 a | 3.1 b | 19.4 b | 1169 b | 18.5 a | 1119 b | 0.2 c | 214 c | 35.7 c |
| 4L | 46.2 a | 3.3 b | 24.9 ab | 1581 a | 23.4 a | 1517 a | 0.4 c | 294 b | 49.4 b |
| 4L+Ca/Mg | 42.3 a | 3.2 b | 24.4 ab | 1357 ab | 19.7 a | 1194 ab | 3.4 b | 265 b | 42.7 bc |
| 8L | 44.1 a | 3.9 a | 30.6 a | 1612 a | 24.5 a | 1444 ab | 4.6 b | 358 a | 60.3 a |
| | Plant Date 2 (6/3/2013 – 8/12/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 44.8 b | 1.6 b | 5.7 c | 89 bc | 4.7 bc | 74 bc | 0.6 b | 149 c | 27.1 e |
| C | 52.1 a | 2.0 b | 2.8 c | 17 c | 0.2 c | 1 c | 1.2 ab | 259 b | 38.2 d |
| Ca/Mg | 50.6 ab | 2.6 a | 10.4 bc | 86 bc | 2.4 bc | 23 bc | 2.1 ab | 369 a | 57.2 c |
| 4L | 52.3 a | 3.0 a | 16.2 ab | 203 ab | 6.9 ab | 98 ab | 0.9 ab | 419 a | 64.1 bc |
| 4L+Ca/Mg | 50.7 ab | 3.0 a | 22.7 a | 345 a | 11.1 a | 179 a | 2.6 a | 450 a | 74.9 a |
| 8L | 47.8 ab | 3.0 a | 19.3 a | 347 a | 9.8 a | 171 a | 1.4 ab | 446 a | 70.6 ab |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

[U]Blossom end rot was calculated as the mean number of fruit affected per plant (within a treatment) over the entire study.

## Tomato Nutrition

### First Planting Date

Leaves sampled from plants grown in the IS medium had more P leaf content than leaves from 8L, and the C had more leaf K content than all other treatments for the first planting date on the nursery yard. Plants grown in the IS medium had the most Ca, and Ca/Mg and 4L had more Ca than 4L+Ca/Mg and 8L. Although Ca/Mg and 4L contain less Ca fertilizer than 4L+Ca/Mg and 8L, they had higher leaf tissue Ca levels, which is unexpected. Furthermore, Ca/Mg contains Ca as calcium sulfate, and 4L contains Ca as dolomitic lime, so the availability of one source over the other cannot be the explanation for this result. Plants from the C still had the least Ca, as expected. Treatment Ca/Mg plants had 45% more Mg than 4L plants, and 4L+Ca/Mg plants had more Mg than the IS and 8L plants. This suggests that magnesium sulfate is a better Mg fertilizer for these tomatoes, because Ca/Mg and 4L+Ca/Mg contained magnesium sulfate while 4L and 8L contained dolomitic lime. The C had the least Mg leaf content (0.19%). Plants from the IS and Ca/Mg and 4L had more S than the C and 8L. Tomato plants grown in 4L+Ca/Mg and 8L had more S than the C. The IS had more leaf Al content than 4L and 4L+Ca/Mg. Plants from the C and 4L+Ca/Mg and 8L had more B than the IS. The IS and 4L+Ca/Mg and 8L had more leaf Cu content than Ca/Mg and 4L. Plants grown in the IS also had more Cu than the C and more Fe than Ca/Mg, 4L, and 4L+Ca/Mg. Plants grown in medium 8L had more Mn in the leaves than the C and Ca/Mg and 4L. The C had more leaf Mn than Ca/Mg and 4L. Plants from the IS had the most Mo, and the C and 8L had the least. Foliage from plants grown in 4L had more Mo than 4L+Ca/Mg. The C and 8L foliage had more Na than the IS, and the IS had the most Zn. Medium 8L leaves had not contained the highest Na in other crops; however, following suit with the explanation of the C containing the highest Na, 8L was among the lower accumulators of Ca and Mg for tomato leaves in this planting date (Table 4.8).

Second Planting Date

Plants grown in the C medium had the most P, and those grown in Ca/Mg had more P than the IS. There were no significant differences for leaf K content for the second planting date. Plants from the IS and 8L had 1 to 3 times more Ca than all other treatments. The IS contained more Ca than many other treatments during the first planting date; however, 8L Ca is higher during this planting date than it was during the first. This may be due to a change in release pattern of dolomitic lime at increased temperatures. Tomato plants grown in medium 8L also had the most Mg, and the IS and 4L+Ca/Mg plants had more than the C and Ca/Mg. This also supports the release pattern of dolomitic lime at the increased temperatures supplying more fertilization during the second planting date, because 4L, 4L+Ca/Mg, and 8L contained dolomitic lime. Treatment 8L foliage had more S than the C and Ca/Mg. There were no significant differences among treatments for Al. Plants from the IS medium and media 4L and 8L had more B than the C and medium Ca/Mg. Foliage from the C had the most Cu, and it had more Fe than the IS. Medium 4L produced plants with more Mn than the IS, Ca/Mg, and 8L. Plants in 8L had more Mo than the C and Ca/Mg and 4L+Ca/Mg. The IS and Ca/Mg foliage had more Mo than the C. Plants grown in the C medium had the most Na and had more Zn than Ca/Mg and 4L. The C was expected to have the most Na, and, in contrast to the first planting date, 8L leaves contained more Ca and Mg and less Na (Table 4.8).

Nitrogen

Plants grown in the C medium and medium 8L had the greatest %N leaf content, and the IS had the least %N for tomato foliage grown on the nursery yard during the first planting date. Plants from 4L+Ca/Mg had more %N than Ca/Mg (Table 3.13). This suggests that the C and Ca/Mg, 4L, 4L+Ca/Mg, and 8L contain more N fertilizer than the IS.

Table 4.8. Mean tomato leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting Date 1 (3/20/2013 – 6/27/2013) | | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| IS | 0.67 a[Y] | 0.93 b | 6.8 a | 0.45 c | 2.4 a | 136 a | 66 b | 14 a | 161 a | 215 ab | 12.0 a | 10482 b | 27 a |
| C | 0.60 ab | 1.48 a | 1.4 d | 0.19 d | 1.0 c | 87 ab | 86 a | 10 bc | 125 ab | 174 b | 1.9 d | 13893 a | 15 b |
| Ca/Mg | 0.51 ab | 0.91 b | 5.3 b | 0.71 a | 2.5 a | 87 ab | 79 ab | 8 c | 101 b | 83 c | 5.4 bc | 11741 ab | 15 b |
| 4L | 0.51 ab | 0.95 b | 5.4 b | 0.49 bc | 2.5 a | 70 b | 78 ab | 7 c | 101 b | 75 c | 6.5 b | 11607 ab | 12 b |
| 4L+Ca/Mg | 0.55 ab | 1.02 b | 4.0 c | 0.62 ab | 2.1 ab | 75 b | 91 a | 11 ab | 110 b | 217 ab | 3.8 cd | 12776 ab | 14 b |
| 8L | 0.46 b | 1.08 b | 3.4 c | 0.38 c | 1.6 b | 94 ab | 92 a | 12 ab | 132 ab | 268 a | 2.2 d | 13896 a | 16 b |
| Planting Date 2 (6/3/2013 – 8/12/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.35 c | 1.11 a | 2.7 a | 0.65 b | 1.2 ab | 53 a | 71 a | 13 b | 78 b | 98 b | 5.4 ab | 12911 b | 40 ab |
| C | 1.01 a | 1.56 a | 0.7 b | 0.23 d | 0.9 b | 97 a | 54 c | 24 a | 153 a | 137 ab | 3.6 bc | 20082 a | 47 a |
| Ca/Mg | 0.58 b | 1.32 a | 0.7 b | 0.42 cd | 0.7 b | 106 a | 60 bc | 12 b | 126 ab | 79 b | 2.9 c | 14658 b | 24 b |
| 4L | 0.41 bc | 1.27 a | 1.4 b | 0.54 bc | 1.1 ab | 52 a | 74 a | 13 b | 98 ab | 199 a | 5.0 ab | 12869 b | 26 b |
| 4L+Ca/Mg | 0.52 bc | 1.47 a | 1.4 b | 0.66 b | 1.0 ab | 70 a | 68 ab | 11 b | 108 ab | 137 ab | 3.7 bc | 12493 b | 38 ab |
| 8L | 0.49 bc | 1.22 a | 2.7 a | 0.92 a | 1.5 a | 75 a | 72 a | 14 b | 104 ab | 87 b | 6.6 a | 15075 b | 31 ab |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Summary

Overall, the top-performing media treatments for tomatoes were 4L+Ca/Mg and 8L, as they produced the greatest biomass and yielded more fruit for both planting dates of 'Patio Princess' tomato, following a lettuce crop.

Tissue samples of tomatoes on the nursery yard showed the least amount of Ca in the C for the first planting date, but similar to the nursery yard it had the same amount of Ca as many other treatments for the second planting date. Ca levels in tomato foliage were not the same in planting dates one and two. The sufficiency range for Ca in tomatoes is 1.5 to 2.4%, and even the C, with no added Ca fertilizer, was only slightly below the sufficiency range (Mills and Jones, 1996). All other treatments were above sufficiency. Sufficiency range for Mg in tomato leaf tissue is 0.3 to 0.8%, and all treatments except the C were within sufficiency. The C had the least Mg for both planting dates. Plants grown in medium 8L had more Mg than the sufficiency range for the second planting date.

**High Tunnel**

Tomato Growth and Yield

First Planting Date

There were no significant final height differences among treatments for the first planting date. Tomato plants grown in medium 4L+Ca/Mg were more vigorous than all other media treatments, with the exception of Ca/Mg. Media Ca/Mg, 4L, 4L+Ca/Mg, and 8L produced vines with more fruit than the IS and C. Medium 4L+Ca/Mg vines produced the highest total fruit weight of all media treatments Plants grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L produced more marketable fruit by umber and weight than those grown in the IS and C media. The C plants had the highest number of fruit with blossom end rot. Plants from media Ca/Mg and 4L+Ca/Mg had heavier vine fresh weights than the IS, C, and medium 4L, and the C plants had the lowest vine fresh weight of all treatments. Media Ca/Mg and

4L+Ca/Mg plants had a heavier vine dry weight than the IS and C. The IS plants had the lowest vine dry weight of all treatments (Table 4.9).

Second Planting Date

Tomato vines grown in 4L+Ca/Mg and 8L were taller than the C and had more vigor than any other treatments at the end of the second planting date. Vines from 4L, 4L_Ca/Mg, and 8L produced more fruit than all other treatments. Plants produced in 4L+Ca/Mg and 8L produced more fruit than all other media treatments. The IS, 4L+Ca/Mg, and 8L produced the most marketable fruit, and they produced more marketable fruit by weight than the C and Ca/Mg. Medium 4L fruit had more blossom end rot by number of fruit than the IS, C, and Ca/Mg. Tomato vines grown in 4L+Ca/Mg and 8L had the greatest vine fresh weights, and 4L, 4L+Ca/Mg, and 8L had a higher fresh weight than the IS, C, and Ca/Mg (Table 4.9).

Tomato Nutrition

First Planting Date

Tomato foliage samples from the IS medium had more P leaf content than Ca/Mg, 4L, 4L+Ca/Mg, and 8L for tomatoes grown under the high tunnel during the first planting date. The C had the most leaf K content, and the IS had more K than 4L+Ca/Mg. Plants grown in the IS medium had 35% more Ca than those grown in medium 4L, and medium 4L plants had more Ca than Ca/Mg, 4L+Ca/Mg, and 8L. It was not expected that the medium containing 2.4 kg/yd$^3$ of dolomitic lime (4L) would have more leaf tissue Ca than the treatment containing 4.7 kg/yd$^3$ dolomitic lime (8L). The C had the least Ca. Plants from 4L+Ca/Mg had more Mg than plants from the IS, C, 4L, and 8L. This may be due to 4L+Ca/Mg containing dolomitic lime and magnesium sulfate fertilizers. Ca/Mg plants, containing only magnesium sulfate (no dolomitic lime), had more Mg than the C. Plants from the C had less S than all other treatments. There were no significant differences for Al, B, and Zn. The C had more Cu leaf content than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and it had more foliage Fe than 4L and

Table 4.9. Growth and yield characteristics of tomato when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (3/20/2013 – 6/20/2013) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 53.3 a[W] | 2.6 c | 13.1 b[V] | 678 c | 9.7 c | 592 c | 1.7 b[U] | 107 d | 18.9 c |
| C | 56.1 a | 2.0 d | 16.6 b | 185 d | 0.9 d | 23 d | 15.5 a | 262 c | 46.5 b |
| Ca/Mg | 55.1 a | 4.0 ab | 34.1 a | 2140 b | 33.1 ab | 2104 ab | 0.3 b | 371 a | 61.3 a |
| 4L | 57.8 a | 3.9 b | 33.5 a | 2116 b | 31.8 ab | 2056 ab | 0.5 b | 287 bc | 51.3 ab |
| 4L+Ca/Mg | 58.4 a | 4.4 a | 38.7 a | 2497 a | 35.1 a | 2335 a | 0.9 b | 376 a | 60.2 a |
| 8L | 54.7 a | 3.9 b | 32.0 a | 2001 b | 29.3 b | 1899 b | 0.4 b | 342 ab | 54.0 ab |
| Plant Date 2 (6/3/2013 – 8/12/2013) | | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 65.4 ab | 2.3 c | 11.9 b | 227 c | 8.5 a | 156 ab | 1.8 bc | 212 d | 38.0 c |
| C | 56.1 b | 2.0 c | 0.3 c | 1 d | 0.0 b | 0.0 c | 0.0 c | 140 e | 26.0 d |
| Ca/Mg | 64.3 ab | 3.0 b | 6.0 bc | 71 d | 1.4 b | 22 c | 0.8 bc | 400 c | 68.0 b |
| 4L | 51.5 ab | 3.2 b | 18.2 a | 313 bc | 3.7 b | 80 bc | 4.3 a | 477 b | 80.1 a |
| 4L+Ca/Mg | 68.6 a | 3.9 a | 20.8 a | 415 ab | 10.5 a | 219 a | 3.1 ab | 558 a | 84.4 a |
| 8L | 69.5 a | 4.1 a | 24.3 a | 511 a | 11.1 a | 234 a | 2.1 abc | 581 a | 87.8 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan’s Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

[U]Blossom end rot was calculated as the mean number of fruit affected per plant (within a treatment) over the entire study.

8L. Leaves from the IS had more Mn than 4L. The IS and 4L foliage had more Mo than the C and 4L+Ca/Mg and 8L. Tomato vines grown in 8L had more Mo than the C. The C plants had the most Na, as expected, and 4L+Ca/Mg had more Na than the IS and Ca/Mg and 4L. Plants from the IS had the least Na of all treatments (Table 4.10).

Second Planting Date

Tomato plants grown in the C medium had more P than any other treatment, and 4L had more P than the IS and 4L+Ca/Mg and 8L for the second planting date. Ca/Mg foliage had more P than the IS and 8L. Medium 4L had the most leaf K content, and Ca/Mg plants had more K than the IS and 4L+Ca/Mg and 8L. Plants from the C had more K than 8L. The IS and 4L, 4L+Ca/Mg, and 8L had more leaf Ca content than C and Ca/Mg. For Mg, plants from 4L+Ca/Mg had 34% more than 8L, and 8L had 91% more than the C. Plants from 4L+Ca/Mg had among the highest Mg in the first planting date as well. Tomato vines grown in 4L had more S than all other treatments, and 4L+Ca/Mg and 8L had more leaf S content than the C and Ca/Mg. The C had the greatest Al leaf content than all other treatments, except 4L, which had more Al than Ca/Mg, 4L+Ca/Mg, and 8L. Vines from the C medium and medium 4L had more B than the IS and 4L+Ca/Mg and 8L. Medium Ca/Mg plants had more B than the IS and 8L. Foliage of the C medium treatment had the most Cu, and the IS and 4L had more Cu than 8L foliage. Treatment 4L vines had more Fe than the IS and 4L+Ca/Mg and 8L. Plants from the C had more Fe than the IS and 8L. The IS had more leaf Mn content than C, Ca/Mg, 4L+Ca/Mg, and 8L. Treatment 4L foliage had more Mn than Ca/Mg, 4L+Ca/Mg, and 8L, and the C had more than 8L. Plants grown in medium 8L had more Mo than the C, IS, and Ca/Mg and 4L+Ca/Mg. The IS and Ca/Mg and 4L had more foliage Mo than the C and Ca/Mg. The C plants had the most Na, followed by 4L. Plants from the C had more Zn than 8L (Table 4.10).

Table 4.10. Mean tomato leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (3/20/2013 – 6/20/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | ----------%---------- | | | | | ----------ppm---------- | | | | | | | |
| IS | 0.86 a[Y] | 1.89 b | 7.7 a | 0.62 bc | 2.1 a | 61 a | 138 a | 10.2 ab | 96 ab | 269 a | 6.9 a | 2893 d | 34 a |
| C | 0.77 ab | 3.21 a | 0.9 d | 0.39 c | 0.8 b | 61 a | 120 a | 13.4 a | 119 a | 110 ab | 3.5 d | 7322 a | 36 a |
| Ca/Mg | 0.58 b | 1.64 bc | 3.9 c | 0.84 ab | 1.7 a | 60 a | 103 a | 8.6 b | 101 ab | 183 ab | 6.0 ab | 3641 cd | 26 a |
| 4L | 0.63 b | 1.52 bc | 5.7 b | 0.71 bc | 2.1 a | 51 a | 124 a | 9.1 b | 85 b | 52 b | 7.0 a | 3267 cd | 23 a |
| 4L+Ca/Mg | 0.63 b | 1.33 c | 3.5 c | 1.07 a | 1.7 a | 58 a | 146 a | 9.3 b | 87 ab | 171 ab | 4.2 cd | 5744 b | 24 a |
| 8L | 0.58 b | 1.45 bc | 3.9 c | 0.64 bc | 1.5 a | 57 a | 128 a | 8.1 b | 88 b | 117 ab | 5.4 bc | 4790 bc | 25 a |
| **Planting Date 2 (6/3/2013 – 8/12/2013)** | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | ----------%---------- | | | | | ----------ppm---------- | | | | | | | |
| IS | 0.35 d | 1.34 cd | 2.2 a | 0.80 ab | 1.0 bc | 41 bc | 89 c | 14.2 b | 66 c | 140 a | 4.7 b | 3122 c | 52 ab |
| C | 0.98 a | 1.88 bc | 0.7 b | 0.35 c | 0.7 d | 60 a | 143 a | 20.6 a | 126 ab | 101 bc | 2.6 c | 13450 a | 81 a |
| Ca/Mg | 0.60 bc | 2.11 b | 0.9 b | 0.87 ab | 0.8 cd | 36 c | 130 ab | 12.0 bc | 109 abc | 78 cd | 2.2 c | 4440 c | 38 ab |
| 4L | 0.69 b | 2.72 a | 2.2 a | 0.88 ab | 1.4 a | 51 ab | 144 a | 13.3 b | 151 a | 131 ab | 5.1 ab | 7323 b | 57 ab |
| 4L+Ca/Mg | 0.47 cd | 1.41 cd | 2.1 a | 0.90 a | 1.1 b | 37 c | 110 bc | 11.2 bc | 84 bc | 80 cd | 4.2 b | 4516 c | 40 ab |
| 8L | 0.34 d | 0.95 d | 2.1 a | 0.67 b | 1.0 b | 36 c | 91 c | 9.0 c | 39 c | 49 d | 6.5 a | 3851 c | 25 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Nitrogen

The C had the greatest N leaf content, and all other treatments had more N than the IS medium for tomatoes grown under the high tunnel during the first planting date (Table 3.13). Nitrogen was most likely concentrated in the C leaf tissue because the plants were smaller.

Summary

Treatment 4L+Ca/Mg was the top-yielding media treatment for fruit and biomass for both planting dates of tomatoes under the high tunnel. Nutritionally, the C had the least Ca of all treatments, below sufficiency, for the first planting date. The C and Ca/Mg had below sufficient Ca for the second planting date. While many of the plants were well above sufficiency for Ca in the first planting date, they were in the sufficiency for the second planting date. They also tended to yield less during the second planting date, as opposed to the same treatment during the first planting date. This difference in yield and nutrient content may be due to very high summer temperatures beginning during the second planting date. All treatments have sufficient or above tissue Mg levels.

**Nursery Yard**

Bell Pepper Growth and Yield

First Planting Date

Bell peppers grown in the C and IS potting medium performed the worst for all parameters measured, except blossom end rot, for the first planting date of bell peppers on the nursery yard. Peppers planted in 8L had significantly greater height, vigor, vine fresh weight, and vine dry weight than plants in all other media treatments. Media Ca/Mg, 4L, 4L+Ca/Mg, and 8L produced plants with the greatest number of fruit. Treatment 4L plants had a greater total fruit weight than Ca/Mg and a greater marketable fruit number and weight than all other treatments. This may suggest that the fertilization needs of bell pepper plants can be adequately met with only 2.4 $kg/yd^3$ of dolomitic lime.

The C, 4L+Ca/Mg, and 8L had the greatest number of fruit with blossom end rot; however plants from 4L+Ca/Mg and 8L produced twice as much total fruit as the IS and C (Table 4.11).

Second Planting Date

Pepper plants from the IS medium were the shortest and least vigorous of all treatments at the end of the second planting date. Those grown in 8L were taller than the C, Ca/Mg, and 4L plants, and 4L+Ca/Mg plants were taller than the C and medium Ca/Mg. Treatment 4L, 4L+Ca/Mg, and 8L were the most vigorous plants. Pepper plants from 4L+Ca/Mg had the highest total fruit number, and the IS had the lowest. Plants from all other treatments were equal. Plants from 4L, 4L+Ca/Mg, and 8L had the highest total fruit weight, marketable fruit number, marketable fruit weight, and vine fresh weight. Treatment 8L performed better during the second planting date compared to other treatments; however, the yields during the second planting dates were lower for overall for treatments in the second planting date. This may be due to differences in environmental conditions. There were no other differences for these parameters. Plants grown in the C medium had the most blossom end rot. Medium 4L+Ca/Mg plants had a heavier vine dry weight than all media treatments, except 8L. Treatment 8L plants had a heavier vine dry weight than the C, IS, and Ca/Mg, and 4L had a heavier dry weight than the C and IS (Table 4.11).

Bell Pepper Nutrition

First Planting Date

Bell peppers grown in the C medium had the highest P leaf content, and 8L had more P than Ca/Mg for the first planting date. The IS plants had more K than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and the C had more K than Ca/Mg. Treatment 4L had the most leaf Ca content, 43% more Ca than the IS, and it also had the highest yield for this planting date. The IS plants had more Ca than the C, 4L+Ca/Mg, and 8L. Pepper plants grown in Ca/Mg and 4L had more Mg than all other treatments. Treatment 4L+Ca/Mg vines had more Mg than the IS and C, and 8L had nearly 2 times more Mg than

Table 4.11. Growth and yield characteristics of bell pepper when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Plant Date 1 (3/20/2013 – 6/27/2013) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 22.7 c[W] | 2.4 c | 2.1 b[V] | 167 c | 1.4 c | 123 c | 0.5 b[U] | 66.9 c | 12.2 c |
| C | 23.1 c | 2.0 c | 2.6 b | 79 c | 0.3 c | 24 c | 2.2 a | 52.9 c | 8.6 c |
| Ca/Mg | 34.5 b | 3.1 b | 5.5 a | 555 b | 4.0 b | 452 b | 0.6 b | 145.9 b | 27.5 b |
| 4L | 35.3 b | 3.6 b | 6.8 a | 717 a | 6.5 a | 677 a | 0.2 b | 181.8 b | 28.0 b |
| 4L+Ca/Mg | 37.1 b | 3.6 b | 6.9 a | 574 ab | 3.3 b | 345 b | 3.0 a | 184.7 b | 34.2 b |
| 8L | 41.1 a | 4.6 a | 7.3 a | 662 ab | 4.3 b | 466 b | 2.6 a | 294.9 a | 44.7 a |
| Plant Date 2 (6/27/2013 – 9/4/2013) | | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪cm▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 21.9 d | 1.1 c | 0.9 c | 44 b | 0.3 b | 22 b | 0.0 c | 29.2 b | 4.7 d |
| C | 28.8 c | 2.4 b | 3.8 b | 60 b | 0.0 b | 0 b | 3.0 a | 32.8 b | 4.9 d |
| Ca/Mg | 28.8 c | 2.6 b | 4.2 b | 117 b | 0.2 b | 11 b | 1.6 b | 49.2 b | 9.2 dc |
| 4L | 32.9 bc | 3.5 a | 5.0 b | 309 a | 2.3 a | 179 a | 0.4 bc | 78.0 a | 14.2 bc |
| 4L+Ca/Mg | 36.0 ab | 4.1 a | 8.7 a | 403 a | 2.3 a | 165 a | 1.0 bc | 105.8 a | 19.7 a |
| 8L | 37.9 a | 3.8 a | 4.8 b | 301 a | 3.0 a | 240 a | 0.0 c | 85.4 a | 16.1 ab |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

[U]Blossom end rot was calculated as the mean number of fruit affected per plant (within a treatment) over the entire study.

the C. Medium 4L plants had more S than the IS and Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and the C had more S than Ca/Mg and 4L+Ca/Mg. The IS had more Al than 8L. The IS pepper plants had the most B, Mn, Mo, and Zn. The C and 8L foliage had more B than Ca/Mg, 4L, and 4L+Ca/Mg. Leaves from the C had more Fe than all other treatments, except 8L. The C and 4L had more Mo than Ca/Mg. There were no significant differences for Na; however Na was above 8,000 ppm for all treatments. This may be due to alkaline water being used for irrigation during two seasons in the same pot (Table 4.12).

Second Planting Date

Bell pepper foliage from plants planted into the C had the most P, and the IS had more P than 8L for bell peppers on the nursery yard during the second planting date. The IS also had more leaf K content than 4L+Ca/Mg. The C and Ca/Mg foliage had 2 to 3.5 times less Ca than all other treatments, which was similar to the results from the first planting date. Plants grown in the IS medium had more Mg than all media treatments, except 4L+Ca/Mg, and 4L+Ca/Mg had more leaf Mg content than the C and Ca/Mg. 8L also had more Mg than the C. The C foliage had the most S, and Ca/Mg had more S than the IS and 8L foliage. Plants in 4L and 5 had more Al than the IS, C, and 8L. Medium 8L plants had more Al than the C. Bell pepper vines grown in media 4L+Ca/Mg and 8L had more B than the C and Ca/Mg. For Cu, the IS pepper plants had more than Ca/Mg, 4L, 4L+ca/Mg, and 8L. Foliage from the C and Ca/Mg had more Cu than 4L+Ca/Mg and 8L. The C had more leaf Fe content than the IS and 4L and 8L, and foliage samples from medium Ca/Mg had more Fe than the IS and 8L. 4L had more Mn than plants from the IS and Ca/Mg and 8L, and 4L+Ca/Mg had more Mn than Ca/Mg. The C had more foliage Mo content than 4L+Ca/Mg and 8L. Plants grown in the IS, 4L, and 8L had more Na than the C and Ca/Mg, and the IS had the most Zn. The IS having high Na does not support previous patterns recognized of those plants high in Ca and Mg being low in sodium; however, 4L and 8L were

relatively low in Ca for this planting date. Sodium was between 7,000 and 11,000 ppm for all treatments (Table 4.12).

Summary

Medium treatment 4L consistently produced the best yields in both planting dates. Based on results from this study 4L is the best selection for growing 'Stiletto' bell peppers on a nursery yard following a cauliflower crop.

The sufficiency range for Ca and Mg in bell pepper leaf tissue is 1.30 to 2.80% and 0.30 to 2.8% respectively (Mills and Jones, 1996). For Ca, nearly all treatments were beneath the sufficiency range except the IS and Ca/Mg in the first planting date. All treatments are below sufficiency range for Mg. This suggests that cauliflower may have been a heavier Ca and Mg feeder than the other fall crops, because bell pepper was planted after cauliflower. Additional fertilization may be needed to grow plants after cauliflower.

**High Tunnel**

Bell Pepper Growth and Yield

First Planting Date

Bell pepper plants grown in the IS and C media treatments performed the worst for all parameters, except blossom end rot, under the high tunnel during the first planting date. Plants growing in Ca/Mg, 4L, 4L+Ca/Mg, and 8L were significantly taller and more vigorous than those plants grown in the IS and C. Media treatments Ca/Mg, 4L+Ca/Mg, and 8L produced plants with a greater fruit number, weight, marketable fruit number, and marketable fruit weight than the IS, C, and 4L. This was in contrast to the nursery yard bell peppers during the same planting date who performed best in medium 4L. The C had the most blossom end rot by number of fruit. Plants from Ca/Mg had a greater vine fresh weight than those from 4L and 8L, and they had a greater vine dry weight than all other treatments (Table 4.13).

Table 4.12. Mean bell pepper leaf tissue nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (3/20/2013 – 6/27/2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.31 bc[Y] | 3.1 a | 1.4 b | 0.12 cd | 0.5 bc | 19 b | 54 a | 4.5 ab | 51 b | 166 a | 4.9 a | 9980 a | 184 a |
| C | 0.45 a | 2.9 ab | 0.2 d | 0.06 d | 0.6 ab | 15 bc | 45 b | 5.6 ab | 78 a | 102 b | 1.8 b | 10040 a | 41 b |
| Ca/Mg | 0.26 c | 2.4 c | 1.3 bc | 0.34 a | 0.4 c | 21 ab | 30 c | 2.1 c | 50 b | 76 b | 0.5 c | 9121 a | 46 b |
| 4L | 0.31 bc | 2.6 bc | 2.0 a | 0.39 a | 0.6 a | 23 ab | 33 c | 2.4 c | 42 b | 82 b | 2.1 b | 8726 a | 46 b |
| 4L+Ca/Mg | 0.31 bc | 2.5 bc | 0.9 c | 0.25 b | 0.4 c | 27 ab | 32 c | 2.6 c | 54 b | 77 b | 1.0 cb | 8262 a | 57 b |
| 8L | 0.36 b | 2.6 bc | 0.9 c | 0.17 bc | 0.5 bc | 11 c | 44 b | 3.9 b | 60 ab | 92 b | 1.4 cb | 7927 a | 64 b |
| Planting Date 2 (6/27/2013 – 9/4/2013) | | | | | | | | | | | | | |
| Treatment | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.30 b | 3.1 a | 0.9 a | 0.41 a | 0.32 c | 5 bc | 52 ab | 10.1 a | 43 c | 96 bc | 3.4 ab | 10287 a | 243 a |
| C | 0.44 a | 2.7 ab | 0.2 b | 0.08 d | 0.60 a | 3 c | 42 b | 7.9 ab | 79 a | 116 abc | 3.9 a | 7294 b | 59 b |
| Ca/Mg | 0.25 bc | 2.4 ab | 0.2 b | 0.11 cd | 0.44 b | 12 ab | 42 b | 6.0 b | 65 ab | 75 c | 3.1 ab | 7618 b | 65 b |
| 4L | 0.24 bc | 2.5 ab | 0.6 a | 0.15 bcd | 0.40 cb | 19 a | 53 ab | 5.4 bc | 58 bc | 169 a | 3.2 ab | 10364 a | 83 b |
| 4L+Ca/Mg | 0.25 bc | 2.0 b | 0.6 a | 0.28 ab | 0.39 cb | 19 a | 58 a | 3.2 c | 62 abc | 160 ab | 2.2 b | 9488 ab | 71 b |
| 8L | 0.22 c | 2.4 ab | 0.7 a | 0.25 bc | 0.32 c | 12 b | 55 a | 3.4 c | 45 c | 96 bc | 2.2 b | 10508 a | 84 b |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Second Planting Date

Bell peppers grown in media 4L+Ca/Mg and 8L were the tallest. Plants produced in Ca/Mg, 4L, 4L+Ca/Mg, and 8L had higher vigor than the IS and C media. Medium 4L+Ca/Mg plants produced more fruit than the IS, C, 4L, and Ca/Mg, and 8L produced more than the IS and C. Treatment 4L plants produced more fruit than the IS. Pepper plants grown in 4L+Ca/Mg and 8L had the highest total fruit weight. For marketable fruit number, 4L+Ca/Mg and 8L produced more than the IS, C, and Ca/Mg. Media 4L+Ca/Mg and 8L produced the highest marketable fruit weight, which was similar to the results from the first planting date of bell pepper under the high tunnel. Plants grown in treatment Ca/Mg had more blossom end rot by number than the IS and 8L. Bell pepper vines grown in medium 8L had a greater vine fresh and dry weight than all other media treatments, except 4L+Ca/Mg. 8L plants had a greater vine fresh and dry weight than the IS, C, Ca/Mg, and 4L (Table 4.13).

Bell Pepper Nutrition

First Planting Date

There were no significant differences for K, S, Mn, and Mo leaf content for the first planting date of bell peppers under the high tunnel. Pepper plants gown in the C medium had more P than those grown in 4L, 4L+Ca/Mg, and 8L. Treatment 4L foliage had more Ca than the IS, C, 4L+Ca/Mg, and 8L, which was similar to the results observed on the nursery yard. Foliage sampled from Ca/Mg plants had more Ca than the IS, C, and 4L+Ca/Mg. The C had the least Ca. Medium Ca/Mg had more leaf Mg content than the C, IS, 4L+Ca/Mg, and 8L. Medium Ca/Mg contained Mg fertilizer as magnesium sulfate. Bell pepper vines grown in the C and IS media had the least Mg, and 4L had more Mg than 8L. Treatment 4L plants had more Al than the IS. The C had more B than Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and plants from the IS had more B than Ca/Mg, 4L, and 4L+Ca/Mg. The IS and C had the most Cu, and the C had the most Fe and Na leaf content. Plants grown in the IS medium had more Zn than all other treatments (Table 4.14).

Table 4.13. Growth and yield characteristics of bell pepper when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant Date 1 (3/20/2013 – 6/20/2013) | | | | | | | | |
| Treatment[Z] | Final Height | Final Vigor[Y] | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 32.0 b[W] | 2.1 b | 1.8 c[V] | 170 c | 1.8 c | 170 c | 0.0 b[U] | 82 c | 12.8 c |
| C | 30.7 b | 2.1 b | 2.0 c | 85 c | 0.5 c | 32 c | 1.4 a | 66 c | 9.1 c |
| Ca/Mg | 50.0 a | 4.1 a | 7.8 a | 962 a | 7.8 a | 962 a | 0.0 b | 257 a | 45.0 a |
| 4L | 47.7 a | 4.0 a | 5.1 b | 563 b | 4.8 b | 549 b | 0.1 b | 210 b | 37.1 b |
| 4L+Ca/Mg | 46.8 a | 3.8 a | 7.7 a | 873 a | 7.3 a | 835 a | 0.3 b | 234 ab | 40.0 b |
| 8L | 47.5 a | 3.9 a | 7.8 a | 888 a | 7.7 a | 875 a | 0.1 b | 221 b | 37.9 b |
| | Plant Date 2 (6/27/2013 – 9/4/2013) | | | | | | | | |
| Treatment | Final Height | Final Vigor | Total Fruit | Total Fruit Weight | Marketable Fruit | Marketable Fruit Weight | Blossom End Rot | Vine Fresh Weight | Vine Dry Weight |
| | ▪▪▪▪cm▪▪▪▪ | ▪▪ (1-5) ▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪#▪▪▪▪ | ▪▪▪▪g▪▪▪▪ | ▪▪▪▪g▪▪▪▪ |
| IS | 31.1 c | 1.9 b | 0.5 d | 12 d | 0.1 c | 6 b | 0.2 b | 74 de | 11.4 de |
| C | 31.9 c | 2.5 b | 1.9 cd | 49 cd | 0.0 c | 0 b | 0.7 ab | 43 e | 6.7 e |
| Ca/Mg | 41.0 b | 3.4 a | 5.1 ab | 190 bc | 0.6 c | 38 b | 1.1 a | 89 cd | 15.5 cd |
| 4L | 40.2 b | 3.8 a | 3.6 bc | 210 b | 1.6 bc | 124 b | 0.5 ab | 115 bc | 20.7 bc |
| 4L+Ca/Mg | 49.0 a | 4.0 a | 7.1 a | 410 a | 3.3 a | 262 a | 0.3 ab | 136 ab | 26.7 ab |
| 8L | 47.9 a | 3.9 a | 5.4 ab | 365 a | 3.1 ab | 262 a | 0.1 b | 174 a | 32.1 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]The vigor scale is as follows: 1 – very poor, not likely to survive; 2 – below mean growth rate, above mean pest damage, coloration problems; 3 – mean growth rate, pest damage, color; 4 – above mean growth, little pest damage, good color; 5- excellent growth, excellent color, no pest damage.

[W]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

[V]Fruit yields are calculated as the mean production per plant (within a treatment) over the entire study.

[U]Blossom end rot was calculated as the mean number of fruit affected per plant (within a treatment) over the entire study.

Second Planting Date

Leaf samples of bell peppers grown in the IS and C media had the most P for the second planting date. Treatments Ca/Mg and 8L had more P than 4L+Ca/Mg. The IS plants had the most K, Mg, Cu, and Zn. Plants from 4L had more K than 4L+Ca/Mg and 8L. The IS and 4L+Ca/Mg had more leaf tissue Ca than Ca/Mg, 4L, and 8L, and the C had the least Ca. Medium treatment 4L+Ca/Mg contains Ca from dolomitic lime as well as calcium sulfate; however, it did not lead to highest leaf tissue Ca in the first planting date. Treatments 4L+Ca/Mg and 6 plants had more Mg than the C and Ca/Mg and 4. This is the expected result, because these media treatments contained more Mg fertilizer than all others. Plants from the C had more S than Ca/Mg, 4L, 4L+ca/Mg, and 8L, and the IS had more S than 4L+Ca/Mg. Media Ca/Mg and 4L foliage had more Al than all other treatments, and 8L foliage had more than the IS and C. Plants grown in 4L+Ca/Mg had more Al than the C. Treatments Ca/Mg leaf samples had more B than 4L and 4L+Ca/Mg, and the C had more Cu than Ca/Mg, 4L, 4L+Ca/Mg, and 8L. There were no significant differences for Fe. The IS and 4L plants had the most Mn, and 4L+Ca/Mg had more than 8L. Treatment 4L had more Mo leaf content than the IS and 4L+Ca/Mg. Plants grown in the IS medium had more Na than 4L, and the IS had more Zn than all other treatments. Medium 4L foliage had more Zn than the C and 8L (Table 4.14).

Summary

Overall, media 4L+Ca/Mg had the most consistent high yields and maintained sufficient Mg levels as compared to plants growing in all other tested media. Therefore, this study finds that media 4L+Ca/Mg is the best medium for planting bell peppers after cauliflower under a high tunnel.

Ca and Mg in the bell pepper leaf tissue levels was below sufficiency range for many treatments. Only Ca/Mg and 4L during the first planting date had sufficient Ca levels, and for the first planting date Ca/Mg, 4L, 4L+Ca/Mg, and 8L had sufficient levels of Mg. The IS and 4L+Ca/Mg had sufficient Mg for the second planting date.

Table 4.14. Mean bell pepper leaf tissue nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting Date 1 (3/20/2013 – 6/20/2013) | | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| IS | 0.32 ab[Y] | 3.5 a | 1.1 c | 0.13 d | 0.3 a | 14 b | 40 ab | 3.7 a | 46 b | 87 a | 1.7 a | 75 b | 125 a |
| C | 0.37 a | 3.4 a | 0.2 d | 0.06 d | 0.3 a | 17 ab | 46 a | 42 a | 68 a | 74 a | 1.6 a | 311 a | 28 b |
| Ca/Mg | 0.29 ab | 3.0 a | 1.6 ab | 0.41 a | 0.4 a | 23 ab | 29 c | 2.4 b | 50 b | 71 a | 0.9 a | 50 b | 49 b |
| 4L | 0.27 b | 2.9 a | 1.9 a | 0.37 ab | 0.4 a | 26 a | 29 c | 2.7 b | 47 b | 72 a | 1.4 a | 54 b | 57 b |
| 4L+Ca/Mg | 0.28 b | 3.3 a | 1.0 c | 0.32 bc | 0.3 a | 21 ab | 31 c | 2.5 b | 48 b | 83 a | 1.5 a | 36 b | 38 b |
| 8L | 0.27 b | 3.1 a | 1.4 bc | 0.25 c | 0.3 a | 18 ab | 33 bc | 2.9 b | 52 b | 73 a | 0.8 a | 64 b | 40 b |
| Planting Date 2 (6/27/2013 – 9/4/2013) | | | | | | | | | | | | | |
| Tmt | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| IS | 0.47 a | 5.0 a | 0.75 a | 0.41 a | 0.37 ab | 6 cd | 47 ab | 7.1 a | 46 a | 126 a | 2.9 b | 50 a | 220 a |
| C | 0.41 a | 3.3 bc | 0.11 c | 0.09 c | 0.39 a | 4 d | 41 ab | 4.7 b | 67 a | 69 bc | 3.7 ab | 31 ab | 39 c |
| Ca/Mg | 0.27 b | 3.4 bc | 0.34 b | 0.16 c | 0.31 bc | 29 a | 55 a | 3.1 c | 67 a | 66 bc | 4.1 ab | 29 ab | 47 bc |
| 4L | 0.24 bc | 3.8 b | 0.39 b | 0.16 c | 0.32 bc | 28 a | 40 b | 3.0 c | 61 a | 109 a | 5.9 a | 22 b | 55 b |
| 4L+Ca/Mg | 0.18 c | 2.6 d | 0.75 a | 0.31 b | 0.28 c | 14 bc | 35 b | 2.3 c | 55 a | 84 b | 3.2 b | 40 ab | 42 bc |
| 8L | 0.28 b | 3.1 cd | 0.51 b | 0.27 b | 0.32 bc | 16 b | 43 ab | 2.5 c | 50 a | 54 c | 4.6 ab | 43 ab | 35 c |

[Z]Treatments (Tmt) are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

**Media Initial and Final pH and Ec**

Initially, all media treatments were below the sufficient pH range of 5.5 to 6.4 (Argo, 1996a). After two weeks, media 8L was within the sufficiency range, while all others remained below. All media treatments, except the IS, were within the recommended Ec of ≤ 2 dS/m (Bilderback, 2001) at the initial measurement. After two weeks, the C and 4L and 8L were beneath the maximum recommended Ec for pine bark media (Table 4.15).

In the final pH and Ec measurements, all treatments were below the recommended Ec. The IS was above the recommended pH for both planting dates of the nursery yard and high tunnel. The C was below the recommended pH range for both planting dates on the nursery yard, and Ca/Mg was below the range for the first planting date on the nursery yard and above it for the second. This may be due to differences in environmental conditions. Under the high tunnel, 4L and 8L were above the recommended pH for the first planting date (Table 4.15).

Table 4.15. Initial and final leachate pH and Ec of media amended with Ca and Mg fertilizer and watered with alkaline irrigation for two production seasons.

| Treatment[Z] | Pre-Planting | | | | Planting Date 1 | | | | Planting Date 2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | | Week 2 | | Final Nursery yard | | Final High Tunnel | | Final Nursery yard | | Final High Tunnel | |
| | pH | Ec (mS/cm) | pH | Ec (mS/cm) | pH | Ec (mS/cm) | pH | Ec (mS/cm) | pH | Ec (mS/cm) | pH | Ec (mS/cm) |
| IS | 5.1 a[Y] | 4.94 a | 5.1 b | 4.70 a | 6.6 a | 0.36 ab | 6.5 ab | 0.35 c | 6.7 a | 0.41 a | 6.6 a | 0.32 b |
| C | 5.0 a | 0.24 c | 4.3 de | 1.09 c | 5.2 d | 0.33 ab | 6.1 c | 0.34 c | 5.3 b | 0.36 a | 6.1 ab | 0.49 ab |
| Ca/Mg | 4.2 c | 1.00 b | 4.1 e | 2.29 b | 6.6 a | 0.31 ab | 6.4 ab | 0.55 a | 5.4 b | 0.41 a | 6.0 b | 0.56 ab |
| 4L | 4.5 bc | 0.24 c | 4.7 c | 1.01 c | 6.4 ab | 0.43 a | 6.6 a | 0.44 b | 5.7 b | 0.46 a | 6.0 ab | 0.45 ab |
| 4L+Ca/Mg | 4.3 c | 1.08 b | 4.5 cd | 2.04 b | 6.1 bc | 0.32 ab | 6.3 b | 0.41 bc | 5.7 b | 0.47 a | 6.2 ab | 0.56 ab |
| 8L | 4.6 b | 0.28 c | 5.8 a | 1.13 c | 5.9 c | 0.28 b | 6.5 ab | 0.40 bc | 6.4 a | 0.40 a | 6.4 ab | 0.63 a |

[Z]Treatments are as follows (per cubic meter): IS – industry standard; C- 0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; Ca/Mg- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4L- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 4L+Ca/Mg- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 8L- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

# CHAPTER 5: CONCLUSIONS

## Fall Crops

Media 4L and 4L+Ca/Mg out-performed all others by producing the greatest fresh weights of the edible portions (yield) of all three crops compared to the IS and C on the nursery yard. Under the high tunnel, 4L+Ca/Mg produced the greatest head fresh weights for cabbage.

### Lettuce

#### Nursery Yard

The media treatments improved vegetable production when irrigated with Baton Rouge alkaline city water. Lettuce irrigated twice daily on the nursery yard with alkaline water, and also exposed to rain water, had a greater head fresh weight at harvest when grown in media 4L and 4L+Ca/Mg compared to plants grown in the IS (treatment 1). All treatments, except the IS, had greater lettuce head fresh weights than the C (treatment 2) for both planting dates on the nursery yard, and the IS was either greater than or similar to the C lettuce head fresh weight. Addition of lime or calcium sulfate increased plant tissue Ca levels compared to the C.

#### High Tunnel

When lettuce was grown under a high tunnel and irrigated twice daily with alkaline Baton Rouge city water, media 4L and 8L had similar to or greater head fresh weights for both planting dates than the IS and C. Lettuce grown in the C medium had the lowest head fresh weight and the least leaf tissue Ca of all treatments. In addition, plants grown in media treatments with magnesium sulfate added, Ca/Mg and 4L+Ca/Mg, had more Mg than the IS, C, and 8L for both planting dates under the high tunnel.

## Cabbage

Nursery Yard

Cabbage grown on the nursery yard had the greatest head fresh weight when grown in 4L, 4L+Ca/Mg, and 8L. Additionally, 4L+Ca/Mg and 8L had a greater leaf fresh weight than the IS and C. Cabbage grown in 8L had a greater leaf dry weight than the C and IS for both planting dates on the nursery yard. As expected, plants grown in the C medium had the least leaf tissue Ca and Mg. Cabbage heads grown in 4L+Ca/Mg had more leaf tissue Ca than the C but were the same or similar to all other treatments.

High Tunnel

Cabbage grown under the high tunnel had a greater head fresh weight than the IS and C when grown in Ca/Mg and 4L+Ca/Mg, and Ca/Mg, 4L, and 4L+Ca/Mg had a greater head dry weight than the IS and C. The C had the least leaf tissue Ca, and 8L had more leaf tissue Mg than the C and IS under the high tunnel.

## Cauliflower

Nursery Yard

All media treatments for cauliflower grew larger heads, by diameter, than the C medium on the nursery yard. A comparison of fresh weights of cauliflower heads indicated 4L, 4L+Ca/Mg, and 8L performed better than the IS and C. Media 4L+Ca/Mg and 8L grew plants with a greater head dry weight than the IS and C. Leaf fresh weight of 4L and 4L+Ca/Mg was greater than the IS and C, and 4L, 4L+Ca/Mg, and 8L had a greater leaf dry weight than the C. Leaf tissue Ca was the lowest for plants grown in the C medium, and media 8L had more leaf tissue Mg than the C for both planting dates.

High Tunnel

Cauliflower grown under the high tunnel grew taller and had a greater head diameter than the C when grown in 4L, 4L+Ca/Mg, and 8L. Plants grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L had a greater head fresh weight than those grown in the C medium. The head fresh weight of cauliflower grown in 4L+Ca/Mg was larger or similar to the IS for both planting dates. Head dry weights for plants grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L were greater than the C and were similar to or greater than the IS, for both planting dates under the high tunnel. Leaf fresh weight of plants grown in 4L+Ca/Mg and 8L was greater than the C and IS, and plants grown in 4L and 8L had greater leaf dry weight than the C and IS. Plants grown in the C medium, as seen in other crops, had the least leaf tissue Ca, and those grown in 4L+Ca/Mg had more leaf tissue Mg than the C.

**Spring Crops**

Based on the fresh weight of the edible portions (yield) of each of the three spring crops, 4L+Ca/Mg and 8L performed the best on the nursery yard during the spring crop study. They produced plants with number and weight of marketable fruit greater than both the IS and C for all crops grown on the nursery yard during the spring. Tomatoes and bell peppers under the high tunnel consistently performed the best in marketable fruit weight and number of marketable fruit when planted in media 4L+Ca/Mg and 8L. In addition, media 4L+Ca/Mg remained within the recommended pH and Ec ranges throughout the study.

**Cucumber**

Nursery Yard

Cucumber plants grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L grew taller than the IS and C. Plants grown in 4L+Ca/Mg and 8L produced more total fruit, marketable fruit number, and marketable fruit weight than the IS. Cucumber vines grown in media 4L, 4L+Ca/Mg, and 8L had a greater vine

fresh and dry weight than the IS and C. Nutritionally, plants grown in 8L had more leaf tissue Mg content than the IS and C, and plants grown in 4L+Ca/Mg had more leaf tissue Mg content than the C.

High Tunnel

Cucumbers grown under the high tunnel had longer vines than the IS when grown in media Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and plants in media 4L+Ca/Mg and 8L produced more fruit than the IS. Plants grown in the IS produced the lowest number of marketable fruit and had the lowest vine fresh weight of all treatments. Cucumbers grown in treatments C, 4L, 4L+Ca/Mg, and 8L produced a larger marketable fruit weight than the IS. Plants grown in 4L and 8L had a larger vine fresh weight than the IS and C.

**Tomato**

Nursery Yard

Tomato plants grown on the nursery yard produced more marketable fruit and had a larger marketable fruit weight than the IS and C when grown in media 4L+Ca/Mg and 8L. Media 4L, 4L+Ca/Mg, and 8L produced plants with a greater vine fresh weight than the IS and C. Plants grown in the C medium had a greater vine fresh and dry weight than the IS, and cucumbers grown in 4L and 8L had a greater vine dry weight than the IS and C. Cucumber leaves from plants grown in the IS medium had more Ca than the C and Ca/Mg, 4L, and 4L+Ca/Mg, and leaves from 8L had more Ca than the C. Plants grown in the C had the least leaf tissue Mg of all media treatments.

High Tunnel

Tomato plants grown in media 4L, 4L+Ca/Mg, and 8L produced more total fruit than the IS and C media under the high tunnel; however, the IS, 4L+Ca/Mg, and 8L produced plants with more marketable fruit and greater marketable fruit weight than the C. Plants grown in Ca/Mg, 4L+Ca/Mg, and 8L had a heavier vine fresh and dry weight than the IS and C. Plants grown in the IS, 4L,

4L+Ca/Mg, and 8L have greater leaf tissue Ca content than the C, and plants grown in Ca/Mg and 4L+Ca/Mg have more Mg than the C as well.

**Bell Pepper**

Nursery yard

Bell peppers grown on the nursery yard produced more marketable fruit than the IS and C when grown in Ca/Mg, 4L, 4L+Ca/Mg, and 8L, and peppers grown in media 4L, 4L+Ca/Mg, and 8L had a greater marketable fruit weight, vine fresh weight, and vine dry weight than the IS and C.  Pepper plants grown in the IS medium and media 4L, 4L+Ca/Mg, and 8L had more leaf tissue Ca than the C.

High Tunnel

Bell peppers grown under the high tunnel in media 4L, 4L+Ca/Mg, and 8L were taller than the IS and C, and media 4L+Ca/Mg and 8L produced plants with more marketable fruit and a greater marketable fruit weight than the IS and C.  Plants grown in 4L, 4L+Ca/Mg, and 8L had a greater vine fresh and dry weight than the IS and C, and plants from the C medium treatment had the least leaf tissue Ca.

**pH and Ec**

On the nursery yard, 4L, 4L+Ca/Mg, and 8L would be recommended because they remained within the recommended pH and Ec for both planting dates.  Under the high tunnel, the C and media Ca/Mg and 4L+Ca/Mg remained within recommended Ec for both planting dates.

**Nitrogen**

Plants grown in the C medium treatment had more N than the IS for both crops (cauliflower and tomato) on the nursery yard, and under the high tunnel, all media treatments produced plants with more N than the IS.

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United States

# Material Safety Data Sheet

Miracle-Gro Lawn Products Inc
14111 Scottslawn Road
Marysville, Ohio 43041
United States

24 h. EMERGENCY TELEPHONE NUMBER
CHEMTREC (U.S.) 1-800-424-9300
CHEMTREC (International) 1-703-527-3887
Non-Emergency Calls
1-937-644-0011

## Miracle-Gro All Purpose (15-30-15)

### 1. Product and company identification

| | | |
|---|---|---|
| **MSDS#** | : | 320000004192 |
| **EPA Registration Number:** | : | RSCO-0113/VI/00 |

### 2. Hazards identification

| | | |
|---|---|---|
| **Physical state** | : | solid [Crystalline powder] |
| **Color** | : | Color-Pantone Blue. Blue. |
| **Odor** | : | Fertilizer |
| **OSHA/HCS status** | : | While this material is not considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200), this MSDS contains valuable information critical to the safe handling and proper use of the product. This MSDS should be retained and available for employees and other users of this product. |
| **Emergency Overview** | | No harmful effects expected. |

**Potential acute health effects**

| | | |
|---|---|---|
| **Inhalation** | : | No known significant effects or critical hazards. |
| **Ingestion** | : | No known significant effects or critical hazards. |
| **Skin** | : | No known significant effects or critical hazards. |
| **Eyes** | : | No known significant effects or critical hazards. |
| **Target organs** | : | Not available. |

**Potential chronic health effects : See section 11 for more information.**

**Over-exposure signs/symptoms**

| | | |
|---|---|---|
| **Inhalation** | : | No specific data. |
| **Ingestion** | : | No specific data. |
| **Skin** | : | No specific data. |
| **Eyes** | : | No specific data. |
| **Medical conditions aggravated by over-exposure** | : | None known. |

**See toxicological information (Section 11)**

## 3. Composition/information on ingredients

**There are no ingredients present which, within the current knowledge of the supplier and in the concentrations applicable, are classified as hazardous to health or the environment and hence require reporting in this section.**

## 4. First aid measures

| | | |
|---|---|---|
| **Eye contact** | : | Check for and remove any contact lenses. Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical attention if symptoms occur. |
| **Skin contact** | : | In case of contact, immediately flush skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Wash clothing before reuse. Clean shoes thoroughly before reuse. Get medical attention if symptoms occur. |
| **Inhalation** | : | Move exposed person to fresh air. If not breathing, if breathing is irregular or if respiratory arrest occurs, provide artificial respiration or oxygen by trained personnel. Get medical attention if symptoms occur. |
| **Ingestion** | : | Wash out mouth with water. Do not induce vomiting unless directed to do so by medical personnel. Never give anything by mouth to an unconscious person. Get medical attention if symptoms occur. |
| **Notes to physician** | : | No specific treatment. Treat symptomatically. Contact poison treatment specialist immediately if large quantities have been ingested or inhaled. |

## 5. Fire-fighting measures

| | | |
|---|---|---|
| **Flammability of the product** | : | No specific fire or explosion hazard. |

**Extinguishing media**

| | | |
|---|---|---|
| **Suitable** | : | Use an extinguishing agent suitable for the surrounding fire. |
| **Not suitable** | : | None known. |
| **Special exposure hazards** | : | Promptly isolate the scene by removing all persons from the vicinity of the incident if there is a fire. No action shall be taken involving any personal risk or without suitable training. |
| **Hazardous thermal decomposition products** | : | No specific data. |
| **Special protective equipment for fire-fighters** | : | Fire-fighters should wear appropriate protective equipment and self-contained breathing apparatus (SCBA) with a full face-piece operated in positive pressure mode. |

## 6. Accidental release measures

| | | |
|---|---|---|
| **Personal precautions** | : | No action shall be taken involving any personal risk or without suitable training. Evacuate surrounding areas. Keep unnecessary and unprotected personnel from entering. Do not touch or walk through spilled material. Put on appropriate personal protective equipment (see Section 8). |
| **Environmental precautions** | : | Avoid dispersal of spilled material and runoff and contact with soil, waterways, drains and sewers. Inform the relevant authorities if the product has caused environmental pollution (sewers, waterways, soil or air). |

**Methods for cleaning up**

**Small spill** : Move containers from spill area. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor.

**Large spill** : Move containers from spill area. Prevent entry into sewers, water courses, basements or confined areas. Vacuum or sweep up material and place in a designated, labeled waste container. Dispose of via a licensed waste disposal contractor. Note: see Section 1 for emergency contact information and Section 13 for waste disposal.

## 7. Handling and storage

**Handling** : Put on appropriate personal protective equipment (see Section 8). Eating, drinking and smoking should be prohibited in areas where this material is handled, stored and processed. Workers should wash hands and face before eating, drinking and smoking. Remove contaminated clothing and protective equipment before entering eating areas.

**Storage** : Store in accordance with local regulations. Store in original container protected from direct sunlight in a dry, cool and well-ventilated area, away from incompatible materials (see Section 10) and food and drink. Keep container tightly closed and sealed until ready for use. Containers that have been opened must be carefully resealed and kept upright to prevent leakage. Do not store in unlabeled containers. Use appropriate containment to avoid environmental contamination.

## 8. Exposure controls/personal protection

**Occupational exposure limits**

**No exposure standard allocated.**
**Consult local authorities for acceptable exposure limits.**

**Recommended monitoring procedures** : If this product contains ingredients with exposure limits, personal, workplace atmosphere or biological monitoring may be required to determine the effectiveness of the ventilation or other control measures and/or the necessity to use respiratory protective equipment. Reference should be made to appropriate monitoring standards. Reference to national guidance documents for methods for the determination of hazardous substances will also be required.

**Engineering measures** : No special ventilation requirements. Good general ventilation should be sufficient to control worker exposure to airborne contaminants. If this product contains ingredients with exposure limits, use process enclosures, local exhaust ventilation or other engineering controls to keep worker exposure below any recommended or statutory limits.

**Hygiene measures** : Wash hands, forearms and face thoroughly after handling chemical products, before eating, smoking and using the lavatory and at the end of the working period. Appropriate techniques should be used to remove potentially contaminated clothing. Wash contaminated clothing before reusing. Ensure that eyewash stations and safety showers are close to the workstation location.

**Personal protection**

**Respiratory** : Use a properly fitted, particulate filter respirator complying with an approved standard if a risk assessment indicates this is necessary.

| | | |
|---|---|---|
| | | Respirator selection must be based on known or anticipated exposure levels, the hazards of the product and the safe working limits of the selected respirator. |
| **Hands** | : | Protective gloves are not required, but may be used in situations were significant contact is expected. |
| **Eyes** | : | Protective eyewear is not required, but may be used in situations were contact is expected. |
| **Skin** | : | No special protective clothing is required. |
| **Environmental exposure controls** | : | Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels. |

## 9. Physical and chemical properties

| | | |
|---|---|---|
| **Physical state** | : | solid [Crystalline powder] |
| **Flash point** | : | Not Applicable |
| **Burning time** | : | Not Applicable |
| **Auto-ignition temperature** | : | Not Applicable |
| **Flammable limits** | : | Not Applicable |
| **Density** | : | 60 lb/ft3 |
| **Color** | : | Color-Pantone Blue. Blue. |
| **Odor** | : | Fertilizer |
| **pH** | : | Not Applicable |
| **Boiling/condensation point** | : | Not Applicable |
| **Melting/freezing point** | : | Not Applicable |
| **Relative density** | : | Not Applicable |
| **Vapor pressure** | : | Not Applicable |
| **Vapor density** | : | Not Applicable |
| **Volatility** | : | Not Applicable |
| **Odor threshold** | : | Not Applicable |
| **Evaporation rate** | : | Not Applicable |
| **Viscosity** | : | Not Applicable |
| **Solubility** | : | Not Applicable |
| **Solubility in water** | : | Not Applicable |

## 10. Stability and reactivity

| | | |
|---|---|---|
| **Chemical stability** | : | The product is stable. |
| **Conditions to avoid** | : | No specific data. |
| **Incompatible materials** | : | No specific data. |
| **Hazardous decomposition products** | : | Under normal conditions of storage and use, hazardous decomposition products should not be produced. |
| **Possibility of hazardous reactions** | : | Under normal conditions of storage and use, hazardous reactions will not occur. |

## 11. Toxicological information

**Acute toxicity**

Conclusion/Summary

**Irritation/Corrosion**

| | |
|---|---|
| Skin | Not available. |
| Eyes | Not available. |
| Respiratory | Not available. |

**Sensitizer**

| | | |
|---|---|---|
| **Conclusion/Summary** | Skin | Not available. |
| | Respiratory | Not available. |

**Chronic toxicity**

Conclusion/Summary Not available.

**Carcinogenicity**

| Product/ingredient name | Result | Species | Dose | Exposure |
|---|---|---|---|---|
| Conclusion/Summary | Not available. | | | |

**Mutagenicity**

Conclusion/Summary Not available.

**Teratogenicity**

| Product/ingredient name | Result | Species | Dose | Exposure |
|---|---|---|---|---|
| Conclusion/Summary | Not available. | | | |

**Reproductive toxicity**

Conclusion/Summary Not available.

## 12.Ecological information

**Ecotoxicity** : No known significant effects or critical hazards.

**Aquatic ecotoxicity**

**Conclusion/Summary** : No known significant effects or critical hazards.

**Persistence/degradability**

**Conclusion/Summary** : No known significant effects or critical hazards.

**Partition coefficient: n-octanol/water** : No known significant effects or critical hazards.

**Other adverse effects** : No known significant effects or critical hazards.

## 13. Disposal considerations

Waste disposal Disposal should be in accordance with applicable regional, national and local laws and regulations.

## 14.Transport information

Not classified as dangerous

## 15.Regulatory information

**United States**

**U.S. Federal regulations** : **United States - TSCA 12(b) - Chemical export notification:** None of the components are listed.
**United States - TSCA 8(a) - Inventory update rule (IUR):** Not determined
**SARA 302/304/311/312 extremely hazardous substances:** No products were found.
**SARA 302/304 emergency planning and notification:** No products were found.
**SARA 302/304/311/312 hazardous chemicals:** No products were found.
**SARA 311/312 MSDS distribution - chemical inventory - hazard identification:** No products were found.

**United States inventory (TSCA 8b)** : Not determined.

**State regulations**

**Massachusetts** :

**New York** :

**New Jersey** :

**Pennsylvania** :

**California Prop. 65** : Not available.

**International regulations**

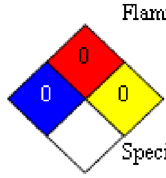
**Canada inventory** : Not determined.

**International lists** : **Australia inventory (AICS):** Not determined.
**Taiwan inventory (CSNN):** Not determined.
**Malaysia Inventory (EHS Register):** Not determined.
**Japan inventory:** Not determined.
**China inventory (IECSC):** Not determined.
**Korea inventory:** Not determined.
**New Zealand Inventory of Chemicals (NZIoC):** Not determined.
**Philippines inventory (PICCS):** Not determined.

## 16.Other information

*Version: Report version Report version Date of issue/Date of revision: Validity date*** Date of previous issue: 00/00/0000*

**National Fire Protection Association (U.S.A.):**

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| **Date of printing** | : | Print date |
| **Date of issue** | : | Validity date***. |
| **Version** | : | Report version.Report version |

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Figure A.1. Industry standard medium material safety data sheet

Nursery yard Cabbage Heads

There were no significant differences for K and Al cabbage head tissue for the first planting date. The C plants had the lowest head tissue Ca and highest B, Fe, Mn, and Zn. The C plants also had more P than Ca/Mg. Cabbage heads grown in all treatments had more Ca than the C by over 164%. The C and media Ca/Mg, 4L+Ca/Mg, and 8L produced cabbage with more Mg than the IS by 62%. Plants grown in the C medium had more S than the IS, Ca/Mg, 4L, and 4L+Ca/Mg. Plants from all treatments had less B than the C. The C and 8L heads had more leaf tissue Cu than all other treatments. Cabbage grown in the IS medium had more Mn than medium Ca/Mg. Treatment 4L heads had the highest Mo. The C cabbage had more Na than treatments IS and 4L. Cabbage produced by the IS, Ca/Mg, and 4L had less Zn than that produced by 8L (Table A.1).

There were no significant head tissue differences for P, K, Mg, S, B, and Fe for the second nursery yard planting date. Medium 4L+Ca/Mg produced cabbage with more Ca than media C, Ca/Mg, and 4L. Heads in 4L+Ca/Mg had more Al than those in the IS, 4L and 8L. The C cabbage and Ca/Mg had more Cu than plants from all other treatments. Cabbage from the C had more Mn than the IS, Ca/Mg, 4L+Ca/Mg, and 8L. The IS, C, and 8L cabbage heads had more Mo than heads from Ca/Mg and 4L+Ca/Mg. Heads from the C media treatments had 5.5% to 211% more Na than all other treatments. The C heads also had greater Zn leaf content than the IS, 4L, 4L+Ca/Mg, and 8L (Table A.1).

In the heads produced on the nursery yard, 4L+Ca/Mg contained similar to or more tissue Ca than other treatments across both planting dates. In the planting of green cabbage (first planting date), the IS had significantly lower Mg than all treatments, except 4L, but there were no differences for the second planting date (red cabbage). As was seen in lettuce, the C contained higher Na, presumably because it contained lower levels of other cations, such as Ca or Mg.

Table A.1. Mean cabbage head nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| | | | | | | Planting Date 1 (12/18/2012) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.59 ab[Y] | 3.4 a | 0.40 a | 0.13 b | 0.43 c | 1.7 a | 26 b | 4.2 b | 33 c | 41 b | 1.7 c | 2342 c | 22 c |
| 2 | 0.75 a | 4.0 a | 0.14 b | 0.21 a | 0.81 a | 4.4 a | 55 a | 7.6 a | 58 a | 81 a | 3.4 b | 7273 a | 59 a |
| 3 | 0.54 b | 3.3 a | 0.47 a | 0.20 a | 0.62 b | 1.5 a | 30 b | 3.8 b | 31 c | 21 c | 2.3 bc | 4610 abc | 21 c |
| 4 | 0.60 ab | 3.4 a | 0.53 a | 0.17 ab | 0.52 bc | 10.2 a | 28 b | 3.7 b | 37 bc | 25 bc | 5.0 a | 4344 bc | 24 c |
| 5 | 0.57 ab | 3.8 a | 0.37 a | 0.20 a | 0.61 bc | 3.6 a | 23 b | 4.0 b | 34 bc | 33 bc | 2.2 bc | 4996 abc | 28 bc |
| 6 | 0.63 ab | 4.0 a | 0.44 a | 0.22 a | 0.63 ab | 6.1 a | 35 b | 7.6 a | 45 b | 36 bc | 3.3 b | 6890 ab | 33 b |
| | | | | | | Planting Date 2 (2/18/2013) | | | | | | | |
| Tmt | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.53 a | 3.4 a | 0.25 ab | 0.22 a | 0.54 a | 1.1 b | 24 a | 3.6 b | 75 a | 40 bc | 3.6 a | 4023 b | 29 b |
| 2 | 0.78 a | 3.8 a | 0.17 b | 0.20 a | 0.71 a | 2.5 ab | 24 a | 5.7 a | 34 a | 90 a | 3.9 a | 13659 a | 56 a |
| 3 | 0.62 a | 3.8 a | 0.18 b | 0.26 a | 0.71 a | 3.9 ab | 29 a | 6.4 a | 43 a | 48 bc | 1.6 b | 8246 b | 39 ab |
| 4 | 0.56 a | 3.2 a | 0.18 b | 0.18 a | 0.59 a | 2.1 b | 23 a | 3.5 b | 28 a | 58 ab | 2.6 ab | 7416 b | 30 b |
| 5 | 0.57 a | 3.7 a | 0.33 a | 0.26 a | 0.72 a | 16.5 a | 23 a | 3.7 b | 53 a | 29 bc | 1.8 b | 6202 b | 32 b |
| 6 | 0.51 a | 3.5 a | 0.25 ab | 0.21 a | 0.54 a | 1.7 b | 24 a | 2.3 b | 18 a | 20 c | 3.4 a | 5954 b | 19 b |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$)

High Tunnel Cabbage Heads

There were no significant differences between P, K, B, Cu, Fe, Mo, and Zn leaf content in cabbage heads for the first planting date. Cabbages grown in the IS, Ca/Mg, and 4L had more Ca than the C medium. Cabbage heads from Ca/Mg had more Mg than the IS, C, and 8L, and they had more S than the IS. Medium 8L cabbage had more Al than all other treatments. Plants grown in the C medium had more Mn than those grown in media Ca/Mg, 4L, and 8L. Heads from treatment 8L had less Na than the C (Table A.2).

For the second planting date, there were no significant differences between P, K, Ca, S, Al, Fe, Na, and Zn head tissue content. Heads from medium 8L had 62.5% more Mg than the C, and 8L heads had more B than the C and 4L+Ca/Mg. Heads grown in medium 4L had more Cu than the IS heads. Heads from the C plants had the most Mn. Heads from the IS had more Mo than the C, Ca/Mg, 4L, and 4L+Ca/Mg (Table A.2).

Nursery yard Cauliflower Heads

There were no significant differences among treatments during the first planting date for head tissue Ca and Al content, and cauliflower heads from the C had more P, Mg, S, B, Cu, Fe, Mn, Na, and Zn than all other treatments. These results are semi-consistent with other crop results; however, it was not expected that the C would have the highest head Mg content of all treatments. Possibly the same hypothesis applied to nitrogen would apply here, because the C cauliflower heads were much smaller than the other treatments. The percent Mg may be higher because there was less head tissue. Cauliflower heads from C, Ca/Mg, 4L, and 4L+Ca/Mg had more B than the IS. For Cu, the C and Ca/Mg heads had more than all other treatments. The cauliflower heads grown in the IS medium had more Mn than media 4L+Ca/Mg and 8L. All media treatments, except 4L+Ca/Mg, had heads with more Mo than Ca/Mg. Heads from 8L had more Zn than those from Ca/Mg (Table A.3).

Table A.2. Mean cabbage head nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 1 (12/18/2012) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.63 a[Y] | 4.0 a | 0.67 a | 0.15 d | 0.48 c | 12 b | 31 a | 3.3 b | 38 a | 54 ab | 2.3 ab | 2794 bc | 30 a |
| 2 | 0.80 a | 4.1 a | 0.14 b | 0.18 cd | 0.68 bc | 8 b | 29 a | 4.8 ab | 38 a | 77 a | 2.1 ab | 8012 ab | 39 a |
| 3 | 0.85 a | 4.8 a | 0.60 a | 0.27 ab | 0.76 ab | 12 b | 33 a | 4.3 ab | 55 a | 29 bc | 1.6 ab | 7773 abc | 43 a |
| 4 | 0.82 a | 4.8 a | 0.65 a | 0.21 bc | 0.57 bc | 19 b | 34 a | 4.4 ab | 51 a | 25 c | 2.7 a | 5062 bc | 39 a |
| 5 | Missing values | | | | | | | | | | | | |
| 6 | 0.61 a | 3.6 a | 0.40 ab | 0.19 cd | 0.51 bc | 2 a | 29 a | 3.4 ab | 39 a | 35 bc | 1.4 ab | 2669 c | 31 a |
| Planting Date 2 (2/18/2013) | | | | | | | | | | | | | |
| Tmt | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.60 a | 3.9 a | 0.25 a | 0.23 ab | 0.48 a | 6.9 a | 27 ab | 3.1 b | 27 a | 46 bc | 3.3 a | 5839 a | 35 a |
| 2 | 0.65 a | 3.6 a | 0.12 a | 0.16 b | 0.64 a | 4.0 a | 21 c | 6.1 ab | 25 a | 71 a | 0.8 cd | 7135 a | 35 a |
| 3 | 0.58 a | 3.6 a | 0.16 a | 0.19 ab | 0.62 a | 5.5 a | 26 abc | 4.6 ab | 29 a | 48 b | 0.4 cd | 6888 a | 33 a |
| 4 | 0.65 a | 4.1 a | 0.20 a | 0.22 ab | 0.66 a | 8.7 a | 26 abc | 5.9 a | 31 a | 31 cd | 1.5 bc | 6540 a | 43 a |
| 5 | 0.55 a | 3.3 a | 0.23 a | 0.18 ab | 0.55 a | 2.4 a | 23 bc | 4.1 ab | 43 a | 29 d | 0.0 d | 5674 a | 36 a |
| 6 | 0.74 a | 4.7 a | 0.36 a | 0.26 a | 0.66 a | 162 a | 30 a | 3.9 ab | 42 a | 27 d | 2.3 ab | 5674 a | 44 a |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Cauliflower heads harvested from plants grown in the C medium had more P than all other treatments during the second planting date. The C and 8L heads had more K than the IS and Ca/Mg. Heads from plants grown in 4L and 5 also had more K than the C. Treatment 8L had 86% more head Ca content than the C and Ca/Mg, and it had 30% more head Ca content than 4L. This would be expected because 8L contains approximately double the Ca fertilizer (in the form of dolomitic lime) of Ca/Mg and 4L. The IS and 4L+Ca/Mg produced heads that also had more Ca than the C and Ca/Mg, which is also expected because 4L+Ca/Mg contains the same amount of Ca fertilizer (made up of dolomitic lime and calcium sulfate) as 8L. Heads from Ca/Mg, 4L, 4L+Ca/Mg, and 8L had more Mg than the IS. The C heads had more S than the IS, 4L, and 8L. Ca/Mg, 4L+Ca/Mg, and 8L also had more head S content than the C. There were no significant differences for Al among treatments. Ca/Mg, 4L, and 4L+Ca/Mg heads had more B than the IS. Heads from the C and Ca/Mg had more Cu than all other treatments. The C treatment heads had more Fe, Mn, and Zn than all other treatments. For Fe, 4L+Ca/Mg heads had more than Ca/Mg. Cauliflower heads from Ca/Mg had more Mn than 4L, 4L+Ca/Mg, and 8L. Heads from Ca/Mg had less Mo than all other treatments except 4L+Ca/Mg. The C had more head tissue Na content than the IS, 4L, 4L+Ca/Mg, and 8L. The IS had the least Na (Table A.3).

Nutrition of cauliflower heads produced varied by planting date; however, the C contained the most Na for both planting dates. Cauliflower head Ca levels were equivalent among media treatments for the first planting date, but lowest in cauliflower heads produced in the C and Ca/Mg media during the second planting date. Mg head levels during the first planting date were highest in the C medium, but the C was similar to the IS and all other treatments in the second planting date. Overall, there were no Ca and Mg differences across both planting dates for head nutrition.

Table A.3. Mean cauliflower head nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Planting Date 1 (12/18/2012) | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.68 b[Y] | 3.8 ab | 0.17 a | 0.177 c | 0.61 c | 10 a | 22 c | 4.2 b | 66 b | 34 b | 2.0 ab | 2919 b | 32 bc |
| 2 | 1.03 a | 4.3 a | 0.10 a | 0.283 a | 1.00 a | 24 a | 65 a | 7.0 a | 104 a | 64 a | 2.7 a | 9377 a | 86 a |
| 3 | 0.56 c | 3.2 b | 0.22 a | 0.195 bc | 0.71 bc | 245 a | 26 bc | 3.6 bc | 44 b | 18 c | 0.7 c | 4758 b | 24 c |
| 4 | 0.64 bc | 3.8 ab | 0.23 a | 0.196 bc | 0.81 b | 31 a | 28 bc | 4.2 b | 44 b | 23 c | 2.6 a | 5012 b | 31 bc |
| 5 | 0.55 c | 3.4 b | 0.20 a | 0.223 b | 0.72 bc | 368 a | 31 b | 3.5 c | 49 b | 22 c | 1.4 bc | 5418 b | 32 bc |
| 6 | 0.56 c | 3.7 ab | 0.14 a | 0.217 bc | 0.75 bc | 199 a | 27 bc | 4.2 b | 46 b | 25 c | 2.2 ab | 4603 b | 35 b |
| | Planting Date 2 (2/27/2013) | | | | | | | | | | | | |
| Tmt | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.56 c | 3.2 c | 0.11 ab | 0.17 b | 0.55 c | 4.7 a | 17 b | 4.3 b | 33 bc | 28 bc | 1.9 a | 2525 d | 35 b |
| 2 | 0.86 a | 4.0 a | 0.07 c | 0.20 ab | 0.88 a | 3.7 a | 19 ab | 6.2 a | 48 a | 50 a | 2.4 a | 6155 a | 65 a |
| 3 | 0.60 bc | 3.5 bc | 0.07 c | 0.22 a | 0.79 ab | 2.5 a | 23 a | 5.7 a | 31 c | 29 b | 0.4 b | 5126 ab | 34 b |
| 4 | 0.60 bc | 3.8 ab | 0.10 b | 0.22 a | 0.67 bc | 2.6 a | 23 a | 4.2 b | 35 bc | 24 cd | 2.4 a | 4054 bc | 32 b |
| 5 | 0.65 bc | 3.7 ab | 0.12 ab | 0.24 a | 0.81 ab | 2.6 a | 24 a | 3.7 bc | 38 b | 21 d | 1.4 ab | 4661 bc | 36 b |
| 6 | 0.66 b | 3.9 a | 0.13 a | 0.24 a | 0.70 b | 2.5 a | 20 ab | 3.2 c | 32 bc | 21 d | 2.5 a | 3780 c | 34 b |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

High Tunnel Cauliflower Heads

Data was only available for cauliflower grown in the IS, C, and Ca/Mg media for the first planting date, and there were no significant differences for any elements, except that cauliflower heads grown in Ca/Mg had 41% more Zn than the IS (Table A.4).

For the second planting date, there were no significant differences for Ca, S, Al, B, Fe, or Zn head content. Cauliflower heads grown in the C medium had more P than the IS and 8L. The IS, C, and 4L had more head tissue K content than 8L heads. Heads from 4L had 45% more Mg than the C, and 62% more Cu than the IS heads. Treatment 4L also had more Cu head content than 4L+Ca/Mg. Heads from plants grown in the C medium had the highest Mn content, and they also had more Mo than those grown in media Ca/Mg and 4L+Ca/Mg. As expected, heads from the C medium had more Na than the IS and medium 4L (Table A.4).

Nursery Yard Cucumber Fruit

There were no significant differences for the elements K, Ca, Al, B, or Mo fruit tissue content. Fruit harvested from plants grown in the C medium had greater P tissue levels than 4L. Fruit from Ca/Mg and 5 had over twice as much Mg as 4L fruit (Table A.5).

These are the two treatments that contain magnesium sulfate fertilizer; however, only 4L+Ca/Mg contained dolomitic lime. Fruit produced by the IS medium and medium 4L had less S than all other treatments (except 8L had missing data). Fruit from the C had more Cu than the IS. Medium 4L+Ca/Mg fruit had more Fe than all other treatments, except the C. The C had more fruit tissue Mn content than all other treatments, and 4L+Ca/Mg fruit had more Mn than 4L. Fruit harvested from the C had the most Na. The C fruit had more Zn than the IS and 4L (Table A.5).

Nursery Yard Cucumber Fruit

There were no significant differences between P, K, Mg, Al, and B for cucumber fruit grown under the high tunnel during the second planting date. Fruit from 8L had 1 to 4 times more Ca than

Table A.4. Mean cauliflower head nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planting Date 1 (12/18/2012) | | | | | | | | | | | | | |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.73 a[Y] | 4.0 a | 0.16 a | 0.19 a | 0.54 a | 8 a | 29 a | 4.4 a | 40 a | 33 ab | 1.2 a | 4685 a | 32 bc |
| 2 | 0.77 a | 4.1 a | 0.16 a | 0.19 a | 0.80 a | 356 a | 34 a | 4.2 a | 39 a | 55 a | 3.2 a | 9834 a | 42 ab |
| 3 | 0.77 a | 4.4 a | 0.16 a | 0.28 a | 0.89 a | 53 a | 29 a | 5.8 a | 68 a | 28 ab | 0.9 a | 6294 a | 45 a |
| 4 | Missing values | | | | | | | | | | | | |
| 5 | Missing values | | | | | | | | | | | | |
| 6 | Missing values | | | | | | | | | | | | |
| Planting Date 2 (2/27/2013) | | | | | | | | | | | | | |
| Tmt | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.69 b | 4.2 a | 0.16 a | 0.25 ab | 0.55 a | 2.5 a | 25 a | 3.7 c | 33 a | 29 b | 2.3 ab | 4589 b | 35 a |
| 2 | 0.94 a | 4.2 a | 0.14 a | 0.22 b | 0.87 a | 1.2 a | 23 a | 5.7 ab | 49 a | 68 a | 3.6 a | 8681 a | 50 a |
| 3 | 0.73 ab | 3.9 ab | 0.14 a | 0.24 ab | 0.74 a | 3.2 a | 26 a | 4.5 abc | 45 a | 26 b | 1.4 b | 7214 ab | 36 a |
| 4 | 0.78 ab | 4.4 a | 0.11 a | 0.32 a | 0.87 a | 2.7 a | 23 a | 6.0 a | 48 a | 29 b | 2.5 ab | 4568 b | 49 a |
| 5 | 0.75 ab | 4.0 ab | 0.17 a | 0.27 ab | 0.86 a | 3.3 a | 26 a | 4.4 bc | 46 a | 21 b | 1.4 b | 6249 ab | 41 a |
| 6 | 0.65 b | 3.6 b | 0.18 a | 0.25 ab | 0.70 a | 3.9 a | 31 a | 4.7 abc | 48 a | 22 b | 2.2 ab | 5637 ab | 36 a |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Table A.5. Mean cucumber fruit nutrition at harvest when produced on a nursery yard with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| Planting Date 2 (5/22//2013) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | ----------%---------- | | | | | ----------ppm---------- | | | | | | | |
| 1 | 0.71 ab[Y] | 3.7 a | 0.36 a | 0.29 ab | 0.20 b | 1.3 a | 20 a | 3.2 b | 20 b | 16 bc | 3.0 a | 2063 c | 23 b |
| 2 | 1.33 a | 4.9 a | 0.11 a | 0.38 ab | 0.81 a | 5.3 a | 33 a | 11.2 a | 59 ab | 71 a | 4.6 a | 14231 a | 76 a |
| 3 | 0.77 ab | 5.0 a | 0.41 a | 0.50 a | 0.68 a | 452 a | 36 a | 8.1 ab | 47 b | 39 bc | 7.2 a | 7673 b | 58 ab |
| 4 | 0.40 b | 2.4 a | 0.20 a | 0.15 b | 0.18 b | 287 a | 16 a | 3.8 ab | 22 b | 14 c | 2.8 a | 1871 c | 21 b |
| 5 | 0.82 ab | 6.0 a | 0.42 a | 0.49 a | 0.66 a | 10.3 a | 41 a | 9.1 ab | 103 a | 44 b | 7.7 a | 5074 bc | 60 ab |
| 6 | ----------Missing values---------- | | | | | | | | | | | | |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.

[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

Fruit results are preliminary because there was a lack of replication. Fruit was only sampled for nutrition during the second planting date, and disease was a problem during that planting. Preliminary results suggest that fruit Mg levels are increased by media fertilization with magnesium sulfate, but Ca levels were not affected by media fertilization with calcium sulfate or dolomitic lime.

fruit from C, Ca/Mg, and 4L, which was expected because 8L contains 8 lbs dolomitic lime per cubic meter, more Ca than all treatments except 4L+Ca/Mg. Fruit harvested from plants grown in the C medium and medium 4L had more Cu than the IS fruit. Treatment 4L had more fruit tissue Fe than the IS, 4L+Ca/Mg, and 8L. Fruit from 4L had more Mn than fruit from the IS, 4L+Ca/Mg, and 8L. The IS and 4L to 6 had more Mo in the fruit than Ca/Mg. Cucumbers from 4L had more Na and Zn than the IS (Table A.6).

Preliminary fruit nutrition results from the high tunnel suggest different results than those found from fruit tested on the nursery yard. Under the high tunnel, Ca levels, not Mg levels, differed by media Ca fertilizer type and amount. Further testing would be needed to determine cucumber fruit nutrition based on media fertilization.

Table A.6. Mean cucumber fruit nutrition at harvest when produced under a high tunnel with Ca and Mg amended organic media and alkaline irrigation for two planting dates.

| | Planting Date 2 (5/22//2013) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tmt[Z] | P | K | Ca | Mg | S | Al | B | Cu | Fe | Mn | Mo | Na | Zn |
| | % | | | | | ppm | | | | | | | |
| 1 | 0.58 a[Y] | 3.10 a | 0.30 ab | 0.28 a | 0.17 b | 1.8 a | 17 a | 3.1 b | 26 c | 13 b | 1.6 a | 1308 c | 22 b |
| 2 | 0.55 a | 2.68 a | 0.23 b | 0.19 a | 0.30 ab | 740 a | 17 a | 8.0 a | 87 abc | 32 ab | 1.4 ab | 3965 abc | 48 ab |
| 3 | 0.52 a | 3.67 a | 0.10 b | 0.28 a | 0.36 ab | 3.9 a | 18 a | 6.6 ab | 97 ab | 24 ab | 0.0 b | 4739 ab | 41 ab |
| 4 | 0.82 a | 4.26 a | 0.20 b | 0.42 a | 0.45 a | 9.1 a | 24 a | 8.5 a | 123 a | 42 a | 2.2 a | 5654 a | 66 a |
| 5 | 0.66 a | 3.63 a | 0.33 ab | 0.42 a | 0.43 a | 3.7 a | 21 a | 7.0 ab | 43 bc | 22 b | 2.9 a | 3060 abc | 41 ab |
| 6 | 0.71 a | 4.13 a | 0.52 a | 0.37 a | 0.32 ab | 603 a | 21 a | 6.2 ab | 54 bc | 19 b | 2.7 a | 2183 ab | 38 ab |

[Z]Treatments (Tmt) 1-6 are as follows (per cubic meter): 1-IS; 2- C (0 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate); 3- 0 kg lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 4- 2.4 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate; 5- 2.4 kg dolomitic lime, 2.4 kg calcium sulfate, 2.4 kg magnesium sulfate; 6- 4.7 kg dolomitic lime, 0 kg calcium sulfate, 0 kg magnesium sulfate.
[Y]Means within columns (within planting date) followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($P \leq 0.05$).

## VITA

Sarah Elizabeth Bertrand received her Bachelor's Degree in December 2010 from Louisiana State University with a Major in Plant and Soil Systems focused in Crop Management as well as minors in Biological Sciences and Environmental Management Systems. After a one year break, she returned to Louisiana State University for her Master's Degree, deciding to focus on Horticulture. She will receive her Master's Degree in December 2014 and intends to enter the workforce in vegetable production upon graduation.