Increasing the overwintering survival of container-grown perennials

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ABSTRACT

Container grown perennials are a popular product offered by nurseries and greenhouses and included in their production but little research has been reported on proper overwintering techniques for herbaceous perennials and ornamental grasses.

In the first experiment rooted liners of *Pennisetum alopecuroides, Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny,' were potted. Treatments included, utilizing two overwintering covers, two fertilizer rates (low or high) and two substrate moisture contents (wet or dry). Covering with either a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric and a single sheet of 4 mil white polyethylene plastic on top of the insulation fabric, wet substrate treatments, low fertility rates and combinations of both, improved survival and vigor for all three tested *Pennisetum* species and cultivars.

In the second experiment, rooted liners of *P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny,' were potted. Treatments included, two transplanting times (young or old), two fertilizer rates (low or high) and two substrate moisture contents (wet or dry) at the UHC and Poplar Ridge Nursery (Montross, VA) (PR). Vigor was improved for *P. alopecuroides* (at PR) and *P.* 'Little Bunny' (at both locations) with the young transplanting time.

In the third experiment, older plant material of *P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny,' were subjected to fertility treatments of no additional fertilizer or top-dressed at a low, medium or high rate . A high fertility rate reduced survival and vigor for *P.* 'Little Bunny.'

In the fourth experiment rooted liners of *Echinacea purpurea* 'Hot Papaya,' *Echinacea purpurea* 'Milkshake,' *Gaillardia* x *grandiflora* 'Gallo Peach,' *Heuchera* x *villosa* 'Pistache,' *Heuchera* x *villosa* 'Brownies,' *P. alopecuroides, P.* 'Cassian,' *P.* 'Hameln' and *P.* 'Little Bunny,' were potted and overwintered at the UHC or Poplar Ridge Nursery (Montross, VA) (PR) or Riverbend Nursery, Inc. (Riner, VA) (RB). Treatments included, utilizing two overwintering covers, two fertilizer rates (low or high) and two substrate moisture contents (wet or dry). Vigor at the UHC, was reduced with the high fertility rate for *E.* 'Hot Papaya' and *H.* 'Brownies.' A double layer of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic on top of the cover, in combination with the wet substrate moisture treatment improved vigor of *E.* 'Hot Papaya.'A double layer of Dewitt N-Sulate™ insulation fabric in combination with the wet substrate moisture content and the high fertility rate reduced *P.* 'Cassian' vigor. No overwintering cover reduced *P.* 'Hameln' vigor. No overwintering cover and the high fertility rate reduced *P.* 'Little Bunny' vigor. Vigor at PR was improved with the high fertility rate for *E.* 'Milkshake,' *G.* 'Gallo Peach' and *H.* 'Brownies.' At RB, a double layer of Dewitt N-Sulate™ insulation fabric in combination with the low fertility treatment and no cover in combination with the high fertility treatment reduced vigor for *E.* 'Milkshake' and *P.* 'Little Bunny,' respectively. No cover in combination with the wet substrate moisture treatment reduced vigor for *G.*'Gallo Peach.'

Dedication

I don't know where to start to my dedication. There are so many people I want to dedicate this to. This will be a dedication and an acknowledgements section.

So first and foremost I dedicate this to God. Without him as a major part of my life I don't know if I would have gotten to where I am today.

I would like to dedicate this to my family. My parents sacrificed everything and I mean everything to get me through undergrad. Without their help I would never have become a graduate twice over. I cannot begin to thank them enough for everything they have done for me over the years. Pushing me to go to college in the first place was a major accomplishment on their part and then putting up with me trying to go my own way for a couple of years is another. Through it all, I'm a better person for listening to them and for having such wonderful parents like them. Mom, Dad, Chelsea, thank you so much for helping me and being there for me through it all. I love you all so much.

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Chapter 1

Literature Review

Popularity of Container Grown Herbaceous Perennials

Herbaceous perennial production in the United States is a growing facet of the horticultural industry. Barrett (2010) concluded from a USDA 2009 survey that perennial production had grown 10% between 2000 and 2005. From the same USDA survey conducted in 2009, results showed that all horticultural crop sales in the U.S. were valued at $11.7 billion. Of that, Virginia sales accounted for $186 million and of that, $23 million were from the sale of container grown perennials. Container grown perennials are included in the product mix offered by many nursery and greenhouse operations, in Virginia, because of their sale value.

Perennial production has been accomplished by either field production or container production. Field production is the traditional method of producing and marketing ornamental trees, shrubs, fruit trees, and perennial flowers (Dunwell, 2009a). The practice of producing bare root plants is accomplished as well by field production. Benefits of field production include being a good production method for larger materials typically used in landscaping, it can be less demanding in terms of maintenance and labor during the growing period, plants do not require winter protection, and field production can have lower start-up costs. Typical perennials which are preferred by growers to use in field production include crops such as daylilies and peonies (Perry, 2006). Retail field production of perennials is typically marketed towards consumers as a dig-your-own operation or as custom dug products. According to Perry (2006), field production of perennials, in the United States, is a method of production which was more popular in the past.

The second method of perennial production is container production. According to Herrick and Perry (1995), containerized production of herbaceous perennials has become increasingly popular as an alternative to field production. Dunwell (2009b) described the container nursery business as the production and marketing of ornamental trees and shrubs, fruit trees, and perennial flowers grown in above-ground containers. Container production has helped revolutionize the nursery business in the last few decades. The advantages of container production include: less acreage required for production, handling convenience, and a nearly year-round harvest and planting season. When compared to field production, container production is more grower controllable and more adaptable to mechanization.

Overwintering Container Grown Perennials

Overwintering container grown perennials is a practice that can be used during the production cycle of a crop. It is a practice that is preformed during cold months when a plant has reached dormancy. Overwintering can be defined as keeping a plant alive but not actively growing during the plant's dormancy period. Rohde and Bahlerao (2007) define dormancy as a plant's inability to initiate growth from its meristems (along with other organs and cells that have the capacity to resume growth) under favorable conditions. Additionally, Rohde and Bahlerao (2007) conclude that a plants ability to resume growth by either elongation or cell division is what distinguishes the meristem (and other organs capable of growth), which have not yet completed their development, from other organs that undergo little or no growth following their release from dormancy.

Overwintering is included in the perennial production cycle for a variety of reasons. The first being holding plants which had not sold from the previous year, to sell the following spring. The second being plant material purchased as plugs (vernalized or non-vernalized), which then can be potted up in late winter or early spring for late spring sales (Smith, 2004). The third being producers transplanting one year old plants into 3.78 liter (1 gallon) to 11.35 liter (3 gallon) containers in September or early October allowing time for the root system to establish and then these plants are overwintered in protective structures in order to sell in the early spring (Smith, 2004). The fourth being producers purchasing plugs and potting them up in the summer or early fall for early spring sales. Finally, many perennials require vernalization, a period when a plant is subjected to low temperatures. Many species will not flower unless they have had their vernalization requirement fulfilled. According to Runkle (2007), satisfying vernalization requirements for some herbaceous perennials is essential to initiate or accelerate flowering.

With the many uses and benefits of overwintering, many growers throughout the mid-Atlantic region experience significant percentages of plant losses during winter dormancy for certain plant species. Factors attributed to these losses, in the literature, include lack of cold hardiness, inadequate substrate moisture levels, improper fertilization, and temperature fluctuations.

Cold Hardiness

Some perennial plants cannot survive low overwintering temperatures and conditions (Bilderback and Bir, 2007). Low temperatures can be detrimental to some perennials because of their specific cold hardiness (Table 1.1). Cold hardiness can be defined as the lowest winter temperature that plant tissue can endure without damage from freezing (Rose, 2001). Low temperatures have been considered to be the primary environmental factor in influencing cold hardiness initiation in herbaceous plants (Li, 1984). Cold hardiness is a plant's ability to acclimate, due to metabolic changes in the plant, to freezing temperatures; this is determined genetically (Rose, 2001).

Table 1.1 Root Hardiness of container grown perennials (Perry, 1998)

Genus	Damaging Growing Media Temperature	Genus	Damaging Growing Media Temperature
TENDER		**INTERMEDIATELY HARDY (Continued)**	
Aster lateriflorus var. hortzontalis	28˚F	Tiarella cordifolia var. collina 'Oakleaf'	21°F
Digitalis x mertonensis	24˚F	Tricyrtis hirta 'Miyazaki'	21°F
Geum Uuellyon 'Mrs. Bradshaw'	24˚F	Verbena 'Homestead Purple'	18°F
Hibiscus moschentos 'Disco' series	above 38°F	Veronica 'Sunny Border Blue'	21°F
Houttuynia cordata 'Chameleon'	28˚F	**HARDY**	
Kniphofia uvaria 'Pfitzer's hybrids'	27˚F	Achillea 'Coronation Gold'	8°F
Polystichum tsussimense	above 38°F	Achillea filipendulina 'Parker's Variety'	12°F
Thelypteris kunthii	28˚F	Campanula takesimana	12°F
Tricyrtis formosana 'Amethystina'	28˚F	Dendranthema grandiflora 'Baby Tears'	below 10°F
INTERMEDIATELY HARDY		Dendranthema grandiflora 'Debonair'	below 10°F
Astilbe x arendsii 'White Gloria'	15°F	Gaillardia x grandiflora 'Monarch Group'	12°F
Campanula glomerata var. acaulis	15°F	Heuchera americana 'Dale's Strain'	12°F
Caryopteris x clandonensis 'Longwood Blue'	21°F	Hylotelephium (Sedum) spectabile 'Brilliant'	-6°F
Chrysanthemum coccineum	21°F	Lythrum salicaria 'Robert'	12°F
Coreopsis grandiflora 'Sunray'	18°F	Monarda 'Marshall's Delight'	8°F
Dendranthema grandiflora 'Emily'	above 10°F	Penstemon fruticosus 'Purple Haze'	12°F
Dendranthema grandiflora 'Megan'	above 10°F	Phlox divaricata subsp. laphamii 'Chattahoochee'	7°F
Dendranthema grandiflora 'Ruby Mound'	above 10°F	Phlox glaberrima 'Morris Berd'	7°F
Dendranthema grandiflora 'Triumph'	above 10°F	Phlox paniculata 'White Admiral'	8°F
Erodium x variabile 'Roseum'	18°F	Physostegia virginiana 'Summer Snow'	7°F
Erysimum hieraciifolium	21°F	Rosmarinus officinalis 'Arp'	12°F
Gaillardia x grandiflora 'Goblin'	14°F	Salvia x superba 'Stratford Blue'	10°F
Hebe macrocarpa 'Margaret'	18°F	Sedum 'Autumn Joy'	-11°F
Hemerocallis 'Joan Senior'	15°F	Tanacetum coccineum 'Robinson's Mix'	10°F
Heuchera sanguinea 'Chatterbox'	14°F	Tiarella cordifolia var. collina 'Slick Rock'	12°F
Leucanthemum x superbum 'Alaska'	15°F	Tiarella cordifolia var. collina 'Laird of Skye'	8°F
Phlox paniculata 'David'	21°F	Tiarella cordifolia 'Running Tapestry'	12°F
Tiarella cordifolia var. collina 'Dunvegan'	15°F	Veronica repens	7°F

Acclimation (Figure 1.1) is dependent on two factors: the genetic capacity of the specific plant species to withstand freezing temperatures and the expression of the genetic capacity in response to certain environmental clues such as changes in photoperiod, low temperature and drought (Chen et al., 1979; Cloutier, 1984; Graham and Patterson, 1982; Guy, 1990; Welling et al., 2002). Additionally, a plant species' inability to resist low temperatures and survive winter periods is a factor in limiting a species' geographical range (Roberts and Niska, 1980). Low temperatures (2°C to 5°C) and light are necessary factors in cold acclimation of herbaceous plants (Kacperska-Palacz, 1978).

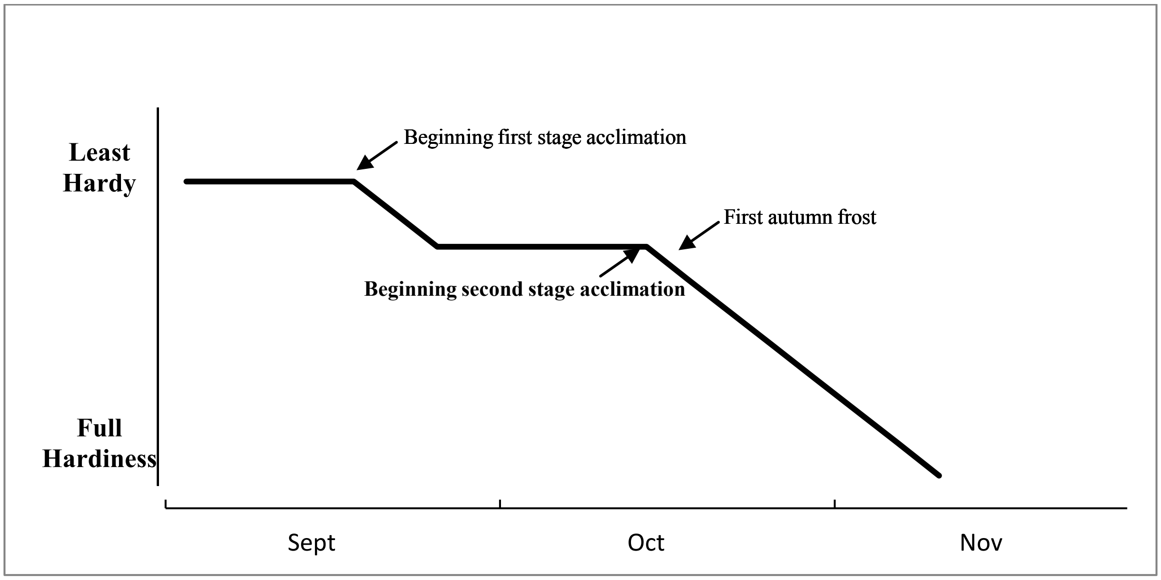

Figure 1.1 Plant acclimation pattern (Adapted from Bilderback and Bir, 2007)

A plant's cold hardiness will fluctuate during different seasons. It has been found that a plant that is killed at temperatures slightly below freezing in the summer may be able to survive temperatures at -196°C in the winter (Weiser, 1970). Cold hardiness changes in response to the environment and the responsiveness of the plant to the environmental changes depends on the growth stage of the plant (Weist et al., 1976).

The roots are one of the most susceptible organs to cold injury in herbaceous plants (Sakai, 1987). Research has shown that roots cannot acclimate to low temperatures as quickly as shoots (Rose, 2001). Cold hardiness in roots can be attributed to the temperature of the soil. Weekly changes in the root hardiness of apple trees coincided with soil temperatures (Wildung et al., 1973). Roots do not go through a period of dormancy but with lower temperatures, root growth slows and hardiness increases. It has been found that in the woody plant species, *Pyracantha coccinea* that there is as much as a 22°C difference in hardiness between the aerial portion of the plant and the roots (Kacperska-Palacz, 1978). Additionally, it has been found that in the woody container grown species, *Ilex cornuta* that the aerial portion of the plant can survive air temperatures of -23°C, while the roots will be killed at -8°C (Whitcomb, 1984).

In regards to herbaceous perennial roots, specifically the young terminals (root tips), do not acclimate to any great extent. The roots respond only to lower temperatures by reaching a quiescent dormancy, which can be defined as a "resting" state in which growth will resume when conditions return to being favorable for growth (Perry, 1998).

Substrate Moisture

The purpose of growing media is to provide support for the plant, and sufficient oxygen, water and nutrients in order for roots to function properly (Ingram et al., 2003). A challenge in overwintering plants in containers is providing the proper amount of moisture.

Soil moisture is important to root hardiness and survival. According to Wildung et al. (1973), improperly hydrated roots of *Malus robusta* (MR) 5 and Malling (M) 26 were less hardy when compared to hydrated roots. Bilderback and Bir (2007), state that plants which are subjected to dry conditions during the fall are less able to withstand severe winter conditions.

Providing adequate moisture is important because in overwintering the main goal is to protect plants, most importantly the root system from temperature extremes. Dry soil freezes much quicker when compared to wet soil because water releases heat as it changes from the liquid to the solid phase (Smith, 2004). This heat helps to protect roots from freezing during low temperature cycles. Thus, watering plants prior to overwintering is essential to plant survivability because the water is used by the plants as a source of heat. When growing media has adequate amounts of moisture then a moisture barrier has been established. This barrier can help to prevent the soil mix from drying out. This also provides an insulating effect the roots, which helps to keep a continuous temperature slightly above that which can cause freeze damage to the roots (Still et al., 1987). Additionally, cool or frozen soils inhibit water movement to plant shoots which need water on uncharacteristically warm winter days (Dunwell and McNiel, 2010).

In growing media, there must be a balance also between the amount of available water and the amount of aeration. Proper oxygen concentrations must be maintained, if not then anaerobic conditions will occur. Anaerobic conditions do not allow the roots to obtain energy from respiration, which will then create an environment conducive to disease development (Ingram et al., 2003).

High moisture levels should be avoided because keeping plants too wet could help to facilitate disease development of *Phytophthora* species (Smith, 2004). Root rots are caused by *Phytophthora* species which reproduce asexually by sporangia and zoospores (Standberg, 2002). When water is provided by irrigation and rain, this facilitates the reproduction and spread of *Phytophthora* species (Standberg, 2002). In container grown perennial production a common *Phytophthora* disease is *Liriope* species leaf and crown rot. *Liriope* species leaf and crown rot is caused by *P. palmivora* (Standberg, 2002). For this *Phytophthora* species to be able to reproduce and spread, an abundant source of water in the soil is needed. If the *Liriope* species are frequently kept at, or near, soil moisture capacity, conditions favorable for infection are created. Hagan and Mullen (2000) have stated that in the production of *Rhododendron* and *Azelea* species, overwatering will contribute to losses from *Phytophthora* root rot. *Phytophthora* root rot is most commonly seen in production nurseries and landscape plantings on poorly drained, waterlogged soils that are prone to flood. Hagan and Mullen (2000) conclude that disease development is usually slow or absent on well-drained sites.

Fertilization

Fertilization of container grown perennials provides nutrients to plants and is essential to plant health and growth during a production cycle. Applying fertilizer to container grown plants can be accomplished by two means, controlled release fertilizers or water soluble fertilizers through a constant liquid feed (or fertigation). Controlled release fertilizer (CRF) is a way to provide nutrients to a plant which are gradually released over a period of time (Dole and Wilkins, 1999; Sonneveld and Voogt, 2009). Controlled release fertilizers may be either incorporated into the growing media or applied by broadcasting (topdressing) on top of the media surface (Chen et al., 2001). Water-soluble fertilizers can be applied through fertigation, which is adding fertilizer to irrigation water (Chen et. al, 2001).

Delivering nutrients to plants by fertigation has been a widely accepted practice (Harrison, 2009). Water soluble fertilizers applied by fertigation are popular with growers because of the high degree of control of nutrition that it provides (Boman and Obreza, 2002). Fertigation is known to produce poor fertilizer use efficiencies and therefore some serious and undesirable environmental consequences (Colangelo and Brand, 1997; Lang and Pannkuk, 1998; Obreza and Sartain, 2010; Wilson and Albano, 2011; Wright, 1987) and because of this, controlled release fertilizers have grown in use (Obreza and Sartain, 2010; Wilson and Albano, 2011; Wright and Niemiera, 1987). Unknown to growers is if the rates recommended and applied in woody ornamental nursery stock are suitable for herbaceous perennials.

Recommendations for proper fertilization of herbaceous perennials vary from source to source and nutrient requirements among plants species can differ (Armitage, 1996; Scoggins, 2005). Cabrera and Perdomo (2003), found that for *Coreopsis* 'Early Sunrise' and 'Zagreb,' *Astilbe* 'Bridal Veil,' *Hemerocallis* 'Stella de Oro,' *Phlox* 'Franz Shubert' and *Rudbeckia*

'Goldsturm' controlled release fertilizer rates may need to be lower than those commonly used on other nursery crops. According to Chen (2010), it is recommended for herbaceous perennials that controlled release fertilizer be incorporated once at the time of transplant and then top-dressed once in the middle of a growing season.

Plants which are receiving adequate levels of nutrients will stand a better chance of surviving over the winter (Bilderback and Bir, 2007). However, fertilizer applied prior to overwintering could cause a flush of growth, potentially preventing hardening-off. This could lead to wintertime losses (Bilderback and Bir, 2007). There is little information on the proper fertilization prior to overwintering for container grown-herbaceous perennials. Overwintering fertility research has mainly focused on woody ornamentals and nursery stock.

In general, for both woody and herbaceous plants, healthy plants that are not excessively vigorous, prior to overwintering, are better able to withstand winter freezes and thus fertilizer applications should provide enough nutrients to sustain only normal growth and development (Berghage and Sellmer, 1999). Vegetative growth slows in late summer to early fall, at which time the rate of nitrogen should be gradually reduced to half of the rate applied during the growing season (Beattie, 1986).

Temperature

Temperature fluctuations can occur frequently while plants are being overwintered. Excessive heat can build up under overwintering covers and inside of overwintering structures during periods of warm weather (Bilderback and Bir, 2007). If this warmth remains, then plants could break dormancy or lose some hardiness and be injured when the temperatures drop to freezing. Perennials have a finite reserve of carbohydrates that are utilized for winter survival and new growth in the spring. At the time of fall dormancy carbohydrate reserves are at their highest level and then decrease as dormancy continues (Vallentine, 2001). If plants break dormancy prematurely then the remaining carbohydrates will be allocated to maximize growth but chilling temperatures could still occur which could lead to plant death. Since the roots of herbaceous perennials undergo quiescence dormancy, short, warm periods of weather can start growth again, which also can result in injury. For this reason, fluctuations in temperature can be harmful. As with most factors, the extent of injury varies with species (Perry, 1998).

Plants which are protected in either a cold-frame (polyhouse), with overwintering covers or both, must be inspected on a regular basis to guarantee that shoot growth has not initiated. It is recommended that if shoot growth has initiated then, the overwintering location should be vented if possible to introduce cool air into the system to slow plant development (Perry, 2006). Growers have been known to cut large holes in the sides of cold-frames to facilitate ventilation. Growers who use thermoblankets as overwintering cover will uncover the plants until the weather becomes colder (Perry, 1998).

Gouin and Link (1979) stated from their results from overwintering woody ornamentals, that fluctuating temperatures under thermal blankets from mid to late winter could create a problem by stimulating premature growth. Plants which had premature growth would be susceptible to late frost injury after the plants were uncovered. According to Havis (1976) woody plant roots can be injured from temperatures as high as -5°C and damage often follows large temperature fluctuations (Roberts, 1980).

Wide temperature fluctuations can also occur under overwintering covers. Perry (1998) states containers overwintered under polyblanket systems tend to warm prematurely during winter thaws or towards the end of the overwintering period. This can initiate shoot growth, which could be injured upon the return of freezing conditions. Perry (1990) conducted studies on different types of coverings and found that on sunny days with no snow cover, air temperatures under Plantfoam™ (polyester spun-bound fabric) was 40°C while temperatures were 18-20°C under reflective (white poly film) covers with an ambient air temperature of 10°C.

These fluctuating temperatures are also a cause of concern for growers on when to cover and uncover plants. When days become shorter and temperature begin to lower in the fall, woody plants respond by going through as many as three levels of hardening (Perry, 1998). Unlike woody plants though, most herbaceous perennials have no woody portions. Most containerized nursery stock is covered as late in the season as weather permits. It is not uncommon to see plants being covered as late as early December in the Mid-Atlantic area, or in mid to late November in the New England area (Perry, 1998). Waiting as long as possible to cover plants will help the plants to achieve a level of hardiness that will minimize the risk of winter injury during overwintering. Research at the University of Vermont, shows that the time of covering is not as crucial as the time of uncovering (Perry, 1998). It is not possible to identify an exact date and time for uncovering containerized plants that have been overwintered because of the variability in weather conditions each year. When uncovering overwintered plants a compromise must be reached between preventing premature shoot growth and guaranteeing that cold weather at the time of uncovering in late winter and early spring does not kill or injure plant parts (Perry, 1998). Smith (2004) suggests that gradual removal of the overwintering covers in February and March, depending on the USDA hardiness zone, is best to avoid plant injury.

The process of taking the cover off the overwintering structure in the spring is just as critical as the overwintering covers on the plants. Gradual removal of the cover, in February for mild areas (such as USDA plant hardiness zones 6–8 and March for cold areas (such as zones 3–5), is suggested (Perry, 1998). The first step, when preparing to take the cover off of the structure is to open the doors and windows at night. After that then small vents can be cut into the ridge of the cover. Then these initially cut out vents should be enlarged. Finally, the cover is removed in late March to April (Perry, 1998).

Also associated with the temperature fluctuations that can occur is the fact that excessive humidity, under overwintering covers or in a cold-frame, could develop resulting in root and shoot diseases such as *Phytophthora* root rot and botrytis if no venting is provided (Smith, 2004). Venting the covers may be advisable during unexpected periods of warm winter weather. Covers are usually so tightly placed over the plants that air exchange under the covers is practically nonexistent. If overwintering in warmer regions, where plants are not covered for long periods, then this is of little concern. If overwintering in colder regions, where plants are covered for longer periods (3-5 months) of time, the development of molds, decay, or rodent damage could be of a concern (Bilderback and Bir, 2007; Perry, 1998; Pyle, 1997).

The conditions that occur during overwintering are conducive to mold and decay development as well as an environment for microorganisms to flourish. Plants which are sprayed with a broad-spectrum fungicide or a combination of two or more fungicides just before overwintering could have fewer problems with plant specific diseases occurring during overwintering. Before overwintering, it is recommended that all foliage is removed because this can help prevent many diseases from developing (Perry, 1998). Along with microorganisms, rodents such as field mice also enjoy the conditions provided during overwintering plants. One aspect to be aware of is overwintered container perennials, under cover, can provide rodents with an environment of warmth and food. Many rodents are known to consume either the foliage of overwintered plants or the roots (Miller, 1999; Wolf and Cerny, 2002). Most growers use some form of poison bait under the covers to control rodent populations but these baits may not be effective, depending on the number of rodents and food needs (Perry, 1998).

Overwintering Techniques

Many techniques can be used when overwintering container grown plants. Plant species and the ability of roots to withstand cold temperatures partially dictates the overwintering technique used (Weist and Steponkus, 1976), as well as the producer's capabilities and budget. Overwintering can take place in unheated or minimally heated cold-frame structures or under no structure at all. When using no structure or unheated cold-frames, overwintering covers can be used to provide plants protection.

Structures

One of the most common systems used to protect overwintered container grown herbaceous perennials is the Quonset-style, polyethylene-covered cold-frame structure (Figure 1.2) (Perry, 1998). A cold-frame is a Quonset type structure that is typically 14' wide, 7' high in the middle and 100' long, covered with either a single or double layer of clear or white polyethylene plastic. Variations among the cold-frame structure, in regards to width, height and length can be seen throughout Virginia. Unheated cold-frames have been growing in popularity for years and offer considerable protection to plants (Davidson and Mechlenberg, 1974; Knewtson et al., 2010; Perry, 1998; Smith, 2004). Cold-frames are easily constructed and can be a fairly inexpensive avenue to pursue to provide winter protection to plants (Smith, 2004).


Figure 1.2 Quonset Style Cold-frame (Credit: William K. Harris)

These structures are typically constructed of wooden frames which serve as a base in which to attach bent galvanized pipe or metal conduit and polyethylene plastic. The bent pipe or conduit is typically referred to as a bow and it provides the basic rib structure which supports the polyethylene (either one layer or two air inflated layers) plastic placed over the bow (Perry, 1998). The polyethylene plastic cover allows certain wavelengths of light to pass through and as a result objects within the structure absorb this light and convert it to heat energy. The plastic cover traps some of this heat during the day and then the stored heat radiates from the structure at night, thus cooling the structure as well as the objects within it (Perry, 1998). When overwintering plants in a poly house, using a single layer of polyethylene covering does a poor job of holding heat inside of that poly house (Good et al., 1976). Furthermore, on a cold winter day heat can radiate out of the poly house in the late afternoon or early evening rapidly. Wien (2009) found that in the winter, air temperatures in a cold-frame during sunny days rose above freezing even when ambient air temperatures stayed below freezing. According to Perry (1998), under average conditions in mild climates, temperatures within these structures do not reach levels injurious to plants stored inside but, conditions can occur in which temperatures may lower inside of the structure to a point that can be detrimental to plants. These conditions can be created when there is extended periods of extreme cold (more than two consecutive nights when ambient temperatures go below 0˚F). Ultimately, cold-frames do have thermal limits in terms of protection for plants.

Considering the initial startup costs of constructing Quonset-style polyethylene structures, costs can be expensive in terms of materials and labor needed. However, according to Perry (1998) a well constructed cold-frame can easily last ten or more years before any major renovations are needed (other than polyethylene plastic replacement). Additionally, when overwintering plants, using cold-frame can be an efficient technique to overwinter plants since thousands of plants can be placed in these frames and be covered with plastic quickly (Perry, 1998).

Weist et al. (1976), found that cold-frames covered with a single layer of clear polyethylene provided more protection than the white polyethylene. Even though better protection was provided by the single layer of clear polyethylene, this environment provided the greatest temperature fluctuations. Weist et al. (1976), also found that fluctuations of air temperatures below 0°C were most rapid in the clear houses, and depended on the relative humidity, which affected the thermal conductivity of the air. Hicklenton (1982), reports that, the benefits of using a single-layered, white polyethylene covered cold-frame is that it is inexpensive but a disadvantage is that often times it will not provide adequate protection during the winter. Hicklenton (1982) also reported that a single layer, white copolymer house, may only provide adequate protection for plants with roots hardy to -8°C in areas with mean annual minimum temperature above -15°C. Good et al. (1976) reported from data collected during the winters of

1974-1975 and 1975-1976 in Ithaca, N.Y. that double layer poly structure provided more protection against outdoor winter temperatures than a single layer house. Weist et al. (1976) found that the best covering for overwintering structures of woody plants was a double layer poly house with the interior being covered with translucent plastic and the exterior being covered with white polyethylene plastic. This type of cold-frame covering helps to moderate low container temperature, high mid-day temperature, desiccation and rapid temperature fluctuation more effectively than single layer poly (clear or translucent) or double layer of clear poly.

Structure-less overwintering systems are mainly utilized because they are of the lowest cost to provide winter protection to plants. Structure-less systems are created by simply laying a type of protective cover over plants and securing the edges of the protective cover. In warmer regions, growers overwinter container plants by placing them on their sides and covering them with white plastic, shade cloth, burlap or straw (Goiun, 1973). The main disadvantage to using a structure-less overwintering system is that the time of the uncovering of plants is much more critical (Goiun, 1973). Uncover as early as possible (if not using white poly plastic) to prevent bud break, or use white poly plastic on top of a thermal blanket because heat buildup is not as much as a factor, thus the problems associated with uncovering too early or too late are reduced (Goiun, 1973).

Iles et al. (1993) evaluated different protective covers used for structure-less overwintering systems and found that utilizing 30 cm of straw between two layers of 4-mil white polyethylene on plants above ground or an 18 cm deep in ground bed protected with one layer of 4-mil white polyethylene and 30 cm of woodchips, provided the greatest moderation of winter low and early spring high temperatures but resulted in severe etiolation. Additionally, Iles et al. (1993) found that a bonded white polyethylene/microfoam overwintering blanket (thermoblanket) with translucent properties, pulled tightly over plants above ground, provided comparable plant survival percentages despite dramatic temperature extremes recorded beneath that cover. Additionally, this cover, in late winter, created an environment conducive to moderate plant growth without formation of etiolated tissue.

Covers

Unfortunately, winter protection in an unheated cold-frame is limited. Unlike field grown nursery stock, plants which are overwintered in containers require additional protection to prevent injury from low temperatures, desiccation and other winter-time associated conditions (Smith, 1977). Plants that are considered marginally hardy when grown in containers should get additional protection in the form of a supplementary poly or thermal blanket (thermoblanket) laid on top of plants, inside the cold-frame (Perry, 1998). Other than using a poly or thermal blanket as a cover, a combination of plastic on top of straw on top of plastic ("sandwich technique") can be used as well.

A thermal blanket effectively encloses and insulates plants from changes in the outside environment, thus preventing temperature extremes (high and low) and helps to maintain a more uniform temperature around the plant (Weist et al., 1976). Iles et al. (1993) stated that microfoam (a type of thermoblanket) is useful for perennial growers in the structure-less overwintering of hardier perennials, especially in areas that have a substantial amount of snow cover for added insulating effect. Placing thermoblankets over plants within a poly structure is another technique that moderates low temperatures. This technique, referred to as the supplementary polyblanket or thermoblanket technique, can create a microclimate surrounding the plants that is 4.4°C-5.5°C warmer than air above the blanket inside the structure (Mader and Feldman, 1948; Perry, 1998).

Options for the type of cover (blanket) that can be used includes thermal blankets, polyethylene plastic and a combination of plastic and straw. Thermal blankets go by the trade names such as Frost Protek™ (Hill Street Home, Inc., Fort Collins, CO) and Dewitt N-Sulate™ (DeWitt Company, Inc., Sikeston, MO) etc. and are made of polypropylene or spun-bound polyester, respectively. Research has shown that using thermal blankets can result in high quality overwintered plants (Hicklenton, 1982).

Perry (1990) studied overwintering of container grown herbaceous perennials in Burlington, Vermont (USDA zone 5). His treatments were: 1) plants left uncovered, subject to ambient conditions; 2) one layer of 4-mil white polyfilm; 3) a layer of 0.63 cm Microfoam™ with a layer of white polyfilm on top; 4) a 0.63 cm layer of Plantfoam™ (similar to Microfoam™) with no layer of polyfilm on top; 5) 3 layers of Microfoam™ with a layer of white polyfilm on top; and 6) a "sandwich" of 30 cm fluffed oat straw between layers of white polyfilm.

Using a rating scale of 1-5, with 1 being dead and 3-5 being saleable, Perry (1990) found that *Lavendula* and *Dianthus* showed no statistically significant difference in plant survival rating among treatments. *Cheiranthus* and *Heuchera* had best survival under 3 layers of microfoam with poly cover or with the "sandwich" cover. These were the only treatments in which *Cheiranthus* was a saleable plant while all treatments for *Heuchera* resulted in saleable plants.

Still et al. (1987) studied overwintering of container grown herbaceous perennials (in Columbus, Ohio (USDA zone 5b). His treatments included: 1) Structure less, 0.64 cm single layer thermal blanket foam with a single layer of 4-mil white copolymer film on top; 2) a 4 m tall hoop poly house covered with 4 mil white copolymer film and plants inside remained uncovered;

3) a 4 m tall hoop poly house covered with 4-mil white copolymer film and plants inside were covered with thermal blanket foam and 4-mil white copolymer film; 4) a 2 m tall hoop poly house covered with one layer of 4 mil white copolymer and one layer of 4-mil clear copolymer and plants were left uncovered; 5) a 2 m tall hoop poly house covered with one layer of 4 mil white copolymer and one layer of 4-mil clear copolymer and plants were covered with a thermal blanket and 4 mil white copolymer film; and 6) plants kept in a minimally heated (temperature set point of 0°C) double polyethylene covered fiberglass greenhouse.

Using a rating scale of 1-5, with 1 being dead and 3-5 being saleable, Still et al. (1987) found that all plant species were of high quality when overwintered in a minimally heated greenhouse. In the single layer poly house where plants were left uncovered, *Digitalis, Gaillardia, Geum, Chrysanthemum* and *Coreopsis* 'Baby Sun' were not of saleable quality. In the single layer poly house, when plants were covered with a thermal blanket, all plant species were of saleable quality. In the double layer poly house, when plants were covered with a thermal blanket, only *Gaillardia, Chrysanthemum* and *Geum* were not of saleable quality. In the double layer poly house, but plants not being covered, only *Gaillardia* and *Geum* were not of saleable quality. Under the structure-less system only *Gaillardia, Geum* and *Coreopsis* 'Baby Sun' were not of saleable quality.

Rationale

Overwintering research has tended to focus on woody ornamental plants in the past. Little research has been done recently on overwintering of container-grown herbaceous perennials and ornamental grasses. Container-grown herbaceous perennials and ornamental grasses are popular products offered by many nurseries and greenhouses. Popularity can be attributed to the fact that there are many varieties and cultivars of herbaceous perennials and ornamental grasses available in a large range of colors, sizes and growth habit. Nurseries and greenhouses are able to produce high quality container-grown herbaceous perennials and ornamental grasses during the normal production cycle, being early spring to late fall. Yet, the unknown is how to produce high quality container-grown herbaceous perennials and ornamental grasses from overwintering. To assist growers in their need for successful overwintering, development of guidelines for what plant age, overwintering covers, fertilization regimes and substrate moisture contents result in survival and improved vigor would be essential.

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Chapter 2

Different Overwintering Techniques Effects On The Survival And Vigor Of Three *Pennisetum* Grasses

Abstract. **Container grown ornamental grasses such as *Pennisetum* species are popular in the ornamental plant industry but seem to be especially problematic when overwintered. Little research has been reported on overwintering of ornamental perennial grasses. Effects of overwintering cover, fertilizer rate and substrate moisture content on the survival and vigor of overwintered plants in a cold frame were investigated for *P. alopecuroides, P. alopecuroides* 'Hameln' and *P. alopecuroides* 'Little Bunny.' In the first experiment, treatments included the utilization of two overwintering covers, two fertility rates and two substrate moisture contents. Covering treatments included, no cover, a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric with a single sheet of 4 mil white polyethylene plastic on top of the insulation fabric placed over the plants. Fertility rates included Harrell's Polyon® 15-9-12 controlled release fertilizer incorporated into the substrate at a rate of 3.17 kg per 2.29 m^3 or 5.59 kg per 2.29 m^3. Substrate moisture content treatments included pots irrigated to container capacity when the average soil moisture content fell below 25% or 15% volumetric water content. In the second experiment, treatments included two transplant times, two fertility rates and two substrate moisture contents at the Urban Horticulture Center (Blacksburg, VA) (UHC) and Poplar Ridge Nursery (Montross, VA) (PR). Transplant time treatments included young (transplanted on September 5, 2009) and old (transplanted on May 2009, July 2009 or August 2008) plants. Fertility treatments included a top-dress of Osmocote® Plus 15-9-12 added at rates of 6 or 15 grams per container. Substrate moisture content treatments included pots irrigated to container capacity when the average soil moisture content fell below 25% or 15% volumetric water content. In the third experiment, treatments included four fertility rates achieved via topdressing. Older plant material (potted on May 2009, July 2009 or August 2008) came pre-incorporated (at time of planting) with Harrell's Polyon® 15-9-12 controlled release fertilizer at a rate of 3.17 kg per 2.29 m^3. Fertility treatments included no added fertilizer, Osmocote® Plus 15-9-12 top-dressed at rates of 4 grams, 10 grams or 15 grams per container. Covering with either a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric with a single sheet of 4 mil white polyethylene plastic on top of the insulation fabric, wet substrate treatments, low fertility rates and combinations of the wet substrate treatment and the low fertility rate, improved survival and vigor for all three tested *Pennisetum* grasses in experiment 1. Vigor was improved for *P. alopecuroides* (at PR) and *P.* 'Little Bunny' (at both locations) with the young transplanting time in experiment 2. A high fertility rate reduced survival and vigor for *P.* 'Little Bunny' in experiment 3.**

Introduction

Perennial production continues to be a growing entity in the horticultural industry. In the middle 1980s the annual rate of growth of perennial production was estimated to be 25-40% (Bennerup, 1984) with 10% growth between 2005 and 2009 (Barrett, 2010). In order to keep up with the growing demand for perennials, many growers are increasing their container production. This increase in container production can be attributed to the ease of handling and transplanting associated with this production method.

Plant material is overwintered for a variety of reasons. The first being holding plants which had not sold from the previous year, to sell the following spring. The second being plant material purchased as plugs which can be potted in late winter or early spring for late spring sales (Smith, 2004). The third being producers transplanting one year old plants into 3.78 liter (1 gallon) to 11.35 liter (3 gallon) containers in September or early October allowing time for the root system to establish, in order to sell in the early spring (Smith, 2004). The fourth being producers purchasing plugs and potting them up in the summer or early fall for early spring sales. Finally, many perennials require vernalization and many species will not flower unless they have had their vernalization requirement fulfilled.

Growers throughout the mid-Atlantic area experience significant percentages of plant losses during winter dormancy for certain plant species. Container grown ornamental grasses such as *Pennisetum* species are growing in popularity in the ornamental plant industry (Garber and Bondari, 1999; Rhodus, 1997; Scoggins, personal communication) but seem to have poor overwintering survival (Brantingham, personal communication; Epps, personal communication; Packett, personal communication).

The overwintering protection that is needed is based on the root hardiness of the plant species and the climate of the production area (Steponkus et al., 1976). Many overwintering practices have been reported in the literature for various woody ornamental species, including the use of poly houses and overwintering covers. Davidson and Mecklenburg (1974), found that evergreens overwintered best in a white polyethylene plastic covered cold-frame. Good et al. (1976) reported that a using a double layer of polyethylene plastic on a cold-frame provided more protection to plants than a single layer of polyethylene plastic covered cold-frame. Weist et al. (1976), determined that cold-frame structures covered with a translucent polyethylene plastic layer inside and a white polyethylene plastic layer outside offered the best protection to woody plant species. Chong and Desjardins (1981) and Desjardins and Chong (1980) found that overwintering covers placed over the plants in cold-frame structures provided effective overwintering protection to woody evergreen species compared to using no cover. Hicklenton (1982) found that using an overwintering cover (insulation blanket) increased the overwintering quality of container-grown *Cotoneaster dammeri* 'C.K. Schneid' and *Juniperus chinensis* 'Pfitzerana-Aureo.' Pellet et al. (1985) concluded that the use of overwintering cover helped to minimize winter injury of several woody plant species.

Root hardiness is one of the main factors to consider when overwintering plants. Container grown plants are more susceptible to freeze damage than plants grown in field production. The roots *of Ilex* opaca *and Thuja ocidentalis* grown in a container can be exposed to a temperature of -15°C (5°F) while roots of field grown *Ilex* opaca *and Thuja ocidentalis* (three inches below the surface) are exposed to -6°C (21°F) at the same time (Steponkus et al., 1976). Much work has been published on the specific root hardiness of several woody plant species. Struder et al. (1978) and Havis (1976) found that the killing temperatures of several woody plants ranged between -3°C to -11°C for young roots and between -8°C to -23°C for mature roots. Mityga and Lanphear (1971) found that young roots of *Taxus cuspidate* are more cold sensitive than more mature roots. The cold hardiness of several woody ornamental plants have been studied and it has been discovered that the roots of most cold sensitive woody plants can be killed by temperatures of less than -6.6°C (Pellet, 1969; Pellet, 1971; Pellet, 1973).

There have been a few published studies on the cold hardiness and overwintering practices of perennials. Fisher (2001) found that perennial species *Aquilegia, Dicentra and Phlox* overwinter well with the use of a cover while *Asclepias* and *Lobelia* overwinter poorly even with the use of cover. Perry and Herrick (1996) found that the vigor of overwintered *Aquilegia, Dianthus* and *Lavandula* decreased as treatment temperatures decreased. Herrick and Perry (1995) found that 15 of 23 container-grown herbaceous perennials survived controlled freezing temperatures to at least -8°C, however 40% of the surviving species were determined unsaleable. Perry (1990) determined that if overwintering covers are used, then ones with a reflective white surface provided the best protection to container grown herbaceous perennials. Still et al. (1987) found, in a controlled freezing study, that *Achillea fiipendulina* 'Parker's Variety', *Gaillardia ×grandiflora* 'Monarch Strain', and *Lythrum salicaria* 'Robert' were hardy to -11°C. *Kniphofia* 'Pfitzer's Hybrid' was hardy only to -2.8°C and no species tested survived temperatures of -14.4°C. We identified only one published study on the overwintering of container-grown ornamental grasses. Meyer and Cunliffe (2004) studied five ornamental grasses (*Schizachyrium scoparium, Sporobolus heterolepis*, *Calamagrostis* x *acutiflora*, *Miscanthus sinensis* 'Purpurascens' and *Miscanthus sinensis* 'Variegatus') and concluded that plants divided in the spring and potted up survived overwintering 100% of the time. Furthermore, they concluded that overwintering survival was species specific when plants were divided in the fall and then potted up. Based on the importance of this problem and the lack of information, research was conducted to determine if utilizing overwintering cover, certain fertility levels, transplanting time and substrate moisture content could increase the survival and vigor of three container grown ornamental perennial grasses.

Materials and Methods

Three experiments were designed to study the effects of overwintering treatments on the survival and vigor of three ornamental perennial grasses (*Pennisetum alopecuroides, Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny'). Overwintering treatments and practices were chosen based on implementation into the production techniques used by growers. All experiments were conducted at the Urban Horticulture Center (UHC, Blacksburg, VA); (USDA Hardiness Zone 6a). Experiment 2 was replicated at Poplar Ridge Nursery (PR, Montross, VA); (USDA Hardiness Zone 7a) to provide an additional hardiness zone.

In accordance with personal communications with a Virginia ornamental grasses liner producer (Packett, personal communication), plants were cut back to 4 inches (10.2 cm) in height once dormant (December 2, 2009). Plants were irrigated to container capacity prior to the start of overwintering treatments. A fungicide drench of etridiazole+thiophanate-methyl (BANROT® 40WP; Scotts-Sierra Horticultural Products Company, Marysville, OH) and mefenoxam (Subdue MAXX™; Syngenta, Basel, Switzerland) was applied at recommended rates (28.3 grams per 37.8 liters of water and 3 millimeters per 37.8 liters of water, respectively) to all plants to alleviate pathogen development as a complicating factor of plant survival. An extra row of containers filled with bark substrate was placed around each treatment block to serve as a "buffer" row as suggested by Perry (1998).

The ambient air temperature outside (UHC only) and inside of the cold-frame (UHC; PR), the ambient air temperature and substrate media temperatures under each type of cover and under no cover, was monitored continually, using WatchDog® Data Loggers (Spectrum® Technologies, Inc., Plainfield, IL), throughout the experiments (Figures 2.1-2.3; Appendix A Figures 2.1-2). The daily light integral (DLI) (mol/(m^2d)) was monitored continually inside the coldfames using WatchDog® Data Loggers throughout the experiment (Tables 2.15-16).

In experiments 1 and 3, media pH and electrical conductivity (EC; mS/cm) were monitored using a HI9812 pH/EC/TDS Meter (Hanna Instruments®, Inc., Woonsocket, RI) at the start and end of the experiment and after each watering event, utilizing the Virginia Tech Pour-through Extraction Method (Wright, 1986) (Tables 2.7-14; Appendix A: Tables 2.1-4, 2.9-11). In experiment 2, media pH was monitored using the HI9812 pH/EC/TDS Meter (Table 2.10; Appendix A: Tables 2.5, 2.7, 2.12-13) utilizing the Virginia Tech Pour-through Extraction Method (Wright, 1986) and EC was monitored using a FieldScout Direct Soil EC Meter (Spectrum® Technologies, Inc**.,** Plainfield, IL) (Tables 2.10-12; Appendix A Tables 2.6; 2.8).

Soil moisture levels were monitored in containers twice a week using a WaterScout SM 100 Soil Moisture Meter (Spectrum® Technologies, Inc.) (Appendix A: Figures 2.3-9). Substrate moisture levels were chosen based on a preliminary dry down experiment conducted at the UHC. The dry down experiment included withholding water from six *Pennisetum alopecuroides* plants (grown in Elite 300 trade gallon containers; pine bark substrate from RB) and determining (with WaterScout SM 100 Soil Moisture Meter) that 15% volumetric water content (VMC) was the point reached before permanent wilting point. Additionally, fully irrigating *Pennisetum alopecuroides* (38% VWC reached at this point) containers and determining (with WaterScout SM 100 Soil Moisture Meter) that 25% VMC would be point of providing irrigation to plants in containers during production.

Experiment 1.

On September 1, 2009 rooted liners of *Pennisetum alopecuroides, Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' (28, 32 and 28 plants per tray, respectively) from Hoffman Nursery, Inc. (Rougemont, NC) were transplanted individually into Elite 300 trade gallon containers (2.8 L) (ITML Horticultural Products, Inc., Akron, OH) using a custom mixed bark substrate (85% pine : 15% peat, volume : volume) provided by Riverbend Nursery, Inc. (RB, Riner, VA). The plants were grown at the UHC in a Quonset-style coldframe structure covered with a single layer of 4 mil white polyethylene plastic (Ginegar Plastic Products Ltd., Piqua, Ohio).

At time of plant dormancy (December 2, 2009), treatments of different types of overwintering covers, two fertility rates and two substrate moisture levels began being monitored. Covering treatments included no cover, a double layer of Dewitt N-Sulate™ (DeWitt Company, Inc., Sikeston, MO) insulation fabric (1.5 ounce weight) or a double layer of Dewitt N-Sulate™ insulation fabric with a single sheet of 4 mil white polyethylene plastic (Ginegar Plastic Products Ltd.) on top of the insulation fabric. Covering treatments were implemented each time nighttime temperatures were forecasted to drop to -6.6°C (20°F) and plants were uncovered each time temperatures went above this threshold as suggested by Still et al. (1986). Covers were applied and removed at this threshold to alleviate temperature as a complicating factor of plant survival.

Fertility treatments included Harrell's Polyon® 15-9-12 (5-6 month release; Harell's LLC., Lakeland, FL) controlled release fertilizer incorporated into the substrate at a rate of 3.17

kg (7 lbs) per 2.29 m^3 (1 yd^3) which represented the low fertilizer rate. Osmocote Plus® 15-9-12 (5-6 month release; The Scotts Company, LLC., Marysville, OH) controlled release fertilizer was added to low fertilizer rate, via incorporation, to achieve a final rate of 5.59 kg (12 lbs) per 2.29 m^3 (1 yd^3), which represented the high fertilizer rate.

Substrate moisture level treatments included irrigating containers to container capacity when the average soil moisture of five randomly sampled pots fell below 25% or 15% VMC which represented wet and dry treatments, respectively.

On May 15, 2010 plants were evaluated for survival (dead or alive) and for vigor based on a five point scale. We utilized the scale developed by Cunliffe and Meyer (2002); 1 = dead, 2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth, 3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth, 4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth and 5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth (Figure 2.4).

Figure 2.4 Vigor rating for *Pennisetum alopecuroides*

The experiment was arranged in a split-plot design with overwintering cover treatments as the whole plot factor and fertilizer rates and substrate moisture levels as the subplot factors. Covering treatments were completely randomized with two replicates. Subplots of fertilizer rates and substrate moisture levels had six replicates with fertilizer rates completely randomized. The treatment design was a 3 x 2 x 2 factorial with three overwintering covers, two fertilizer rates and two substrate moisture levels for a total of 12 treatments. Data were subjected to analysis of variance procedures (ANOVA) for interaction between treatments on overwintering survival and vigor. Mean separations were performed on significant effects using JMP Version 8 (SAS Institute, Inc., Cary, N.C.).

Experiment 2.

On September 5, 2009 *P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny' liners from PR were transplanted individually into trade gallon containers (2.8 L) (Myers Industries, Inc., Akron OH) using a custom mixed bark substrate (85% pine : 15% peat, volume : volume) at PR.

Finished plants secured from RB included *P. alopecuroides* and *P.* 'Hameln' liners planted in trade gallon containers (2.8 L) (Myers Industries, Inc.) in May and July 2009 respectively, and *P.* 'Little Bunny' liners planted into 5.50 square containers (1.9 L) (Myers Industries, Inc.), in August 2008.

The experiment was conducted in a Quonset-style coldframe structure covered with a single layer of polyethylene plastic at the UHC or in a Quonset-style coldframe structure covered with a single layer of polyethylene plastic (6 mil clear TUFFLITE™; Berry Plastics Corporation, Evansville, IN) at PR.

Plants inside the cold frames were covered with a double layer of Dewitt N-Sulate™ insulation fabric (1.5 ounce weight) each time nighttime temperatures were forecasted to drop to -6.6°C (20°F) and plants were uncovered each time temperatures went above this threshold as suggested by Still et al. (1986). Covers were applied and removed at this threshold to alleviate temperature as a complicating factor of plant survival.

At time of plant dormancy (December 2, 2009), treatments including two different planting ages, two fertilizer rates and two substrate moisture levels began being monitored.

Planting age. Plants designated as young (*P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny') were those planted on September 5, 2009 and plants designated as old (*P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny') were those finished plants secured from RB.

Fertilizer rate. A top-dress of Osmocote® Plus 15-9-12 was applied at rates of 6 or 15 grams per container, representing low and high fertility, respectively. Harrell's Polyon® 15-9-12 controlled release fertilizer was pre-incorporated into the substrate (at time of planting) at a rate of 3.17 kg (7 lbs) per 2.29 m^3 (1 yd^3).

Substrate moisture level. Treatments included irrigating containers to container capacity when the average soil moisture of five randomly sampled containers fell below 25% or 15% VMC which represented wet and dry treatments, respectively.

On April 15 and May 15, 2009 plants from PR and the UHC, respectively, were evaluated for survival (dead or alive) and for vigor based on a five point scale as described in experiment 1.

The experiment was arranged in a split-plot design with substrate moisture levels as the main plot factor and fertilizer rate and plant age as subplot factors. Substrate moisture levels were completely randomized with two replicates. Subplots of fertilizer rates and plant age had six replicates with fertilizer rates and plant age completely randomized. The treatment design was a 2 x 2 x 2 factorial with two planting times, two fertility rates and two substrate moisture levels for a total of eight treatments. Data were analyzed as previously described.

Experiment 3.

Finished plants secured from RB included *P. alopecuroides* and *P.* 'Hameln' liners planted in trade gallon containers (2.8 L) (Myers Industries, Inc.) in May and July 2009 respectively, and *P.* 'Little Bunny' liners planted into 5.50 square containers (1.9 L) (Myers Industries, Inc.), in August 2008. As in experiment 2, plants were grown in a Quonset-style coldframe structure covered with a single layer of polyethylene plastic at the UHC and were covered with a double layer of Dewitt N-Sulate™ insulation fabric, covered and uncovered at same temperature thresholds.

At time of plant dormancy (December 2, 2009), treatments which included four fertilizer rates began being monitored. The substrate contained Harrell's Polyon® 15-9-12 controlled release fertilizer that was incorporated (at time of planting) at a rate of 3.17 kg (7 lbs) per 2.29 m^3 (1 yd^3). Fertility rates were achieved via topdressing with Osmocote® Plus 15-9-12 at rates of 0 grams, 4 grams, 10 grams or 15 grams per container, representing no additional fertilizer, low, medium and high fertilizer rates, respectively.

Soil moisture level was monitored in pots twice a week as described previously (Appendix: Figure 2.10). Containers were irrigated to container capacity when the average soil moisture of five randomly sampled pots fell below 25% VMC.

On May 15, 2010 plants were evaluated for their survival (dead or alive) and for their vigor based on a five point scale as described in experiment 1.

The experiment was arranged in a completely randomized block design with six replicates. Data were analyzed as previously described.

Results and Discussion

Experiment 1.

For the low fertility treatment, average initial leachate EC ranged from 3.54 mS/cm to 4.04 mS/cm and pH ranged from 6.1 to 6.5 using the pour-through extraction method (Table

2.7). For the high fertility treatment, average initial leachate EC ranged from 3.23 mS/cm to 4.73 mS/cm and pH ranged from 6.1 to 6.5 using the pour-through extraction method (Table 2.7).

From November 2009 to May 2010, average air temperature outside of cold-frame was 7.8°C, with high and low temperature extremes of 29.4°C and -17.8°C, respectively. From November 2009 to May 2010, average air temperature inside of the cold frame was 7.2°C, with high and low temperature extremes of 37.7°C and -10.9°C, respectively with an average media temperature of 7.2°C, with high and low temperature extremes of 33.5°C and -6.9°C, respectively. From December 2009 to March 2010, average air temperature under no additional cover was 3.9°C, with high and low temperature extremes of 31.5°C and -10.9°C, respectively with an average media temperature of 4.0°C, with high and low temperature extremes of 20.5°C and -6.9°C, respectively. From December 2009 to March 2010, average air temperature under the Dewitt N-Sulate™ was 4.3°C, with high and low temperature extremes of 35.3°C and -7.9°C, respectively with an average media temperature of 4.3°C, with high and low temperature extremes of 27.9°C and -0.3°C, respectively. From December 2009 to March 2010, average air temperature under the Dewitt N-Sulate™ + Poly was 4.0°C, with high and low temperature extremes of 28.9°C and -8.4°C, respectively with an average media temperature of 4.0°C, with high and low temperature extremes of 20.4°C and -0.1°C, respectively. From December 1, 2009 to March 22, 2010, covers were applied 82 days and then removed 49 days, covers were no longer utilized after March 27, 2010. Average DLI, inside of cold-frame, from Novemeber 2009 to May 2010 was 7.63 mol/(m^2d) (Table 2.15).

At time of fungicide treatment (December 2, 2009) plants were irrigated to container capacity, plants did not dry down to the predetermined thresholds until spring. On May 3, 2010, media containing *P. alpecuroides, P.* 'Hameln' and *P.* 'Little Bunny' subjected to the wet VWC was irrigated to container capacity and on April 13, 2010, media subjected to the dry VWC was irrigated to container capacity.

On January 28, 2010, a tank mix of chlorothalonil (Daconil ULTREX®; Syngenta, Basel, Switzerland) and azoxystrobin (Heritage®; Syngenta, Basel, Switzerland) was applied to all tested *Pennisetum* grasses, at the UHC, to control Botrytis.

Treatments affected survival for all three tested *Pennisetum* grasses (Table 2.1a). *P.* 'Little Bunny' survival was affected by covering treatments in combination with fertility treatments. When providing no cover, 100% of the *P.* 'Little Bunny' did not survive overwintering. However, improved survival resulted from the use of low fertility under either a double layer of Dewitt N-Sulate™ insulation fabric (75% survival) or a combination of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic in combination (75% survival) (Table 2.1b).Covering treatments in combination with substrate moisture treatments affected the overwintering survival of *P. alopecuroides* and *P.* 'Hameln.' Overwintering survival was improved with the use of either a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic in combination with the wet substrate moisture treatment (Table 2.1c).

Vigor was affected by treatments for all three tested *Pennisetum* grasses (Table 2.2a). *P.* 'Little Bunny' vigor was affected by covering treatments in combination with fertility treatments. Low fertility combined with either a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic improved vigor (from a 1.0 to a 1.9; Table 2.2b). Statistically, the utilization of overwintering covers increased the vigor but from the standpoint of a producer trying to sell this plant, the increase would not have been relevant. On the five point scale utilized, a saleable plant would receive a rating above a 4.0. Improved vigor for *P. alopecuroides* and *P.* 'Hameln' resulted from the use of either a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic (Table 2.2c). The low fertility treatment improved vigor for *P. alopecuroides* and *P.* 'Hameln' as well (Table 2.2c). For *P.* 'Hameln,' vigor was improved with the wet substrate moisture content treatment (Table 2.2c). Again, statistically, the utilization of overwintering covers and low fertility increased the vigor but from the standpoint of a producer trying to sell this plant, the increase would not have been relevant.

The overwintering survival and increased vigor of the three tested *Pennisetum* grasses with the use of covers agrees with Mader and Feldman (1948) and Perry (1998). Both, Mader and Feldman (1948) and Perry (1998), state that using thermoblankets in a poly structure (referred to as the supplementary polyblanket technique) can create a microclimate around the plants which can be 4.4°C to 5.5°C warmer that the air above the blanket in the structure. This agrees with our temperature data (Figures 2.2-3) and additionally, we found that this temperature buffering holds true for the temperature of the uncovered media when compared to the covered media (Figures 2.2-3). Our findings of improved vigor with the use of overwintering cover when compared to the use of no cover agrees with Still et al. (1987), who also found that using overwintering covers increased the saleable quality of plants.

Providing adequate moisture to the three *Pennisetum* cultivars along with the use of overwintering cover increased overwintering survival. Adequate moisture is needed to protect the plant roots from extreme temperatures which could harm or potentially kill roots (Smith, 2004). Additionally, according to Dunwell and McNiel (2010), cool or frozen soil will slow or prevent water movements to plant shoots, which will need water on days when warmth occurs. Temperature of the media of non-covered plants often times approached 0°C (Figure 2.1), with the lowest recorded media temperature at -6.9°C and the protection provided by both covers (lowest recorded media temperature at -0.3°C and -0.9°C for Dewitt N-Sulate™ and Dewitt N-Sulate™ + Poly, respectively) and wet substrate moisture content could contribute to the increases in vigor and survival seen.

Little published research is available about the appropriate range the EC and pH should be managed at to produce *Pennisetum* grasses. Based on trials of several respected growers (Emerald Coast Growers, 2010; Proven Winners, 2011; Walters Gardens, 2011) recommendations for the three tested *Pennisetum* species and cultivars are for low levels of fertilizer to be applied with an optimal EC range of 0.6 mS/cm to 1.5 mS/cm, respectively. The initial average (3.95 mS/cm) and final average (2.12 mS/cm) of EC values for the high fertilizer treatment (Tables 2.7; 2.9, respectively) were above recommended ranges which could contribute to decreased survival and vigor for the high fertility treatment compared to the initial average (3.72 mS/cm) and final average (1.28 mS/cm) of EC values for the low fertilizer treatment(Tables 2.7; 2.9, respectively).

Experiment 2.

At the UHC, for the low fertility treatments, average initial leachate EC ranged from 0.17 mS/cm to 0.53 mS/cm and pH ranged from 6.7 to 7.0 using the pour-through extraction method (Table 2.10). For the high fertility treatments, average initial leachate EC ranged from 0.72 mS/cm to 0.97 mS/cm and pH ranged from 6.2 to 6.7 using the pour-through extraction method (Table 2.10).

At PR, for the low fertility treatments, average initial leachate EC ranged from 0.19 mS/cm to 0.30 mS/cm and pH ranged from 6.1 to 6.7 using the pour-through extraction method (Table 2.10). For the high fertility treatments, average initial leachate EC ranged from 0.30 mS/cm to 0.56 mS/cm and pH ranged from 5.9 to 6.6 using the pour-through extraction method (Table 2.10).

At the UHC, From September 2009 to May 2010, average air temperature outside of cold-frame was 7.8°C, with high and low temperature extremes of 29.4°C and -17.8°C, respectively. From November 2009 to May 2010, average air temperature inside the cold-frame was 7.2 °C, with high and low temperature extremes of 37.7°C and -10.9°C, respectively. Average DLI inside the cold-frame from November 2009 to May 2010 was 7.63 mol/(m^2d) (Table 2.15). From December 2009 to March 2010, average air temperature under no additional cover was 3.9°C, with high and low temperature extremes of 31.5°C and -10.9°C, respectively with an average media temperature of 4.0°C, with high and low temperature extremes of 20.5°C and -6.9°C, respectively. From December 2009 to March 2010, average air temperature under the Dewitt N-Sulate™ was 4.7°C, with high and low temperature extremes of 34.6°C and -7°C, respectively with an average media temperature of 4.8°C, with high and low temperature extremes of 27.4°C and -0.8°C, respectively. From December 1, 2009 to March 22, 2010, covers were applied 82 days and then removed 49 days, covers were no longer utilized after March 27, 2010.

At PR, from November 2009 to May 2010, average air temperature inside the cold-frame) was 8.1°C, with high and low temperature extremes of 38.8°C and -8.2°C, respectively. Average DLI inside the cold-frame from November 2009 to April 2010 was 14.0 mol/(m^2d) (Table 2.16). From December 2009 to March 2010, average air temperature inside the cold-frame with no cover was 6.5°C, with high and low temperature extremes of 38.8°C and -8.2°C, respectively with an average media temperature of 6.8°C, with high and low temperature extremes of 28.3°C and -3.6°C, respectively. From December 2009 to March 2010, average air temperature under the Dewitt N-Sulate™ was 7.0°C, with high and low temperature extremes of 36.0°C and -5.6°C, respectively with an average media temperature of 7.0°C, with high and low temperature extremes of 24.4°C and -3.6°C, respectively. From December 1, 2009 to March 22, 2010, covers were applied 41 days and then removed 27 days, covers were no longer utilized after February 17, 2010.

At the UHC, at time of fungicide treatment (December 2, 2009) plants were irrigated to container capacity, plants did not dry down to the predetermined thresholds until spring. On May 3, 2010, media containing old *P. alopecuroides*, subjected to the wet VWC, was irrigated to container capacity and on April 29, 2010, media containing young *P.* 'Hameln,' subjected to the dry VWC, was irrigated to container capacity.

At PR, at time of fungicide treatment (December 5, 2009) plants were irrigated to container capacity, plants did not dry down to the predetermined thresholds until spring. On March 18, 2010, media containing old *P. alopecuroides* and young *P.* 'Hameln,' subjected to the wet VWC was irrigated to container capacity; media containing old *P.* 'Little Bunny,' subjected to the dry VWC was irrigated to container capacity.

At the UHC, 100% of *P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny' survived overwintering, therefore no treatment was significant (table not shown). Overall vigor of *P.* 'Little Bunny was affected at the UHC (Table 2.3a) with the young plant age (planted Sept. 5, 2009) or the low fertilizer treatment improving vigor (Table 2.3b). Based on the five point scale, the young *P.* 'Little Bunny' and the utilization of low fertility increased the vigor and from the standpoint of a producer trying to sell this plant, the increase would have resulted in a more saleable plant.

At PR, 100% of *P. alopecuroides, P.* 'Hameln' and *P.* 'Little Bunny,' survived overwintering, therefore no treatment was significant (table not shown). Overall vigor was affected for *P. alopecuroides* and *P.* 'Little Bunny' (Table 2.4a) with the young plant age (planted Sept. 5, 2009) improving vigor (Table 2.4b). Based on the five point scale, the young *P.* 'Little Bunny' increased the vigor and from the standpoint of a producer trying to sell this plant, this increase would have resulted in a more saleable plant. For *P. alopecuroides* the increase in vigor would not have resulted in a more saleable plant from the standpoint of a producer because the increase would not be visible (from a 4.6 to a 5).

Many growers will transplant plugs into 3.7 to 11.1 L (1 to 3 gallon) containers in September or early October to allow time for proper root establishment (Smith, 2004). In herbaceous plants, the roots are one of the most susceptible organs to cold injury (Sakai and Larcher, 1987) and therefore root establishment is essential. Even so, root-bound plant material has been found to overwinter poorly (Walters Gardens, 2010). Planting *P. alopecuroides* and *P.* 'Little Bunny' in early September 2009 (young treatment), compared to May 2009 and August 2008, respectively (old treatment) could lessen the chance for the plant material to be root bound, thus increasing overwintering vigor.

Little published research is available about the appropriate range the EC and pH should be managed at to produce *Pennisetum* grasses. Based on trials of several respected growers (Emerald Coast Growers, 2010; Proven Winners, 2011; Walters Gardens, 2011) recommendations for the three tested *Pennisetum* grasses are for low levels of fertilizer to be applied with an optimal EC range of 0.6 mS/cm to 1.5 mS/cm, respectively. The final average

EC value for the high fertilizer treatment (1.36 mS/cm) for young *P.* 'Little Bunny,' (at the UHC) (Table 2.11) may have contributed to the reduced vigor from the high fertility treatments when compared to the final average EC value for the low fertilizer treatment (0.81 mS/cm) for young *P.* 'Little Bunny,' at the UHC (Table 2.11).

Experiment 3.

Average initial leachate EC was 0.11 mS/cm, 0.19 mS/cm and 0.29 mS/cm for *Pennisetum alopecuroides, Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny,' respectively using the pour-through extraction method (Table 2.13). Average initial leachate pH was 5.4, 6.2 and 5.5 for *Pennisetum alopecuroides, Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny,' respectively using the pour-through extraction method (Table 2.13).

From September 2009 to May 2010, average air temperature outside the cold-frame was 7.8°C, with high and low temperature extremes of 29.4°C and -17.8°C, respectively. From November 2009 to May 2010, average air temperature inside the cold-frame was 7.2 °C, with high and low temperature extremes of 37.7°C and -10.9°C, respectively. Average DLI inside the cold-frame from November 2009 to May 2010 was 7.63 mol/(m^2d) (Table 2.15).

From December 2009 to March 2010, average air temperature under no additional cover was 3.9°C, with high and low temperature extremes of 31.5°C and -10.9°C, respectively with an average media temperature of 4.0°C, with high and low temperature extremes of 20.5°C and -6.9°C, respectively. From December 2009 to March 2010, average air temperature under the Dewitt N-Sulate™ was 4.3°C, with high and low temperature extremes of 35.3°C and -7.9°C, respectively with an average media temperature of 4.3°C, with high and low temperature extremes of 27.9°C and -0.3°C, respectively. From December 1, 2009 to March 22, 2010, covers were applied 41 days and then removed 27 days, covers were no longer utilized after February 17, 2010.

At time of fungicide treatment (December 2, 2009) plants were irrigated to container capacity, plants did not dry down to the predetermined thresholds until spring. On May 3, 2010 and April 6, 2010, media containing *P. alopecuroides* was irrigated to container capacity. On April 6, 2010 and March 18, 2010, media containing *P.* 'Little Bunny,' was irrigated to container capacity. On April 6, 2010, media of containing *P.* 'Hameln,' was irrigated to container capacity.

Fertility treatments affected the overwintering survival and vigor of *P.* 'Little Bunny' (Table 2.5a; 2.6b, respectively). The use of the high fertility treatment reduced both the overwintering survival and vigor (Table 2.5b; 2.6b, respectively). Based on the five point scale, *P.* 'Little Bunny' increased the vigor but from the standpoint of a producer trying to sell this plant, the increase would not have been relevant.

Plants, properly fertilized prior to overwintering, may stand a better chance of surviving the winter (Bilderback and Bir, 2007). Applying fertilizer, right before plant dormancy, could cause a flush of growth, thus preventing hardening-off of the plant (Bilderback and Bir, 2007). In experiment one, the low fertility treatment improved the survival of *P.* 'Little Bunny,' and improved the vigor of all three tested grasses. It can be concluded that too high an EC may compromise survival and decrease vigor, based on species. Based on trials of several respected growers (Emerald Coast Growers, 2010; Proven Winners, 2011; Walters Gardens, 2011) recommendations for the three tested *Pennisetum* grasses are for low levels of fertilizer to be applied with an optimal EC range of 0.6 mS/cm to 1.5 mS/cm, respectively. The final average EC value for the high fertility treatment (2.22 mS/cm) for *P.* 'Little Bunny,' (Tables 2.14) may have contributed to the reduced vigor in the high fertility treatments compared to the final average EC value for the low fertility treatment (1.27 mS/cm) (Tables 2.14).

In conclusion, we have found that utilizing an overwintering cover may help to improve survival and vigor. Without an overwintering cover, 100% of *P.* 'Little Bunny' did not survive and vigor was reduced in experiment one. Additonally, in experiment one, utilizing cover improved survival and vigor for both *P. alopecuroides* and *P.* 'Hameln.' Providing plants with adequate moisture throughout the winter helps to improve plant vigor in the spring. In experiment one, with the wet VWC, survival for *P. alopecuroides* was increased and both survival and vigor was increased for *P.* 'Hameln.' We found that plants transplanted in the late summer early/fall had an increase in vigor when compared to plans transplanted in the early spring or before. This was evident in experiment two, where at both locations (UHC and PR), young *P.* 'Little Bunny' had improved vigor compared to old *P.* 'Little Bunny.' Additionally, we found that young *P. alopecuroides* (at PR) had increased vigor when compared to old *P. alopecuroides.* Finally, we found that high fertility rates during overwintering can also increase overwintering losses and reduce vigor. The negative effects of high fertility were seen in all three experiments. In experiment one and three, low fertility increased both survival and vigor for *P.* 'Little Bunny.' In experiment two, at the UHC, vigor for *P.* 'Little Bunny' was improved with the use of low fertility.

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Table 2.1a. Analysis of variance summary for fertilizer rate, covering and substrate moisture content effects on overwintering survival of *Pennisetum alopecuroides, Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' in experiment 1.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Fert Rate	1	1.13	7.64	0.0076*	0.13	1.45	0.2330	2.35	17.24	0.0001*
Covering	2	4.69	15.94	<.0001*	1.58	9.19	0.0003*	3.69	13.57	<.0001*
Fert Rate*Covering	2	0.25	0.85	0.4329	0.08	0.48	0.6188	1.19	4.39	0.0167*
Moisture	1	0.13	0.85	0.3605	0.13	1.45	0.2330	0.01	0.10	0.7505
Fert Rate* Moisture	1	0.01	0.09	0.7598	0.01	0.16	0.6894	0.01	0.10	0.7505
Covering* Moisture	2	1.08	3.68	0.0311*	0.58	3.39	0.0404*	0.19	0.71	0.4937
Fert Rate*Covering* Moisture	2	0.19	0.66	0.5204	0.19	1.13	0.3301	0.03	0.10	0.9031

n=6
*Significant at $P \leq 0.05$

Table 2.1b. Significant effect of covering treatment and fertilizer rate on the overwintering survival of *Pennisetum* 'Little Bunny' in experiment 1.

Treatment		% Survival *P.* 'Little Bunny'
Covering	Fert Rate	
No Cover	Low	0b[z]
	High	0b
N-Sulate™	Low	75a
	High	25b
N-Sulate™ + Poly	Low	75a
	High	17b
P-value		0.0167

n=6
[z]Mean separation within a column by Tukey's HSD test

Table 2.1c. Significant effect of covering treatment and moisture content on the overwintering survival of *Pennisetum alopecuroides* and *Pennisetum* 'Hameln' in experiment 1.

Treatment		% Survival	
		P. alopecuroides	*P.* 'Hameln'
Covering	Moisture		
No Cover	Wet	8c[z]	83ab[z]
	Dry	50b	50b
N-Sulate™	Wet	83a	92a
	Dry	83a	100a
N-Sulate™ + Poly	Wet	92a	100a
	Dry	75ab	100a
P-value		0.0311	0.0404

n=6
[z]Mean separation within a column by Tukey's HSD test

Table 2.2a. Analysis of variance summary for fertilizer rate, covering and substrate moisture content effect on the overall vigor of *Pennisetum alopecuroides, Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' in experiment 1.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Fert Rate	1	22.22	14.55	0.0003*	22.22	20.41	<.0001*	3.13	14.61	0.0003*
Covering	2	48.36	15.83	<.0001*	20.03	9.20	0.0003*	4.53	10.58	0.0001*
Fert Rate*Covering	2	4.53	1.48	0.2354	2.69	1.24	0.2975	1.58	3.70	0.0305*
Moisture	1	1.39	0.91	0.3442	5.56	5.10	0.0275*	0.01	0.06	0.7997
Fert Rate*Moisture	1	0.22	0.15	0.7043	1.39	1.28	0.2632	0.13	0.58	0.4476
Covering*Moisture	2	6.03	1.97	0.148	4.36	2.00	0.1439	0.03	0.06	0.9372
Fert Rate*Covering*Moisture	2	2.86	0.94	0.3977	0.36	0.17	0.8476	0.08	0.19	0.8235

n=6
*Significant at P≤ 0.05

Table 2.2b. Significant effect of covering treatment and fertilizer rate on the overall vigor of *Pennisetum* 'Little Bunny' in experiment 1.

Treatment		Vigor Rating[z]
		P. 'Little Bunny'
Covering	Fert Rate	
No Cover	Low	1.0b[y]
	High	1.0b
N-Sulate™	Low	1.9a
	High	1.3b
N-Sulate™ + Poly	Low	1.8a
	High	1.2b
P-value		0.0305

n=6
[y]Mean separation within a column by Tukey's HSD test
[z]Vigor Rating:
1 = dead
2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth
3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth
4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth
5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth

Table 2.2c. Significant effect of covering treatment, fertilizer rate and substrate moisture content on the overall vigor of *Pennisetum alopecuroides* and *Pennisetum* 'Hameln' in experiment 1.

	Vigor Rating[z]	
Treatment	*P. alopecuroides*	*P.* 'Hameln'
Covering		
No cover	1.5b[y]	2.3b[y]
N-Sulate™	3.4a	3.3a
N-Sulate™ + poly	3.2a	3.5a
P-value	0.0003	<.0001
Fert Rate		
Low	3.3a[y]	3.6a[y]
High	2.1b	2.5b
P-value	<.0001	0.0003
Moisture		
Wet	NS	3.3a[y]
Dry	NS	2.8b
P-value		0.0275

n=6

[y]Mean separation within a column by Tukey's HSD test

NS=Not Significant

[z]Vigor Rating:

1 = dead

2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth

3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth

4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth

5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth

Table 2.3a. Analysis of variance summary for plant age, fertilizer rate and substrate moisture content effects on the overall vigor of *Pennisetum alopecuroides, Penniseutm* 'Hameln,' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA) in experiment 2.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Age	1	0.00	0.00	1.0000	0.19	1.45	0.2353	63.02	105.77	<.0001*
Moisture	1	0.00	0.00	1.0000	0.19	1.45	0.2353	0.02	0.04	0.8526
Age*Moisture	1	0.08	2.00	0.1650	0.02	0.16	0.6901	1.02	1.71	0.1980
Fert Rate	1	0.08	2.00	0.1650	0.19	1.45	0.2353	2.52	4.23	0.0463*
Age*Fert Rate	1	0.00	0.00	1.0000	0.19	1.45	0.2353	0.52	0.87	0.3554
Moisture*Fert Rate	1	0.00	0.00	1.0000	0.02	0.16	0.6901	0.02	0.04	0.8526
Age*Moisture*Fert Rate	1	0.08	2.00	0.1650	0.02	0.16	0.6901	0.52	0.87	0.3554

n=6
*Significant at P≤ 0.05

Table 2.3b. Significant effect of plant age and fertilizer rate on the overall vigor of *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA) in experiment 2.

Treatment	Vigor Rating[z] *P.* 'Little Bunny'
Age	
Young	4.9a[y]
Old	2.6b
P-value	<.0001
Fert Rate	
Low	4.0a[y]
High	3.5b
P-value	0.0463

n=6

[y]Mean separation within a column by Tukey's HSD test

[z]Vigor Rating:

1 = dead

2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth

3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth

4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth

5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth

Table 2.4a. Analysis of variance summary for plant age, fertilizer rate and substrate moisture content effect on the overall vigor of *Pennisetum alopecuroides, Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) in experiment 2.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Age	1	1.69	7.11	0.0110*	0.02	0.00	1.0000	14.08	16.73	0.0002*
Moisture	1	0.02	0.09	0.7686	0.02	0.00	1.0000	2.08	2.48	0.1235
Age*Moisture	1	0.02	0.09	0.7686	0.02	0.00	1.0000	0.00	0.00	1.0000
Fert Rate	1	0.02	0.09	0.7686	0.02	0.00	1.0000	2.08	2.48	0.1235
Age*Fert Rate	1	0.02	0.09	0.7686	0.02	0.00	1.0000	0.00	0.00	1.0000
Moisture*Fert Rate	1	0.02	0.09	0.7686	0.02	0.00	1.0000	0.33	0.40	0.5327
Age*Moisture*Fert Rate	1	0.02	0.09	0.7686	0.02	0.00	1.0000	0.75	0.89	0.3508

n=6
*Significant at $P \leq 0.05$

Table 2.4b. Significant effect of plant age on the overall vigor of *Pennisetum alopecuroides*, and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) in experiment 2.

	Vigor Rating[z]	
Treatment	*P. alopecuroides*	*P.* 'Little Bunny'
Age		
Young	5.0a[y]	4.8a[y]
Old	4.6b	3.7b
P-value	0.0110	0.0002

n=6
[y]Mean separation within a column by Tukey's HSD test
[z]Vigor Rating:
1 = dead
2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth
3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth
4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth
5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth

Table 2.5a. Analysis of variance summary for fertilizer rate effect on the overwintering survival of *Pennisetum alopecuroides, Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' in experiment 3.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Fert Rate	3	0.00	0.00	1.0000	0.00	0.00	1.0000	2.0625	4.7143	0.0061*

n=6
*Significant at P≤ 0.05

Table 2.5b. Significant effect of fertilizer rate on the overwintering survival of *Pennisetum* 'Little Bunny' in experiment 3.

	% Survival
Treatment	*P.* 'Little Bunny'
Fert Rate	
Zero	92a[z]
Low	83a
Medium	92a
High	42b

n=6
[z]Mean separation within a column by Tukey's HSD test

Table 2.6a. Analysis of variance summary for fertilizer rate effect on the overall vigor of *Pennisetum alopecuroides, Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' in experiment 3.

		P. alopecuroides			*P.* 'Hameln'			*P.* 'Little Bunny'		
Source	DF	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value	Mean Square	F Ratio	P-value
Fert Rate	3	0.72916667	0.4701	0.7047	1.7291667	1.663	0.1887	11.5625	4.0946	0.0120*

n=6
*Significant at P≤ 0.05

Table 2.6b. Significant effect of fertilizer rate on the overall vigor for *Pennisetum* 'Little Bunny' in experiment 3.

	Vigor Rating[z]
Treatment	*P.* 'Little Bunny'
Fert Rate	
Zero	2.9a[y]
Low	2.3ab
Medium	2.6ab
High	1.6b
P-value	0.0120

n=6
[y]Mean separation within a column by Tukey's HSD test
[z]Vigor Rating:
1 = dead
2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth
3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth
4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth
5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth

Table 2.7. Average initial pH and EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' in experiment 1.

	pH		EC	
	Young		Young	
Plant Species	Low	High	Low	High
P. alopecuroides	6.2	6.2	3.54	4.73
P. 'Hameln'	6.1	6.1	4.04	3.89
P. 'Little Bunny'	6.5	6.5	3.57	3.23

n=5
Taken on 9/15/2009

Table 2.8. Average final pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' in experiment 1.

	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	4.9	5.3	4.8	4.9	5.6	5.4	4.8	4.9	5.4	5.4	5.2	4.9
P. 'Hameln'	5.2	5.1	5.5	5.1	5.2	5.0	5.4	4.9	5.2	4.8	5.3	4.9
P. 'Little Bunny'	5.1	5.3	4.9	5.2	5.3	5.2	5.1	5.1	5.0	5.1	5.0	5.0

n=3
Taken on 5/15/2010

Table 2.9. Average final EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' in experiment 1.

	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	2.21	0.96	1.93	3.03	1.14	1.69	1.49	1.75	1.21	0.94	1.76	2.19
P. 'Hameln'	1.36	1.28	2.06	2.54	1.44	1.29	2.69	1.33	0.96	1.59	2.45	2.03
P. 'Little Bunny'	0.82	1.51	1.93	2.49	0.63	0.89	1.76	2.19	1.74	1.44	1.94	2.62

n=3
Taken on 5/15/2010

Table 2.10. Average initial pH and EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA) and Poplar Ridge Nursery (Montross, VA) in experiment 2.

	pH				EC			
	Young		Old		Young		Old	
Plant Species	Low	High	Low	High	Low	High	Low	High
P. alopecuroides	6.7	6.7	6.2	6.7	0.48	0.80	0.24	0.30
P. 'Hameln'	7.0	7.0	6.7	6.7	0.17	0.97	0.30	0.56
P. 'Little Bunny'	6.8	6.8	6.4	6.1	0.53	0.72	0.19	0.30

n=5
Taken 9/14/2009

Table 2.11. Average final EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA) in experiment 2.

	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	0.12	0.20	0.34	1.26	0.14	0.12	0.35	0.61
P. 'Hameln'	0.22	0.34	1.22	0.79	0.26	0.24	0.55	0.80
P. 'Little Bunny'	0.79	0.82	1.48	1.24	0.28	0.35	0.42	0.52

n=3
Taken on 5/15/2010

Table 2.12. Average final EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) in experiment 2.

	Evaluation # 3							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	0.32	0.53	0.50	1.25	0.06	0.19	0.86	0.38
P. 'Hameln'	0.35	0.19	0.60	0.60	0.14	0.15	0.35	0.40
P. 'Little Bunny'	0.46	0.49	0.56	0.61	0.31	0.31	0.43	0.76

n=3
Taken on 4/15/2010

Table 2.13. Average initial pH and EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' in experiment 3.

	Evaluation # 1	
	Old	
Plant Species	pH	EC
P. alopecuroides	5.4	0.11
P. 'Hameln'	6.2	0.19
P. 'Little Bunny'	5.5	0.12

n=5
Taken on 9/13/2009

Table 2.14. Average final pH and EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' in experiment 3.

	pH				EC			
	Fertilizer Rate				Fertilizer Rate			
Plant Species	None Added	Low	Medium	High	None Added	Low	Medium	High
P. alopecuroides	6.8	6.3	6.8	6.6	0.13	0.25	0.79	1.31
P. 'Hameln'	6.6	6.8	5.8	5.8	0.51	0.53	1.83	3.43
P. 'Little Bunny'	7.3	7.5	6.9	7.0	0.89	1.27	2.11	2.22

n=3

Taken on 5/15/2010

Table 2.15. Average monthly Daily Light Integral (DLI) (mol/(m^2d)) from the Urban Horticulture Center (Blacksburg, VA) over the course of experiments 1, 2 and 3.

Month	Year	DLI (mol/(m^2d))
November	2009	3.83
December	2009	4.50
January	2010	5.25
February	2010	7.35
March	2010	9.94
April	2010	15.06
May	2010	7.46

Table 2.16. Average monthly Daily Light Integral (DLI) (mol/(m^2d)) from Poplar Ridge Nursery (Montross, VA) over the course of experiment 2.

Month	Year	DLI (mol/(m^2d))
November	2009	6.14
December	2009	5.87
January	2010	7.49
February	2010	12.31
March	2010	19.69
April	2010	32.51

Figure 2.1. Outside air temperature, uncovered air temperature and uncovered media temperature, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 1 from 11/19/2009 to 5/8/2010.

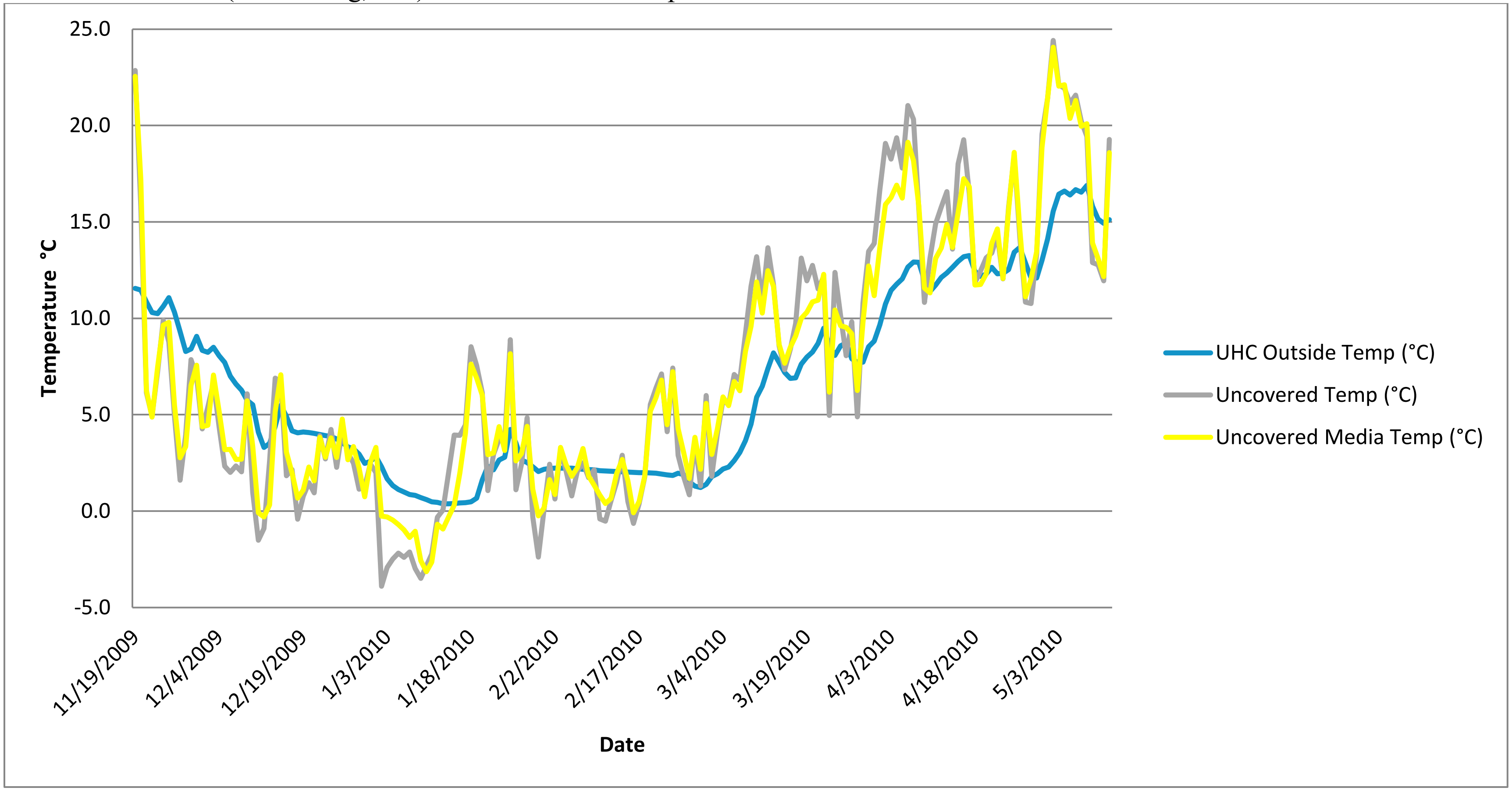


Figure 2.2. Outside air temperature, uncovered media and air temperature inside and air and media temperatures under cover treatments, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 1 from 11/19/2009 to 5/8/2010.

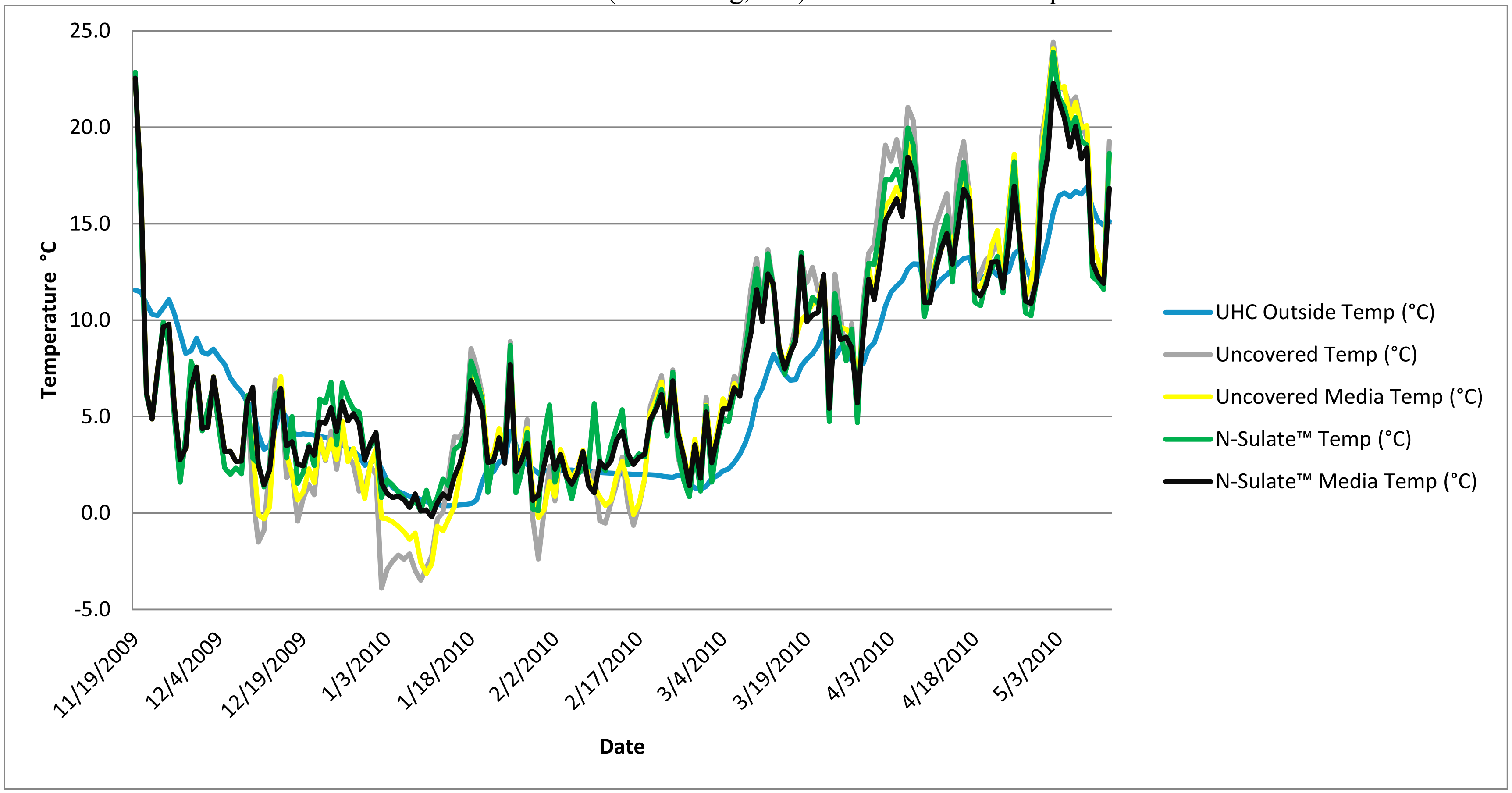
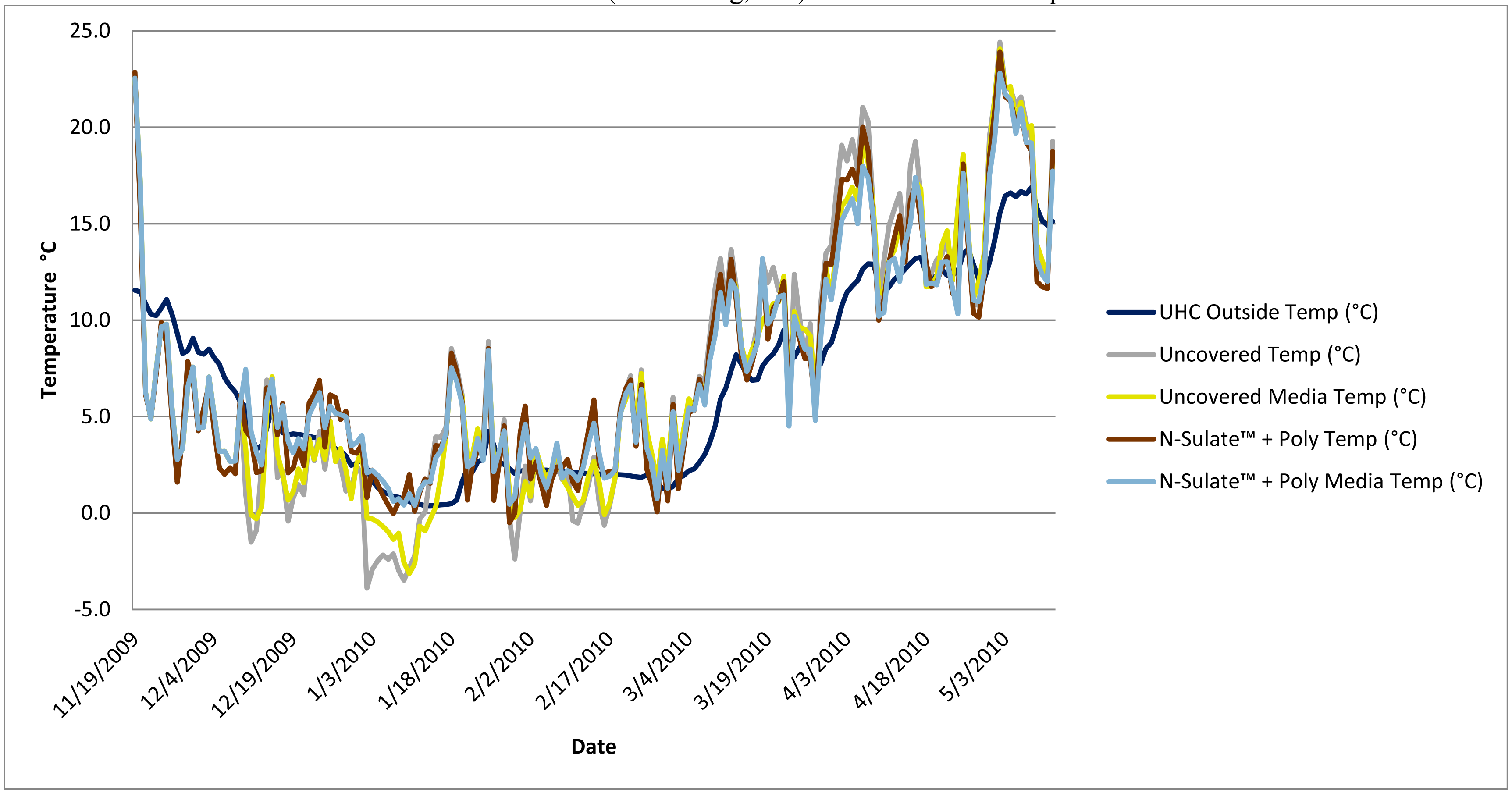


Figure 2.3. Outside air temperature, uncovered media and air temperature inside and air and media temperatures under cover treatments, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 1 from 11/19/2009 to 5/8/2010.



Chapter 3

Increasing The Overwintering Survival Of Container Grown Perennials

Abstract. **Container grown herbaceous perennials are a growing product offered in the horticulture industry. A problem producers are facing is overwintering of herbaceous perennials. Little research has been reported on overwintering of container grown herbaceous perennials. Effects of overwintering cover, fertilizer rate and substrate moisture content on the survival and vigor of overwintered plants were investigated for *Echinacea purpurea* 'Hot Papaya' (from two different sources), *Echinacea purpurea* 'Milkshake,' *Gaillardia* x *grandiflora* 'Gallo Peach,' *Heuchera* x *villosa* 'Pistache,' *Heuchera* x *villosa* 'Brownies,' *Pennisetum alopecuroides, Pennisetum alopecuroides* 'Cassian,' *Pennisetum alopecuroides* 'Hameln' and *Pennisetum alopecuroides* 'Little Bunny.' Rooted liners were potted, treatments included the utilization of two overwintering covers, two fertility rates and two substrate moisture contents at the Urban Horticulture Center (Blacksburg, VA) (UHC), Poplar Ridge Nursery (Montross, VA) (PR) and Riverbend Nursery, Inc. (Riner, VA) (RB). Covering treatments included no cover, a double layer of Dewitt N-Sulate™ insulation fabric or a double layer of Dewitt N-Sulate™ insulation fabric with a single sheet of 4 mil white polyethylene plastic on top of the insulation fabric placed over the plants. Fertility treatments included Harrell's Polyon® 17-5-11 controlled release fertilizer incorporated into the substrate at a rate of 3.17 kg (7 lbs) per 2.29 m^3 (1 yd^3) as the Low treatment and Osmocote Plus® 15-9-12 controlled release fertilizer added to the Low treatment, via incorporation, at a rate of 2.44 kg (5.4 lbs) per 2.29 m^3 (1 yd^3) to achieve the High fertility treatment of 5.62 kg (12.4 lbs) per 2.29 m^3 (1 yd^3). Substrate moisture content treatments included pots irrigated to container capacity when the average soil moisture content of five randomly sampled pots fell below 25% (Wet) or 15% (Dry) volumetric water content. Vigor at the UHC was reduced with the high fertility rate for *E.* 'Hot Papaya' (Creekhill Nursery) and *H.* 'Brownies.' A double layer of Dewitt N-Sulate™ insulation fabric and white polyethylene plastic on top of the cover, in combination with the wet substrate moisture treatment improved vigor of *E.* 'Hot Papaya' (Holtex Enterprises). A double layer of Dewitt N-Sulate™ insulation fabric in combination with the wet substrate moisture content and the high fertility rate reduced the vigor of *P.* 'Cassian.' No overwintering cover reduced the vigor of *P.* 'Hameln.' No overwintering cover and the high fertility rate reduced the vigor of *P.* 'Little Bunny.' Overall vigor at PR was improved with the high fertility rate for *E.* 'Milkshake,' *G. x grandiflora* 'Gallo Peach' and *H.* 'Brownies.' At RB, a double layer of Dewitt N-Sulate™ insulation fabric in combination with the low fertility treatment and no cover in combination with the high fertility treatment reduced vigor for *E.* 'Milkshake' and *P.* 'Little Bunny,' respectively. No cover in combination with the wet substrate moisture treatment reduced vigor for *G. x grandiflora* 'Gallo Peach.'**

Introduction

There has been an increase in the number of growers producing herbaceous perennials in containers, because of this, more perennial growers have to face the issues associated with overwintering. In an unpublished survey (Harris, 2010), results showed that a majority of growers are including overwintering as part of their production cycle but the practices for overwintering varied. Research has focused on overwintering practices of woody ornamental plants. Gouin (1973) and Dunwell and McNiel (2009) report that when overwintering container-grown woody ornamental plants, soil moisture needs to be monitored and winter protection, in the form of a cold-frame or thermal blanket, needs to be provided to the plants. Davidson and Mecklenburg (1974) reported that the best environment for overwintering evergreens (*Taxus cuspidate, Thuja occidentalis, Juniperus chinensis* 'Pfitzeriana' and *Rhododendron catawbiense*), without providing irrigation, was in a white polyethylene plastic covered cold-frame structure. Providing at least one layer of an overwintering cover (thermal blanket, microfoam, polyblanket) will provide additional protection to overwintered, container-grown, woody ornamentals (Desjardins and Chong, 1980; Chong and Desjardins, 1981; Hicklenton, 1982; Pellet et al., 1985). Gouin and Link (1979) found that overwintering survival of *Ilex crenata, Buxus sempervirens, Prunus laurocerasus* and *Cotoneaster congestus* was improved by using a thermal blanket and top growth of surviving plants was increased by irrigating plants once a week during the winter.

Not many current studies have been published related to overwintering practices for container-grown perennials. Providing winter protection in the form of either a thermal blanket or cold-frame structure improves the overwintering survival and vigor of specific species of container-grown perennials. Cunliffe and Meyer (2004) found that container size and media did not affect the overwintering survival of *Schizachyrium scoparium, Sporobolus heterolepis, Calamagrostis* x *acutiflora* 'Karl Foerster,' *Miscanthus sinensis* 'Purpurascens' and *Miscanthus sinensis* 'Variegatus,' but a larger container size increased vigor. Furthermore, overwintering survival was species specific, with lower survival for *Sporobolus heterolepis* and *Miscanthus sinensis* 'Variegatus' than the other species. Perry (1998) reported that successful overwintering survival of container-grown herbaceous perennials can be attributed to a plant's specific cold hardiness, the type of low temperature protection provided (cold-frame or thermal blankets), fertilization and irrigation (Dimke et al., 2008; Fisher, 2001; Iles et al., 1993; Perry, 1990; Smith, 1993; Still et al., 1987).

A main factor to consider when overwintering plants is the hardiness of the root system. Container grown plants are more susceptible to freezing damage than plants grown in the field. Roots of *Ilex opaca* and *Thuja ocidentalis* grown in a container may be exposed to a temperature of -15°C (5°F) compared to roots of field grown *Ilex opaca* and *Thuja ocidentalis* (three inches below the surface) which are exposed to -6°C (21°F) at the same time (Steponkus et al., 1976). Overwintering success depends on the protection provided and according to Perry (1998) overwintering survival may be affected by the rate of temperature drop and the temperature fluctuation, as well as soil moisture. The factors of temperature and soil moisture have been studied in the overwintering of alfalfa (Paquin et al., 1987), but they have yet to be studied for container grown perennials.

Results of an unpublished survey (Harris, 2010) and personal communications with growers (Packett, personal communication; Epps, personal communication and Brantingham, personal communication) indicate that many growers are having trouble overwintering various container-grown ornamentals. Based on the inquires from the industry and the lack of up to date information on overwintering practices for container grown perennials, research was conducted to determine overwintering practices that could increase the survival and vigor of many container grown perennials.

Materials and Methods

The experiment was designed to study the effects of overwintering treatments on the survival and vigor of popular container-grown perennials based on requests from growers (Harris, 2010; Packett, personal communication; Epps, personal communication and Brantingham, personal communication). Overwintering treatments and practices were chosen based on their feasibility of implementation into the production practices used by growers. The experiment was conducted at the Urban Horticulture Center (UHC; Blacksburg, VA; USDA Hardiness Zone 6a). The study was replicated at Poplar Ridge Nursery (PR; Montross, VA; USDA Hardiness Zone 7a) and Riverbend Nursery, Inc. (RB; Riner, VA; USDA Hardiness Zone 5b) to provide an additional hardiness zones.

On September 3, 2010 rooted liners of *Echinacea purpurea* 'Hot Papaya' from Creek Hill Nursery, Leola, PA and Holtex Enterprises, Trumbauersville, PA (72 plants per tray), *Echinacea purpurea* 'Milkshake' from North Creek Nurseries, Landenberg, PA (72 plants per tray), *Gaillardia* x *grandiflora* 'Gallo Peach' from Green Leaf Plants®, Lancaster, PA (72 plants per tray), *Heuchera* x *villosa* 'Pistache' from Creek Hill Nursery, (72 plants per tray), *Heuchera* x *villosa* 'Brownies' from North Creek Nurseries, (72 plants per tray), *Pennisetum alopecuroides , Pennisetum alopecuroides* 'Cassian,' *Pennisetum alopecuroides* 'Hameln' and *Pennisetum alopecuroides* 'Little Bunny' from Hoffman Nursery, Inc., Rougemont, NC (32 plants per tray) were transplanted individually into Elite 300 trade gallon containers (2.8 L) (ITML Horticultural Products, Inc., Akron, OH) using a custom mixed bark substrate (85% pine : 15% peat volume : volume) provided by RB.

All tested plant species and cultivars were grown in a Quonset-style cold-frame structure covered with a single layer of polyethylene plastic (4 mil white polyethylene plastic; Ginegar Plastic Products Ltd., Akron, OH) located at the UHC. Tested plant species and cultivars of *E.* 'Milkshake,' *G.* 'Gallo Peach,' *H.* 'Brownies,' *P.* 'Little Bunny' were grown in a Quonset-style cold-frame structure covered with a single layer of polyethylene plastic (6 mil clear TUFFLITE™; Berry Plastics Corporation, Evansville, IN) at PR or in a Quonset-style cold-frame structure covered with a single layer of polyethylene plastic (3 mil white polyethylene plastic; Wyatt-Quarles Seed Company, Garner, NC) located at RB.

In accordance with previous research and personal communications with a Virginia ornamental grasses liner producer (Packett, personal communication), plants were cut back to 4 inches (10.2 cm) in height once dormant. Plants were irrigated to container capacity prior to the start of overwintering treatments. A fungicide drench of etridiazole+thiophanate-methyl (BANROT® 40WP; Scotts-Sierra Horticultural Products Company, Marysville, OH) and mefenoxam (Subdue MAXX™; Syngenta, Basel, Switzerland) was applied at recommended rates (28.3 grams per 37.8 liters of water and 3 millimeters per 37.8 liters of water, respectively) to all plants to alleviate pathogen development as a complicating factor of plant survival. An extra row of containers filled with custom bark substrate was placed around each block to serve as a "buffer" row as suggested by Perry (1998).

At each location, the ambient air temperature inside and outside of the cold-frame, the ambient air temperature and substrate media temperatures under each type of cover and under no cover, was monitored continually, using WatchDog® Data Loggers (Spectrum® Technologies, Inc., Plainfield, IL), throughout the experiment (Figures 3.1-3, Appendix B: Figures 3.1-6). At each location, the daily light integral (DLI) (mol/(m^2d)) in each poly house, was monitored continually, using WatchDog® Data Loggers throughout the experiment (Tables 3.15-17).

At time of plant dormancy, treatments (December 1, 2010 (UHC); December 3, 2010 (RB) and December 4, 2010 (PR) went into effect which included three different types of overwintering covers, two fertility rates and two substrate moisture levels. Covering treatments included, no cover, a double layer of Dewitt N-Sulate™ insulation fabric (1.5 ounce weight) or a double layer of Dewitt N-Sulate™ insulation fabric with a single sheet of 4 mil white polyethylene plastic on top of the insulation fabric. Covering treatments began at time of first forecasted nighttime temperature reaching 20°F and uncovered when temperatures went above this threshold as suggested by Still et al. (1986). Covers were applied and removed at this threshold to alleviate temperature as a complicating factor of plant survival.

Fertility treatments included Harrell's Polyon® 17-5-11 (5-6 month release) (Harell's LLC., Lakeland, FL) controlled release fertilizer incorporated into the substrate at a rate of 3.17 kg (7 lbs) per 2.29 m^3 (1 yd^3) which represented the low fertility rate.

Osmocote Plus® 15-9-12 (5-6 month release) (The Scotts Company, LLC., Marysville, OH) controlled release fertilizer was added to the low fertility rate, via incorporation, at a rate of 2.44 kg (5.4 lbs) per 2.29 m^3 (1 yd^3) to achieve a final fertility rate of 5.62 kg (12.4 lbs) per 2.29 m^3 (1 yd^3), which represented the high fertility rate. Media pH and electrical conductivity (EC) were monitored using the HI9812 pH/EC/TDS Meter (Hanna Instruments®, Inc., Woonsocket, RI) at the start, during the middle and at the end of the experiment (at each location) utilizing the Virginia Tech Pour-through Extraction Method (Wright, 1986) (Tables 3.5-10; 3.11-14; Appendix B: Tables 3.1-8).

Substrate moisture level treatments included irrigating pots to container capacity when the average soil moisture of five randomly sampled pots fell below 25% or 15% volumetric water content (VMC), which represented wet and dry treatments, respectively. Soil moisture levels were monitored in pots twice a week using a WaterScout SM 100 Soil Moisture Meter (Spectrum® Technologies, Inc., Plainfield, IL) (Figures 3.4-6, Appendix B: Figures 3.7-13).

At the time we determined plants to be market ready (species specific and location specific), we evaluated them for their survival (dead or alive) and for their vigor based on a five point scale. We determined that plants receiving a vigor rating (either scale) of 4 or above would be, from a producers marketability standpoint, saleable.

We utilized the vigor scale developed by Perry (1990): 1 = dead with no re-growth of shoots, 2 = having very limited re-growth, 3 = having marginal re-growth, 4 = having good re-growth and 5 = having the most vigorous re-growth (Figure 3.7) for rating of herbaceous perennials.

Figure 3.7 Vigor rating for *Heuchera* x *villosa* 'Pistache'

We utilized the scale developed by Cunliffe and Meyer (2002); 1 = dead, 2 = diffuse growth and new crown diameter less than 1/2 the diameter of old crown growth, 3 = expansive growth and new crown diameter less than 1/2 the diameter of old crown growth, 4 = diffuse growth and new crown diameter more than 1/2 the diameter of old crown growth and 5 = expansive growth and new crown diameter more than 1/2 the diameter of old crown growth, for rating of the tested *Pennisetum* species and cultivars.

On April 8, 2011, *Heuchera* x *villosa* 'Brownies' and *Heuchera* x *villosa* 'Pistache' from the UHC were determined to be market ready and were evaluated. On May 10, 2011, *Echinacea purpurea* 'Hot Papaya' (Creek Hill Nursery and Holtex Enterprises), *Echinacea purpurea* 'Milkshake,' *Gaillardia* x *grandiflora* 'Gallo Peach,' *Pennisetum alopecuroides, Pennisetum alopecuroides* 'Cassian,' *Pennisetum alopecuroides* 'Hameln' and *Pennisetum alopecuroides* 'Little Bunny' from the UHC were evaluated.

On April 9, 2011, *Heuchera* x *villosa* 'Brownies' and *Gaillardia* x *grandiflora* 'Gallo Peach' from PR were determined to be market ready and were evaluated. On May 10, 2011, *Echinacea purpurea* 'Milkshake' and *Pennisetum alopecuroides* 'Little Bunny' from PR were evaluated.

On April 12, 2011, *Heuchera* x *villosa* 'Brownies' from RB were determine to be market ready and were evaluated On May 11, 2011, *Echinacea purpurea* 'Milkshake,' *Gaillardia* x *grandiflora* 'Gallo Peach' and *Pennisetum alopecuroides* 'Little Bunny' from RB were evaluated.

The experiment was arranged in a split-plot design with overwintering cover treatments as the whole plot factor and fertilizer rates and substrate moisture levels as the subplot factors. Covering treatments were completely randomized with two replicates. Subplots of fertilizer rates and substrate moisture levels had six replicates with fertilizer rates completely randomized. The treatment design was a 3 x 2 x 2 factorial with three overwintering covers, two fertilizer rates and two substrate moisture levels for a total of 12 treatments. Data were subjected to analysis of variance procedures (ANOVA) for interaction between treatments on overwintering survival and vigor.   Mean separations were performed on significant effects using JMP Version 8 (SAS Institute, Inc., Cary, N.C.).

Results and Discussion

For plants at the UHC, the low fertility average initial leachate pH ranged from 5.3 to 7.2 and EC ranged from 0.57 mS/cm to 1.32 mS/cm using the pour-through extraction method. The high fertility average initial leachate (high fertility) pH ranged from 5.1 to 6.8 and EC ranged from 1.65 mS/cm to 4.59 mS/cm using the pour-through extraction method (Tables 3.5; 3.6).

For plants at RB, the low fertility average initial leachate pH ranged from 6.6 to 7.2 and EC ranged from 1.27 mS/cm to 1.94 mS/cm using the pour-through extraction method. The high fertility average initial leachate pH ranged from 6.1 to 6.8 and EC ranged from 3.31 mS/cm to 5.00 mS/cm using the pour-through extraction method (Tables 3.7; 3.8).

For plants at PR, the low fertility average initial leachate pH ranged from 5.9 to 7.8 and EC ranged from 0.87 mS/cm to 2.66 mS/cm using the pour-through extraction method. The high fertility average initial leachate pH ranged from 6.3 to 7.0 and EC ranged from 1.55 mS/cm to 3.51 mS/cm using the pour-through extraction method (Tables 3.9; 3.10).

At the UHC, from September 2010 to May 2011, average air temperature outside the cold-frame was 8.1°C, with high and low temperature extremes of 33.3°C and -13.2°C, respectively. From November 2010 to May 2011, average air temperature inside the cold-frame was 8.5°C, with high and low temperature extremes of 35.8°C and -10.9°C, respectively. Average DLI inside the cold-frame from November 2010 to May 2011 was 7.44 mol/(m^2d) (Table 3.15).

At RB, from October 2010 to May 2011, average air temperature outside the cold-frame was 4.8°C, with high and low temperature extremes of 31.3°C and -14.3°C, respectively. From October 2010 to May 2011, average air temperature inside the cold-frame was 5.5°C, with high and low temperature extremes of 37.8°C and -10.6°C, respectively. Average DLI inside of cold-frame from November 2010 to May 2011 was 9.44 mol/(m^2d) (Table 3.16).

At PR, from October 2010 to May 2011, average air temperature outside the cold-frame was 7.1°C, with high and low temperature extremes of 37.3°C and -12.6°C, respectively. From October 2010 to May 2011, average air temperature inside the cold-frame was 8.7°C, with high and low temperature extremes of 40.2°C and -9.3°C, respectively. Average PAR inside of cold-frame from November 2010 to May 2011 was 17.72 mol/(m^2d) (Table 3.17).

At the UHC, from December 2010 to March 2011, average air temperature inside the cold-frame with no additional cover was 4.2°C, with high and low temperature extremes of 32.4°C and -10.9°C, respectively with an average media temperature of 4.6°C, with high and low temperature extremes of 29.9°C and -4.6°C, respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ was 4.6°C, with high and low temperature extremes of 30.8°C and -5.6°C, respectively with an average media temperature of 4.9°C, with high and low temperature extremes of 22.8°C and -0.3°C, respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ + Poly was 4.7°C, with high and low temperature extremes of 31.6°C and -5.6°C, respectively with an average media temperature of 5.1°C, with high and low temperature extremes of 17.9°C and 0.1°C, respectively. From December 1, 2010 to March 22, 2011, covers were applied 65 days and then removed 34 days, covers were no longer utilized after March 31, 2011.

At RB, from December 2010 to March 2011, average air temperature inside the cold-frame with no additional cover was 3.0°C, with high and low temperature extremes of 28.2°C and -10.6°C, respectively with an average media temperature of 2.8°C, with high and low temperature extremes of 18.0°C and -1.3°C, respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ was 4.9°C, with high and low temperature extremes of 29.5°C and -5.8°C, respectively with an average media temperature of 5.2°C, with high and low temperature extremes of 18.7°C and -0.1°C, respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ + Poly was 4.8°C, with high and low temperature extremes of 27.9°C and -5.9°C, respectively with an average media temperature of 4.9°C, with high and low temperature extremes of 16.8°C and 0.2°C, respectively. From December 1, 20010 to March 22, 2011, covers were applied 72 days and then removed 53 days, covers were no longer utilized after March 31, 2011.

At PR, from December 2010 to March 2011, average air temperature inside the cold-frame with no additional cover was 5.8°C, with high and low temperature extremes of 38.4°C and -9.3°C, respectively with an average media temperature of 5.1°C, with high and low temperature extremes of 26.4°C and -0.3°C respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ was 5.2°C, with high and low temperature extremes of 39.3°C and -7.1°C, respectively with an average media temperature of 5.4°C, with high and low temperature extremes of 25.2°C and -0.8°C, respectively. From December 2010 to March 2011 average air temperature under the Dewitt N-Sulate™ + Poly was 6.0°C, with high and low temperature extremes of 42.1°C and -6.1°C, respectively with an average media temperature of 6.5°C, with high and low temperature extremes of 26.8°C and 0.6°C, respectively. From December 1, 2010 to March 22, 2011, covers were applied 35 days and then removed 30 days, covers were no longer utilized after March 5, 2011.

At the UHC, between December 13, 2010 and January 24, 2011, media subjected to wet and dry VWC containing all plants were frozen five times (Table 3.18). At time of fungicide treatment (December 1, 2009) plants were irrigated to container capacity. Additionally, media subjected to wet VWC containing certain plant species were irrigated to container capacity between one and four times throughout the course of the experiment

(Table 3.18). Media subjected to dry VWC containing certain plant species were irrigated to container capacity between one and five times throughout the course of the experiment (Table 3.18).

At RB, between December 8, 2010 and January 12, 2011, media subjected to wet and dry VWC containing all plants were frozen five times (Table 3.19). At time of fungicide treatment (December 3, 2009) plants were irrigated to container capacity. Additionally, media subjected to wet VWC containing certain plant species were irrigated to container capacity between one and four times throughout the course of the experiment (Table 3.19). Media subjected to dry VWC containing certain plant species were irrigated to container capacity between one and two times throughout the course of the experiment (Table 3.19).

At PR, at time of fungicide treatment (December 2, 2009) plants were irrigated to container capacity. Additionally, media subjected to wet VWC containing certain plant species were watered to container capacity five times throughout the course of the experiment (Table 3.20). Media subjected to dry VWC containing certain plant species were watered to container capacity between two and three times throughout the course of the experiment (Table 3.20).

On January 4, 2011; January 10, 2011 and March 2, 2011 at the UHC and on March 16, 2011 at RB, a tank mix of chlorothalonil (Daconil ULTREX®; Syngenta, Basel, Switzerland) and azoxystrobin (Heritage®; Syngenta, Basel, Switzerland) was applied to all tested plant species and cultivars to control Botrytis.

Treatment affected survival for *E.* ‘Hot Papaya’ (Holtex Enterprises) and *P.* ‘Little Bunny’ at the UHC (Tables 3.1a and 3.1b). The combination of no overwintering cover, the dry substrate moisture content and the high fertility treatment reduced survival of *E.* 'Hot Papaya' (Holtex Enterprises) (Table 3.1c). The use of the high fertility rate reduced survival of *P.* 'Little Bunny.' (Table 3.1d). At PR and RB all plants survived overwintering, therefore no treatment was significant (Tables not shown).

Vigor was affected for *E.* 'Hot Papaya' (Creek Hill Nursery), *E.* 'Hot Papaya' (Holtex Enterprises), *G.* x *grandiflora* 'Gallo Peach,' *H.* 'Brownies,' *P.* 'Cassian,' *P.* 'Hameln' and *P.* 'Little Bunny' at the UHC (Tables 3.2a, 3.2b). The use of the double layer of Dewitt N-Sulate™ insulation fabric in combination with the wet substrate moisture content and the high fertility rate reduced the vigor of *P.* 'Cassian' (Table 3.2c). The use of the Dewitt N-Sulate™ insulation fabric and white polyethylene plastic in combination with the wet substrate moisture treatment improved vigor of *E.* 'Hot Papaya' (Holtex Enterprises) (Table 3.2d). The use of the low fertility rate improved the vigor of *E.* 'Hot Papaya' (Creek Hill Nursery) (Table 3.2e). The use of the high fertility rate reduced the vigor of *H.* 'Brownies' (Table 3.2e). The use of no overwintering cover reduced the vigor of *G.* x *grandiflora* 'Gallo Peach' and *P.* 'Hameln' (Table 3.2e). The use of no overwintering cover and the high fertility rate reduced the vigor of *P.* 'Little Bunny' (Table 3.2e).

All plants had 100% survival at PR therefore treatments were not significant (table not shown). Vigor was affected for *E.* 'Milkshake,' *G. x grandiflora* 'Gallo Peach' and *H.* 'Brownies' at PR (Table 3.3a). The use of the high fertility rate improved the vigor of all three species (Table 3.3b).

All plants had 100% survival at RB therefore treatments were not significant (table not shown). Vigor was affected for *E.* 'Milkshake,' *G. x grandiflora* 'Gallo Peach' and *P.* ‘Little Bunny’ at RB (Tables 3.4a, 3.4b). The use of the double layer of Dewitt N-Sulate™ insulation fabric in combination with the low fertility rate reduced the vigor of *E.* ‘Milkshake’ (Table 3.4c). The use of no cover in combination with the high fertility rate reduced the vigor of *P.* ‘Little Bunny’ (Table 3.4c). The use of no cover in combination with the wet substrate moisture treatment reduced the vigor of *G. x grandiflora* ‘Gallo Peach’ (Table 3.4d).

The decrease in overwintering survival for *Echinacea* ‘Hot Papaya’ (Holtex Enterprises) with the use of no cover, high fertility rate and the dry substrate moisture content (Table 3.1c) could be explained by the high soluble salt levels (EC) obtained from midpoint pour-throughs (3.21 mS/cm; Table 3.11) at the UHC from the high fertility treatment compared to no cover, low fertility rate and the dry substrate moisture content EC (0.94 mS/cm; Table 3.11) . In combination with the high fertility rate, the dry substrate moisture content affected survival. High concentrations of nutrients can be a result of inadequate irrigation frequency, as explained by Smith and Lopez (2008), which could be explained by the dry substrate moisture content (Figure 3.3).

The reduction in the overwintering survival for *P.* ‘Little Bunny’ with the use of the high fertility rate at the UHC (Table 3.1d) could be explained by the range of high soluble salt levels (EC) obtained from the mid-point pour-through (2.11 mS/cm to 3.79 mS/cm; Table 3.11) and final pour-through (1.53 mS/cm to 2.51 mS/cm; Table 3.12) compared to the range of soluble salt levels (EC) from the low fertility rate obtained from the mid-point pour-through (1.28 mS/cm to 1.85 mS/cm; Table 3.11) and final pour-through (0.73 mS/cm to 1.40 mS/cm; Table 3.12) . The nutrients accumulated during overwintering and these excessive nutrient concentrations may have injured the roots as found in similar studies (Smith and Lopez, 2008). When compared to the EC (electrical conductivity) values (High fertility) obtained from the final pour-through at RB (2.02 mS/cm to 4.49 mS/cm; Table 3.13), EC values for *P.* 'Little Bunny' from the UHC (1.53 mS/cm to 2.51 mS/cm; Table 3.12) are similar and at PR (0.30 mS/cm to 0.34mS/cm; Table 3.14), EC values were lower when compared to both the UHC and RB. Only at the UHC was the survival statistically significant (Table 3.1a and 3.1d) but at RB survival percentage for the high fertility treatment was 92% while survival percentage for the low fertility treatment was 100% (Data not shown due to lack of statistical significance).

Accounting for the decrease in overwintering survival, in combination with the fertility treatments and substrate moisture treatments is the use of no overwintering cover. Both, Mader and Feldman (1948) and Perry (1998), state that using thermoblankets in a poly structure (referred to as the supplementary polyblanket technique) can create a microclimate around the plants which can be 4.4°C to 5.5°C warmer that the air above the blanket in the structure. This agrees with our temperature data (Figures 3.2-3) and additionally, we found that this temperature buffering holds true for the temperature of the uncovered media when compared to the covered media (Figures 3.2-3).

The decrease in overwintering vigor of *E.* 'Hot Papaya' (Creek Hill Nursery) (from 4.9 to 4.3; Table 3.2e) and *H.* 'Brownies (from a 5.0 to 4.8; Table 3.2e), at the UHC, with the use of the high fertility rate could be explained, as above, by the range of high soluble salt levels (EC) obtained in the mid-point (2.15 mS/cm to 3.13 mS/cm and 2.23 mS/cm to 3.07 mS/cm, respectively; Table 3.11) and final (0.48 mS/cm to 1.17 mS/cm and 1.07 mS/cm to 1.97 mS/cm, respectively; Table 3.12) pour-through. Statistically, the low fertility treatment increased the vigor, for both plant species, but from the standpoint of a producer trying to sell this plant, the increase would not have been relevant for *H.* 'Brownies. On the five point scale utilized, a saleable plant would receive a rating above a 4.0.

The decrease in overwintering vigor for *P.* 'Little Bunny,' at the UHC and RB and *E.* 'Milkshake,' at RB, is attributed to the covering treatments and the fertility treatments. At both RB and at the UHC, the use of no cover for *P.* 'Little Bunny' and the high fertility rate decreased vigor. This agrees with the data from the previous year's experiment (Chapter 2). *P.* 'Little Bunny' benefits from overwintering cover and low fertility rates. The low fertility treatment and utilization of covers increased the vigor of *P.* 'Little Bunny,' and from the standpoint of a producer trying to sell this plant, the increase would have been relevant.

E. 'Milkshake,' at RB had decreased vigor with the use of N-Sulate™ cover and the low fertility rate. This is a trend not consistent with other research but could be explained by the range of EC values (Low fertility) obtained at the initial (1.21 mS/cm to 1.53 mS/cm; Table 3.8) and final (0.59 mS/cm to 0.97 mS/cm; Table 3.13) pour-through data collection points. The utilization of the fertilizer during plant growth, from the initial collection until the final collection, may have caused the plant to have a reduced vigor rating when compared to the high fertility treatment, which still had adequate fertility levels (0.72 mS/cm to 2.70 mS/cm; Table 3.13) at the final collection point. Statistically, the low fertility treatment and the use of N-Sulate™ cover reduced the vigor, but from the standpoint of a producer trying to sell this plant, the increase would not have been relevant.

The decrease in overwintering vigor of *G. x grandiflora* 'Gallo Peach,' at RB was with the use of no cover and the wet substrate moisture treatment. Pilon (2010) reports that if the substrate is kept wet for a long period of time, then this could result in weak stems and poor growth of the plant. In combination with the wet substrate treatment, the use of no cover resulted in poor overall vigor. This agrees with Still et al. (1987) who found that *Gaillardia* overwintered in a single layer poly house and left uncovered resulted in poor saleable quality. The use of no cover and wet substrate decreased the vigor and from the standpoint of a producer trying to sell this plant, this decrease would have been relevant.

The increase in overwintering vigor of *E.* 'Hot Papaya' (Holtex Enterprises) at the UHC with the use of N-Sulate™ cover and the wet substrate treatment has been seen with other tested plant species and cultivars in this experiment, agreeing with literature and supporting the fact that overwintered crops benefit from cover and moisture. From the standpoint of a producer trying to sell this plant, the increase would have been relevant.

Vigor was decreased for *P.* 'Cassian,' at the UHC with the combination of N-Sulate™ cover, high fertility rate and the wet substrate treatment. This could possibly be explained by, under this combination of treatments, the final range of EC values (1.13 mS/cm to 2.23 mS/cm; Table 3.12) being the highest when compared to the other treatments. This high EC value could have reduced the visual "fullness" (number of regenerated tillers) of the plant in the container which could explain the reduction seen in vigor. Statisticaly, the vigor was decreased but from the standpoint of a producer trying to sell this plant, this decrease would have been relevant because a vigor rating of 4 or above would be a sellable plant.

Vigor was decreased with the use of no overwintering cover for *G.* x *grandiflora* 'Gallo Peach' and *P.* 'Hameln' at the UHC. For *P.* 'Hameln,' this agrees with the data from the previous year's experiment (Chapter 2). The use of covers increased the vigor and from the standpoint of a producer trying to sell this plant, the increase would have been relevant for *G.* x *grandiflora* 'Gallo Peach.' For *P.* 'Hameln' though, the statistical difference from the use of covers would not have been relevant from the standpoint of a producer selling this plant.

At PR, the vigor for *E.* 'Milkshake,' *G. x grandiflora* 'Gallo Peach' and *H.* 'Brownies' was increased with the use of the high fertility rate. Only for *G. x grandiflora* 'Gallo Peach' would the increase in vigor be relevant from a producer's standpoint. This increase can be explained by the fact that the soluble salt levels never reached a level of being excessive, which is seen in the final EC values obtained (0.14 mS/cm to 0.47 mS/cm; Table 3.14). The higher fertility treatment provided the proper nutrients for adequate growth and vigor. These lower EC values can be attributed to the additional watering events which occurred at Poplar Ridge Nursery, in comparison to the other sites (Figures 3.4, 3.5). These additional watering events helped to prevent excessive soluble salt levels from accumulating and proper container media and nutrition management is a key in producing quality container grown plants Davidson et al. (2000).

In conclusion, we have found that overwintering survival and vigor can vary with plant species and location. For some plant species depending on location, such as *E* 'Hot Papaya,' *G.* 'Gallo Peach' and *P.* 'Little Bunny' vigor can be improved if plants are covered during overwintering. Growing media used for overwintering crops should be tested frequently to track fluctuations in electrical conductivity (EC). Too high an EC could result in poor overwintered quality or survival and too low of an EC at time of finishing a crop could also affect the quality. Providing plants such as *G.* 'Gallo Peach' with adequate moisture throughout the winter helps to improve plant vigor in the spring and helps to keep soluble salts levels from accumulating. Again, this is crop dependent, as we found that some crops overwinter poorly if in wet media for extended periods of time. For some plant species a combination of overwintering covers, fertility treatments and substrate moisture treatments could either improve or reduce overwintering survival and vigor. Grower management practices must include a program of monitoring plant covering, fertility and substrate moisture in order for successful overwintering.

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Table 3.1a. Analysis of variance summary for fertility rate, covering and substrate moisture content effects on overwintering survival of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya’ (HOL), *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies,’ *Heuchera* ‘Pistache,’ *Pennisetum alopecuroides, Pennisetum* ‘Cassian,’ *Pennisetum* 'Hameln,’ and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Fertility Rate				Covering				Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	1	0.13	3.00	0.0884	2	0.08	1.00	0.3739	1	0.01	0.33	0.5659
E. 'Hot Papaya' (HOL)	1	1.13	13.06	0.0006*	2	0.08	0.48	0.6188	1	0.13	1.45	0.2330
E. 'Milkshake'	1	0.00	0.00	1.0000	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
G. ‘Gallo Peach’	1	0.01	1.00	0.3213	2	0.03	1.00	0.3739	1	0.01	1.00	0.3213
H. 'Brownies'	1	0.00	0.00	1.0000	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
H. 'Pistache'	1	0.01	1.00	0.3213	2	0.03	1.00	0.3739	1	0.01	1.00	0.3213
P. alopecuroides	1	0.00	0.00	1.0000	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Cassian'	1	0.00	0.00	1.0000	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Hameln'	1	0.00	0.00	1.0000	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Little Bunny'	1	0.89	10.00	0.0025*	2	0.36	2.03	0.1401	1	0.00	0.00	1.0000

n=6
*Significant at P≤ 0.05

Table 3.1b. Analysis of variance summary of interaction effects for fertility rate, covering and substrate moisture content effect on overwintering survival of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides, Pennisetum* 'Cassian,' *Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Fertility Rate*Covering				Fertility Rate*Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	2	0.08	1.00	0.3739	1	0.01	0.33	0.5659
E. 'Hot Papaya' (HOL)	2	0.08	0.48	0.6188	1	0.13	1.45	0.2330
E. 'Milkshake'	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
G. 'Gallo Peach'	2	0.03	1.00	0.3739	1	0.01	1.00	0.3213
H. 'Brownies'	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
H. 'Pistache'	2	0.03	1.00	0.3739	1	0.01	1.00	0.3213
P. alopecuroides	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Cassian'	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Hameln'	2	0.00	0.00	1.0000	1	0.00	0.00	1.0000
P. 'Little Bunny'	2	0.36	2.03	0.1401	1	0.00	0.00	1.0000

	Covering*Moisture Content				Fertility Rate*Covering*Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	2	0.03	0.33	0.7178	2	0.03	0.33	0.7178
E. 'Hot Papaya' (HOL)	2	0.58	3.39	0.0404*	2	0.58	3.39	0.0404*
E. 'Milkshake'	2	0.00	0.00	1.0000	2	0.00	0.00	1.0000
G. 'Gallo Peach'	2	0.03	1.00	0.3739	2	0.03	1.00	0.3739
H. 'Brownies'	2	0.00	0.00	1.0000	2	0.00	0.00	1.0000
H. 'Pistache'	2	0.03	1.00	0.3739	2	0.03	1.00	0.3739
P. alopecuroides	2	0.00	0.00	1.0000	2	0.00	0.00	1.0000
P. 'Cassian'	2	0.00	0.00	1.0000	2	0.00	0.00	1.0000
P. 'Hameln'	2	0.00	0.00	1.0000	2	0.00	0.00	1.0000
P. 'Little Bunny'	2	0.08	0.47	0.6281	2	0.08	0.47	0.6281

n=6
*Significant at $P \leq 0.05$

Table 3.1c. Significant effect of covering treatment, fertility rate and substrate moisture content on the overwintering survival of *Echinacea* 'Hot Papaya' (HOL) at the Urban Horticulture Center (Blacksburg, VA).

Treatment			% Survival *E.* 'Hot Papaya' (HOL)
Fertility Rate	Cover	Moisture Content	
Low	No Cover	Wet	100a[z]
		Dry	100a
	N-Sulate™	Wet	100a
		Dry	100a
	N-Sulate™ + Poly	Wet	100a
		Dry	100a
High	No Cover	Wet	100a
		Dry	33c
	N-Sulate™	Wet	67ab
		Dry	83ab
	N-Sulate™ + Poly	Wet	83ab
		Dry	83ab
P-value			0.0404

n=6

[z]Mean separation within a column by Tukey's HSD test.

Table 3.1d. Significant effect of fertility rate on the overwintering survival of *Pennisetum* ‘Little Bunny’ at the Urban Horticulture Center (Blacksburg, VA).

	% Survival
Treatment	*P.* 'Little Bunny'
Fertility Rate	
Low	100a[z]
High	89b
P-value	0.0025

n=6
[z]Mean separation within a column by Tukey’s HSD test.

Table 3.2a. Analysis of variance summary for fertility rate, covering and substrate moisture content effects on overwintering vigor of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides, Pennisetum* 'Cassian,' *Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Fertility Rate				Covering				Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	1	6.72	6.91	0.0108*	2	0.08	0.04	0.9581	1	1.39	1.43	0.2367
E. 'Hot Papaya' (HOL)	1	25.68	19.30	<.0001*	2	3.08	1.16	0.3208	1	6.13	4.60	0.036*
E. 'Milkshake'	1	0.01	0.04	0.8422	2	0.53	0.76	0.4721	1	1.13	3.24	0.0769
G. 'Gallo Peach'	1	0.89	1.07	0.3058	2	8.78	5.27	0.0078*	1	0.00	0.00	1.0000
H. 'Brownies'	1	0.68	6.62	0.0126*	2	0.08	0.41	0.6685	1	0.13	1.22	0.2745
H. 'Pistache'	1	3.13	3.21	0.0785	2	1.75	0.90	0.4130	1	0.35	0.36	0.5529
P. alopecuroides	1	0.01	0.20	0.6563	2	0.25	1.80	0.1741	1	0.13	1.80	0.1848
P. 'Cassian'	1	3.13	15.00	0.0003*	2	0.11	0.27	0.7668	1	0.13	0.60	0.4416
P. 'Hameln'	1	0.13	0.67	0.4157	2	1.44	3.88	0.026*	1	0.13	0.67	0.4157
P. 'Little Bunny'	1	58.68	49.94	<.0001*	2	8.53	3.63	0.0325*	1	0.13	0.11	0.7454

n=6
*Significant at $P \leq 0.05$

Table 3.2b. Analysis of variance summary of interaction effects for fertility rate, covering and substrate moisture content effect on overwintering vigor of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya’ (HOL), *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies,’ *Heuchera* ‘Pistache,’ *Pennisetum alopecuroides, Pennisetum* ‘Cassian,’ *Pennisetum* 'Hameln,’ and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Fertility Rate*Covering				Fertility Rate*Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	2	0.36	0.19	0.8310	1	0.06	0.06	0.8119
E. 'Hot Papaya' (HOL)	2	1.69	0.64	0.5325	1	4.01	3.02	0.0875
E. 'Milkshake'	2	0.69	1.00	0.3739	1	0.13	0.36	0.5508
G. ‘Gallo Peach’	2	1.78	1.07	0.3506	1	0.50	0.60	0.4416
H. 'Brownies'	2	0.03	0.14	0.8739	1	0.35	3.38	0.0710
H. 'Pistache'	2	1.08	0.56	0.5767	1	1.68	1.72	0.1942
P. alopecuroides	2	0.03	0.20	0.8193	1	0.01	0.20	0.6563
P. 'Cassian'	2	0.00	0.00	1.0000	1	0.35	1.67	0.2017
P. 'Hameln'	2	0.33	0.90	0.4138	1	0.68	3.66	0.0606
P. 'Little Bunny'	2	5.36	2.28	0.1109	1	0.01	0.01	0.9138

	Covering*Moisture Content				Fertility Rate*Covering*Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Hot Papaya' (CH)	2	2.86	1.47	0.2378	2	3.69	1.90	0.1585
E. 'Hot Papaya' (HOL)	2	11.08	4.16	0.0202*	2	5.36	2.01	0.1423
E. 'Milkshake'	2	2.08	3.00	0.0573	2	0.25	0.36	0.6992
G. ‘Gallo Peach’	2	1.00	0.60	0.5521	2	1.00	0.60	0.5521
H. 'Brownies'	2	0.25	1.22	0.3035	2	0.19	0.95	0.3940
H. 'Pistache'	2	4.19	2.15	0.1253	2	0.19	0.10	0.9052
P. alopecuroides	2	0.25	1.80	0.1741	2	0.03	0.20	0.8193
P. 'Cassian'	2	4.00	9.60	0.0002*	2	2.78	6.67	0.0024*
P. 'Hameln'	2	0.33	0.90	0.4138	2	0.44	1.19	0.3101
P. 'Little Bunny'	2	0.08	0.04	0.9652	2	3.03	1.29	0.2832

n=6
*Significant at $P \leq 0.05$

Table 3.2c. Significant effect of covering treatment, fertility rate and substrate moisture content on the overwintering vigor of *Pennisetum* 'Cassian' at the Urban Horticulture Center (Blacksburg, VA).

Treatment			Vigor Rating[z] *P.* 'Cassian'
Fertility Rate	Cover	Moisture Content	
Low	No Cover	Wet	5.0a[y]
		Dry	5.0a
	N-Sulate™	Wet	4.8ab
		Dry	5.0a
	N-Sulate™ + Poly	Wet	5.0a
		Dry	5.0a
High	No Cover	Wet	5.0a
		Dry	4.2ab
	N-Sulate™	Wet	4.0b
		Dry	5.0a
	N-Sulate™ + Poly	Wet	5.0a
		Dry	4.2ab
P-value			0.0024

n=6
[y]Mean separation within a column by Tukey's HSD test.
[z]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.2d. Significant effect of covering treatment and substrate moisture content on the overwintering vigor of *Echinacea* 'Hot Papaya' (HOL) at the Urban Horticulture Center (Blacksburg, VA).

Treatment		Vigor Rating[z] *E.* 'Hot Papaya' (HOL)
Cover	Moisture Content	
No Cover	Wet	5.0a[y]
	Dry	3.3c
N-Sulate™	Wet	4.3abc
	Dry	4.0bc
N-Sulate™ + Poly	Wet	4.5ab
	Dry	4.7ab
P-value		0.0202

n=6
[y]Mean separation within a column by Tukey's HSD test.
[z]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.2e. Significant effect of covering treatment and fertility rate on the overwintering vigor of *Echinacea* 'Hot Papaya' (HOL), *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Pennisetum* 'Hameln,' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Vigor Rating[z]				
Treatment	*E.* 'Hot Papaya' (CH)	*G.* 'Gallo Peach'	*H.* 'Brownies'	*P.* 'Hameln'	*P.* 'Little Bunny'
Cover					
No cover	NS	4.0b[y]	NS	4.6b[y]	3.4b[y]
N-Sulate™	NS	4.8a	NS	5.0a	4.2a
N-Sulate™ + poly	NS	4.6ab	NS	4.9ab	4.1a
P-value		0.0078		0.0260	0.0325
Fertility Rate					
Low	4.9a[y]	NS	5.0a[y]	NS	4.8a[y]
High	4.3b	NS	4.8b	NS	3.0b
P-value	0.0108		0.0126		<.0001

n=6
[y]Mean separation within a column by Tukey's HSD test.
NS=Not Significant
[y]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.3a. Analysis of variance summary for fertility rate, covering and substrate moisture content effects on overwintering vigor of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA).

	Fertility Rate				Covering				Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Milkshake'	1	0.68	4.02	0.0496*	2	0.08	0.25	0.7828	1	0.13	0.74	0.3938
G. 'Gallo Peach'	1	16.06	38.03	<.0001*	2	0.69	0.82	0.4443	1	0.22	0.53	0.4710
H. 'Brownies'	1	2.00	9.73	0.0028*	2	0.86	2.09	0.1320	1	0.06	0.27	0.6051
P. 'Little Bunny'	1	0.06	0.22	0.6391	2	0.25	0.50	0.6090	1	0.22	0.89	0.3496

n=6

*Significant at $P \leq 0.05$

Table 3.3b. Significant effect of covering treatment, fertility rate and substrate moisture content on the overwintering vigor of *Echinacea* ‘Milkshake’ *Gaillardia* ‘Gallo Peach’ and *Heuchera* ‘Brownies’ at Poplar Ridge Nursery (Montross, VA).

	Vigor Rating[z]		
Treatment	*E.* 'Milkshake'	*G.* ‘Gallo Peach’	*H.* 'Brownies'
Fertility Rate			
Low	4.7b[y]	4.0b[y]	4.5b[y]
High	4.9a	5.0a	4.8a
P-value	0.0496	<.0001	0.0028

n=6
[y]Mean separation within a column by Tukey’s HSD test.
[z]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.4a. Analysis of variance summary for fertility rate, covering and substrate moisture content effects on overwintering vigor of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' and *Pennisetum* 'Little Bunny' at Riverbend Nursery, Inc. (Riner, VA).

	Fertility Rate				Covering				Moisture Content			
Plant Species	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Milkshake'	1	6.13	11.67	0.0011*	2	2.11	2.01	0.1428	1	0.68	1.30	0.2594
G. 'Gallo Peach'	1	2.35	2.30	0.1344	2	26.08	12.79	<.0001*	1	7.35	7.21	0.0094*
H. 'Brownies'	1	2.35	3.86	0.0541	2	2.58	2.12	0.1285	1	0.01	0.02	0.8804
P. 'Little Bunny'	1	13.13	26.41	<.0001*	2	8.21	8.26	0.0007*	1	0.21	0.41	0.5232

n=6

*Significant at $P \leq 0.05$

Table 3.4b. Analysis of variance summary of interaction effects for fertility rate, covering and substrate moisture content effect on overwintering vigor of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' and *Pennisetum* 'Little Bunny' at Riverbend Nursery, Inc. (Riner, VA).

		Fertility Rate*Covering				Fertility Rate*Moisture Content			
Plant Species	Source	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Milkshake'		2	4.33	4.13	0.0209*	1	0.01	0.03	0.8713
G. 'Gallo Peach'		2	3.69	1.81	0.1722	1	0.68	0.67	0.4171
H. 'Brownies'		2	3.03	2.49	0.0916	1	2.35	3.86	0.0541
P. 'Little Bunny'		2	6.75	6.79	0.0023*	1	0.05	0.10	0.7492
		Covering*Moisture Content				Fertility Rate*Covering*Moisture Content			
Plant Species	Source	DF	Mean Square	F Ratio	P-value	DF	Mean Square	F Ratio	P-value
E. 'Milkshake'		2	1.44	1.38	0.2605	2	0.78	0.74	0.4811
G. 'Gallo Peach'		2	14.53	7.13	0.0017*	2	2.03	0.99	0.3759
H. 'Brownies'		2	3.03	2.49	0.0916	2	2.03	1.67	0.1975
P. 'Little Bunny'		2	2.46	2.48	0.0928	2	0.60	0.60	0.5529

n=6
*Significant at $P \leq 0.05$

Table 3.4c. Significant effect of covering treatment, fertility rate and substrate moisture content on the overwintering vigor of *Echinacea* 'Milkshake' and *Pennisetum* 'Little Bunny' at Riverbend Nursery, Inc. (Riner, VA).

		Vigor Rating[z]	
Treatment		*E.* 'Milkshake'	*P.* 'Little Bunny'
Cover	Fertility Rate		
No Cover	Low	4.4a[y]	4.8a[y]
	High	4.5a	3.2c
N-Sulate™	Low	3.4b	5.0a
	High	4.7a	4.1b
N-Sulate™ + Poly	Low	4.0ab	4.9a
	High	4.4a	4.8a
P-value		0.0209	0.0023

n=6
[y]Mean separation within a column by Tukey's HSD test.
[z]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.4d. Significant effect of covering treatment, fertility rate and substrate moisture content on the overwintering vigor of *Gaillardia* 'Gallo Peach' at Riverbend Nursery, Inc. (Riner, VA).

Treatment		Vigor Rating[z]
		G. 'Gallo Peach'
Cover	Moisture Content	
No Cover	Wet	2.9c[y]
	Dry	3.3bc
N-Sulate™	Wet	4.9a
	Dry	3.1c
N-Sulate™ + Poly	Wet	4.8a
	Dry	4.3ab
P-value		0.0017

n=6
[z]Mean separation within a column by Tukey's HSD test.
[y]Vigor Rating:
1 = dead with no re-growth of shoots
2 = having very limited re-growth
3 = having marginal re-growth
4 = having good re-growth
5 = having the most vigorous re-growth

Table 3.5. Average initial pH of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides*, *Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	6.9	6.0	6.6	5.7	6.0	6.7	5.6	6.5	6.1	6.4	5.9	6.2
E. 'Hot Papaya' (HOL)	7.1	6.3	6.8	5.8	6.3	6.4	5.8	6.3	6.1	6.7	5.7	6.6
E. 'Milkshake'	6.7	5.8	6.6	5.7	6.0	7.0	5.6	6.6	6.5	6.4	6.0	6.1
G. 'Gallo Peach'	6.8	6.0	6.6	6.0	6.1	6.6	5.8	6.2	6.2	6.7	6.0	6.3
H. 'Brownies'	7.1	6.1	6.5	5.6	6.2	6.9	5.9	6.5	6.2	6.5	5.8	6.4
H. 'Pistache'	7.1	6.0	6.7	5.9	6.2	6.6	5.9	6.3	6.2	6.7	5.7	6.5
P. alopecuroides	6.8	6.0	6.6	5.6	6.2	6.3	5.8	6.2	6.2	6.6	6.0	6.3
P. 'Cassian'	6.8	6.0	6.5	5.8	6.0	6.8	5.4	6.6	6.3	6.1	5.7	6.0
P. 'Hameln'	6.7	5.3	6.6	5.1	6.1	6.3	5.5	5.7	6.7	6.1	6.1	5.9
P. 'Little Bunny'	7.2	6.1	6.5	5.5	6.1	6.5	5.6	6.0	6.1	6.7	5.7	6.4

n=3

Taken on 10/20/10

Table 3.6. Average initial EC (mS/cm) of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya’ (HOL), *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies,’ *Heuchera* ‘Pistache,’ *Pennisetum alopecuroides*, *Pennisetum* ‘Cassian,’ *Pennisetum* ‘Hameln’ and *Pennisetum* ‘Little Bunny’ at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	1.07	0.82	3.04	2.84	1.20	1.24	2.89	3.65	1.04	0.57	2.49	2.65
E. 'Hot Papaya' (HOL)	1.06	0.59	2.71	2.37	0.70	1.32	2.73	2.55	0.81	0.90	2.44	2.15
E. 'Milkshake'	1.05	0.90	2.82	2.97	1.41	1.21	4.02	3.16	1.12	0.92	3.73	1.80
G. ‘Gallo Peach’	1.02	1.10	3.61	2.19	1.01	1.25	2.50	2.61	1.02	0.73	3.29	3.03
H. 'Brownies'	0.75	0.76	3.02	2.71	1.24	1.18	2.95	2.78	1.02	1.51	2.81	2.33
H. 'Pistache'	1.14	0.57	2.04	2.14	0.79	0.81	2.56	2.03	0.81	0.88	2.96	1.65
P. alopecuroides	1.10	0.85	4.02	2.60	1.00	1.10	2.77	3.36	1.17	1.21	2.89	3.56
P. 'Cassian'	1.09	0.99	4.09	2.94	1.03	0.93	4.59	3.23	0.78	0.80	4.20	2.93
P. 'Hameln'	0.77	0.99	2.58	2.64	0.98	1.03	3.83	2.37	1.15	0.94	3.93	2.19
P. 'Little Bunny'	1.17	1.06	3.62	2.89	1.06	1.19	3.33	3.81	1.30	1.08	3.34	3.30

n=3

Taken on 10/20/10

Table 3.7. Average initial pH of *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies’ and *Pennisetum* ‘Little Bunny’ at Riverbend Nursery (Riner, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	7.0	7.0	6.7	6.5	6.6	6.7	6.6	6.5	7.2	6.8	6.6	6.5
G. ‘Gallo Peach’	7.0	7.0	6.5	6.5	6.6	6.7	6.1	6.4	7.2	6.8	6.4	6.4
H. 'Brownies'	6.9	6.7	6.3	6.7	6.8	6.8	6.2	6.4	7.1	7.0	6.3	6.3
P. 'Little Bunny'	6.8	6.9	6.6	6.6	6.9	7.1	6.8	6.4	7.0	7.1	6.4	6.7

n=3

Taken on 10/26/10

Table 3.8. Average initial EC (mS/cm) of *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies’ and *Pennisetum* ‘Little Bunny’ at Riverbend Nursery (Riner, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	1.34	1.45	3.99	4.73	1.61	1.21	4.13	4.01	1.31	1.53	4.94	4.09
G. ‘Gallo Peach’	1.27	1.39	3.88	3.35	1.35	1.62	3.63	3.80	1.44	1.94	4.28	4.22
H. 'Brownies'	1.66	1.55	3.73	3.81	1.68	1.46	4.38	3.31	1.62	1.40	4.59	4.55
P. 'Little Bunny'	1.37	1.57	4.92	5.00	1.45	1.42	4.15	4.67	1.38	1.39	4.50	4.66

n=3

Taken on 10/26/10

Table 3.9. Average initial pH of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	6.6	6.8	6.5	6.4	7.8	6.9	6.8	6.4	6.7	7.0	6.7	6.6
G. 'Gallo Peach'	7.0	6.5	6.7	6.7	7.1	6.8	6.6	6.8	7.1	7.2	6.9	7.0
H. 'Brownies'	5.9	6.9	6.3	6.5	7.0	7.0	6.7	6.6	7.1	6.8	6.8	6.7
P. 'Little Bunny'	7.0	7.2	6.8	6.7	7.0	6.9	6.7	6.8	6.9	6.9	6.6	6.5

n=3

Taken on 10/22/10

Table 3.10. Average initial EC (mS/cm) of *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies’ and *Pennisetum* ‘Little Bunny’ at Poplar Ridge Nursery (Montross, VA).

	Evaluation # 1											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	1.27	1.27	2.35	3.01	1.13	1.26	2.79	3.51	0.87	1.06	3.24	2.92
G. ‘Gallo Peach’	1.31	1.38	2.53	2.43	1.04	1.45	2.36	1.55	1.18	1.07	2.49	2.04
H. 'Brownies'	1.12	1.15	2.99	3.04	1.17	1.32	2.77	3.48	1.15	0.96	2.24	2.78
P. 'Little Bunny'	1.04	2.66	2.96	3.11	1.01	1.03	2.06	2.89	1.00	1.21	2.93	2.85

n=3

Taken on 10/22/10

Table 3.11. Average midpoint EC (mS/cm) of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides*, *Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 2											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	1.38	1.13	3.08	2.15	1.56	1.37	2.73	2.19	1.54	1.77	3.13	2.75
E. 'Hot Papaya' (HOL)	1.57	0.94	3.12	3.21	1.07	1.31	2.43	3.03	1.27	1.44	3.34	3.18
E. 'Milkshake'	1.30	1.57	4.18	3.11	1.48	1.33	2.99	2.89	1.55	1.61	3.82	3.34
G. 'Gallo Peach'	1.46	1.28	3.90	2.31	1.28	1.44	2.60	3.32	1.72	1.25	3.02	2.78
H. 'Brownies'	1.15	0.66	3.05	2.33	1.28	1.39	3.07	2.43	1.47	1.19	2.57	2.92
H. 'Pistache'	1.34	0.65	2.59	2.67	1.30	0.83	2.12	2.64	1.26	1.14	3.60	3.15
P. alopecuroides	1.63	1.12	3.68	3.60	1.51	1.83	3.52	4.17	1.38	1.71	3.38	3.06
P. 'Cassian'	1.53	1.27	4.07	3.29	1.20	1.16	3.51	2.97	1.04	1.30	4.04	4.60
P. 'Hameln'	1.20	1.83	2.95	2.52	1.33	1.38	3.57	2.67	1.71	1.66	4.43	3.59
P. 'Little Bunny'	1.41	1.68	3.73	2.11	1.28	1.54	3.12	3.79	1.85	1.38	3.73	2.18

n=3

Taken on 3/1/11

Table 3.12. Average final EC (mS/cm) of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides*, *Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	0.42	0.40	0.96	1.17	0.31	0.76	0.60	1.07	0.34	0.33	0.48	0.76
E. 'Hot Papaya' (HOL)	0.48	0.41	0.50	1.25	0.28	0.38	1.08	0.65	0.41	0.53	0.77	0.82
E. 'Milkshake'	0.42	0.33	1.44	0.60	0.37	0.49	0.57	1.96	0.54	0.52	0.85	0.79
G. 'Gallo Peach'	0.53	0.65	1.35	1.32	0.28	0.52	0.31	0.77	0.40	0.40	0.66	0.51
H. 'Brownies'*	0.50	0.26	1.22	1.08	0.60	0.40	1.35	1.20	0.59	0.60	1.07	1.97
H. 'Pistache'*	0.74	0.83	2.14	2.41	0.79	0.77	1.94	1.81	0.81	0.80	1.95	2.80
P. alopecuroides	0.66	0.78	2.26	2.62	0.72	0.31	1.52	1.79	0.39	0.58	0.68	0.84
P. 'Cassian'	0.65	0.46	2.16	2.11	0.85	0.32	2.53	1.13	0.44	0.50	2.12	1.77
P. 'Hameln'	0.65	1.31	1.79	1.44	0.68	0.54	2.30	1.31	1.04	0.54	3.01	1.45
P. 'Little Bunny'	0.80	1.40	2.51	2.26	0.84	0.73	1.56	2.26	0.74	0.74	1.53	1.87

n=3

Taken on 5/11/11

* Taken on 4/12/11

Table 3.13. Average final EC (mS/cm) of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Riverbend Nursery (Riner, VA).

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	0.45	0.85	0.72	2.20	0.77	0.97	1.58	2.70	0.59	0.75	1.48	1.75
G. 'Gallo Peach'	0.80	0.77	3.68	4.34	0.64	1.22	0.85	2.39	0.49	0.38	1.12	0.98
H. 'Brownies'*	0.65	0.54	1.53	1.77	0.36	0.36	1.29	1.80	0.36	0.47	1.64	1.33
P. 'Little Bunny'	1.12	1.09	3.40	4.49	0.80	1.11	3.38	3.28	0.75	0.73	2.16	2.02

n=3

Taken on 5/12/11

* Taken on 4/14/11

Table 3.14. Average final EC (mS/cm) of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA).

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	0.26	0.27	0.22	0.14	0.14	0.17	0.18	0.29	0.15	0.20	0.24	0.20
G. 'Gallo Peach'*	0.45	0.43	0.47	0.47	0.24	0.34	0.19	0.29	0.23	0.26	0.26	0.34
H. 'Brownies'*	0.24	0.22	0.19	0.20	0.26	0.22	0.28	0.20	0.23	0.32	0.22	0.32
P. 'Little Bunny'	0.31	0.34	0.32	0.32	0.23	0.29	0.31	0.30	0.30	0.33	0.31	0.34

n=3

Taken on 5/11/11

* Taken on 4/11/11

Table 3.15. Average monthly Daily Light Integral (DLI) (mol/(m^2d)) from the Urban Horticulture Center (Blacksburg, VA) over the course of the experiment.

Month	Year	DLI (mol/(m^2d))
November	2010	6.17
December	2010	3.84
January	2011	4.48
February	2011	6.54
March	2011	7.48
April	2011	11.63
May	2011	11.94

Table 3.16. Average monthly Daily Light Integral (DLI) (mol/(m^2d)) from Riverbend Nursery (Riner, VA) over the course of the experiment.

Month	Year	DLI (mol/(m^2d))
November	2010	15.85
December	2010	4.29
January	2011	4.26
February	2011	6.32
March	2011	7.48
April	2011	12.47
May	2011	15.40

Table 3.17. Average monthly Daily Light Integral (DLI) (mol/(m^2d)) from Poplar Ridge Nursery (Montross, VA) over the course of the experiment.

Month	Year	DLI (mol/(m^2d))
October	2010	13.50
November	2010	9.48
December	2010	9.58
January	2011	15.79
February	2011	19.58
March	2011	24.80
April	2011	31.29
May	2011	13.50

Table 3.18. Irrigation events of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya’ (HOL), *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies,’ *Heuchera* ‘Pistache,’ *Pennisetum alopecuroides*, *Pennisetum* ‘Cassian,’ *Pennisetum* ‘Hameln’ and *Pennisetum* ‘Little Bunny’ at the Urban Horticulture Center (Blacksburg, VA).

	No Cover		N-Sulate		N-Sulate + Poly	
Date	Wet	Dry	Wet	Dry	Wet	Dry
13-Dec-10	*	*	*	*	*	*
12/20/2010	*	*	*	*	*	*
12/30/2010	*	*	*	*	*	*
1/10/2011	*	*	*	*	*	*
1/24/2011	*	*	*	*	*	*
3/7/2011	1; 4	Not Watered	2	Not Watered	1; 7	Not Watered
3/14/2011	2; 6; 7; 8; 10	2	1; 4; 5; 6; 7; 8	Not Watered	4; 5; 6; 8; 9	Not Watered
4/5/2011	5	Not Watered	5	Not Watered	Not Watered	Not Watered
4/13/2011	9	Not Watered	2	Not Watered	Not Watered	Not Watered
4/18/2011	N/A	4; 8; 9	1	2	1; 2; 3; 4	Not Watered
4/25/2011	2; 3; 4	Not Watered	2; 3; 4; 7; 8; 9	1; 2; 3	8; 9	1; 2; 3
5/2/2011	Not Watered	2; 4; 8	Not Watered	1; 2; 4; 7	Not Watered	1; 2; 4; 9
5/9/2011	Not Watered	5; 10	Not Watered	2; 4; 7; 8	Not Watered	2; 3; 4; 8; 10

* Containers frozen
1 = E. Hot Papaya (CH)
2= E. Hot Papaya (HOL)
3 = E. 'Milkshake'
4 = G. 'Gallo Peach'
5 = H. 'Brownies'
6 = H. 'Pistache'
7 = P. alopecuroides
8 = P. 'Cassian'
9 = P. 'Hameln'
10 = P. 'Little Bunny'

Table 3.19. Irrigation events of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Riverbend Nursery, Inc. (Riner, VA)

	No Cover		N-Sulate		N-Sulate + Poly	
Date	Wet	Dry	Wet	Dry	Wet	Dry
12/8/2010	*	*	Not Watered	Not Watered	Not Watered	Not Watered
12/15/2010	*	*	Not Watered	*	Not Watered	Not Watered
12/20/2010	*	*	Not Watered	*	Not Watered	Not Watered
12/30/2010	*	*	Not Watered	Not Watered	*	*
1/6/2011	*	*	Not Watered	Not Watered	Not Watered	*
1/12/2011	*	*	Not Watered	Not Watered	Not Watered	*
3/4/2011	Not Watered	Not Watered	2	Not Watered	Not Watered	Not Watered
3/9/2011	3	Not Watered	Not Watered	Not Watered	Not Watered	Not Watered
3/30/2011	Not Watered	Not Watered	3	Not Watered	Not Watered	2
4/14/2011	2; 4	1; 2; 4	1; 4	1; 2	1; 4	1;4
4/21/2011	1	1	1; 2	Not Watered	2	Not Watered
5/3/2011	1; 2	Not Watered	Not Watered	Not Watered	Not Watered	Not Watered

* Containers frozen
1 = E. 'Milkshake'
2 = G. 'Gallo Peach'
3 = H. 'Brownies'
4 = P. 'Little Bunny'

Table 3.20. Irrigation events of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nusery (Montross, VA).

PR 3.20	No Cover		N-Sulate		N-Sulate + Poly	
Date	Wet	Dry	Wet	Dry	Wet	Dry
2/1/2011	Not Watered	Not Watered	Not Watered	1	Not Watered	Not Watered
2/8/2011	Not Watered	Not Watered	Not Watered	Not Watered	Not Watered	1; 4
2/21/2011	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered
2/28/2011	Not Watered	Not Watered	Not Watered	Not Watered	Not Watered	3
2/31/2011	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered
3/18/2011	1; 2; 3; 4	1; 4	1; 2; 3; 4	1; 4	1; 2; 3; 4	1; 4
4/7/2011	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered
4/22/2011	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4
5/2/2011	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered	1; 2; 3; 4	Not Watered

* Containers frozen

1 = E. 'Milkshake'

2 = G. 'Gallo Peach'

3 = H. 'Brownies'

4 = P. 'Little Bunny'

Figure 3.1. Outside air temperature, inside air temperature and uncovered media temperature, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment from 10/1/2010 to 5/9/2011.

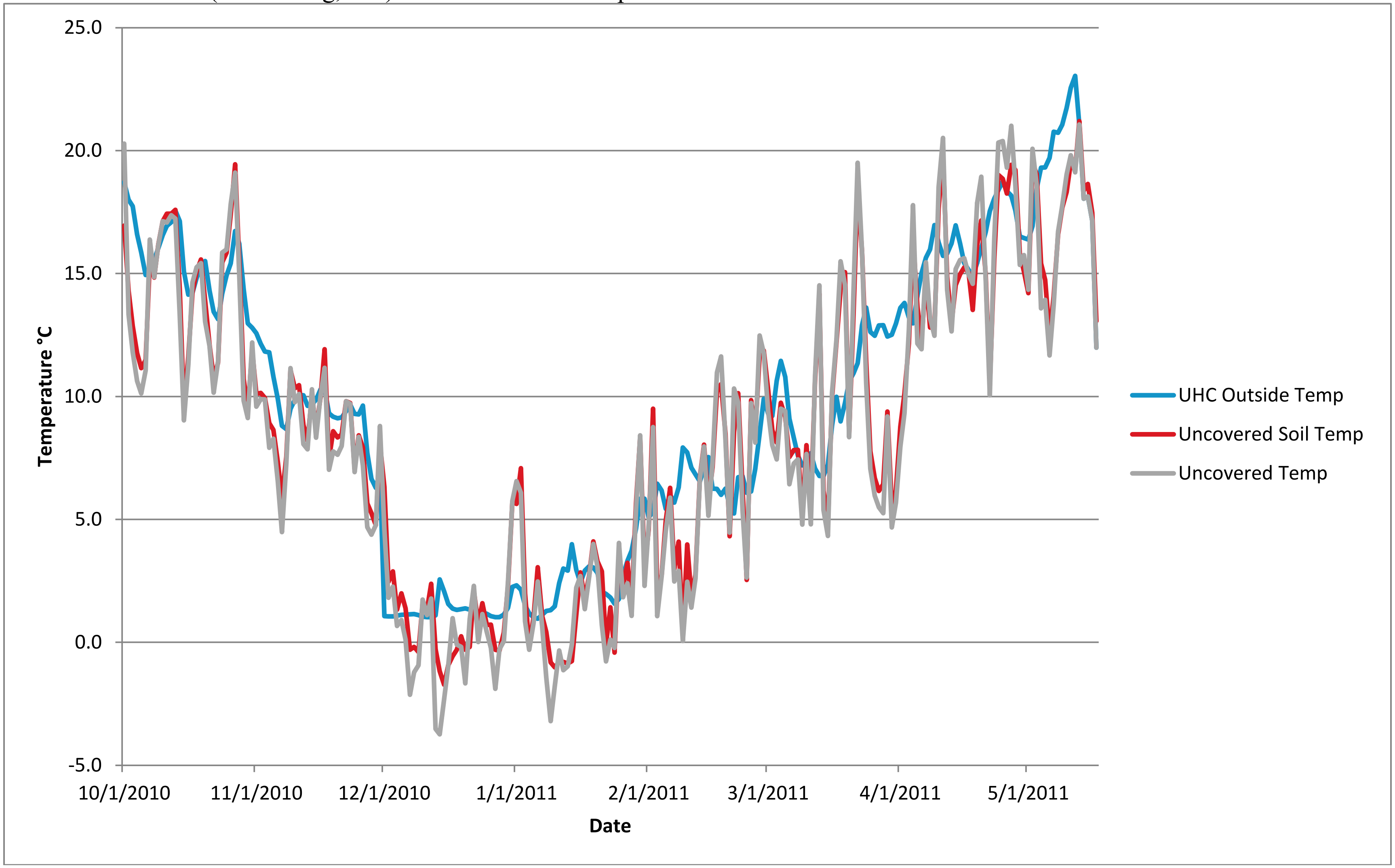


Figure 3.2. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment from 10/1/2010 to 5/9/2011.

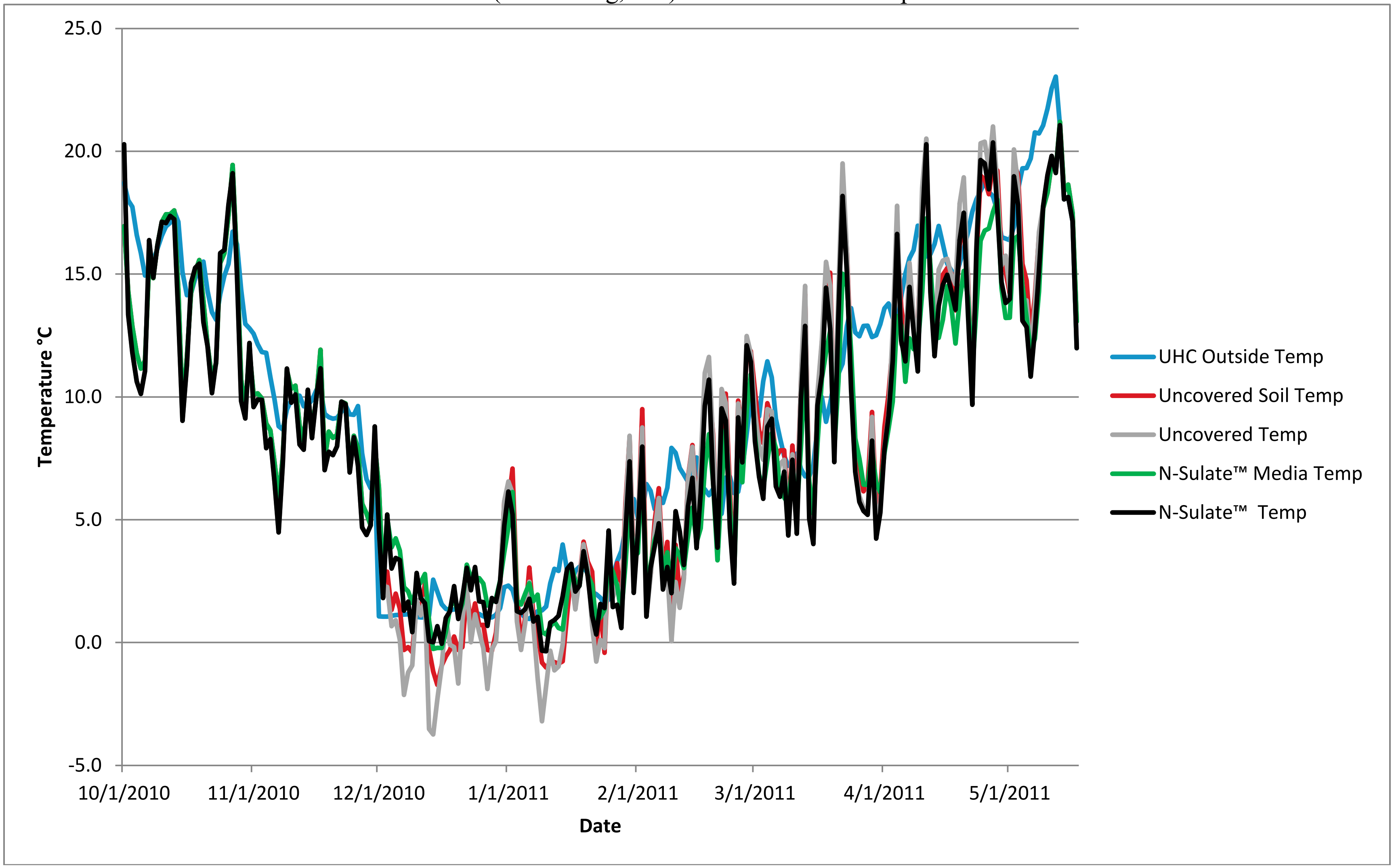


Figure 3.3. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiment from 10/1/2010 to 5/9/2011.

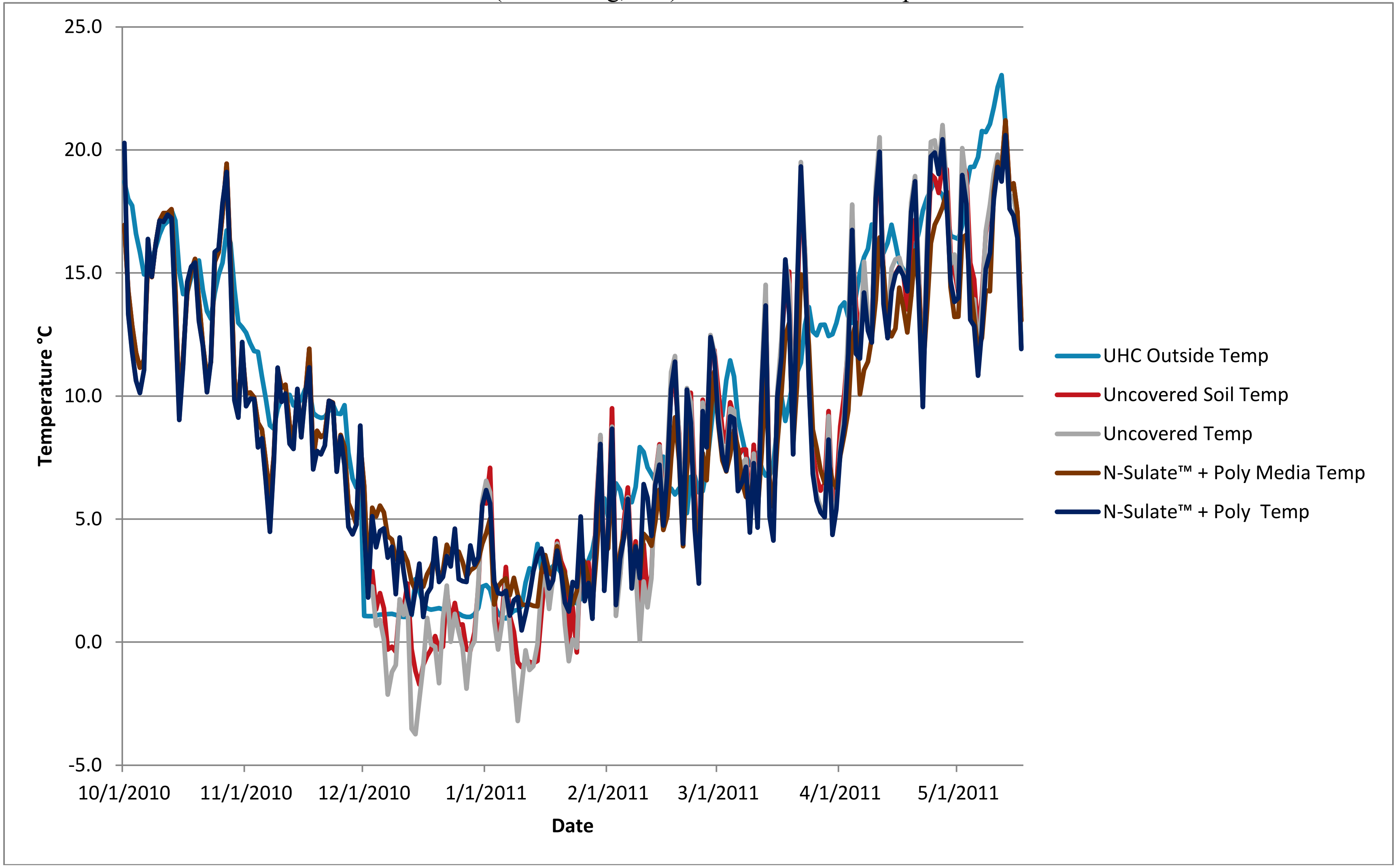


Figure 3.4. Average substrate moisture content (for Dry treatment) of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya (HOL) and *Echinacea* ‘Milkshake’ from the Urban Horticulture Center (Blacksburg, VA) over the course of the experiment from 12/6/2010 to 5/9/2011.

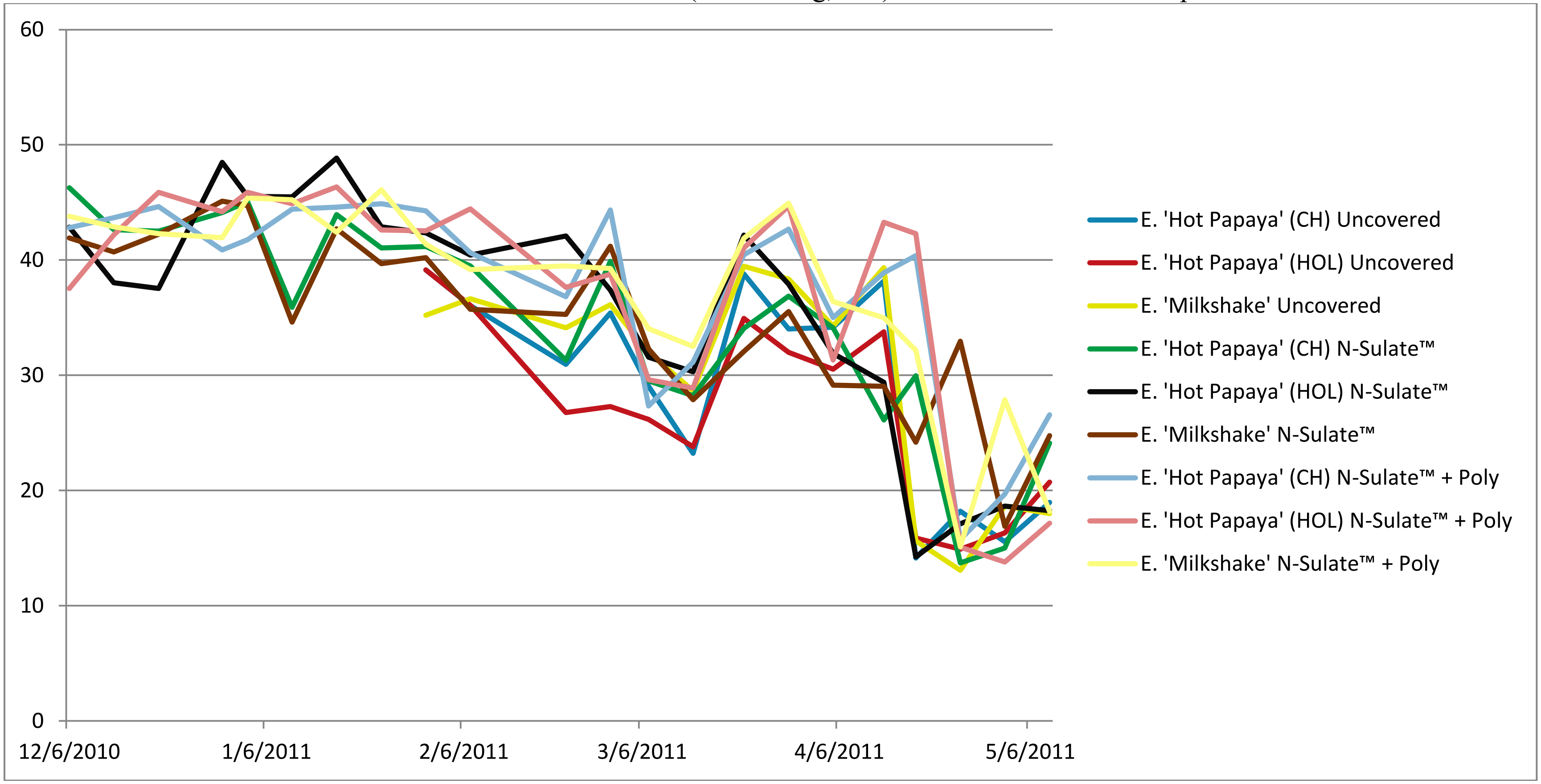


Figure 3.5. Average substrate moisture content (for Wet treatment) for *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' from Poplar Ridge Nursery (Montross, VA) over the course of the experiment from 12/3/2010 to 5/4/2011.

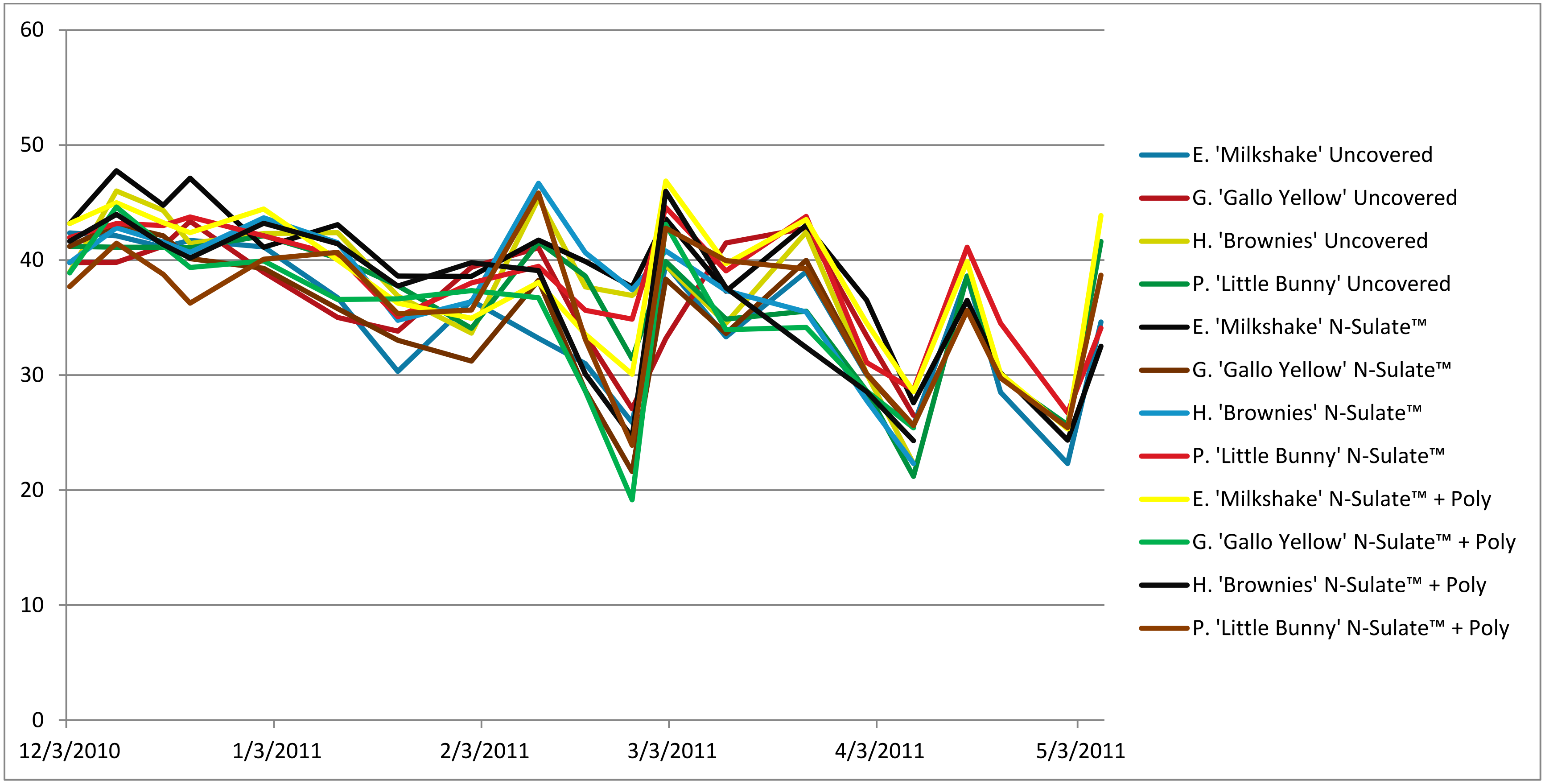
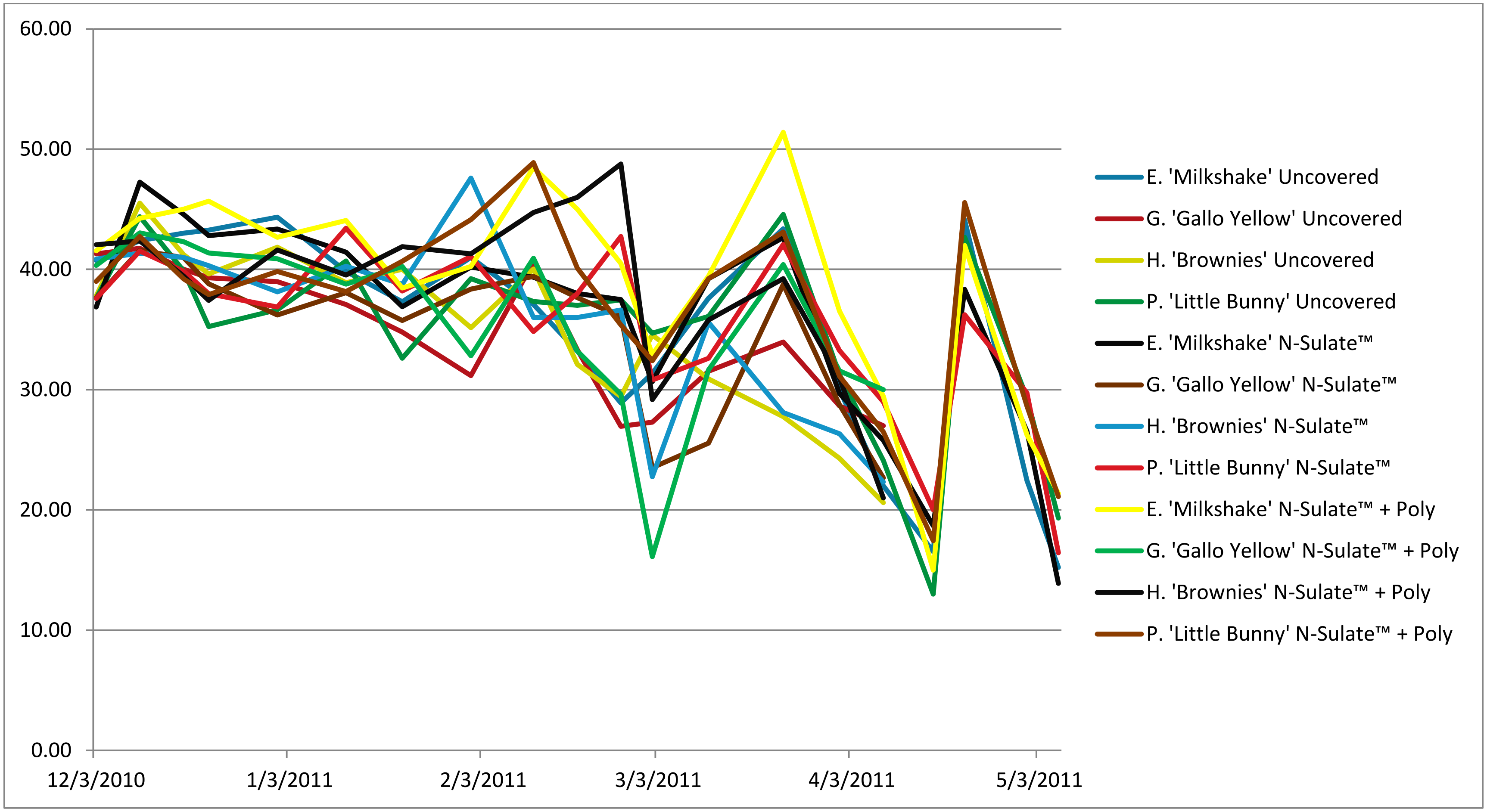


Figure 3.6. Average substrate moisture content (for Dry treatment) for *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' from Poplar Ridge Nursery (Montross, VA) over the course of the experiment from 12/3/2010 to 5/4/2011.



Appendix A

Figure 2.1. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at the Urban Horticulture Center (Blacksburg, VA) over the course of experiments 2 and 3 from 11/19/2009 to 5/8/2010.

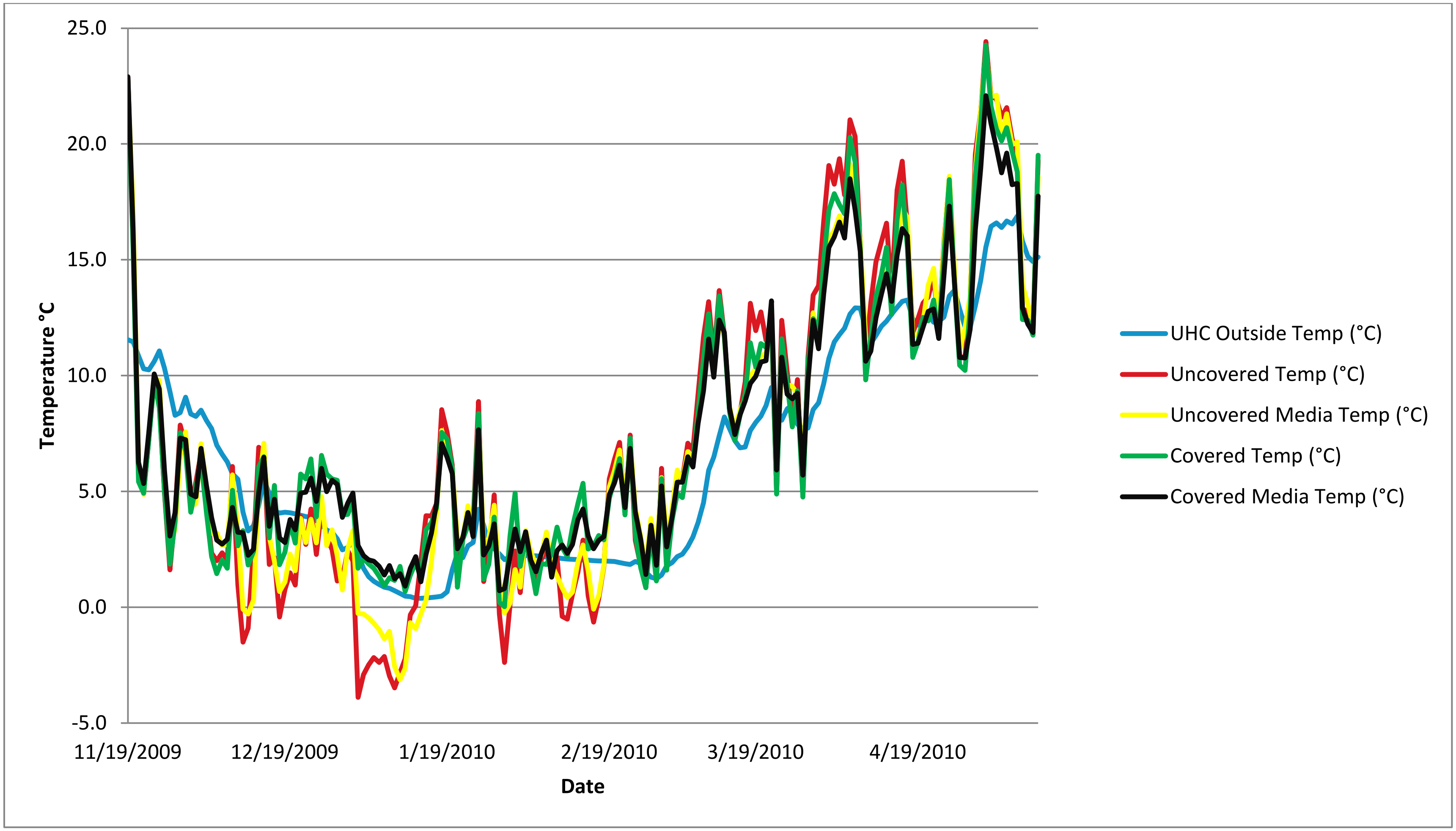


Figure 2.2. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at the Poplar Ridge Nursery (Montross, VA) over the course of experiment 2 from 11/4/2009 to 5/8/2010.

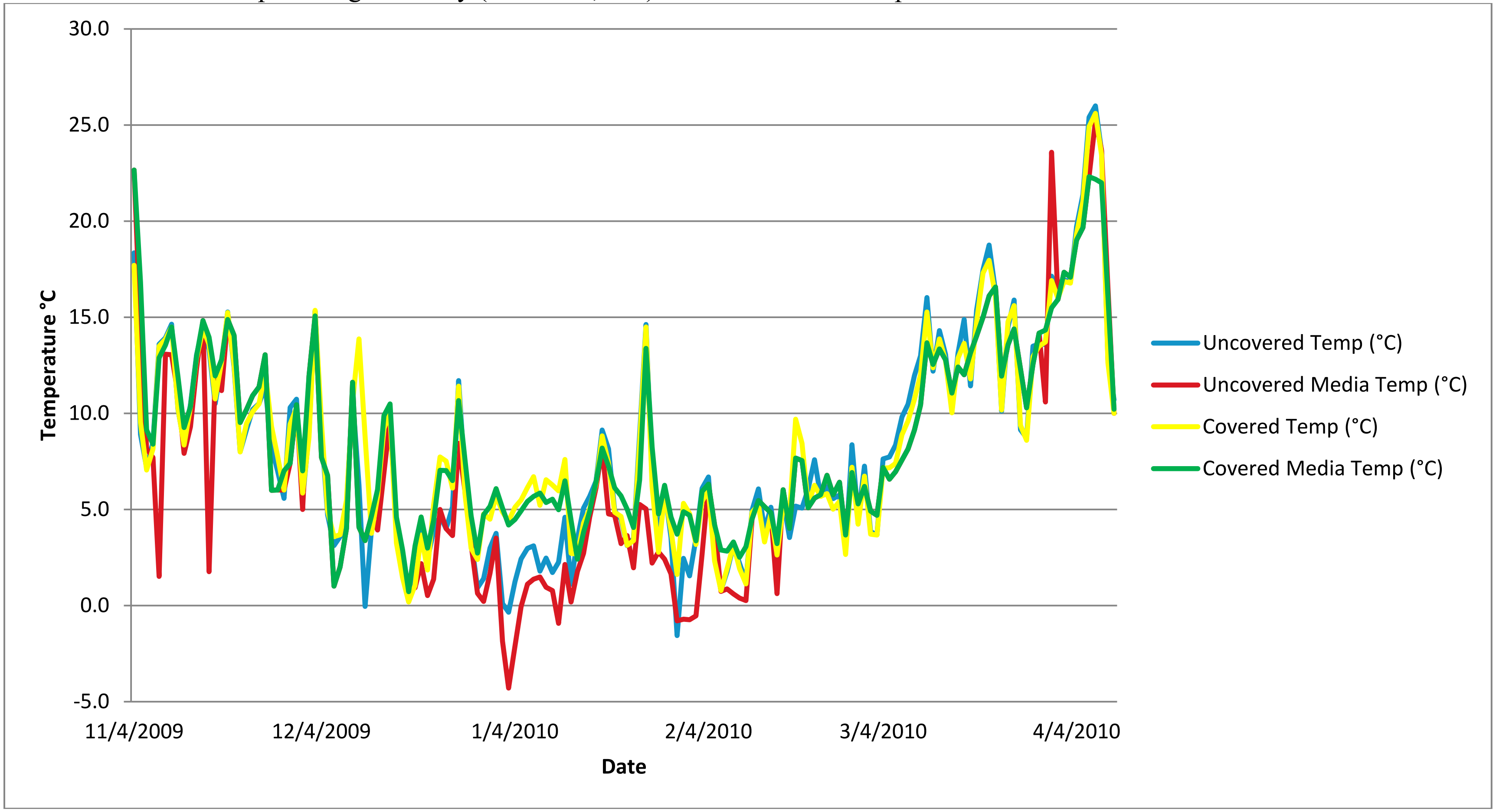


Figure 2.3. Average substrate moisture content (for Wet treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 1 from 1/14/2009 to 5/8/2010.

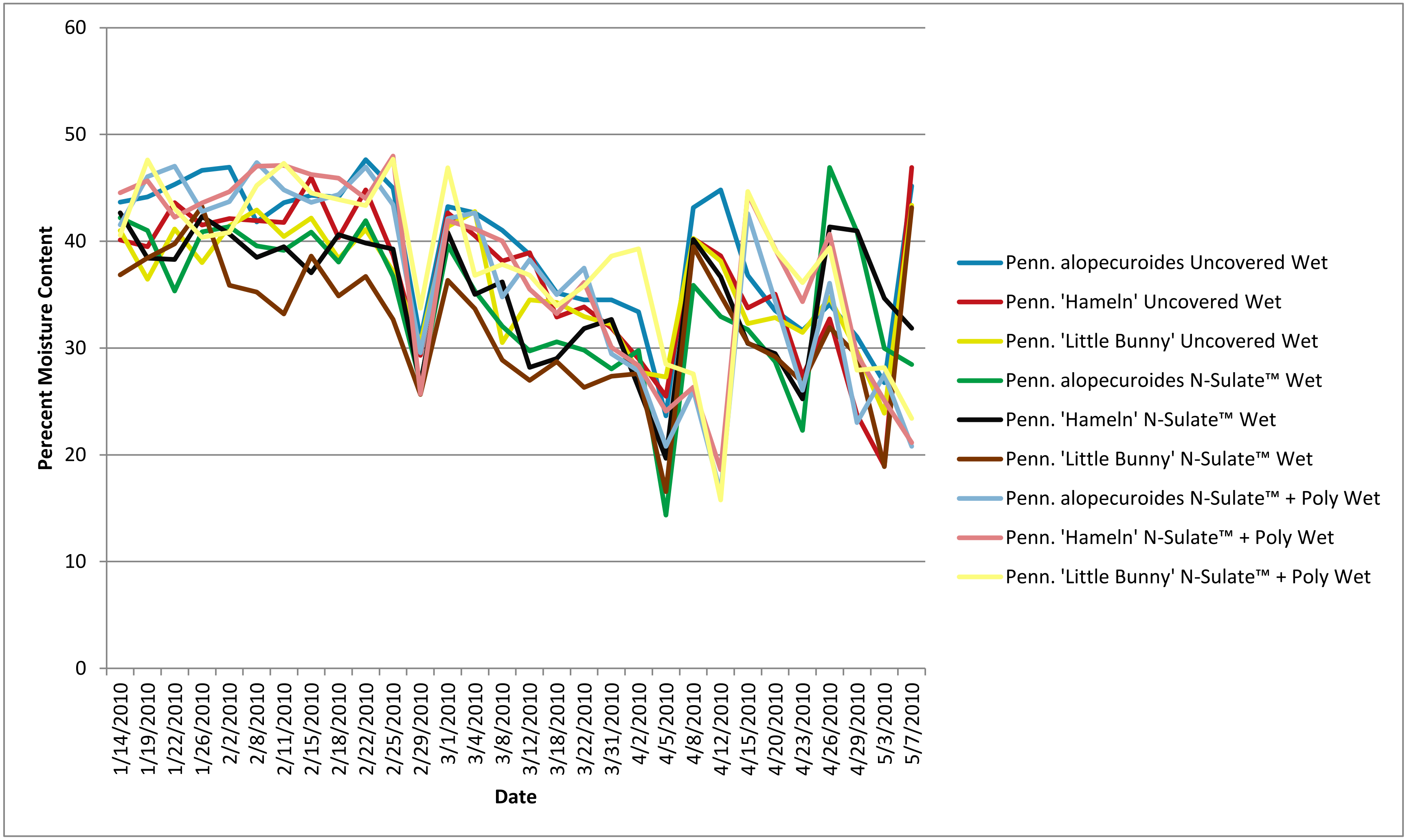


Figure 2.4. Average substrate moisture content (for Dry treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 1 from 1/14/2009 to 5/8/2010.

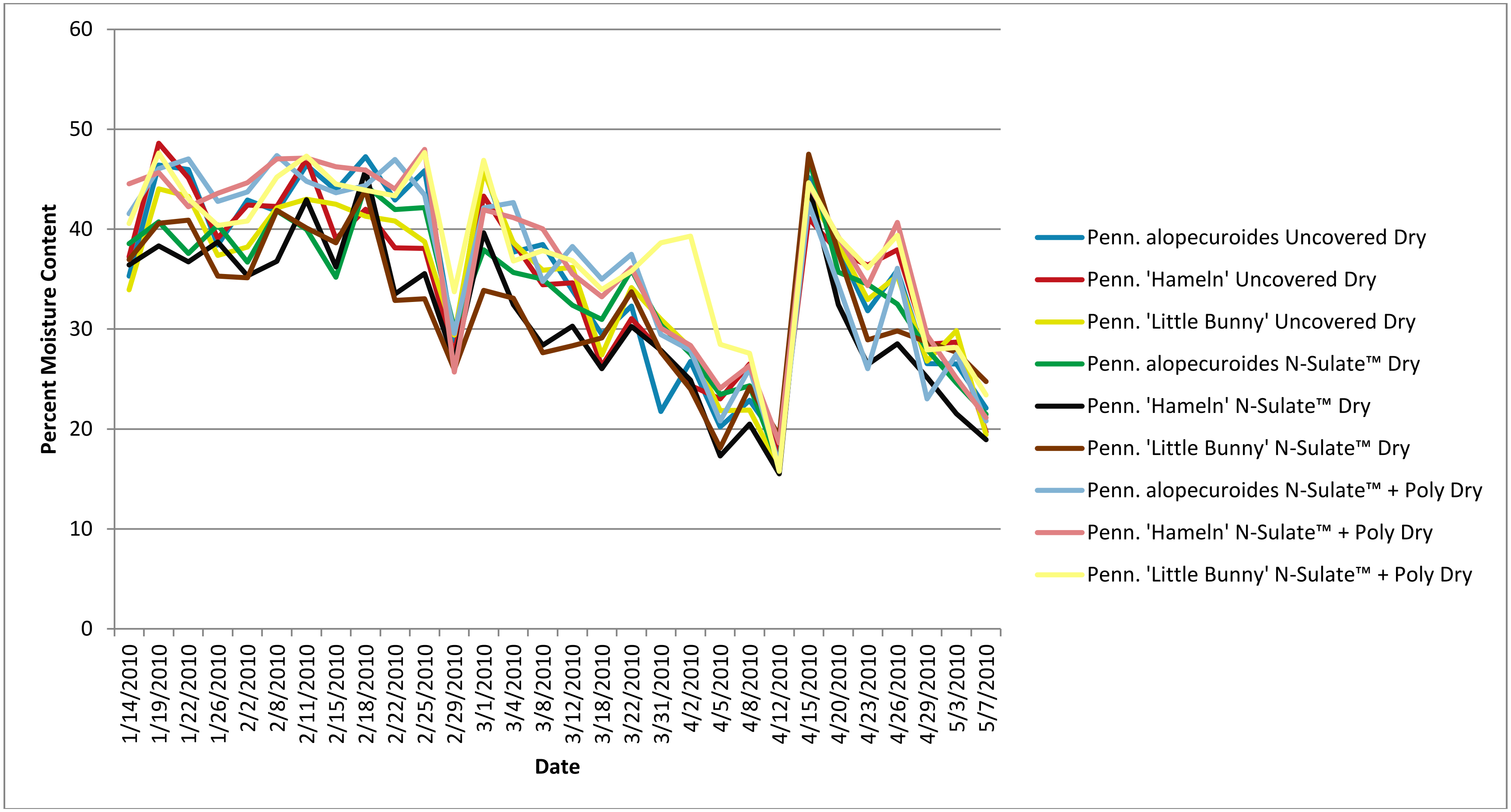


Figure 2.5. Average substrate moisture content (for Wet treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 2 from 1/14/2009 to 5/8/2010.

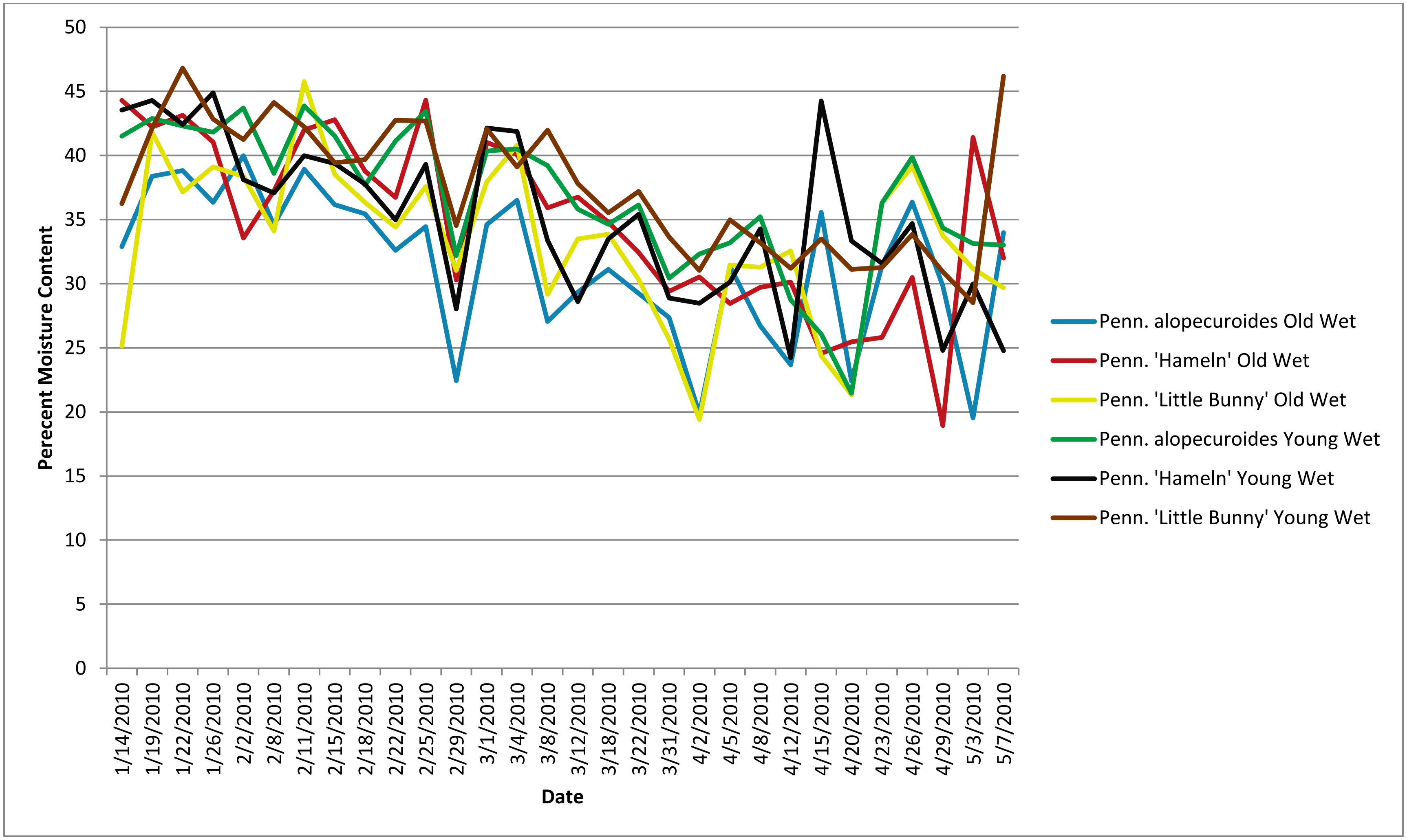


Figure 2.6. Average substrate moisture content (for Dry treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) over the course of experiment 2 from 1/14/2009 to 5/8/2010.

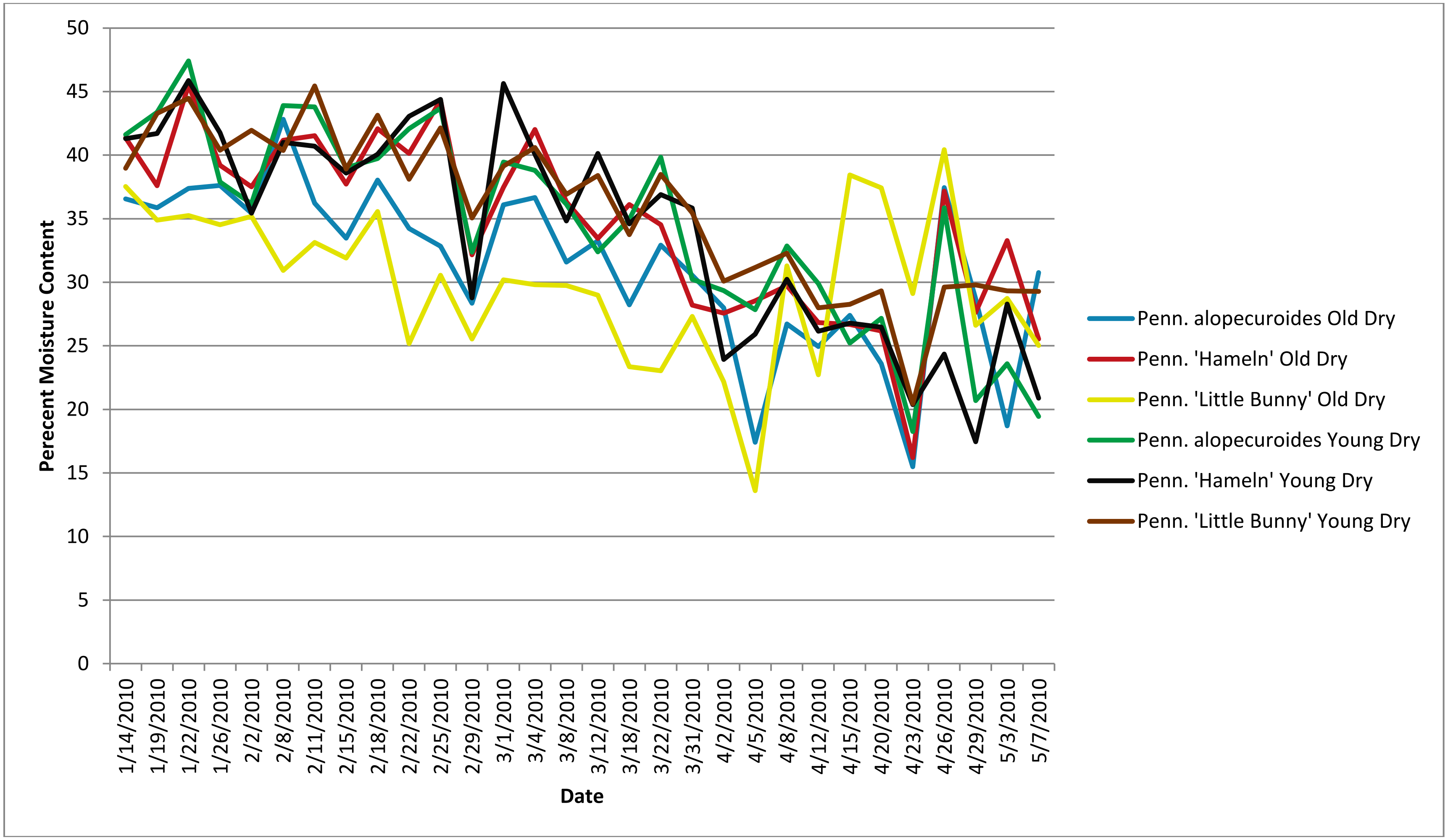


Figure 2.7. Average substrate moisture content (for Wet treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from Poplar Ridge Nursery (Montross, VA) over the course of experiment 2 from 1/20/2009 to 4/8/2010.

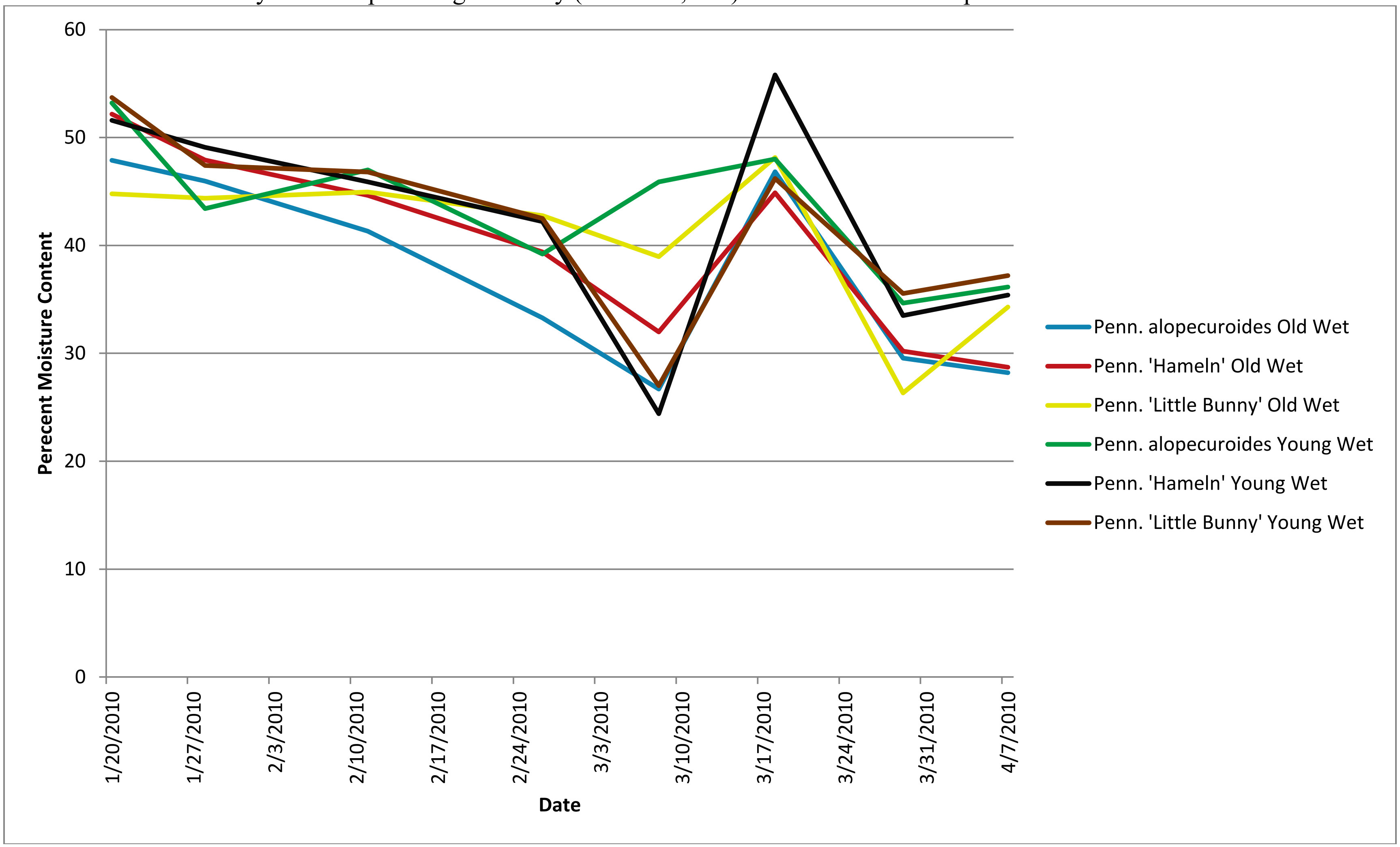


Figure 2.8. Average substrate moisture content (for Dry treatment) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from Poplar Ridge Nursery (Montross, VA) over the course of experiment 2 from 1/20/2009 to 4/8/2010.

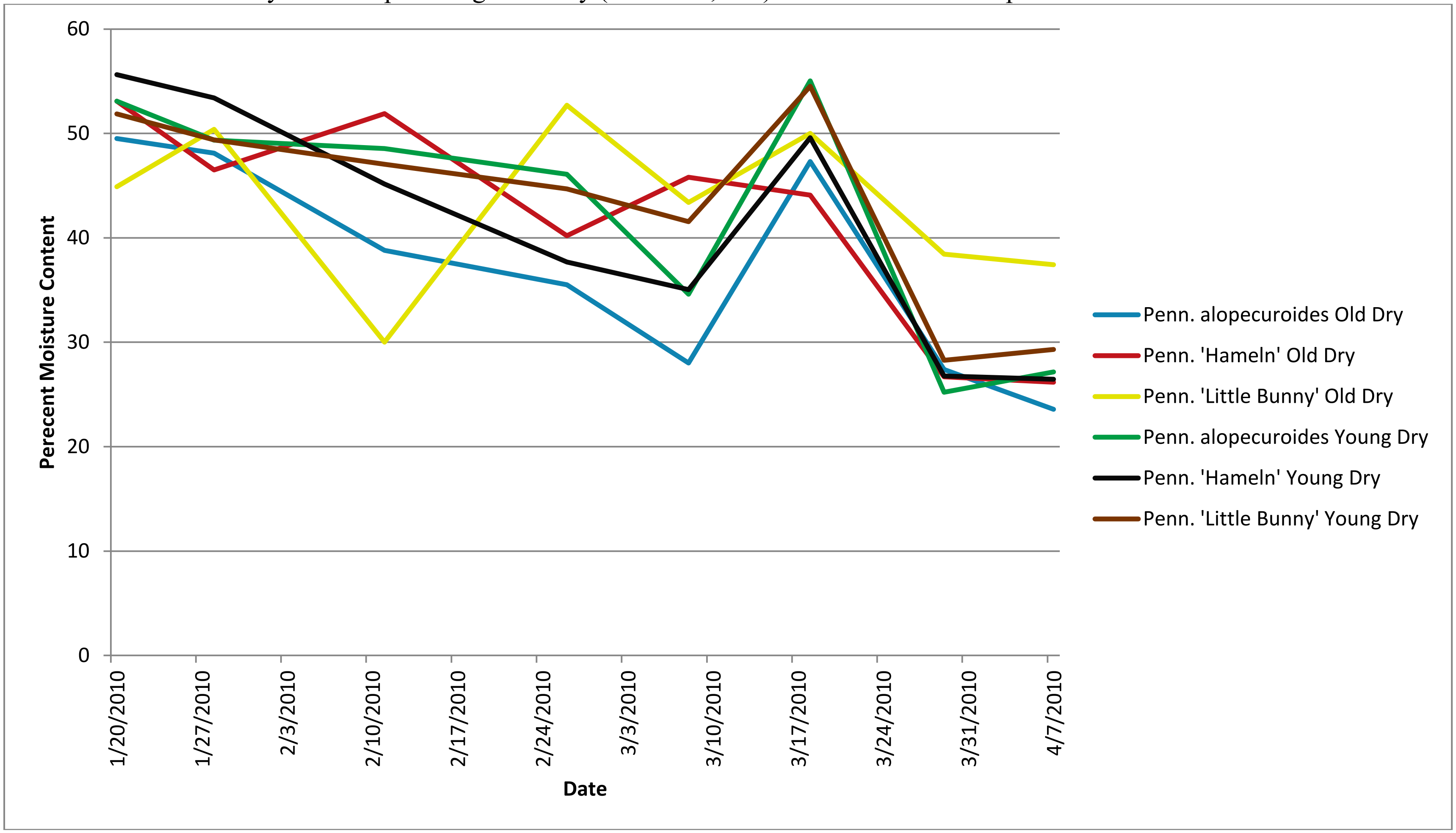


Figure 2.9. Average substrate moisture content from the Urban Horticulture Center (Blacksburg, VA) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' over the course of experiment 3 from 1/13/2009 to 5/8/2010.

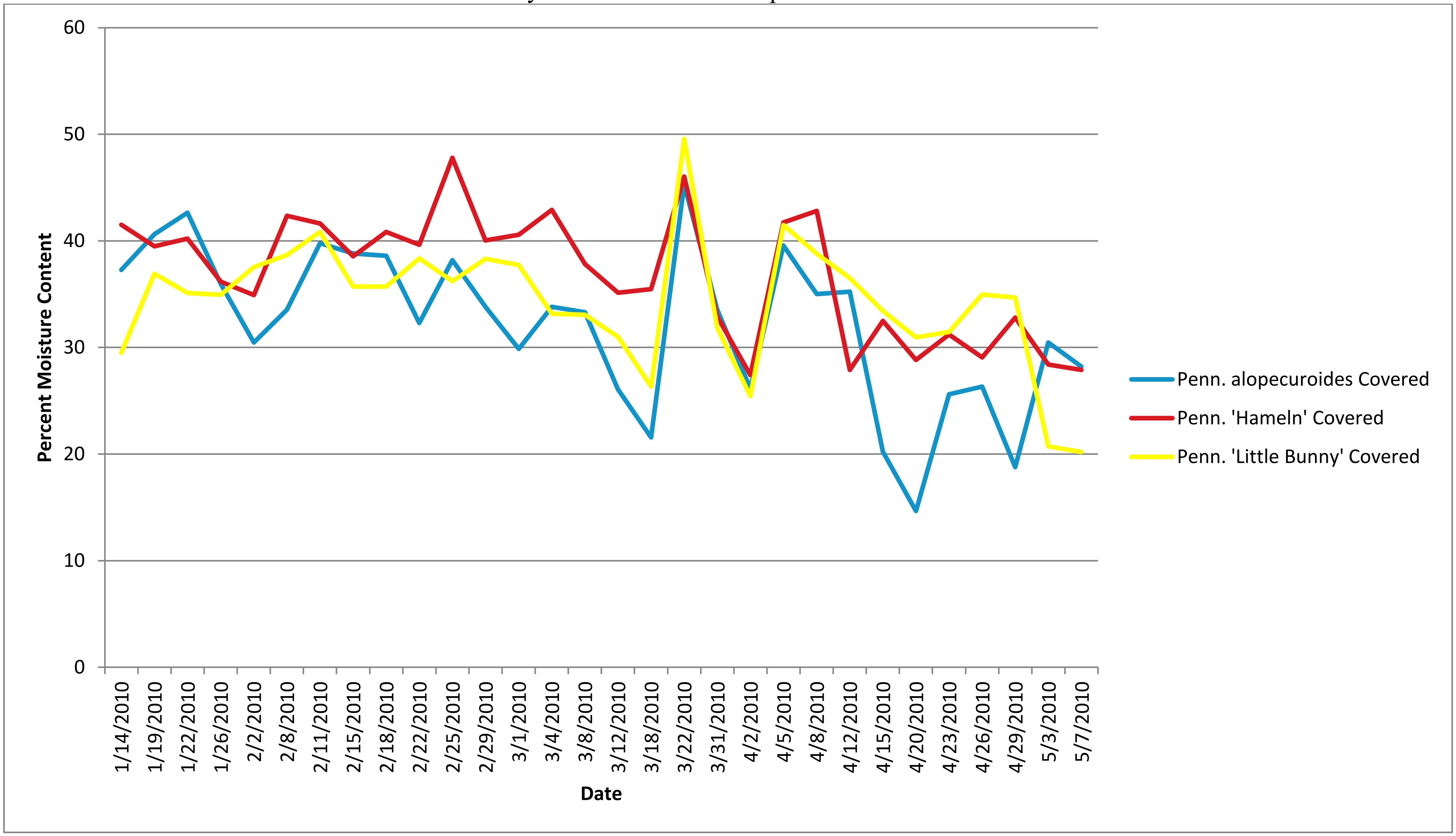


Table 2.1. Average pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' after a watering event in experiment 1.

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	5.6	.	5.1	.	.	.	.	.	5.6	.	5.4	.
P. 'Hameln'	5.7	.	5.3	.	.	.	.	.	5.5	.	5.4	.
P. 'Little Bunny'	5.7	.	5.2	.	5.5	.	5.4	.	5.6	.	5.5	.

n=3
Taken on 5/3/2010

Table 2.2. Average EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' after a watering event in experiment 1.

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	0.83	.	1.44	.	.	.	.	.	1.06	.	0.58	.
P. 'Hameln'	0.98	.	1.51	.	.	.	.	.	1.50	.	0.46	.
P. 'Little Bunny'	0.72	.	1.65	.	0.71	.	1.43	.	1.25	.	0.84	.

n=3
Taken on 5/3/2010

Table 2.3. Average pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' after a watering event in experiment 1.

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	.	5.7	.	5.4	.	5.6	.	5.4	.	5.3	.	5.3
P. 'Hameln'	.	5.7	.	5.4	.	5.6	.	5.4	.	5.5	.	5.2
P. 'Little Bunny'	.	5.5	.	5.3	.	5.4	.	5.7	.	5.8	.	5.2

n=3
Taken on 4/13/2010

Table 2.4. Average EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' after a watering event in experiment 1.

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	.	0.39	.	1.98	.	0.56	.	0.87	.	0.50	.	0.94
P. 'Hameln'	.	0.32	.	1.04	.	0.69	.	0.97	.	0.57	.	1.14
P. 'Little Bunny'	.	0.74	.	1.23	.	0.82	.	1.13	.	0.62	.	0.94

n=3
Taken on 4/13/2010

Table 2.5. Average pH of *Pennisetum alopecuroides* and *Pennisetum* 'Hameln' at the Urban Horticulture Center (Blacksburg, VA) after a watering event in experiment 2.

	Evaluation # 2							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides *	.	.	.	.	6.4	6.1	6.4	6.1
P. 'Hameln'**	.	7.2	.	6.9	7.2	.	7.1	.

n=3

*Taken on 5/3/2010

**Taken on 4/29/2010

Table 2.6. Average EC (mS/cm) of *Pennisetu alopecuroides* and *Pennisetum* 'Hameln' at the Urban Horticulture Center (Blacksburg, VA) after a watering event in experiment 2.

	Evaluation # 2							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides *	.	.	.	.	0.33	0.21	0.28	0.97
P. 'Hameln' **	.	0.35	.	0.62	0.37	.	0.60	.

n=3
*Taken on 5/3/2010
**Taken on 4/29/2010

Table 2.7. Average pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) after a watering event in experiment 2.

	Evaluation # 2							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	.	.	.	.	6.7	.	6.5	.
P. 'Hameln'	6.6	.	6.7	.	.	.	.	.
P. 'Little Bunny'	.	.	.	.	.	6.5	.	6.2

n=3
Taken on 3/18/2010

Table 2.8. Average EC (mS/cm) of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) after a watering event in experiment 2.

	Evaluation # 2							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	.	.	.	.	0.19	.	0.40	.
P. 'Hameln'	0.34	.	0.61	.	.	.	.	.
P. 'Little Bunny'	.	.	.	.	.	0.29	.	0.54

n=3
Taken on 3/18/2010

Table 2.9. Average pH and EC (mS/cm) of *Pennisetum alopecuroides* and *Pennisetum* ‘Little Bunny’ after a watering event in experiment 3.

	pH				EC			
Plant Species	No added	Low	Medium	High	No added	Low	Medium	High
P. alopecuroides	6.9	6.8	6.8	6.5	0.23	0.37	1.14	1.78
P. 'Little Bunny'	6.4	6.4	5.8	5.9	0.21	0.61	1.56	2.44

n=3

Taken on 3/18/2010

Table 2.10. Average pH and EC (mS/cm) of *Pennisetum alopecuroides, Pennisetum* ‘Hameln’ and *Pennisetum* ‘Little Bunny’ after a watering event in experiment 3.

	pH				EC			
Plant Species	No added	Low	Medium	High	No added	Low	Medium	High
P. alopecuroides	7.3	7.2	7.1	6.8	0.39	0.48	2.65	3.78
P. 'Hameln'	7.7	7.6	7.5	7.2	0.39	1.00	1.70	2.62
P. 'Little Bunny'	6.6	6.8	7.0	6.9	0.15	0.30	0.85	2.09

n=3
Taken on 4/6/2010

Table 2.11. Average pH and EC (mS/cm) of *Pennisetum alopecuroides* in after a watering event experiment 3.

	pH				EC			
Plant Species	No added	Low	Medium	High	No added	Low	Medium	High
P. alopecuroides*	5.9	6.0	7.1	5.9	0.11	0.55	0.97	1.51
P. alopecuroides**	6.8	6.6	6.4	6.5	0.07	0.20	0.42	1.14

n=3

*Taken on 4/23/2010

**Taken on 5/3/2010

Table 2.12. Average final pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA) in experiment 2.

	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	6.7	6.3	6.5	6.0	6.6	6.6	6.8	5.8
P. 'Hameln'	7.0	6.4	6.4	6.1	6.9	6.4	6.5	6.3
P. 'Little Bunny'	7.1	6.7	6.5	6.0	6.5	6.8	7.5	7.2

n=3
Taken on 5/15/2010

Table 2.13. Average final pH of *Pennisetum alopecuroides*, *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA) in experiment 2.

	Evaluation # 3							
	Young				Old			
	Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
P. alopecuroides	6.2	6.4	6.6	6.6	6.2	6.5	6.0	5.7
P. 'Hameln'	6.8	6.8	6.5	6.5	6.6	6.8	6.0	6.5
P. 'Little Bunny'	6.8	6.6	6.4	6.1	6.2	6.1	5.9	5.6

n=3

Taken on 4/15/2010

Appendix B

Figure 3.1. Outside air temperature, inside air temperature and uncovered media temperature, inside the coldframe at Riverbend Nursery, Inc (Riner, VA) from 11/3/2010 to 5/8/2011.

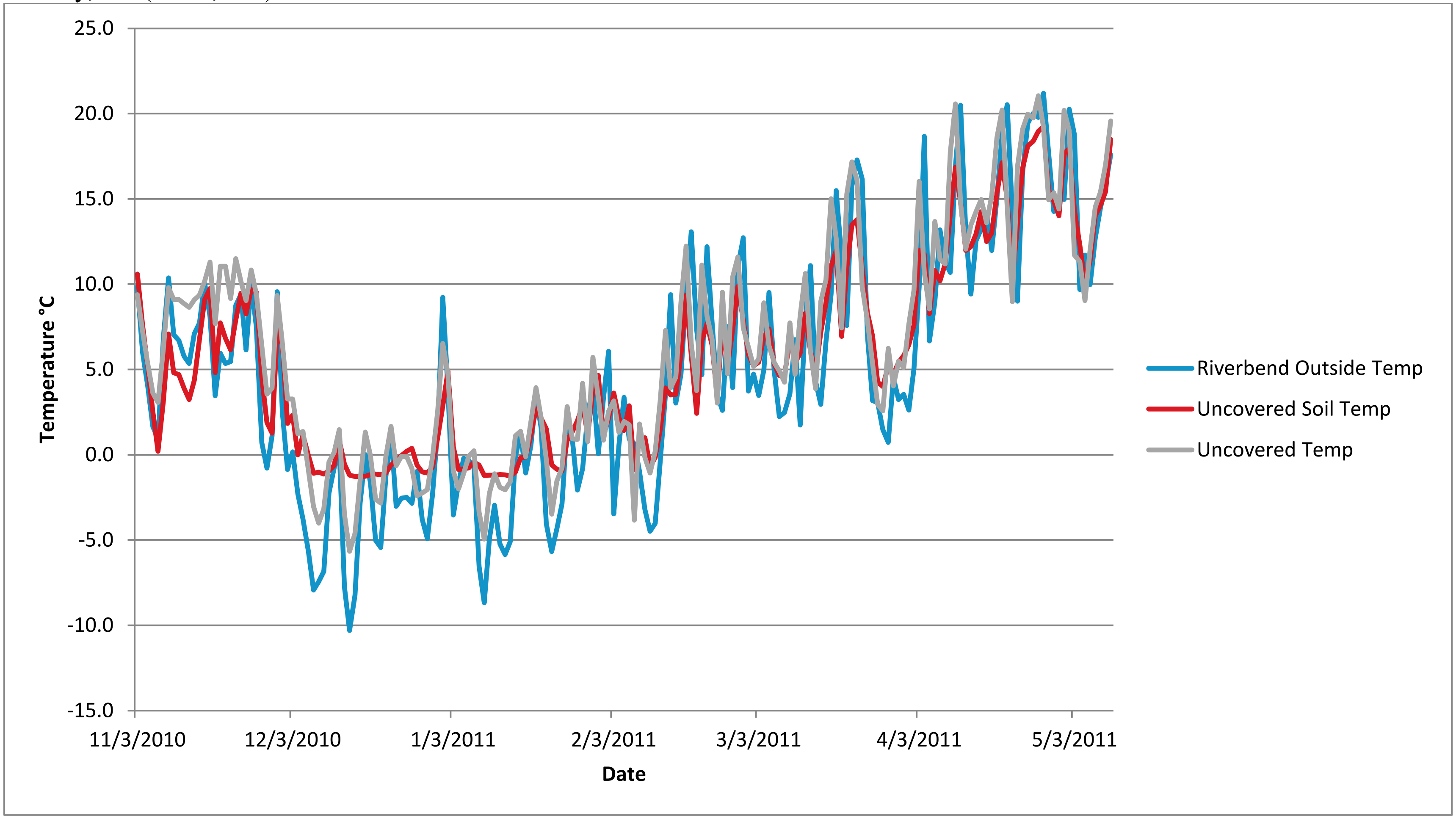


Figure 3.2. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at Riverbend Nursery, Inc (Riner, VA) from 11/3/2010 to 5/8/2011.

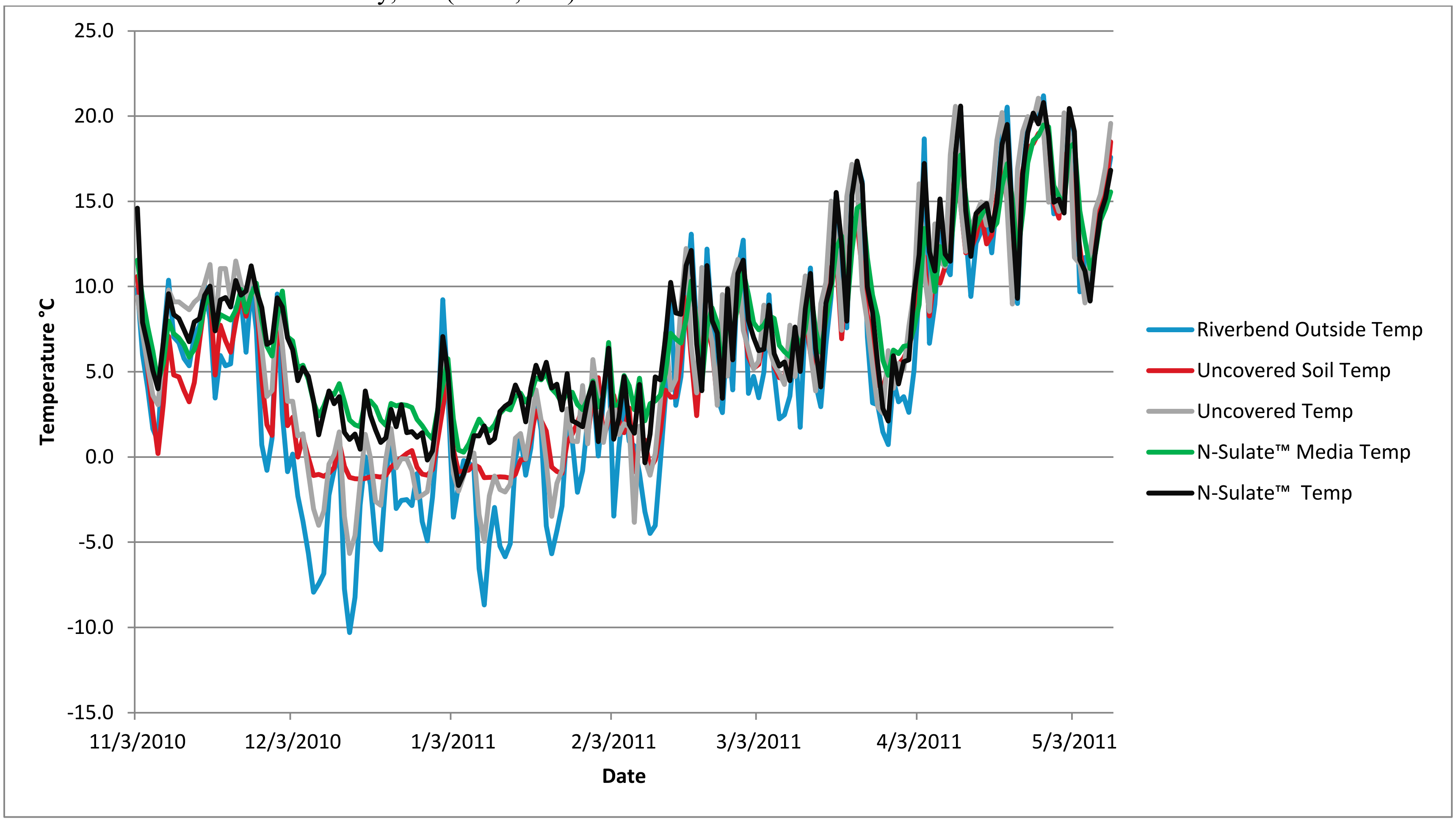


Figure 3.3. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at Riverbend Nursery, Inc (Riner, VA) from 11/3/2010 to 5/8/2011.

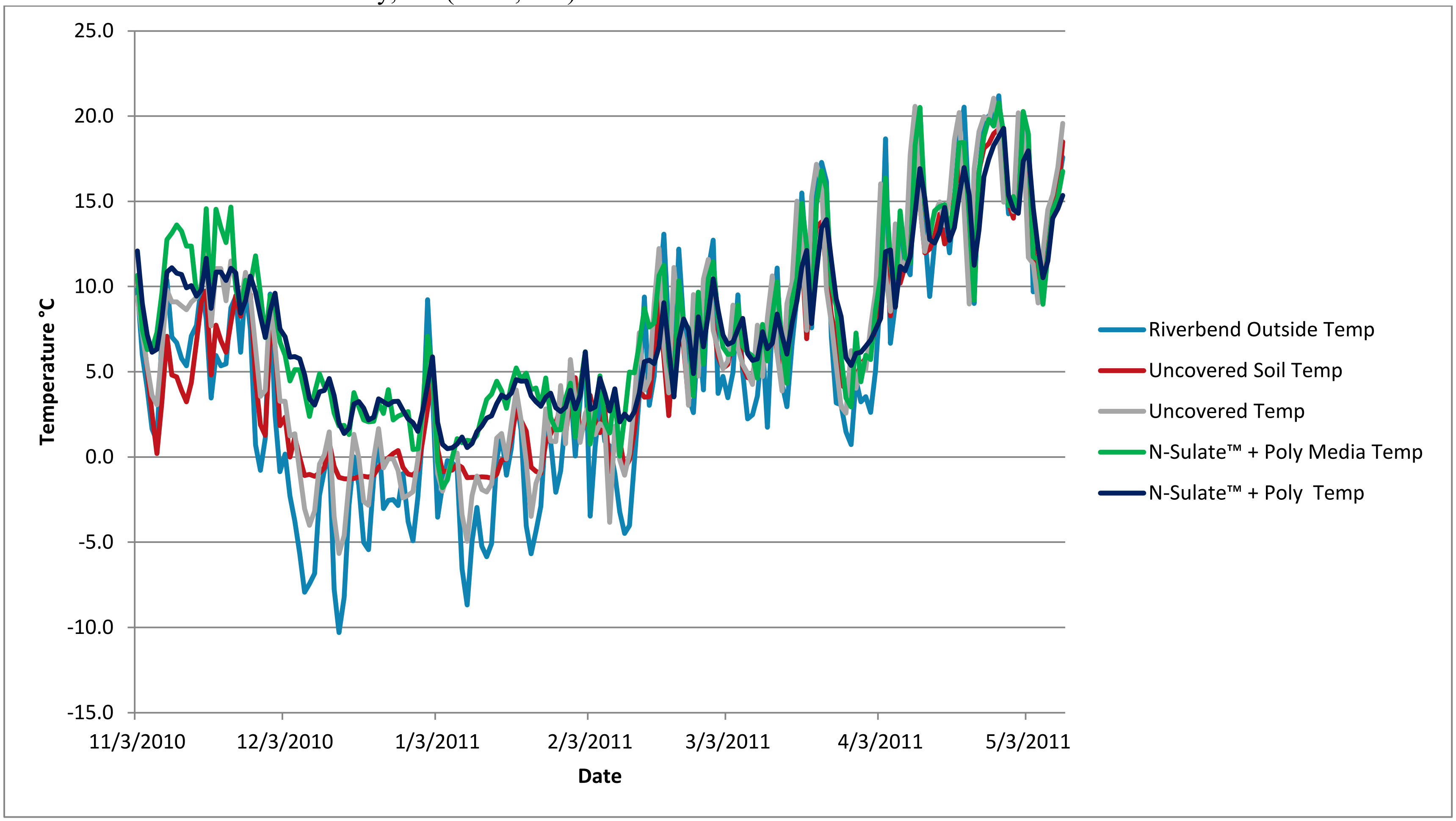


Figure 3.4. Outside air temperature, inside air temperature and uncovered media temperature, inside the coldframe at Poplar Ridge Nursery (Montross, VA) over the course of experiment from 10/23/2010 to 5/4/2011.

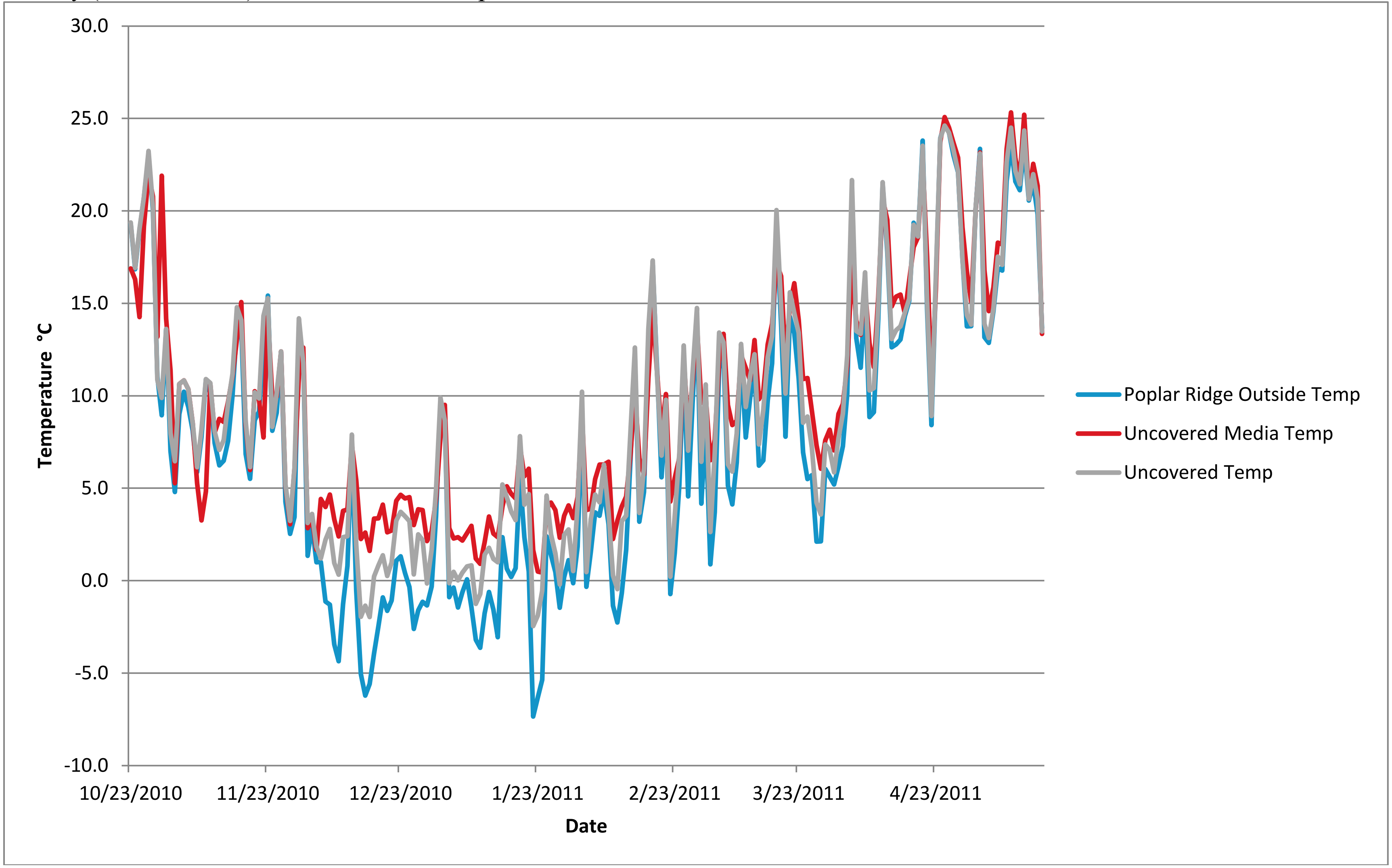


Figure 3.5. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at Poplar Ridge Nursery (Montross, VA) over the course of experiment from 10/23/2010 to 5/4/2011.

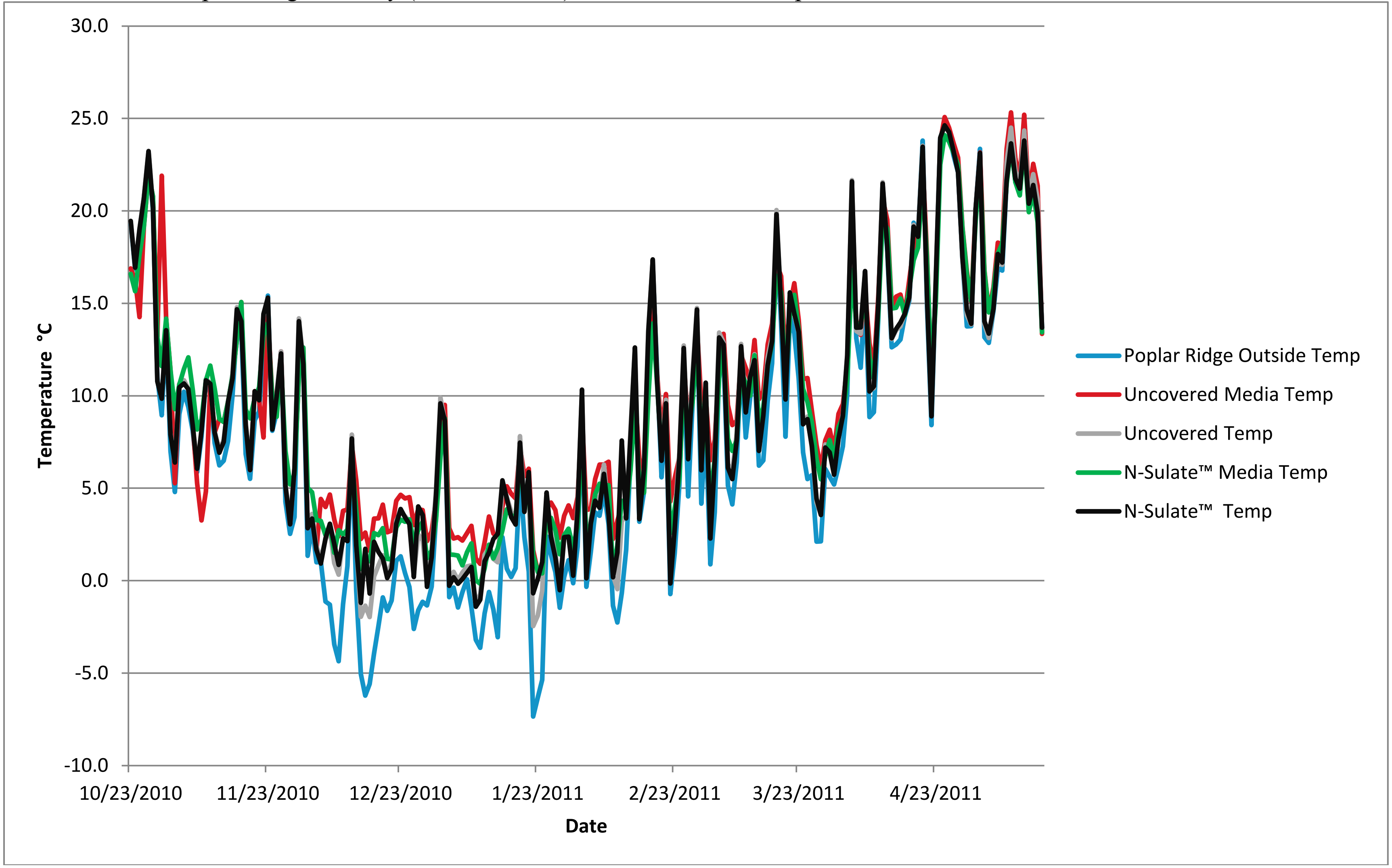


Figure 3.6. Outside air temperature, inside air temperature, uncovered media and media temperatures under cover treatments, inside the coldframe at Poplar Ridge Nursery (Montross, VA) over the course of experiment from 10/23/2010 to 5/4/2011.

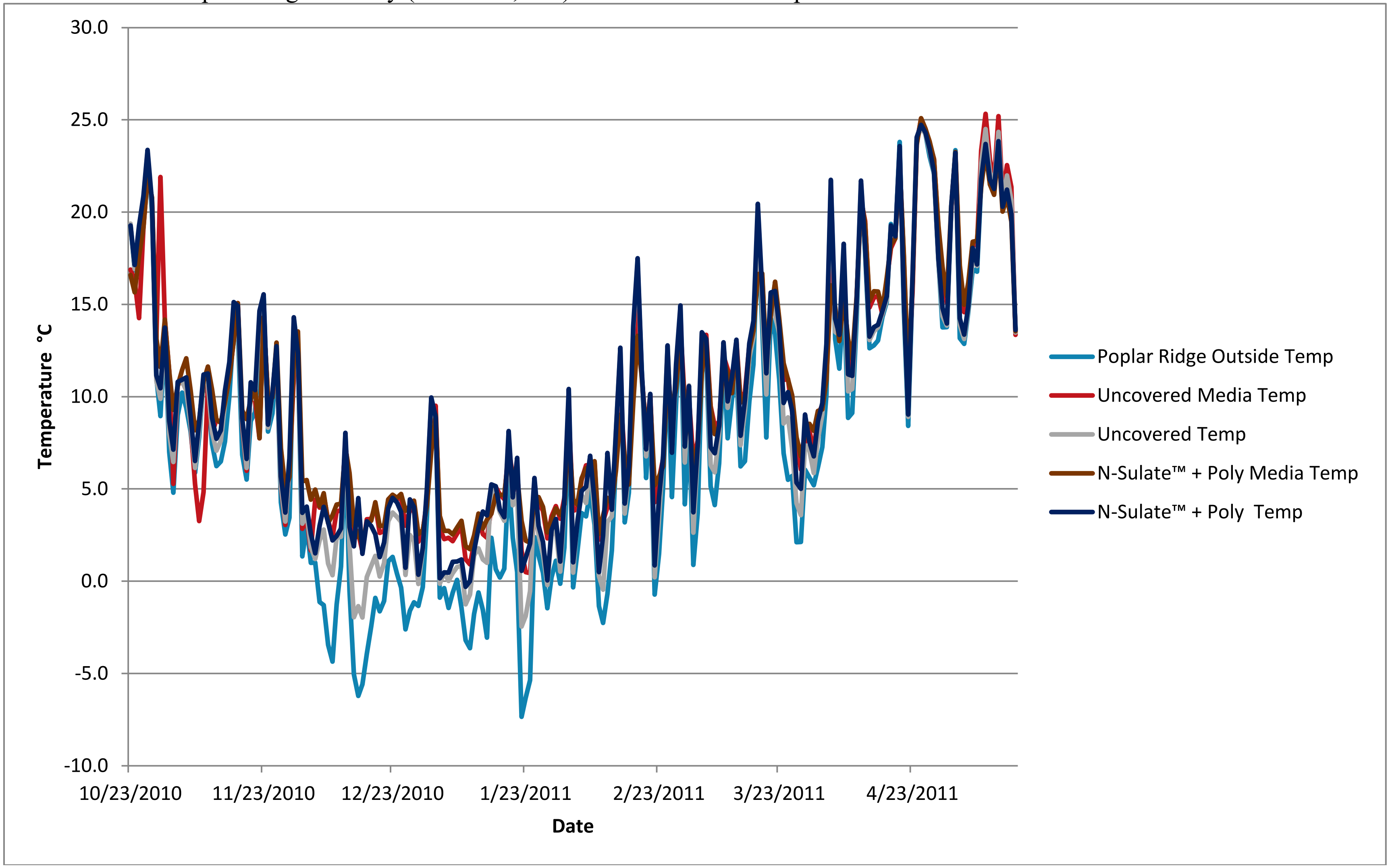


Figure 3.7. Average substrate moisture content (for Wet treatment) of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya (HOL) and *Echinacea* 'Milkshake' from the Urban Horticulture Center (Blacksburg, VA) from 12/6/2010 to 5/8/2011.

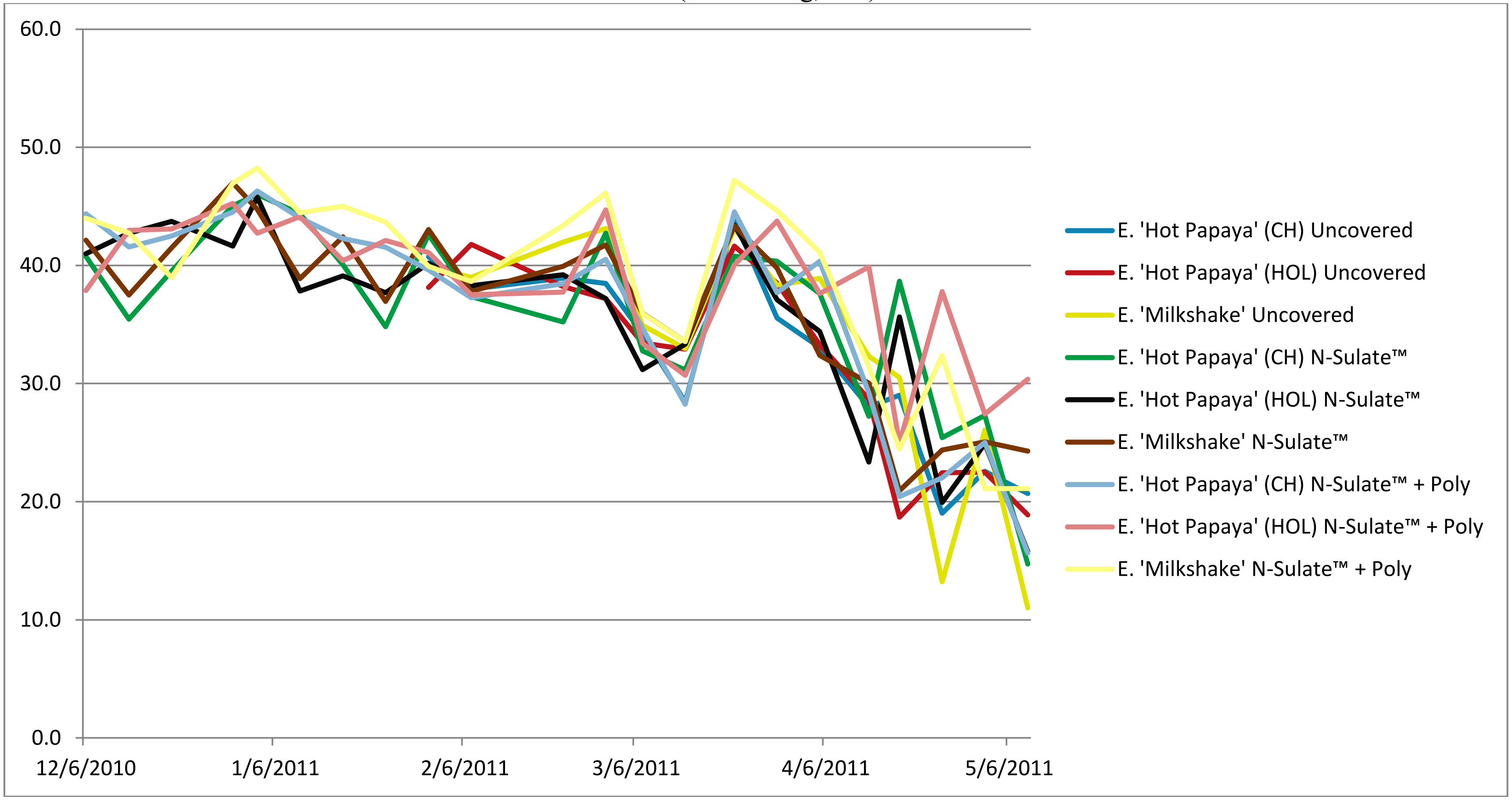


Figure 3.8. Average substrate moisture content (for Wet treatment) for *Gaillardia* ‘Gallo Peach,’ *Huecehra* ‘Brownies’ and *Heuchera* ‘Pistache’ from the Urban Horticulture Center (Blacksburg, VA) from 12/6/2010 to 5/8/2010.

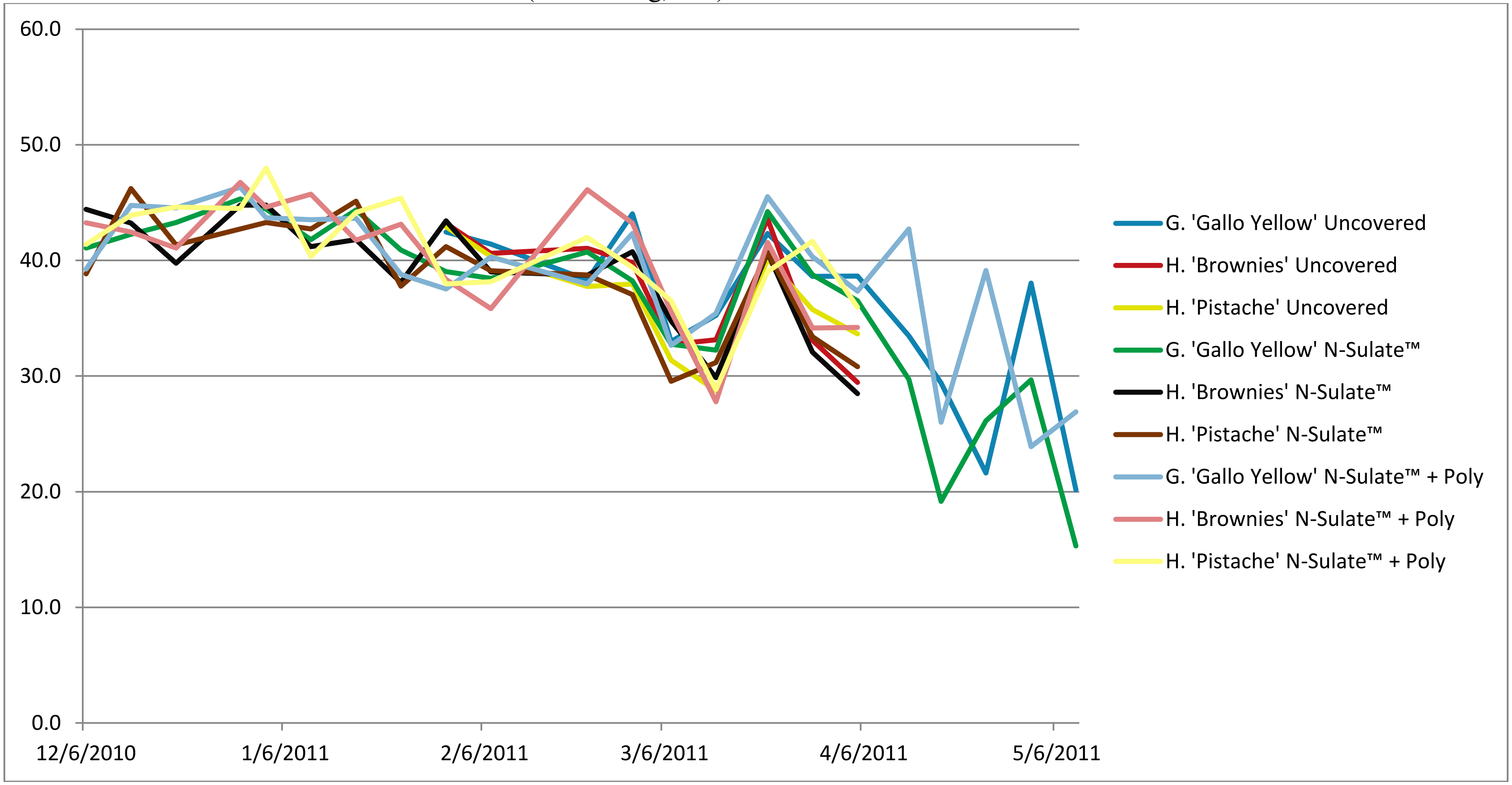


Figure 3.9. Average substrate moisture content (for Wet treatment) for *Pennisetum alopecuroides, Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) from 12/6/2010 to 5/8/2011.

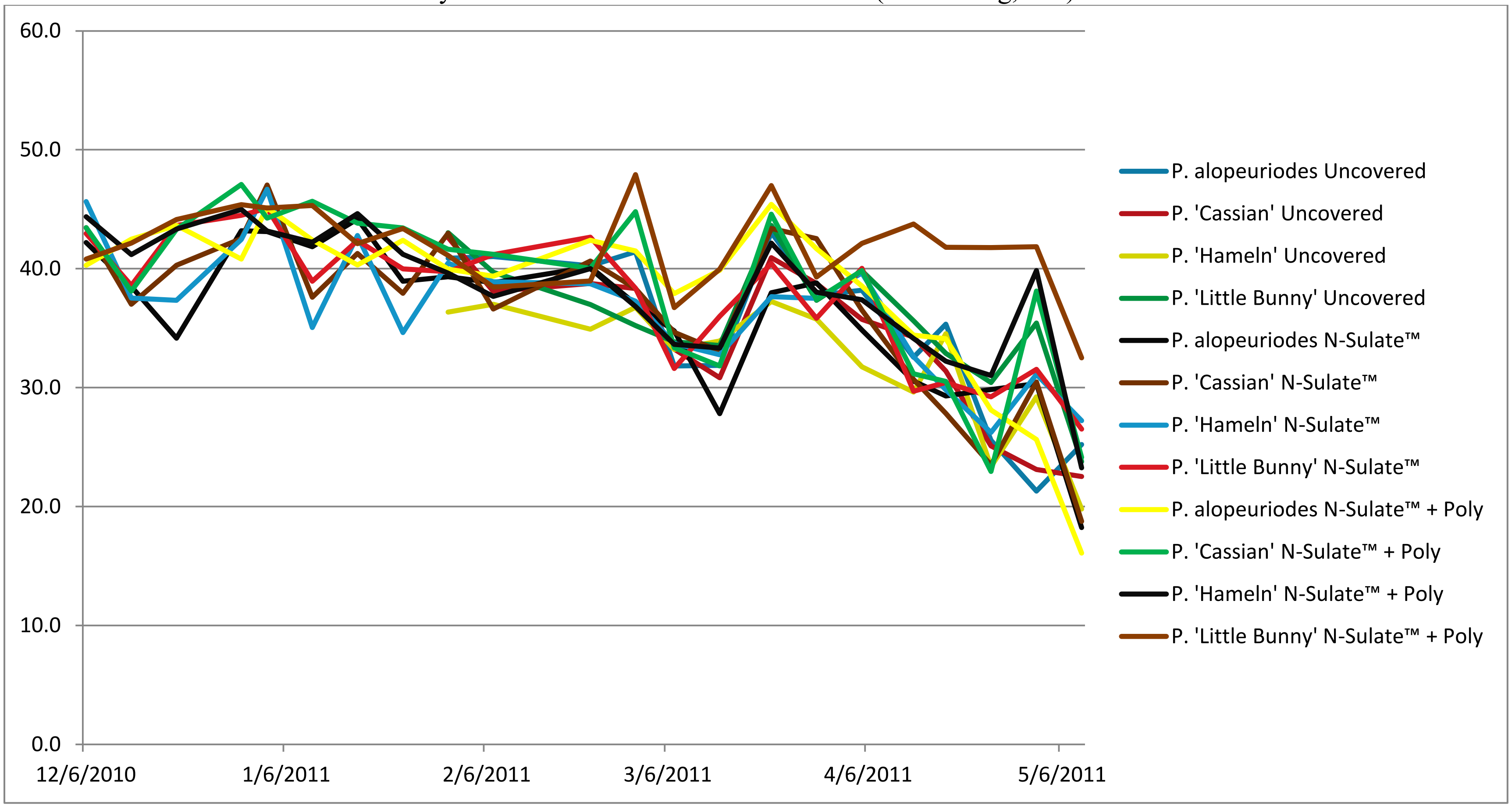


Figure 3.10. Average substrate moisture content (for Dry treatment) for *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Heuchera* 'Pistache' from the Urban Horticulture Center (Blacksburg, VA) from 12/6/2010 to 5/8/2011.

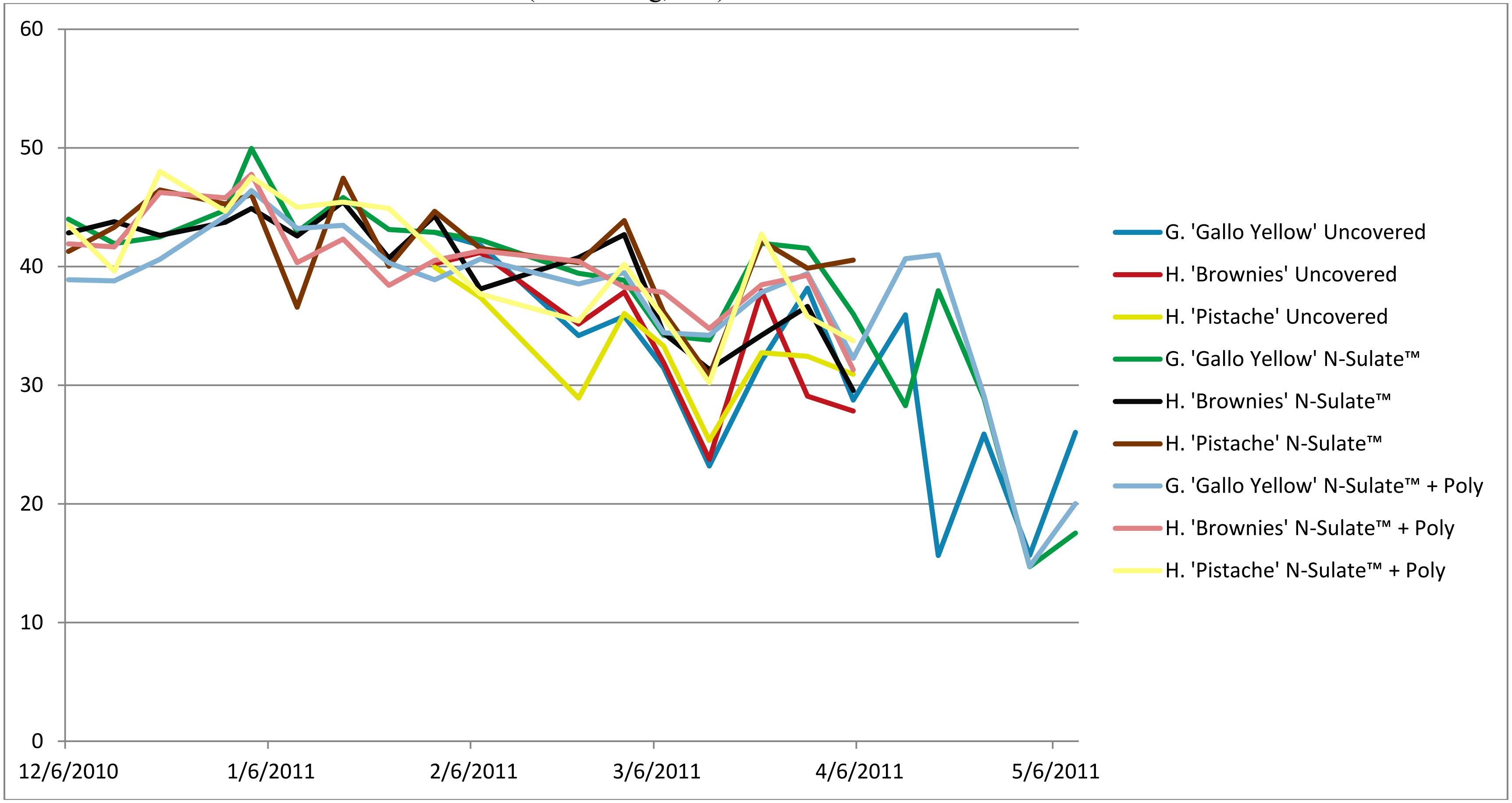


Figure 3.11. Average substrate moisture content (for Dry treatment) for *Pennisetum alopecuroides, Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' from the Urban Horticulture Center (Blacksburg, VA) from 12/6/2010 to 5/8/2011.

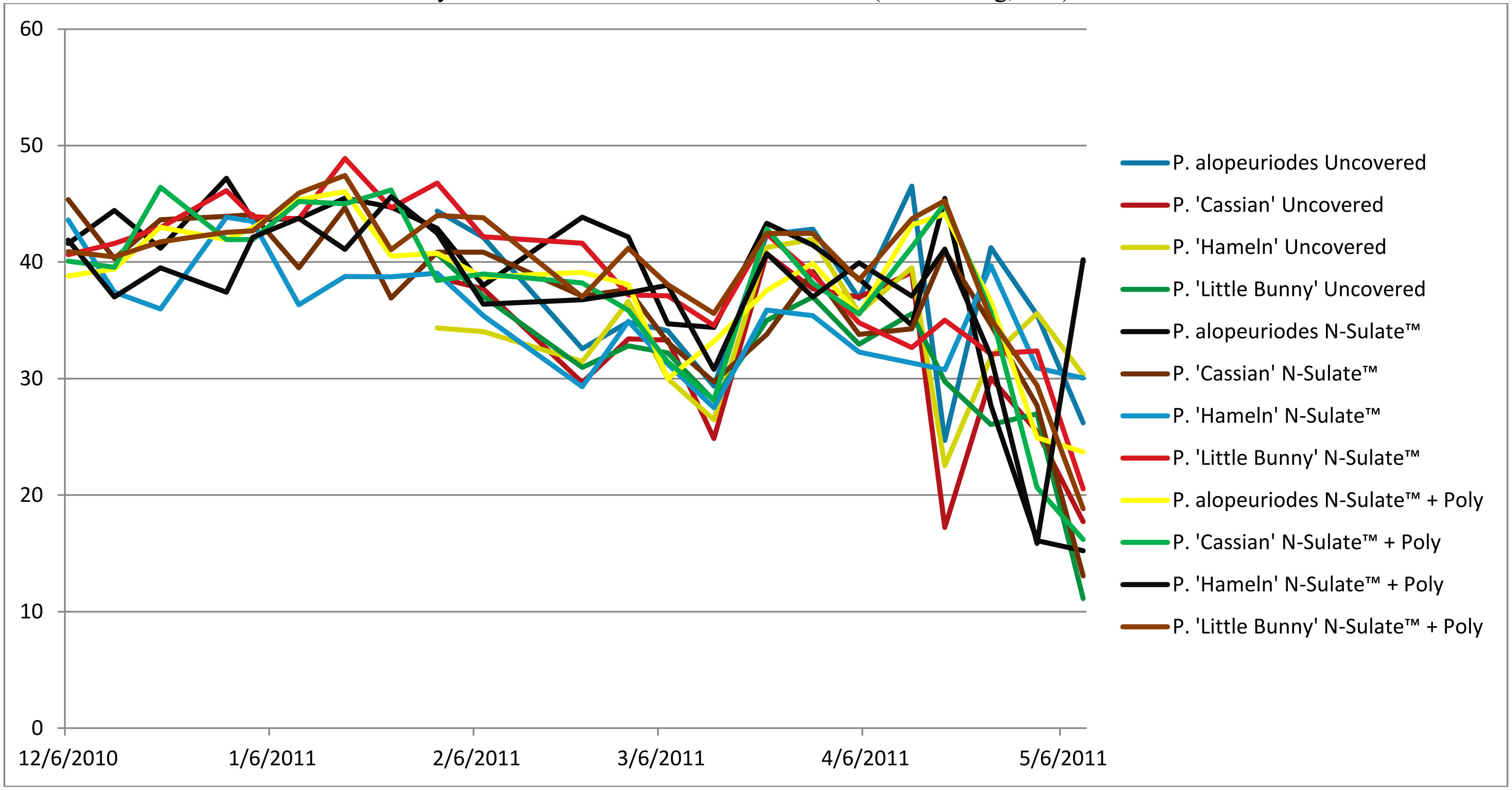


Figure 3.12. Average substrate moisture content (for Wet treatment) for *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies’ and *Pennisetum* ‘Little Bunny’ from Riverbend Nursery (Riner, VA) from 12/8/2010 to 5/9/2011.

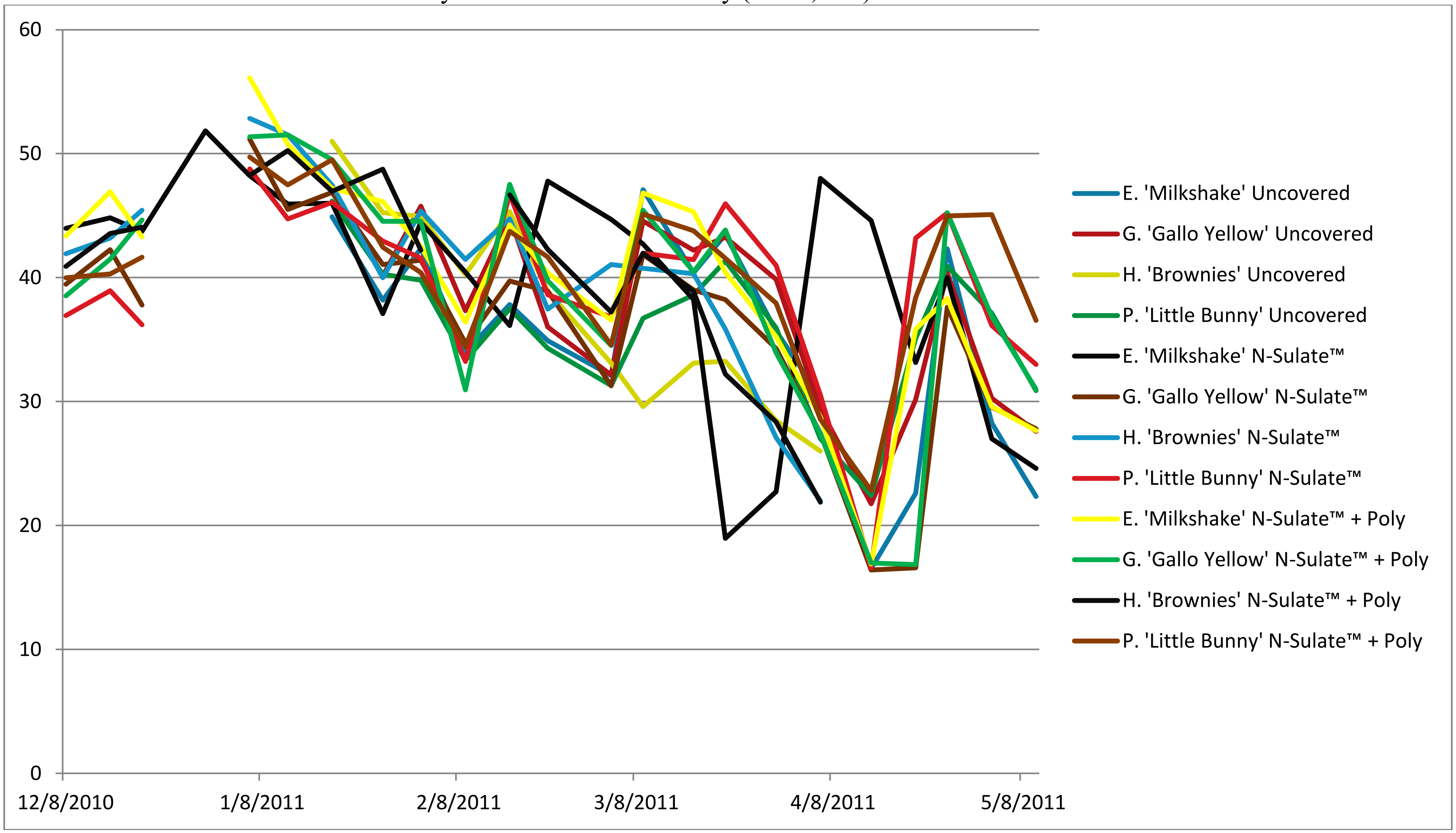


Figure 3.13. Average substrate moisture content (for Dry treatment) for *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' from Riverbend Nursery (Riner, VA) from 12/8/2010 to 5/9/2011.

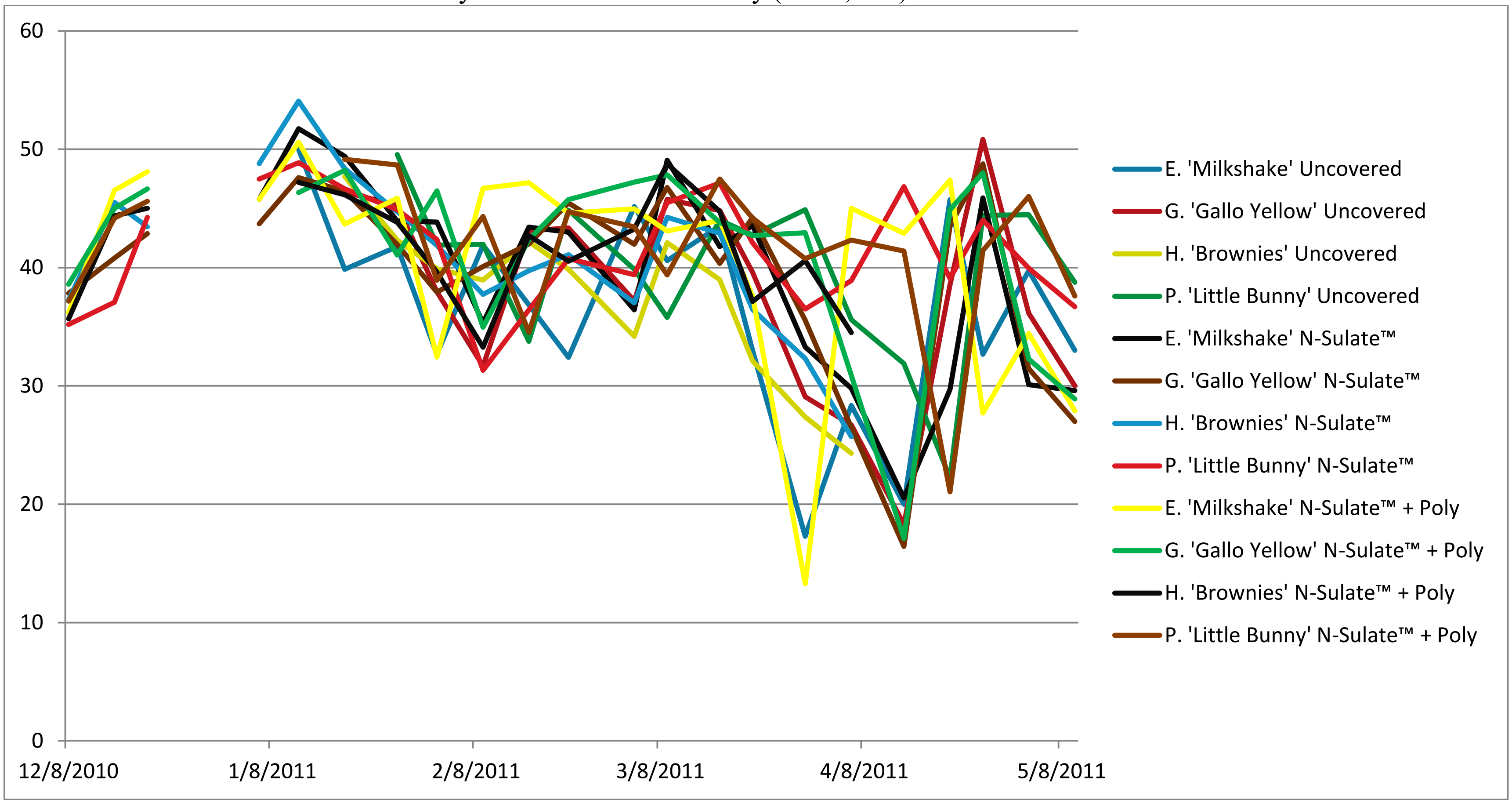


Table 3.1. Average midpoint pH of *Echinacea* ‘Hot Papaya’ (CH), *Echinacea* ‘Hot Papaya’ (HOL), *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies,’ *Heuchera* ‘Pistache,’ *Pennisetum alopecuroides*, *Pennisetum* ‘Cassian,’ *Pennisetum* ‘Hameln’ and *Pennisetum* ‘Little Bunny’ at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 2											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	6.2	6.7	6.4	6.4	6.5	6.8	6.2	6.5	6.4	6.2	6.3	6.1
E. 'Hot Papaya' (HOL)	6.7	6.6	6.2	6.5	6.5	6.6	6.5	6.2	6.6	6.7	6.1	6.2
E. 'Milkshake'	5.7	6.4	6.0	6.1	6.4	6.7	6.1	6.0	6.5	6.5	6.1	6.4
G. ‘Gallo Peach’	6.6	6.7	6.1	6.5	6.5	6.7	6.4	6.3	6.6	6.6	6.5	6.4
H. 'Brownies'	6.8	6.6	6.4	6.4	6.5	6.9	6.4	6.2	6.5	6.7	6.4	6.4
H. 'Pistache'	6.5	6.8	6.4	6.4	6.8	6.6	6.6	6.1	6.6	6.5	6.4	6.4
P. alopecuroides	6.5	6.7	6.2	6.2	6.5	6.6	6.3	6.0	6.6	6.5	6.4	6.4
P. 'Cassian'	6.0	6.6	6.0	6.1	6.7	6.9	6.1	6.1	6.6	6.3	6.0	6.1
P. 'Hameln'	5.4	6.6	6.3	6.1	6.2	6.6	5.9	6.1	6.3	6.3	6.1	6.2
P. 'Little Bunny'	6.4	6.7	6.3	6.3	6.8	6.6	6.3	6.0	6.6	6.6	6.1	6.4

n=3

Taken on 3/1/11

Table 3.2. Average final pH of *Echinacea* 'Hot Papaya' (CH), *Echinacea* 'Hot Papaya' (HOL), *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies,' *Heuchera* 'Pistache,' *Pennisetum alopecuroides*, *Pennisetum* 'Cassian,' *Pennisetum* 'Hameln' and *Pennisetum* 'Little Bunny' at the Urban Horticulture Center (Blacksburg, VA).

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Hot Papaya' (CH)	6.7	6.7	6.6	6.5	6.7	6.5	6.7	6.5	6.7	6.7	6.7	6.5
E. 'Hot Papaya' (HOL)	6.5	6.5	6.4	6.3	6.6	6.7	6.2	6.6	6.6	6.6	6.6	6.4
E. 'Milkshake'	6.7	6.8	6.5	6.6	6.8	6.8	6.7	6.5	6.8	6.8	6.6	6.5
G. 'Gallo Peach'	6.7	6.9	6.5	6.6	6.8	6.8	6.7	6.6	6.8	6.8	6.7	6.7
H. 'Brownies'*	7.0	7.1	6.9	6.7	6.8	7.0	6.6	6.7	7.1	6.9	6.8	6.5
H. 'Pistache'*	7.0	6.9	6.4	6.5	7.3	6.9	6.6	6.6	7.0	7.0	6.5	6.4
P. alopecuroides	6.8	7.0	6.4	6.4	6.6	7.0	6.4	6.4	6.9	7.0	6.7	6.5
P. 'Cassian'	6.6	6.7	6.2	6.3	6.6	6.8	6.0	6.4	6.8	6.4	6.3	6.3
P. 'Hameln'	6.7	6.5	6.5	6.4	6.7	6.8	6.2	6.5	6.7	6.5	6.0	6.4
P. 'Little Bunny'	6.8	6.7	6.4	6.5	6.8	6.8	6.5	6.4	6.8	6.8	6.5	6.4

n=3

Taken on 5/11/11

* Taken on 4/12/11

Table 3.3. Average midpoint pH of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Riverbend Nursery (Riner, VA).

	Evaluation # 2											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	5.5	6.3	5.6	6.2	6.4	6.4	6.0	5.8	6.2	6.5	5.9	6.2
G. 'Gallo Peach'	6.2	6.5	5.9	6.0	6.7	6.4	6.2	6.2	6.4	6.2	6.1	5.7
H. 'Brownies'	6.7	6.3	6.1	6.2	6.8	6.6	6.2	6.2	6.6	6.5	5.9	6.1
P. 'Little Bunny'	6.4	6.3	6.1	5.8	6.4	6.4	6.1	6.1	6.3	6.6	6.0	5.9

n=3

Taken on 3/4/11

Table 3.4. Average midpoint EC (mS/cm) of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Riverbend Nursery (Riner, VA).

	Evaluation # 2											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	1.33	2.18	4.53	4.47	1.72	1.72	4.95	5.22	1.76	2.19	5.27	3.86
G. 'Gallo Peach'	1.69	1.70	4.84	3.93	1.33	2.12	4.32	3.43	1.77	1.67	3.44	4.56
H. 'Brownies'	1.41	1.48	3.53	4.27	1.32	1.17	3.58	3.65	1.23	1.22	3.25	2.88
P. 'Little Bunny'	1.45	1.81	3.73	5.51	1.64	2.01	4.86	4.90	1.58	1.82	3.52	4.39

n=3

Taken on 3/4/11

Table 3.5. Average final pH of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Riverbend Nursery (Riner, VA).

	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	6.5	6.5	6.4	5.9	6.5	6.5	6.2	6.1	6.5	6.5	6.4	6.4
G. 'Gallo Peach'	6.8	6.6	6.0	6.0	7.1	6.5	6.6	6.3	6.7	6.8	6.5	6.5
H. 'Brownies'*	6.9	7.1	6.2	6.4	7.0	7.0	6.5	6.7	7.2	7.1	6.6	6.8
P. 'Little Bunny'	6.7	6.7	6.0	5.8	6.8	6.6	6.1	6.0	6.7	6.7	6.4	6.2

n=3

Taken on 5/12/11

* Taken on 4/14/11

Table 3.6. Average midpoint pH of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA).

	Evaluation # 2											
pH	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	5.9	6.3	6.1	6.1	6.4	6.5	6.1	6.4	6.6	6.4	6.2	6.2
G. 'Gallo Peach'	6.3	6.7	6.1	6.4	6.6	6.3	6.4	6.4	6.4	6.5	6.4	6.3
H. 'Brownies'	6.3	6.4	5.9	6.2	6.4	6.5	6.3	6.5	6.4	6.4	6.2	6.1
P. 'Little Bunny'	6.4	6.7	6.1	6.3	6.6	6.3	6.3	6.0	6.3	6.4	6.2	6.2

n=3

Taken on 2/26/11

Table 3.7. Average midpoint EC (mS/cm) of *Echinacea* ‘Milkshake,’ *Gaillardia* ‘Gallo Peach,’ *Heuchera* ‘Brownies’ and *Pennisetum* ‘Little Bunny’ at Poplar Ridge Nursery (Montross, VA).

	Evaluation # 2											
EC	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	1.15	0.78	1.76	1.35	0.82	0.86	1.59	1.55	0.80	0.70	1.18	1.84
G. ‘Gallo Peach’	1.36	0.50	2.36	0.99	0.64	0.48	1.08	0.62	0.78	0.67	0.99	0.83
H. 'Brownies'	0.87	0.47	2.87	0.97	0.56	0.41	1.32	0.89	0.56	0.45	1.06	1.66
P. 'Little Bunny'	0.96	0.71	2.10	1.36	0.71	0.75	1.26	1.66	0.90	0.98	1.53	1.45

n=3

Taken on 2/26/11

Table 3.8. Average final pH of *Echinacea* 'Milkshake,' *Gaillardia* 'Gallo Peach,' *Heuchera* 'Brownies' and *Pennisetum* 'Little Bunny' at Poplar Ridge Nursery (Montross, VA).

pH	Evaluation # 3											
	Uncovered				N-Sulate™				N-Sulate™ + Poly			
	Low		High		Low		High		Low		High	
Plant Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
E. 'Milkshake'	6.4	6.4	6.6	6.3	6.4	6.4	6.3	6.2	6.5	6.4	6.5	6.3
G. 'Gallo Peach'*	6.9	6.7	6.4	6.7	6.8	6.8	6.7	6.8	6.6	6.8	6.6	6.7
H. 'Brownies'*	6.8	6.7	6.6	6.7	6.8	6.6	6.7	6.7	6.7	6.8	6.7	6.5
P. 'Little Bunny'	6.5	6.4	6.4	6.3	6.5	6.4	6.5	6.5	6.5	6.5	6.4	6.4

n=3

Taken on 5/11/11

* Taken on 4/11/11