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Evaluation of Rapidly Growing Vegetation on Mississippi Roadsides

Timothy Bradford Jr.

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By

Timothy Bradford Jr.

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By

Timothy Bradford Jr.

Approved:

Barry R. Stewart
Associate Professor of Plant and Soil Sciences
(Major Professor)

Paul D. Meints
Committee Participant of Plant and Soil Sciences
(Committee Member)

Gregg C. Munshaw
Committee Participant of Plant and Soil Sciences
(Committee Member)

John W. Guyton, III
Associate Extension Professor of Biochemistry, Molecular Biology, Entomology, and Plant Pathology
(Committee Member)

William L. Kingery
Professor of Plant and Soil Sciences
(Graduate Coordinator)

J. Mike Phillips
Department Head of Plant and Soil Sciences

George M. Hopper
Dean of the College of Agriculture and Life Sciences

Name: Timothy Bradford Jr.

Date of Degree: August 17, 2013

Institution: Mississippi State University

Major Field: Agronomy

Major Professor: Barry R. Stewart

Title of Study: Evaluation of rapidly growing vegetation on Mississippi roadsides

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Candidate for Degree of Master of Science

Non-point source pollution caused by erosion from road construction poses hazardous environmental effects. Percolation and infiltration of nutrients into groundwater can also be detrimental to the surrounding environment. In addition, annual roadside maintenance budget exceeded $14 million in 2011 for Mississippi. Objectives of this research were to evaluate rapidly established short-statured species in an effort to prevent erosion, combat non-point source pollution, reduce mowing cost, and provide quick cover following propagation. Factors evaluated were rate of establishment, plant cover, and mowing requirement. MDOT's standard seed mix was evaluated along with Pennington's SlopeMaster™ product and different combinations of selected plant species. Visual and image analysis showed oilseed radish plants established the quickest and provided the most cover. All sod treatments provided instant cover while Pennington's Slopemaster™ product, as well as mixes that contained bermudagrass or bahiagrass, provided sufficient cover, but not in a timely manner.

DEDICATION

To all those lost souls who have forgotten to believe in the immensity of love.

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CHAPTER I

INTRODUCTION

The highway or road system makes a very important contribution to the overall economy of countries around the world. In land acreage, roads and roadsides cover 1% of the U. S. (Forman and Alexander, 1998) and span 6.2 million km. To give some perspective, cropland makes up 14% total acreage in the United States (Economic Research Service, 2007). As of 2004, Mississippi had 224,175 km of public roads (Federal Highway Administration, 2009) and today that number is increasing with more being constructed. Many complications are associated with roadsides following construction. Most road construction begins with clearing existing vegetative cover; which leads to bare surfaces being exposed to erosive forces (Barrett et al., 1995). Dust and glare from bare surfaces are also major concerns for the public and can make driving strenuous (Barrett et al., 1995 & Forman and Alexander, 1998).

Other major problems of post highway construction include: water runoff, sediment deposition, and detachment and movement of nutrients and fertilizers (Barrett et al. 1995 & Forman and Alexander, 1998). Geiser (1974) reported that during turnpike construction in Germany, groundwater quality was reduced due to the constant vibrations and disturbance which resulted in an increased number of bacteria in groundwater. Garton (1977) evaluated the effect of sedimentation resulting from road construction on streams and aquatic animal populations. He noted that diesel spills and sedimentation caused a large number of fish deaths. Another consequence of post-highway construction is the poor condition of the soil left on the completed roadside. Removal of topsoil and associated nutrients leaves only infertile parent material. This makes plant growth difficult (Bradshaw, 2004).

Mississippi Department of Environmental Quality (MDEQ) and the United States Environmental Protection Agency (EPA) have been combating the issue of nonpoint source (NPS) pollution for years. One major contributor of NPS pollution is the sediment loss during highway construction. This type of pollution, also referred to as polluted runoff, comes from various sources such as construction sites, waste facilities, and agricultural fields. Runoff can contain sediment and nutrients that can percolate into groundwater causing toxicity and promoting the growth of bacteria (MDEQ, 2010).

A key component in controlling erosion and decreasing the amount of hazardous runoff is establishing vegetation (Barrett et al. 1995). The effect of established vegetation on soil stabilization has been well documented. The extensive network of plant roots, root hairs, and associated microbial activity produces soil-binding agents and reduces soil erosion (Angers & Caron, 1998). Ellison (1944, 1947) showed that raindrops detach soil particles and breakdown aggregates. The diameter of a raindrop creates a terminal velocity that governs the ability to detach soil particles once it reaches the ground (Laws, 1941). Plant cover has been shown to absorb the kinetic energy of the raindrop to reduce impact; thus, decreasing the erosive effects of raindrops (Shaw 1959). Plants also have been known to act as a filter by absorbing toxins and trapping sediments (Robinson et al., 1996). By utilizing plant species that establish rapidly will ensure decreased sediment deposition and erosion caused by NPS.

Many of the plant species used on roadsides today require extensive maintenance. Mowing and fertilization must be performed to maintain safety and aesthetics, resulting in increasing costs to state budgets (Johnson, 1998). These maintenance costs may add up to millions of dollars each year. In addition to mowing and fertilization, herbicide applications, fuel, and equipment maintenance is also required. In Mississippi and surrounding states, maintenance was reported to reach millions of dollars annually (Johnson, 1998). Mississippi spent $14,650,000 on roadside maintenance in 2011. This included chemical weed and erosion control, beautification, litter pickup, mowing, timber and brush cutting, and spot spraying (Ken Hauser, personal communication March 27, 2012). Reducing these practices could lead to funds being available for road improvement or to other state agencies.

Highways and roadways have other beneficial effects also. Studies have shown that fully vegetated roadsides can have a positive effect on a person's mental health state (Cackowski and Nasar, 2003). Akbar, et al., (2003) argue that the aesthetics of roadside vegetation is an important aspect of public roads based on public perception.

In an attempt to combat the issue of NPS pollution, EPA has started to enforce different areas of the Clean Water Act of 1972 by requiring construction sites to have 70% vegetative cover in 30 days (EPA, 2003). The main goal of this research is to identify mixes of warm and cool-season plants that establish quickly on Mississippi roadsides. A secondary objective is to identify those species that provide good quality and dense cover that will require minimal maintenance while stabilizing disturbed soils. This research will also investigate the use of hydroseeding and hydromulching for the establishment of vegetation upon completion of construction.

CHAPTER II

LITERATURE REVIEW

Current MS roadside vegetation mixes include a number of plant species. Some are desirable and effective in terms of growth habit and vigor, but several species would not be considered low maintenance. The current mix of species requires the use of fertilizers, frequent mowing, and is somewhat slow to germinate and establish during periods of low rainfall. The North Carolina Department of Transportation has determined the annual cost of routine roadside mowing to be $16 million and found that a reduction in mowing occurrences reduced maintenance costs by $4 million (Johnson, 1998). The current mix of plant species and seeding rates used in Mississippi consists of: bermudagrass, (*Cynodon dactylon* (L.) Pers., 22.7 kg ha^{-1}), bahiagrass, (*Paspalum notatum* Flüggé, 28.4 kg ha^{-1}), tall fescue, (*Festuca arundinacea* Schreb., 28.4 kg ha^{-1}), and sericea lespedeza, (*Lespedeza cuneata* (Dum. Cours.) G. Don, 22.7-34.1 kg ha^{-1}). Crimson clover (*Trifolium incarnatum* L., 22.7 kg ha^{-1}) is added for fall and winter plantings (MS Vegetation Schedule). For temporary erosion control, brown-top millet (*Panicum ramosum* L., 22.7 kg ha^{-1}), annual ryegrass (*Lolium multiflorium* Lam., 28.4 kg ha^{-1}), and oats (*Avena sativa* L., 102.3 kg ha^{-1}) are utilized.

Warm-Season Grasses

Bahiagrass is native to South America (Newman, 2007). It has been widely used in the southern United States since 1914 (Trenholm, et al., 1991a). It normally reaches heights of 20-76 cm (Houck, 2009) and has low fertilizer requirements (Trenholm, et al., 1991a). The variety 'Pensacola' is often used in the southeastern United States for lawns, roadsides, forage, and hay. It is a good choice for home lawns and roadsides due to its extensive root system, drought tolerance, and ease of establishment from seed. Its popularity is derived from its low maintenance and adaptation to infertile soils (Trenholm et al., 1991a). However, bahiagrass presents some challenges if it is to be used on a low maintenance roadside. Bahiagrass has a tendency to grow tall and produce abundant seedheads that can be 30-60 cm in addition to original leaf height. This tall seedhead can be undesirable to the eye (Nelson et al., 1993). Removing these seedheads requires frequent mowing which prompts regrowth and poses safety concerns to the public with large equipment on roadsides (Nelson et al., 1993), or the use of plant growth regulators (PGR's) (Goatley et al., 1996). Broadcast seeding is usually the popular choice for establishment because of its ease and reduced expense.

Bermudagrass is one of the most extensively used grasses in the southeast. Introduced from Africa, it can reach a height of 30-45 cm and requires 198-396 kg N ha^{-1} per year (Turgeon, 2002). It is widely used in southeastern U.S. lawns because of its aggressive growth habitat, superior drought tolerance, relative ease in establishment from seed, and ability to recover from traffic and cold (Patton and Boyd, 2008; Jennings et al., 2006). It has a deep root system and forms a dense ground cover by stolons and rhizomes (Patton and Boyd, 2008). Common bermudagrass is almost exclusively seeded on MS roadsides. Improved turf-type cultivars such as 'Riviera' and 'Yukon' have increased traffic and cold tolerances and have reduced growth rates compared to common (Patton and Boyd, 2008). Hybrid bermudagrass (*Cynodon dactylon* x *C.* transvaalensis) such as 'Tifway', 'Tifgreen', and 'MS-Xpress' are sterile and must be propagated vegetatively. These are finer textured than common bermudagrass and usually require a strict management plan including frequent fertilization and mowing to maintain quality (Patton and Boyd, 2008). They have low tolerances for insects, nematodes, and diseases, which limit their use for low maintenance conditions (Trenholm et al., 1991b). The use of bermudagrass for low maintenance roadsides is questionable because of its high maintenance requirements. However, because of its ease of establishment, it is frequently used. Roadside bermudagrass turf is of low quality and fertilizer applications are required in order to remain prolific and appealing (Trenholm et al., 1991b).

Brown-top millet is included in the Mississippi Department of Transportation MDOT species mix, but only used for temporary cover. Brown-top millet is a bunch-type annual that is native to Southeast Asia (Hancock, 2010). Brown-top millet has a variety of uses including: forage production, grazing, food for wildlife, straw production, and erosion control (Hancock, 2010). Its rapid establishment and quick growth are very appealing; however, its height (0.6-1.5 m) and rapid growth are not favorable for maintenance (Hancock, 2010). If managed correctly, brown-top millet also reseeds readily which helps ensure dense stands in the future.

Carpetgrass (*Axonopus affinis* Chase) is not currently used for roadside establishment in MS. However, it possesses several characteristics that may make it a suitable choice for roadside vegetation. Carpetgrass is a perennial grass that is native to

Central America, the West Indies, and the U.S that reaches 20-50 cm in height (USDA, 2002a). This grass is ideal for low maintenance turf and only requires 99 kg N ha^{-1} or less per year (Turgeon, 2002). Carpetgrass can be easily established by seed and has been used in areas of access roads because of its adaptability to low fertility and moist to wet soils (Turgeon, 2002). Carpetgrass spreads by slow growing, creeping stolons and its thick leaf blades have also been known to be a weed suppressant. Due to its relatively slow lateral and upright growth, it is ideal for low maintenance management systems; however, it is detrimental for rapid roadside establishment. It provides an exceptional root system that improves soil structure that can lead to the succession of other plant species (Valenzuela & Smith, 2002).

Centipedegrass (*Eremochloa ophiuroides* (Munro) Hack.) is widely used in the Southern United States because of its low maintenance and low fertilizer inputs. It is low growing, reaching a maximum height of 28 cm with a fertilizer requirement of 50 kg N ha^{-1} per year (Turgeon, 2002). Native to South Asia, this plant spreads by short stolons that enable it to cover bare spaces on the surface. The slow vertical and lateral growth makes this a popular choice for roadsides and lawns, but is detrimental for rapid establishment (Johnson, 1998). Centipedegrass has moderate shade tolerance and even though it has shallow root systems, it is able to tolerate some drought. The variety 'TifBlair', developed and released by USDA-ARS in 1997 in Tifton, Georgia may be a suitable roadside variety because of its ability to adapt to and grow on acidic and poor soils (Samples & Sorochan, 2007). Centipedegrass also has limited cold tolerance but will persist in Mississippi's moderate winters.

Zoysiagrass (*Zoysia japonica* Steud.); also referred to as Japanese Lawngrass, is a grass native to China and Southeast Asia. Mature stands will reach a height of 10 cm and only require 75-151 kg N ha^{-1} per year (Turgeon, 2002). It is adapted to tropical, subtropical, and temperate climates. Used extensively for lawns and parks, it is a desirable turf because of its wear and cold tolerance (Turgeon, 2002). Spreading by stolons and rhizomes, it produces an attractive sod. However, one major drawback to zoysiagrass is its slow establishment and growth (Turgeon, 2002). 'Meyer' is the leading and most widely used vegetatively propagated cultivar of zoysiagrass, (Dunn, 1991; Turgeon, 2002) while the National Turfgrass Evaluation Program (NTEP) shows 'Zenith' to have the best overall quality rating for Mississippi among the seeded zoysiagrasses. 'Chinese Common' and 'Companion' are two other seeded cultivars available, but did not rate as highly as 'Zenith'. In addition to 'Zenith', 'Panda' is another seeded cultivar used in the southeast.

Cool-Season Grasses

Annual ryegrass (*Lolium multiflorium* Lam.,) is a short lived, bunch type grass native to Europe that grows to 91-121 cm with an N requirement of 101-303 kg N ha^{-1} annually (Turgeon, 2012). Its uses in the United States include forage, hay production, lawns, and recreational areas. It is occasionally used in subtropical climates for overseeding in lawns and athletic fields during dormant conditions of warm-season grasses (Turgeon, 2002). In these subtropical areas, it is mainly used for temporary cover because of its inability to tolerate high temperature extremes. Annual ryegrass has aggressive seedling growth and extremely vigorous root systems that hold soil in place. These characteristics make it desirable for erosion control and systems that require quick establishment such as in hydroseeding (Valenzuela & Smith, 2002). Its growth improves organic matter levels in the soil while increasing infiltration and improving soil structure. It is also efficient in storing nitrogen and reducing leeching. Shorter turf-type varieties of annual ryegrass have recently become available. Although not heat tolerant, characteristics of turf-type annual ryegrass make it a strong candidate in seeding mixes and worth exploring for use on roadsides.

Creeping red fescue (*Festuca rubra* L. ssp. rubra) has shown potential for erosion control. Introduced from Northern Europe, it creates a dense sod suitable for lawns, disturbed areas, and recreational uses while reaching heights up to 60 cm and requiring 101 kg N ha^{-1} per year or less (Turgeon 2002). This cool-season plant spreads by short rhizomes and is adapted to calcareous soil, but it is also able to tolerate considerable acidity and can flourish in sun or shade (Turgeon, 2002). Its nitrogen requirement creates a feasible option for use along roadsides and improved cultivars have shown improved drought and disease resistance (Turgeon, 2002). Mississippi summers usually do not produce much rain which is also accompanied by high heat making survival during this time difficult. Although the heat tolerance of this species will likely not allow it to persist in full-sun areas in the mid-south, it may be beneficial in a fall planting; however, its slow establishment rate may hinder rapid cover.

Tall fescue has been implemented in the past as an erosion control plant because it is widely adapted to many soil types and harsh environmental conditions (Turgeon, 2002; USDA, 2002c). Tall fescue is a bunch-type grass that can reach heights ranging from 91-121 cm with fertilizer requirements ranging from 50-250 kg N ha^{-1}. Tall fescue is very versatile, and is adapted to a fairly broad range of soil conditions and also tolerant of heat and drought conditions (Turgeon, 2002). It is used extensively in the southern U.S. for hay, lawns, grazing, and recreational use. ‘Kentucky 31’ is one of the most widely used cultivars because of its growth characteristics, tolerances, and presence of *Neotyphodium cenophialum* endophyte, which increases its stress tolerances in a symbiotic relationship (Turgeon, 2002). It is commonly used on Mississippi roadsides and in pastures because of its aggressive growth and ability to persist throughout the summers. Higher quality turf-type cultivars such as ‘Rebel’ and ‘Jaguar’ require a more intensive level of management. It is relatively easy to establish from seed. Rapid germination and ability to perform after hydroseeding make it even more desirable (USDA, 2002d).

Broadleaf Plants

Crimson clover (*Trifolium incarnatum* L.) has been used in the United States since its introduction in the 1800’s (Hannaway and Myers, 2004). Native to the Mediterranean region, this winter annual is mainly overseeded in warm-season species to provide winter grazing (Hannaway and Myers, 2004). Its ability to re-seed makes it a valuable component in a roadside species mix; however, its intolerance of high temperature and water requirements are the main drawbacks of using it as a desired species on a low maintenance roadside (Hannaway and Myers, 2004).

Oilseed radish (*Raphanus sativus* L. var. *oleiferus*) has been used as a cover crop for a number of years. It is a member of the mustard family that includes many other cover crops. It has the ability to withstand temperatures as low as -4°C which makes it attractive to farmers with no till management systems (Sundermeier, 2008). Its biomass production and rapid growth rate allows farmers to quickly regain their expenses either by harvest or planting a following crop (Sundermeier, 2008). Research on its effectiveness for use on roadsides has not been done. The large taproots produced by oilseed radish help alleviate compacted soils by their growth and decomposition. Doing this improves soil quality while also providing a dense canopy to suppress weeds, but also may suppress desired species as well (Ngouajio and Mutch, 2004). This could be extremely effective on roadsides due to the conditions that remain following construction. Its characteristics as a cover crop for quick growth and short growing cycle could be successful in doing the same for grass species along roadsides. Oilseed radish can be planted in late spring or late summer and can quickly produce large amounts of biomass that is ideal for erosion control on roadsides. Seed is readily available and can either be broadcast or drilled.

Red clover (*Trifolium pretense* L.) is a rapidly growing perennial crop that can reach heights of 45-76 cm and can grow on a variety of soils; with optimal performance on soils with a pH of 6.0 or higher. It grows well on loamy and clay soils and can survive temperatures as low as -34°C (Sattell et al., 1998). It provides good soil stabilization because of extensive tap and surface roots (Sattell et al., 1998). A leguminous plant that fixes nitrogen facilitates the use of available nitrogen for other plants (USDA, 2002c). Usually used as a cover crop, its rapid growth and deep taproots break soil aggregates, thus making it ideal for roadside establishment (Sattell et al., 1998). Seed are readily available and can be established by either drill or broadcast (USDA, 2002c). Many cultivars today are tailored for leaf biomass production and disease resistance (Sattell et al., 1998; USDA, 2002c). 'Mammoth Red', 'Medium Red', and 'Kenland' are cultivars used for biomass production (Sattell et al., 1998), while 'Acclaim', 'Rally', and 'Renegade II' are cultivars that are highly resistant to disease (USDA, 2002c).

White Clover (*Trifolium repens* L.) is a perennial legume that originated in Europe and is widely used in the United States for pastures and wildlife habitats that can reach a height of 15 cm. Due to its spreading via stolons and ability to reseed itself, it can be used on roadsides as an effective erosion control measure (USDA, 2002e). It is adapted to well drained and fertile soils with a pH ranging from 6-7 (USDA, 2002e). White clover seed is readily available and can be established easily. It can either be drilled or broadcast seeded. Improved cultivars such as 'Ladino', 'Pilgrim', and 'New York', are recommended for large growth, intermediate growth, and small growth respectively (USDA, 2002e). Also because white clover is a legume, it has the ability to fix nitrogen for its own use and once it dies that nitrogen is available for other plants to use (USDA, 2002e).

Sod

Sod can be the most expensive, yet sometimes the most efficient way to provide instant ground cover (Landschoot, 2012). Low maintenance species such as zoysiagrass and centipedegrass sod can be an alternative to seeding and waiting for grass establishment. Sod also has benefits for erosion control. This factor could be a major benefit following roadside construction.

Mulch

With the increased construction of highways, unprotected surfaces are one of most notable aspects of the construction process. The concern with these non-vegetated slopes is the increased chance of soil erosion. Mulch has been used to reduce erosion on roadsides, agricultural fields, and landscapes (Dudeck et al., 1970). Mulch has been shown to be effective in covering bare soils and providing stabilization while aiding in seedling growth (Booze-Daniels et al., 2000; Norland, 2000). Surface mulches are usually referred to as materials that when placed on the soil surface, aid in vegetative establishment by providing positive microclimate conditions (Booze-Daniels et al., 2000; Norland, 2000). Mulch has been shown to have many functions and benefits when used with planting by helping seed stay in place, suppressing weeds, retaining soil moisture, providing organic matter, and reducing erosion (Dudeck et al., 1970; Mostaghimi, et al., 1994; Osborne and Gilbert, 1976). Mulches also increase infiltration, surface wetness, and water-holding capacity (Norland, 2000). Organic mulches such as straw from wheat or oats are preferred because they are natural materials. In addition, straw is long fibered which is preferred over wood or paper mulches, which are short fibers. Long fibered mulches decompose faster and are more effective in trapping sediment and reducing the force of water flow (Booze-Daniels et al., 2000; Norland, 2000). Although long-fibered mulches have been reported to be more effective, short fibered mulches can be just as effective with proper rates (Booze-Daniels et al., 2000; Norland, 2000). The proper mulching rates determine the effectiveness of control. A light mulch cover should facilitate seedling growth by providing gas exchange while at the same time, holding the soil and moisture in place; thus, a light application of mulch is more effective than a heavy application (Booze-Daniels et al., 2000; Norland, 2000). It also may ensure success where a gully washing at the wrong time or where conventional establishment may be a disaster. However, application rates can vary based on slope steepness and plant materials. Steep slopes require more material than flatter terrain.

Hydroseeding

Hydroseeding is a very popular method when applying a quick cover to bare slopes on roadsides (Booze-Daniels et al., 2000). This method allows one to plant seed with a mixture of water, mulch, fertilizer, and different soil stabilizers. It is also very effective in spreading seed in distances up to 60 m (Norland, 2000; Booze-Daniels et al., 2000). One benefit of hydroseeding is that it can immediately provide seeds with materials needed for growth (i.e. fertilizer, water) along with mulch and any other appropriate additives in a single application (Booze-Daniels et al., 2000; Norland, 2000). Mostaghimi et al. (1994) found that hydroseeding decreased runoff by 8% compared to straw mulch alone. Although hydroseeding has many advantages, it also has disadvantages. Hydroseeding can take up to 30% more seed than broadcasting or drilling because of fertilizer injury or pump agitation damaging seed (Booze-Daniels et al., 2000). Also hydroseeding can present expensive up front cost because of specialized pumping equipment, the use of water, and the cost of the hydroseeder itself.

Hydroseeding is effective in preventing erosion when used in combination with other materials such as fertilizer and mulch (Booze-Daniels et al., 2000; Norland, 2000). It is mainly used for disturbed areas needing rapid cover where follow up maintenance is minimal (California Stormwater BMP Handbook Construction, 2003). Using a hydroseeder during application may be more cost effective in the long run when compared to the traditional methods for seeding applications because of subsequent applications and mulch and fertilizers. These additional methods require more input and time; therefore, increasing total cost. Although using a hydroseeder in the short term may be more expensive, it can be beneficial in saving time when considering time dedicated to traditional inputs such as fertilizer application and mulch application. An essential component of hydroseeding is providing mulch and seeding shortly after construction is completed to reduce the length of time the disturbed area is exposed (Booze-Daniels et al., 2000; Norland, 2000).

CHAPTER III

MATERIALS AND METHODS

Summer Germination Studies

Germination tests were conducted to determine what species were compatible with summer planting. Germination tests evaluated seed germination under elevated temperatures that would be present in summer plantings. Three replications of 50 seeds were placed in petri dishes lined with filter paper, moistened with deionized water, and placed in a germination chamber (Hoffman Manufacturing Company C3OASIS Commercial Refrigerator Albany, OR). Chambers were set with a 16 hr photoperiod and one of three day/night temperature regimes of 35/25, 30/20, or 25/15°C. Dishes were inspected each day to determine moisture content. If water was needed, deionized water was added until the filter paper was moist. Dishes were also observed for germination daily. If germination had occurred, it was noted. Seeds were considered germinated once visual evidence supported the emergence of the radical. Germination was counted at 7, 14, and 21 days after initial placement in germination chambers. Seeds that did not germinate by the final count on day 21 were considered unviable. Germination tests were initiated for 2011 and 2012 summer plantings on April 18, 2011 and January 9, 2012 respectively. Germination counts were done on April 25, May 2, & 9 2011 for the 2011 planting and on January 16, 23, & 30, 2012 for the 2012 planting. The GLM procedure was used (SAS Version 9.2, SAS Institute, Cary, NC) to examine the effect of different temperature regimes on percent germination of each species. The means were separated using Fisher's protected least significant difference (LSD) procedure with a significance level of 0.05.

Species selection, cultivar selection, and seeding rates

Species selection was based on performance in the growth chambers. Considerations were also taken for species that would be beneficial and appropriate for providing establishment later in the season (Table 1). National Turfgrass Evaluation Program (NTEP) trials were referenced when selecting cultivars for tall fescue to determine which were suitable based on performance.

Table 1 Species and cultivar used for summer planting.

Species	Common Name	Cultivar
Axonopus affinis	Carpetgrass	Common
Cynodon dactylon	Bermudagrass	Mowhawk
**C. dactylon x C. transvaalensis*	Hybrid Bermudagrass	MS-Express
Eremochloa ophiuroides	Centipedegrass	TifBlair
**Eremochloa ophiuroides*	Centipedegrass	Common
Festuca arundinacea	Tall Fescue	Faith
Festuca rubra	Creeping Red Fescue	Common
Lolium multiflorium	Annual Ryegrass	Gulf
Lolium multiflorium	Annual Ryegrass	Panterra**
Lolium perenne	Perennial Ryegrass	V.I.P.**
Panicum ramosum	Brown-top Millet	Common
Paspalum notatum	Bahiagrass	Pensacola
Poa arachnifera	Texas Bluegrass	Reveille
Raphanus sativus L. var. *oleiferus*	Oilseed Radish	Common
Slope Master ™		
Trifolium incarnatum	Crimson Clover	Common
Trifolium pretense	Red Clover	Bulldog Red
Trifolium repens	White Clover	Durana
Zoysia japonica	Zoysiagrass	Zenith
**Zoysia japonica*	Zoysiagrass	Palisades

*Denotes sod treatment.
**Denotes blend

Seeding rates for seed mixtures were adjusted based on Pure Live Seed (PLS) data for each species from seed labels (kg ha^{-1}). Each species was weighed and placed in brown paper bags in equivalent weights corresponding to plot size (Table 2).

Table 2 Species seeding rates, recommended rates, and pure live seed (PLS) rates (kg ha^{-1}) used for summer roadside planting.

Species	**Recommended Rate (kg ha^{-1})**	**PLS**	**Rate Used (kg ha^{-1})**
Axonopus affinis[T]	195.1	82.9	235.1
*Cynodon dactylon**[T]	48.7	18.9	257.7
Eremochloa ophiuroides[T]	48.7	89.0	54.7
*Festuca arundinacea**[T]	243.9	95.0	256.7
Festuca rubra[T]	146.3	91.8	159.4
*Lolium multiflorium**[P] (Gulf)	48.8	86.1	56.7
*Panicum ramosum**[P]	16.8	70.5	23.8
*Paspalum notatum**[T]	243.9	78.0	312.7
Poa arachnifera[T]	97.6	48.0	203.3
Raphanus sativus L. var. *oleiferus*[T]	97.6	98.9	98.6
Slope Master™[P]	56.0		
*Trifolium incarnatum**[P]	22.4	55.0	40.7
Trifolium pretense[P]	11.2	55.0	20.4
Trifolium repens[P]	3.4	56.6	6.1
Zoysia japonica[T]	48.7	84.4	57.7

[P] Indicates recommended rates based on pasture establishment.
[T] Indicates recommended rates based on turfgrass establishment.
*Indicates species used MDOT's current seeding mixture.

Summer Planting 2011

The summer planting plot area was provided by MDOT along Highway 25 near Starkville, MS. Replications 1 and 2 were located along the southbound lanes just south of the Hwy 12 Starkville exit and replications 3 and 4 were located along the northbound lanes just north of Longview Rd. and 2 miles south of the Hwy 12 Starkville exit. According to Web Soil Survey replication 1 was mapped as Adaton (Fine-silty, mixed, active, thermic Typic Endoaqualf) (USDA National Cooperative Soil Survey, 1997a), replications 2 & 4 as Sessum (Fine, smectitic, thermic Chromic Dystraquerts) (USDA National Cooperative Soil Survey, 2000), and replication 3 as Faulkner (Fine-silty, siliceous, active, thermic Aquic Paleudalfs) (USDA National Cooperative Soil Survey, 1997b). The vegetation at the selected areas was sprayed until wet with one application of glyphosate at 3% v/v to ensure elimination of existing vegetation. After vegetative kill, the sites were mowed, disked, and tilled using a Blecavator™ 5V175. Composite soil samples were taken from each replication and submitted to the MSU Soil Testing Lab to determine pH, lime requirement, and nutrient status. The experimental design was a randomized complete block (RCB) with four replications. Each block consisted of 85 plots with each plot being 1.82 x 3.04 m (Table 3). The MDOT standard fertilizer application of 1,136 kg ha^{-1} of 13-13-13 was surface applied just prior to planting with a push cyclone spreader. Plots were hand seeded due to small size. Planting and fertilization for replications 1-4 took place June 8 through June 13, 2011. Based on soil test recommendations, 4864.9 kg ha^{-1} of pelletized lime was surface applied to replication three. Each replication contained three sod treatments, bermudagrass (MS-Express), zoysiagrass (Palisades), and centipedegrass (Common). After installation, if adequate rainfall did not occur, each sod treatment was watered every other day for a period of two weeks with a FINN T60 hydroseeder. Sod was watered until turf and attached soil were adequately moistened and runoff was observed.

Summer Planting 2012

The 2012 summer experimental site was located south of Columbus, Mississippi at the intersection of MS highway 45 South and Gilmer-Wilbun road in the median of a newly constructed four-laned highway. According to Web Soil Survey, the experimental area was mapped a Leeper (Fine, smectitic, nonacid, thermic Vertic Epiaquepts) (USDA National Cooperative Soil Survey, 2012a). The experimental procedure varied from year one by the application of wheat straw mulch and cultural practices applied to brown-top millet bringing the total number of plots per replication to 90. The experiment was planted June 19, 2012. Wheat straw mulch was hand applied on each plot and brown-top millet was mowed when seedheads were visible and before the seed had become viable. Identical approaches were taken to planting and watering sod in the summer of 2012 as in the previous year.

Treatments were combined such that one treatment consisted of a three species mixture. All treatments included either white or red clover, with the exception of the stand-alone plots, the sod treatments, the MDOT standard, and the added mixes planted exclusively for year two that contained brown-top millet, bermudagrass, and oilseed radish. All treatments that included red or white clover were arranged so that each species was placed with each other (Table 3). The control was MDOT's current mix of plant species that include bermudagrass at a planting rate of 22.7 kg ha^{-1}, bahiagrass at 28.4 kg ha^{-1}, and crimson clover at 22.7 kg ha^{-1}. Pennington's Slopemaster product which on a weight basis consisted of 39.2 % Greystone tall fescue, 9.9% Mowhawk bermudagrass, 6.4% Durana white clover, 4.8% Sahara bermudagrass, and 4.8% brown-top millet was also evaluated. The turf-type annual ryegrass that was used was Barenbrug SOS 400 Blend (hereafter referred to as AR-P) which contained 49.7% Panterra turf annual ryegrass and 49.5% Panterra V turf annual ryegrass. The perennial ryegrass used was V.I.P. blend (hereafter referred to as PR) that consisted of Laredo, Paragon, and Evening Shade perennial ryegrass. ‘Gulf’ annual ryegrass (hereafter referred to as AR-G) was the only annual ryegrass species that was not used as a blend.

Table 3 Species treatment mixes for summer roadside planting.

1. Radish Centipede Red Clover	2. Radish Centipede White Clover	3. Radish AR-G Red Clover
4. Radish AR-G White Clover	5. Radish Zoysia Red Clover	6. Radish Zoysia White Clover
7. Radish Creeping Red Fescue Red Clover	8. Radish Creeping Red Fescue White Clover	9. Radish Tall Fescue Red Clover
10. Radish Tall Fescue White Clover	11. Radish Carpetgrass Red Clover	12. Radish Carpetgrass White Clover
13. Radish Texas Bluegrass Red Clover	14. Radish Texas Bluegrass White Clover	15. Radish Bermudagrass Red Clover
16. Radish Bermudagrass White Clover	17. Centipede AR-G Red Clover	18. Centipede AR-G White Clover
19. Centipede Zoysia Red Clover	20. Centipede Zoysia White Clover	21. Centipede Creeping Red Fescue Red Clover
22. Centipede Creeping Red Fescue White Clover	23. Centipede Tall Fescue Red Clover	24. Centipede Tall Fescue White Clover
25. Centipede Carpetgrass Red Clover	26. Centipede Carpetgrass White Clover	27. Centipede Texas Bluegrass Red Clover
28. Centipede Texas Bluegrass White Clover	29. Centipede Bermudagrass Red Clover	30. Centipede Bermudagrass White Clover
31. AR-G Zoysia Red Clover	32. AR-G Zoysia White Clover	33. AR-G Creeping Red Fescue Red Clover

Table 3 (Continued).

34. AR-G Creeping Red Fescue White Clover	35. AR-G Carpetgrass Red Clover	36. AR-G Carpetgrass White Clover
37. AR-G Texas Bluegrass Red Clover	38. AR-G Texas Bluegrass White Clover	39. AR-G Bermudagrass Red Clover
40. AR-G Bermudagrass White Clover	41. AR-G Tall Fescue Red Clover	42. AR-G Tall Fescue White Clover
43. Zoysia Creeping Red Fescue Red Clover	44. Zoysia Creeping Red Fescue White Clover	45. Zoysia Tall Fescue Red Clover
46. Zoysia Tall Fescue White Clover	47. Zoysia Carpetgrass Red Clover	48. Zoysia Carpetgrass White Clover
49. Zoysia Texas Bluegrass Red Clover	50. Zoysia Texas Bluegrass White Clover	51. Zoysia Bermudagrass Red Clover
52. Zoysia Bermudagrass White Clover	53. Creeping Red Fescue Tall Fescue Red Clover	54. Creeping Red Fescue Tall Fescue White Clover
55. Creeping Red Fescue Carpetgrass Red Clover	56. Creeping Red Fescue Carpetgrass White Clover	57. Creeping Red Fescue Texas Bluegrass Red Clover
58. Creeping Red Fescue Texas Bluegrass White Clover	59. Creeping Red Fescue Bermudagrass Red Clover	60. Creeping Red Fescue Bermudagrass White Clover
61. Tall Fescue Carpetgrass Red Clover	62. Tall Fescue Carpetgrass White Clover	63. Tall Fescue Texas Bluegrass Red Clover
64. Tall Fescue Texas Bluegrass White Clover	65. Tall Fescue Bermudagrass Red Clover	66. Tall Fescue Bermudagrass White Clover
67. Carpetgrass Texas Bluegrass Red Clover	68. Carpetgrass Texas Bluegrass White Clover	69. Carpetgrass Bermudagrass Red Clover

Table 3 (Continued).

70. Carpetgrass Bermudagrass White Clover	71. Texas Bluegrass Bermudagrass Red Clover	72. Texas Bluegrass Bermudagrass White Clover
73. Slope Master ™ (Mohawk Bermudagrass, Sahara Bermudagrass, Durana White Clover, Browtop Millet, Tall Fescue)	74. Bahiagrass	75 .Centipede
76. Tall Fescue	77. Texas Bluegrass	78. Carpetgrass
79. Zoysia	80. Bermudagrass	81. Zoysia (Sod)
82. Centipede (Sod)	83. Bermudagrass (Sod)	84. Bahiagrass Bermudagrass
85. Bahiagrass Bermudagrass Crimson Clover (MDOT Standard)	*86. Brown Top Millet	*87. Brown Top Millet Bermudagrass
*88. Brown Top Millet Tall Fescue	*89. Brown Top Millet Tall Fescue Bermudagrass	*90. Brown Top Millet Carpetgrass

*Denotes 2012 summer planting only.

Fall Planting

For the fall planting, two experiments were conducted at a section along a roadside in the northeast corner of the R.R. Foil Plant Science Research Facility (North Farm) at Mississippi State University in 2011 and 2012. The site was mapped by Web Soil Survey as Savannah (Fine-loamy, siliceous, semiactive, thermic Typic Fragiudults) (USDA National Cooperative Soil Survey, 2012b). The vegetation at the selected areas was sprayed until wet with one application of glyphosate at 3% v/v to ensure elimination of existing vegetation and the plots were tilled using a Blecavator following the kill of vegetation. Soil samples were submitted to Mississippi State University Soil Testing Lab to determine pH and nutrient status. The experimental design was a randomized complete block (RCB) with four replications. Seeding rates for seed treatments were based on PLS data for each species (kg ha^{-1}) and seeds were weighed and placed in brown paper bags in equivalent weights corresponding to plot size (Table 4).

Table 4 Species seeding rates, recommended rates, and pure live seed (PLS) rates (kg ha^{-1}) used for fall roadside planting experiments.

Species	**Recommended Rate (kg ha^{-1})**	**PLS**	**Rate Used (kg ha^{-1})**
Axonopus affinis^{T}	195.1	82.9	235.1
*Cynodon dactylon**^{T}	48.7	18.9	120.1
Eremochloa ophiuroides^{T}	48.7	89.0	59.7
*Festuca arundinacea**^{T}	243.9	95.0	279.7
Festuca rubra^{T}	146.3	91.8	173.3
*Lolium multiflorum**^{P} (Gulf)	48.8	86.1	62.0
*Lolium multiflorum**^{T} (Panterra)	731.8	89.3	819.4
Lolium perenne^{T} (VIP)	731.8	72.0	1016.4
Poa arachnifera^{T}	97.6	48.0	203.3
Raphanus sativus L. var. *oleiferus*^{T}	97.6	98.9	98.6
Slope Master™^{P}	56.0		
Trifolium pretense^{P}	11.2	55.0	19.8
Trifolium repens^{P}	3.4	56.6	6.1
Zoysia japonica^{T}	48.7	84.4	58.1

^{P} Indicates recommended rates based on pasture establishment.
^{T} Indicates recommended rates based on turfgrass establishment.
*Indicates species used MDOT's current seeding mixture.

Species were selected based on suitability for fall planting by determining adaptability of plant growth of temperatures present in the fall, however, some warm season species were included to evaluate the effectiveness of out of season plantings.

Treatments were assigned such that one treatment consisted of three species. Each treatment contained white clover, with the exception of the treatment that contained only tall fescue and white clover and the stand-alone plots (Table 5).

Table 5 Species treatment mixes for fall planting.

1. Radish Centipede White Clover	2. Radish PR White Clover	3. Radish Zoysia White Clover
4. Radish Creeping Red Fescue White Clover	5. Radish Tall Fescue White Clover	6. Radish Carpetgrass White Clover
7. Radish Texas Bluegrass White Clover	8. Radish Bermudagrass White Clover	9. AR-P PR White Clover
10. AR-G Zoysia White Clover	11. AR-G Creeping Red Fescue White Clover	12. AR-G Carpetgrass White Clover
13. AR-G Texas Bluegrass White Clover	14. AR-G Tall Fescue White Clover	15. AR-P Creeping Red Fescue White Clover
16. Tall Fescue White Clover	17. AR-P Zoysia White Clover	18. Creeping Red Fescue Carpetgrass White Clover
19. Creeping Red Fescue Texas Bluegrass White Clover	20. Creeping Red Fescue Zoysia White Clover	21. Tall Fescue Texas Bluegrass White Clover
22. Tall Fescue Bermudagrass Red Clover	23. Tall Fescue Bermudagrass White Clover	24. Texas Bluegrass Bermudagrass White Clover
25. Slope Master ™ (Mohawk Bermudagrass, Sahara Bermudagrass, Durana White Clover, Browtop Millet, Tall Fescue)	26. Tall Fescue	27. Texas Bluegrass
28. Creeping Red Fescue		

In addition, Pennington's Slopemaster® product was also evaluated. Experiments were planted on November 1, 2011 and October 5, 2012. Plot areas were fertilized with 48.8 kg ha^{-1} of 13-13-13 on November 2, 2011 and October 5, 2012; respectively.

Hydro-mulching Experiment

A hydroseeding/hydromulching experiment was performed to evaluated use on roadsides in determining its effectiveness in relation to time of establishment and germination. The experimental site was located in the northwest corner of the R.R. Foil Plant Science Research Facility (North Farm) at Mississippi State University. According to Web Soil Survey, the experimental area was mapped a Leeper (Fine, smectitic, nonacid, thermic Vertic Epiaquepts) (USDA National Cooperative Soil Survey, 2012a). Twelve different mulch products were evaluated along with a control plot that consisted of a bare soil with no mulch (Table 6). A blend of bermudagrass, (*Cynodon dactylon* (L.) Pers., 22.7 kg ha^{-1}), crimson clover (*Trifolium incarnatum* L., 22.7 kg ha^{-1}) and tall fescue, (*Festuca arundinacea* Schreb., 28.4 kg ha^{-1}) were weighed and placed in number 2 brown paper bags (Table 7).

Table 6 Mulch treatments evaluated. Rates used based on manufacturers recommendations.

Mulch	Rate (kg ha^{-1})
Control (No Mulch)	
Hydrostraw™ All-Purpose Straw	2,270
Hydrostraw™ Original	3,470
FINN TRU-Blend	2,310
FINN TRU-Max	3,470
FINN TRU-Bond BFM	3,470
FINN TRU-Blend with Hydrostick	2,310
Flexterra-FGM	3,470
Coco Flex	3,470
FINN TRU-Wood	2,310
Hydrostraw™ BFM	3,470
Terra Mulch Cellulose	2,890
Hydrostraw™ Guar Plus	3,470

Table 7 MDOT Standard fall seeding mix of seed species, cultivar, and rates used for hydro-mulching experiment (kg ha^{-1}).

Species	**Cultivar**	**Recommended Rate (kg ha^{-1})**	**PLS**	**Rate Used (kg ha^{-1})**
Cynodon dactylon (L.) Pers.	Common	22.7	18.9	120.1
Trifolium incarnatum L.	Common	22.7	98.0	23.1
Festuca arundinacea Schreb.	Kentucky-31	28.4	80.7	405.0

The experimental design was a randomized complete block, replicated four times. Plot size was 3.65 x 3.65 m. The hydroseeder was calibrated by timing the volume of material that was sprayed over a set amount of time. Seed and mulch were placed in the hydroseeder at each of their proper rates, agitated, and then sprayed on appropriate plots using a FINN T 60 hydroseeder. Hydrostraw™ All-purpose Straw was hand applied at a rate of 2273 kg ha^{-1} (MDOT's standard mulch rate). Soil samples were submitted to the MSU Soil Testing Lab and plots were fertilized by a push cyclone spreader at a rate of 48.8 kg N ha^{-1} of 13-13-13 and seeded on September 26-30, 2011. Evaluation consisted of effectiveness for establishment and germination.

Data Collection & Analysis

The plots for both summer and fall plantings were observed every seven days after planting for four weeks or until 100 percent cover had been achieved. Initial days to germination were documented and percent cover was visually estimated after germination for summer plantings only. In addition to visual estimation, digital imagery was also used to evaluate percent cover for both summer and fall plantings and was performed weekly for the first four weeks after planting and then monthly until 100 percent of cover was achieved. Images were taken with a Nikon® D90 camera placed in 61 x 51 x 61 cm lightbox and analyzed by using SigmaScan Pro 5 to measure the green pixels in each digital photograph and calculating a percentage of cover in the photograph (Booth et al., 2006; Richardson et al., 2001) (Figure 1). The lightbox, powered by an electric generator, was placed in an area of each plot that showed a representative sample of cover present (Figure 2). Time-domain reflectometry (Field Scout ™ TDR 300 Soil Moisture Meter, Spectrum Technologies Plainfield, Illinois) with 10.16 cm probes was used to determine soil volumetric water content (VWC) by taking three readings per plot (upper slope, middle, and lower slope). Plant height (cm) for both summer and fall plantings were documented by measuring from the base to the tip of the tallest and most dominant plant species present from each plot and recorded after initial 30-day period. The GLM procedure was used (SAS Version 9.2, SAS Institute, Cary, NC) to evaluate percent cover provided by different treatments/mixes at different time intervals, days after planting (DAP), and the means were separated using Fisher's least significant difference (LSD) procedure with a significance level of 0.05. This data allowed us to determine what species mixes were effective in rapid establishment and cover.

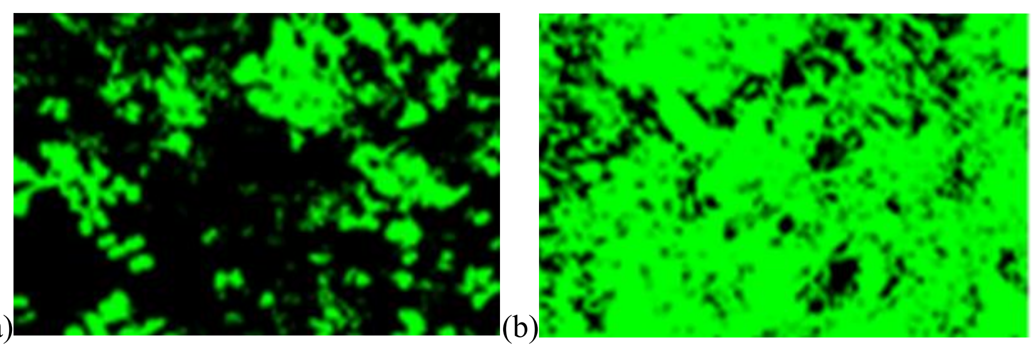
(a) (b)


Figure 1 SigmaScan Pro 5 cover analysis

(a) SigmaScan Pro 5 cover at 25.2 % (R-AR-P-WC).
(b) SigmaScan Pro 5 cover at 80% (R-AR-P-WC).

Figure 2 The lightbox that was used to analyze vegetative cover.

Desired plant species and weed composition was observed and documented throughout the initial 30-day period after planting and after this period had elapsed, only the weed species that were not documented in the initial 30 days were recorded. After 30 days had elapsed visual ratings and digital image analysis were performed once a month to determine if any noticeable changes in cover were present. Fall 2012 planting differed only from the previous year planting by evaluating 'Falcon V' tall fescue in substitution for 'Faith' tall fescue.

For only the fall plantings, deer activity was monitored and visually rated on a scale of 1-5 with 1 being minimal to no activity and 5 being most/substantial amount of activity (Table 8). Ratings were based on appearance of grazing and traffic by deer within each plot.

Table 8 Deer activity ratings for deer activity along roadsides for fall 2011 and 2012 studies.

Rating	Description
1	Minimal or no activity from grazing/grazing damage and/or foot traffic (less than 10% damage)
2	Slight activity from grazing/grazing damage and/or foot traffic (greater than 10%)
3	Moderate activity from grazing/grazing damage and/or foot traffic (greater than 50%)
4	Heavy activity from grazing/grazing damage and/or foot traffic (greater than 75%)
5	Extreme activity from grazing/grazing damage and/or foot traffic (greater than 90% damage)

CHAPTER IV

RESULTS & DISCUSSIONS

2011

Germination Chambers

In the optimum conditions of the germination chambers, most species germinated very well (Tables 8 & 9). The germination tests showed that oilseed radish seeds had completely germinated in 42 hours. This is consistent with the findings of Ngouajio et al. (2004). No other species exhibited vigorous germination similar to that of oilseed radish. No seed of any species germinated between 14 and 21 days, thus data are not shown. At the seven and 14 days counting interval for both the 25/15 and 30/20°C temperature regimes as well as the seven day count for the 35/25°C regime oilseed radish had significantly higher germination than all other species. At 14 days, oilseed radish, centipedegrass, and AR-G had significantly more germination than any other species. During the first year, red clover and white clover also germinated well at 25/15 & 30/20°C at seven and after 14 days which is consistent with optimal planting temperatures for these species (USDA, 2002e). Tall fescue did not perform as expected, which may have been due to a seed quality issue. Neither little bluestem nor seashore paspalum were rapid germinators either.

In 2012, additional species were added that were known to have rapid germination. Oilseed radish, as in the first year, germinated extremely quickly, completely germinating after 46 hours (Tables 10 & 11). After seven days at 25/15°C, oilseed radish, AR-G, AR-P, PR, red clover, and carpetgrass had significantly more germination than all other species. At 25/15°C after 14 days oilseed radish, AR-G, AR-P, PR, centipedegrass, red clover, carpetgrass, and tall fescue had significantly more germination than any other species. The 30/20°C temperature regime at seven days revealed a significantly higher germination percentage for oilseed radish, AR-G, AR-P, PR, and red clover and after 14 days creeping red fescue and white clover joined this group. At 35/25°C after seven days oilseed radish, AR-G, red clover, and centipedegrass had higher germination than other species, and after 14 days PR, along with the aforementioned species, had more germination than the other species. The rapid germination of the ryegrasses are consistent with the findings of Booze-Daniels et al. (2000).

Table 9 Germination of species after 7 days (d) at 25/15, 30/20, and 35/15°C for 2011.

Species	**Cultivar**	**Germination Chamber Temperature (°C)**		
		25/15	30/20	35/25
		% Germination		
Oilseed Radish	Common	100 a	100 a	100 a
Red Clover	Bulldog Red	90.0 b	86.0 b	67.3 b
Annual Ryegrass	Gulf	87.3 b	60.0 d	89.3 a
White Clover	Durana	79.3 c	77.3 c	45.3 c
Little Bluestem	Cimarrom	11.3 d	8.6 f	18.0 e
Carpetgrass	Common	0 e	0.6 g	0.0
Tall Fescue	Faith	0 e	0 g	15.3 e
Creeping Red Fescue	Common	0 e	0 g	24.6 d e
Zoysia	Zenith	0 e	0.6 g	30.0 d
Centipedegrass	TifBlair	0 e	46.0 e	91.3 a
Seashore Paspalam	Sea Spray	0 e	0 g	19.3 de

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

Table 10 Germination of species after 14 days (d) at 25/15, 30/20, and 35/25°C for 2011.

Species	Cultivar	Germination Chamber Temperature (°C)		
		25/15	30/20	35/25
		% Germination		
Oilseed Radish	Common	100 a	100 a	100 a
Red Clover	Bulldog Red	90.0 b	86.0 b	67.3 b
Annual Ryegrass	Gulf	87.3 b	60.0 d	89.3 a
White Clover	Durana	79.3 c	77.3 c	45.3 c
Little Bluestem	Cimarron	11.3 d	8.6 e	18.0 e
Carpetgrass	Common	0 e	0.6 f	0.0 f
Tall Fescue	Faith	0 e	0 f	15.3 e
Creeping Red Fescue	Common	0 e	0 f	24.6 de
Zoysia	Zenith	0 e	0.6 f	30.0 d
Centipedegrass	TifBlair	0 e	78.0 c	91.3 a
Seashore Paspalam	Sea Spray	0 e	0 f	19.3

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

Table 11 Germination of species after 7 days (d) at 25/15, 30/20, and 35/25°C for 2012.

Species	Cultivar	Germination Chamber Temperature (°C)		
		25/15	30/20	35/25
		% Germination		
Oilseed Radish	Common	100.0 a	100 a	100 a
Annual Ryegrass	Gulf	98.7 a	100 a	92.0 a
Annual Ryegrass	Panterra	97.3 ab	100 a	72.0 bc
Perennial Ryegrass	V.I.P.	96.7 ab	100 a	72.0 bc
Red Clover	Bulldog Red	83.3 abc	88.0 ab	84.0 ab
Carpetgrass	Common	82.0 abc	66.7 c	62.6 cd
Tall Fescue	Faith	68.0 bcd	48.6 d	5.3 e
Creeping Red Fescue	Common	58.0 cd	72.0 bc	0 e
White Clover	Durana	48.8 de	76.6 bc	13.3 e
Zoysia	Zenith	26.6 ef	8.6 e	48.7 d
Centipedegrass	TifBlair	23.3 ef	36.0 d	85.3 ab
Texas Bluegrass	Reveille	4.0 f	5.3 e	0 e

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$

Table 12 Germination of species after 14 days (d) at 25/15, 30/20, and 35/15°C for 2012.

Species	Cultivar	Germination Chamber Temperature (°C)		
		25/15	30/20	35/25
		% Germination		
Oilseed Radish	Common	100 a	100 a	100 a
Annual Ryegrass	Gulf	99.3 a	100 a	95.3 ab
Annual Ryegrass	Panterra	98.6 a	100 a	76.0 bc
Perennial Ryegrass	V.I.P.	96.6 a	100 a	78.0 abc
Red Clover	Bulldog Red	83.3 abc	88.0 ab	88.6 abc
Carpetgrass	Common	91.3 ab	68.6 bcd	67.3 c
Tall Fescue	Faith	85.3 abc	62.0 cd	24.0 d
Creeping Red Fescue	Common	66.7 bcd	85.3 ab	15.3 ed
White Clover	Durana	50.2 de	77.3 abc	36.6 d
Zoysia	Zenith	56.6 cd	11.3 e	72.0 c
Centipedegrass	TifBlair	87.3 ab	47.3 d	96.6 ab
Texas Bluegrass	Reveille	26 e	12.6 e	0 e

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

From the data recorded, I noticed that most germination occurred within the first 14 days under ideal conditions; these conditions however, are not always present in field situations (Dudeck et al., 1970). Little bluestem; being a native grass, should not be used for rapid vegetation establishment because of its slow germination and inability to vie with other competitive species for successful establishment (Robocker et al., 1953). Oilseed radish shows promise because of its short germination time throughout a range of temperatures (Ngouajio and Mutch, 2004.) The ryegrasses as shown in this experiment are better suited and shown to be beneficial for establishment during roadside vegetation because of their rapid germination (Booze-Daniels et al., 2000). Tall fescue did not perform well in the higher temperatures, which is evidence that tall fescue should not be planted when soil temperatures are 30°C or higher, as they are in the summer months (Beard, 1973; Booze-Daniels, 2000).

Field Experiment
Summer Plantings

2011

Weather

The summers in Mississippi are typically hot and can become extremely dry, which was the case in 2011 (Table 13). First rainfall after planting was timely; however, subsequent rainfall was not consistent (Figure 3). High volumes of rainfall during short periods coupled with long periods of no rainfall did not seem to aid in establishment. More detailed graphs and figures are located in Appendix A and Appendix B

Table 13 Summary of precipitation (mm) data during the summer planting of 2011.

Month	Mean Annual Rainfall (mm)	2011 Rainfall (mm)
June	105.6	107.7
July	107.9	108.0
August	87.1	57.4

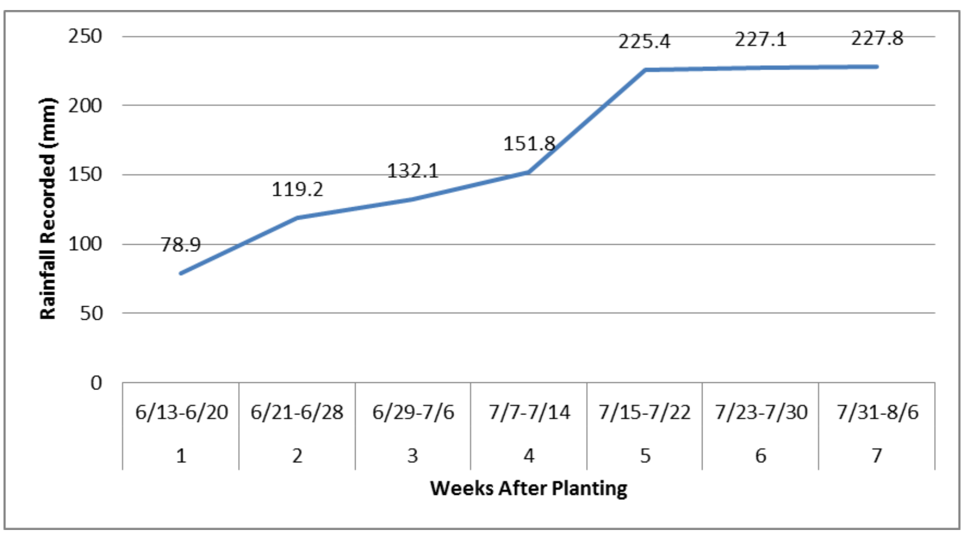


Figure 3 Rainfall recorded seven weeks after planting during summer 2011.

Soil Fertility

Prior to planting, soil fertility levels were evaluated. The experimental site for 2011 was an established roadside and likely was fertilized during establishment as fertility levels were adequate. According to Mississippi State University Soil Testing Lab, lime was only found to be needed in replication three, at the rate of 5,668 kg ha^{-1}. Phosphorus levels ranged from medium to high while potassium levels ranged from high to very high. These recommendations also recommended applying 91 kg ha^{-1} of actual nitrogen and 45 kg ha^{-1} P_2O_5 per year for three consecutive years. There was no recommendation for potassium due to the fact that levels were high (Table 14).

Table 14 Soil test results for the summer 2011 planting.

Replication	pH	P kg ha^{-1}	K kg ha^{-1}
1	7.5	55.6	394.3
2	7.1	104.5	407.9
3	5.3	59.0	357.9
4	7.6	73.8	431.8
Mean	6.9	73.2	398.0
Std Dev	1.1	22.3	30.9

Establishment

Soils at the experimental areas were tilled well and were favorable for establishment and timely rainfall aided germination. The experimental sites recorded a total of 78.9 mm seven days after planting and an additional 40.3 mm total rainfall was recorded between eight and 14 days after planting. Oilseed radish germinated five days after planting and three days after the first rain event. Brown-top millet contained in Pennington's Slope Master™ product germinated six days after planting and four days after first rain event. Undesired species also germinated along with oilseed radish, three days after the first rain event. Bermudagrass and bahiagrass started to emerge sixteen days after planting. Slower germinating warm-season grasses (zoysiagrass, centipedegrass, and carpetgrass) did not appear within the first month of seeding. Only 30.9 mm of rain was recorded from 15-30 days after planting, totaling 150.1 mm during the 30-day period that was being evaluated (Figure 1).

Cover

Intense weed pressure was encountered and the analysis of the first summer data was confounded by these weeds and somewhat inconclusive. The only treatments that were identifiable were the sod treatments and ones that contained oilseed radish. All other treatments were indistinguishable because of weed pressure. The majority of weeds present were: knotroot foxtail (*Setaria parviflora*), pitted morning glory (*Ipomoea lacunose*), johnsongrass (*Sorghum halepense*), spotted spurge (*Euphorbia maculate*), ragweed (*Ambrosia artemisiifolia*), and wooly croaton (*Croton capitatus*).

Data was taken 15 days after of germination, 17 days after the first rain event, which was 22 days after planting. Heavy weed pressure and lack of desired species in each plot led to cover data not being analyzed beyond 22 days after planting. Sod treatments provided instant plot and vegetative cover, which when statistically analyzed, were consistent with expected outcomes except that of zoysiagrass sod. The digital analysis for the zoysiagrass sod treatments did not account for brown vegetation that was present at the time of ratings, rendering a less that 70% cover rating. I believe the brown vegetation on sod plots were a result of portions of sod that did not establish well during placement and watering. All cover data present except that of oilseed radish was weed cover. Inability to detect desired species within weed species led to treatment data being analyzed based on cover ratings for the mean of all oilseed radish plots and stand-alone plots (which were all weeds) within each replication (treatments 74-80) (Table 3).

The digital image analysis data for cover and establishment did not show differences among treatments. This non-significance is not consistent with expected outcomes based on species included in the mixtures. The ratings are confounded by cover provided by weed species (Figure 4). Data for all treatments can be examined in Appendix C and D.

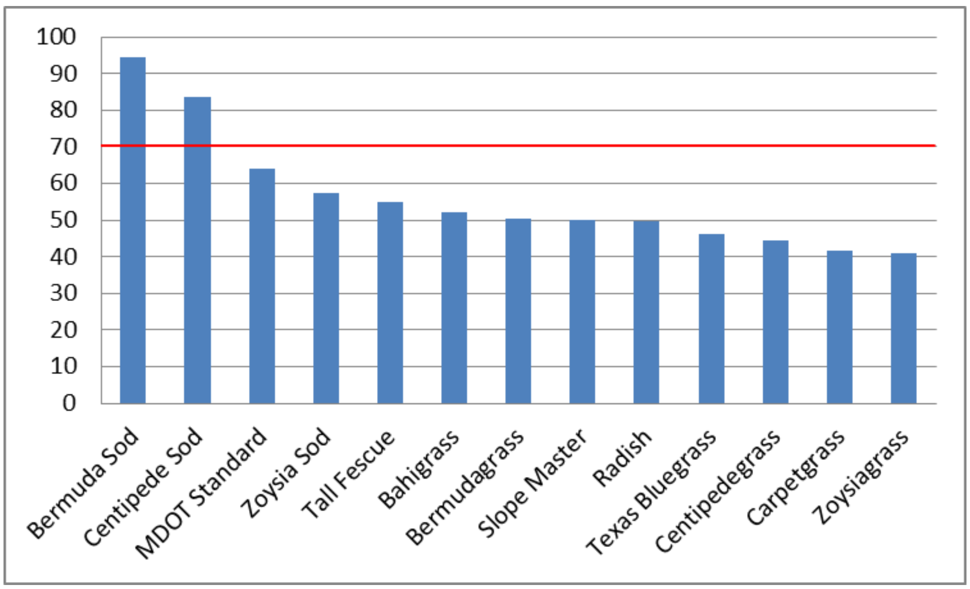


Figure 4 Cover data 22 days after planting for summer 2011.

In all replications, oilseed radish provided shortest time to establishment and the most rapid significant cover. Because of its rapid establishment and large amounts of cover provided, oilseed radish protects the soil from potential erosion hazards (Ngouajio et al., 2004). Most mixes that contained oilseed radish achieved 70% cover in 30 days.

Bermudagrass, bahiagrass, and the brown-top millet contained in Pennington's Slope Master product established well, but did not provide enough cover for the required 70% in 30 days. I believe that the high rate of fertilizer at the time of establishment aided in the rapid establishment of weed species; therefore, increasing the amount of competition for the desired species (Beard, 1973).

One year later, there were few desired species remaining other than the sod treatments, and small amounts of white clover. Compared to other desired species planted, there was substantially more bahiagrass present. Only a few radish treatments were identifiable by plant material. In plots where oilseed radish were planted one year prior, different weed composition and weed heights were observed. In plots that contained oilseed radish, knotroot foxtail and johnsongrass were still present the following year, but knotroot foxtail was less dense and johnsongrass was shorter in stature than plots that did not contain oilseed radish. I believe that the rapid establishment and quick cover provided by oilseed radish; suppressed desirable and weed species during establishment and weed occurrence the following year (Ngouajio et al., 2004). Pennington's Slope Master™ also performed poorly. Only the brown-top millet contained in the product was identifiable.

Throughout this study, there seemed to be little relationship between volumetric water content (VWC) measured in the field and germination of desired plant species. On certain occasions, the TDR would display readings higher than 100% in areas of standing water and readings slightly lower than 100% in areas without standing water. Additionally, there were also inconsistencies with moisture statuses and vegetation present. The summer of 2011 data showed that the second replication consistently had higher VWC than any other site. However, contrary to the expected outcome, replication two had the least amount of vegetation. The opposite was also true for replication three. Volumetric water content was the lowest in replication three, but germination was identified first in those plots, and had the highest amount of desired species present. Due to the inconsistencies with the TDR regarding moisture and germination, no conclusions could be made concerning VWC and germination.

2012

Weather

In contrast to the 2011 field experiment, early rainfall amounts in 2012 were much lower and did not occur in a timely fashion (Table 15). The first rain event did not occur until 17 days after planting. This severely delayed germination. Further, the reoccurrence and accumulation of rainfall in a short amount of time allowed for cool-season species to start germination, but faltered under high summer temperatures. More information about rainfall and temperature can be seen in Appendix A and Appendix B.

Table 15 Summary of precipitation (mm) data during the summer planting of 2012.

Month	Mean Annual Rainfall (mm)	2012 Rainfall (mm)
June	123.4	75.9
July	107.7	107.4
August	102.1	108.9

Soil Fertility

Soil fertility conditions for 2012 did not show extreme differences from that of 2011 (Table 16). Since the experimental site was a newly constructed roadside, sulfur levels were extremely low because little organic matter was present. No lime was needed on any replication and phosphorous levels ranged from medium to high while all potassium levels were high. According to Mississippi State University Soil Testing Lab, only 45 kg ha^{-1} of P_2O_5 was recommended to replications three and four for three consecutive years.

Recommendations also indicated the application of 91 kg ha^{-1} actual nitrogen for three consecutive years. Compared to the recommendations from the MSU Soil Testing Lab the 1,136 kg ha^{-1} of 13-13-13 of fertilizer MDOT specifies is excessive. Phosphorous and potassium for these sites were not needed and actual nitrogen applied was 62% more than what was specified. I believe that the correct interpretation of soil tests and proper blend of fertilizers would aid in improved establishment of roadside vegetation and decrease cost associated with roadside establishment. I can conclude that reducing fertilizer applications would also aid in combating non-point source pollution.

Table 16 Soil test results for the experimental site for 2012 planting.

Replication	pH	P kg ha^{-1}	K kg ha^{-1}
1	7.8	87.5	247.7
2	7.7	93.1	268.1
3	7.4	47.7	259.0
4	7.5	67.0	284.0
Mean	7.6	73.8	264.7
Std Dev	0.2	17.9	13.3

Establishment

The first rain event did not occur until 7/6/12, seventeen days after planting (Figure 5). Between 17 and 30 days after planting, 75.7 mm rain fell. Sod treatments provided instant cover and establishment as expected. Oilseed radish was the quickest species to germinate, with first signs of germination being shown nineteen days after planting, two days after the first rain event. Brown-top millet, AR-G, and PR all started to germinate twenty days after planting, three days after the first rain event. The ryegrasses AR-G and PR germinated quickly, but soon succumbed to the extreme heat conditions. Bahiagrass, bermudagrass, centipedegrass, zoysiagrass, and white clover germinated, but did not establish well within the first month.

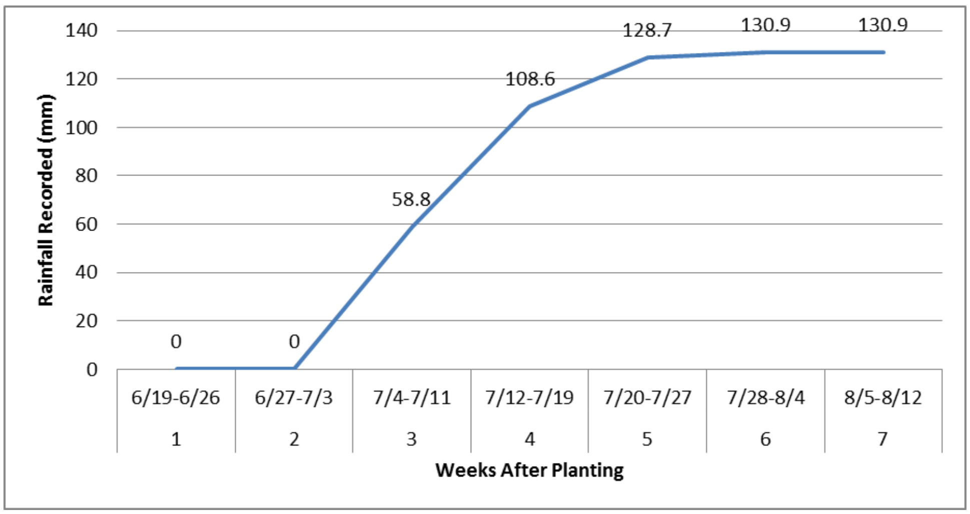


Figure 5 Rainfall recorded seven weeks after planting during summer 2012.

Cover

First cover ratings were taken 28 days after planting. At that time, five radish treatments had achieved 70% cover based on digital imaging. Differences were observed among treatment mixes at 28, 35, 42, & 56 days after planting (Appendix E-J). At 35 days after planting, thirteen of the sixteen treatments that contained oilseed radish had achieved 70% cover based on digital imaging. When visual ratings were analyzed, all oilseed radish plots achieved 70% cover at 35 days after planting. At 42 days after planting, three of six treatments containing brown-top millet achieved 70% cover. Pennington's Slope Master reached 35.92% cover 56 days after planting. Bermudagrass plots started to achieve substantial cover 42 days after planting which was 30 days after the first rain. Oilseed radish cover was negatively affected at 56 days after planting because of dying back and yellowing of foliage that could not be detected in digital image analysis.

The wheat straw mulch applied was beneficial, but contained a large amount of viable wheat seeds that infested plots. Wheat cover was insignificant in terms of providing additional cover to oilseed radish and brown-top millet plots because of competition. Wheat negatively affected bermudagrass and bahiagrass cover initially, but was not a factor in bahiagrass plots 60 days after germination. I anticipated that the wheat would succumb to the heat of the Mississippi summer, but it persisted until the study was completed. It was observed that wheat straw aided in germination of bahiagrass and bermudagrass (Booze-Daniels et al., 2000).

In preliminary discussions, one main concern was the height of plant species. There was a significant difference in plant height among treatment mixes with brown-top millet being the tallest of all desired plant species across all treatment mixes (Table 17). Means for height in oilseed radish ranged from 11.4-17.7 cm. All sod treatments were shorter than the seed plots and bermudagrass was shortest sod treatment. Seeded bermudagrass did not germinate or establish well and I believe poor seed led to poor performance and did not render any height data. Upon further observations after the mandated 30 days, centipedegrass appeared to suppress more weeds that the other sod species which is attributed to its allelopathic ability (Johnson, 1998)

Table 17 Plant height (cm) measured 42 days after planting for 2012.

Treatment	Height (cm)
Brown-top Millet & Bermudagrass	43.8 a
Brown-top Millet	41.9 a
Brown-top Millet & Tall Fescue	40.6 a
Brown-top Millet & Carpetgrass	40.0 a
Brown-top Millet, Tall Fescue, Bermudagrass	31.8 b
Pennington's Slope Master	31.8 b
Oilseed Radish	15.8 cd
Bahiagrass (Stand-Alone)	11.4 def
Centipedegrass (Sod)	8.9 defg
Zoysiagrass (Sod)	8.6 efg
Bermudagrass (Sod)	4.1 g
LSD (0.05)	6.8

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

Fall Plantings

2011

Establishment

Rainfall was extremely favorable and weed pressure was less intense for the fall plantings. In 2011, the study area received 4.8 mm of rainfall two days after planting and sixteen days after planting a total of 21 mm of rain had been recorded. A total of 62.2 mm of rainfall occurred during the first 30 days after planting. The rainfall recorded occurred at essential times in relation to germination and establishment (Figure 6) (Appendix B). Oilseed radish, PR, AR-G, and AR-P began to germinate six days after planting. The oilseed radish and ryegrass mix as well as oilseed radish and tall fescue performed well and neither species seemed to inhibit the growth of the other.

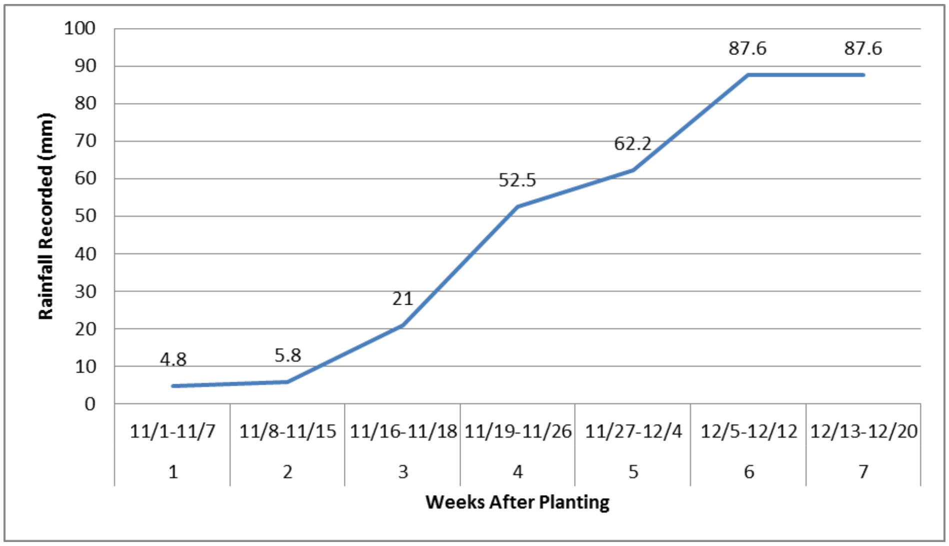


Figure 6 Rainfall recorded for seven weeks after planting during fall 2011.

Cover

At 30 days after planting, no treatment achieved 70 % cover. However, the mixture of oilseed radish, PR, and white clover (R-PR-WC) came very close with 68.3% (Figure 5). At 37 days after planting, three treatments achieved 70% cover (Figure 7) (Appendix K). Treatments R-PR-WC, AR-P- PR-WC, and AR-P- zoysiagrass-WC (AR-P-ZG-WC) achieved 80%, 85.4 %, 71.4% cover; respectively. At 44 days after planting, R-PR-WC (84.7%), AR-P-PR-WC (79.1%), AR-P-ZG-WC (83.4%) & AR-P-creeping red fescue, and WC (AR-P-CRF-WC) (80%) all achieved 70% cover. In the experiment, Inoticed that weed pressure encountered in the fall was less intense than the summer. This coincides with results found by Beard (1973). The majority of weeds present were Carolina geranium (*Geranium carolinianum* L.) and henbit (*Lamium amplexicaule* L.), but were insignificant in cover ratings. White and red clovers did not germinate nor exhibit vigorous growth as quickly as other species, but began to contribute to total cover

90 days after planting. It was also observed that no additional benefit was provided by red clover in comparison to white clover regarding cover. With data from the summer and fall plantings, white clover appears best suited for fall plantings when there are lower temperatures, with optimum temperatures ranging from 18°C-30°C and when wetter conditions are present (Brady, 1986). Oilseed radish foliage started to decrease five months after planting because of flowering and began the process to set seed. Plots containing tall fescue did not achieve 70% cover until 12 weeks after planting. At 172 days after planting, mean height of tall fescue was the shortest of all species that provided substantial cover (10.46 cm) (Table 18). During the fall planting, it was observed that no warm-season species added to establishment.

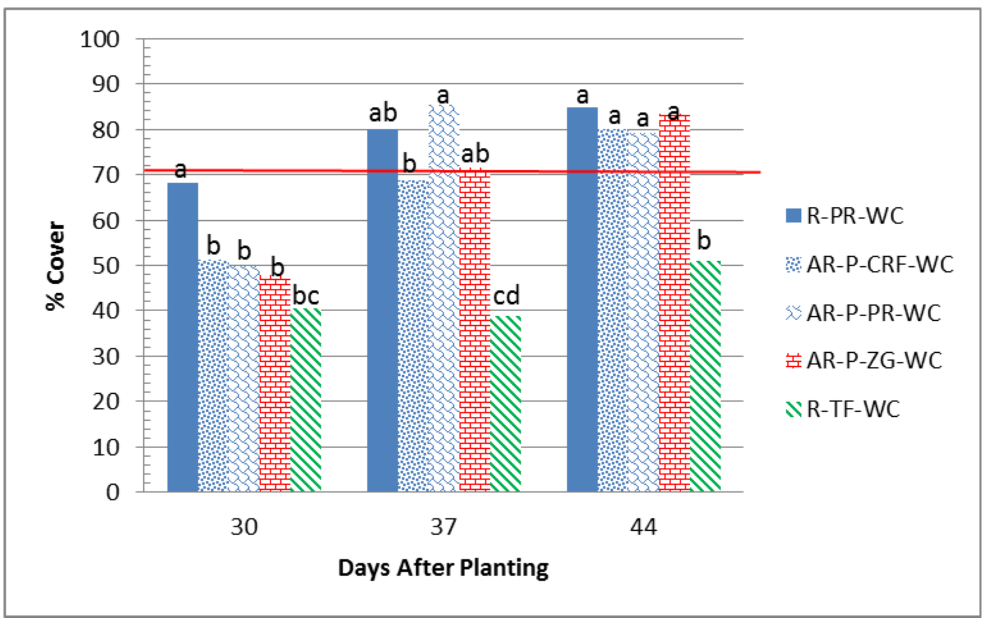


Figure 7 Percent cover for selected or high cover treatments 30, 37, & 44 days after planting.

Table 18 Plant height (cm) of all treatments for fall 2011 planting 172 days after planting (May 2012).

Treatment	Height (cm)
Radish[M], Bermudagrass, White Clover	50.1 a
Radish, AR-P[M], White Clover	47.6 a
Radish[M], Carpetgrass, White Clover	45.0 a
Radish[M], Centipede, White Clover	43.1 ab
Radish[M], Texas Bluegrass, White Clover	41.2 abc
Radish, Tall Fescue, White Clover	33.6 bcd
Radish[M], Creeping Red Fescue, White Clover	32.2 cd
AR-G[M], Tall Fescue, White Clover	30.4 d
AR-G[M], Carpetgrass, White Clover	30.4 d
AR-G[M], Zoysia, White Clover	29.2 d
AR-G[M], Creeping Red Fescue, White Clover	27.9 d
AR-G[M], Texas Bluegrass, White Clover	27.3 d
AR-P[M], PR , White Clover	8.2 ef
Slope Master®	8.2 ef
Creeping Red Fescue[M], Carpetgrass, White Clover	8.2 ef
AR-P[M], Zoysia, White Clover	8.2 ef
Texas Bluegrass[M], Bermudagrass, White Clover	8.1 ef
Creeping Red Fescue[M], Texas Bluegrass, White Clover	6.9 ef
Creeping Red Fescue[M]	6.3 ef
Creeping Red Fescue[M], Zoysia, White Clover	6.3 ef
Tall Fescue[M], Bermudagrass, White Clover	5.7 ef
Tall Fescue[M], Texas Bluegrass, White Clover	4.2 ef
Tall Fescue	4.1 ef
Tall Fescue[M], White Clover	4.1 ef
Texas Bluegrass	2.2 ef

[M] Indicates tallest species that was measured.
*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

Deer Activity

Another objective in addition to evaluating species/treatment mixes was to determine deer activity associated with each treatment. Deer activity, in regard to this study, consists of evidence or non-evidence of grazing, amount of deer traffic or non-traffic, and also intensity of grazing pressure if evidence of grazing was present. It appeared that damage/grazing done to each plot were consistent with plots that received heavy traffic. Plots were examined for number of tracks present, percentage of vegetation trampled, and amount of vegetation grazed. After inspection, it appeared that grazing was not a continuing event. A significant difference was noted in treatment mixes with respect to deer activity and there was a significant difference in treatments containing oilseed radish and other cool season grass blends of PR and AR-P.

On plots that were grazed heavily with treatments that contained oilseed radish, deer did not graze oilseed radish. Least square means performed on treatments revealed the highest activity (3.5) being on the AR-P-PR-WC; AR-G-TF-WC; and AR-P-CRF-WC treatment mixtures (Table 19). At the time grazing ratings were performed, clover establishment was not substantial; therefore, no grazing was noted on clover.

Table 19 Means of deer activity of notable species mixes (taken December 15, 2011).

Treatment	Deer Activity
AR-P, PR, White Clover	3.5 a
AR-G, Tall Fescue, White Clover	3.5 a
AR-P, Creeping Red Fescue, White Clover	3.5 a
AR-P, Zoysiagrass, White Clover	3.3 ab
AR-G Creeping Red Fescue, White Cover	3.3 ab
Tall Fescue, Bermudagrass, Red Clover	3.0 abc
AR-G, Carpetgrass, White Clover	3.0 abc
Radish, PR, White Clover	3.0 abc
AR-G, Texas Bluegrass, White Clover	2.8 bcd
Tall Fescue, White Clover	2.8 bcd
Creeping Red Fescue, Texas Bluegrass, White Clover	2.8 bcd
AR-G, Zoysia, White Clover	2.8 bcd
Tall Fescue, Texas Bluegrass, White Clover	2.8 bcde
Creeping Red Fescue, Carpetgrass, White Clover	2.5 cde
Tall Fescue, Bermudagrass, White Clover	2.5 cde
Tall Fescue	2.5 cde
Creeping Red Fescue, Zoysia, White Clover	2.3 de
Radish, Bermudagrass, White Clover	2.3 de
Creeping Red Fescue	2.3 de
Radish, Centipede, White Clover	2.3 de
Radish, Zoysia, White Clover	2.0 e
Radish, Tall Fescue, White Clover	2.0 e
Radish, Texas Bluegrass, White Clover	2.0 e
Texas Bluegrass, Bermudagrass, White Clover	2.0 e
Slope Master	2.0 e
Radish, Carpetgrass, White Clover	2.0 e
Texas Bluegrass	2.0 e
Radish, Creeping Red Fescue, White Clover	2.0 e

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

2012

Establishment

Similar to the 2011 fall planting, the experimental site in 2012 received timely and adequate rainfall (Figure 8) (Appendix B). Weed pressure was extremely low during establishment. The first seven days after planting 0.8 mm of rain fell and a total of 89 mm was recorded. This timely rainfall proved beneficial in germination of oilseed radish, PR, and AR-P; all of which started germination within five days after planting (Appendix B). As in the previous year planting, oilseed radish and PR height stayed relativity low. 'Falcon V' tall fescue had similar germination to 'Faith', but established faster. Also similar to the previous year, no warm-season grasses that were planted germinated. I can conclude from this, planting warm-season grasses out of season is not beneficial. This also coincides with results obtained by Beard (1973) showing planting out of season species is not beneficial in establishment.

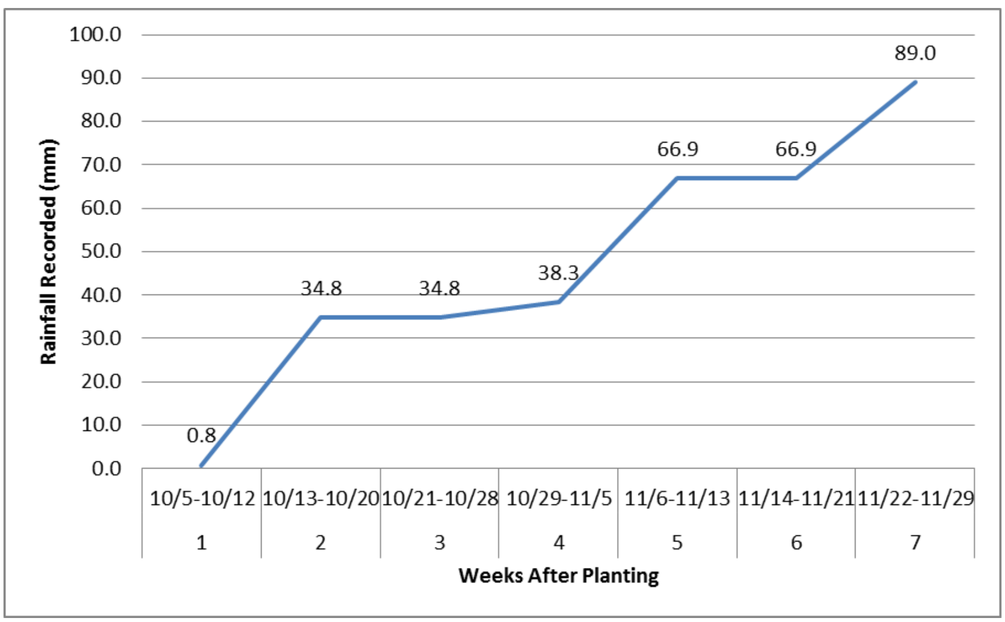


Figure 8 Rainfall recorded for seven weeks during fall 2012.

Cover

The first ratings were taken 30 days after planting. At this time, although significant establishment had been achieved, no treatment reached 70% cover. The AR-P and PR mixture (66%) achieved the highest cover rating (Figure 9) (Appendix L). Oilseed radish, as in the previous year, did not inhibit the growth of perennial ryegrass when included in mixtures together and at 30 days after planting achieved 62% cover. At 37 days after planting, only two treatments reached 70% cover, the AR-P-PR-WC mixture (91%) and AR-P-ZG-WC (72%) (Appendix H). ‘Falcon V’ tall fescue did not provide rapid cover; however, it did establish faster than ‘Faith’ and I believe it would be beneficial for roadside plantings in Mississippi because of its reported heat tolerance and ability to persist through summers. I believe that because of larger foliage provided by oilseed radish, planting this species, along with a grass species, would be better suited in areas of steeper slopes than plantings of grass species alone (Ngouajio, et al., 2004).

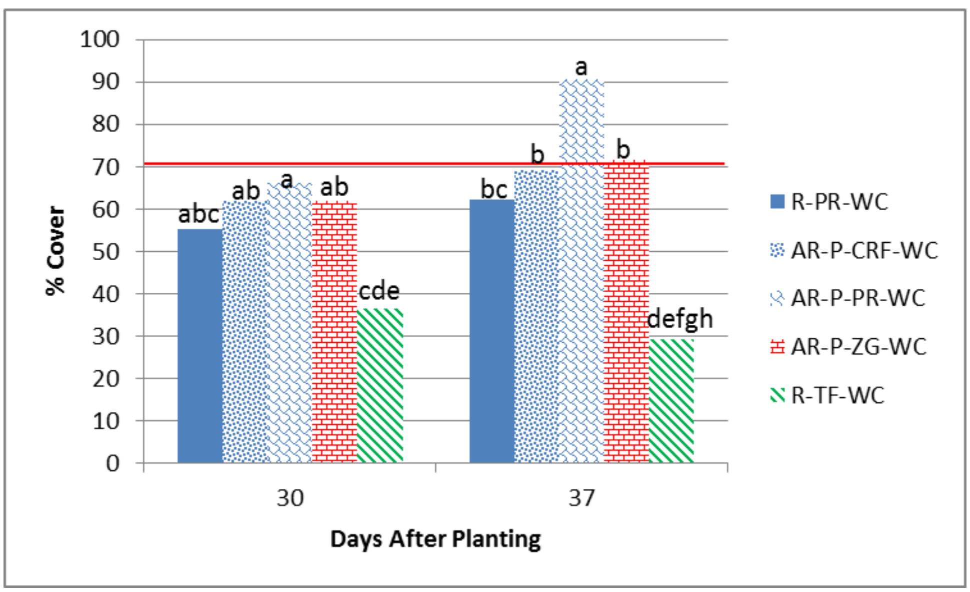


Figure 9 Percent cover for notable treatments 30 & 37 days after planting.

Deer Activity

Deer activity was not monitored nor recorded in the fall of 2012. I believe because of Tennessee Valley Authority (TVA) establishment of new power lines, deer habitat was destroyed and therefore no grazing or deer activity occurred.

Mulch Study

Establishment

The month of October in Mississippi is often dry. This was consistent during the testing period as only 10.9 mm of rain fell during the initial 30 days after planting (Figure 10) (Appendix B). Consequently, germination was delayed and time to significant establishment was increased. Dense stands of tall fescue and crimson clover were not observed until the following spring. All-purpose straw that was hand applied to mimic the current practices of mulch performed by MDOT was among the quickest to aid in establishment, along with all other Hydorstraw™ treatments. Straw treatments also appeared to suppress weed species in the initial stages of establishment which did not negatively affect cover ratings as much as other mulch treatments (Booze-Daniels et al., 2000). I noticed that all other products seemed to be detrimental to seed germination. All Finn products (wood, wood & paper blends) appeared to delay seed germination and establishment by covering seed underneath a heavy surface of mulch. This corroborates the findings of Booze-Daniels et al., (2000) in that using certain mulches would be detrimental in establishment because of seed being suspended in mulch. These products were noticed to delay germination and establishment of desired species and seemed to enhance the onset of weed establishment. I also noticed that due to seeding with the hydroseeder seed were being suspended in the mulch longer. These seeds were exposed to the elements and some seed had little to no soil contact which is what Booze-Daniels et al. (2000) found to be true. This is likely the reason recommendations are in place for using higher seed rates when plating with a hydroseeder (Norland, 2000; Booze-Daniels et al., 2000).

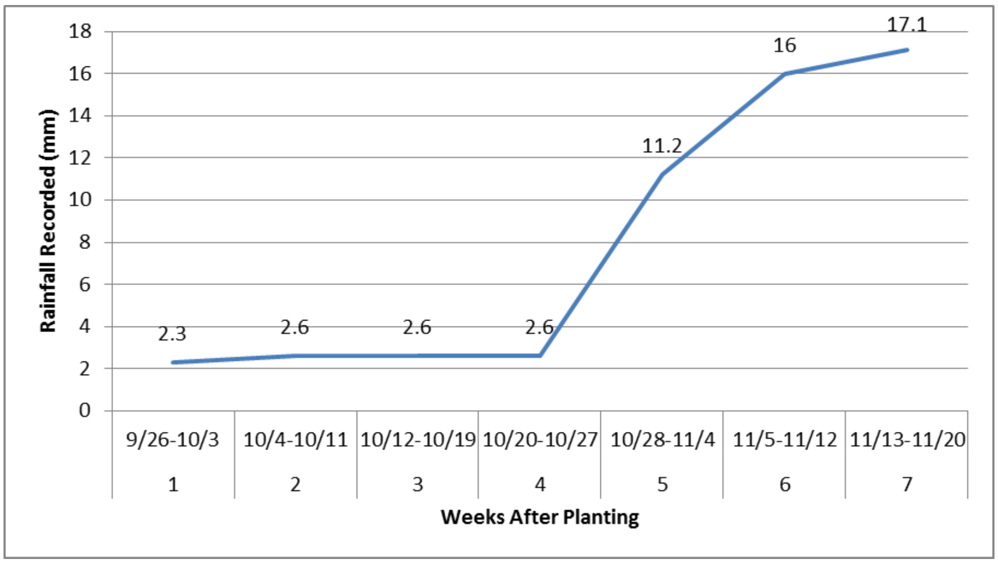


Figure 10 Rainfall recorded for seven weeks during fall 2011.

Cover

Because of the lack of rainfall during the first 30 days after the hydromulch study was initiated in the fall of 2011, little vegetative cover was present and no treatment reached 70% vegetative cover; therefore no visual ratings or digital imaging were performed. Substantial vegetative cover was not present until 48 days after planting and only two treatments, Terra-Mulch Cellulose and All-Purpose Straw, attained 70% cover after 62 days (Figure 11). Of the treatments that achieved the 70% cover, the All-Purpose Straw contained the most desired species and the plots that contained Terra-

Mulch Cellulose hydraulic mulch was mainly weed cover. I observed that straw treatments were the most beneficial in promoting seed germination and enhancing establishment (Booze-Daniels et al., 2000). Terra Mulch Cellulose mulch treatment was largely weed cover, along with all other treatments except Hydrostraw™ products. Ninety days after planting all treatments resembled each other in species composition consisting of tall fescue and crimson clover. Crimson clover was the more dominant of the two until after the first spring mowing in March, when tall fescue became more prevalent.

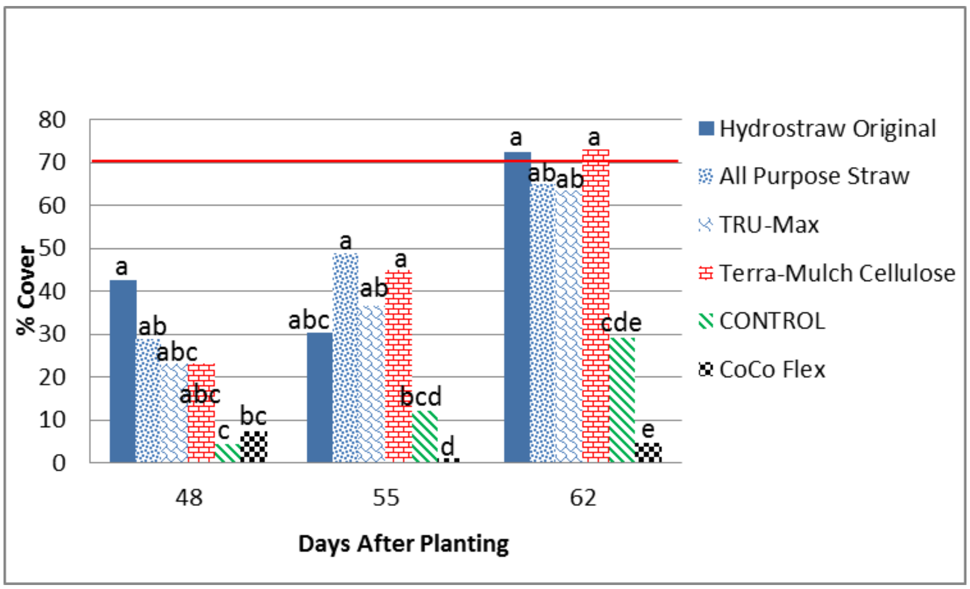


Figure 11 Vegetative cover for the hydromulching experiment over time.

Moisture

Very little rainfall occurred during the first 48 days after planting, totaling 13.7 mm. However; from 41 to 48 days after planting, a total of 16 mm of rainfall was recorded. Between 48 and 55 days after planting, 17 mm of precipitation was recorded, from 55 to 62 days after planting, 61.4 mm of precipitation was recorded, and 62 to 69 days after planting, 25.6 mm of precipitation was recorded. Time intervals showed significant differences in volumetric water content. In the week prior to the first cover ratings were performed, Hydrostraw™ All Purpose Straw (APS) showed the highest volumetric water content readings and the control plot with no mulch and Terra Mulch Cellulose (TMC) were the weakest performers. The remainder of the rating period showed no significant difference in regard to a best or worst performer of mulch and moisture during establishment (Figure 12).

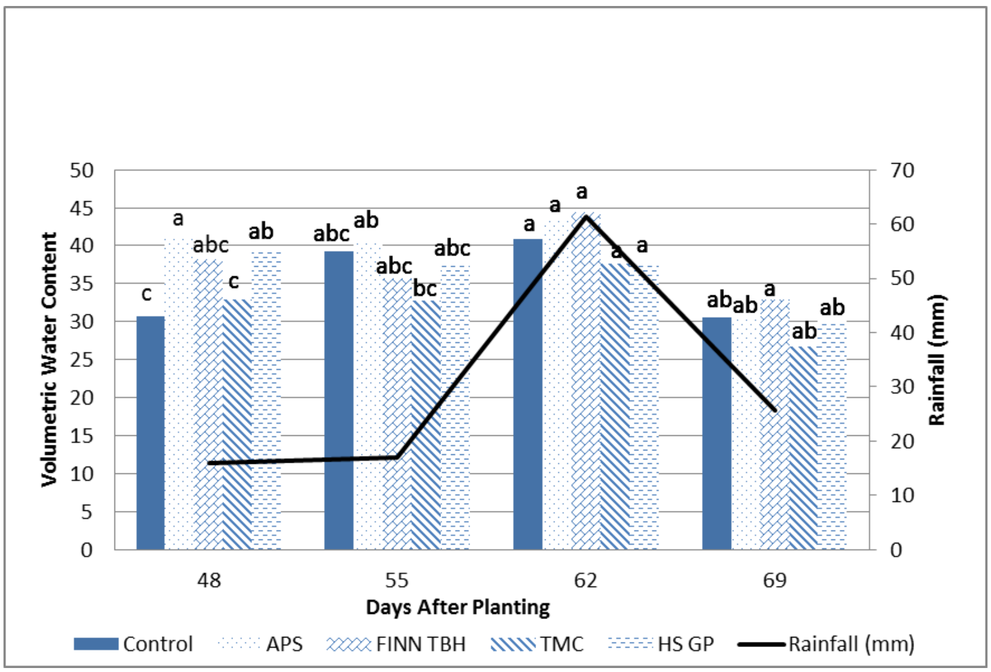


Figure 12 Volumetric water content of soil during establishment under mulch treatments.

CHAPTER V

CONCLUSIONS

The mandate of establishing 70% cover in 30 days after construction is well intentioned in theory; however, it brings up concern. The first process in seed germination is the imbibition of water. No germination will occur on any post construction site unless there is water available for the seed to imbibe. The post-construction window for sufficient cover would be better suited to start closer in response to rain events, not days after construction is completed. Concern for nutrients and sediment pollution is also minimal if no rainfall event has occurred.

From the findings in this study, a range of 30-60 mm of precipitation is needed for oilseed radish to germinate. Subsequent rain is needed to facilitate the further growth and establishment of oilseed radish and any other species. Heat units accumulated in the summer allow for larger oilseed radish plants; therefore, increasing leaf area and decreasing potential for non-point source pollution.

This study showed more favorable results in the fall than the summer in regard to establishment because of less weed pressure and more moisture availability. This is consistent with recommendations from Beard (1973) who showed better results for fall than summer plantings. Oilseed radish performed favorably in both summer and fall. The latter achieved greater success in establishing seeding mixtures and faster germination (Ngouajio et al., 2004). Radish provided the 70% cover quicker than the mandated 30 days in both summer and fall, but the fall temperatures and moisture allowed the ryegrasses to offer more permanent cover. Turf-type tall fescue showed promise in reducing and possibly eliminating the occurrence of mowing because of its short stature. Mixes containing oilseed radish, turf-type tall fescue, AR-P, AR-G, PR, and red or white clovers show potential for rapid roadside establishment while combating NPS in the fall. While it is doubtful that AR-P, AR-G, and PR would last through the summer, turf-type tall fescue may survive the Mississippi summer.

The composition of the seeding mixes according to the MS Vegetation Schedule shows validity, but also cause for concern. If seeding is done in the summer or the fall, as it was performed in this study, the inclusion of certain plant species proves to be futile. Beard (1973) warned that planting cool season turfgrasses in midsummer is generally avoided and ineffective because of low moisture, high temperatures, and weed competition. Planting warm or cool-season grass species out of season is a practice that should be used with extreme caution. Attempting to establish grass species out of season may result in germination, but does not ensure successful vegetative establishment. From data recorded from the experiment, clover species are best suited for fall plantings when the weather is more favorable.

Beard (1973) also states that pure live seed (PLS) should be taken into account when attempting to establish turf species. This agrees with the successful results of this study when shown in comparison to MDOT's seeding rates, which did not specify or take into account PLS recommendations. Lower seeding rates may be economical when establishment rate is not critical; however, in an attempt to improve establishment and achieve 70% cover in a short amount of time, more emphasis should be placed on a combination of timing and seeding of grass species and/or PLS rates. More money can be saved taking these approaches while also ensuring significant cover and establishment while attempting to reach 70% cover in 30 days. From the experimental data collected, it would be more beneficial to purchase more season appropriate species than attempting to mix with species that are out of season. This experiment sometimes used higher seeding rates than that of the MS Vegetation Schedule; however, this practice may be beneficial in providing greater success of establishment and cover. Also, the turf-type grasses in this experiment are not the large pasture grasses usually used on roadsides; therefore, seeding rates need to be adjusted.

The use of sod on roadsides is also a viable option because of the successful results that were found in the experimental study. In this situation, water is the critical factor. During the period immediately following installation, the sod was watered as needed. Due to the heat and lack of rainfall, it was necessary to water every other day for a period of two weeks. This was discontinued after sod rooting and adequate rainfall. Sod provides instant vegetative cover, reducing erosion and non-point source pollution and weed potential. Based on the soil test results from the experiment, only the subsequent application of nitrogen is needed to keep sod productive. Using the correct rate of fertilizer and applying only the nutrients needed would be beneficial on Mississippi roadsides.

'MS-Express' bermudagrass and 'Meyer' zoysiagrass in this study tended to have slower vertical growth than centipedegrass sod, but centipedegrass retained its color longer than bermudagrass and zoysiagrass leading into fall dormancy. Upon inspection one year later, centipedegrass height was also shorter in stature, and without the occurrence of mowing it was more aesthetically appealing than the other species. None of the three sodded grass species reached heights to trigger mowing. Likely without additional fertilizer applications bermudagrass and zoysiagrass would not perform as well as centipede and remain competitive against weeds.

The amount of fertilizer that is applied under MDOT specifications at the time of planting is excessive. If there is a major rain event shortly after the application of fertilizer, the majority of the nutrients could be washed away from the site into surrounding areas contributing to the issue of NPS pollution. Fertilization is essential in almost all cases for plants to be productive, but the amount of fertilizer applied at planting, according to MDOT's Vegetation Schedule, may not be beneficial for seedling growth. The amount of excess fertilizer may hinder germination, and could prove to be detrimental in later growth of the seedlings and promoting the onset and establishment of weeds. The 1,136 kg ha^{-1} of 13-13-13 at the time of planting in an attempt to maximize establishment and minimize application cost is not only wasteful, but also not a best management practice. Beard (1973) instructs a minimum of two fertilizer applications per year and light frequent applications of fertilizers are better than heavy infrequent applications for maintenance. Also, based on soil test recommendations from the experiment, the Mississippi State University Soil Testing Laboratory showed a requirement of little to no application of phosphorus and potassium on the experimental sites. This further validates claims of the need to reduce the excessive amounts of fertilizer applied to establishment sites.

Hydromulching is an effective way in providing quick cover for disturbed areas. The mulch can act as a cover to combat raindrop impact and particle detachment causing erosion. In this study, Hydrostraw™ products were the easiest to apply and provided quicker vegetative cover compared to wood and paper mulches. Hand applied All-Purpose Straw provided the quickest vegetative cover and all Hydrostraw™ products suppressed weeds better than wood and paper mulch products. Wood products seemed to smother seeds under thick fibers which appeared to inhibit germination and establishment, but also provided protection from erosion. The hydromulch products that were evaluated in the experiment were not significantly different from each other or the control in regard to moisture holding capacity.

Future research should be conducted to determine more feasible planting rates of radish to accommodate better establishment of companion species for summer plantings. Also, further research is needed to determine the effects of seed placement directly onto the soil and prior to the application of hydromulch versus combining all materials within a hydroseeder for effective vegetative establishment.

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APPENDIX A

DAILY MAXIMUM AND MINIMUM AIR TEMPERATURES (°C) RECORDED FOR SUMMER 2011 AND 2012 PLANTINGS

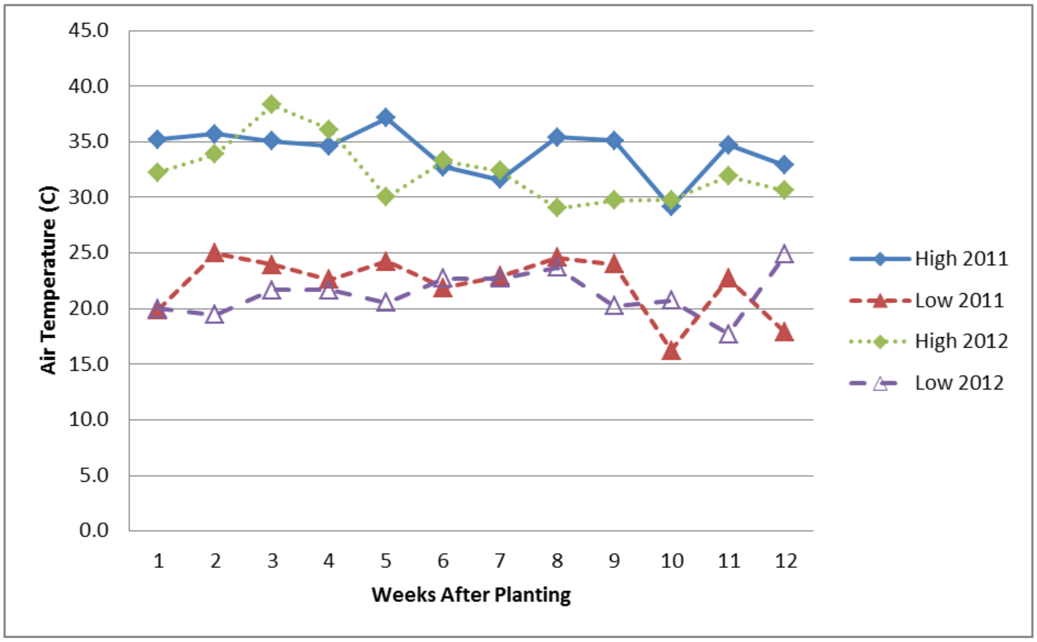
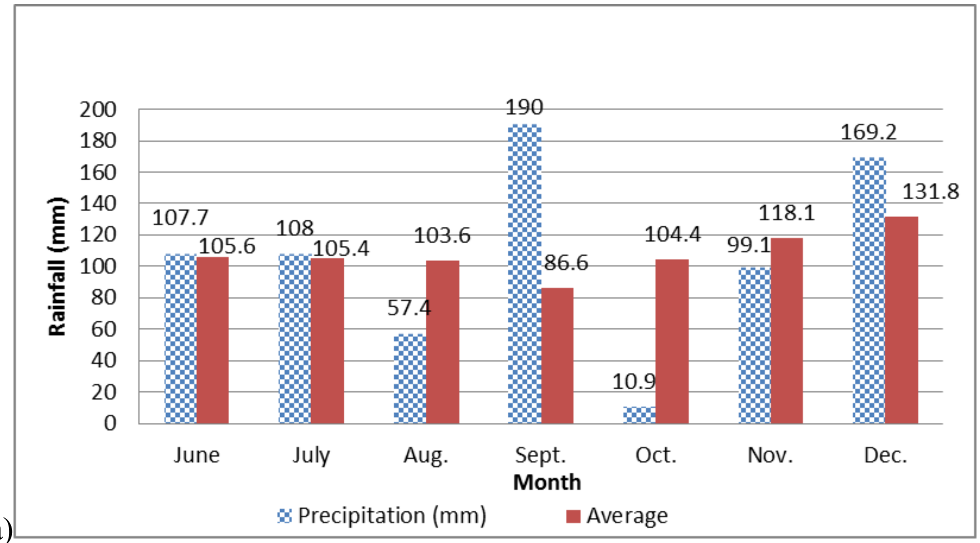


Figure 13 Daily maximum and minimum air temperatures (°C) recorded for summer 2011 and 2012 plantings.

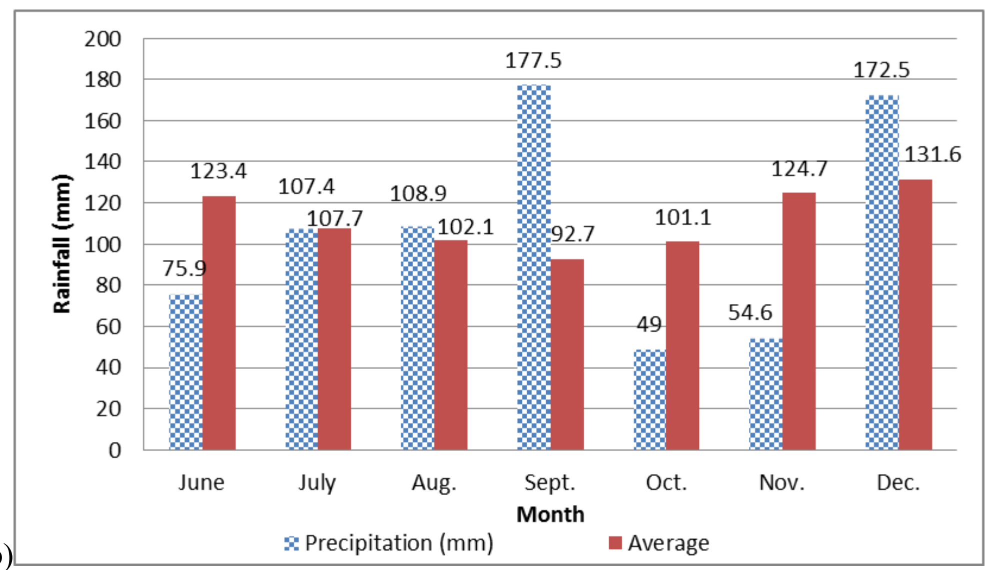
APPENDIX B

COMPARISON OF PRECIPITATION RECORDED AND AVERAGE RAINFALL

FROM JUNE-DECEMBER OF 2011 & 2012



(a)



(b)

Figure 14 Rainfall recorded and average rainfall amounts from June-December for research sites during 2011 & 2012.

(a) 2011 rainfall.
(b) 2012 rainfall.

APPENDIX C

SIGMASCAN MEAN COVER RATINGS 22 DAYS AFTER PLANTING FOR 2011

SUMMER PLANTING

Table 20 Sigmascan mean cover ratings 22 days after planting for 2011 summer planting.

Trtmt	Mean	Trtmt	Mean	Trtmt	Mean
83	94.65 a	60	52.28 cdefghijk	67	42.48 cdefghijkl
82	83.65 ab	29	52.15 cdefghijk	20	42.43 cdefghijkl
31	65.20 bc	74	51.98 cdefghijk	65	41.78 cdefghijkl
84	64.13 bcd	7	51.48 cdefghijkl	59	41.43 cdefghijkl
85	64.03 bcde	80	50.58 cdefghijkl	79	40.95 cdefghijkl
30	62.68 bcdef	73	50.05 cdefghijkl	61	40.90 cdefghijkl
18	61.78 bcdef	17	49.90 cdefghijkl	33	40.20 cdefghijkl
1	61.45 bcdef	23	49.80 cdefghijkl	25	40.18 cdefghijkl
19	60.20 bcdefg	32	49.63 cdefghijkl	47	39.63 cdefghijkl
36	58.25 bcdefg	12	49.63 cdefghijkl	40	39.45 cdefghijkl
71	58.23 bcdefgh	21	48.05 cdefghijkl	52	39.40 cdefghijkl
81	57.35 bcdefgh	8	47.60 cdefghijkl	64	38.73 cdefghijkl
37	57.30 bcdefgh	4	46.65 cdefghijkl	38	36.98 defghijkl
42	56.73 bcdefghi	24	46.20 cdefghijkl	39	36.95 defghijkl
9	56.73 bcdefghi	77	46.20 cdefghijkl	72	36.48 defghijkl
15	56.25 bcdefghi	34	46.03 cdefghijkl	54	36.33 efghijkl
14	56.03 bcdefghi	69	45.80 cdefghijkl	27	36.13 fghijkl
2	56.00 bcdefghi	46	44.58 cdefghijkl	62	35.73 fghijkl
76	55.10 cdefghi	75	44.33 cdefghijkl	43	33.55 ghijkl
3	55.03 cdefghi	51	44.18 cdefghijkl	63	32.48 ghijkl
35	54.75 cdefghij	44	44.10 cdefghijkl	57	32.08 hijkl
13	53.95 cdefghij	41	44.00 cdefghijkl	56	32.03 hijkl
45	53.93 cdefghij	68	43.80 cdefghijkl	55	31.15 hijkl
49	52.90 cdefghij	66	43.78 cdefghijkl	26	29.53 ijkl
6	52.78 cdefghij	11	43.65 cdefghijkl	50	27.13 jkl
70	52.68 cdefghijk	58	43.65 cdefghijkl	53	24.98 kl
48	52.35 cdefghijk	16	43.60 cdefghijkl	10	23.85 l
22	52.30 cdefghijk	5	42.55 cdefghijkl		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

APPENDIX D

VISUAL MEAN COVER RATINGS 22 DAYS AFTER PLANTING FOR 2011

SUMMER PLANTING

Table 21 Visual mean cover ratings 22 days after planting for summer 2012.

Trtmt	Mean	Trtmt	Mean	Trtmt	Mean
81	100 a	74	37.50 efghijklm	79	31.50 ijklm
82	100 a	65	37.50 efghijklm	40	31.50 ijklm
83	100 a	76	36.50 fghijklm	51	31.50 ijklm
1	63.75 b	77	36.50 fghijklm	41	30.75 ijklm
3	62.50 bc	36	36.25 fghijklm	80	30.50 ijklm
13	60.00 bcd	23	36.25 fghijklm	43	30.50 ijklm
6	56.25 bcde	11	36.25 fghijklm	78	30.25 ijklm
14	56.25 bcde	24	36.00 fghijklm	62	30.00 ijklm
84	52.50 bcdef	18	35.75 fghijklm	55	29.00 jklm
85	52.00 bcdefg	39	35.75 fghijklm	17	28.50 jklm
2	51.25 bcdefg	75	35.75 fghijklm	64	28.25 klm
9	51.25 bcdefgh	68	35.25 fghijklm	63	28.25 klm
12	48.75 bcdefghi	25	35.25 fghijklm	52	27.75 klm
10	48.75 bcdefghi	44	34.50 fghijklm	53	27.75 klm
5	48.75 bcdefghi	71	34.25 fghijklm	47	27.50 klm
30	47.50 bcdefghij	22	34.00 fghijklm	56	27.25 klm
15	47.50 bcdefghij	38	34.00 fghijklm	20	27.25 klm
73	46.25 bcdefghijk	32	34.00 fghijklm	59	26.50 lm
8	43.75 cdefghijkl	67	34.00 fghijklm	26	26.25 lm
16	43.75 cdefghijkl	28	33.75 fghijklm	49	26.25 lm
19	43.75 cdefghijkl	69	33.50 fghijklm	57	25.25 lm
4	43.75 cdefghijkl	33	33.25 ghijklm	21	24.00 m
7	42.50 defghijklm	45	32.75 hijklm	34	23.75 m
48	42.25 defghijklm	27	32.50 hijklm	54	23.75 m
42	41.25 defghijklm	61	32.50 hijklm	50	23.75 m
31	38.75 efghijklm	70	32.50 hijklm		
29	38.75 efghijklm	66	32.25 ijklm		
37	38.75 efghijklm	58	32.00 ijklm		
35	38.75 efghijklm	72	32.00 ijklm		
60	37.50 efghijklm	46	31.75 ijklm		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

APPENDIX E

SIGMASCAN MEAN COVER RATINGS 28 DAYS AFTER PLANTING FOR 2012

SUMMER PLANTING

Table 22 SigmaScan mean cover ratings 28 days after planting for 2012 summer planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
2	58.38 a	90	9.42 hij	21	4.96 j
14	47.90 ab	42	9.40 ij	32	4.95 j
16	46.86 ab	17	9.31 ij	25	4.88 j
8	46.50 ab	46	8.70 ij	33	4.86 j
15	46.49 ab	54	8.63 ij	75	4.79 j
83	45.90 ab	41	8.07 ij	48	4.78 j
1	45.12 ab	84	7.90 ij	49	4.77 j
3	44.62 ab	40	7.87 ij	78	4.74 j
7	43.86 abc	36	7.47 ij	35	4.62 j
82	40.60 bcd	37	7.28 ij	71	4.52 j
10	40.21 bcd	61	7.26 ij	59	4.37 j
6	39.97 bcd	66	7.24 ij	47	4.33 j
9	35.10 bcde	70	7.08 ij	29	4.26 j
4	28.37 cde	63	6.99 ij	45	4.21 j
13	28.11 def	77	6.92 ij	50	3.93 j
12	27.01 defg	55	6.73 ij	38	3.74 j
5	26.90 defg	19	6.45 ij	56	3.72 j
81	25.11 defgh	20	6.42 ij	30	3.69 j
76	21.38 efghi	52	6.00 ij	79	3.55 j
11	18.54 fghij	43	5.88 ij	67	3.54 j
80	17.86 fghij	22	5.85 ij	26	3.52 j
34	16.25 fghij	64	5.76 ij	62	3.49 j
88	12.09 ghij	23	5.57 j	44	3.46 j
87	10.98 hij	18	5.46 j	28	3.45 j
65	10.86 hij	27	5.43 j	68	3.45 j
86	10.40 hij	73	5.40 j	60	3.32 j
39	10.33 hij	69	5.39 j	24	3.16 j
74	10.22 hij	31	5.37 j	72	3.09 j
89	9.79 hij	53	5.27 j	51	2.91 j
85	9.56 hij	58	4.99 j	57	2.88 j

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

APPENDIX F

VISUAL MEAN COVER RATINGS 28 DAYS AFTER PLANTING FOR SUMMER

2012 PLANTING

Table 23 Visual mean cover ratings 28 days after planting for summer 2012.

Trtmt	Mean	Trtmt	Mean	Trtmt	Mean
83	100.00 a	89	30.00 ghijklmn	31	18.50 klmnopqr
82	100.00 a	18	30.00 ghijklmn	55	17.75 klmnopqr
81	77.50 ab	17	29.50 ghijklmno	67	17.50 klmnopqr
2	67.50 bc	80	29.50 ghijklmno	74	17.50 klmnopqr
1	65.00 bcd	35	27.50 hijklmnop	50	16.50 klmnopqr
15	65.00 bcd	22	27.50 hijklmnop	70	15.75 klmnopqr
14	62.50 bcd	65	27.50 hijklmnop	73	13.75 lmnopqr
10	62.50 bcd	45	26.25 hijklmnopq	59	13.75 lmnopqr
7	62.50 bcd	32	26.00 hijklmnopq	33	13.75 lmnopqr
4	61.25 bcd	37	25.50 hijklmnopqr	71	13.75 lmnopqr
13	60.00 bcde	24	25.00 hijklmnopqr	26	13.50 lmnopqr
16	58.75 bcde	86	25.00 hijklmnopqr	43	13.25 lmnopqr
3	57.50 bcde	63	23.75 ijklmnopqr	49	12.00 lmnopqr
8	53.75 cdef	76	23.75 ijklmnopqr	38	11.50 lmnopqr
9	51.25 cdefg	19	22.50 ijklmnopqr	48	11.25 lmnopqr
6	47.50 cdefgh	34	22.00 jklmnopqr	79	11.25 lmnopqr
5	45.00 cdefghi	36	21.75 jklmnopqr	47	11.00 lmnopqr
41	45.00 cdefghi	21	21.50 jklmnopqr	25	9.50 mnopqr
12	43.00 defghij	87	20.75 jklmnopqr	60	9.25 mnopqr
11	38.00 efghijk	62	20.75 jklmnopqr	51	8.75 mnopqr
88	37.50 efghijk	64	20.50 jklmnopqr	44	7.75 nopqr
42	37.50 efghijk	69	20.00 klmnopqr	52	7.00 opqr
53	32.50 fghijkl	85	20.00 klmnopqr	56	7.00 opqr
54	32.50 fghijkl	58	20.00 klmnopqr	78	6.50 pqr
61	32.50 fghijkl	40	19.50 klmnopqr	28	5.75 pqr
66	32.50 fghijkl	27	19.25 klmnopqr	72	5.50 pqr
90	32.50 fghijkl	75	18.75 klmnopqr	29	4.75 qr
39	30.75 ghijklm	20	18.75 klmnopqr	77	4.50 qr
23	30.00 ghijklmn	84	18.75 klmnopqr	30	3.25 qr
46	30.00 ghijklmn	68	18.75 klmnopqr	57	4.50 r

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

APPENDIX G

SIGMASCAN MEAN COVER RATINGS 35 DAYS AFTER PLANTING FOR 2012 SUMMER PLANTING

Table 24 SigmaScan mean cover ratings 35 days after planting for 2012 summer planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
7	92.54 a	56	22.36 ijklmno	45	12.49 mno
3	89.98 ab	37	22.34 ijklmno	21	12.22 mno
13	89.41 ab	85	20.83 jklmno	40	12.07 mno
1	87.18 acb	19	20.54 jklmno	71	12.06 mno
2	84.87 abc	36	19.97 jklmno	48	11.43 mno
83	83.98 abcd	27	19.86 jklmno	29	11.00 mno
6	83.88 abcd	73	19.73 jklmno	26	10.37 mno
15	83.05 abcde	77	19.28 jklmno	59	10.35 mno
14	82.47 abcde	64	19.21 jklmno	79	10.33 mno
5	81.58 abcde	46	19.05 jklmno	53	10.33 mno
16	81.30 abcde	50	18.80 jklmno	69	10.32 mno
8	80.75 abcde	63	18.79 jklmno	65	10.27 mno
9	80.58 abcde	22	18.70 jklmno	20	9.91 mno
12	75.94 abcde	35	17.93 klmno	38	9.62 mno
81	71.22 abcde	66	17.85 klmno	60	9.54 mno
82	69.57 bcde	74	16.69 lmno	42	9.11 mno
11	66.10 cdef	58	16.62 lmno	78	8.86 mno
10	62.75 def	43	16.14 mno	76	8.86 mno
4	61.24 efg	62	15.67 mno	49	7.79 no
88	46.00 fgh	24	15.40 mno	47	7.75 no
86	44.09 fghi	55	15.20 mno	51	7.14 no
87	40.37 ghij	23	14.95 mno	28	7.07 no
17	39.13 hijk	52	14.94 mno	68	6.80 no
54	38.48 hijkl	61	14.67 mno	31	6.64 no
89	30.79 hijklm	80	14.64 mno	30	6.52 no
41	28.23 hijklmn	75	13.96 mno	25	5.80 o
72	26.71 hijklmno	32	13.85 mno	67	5.75 o
84	25.88 hijklmno	18	13.03 mno	44	5.53 o
90	24.56 hijklmno	39	12.96 mno	33	5.16 o
70	23.97 hijklmno	34	12.89 mno	57	4.66 o

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

APPENDIX H

VISUAL MEAN COVER RATINGS 35 DAYS AFTER PLANTING FOR SUMMER

2012 PLANTING

Table 25 Visual mean cover ratings 35 days after planting for 2012 summer planting.

Trtmt	Mean	Trtmt	Mean	Trtmt	Rep
81	100.00 a	42	37.50 fghijkl	51	23.75 hijklmnop
82	100.00 a	65	37.50 fghijkl	53	23.75 hijklmnop
83	100.00 a	37	37.50 fghijkl	30	23.25 hijklmnop
4	91.25 ab	46	36.25 fghijklm	75	22.75 hijklmnop
7	91.25 ab	54	36.25 fghijklm	58	22.50 hijklmnop
10	91.00 ab	39	36.25 fghijklm	59	22.00 hijklmnop
15	87.25 abc	55	35.00 fghijklmn	76	21.25 hijklmnop
2	86.25 abc	47	33.00 fghijklmno	24	21.25 hijklmnop
14	86.00 abc	62	32.50 fghijklmnop	38	21.25 hijklmnop
13	85.00 abc	64	31.25 fghijklmnop	25	21.25 hijklmnop
8	84.75 abc	66	31.25 fghijklmnop	31	21.25 hijklmnop
1	83.50 abc	18	31.25 fghijklmnop	79	20.50 hijklmnop
16	82.25 abc	43	31.25 fghijklmnop	48	18.75 ijklmnop
9	78.75 abc	90	31.25 fghijklmnop	67	18.75 ijklmnop
6	77.50 abc	73	31.25 fghijklmnop	60	18.25 jklmnop
3	75.00 bcd	40	30.00 fghijklmnop	80	17.50 jklmnop
12	75.00 bcd	35	30.00 fghijklmnop	68	16.25 klmnop
11	66.25 cde	70	30.00 fghijklmnop	78	15.75 lmnop
5	52.50 def	33	30.00 fghijklmnop	49	15.00 lmnop
45	51.25 defg	22	30.00 fghijklmnop	29	14.25 lmnop
86	43.75 efgh	63	28.75 fghijklmnop	28	13.75 lmnop
17	43.75 efgh	32	28.75 fghijklmnop	52	13.75 lmnop
61	43.75 efgh	21	28.75 fghijklmnop	34	13.75 lmnop
74	42.50 efghi	89	28.75 fghijklmnop	50	13.75 lmnop
84	41.25 fghij	36	27.50 ghijklmnop	56	12.50 mnop
41	41.25 fghij	27	27.50 ghijklmnop	44	11.75 nop
85	41.25 fghij	19	27.50 ghijklmnop	57	11.25 nop
88	40.00 fghijk	23	26.25 hijklmnop	72	10.00 op
87	40.00 fghijk	71	25.00 hijklmnop	77	8.75 p
26	37.50 fghijkl	69	23.75 hijklmnop	20	8.75 p

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*

APPENDIX I

SIGMASCAN MEAN COVER RATINGS 42 DAYS AFTER PLANTING FOR 2012

SUMMER PLANTING

Table 26 SigmaScan mean cover ratings 42 days after planting for 2012 summer planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
83	92.76 a	17	22.49 ghij	18	10.89 ghij
13	89.28 ab	64	21.83 ghij	61	10.75 ghij
16	89.15 ab	84	20.60 ghij	40	10.69 ghij
1	88.37 abc	73	20.43 ghij	63	9.95 ghij
7	86.15 abcd	50	19.98 ghij	37	9.53 ghij
15	85.30 abcd	71	19.79 ghij	52	8.87 ghij
4	83.35 abcd	39	19.29 ghij	30	8.70 hij
10	82.48 abcd	21	18.91 ghij	45	8.48 hij
3	81.85 abcd	85	17.88 ghij	77	8.41 hij
8	80.52 abcd	27	17.83 ghij	67	8.37 hij
2	79.66 abcd	54	17.42 ghij	58	8.06 hij
5	79.65 abcd	65	16.68 ghij	49	7.91 hij
14	79.07 abcd	55	16.57 ghij	41	7.47 hij
90	76.70 abcd	20	16.51 ghij	31	7.38 hij
6	74.70 abcd	75	15.88 ghij	24	7.37 hij
82	74.22 abcde	36	14.77 ghij	23	7.34 hij
87	71.42 abcde	48	14.38 ghij	47	7.24 hij
86	69.73 abcde	32	14.26 ghij	51	7.15 ij
9	68.82 bcde	43	14.22 ghij	33	6.70 ij
81	68.51 bcde	22	14.04 ghij	25	6.05 ij
11	65.02 cde	78	14.02 ghij	56	5.90 ij
12	64.53 de	59	13.68 ghij	60	5.74 ij
88	63.44 de	69	13.44 ghij	53	5.50 ij
89	51.00 ef	68	13.21 ghij	28	5.21 ij
80	32.40 fg	46	12.93 ghij	72	4.70 ij
76	30.86 fgh	66	12.89 ghij	42	4.47 j
70	28.17 fghi	26	12.88 ghij	62	4.45 j
19	26.63 ghij	35	12.66 ghij	38	4.03 j
34	26.33 ghij	79	12.43 ghij	57	3.84 j
74	26.45 ghij	29	11.48 ghij	44	3.27 j

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at $P<0.05$.

APPENDIX J

VISUAL MEAN COVER RATINGS 42 DAYS AFTER PLANTING FOR SUMMER

2012 PLANTING

Table 27 Visual mean cover ratings 42 days after planting for summer 2012 planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
83	100.00 a	24	43.75 fghijkl	20	27.50 ijklm
82	100.00 a	71	42.50 fghijkl	48	27.50 ijklm
2	97.50 ab	65	41.25 ghijkl	73	26.25 ijklm
9	97.00 ab	27	40.00 ghijklm	64	26.25 ijklm
7	97.00 ab	19	40.00 ghijklm	29	26.25 ijklm
15	97.00 ab	55	39.50 ghijklm	30	26.25 ijklm
16	96.00 ab	22	38.75 ghijklm	63	26.25 ijklm
14	96.00 ab	23	38.75 ghijklm	37	26.00 ijklm
13	96.00 ab	39	38.25 ghijklm	26	25.00 ijklm
3	95.75 ab	17	37.50 hijklm	31	22.50 jklm
4	95.00 ab	59	37.50 hijklm	79	21.75 klm
8	95.00 ab	40	36.50 hijklm	68	21.25 klm
6	95.00 ab	76	36.25 hijklm	62	21.25 klm
10	95.00 ab	80	35.75 hijklm	33	20.00 klm
1	92.50 abc	41	35.75 hijklm	47	20.00 klm
5	88.50 abc	32	35.00 hijklm	52	18.75 klm
81	82.50 abcd	85	35.00 hijklm	50	18.75 klm
90	81.75 abcd	35	35.00 hijklm	58	18.75 klm
11	79.75 abcd	51	35.00 hijklm	53	18.75 klm
12	76.00 abcde	54	33.75 hijklm	28	17.50 klm
88	72.50 abcdef	36	33.75 hijklm	25	17.50 klm
86	68.75 bcdefg	69	33.50 hijklm	49	16.25 klm
87	62.50 cdefgh	34	32.50 hijklm	77	16.25 klm
74	55.00 defghi	66	31.25 hijklm	67	15.75 lm
89	53.25 defghij	43	30.75 ijklm	56	13.75 lm
45	45.00 efghijk	42	33.75 ijklm	38	13.75 lm
46	45.00 efghijk	75	29.50 ijklm	78	13.25 lm
18	45.00 efghijk	70	28.25 ijklm	72	9.50 m
61	43.75 fghijkl	21	28.25 ijklm	57	9.50 m
84	43.75 fghijkl	60	27.50 ijklm	44	9.25 m

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*

APPENDIX K

SIGMASCAN MEAN COVER RATINGS 37 & 44 DAYS AFTER PLANTING FOR

FALL 2011 PLANTING

Table 28 SigmaScan mean cover ratings 37 days after planting for fall 2011 planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
9	85.45 a	7	29.85 cdef	16	9.95 hijkl
2	80.07 ab	13	27.30 cdefg	19	6.10 ijkl
17	71.42 ab	11	24.95 defg	18	5.15 jkl
15	68.87 b	10	21.05 efgh	24	4.36 kl
6	39.90 c	8	20.12 efghi	20	4.03 kl
5	38.95 cd	22	19.12 fghij	25	3.47 kl
3	36.97 cd	12	17.52 ghijk	28	1.62 l
14	34.62 cde	23	14.25 ghijkl	27	0.81 l
1	31.70 cdef	26	14.20 ghijkl		
4	31.37 cdef	21	13.43 ghijkl		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

Table 29 SigmaScan mean cover ratings 44 days after planting for fall 2011 planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
2	84.75 a	14	34.92 cdef	19	13.20 ijklmn
17	83.47 a	3	31.45 defg	16	11.87 ijkmn
15	80.05 a	4	28.60 defgh	18	9.45 jklmn
9	79.10 a	22	25.57 defghi	20	8.37 jklmn
5	50.97 b	21	24.90 defghi	28	7.50 klmn
7	47.00 bc	13	24.72 defghi	24	3.20 mn
6	39.55 bcd	10	22.45 efghi	25	2.77 n
1	37.30 bcde	12	22.07 fghijk	27	0.50 n
8	36.82 bcdef	23	17.87 ghijklm		
11	36.27 bcdef	26	15.70 hijklm		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05*.

APPENDIX L

SIGMASCAN MEAN COVER RATINGS 30 & 37 DAYS AFTER PLANTING FOR

FALL 2012 PLANTING

Table 30 SigmaScan mean cover ratings 30 days after planting for fall 2012 planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
9	66.09 a	1	28.14 def	16	12.54 fghi
15	61.87 ab	4	26.63 defg	18	10.19 fghi
17	61.82 ab	22	26.01 defg	19	8.26 fghi
2	55.17 abc	11	25.31 defgh	28	5.06 ghi
10	43.90 abcd	12	17.82 efghi	25	4.38 ghi
8	41.75 bcd	21	15.92 efghi	27	4.26 ghi
14	37.03 cde	23	15.62 efghi	20	3.35 hi
5	36.43 cde	13	15.43 efghi	24	2.81 i
7	30.37 de	3	13.10 fghi		
6	30.19 def	26	12.79 fghi		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05.*

Table 31 SigmaScan mean cover ratings 37 days after planting for fall 2012 planting.

Treatment	Mean	Treatment	Mean	Treatment	Mean
9	90.65 a	5	29.20 defgh	13	20.85 fghij
17	71.56 b	23	27.83 defgh	3	13.67 ghij
15	69.10 b	8	25.45 efghi	25	13.45 ghij
2	62.21 bc	16	25.39 efghi	4	13.24 ghij
11	45.36 cd	18	23.21 fghij	20	11.29 hij
14	42.86 de	7	23.13 fghij	28	9.11 hij
10	37.65 def	26	22.84 fghij	24	7.26 ij
6	33.34 def	1	22.81 fghij	27	6.13 j
21	30.66 defg	19	22.16 fghij		
22	30.04 defg	12	21.88 fghij		

*Values with the same letter within each column are not statistically different according to Fisher's LSD test at *P<0.05.*