MANAGEMENT PRACTICES TO IMPROVE ESTABLISHMENT OF TIFTON 85 BERMUDAGRASS

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE

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To my family Dilvan, Ivone and Nathália Baseggio

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Tifton 85 bermudagrass is a hybrid with excellent agronomic characteristics, but must be planted by vegetative cuttings. The high planting costs and the problems with desiccation of planting material led to revisiting management practices to improve survival and time to achieve an established stand. The overall objective of this research was to evaluate the effect of management practices for planting Tifton 85 bermudagrass on establishment success and length of time from planting to utilization. This was accomplished through three studies.

The objective of Study 1 was to evaluate the effect of stolon type (long, upper section, lower section, and short stolons) and soil cover (totally or partially covered) at planting on effective establishment. Partially vs. completely covering stolons at planting accelerated emergence, bermudagrass cover and increased dry matter harvested.

The objective of Study 2 was to quantify the effects of stolon planting rates (1120, 1570, 2020, 2470, and 2920 kg ha^{-1}) on bermudagrass and weed cover and bermudagrass mass accumulation. Higher planting rates resulted in greater bermudagrass frequency up to 69 d after planting and for ground cover up to 99 d. All treatments had satisfactory ground cover three months after planting. Very low and low rates showed higher weed competition the spring after

summer planting. Very high, high and medium rates had greater herbage mass accumulation than low and very low early in the following year.

Study 3 focused on the use of rhizomes as planting material, and the objective was to quantify the effects of planting rates (2.6, 5.2, and 10.4 m^3 ha^{-1}), and depths (6 and 12 cm) on establishment success, measured as bermudagrass cover and herbage mass accumulation. Planting at 12 cm accelerated emergence and cover and increased herbage DM in summer, and the difference in planting depths was more pronounced when using the low rate. The medium rate was most cost-efficient and appears ready to be used in sandy soils.

CHAPTER 1
INTRODUCTION

Bermudagrass is a highly productive warm-season grass adapted to the humid southeastern US where mild winters and warm climate are prevalent. Bermudagrass quality has been long recognized and the need for better varieties was responsible for a breeding program conducted by Burton (1947), which led to the development of successful cultivars known today. Hybrid bermudagrasses, such as 'Coastal' (*Cynodon dactylon)* and 'Tifton 85' (*Cynodon spp.*), are important grasses in Florida for hay production and pasture (Hill et al., 2001). The release of Tifton 85 represented a significant enhancement in economic return for the same level of pasture inputs (Bouton, 2007). Hybrids, however, do not produce viable seed and must be propagated vegetatively by stolons or rhizomes (Burton et al., 1993; Taliaferro et al., 2004).

Planting costs using vegetative propagation are high and establishment failures have been reported (Newman and Harrison, 2011). When planted in sandy, well-drained soils under dry-weather conditions, planting material can desiccate and the establishment will likely fail. There are a number of forms of stem cuttings that can vary in root and shoot development. Owen and Maynard (2007) observed that larger cuttings are likely to root better because of increased carbohydrate reserves. Starch reserves are consistently lower in the younger, upper-stem tissue than in the middle and basal nodes (Volterrani et al., 2012). Therefore, strategies for cutting the planting material from the nursery need to be evaluated in order to enhance sprouting and emergence success and minimize risk, mainly under challenging environmental conditions. Moreover, leaving parts of stolons uncovered in the planting process, as described by Greene et al. (1992) and Beaty (1966), could facilitate sprout emergence.

Under challenging environmental conditions, it may be important to compensate for potential loss of planting material by using higher plantings rates. An optimum planting rate for either bermudagrass stolons or rhizomes can be determined only with a cost-benefit analysis. Another aspect to be considered when using rhizomes is optimum planting depth. Shallow planting can increase rhizome survival, sprouting, and emergence as well as ground cover and dry matter production (Chiles et al., 1966; Bourdôt, 1984; Chamblee et al., 1989). Placed too shallow, however, the rhizome may dry out without irrigation (Stichler and Bade, 2003) or be damaged by freezing (Burton et al., 1993). In addition, sandy soils with high permeability such as in the Suwanee River basin may not hold enough moisture and thus deeper planting could be required.

Within the context of high planting costs and the problem of desiccation of planting material, there is need to revisit management practices to improve survival and reduce time to achieve an established stand on these deep sandy soils conditions. The overall objective of this research is to evaluate the effect of planting practices of Tifton 85 bermudagrass to improve establishment and shorten time from planting to utilization.

In order to achieve this objective, three experiments were conducted using stolons and rhizomes. Results are presented in three chapters that describe the effects of i) stolon type and soil cover (Chapter 3), ii) stolon planting rate (Chapter 4), and iii) planting rate and depth using rhizomes (Chapter 5) on the establishment of Tifton 85 bermudagrass.

CHAPTER 2
LITERATURE REVIEW

Vegetative Propagation

Vegetative propagation of bermudagrasses in the southeastern US provides hybrids with improved forage yield and quality for producers (Hanna and Anderson, 2008). In the 1940s, when the first hybrid bermudagrass, ‘Coastal’, was released there was little known about planting bermudagrass using vegetative material. Interest in Coastal increased, expanding vegetative propagation on a commercial scale to numerous species. Vegetative propagation remains the main method of planting bermudagrass hybrids after many decades, and it is the only method of distribution for ‘Tifton 85’ bermudagrass, the latest cultivar released and one of the best bermudagrass cultivars since Coastal (Hanna and Anderson, 2008).

Recently, there has been increased interest in establishment of new bermudagrass pastures and renovation of old ones. Tifton 85 bermudagrass is preferred for intensive grazing systems because of its greater production and ability to support higher stocking rates compared to other hybrids. The first fields of bermudagrass were planted 40 to 50 yr ago, and with increasing age, pastures have become degraded and yield has decreased, necessitating renewal of these old fields (Hanna and Anderson, 2008). Furthermore, the high production costs resulting from confined livestock production has led producers to search for new, lower-cost alternatives (Thornton, 2010). This has moved them away from annual cropping and toward grazing of perennial forages, an option that has led to the use of superior bermudagrass hybrids for pasture. Tifton 85 bermudagrass has played a major role in keeping beef and milk production profitable since its introduction nearly two decades ago (Hanna and Anderson, 2008).

Vegetative propagation, however, requires more labor and is more expensive than propagation through seed. Establishment costs including land preparation, rhizomes or stolons, planting, fertilizer, and weed control are about fifty percent greater for vegetative propagation than that using seed (Newman and Harrison, 2011). Nevertheless, producers expect to plant large areas in short periods of time and wish to shorten time from planting to utilization.

One advantage of Tifton 85 bermudagrass is that it can be propagated either by above ground stems, technically known as stolons, or by rhizomes (Burton et al., 1993); and it roots more easily from stolons than some other hybrid grasses (Stichler and Bade, 2003). Stolons may grow more than 7.5 cm per day developing roots and shoots at each node when soil moisture and growing conditions are favorable (Burton et al., 1993).

The ability of a grass to tiller from every leaf axil is an advantage during establishment, since rapid tillering will ensure greater leaf area and earlier occurrence of complete light interception (Jewiss, 1972). Patton et al. (2007) suggested that genotypes with rapid establishment produce a greater proportion of stems (stolons and rhizomes) than leaves compared with slow-establishing genotypes. In their study, stolon growth rate ranged from 1.7 to 11.3 mm d^{-1}. This rapid growth constitutes an advantage because, compared with rhizomes, propagation through stolons allows for larger areas to be planted. Also, planting stolons makes it possible to plant later in the growing season as long as soil moisture is sufficient and does not require that the area used for planting material be given several years to regain vigor before being used again as a source of planting material.

Stolons enable the plant to search and capture light, whereas rhizomes serve as storage organs for meristems and carbohydrates (Dong and Pierdominici, 1995). During establishment, under normal conditions, more tillers can be originated from rhizomes than from stolon fragments (Fernandez, 2003). In this study, stolons presented higher sprouting efficiency, but due to the increased competition for limited storage resources, stolons showed greater proportion of dead sprouts compared to the use of rhizome fragments. In the same study, the author observed that young tillers originating from stolons had higher proportion of aerial mass than those originating from rhizomes, and in turn there was greater production of new rhizomes on tillers originated from rhizomes. Therefore, above- to below-ground mass ratio was higher during the establishment phase using stolons than rhizomes. Branching intensity of rhizomes and stolons increased with increasing light intensity and in general, stolons branched more than rhizomes but rhizomes had more dormant buds than stolons (Dong and Pierdominici, 1995).

Cynodon plants fail to develop rhizomes under low light intensity. Rochecouste (1962) planted single-bud rhizomes of Coastal bermudagrass and observed that a primary shoot was developed at the first month and up to 20 buds may be formed at the basal node of this shoot. Usually not more than seven to twelve buds develop into tillers. Horizontal growth begins when the primary shoot and tillers reach 10 to 15 cm long, resulting in the formation of stolons.

Problem of Desiccation and Other Pre-Planting Conditions

Stolons must be planted in moist soil to avoid wilting. If they are scattered on hot dry soil, they can die in a few minutes (Burton, 2011). Therefore, stolons must be planted under moisture conditions, whether it is irrigated or during the rainy season. One advantage of Florida’s climate is the abundance of the summer rains (Figure 2-1). During the months of June through September, convective rainfall occurs during many days in Florida. Portions of peninsular Florida observe more seasonal thunderstorm activity than any other part of the United States (Brenner, 2004). Therefore, planting in this region can occur over a relatively long period of time and chances are increased for new plantings to succeed.

Despite the favorable distribution of rain, many regions of Florida still have problems with desiccation of planting material. It happens because the soils, particularly in the Suwannee River basin, are deep sands with rapid permeability and low moisture retention (Soil Survey

Staff, 2013). If the material is planted during the hottest time of day or the field does not receive water for a couple of days, the planting material will lose viability and the establishment will likely fail.

Established bermudagrass is known for its vigor and drought tolerance (Rodriguez et al., 2001). Under drought stress, the aboveground structures die off, but the grass will keep growing from its rhizomes (Shi et al., 2012). However, when recently planted, sprigs lack a mature root system and then are more susceptible to drought stress, nutrient deficiencies, and weed competition. Beaty (1966) observed high sprouting capacity of Coastal bermudagrass stems, where 94.5% of all the stolons and rhizomes were capable of producing sprouts. Even when planting material was stored for 20 d in moist sawdust at 21ºC, sprouting percentage was 93%. And sprouting of both stolons and rhizomes stored at 4ºC was only slightly reduced. This indicates that potential emergence is high and if stems are stored at temperatures cool enough to prevent development of sprouts and above freezing with sufficient moisture, no serious reduction in sprouting will occur. However, it has been observed that the survival of Coastal bermudagrass stolons and buds from actively growing plants was critically low after exposure to low relative humidity (Webb, 1959). Also, the author indicated that rhizomes taken from dormant plants were able to tolerate a longer period of desiccation. Therefore, rhizomes planted in early March, when they are still dormant, are more likely to maintain their viability.

The stress associated with cutting, transporting and transplanting stolons and rhizomes is significant and is not a slow process as would occur under the development of natural drought stress. Some authors have shown how pretreatments of grass nursery with chemicals for reducing leaf area may be of benefit to stimulate natural drought-tolerance mechanisms (Shatters et al., 1998). In fact, the authors observed that Tifton 85 treated with ethephon showed more rapid bud and root development and reduced leaf surface area, improving the rate of pasture establishment.

One problem in using stolons as propagation material is that they need to be cut from the nursery area, baled wet for transportation to the receiving field, and planted soon after. If the material is kept baled for a long time, moisture in the wet bales may increase their temperature to a limit that can damage planting material, reducing its viability. This critical issue has been evidenced since the beginning of utilization of vegetative propagation. In the early 1950s, tons of ice were used on top of the loaded material during transport to keep it from overheating (Hanna and Anderson, 2008).

Stolon Planting

Characteristics and General Recommendations

Conventional planting recommendations indicate that stems must be 8- to 12- wk old with six or more nodes and should usually be about 60-cm long (Mueller et al., 1993). Greene et al. (1992) proved that even 2-wk-old cuttings are able to produce roots and new shoots. However, the percentage of survival was less than 20%. Therefore, stolons should be allowed to grow longer before cutting to accumulate enough reserves. It is also suggested that planting material receives 35 to 50 kg of N fertilizer ha^{-1} 2 wk before harvesting the nursery and 30 kg N ha^{-1} after planting, as soon as the bermudagrass plants start to grow (Mislevy and Dunavin, 1993). Alderman et al. (2011) showed that N fertilization of Tifton 85 bermudagrass affects the degree and duration of N and carbohydrate reserve utilization. In their study, increasing N fertilization increased leaf, stem, rhizome, and root N concentration and shoot growth. It enhanced total nonstructural carbohydrate reserve utilization for regrowth, stimulated leaf area expansion, and increased canopy photosynthesis, resulting in increased shoot growth for N rates up to 90 kg N ha^{-1} regrowth $period^{-1}$. Thus, N fertilization of nursery areas plays a critical role in the establishment vigor of planting material.

Nitrogen is the most heavily applied nutrient, while potassium plays a major role in plant water status, and phosphorous deficiency may occur due to limited rooting during establishment. A ratio of 1-0.4-0.8 for N-P-K in elemental form was recommended for establishing turf bermudagrass in sandy soils (Rodriguez et al., 2001). When P was not applied, lower cover rates were observed, indicating the need of nutrient application in soils with low initial P levels.

Borrowing information from bermudagrass establishment in turf, several studies show the benefits of N fertilization. Guertal and Evans (2006) found the best ground cover percentage and shoot density was achieved with N rates from 34 to 43 kg ha^{-1} wk^{-1} for 4 wk in a loamy sand soil in Alabama. In addition, Johnson (1973) showed that application of N biweekly or monthly increased 'Tifway' bermudagrass cover as compared to no N application. Rodriguez et al. (2001) applied N at 49 kg ha^{-1} wk^{-1} and found that 100% ground cover was achieved in 5 to 11 wk.

In addition, the establishment of Tifton 85 bermudagrass is greatly improved when weeds are controlled, especially early in stand life (Butler et al., 2006). Johnson (1973) observed repeated post-emergence treatments resulted in good weed control and 91 to 96% turfgrass ground cover, using Tifway bermudagrass in Georgia. And when not applying any herbicide, ground cover was only 36%.

Planting Rate

Planting rate is another aspect of bermudagrass vegetative propagation that needs to be revisited because of the wide range of recommendations. Higher planting rates will ensure more rapid colonization and ground coverage, but those are only recommended if the planting material is readily available or can be obtained at a low cost. Evers et al. (2002) observed that the highest planting rate resulted in the highest forage production the year after planting. Also, they showed that Tifton 85 achieved about 45% cover at the end of the establishment year using low planting density and produced almost 6 tons DM ha^{-1} the following year. Burton et al. (1993) found that Tifton 85 can completely cover the ground in less than 3 mo. Evers et al. (2001) showed that Tifton 85 yielded over 9000 kg ha^{-1} accumulated herbage DM the year following establishment without irrigation and even with a severe summer drought.

Few studies exist relative to the evaluation of planting rate on time to an established stand under extreme sandy soil conditions such as those of the Suwannee River basin. Mislevy et al. (1995) suggested that the optimum rate for planting bermudagrass stem cuttings is about 1500 kg ha^{-1} if common bermudagrass had been growing on the field. Lazo et al. (1995) observed acceptable stand at 176 d after planting hybrid bermudagrass at a rate of 2000 kg ha^{-1}, while 1000 kg ha^{-1} resulted in increased weed competition and a sparse stand that required additional time for canopy closure. In addition, a rate of 2500 kg ha^{-1} decreased establishment success because excessive plant material prevented adequate incorporation of stem cuttings into the soil.

Although higher planting densities are supposed to achieve full ground cover faster, populations tend to converge, irrespective of planting density, at some common tiller density and tiller size if grown for long periods. Kays and Harper (1974) reported total tiller numbers started to decline after the second harvest in the high density plots, after the third in the intermediate densities, and at the fourth harvest in the lowest density. While different extension papers from different states recommend rates around 1350 to 1680 kg ha^{-1} when using stolons of Tifton 85 as planting material (Mislevy, 1996), many establishment failures continue to be reported in the extremely sandy soils of north central Florida (Newman, Y.C., 2011, personal communication). Additional research is needed to provide specific information for these soil conditions and to assess the advantages of different planting rates.

Stolon Type and Soil Cover

One question that producers may also ask is that of the most appropriate planting material size and placement in the soil. Considering stem pieces with the same number of nodes, studies have shown that the larger the stolon or rhizome fragment the earlier the emergence (Fernandez, 2003). This has been attributed to longer cuttings having larger reserves, which are required for root development. Starch reserves are consistently lower in the less mature tissues than in the middle and basal nodes (Volterrani et al., 2012). The largest stolon fragments resulted in the highest aboveground mass, and total stolon length per tiller increased with planted stolon and rhizome size, but the size effect was more marked for stolons (Fernandez, 2003). The author also observed higher sprouting efficiency for stolon than for rhizome fragments. Sollenberger et al. (1990) observed that removing the apical meristem of elephantgrass resulted in early initiation of shoot growth, but measurable root growth did not begin until 2 wk after planting, what resulted in death of many shoots at 6 wk after planting. Moreover, they observed that undefoliated stems produced minimal early shoot growth, but nearly all shoots survived through 6 wk postplant, probably because of a greater nutrient content in the planted material.

Planting of stolons may be an advantage, since higher sprouting tends to cover the ground quicker. However, it may likewise be a disadvantage. Weaker apical dominance, and consequently a higher sprouting efficiency, may increase competition for limited storage resources, which can be detrimental during an environmental stress (Fernandez, 2003). This reserve depletion could explain the higher proportion of dead sprouts from small- and medium-sized stolon fragments than from rhizome fragments, as well as the lower number of tillers established from stolon than from rhizome fragments in his experiment. In general, reduction in fragment mass (for equal node number) caused lower establishment, a delayed emergence and, consequently, a reduction in total plant dry weight. By studying 81 species, larger stem cuttings rooted better because of increased carbohydrate reserves (Owen and Maynard, 2007). Horowitz (1972a) did not find any difference between rhizome fragments with one node and several nodes on germination percentage. On the other hand, Montesbravo et al. (1985) observed greater emergence of 2- and 3-node fragments compared to 1-node fragments.

Greene et al. (1992), studying propagation of hybrid bermudagrasses, covered all the nodes of vegetative cuttings with planting mix and left as much internode space as possible uncovered. Similarly, Beaty (1966) used three-node sprigs and covered two nodes with soil and left the third node uncovered. The approach used by Greene et al. (1992) and Beaty (1996) could facilitate sprout emergence compared to totally covered, without being as prospect to desiccation as leaving all the planting material above ground. Also, Masters et al. (2004) indicated that 75% of the stem cutting should be covered to a depth of 5 to 7 cm and at least two nodes should be left exposed above soil surface.

Rhizome Planting

Characteristics and General Recommendations

Another alternative for planting Tifton 85 bermudagrass is the utilization of rhizomes. Dormant rhizomes are less susceptible to drought stress from incoming solar radiation. One problem using dormant rhizomes is that half or more of them may be dead and live ones may not have enough reserves to establish a live plant (Burton, 2011). The author also indicated that in South Georgia maximum rhizome reserves can be obtained by not cutting well-fertilized grass after 15 September. Leaving the last growth will help to keep the grass dormant during warm winter periods that otherwise would make the rhizomes produce tops that exhaust reserves when killed by a freeze.

Keeley and Thullen (1989) indicated that initial growth of bermudagrass planted in March, April, and May was very slow. However, since these treatments grew longer, they produced about 60% more dry matter than those planted in June, July, and August and harvested in December. This could be considered an advantage of planting rhizomes, since they are usually planted when they are still dormant.

Dormant rhizomes of Tifton 85 can be planted from December until March (Burton, 2011). They should be covered with at least 5 cm of soil to protect them from freezing. Delaying planting dormant rhizomes until February will reduce chances of winterkill. In the Southeast, planting is usually recommended from February to April, when rhizomes are still dormant and temperatures cool (Mueller et al., 1992). Chamblee et al. (1989), evaluating different bermudagrass cultivars in North Carolina, found that March plantings for all cultivars proved superior to fall plantings in 2 of the 3 yr. Woodle (1954) also noted that spring is the best time for establishment of bermudagrass by rhizome because of the generally favorable moisture status. Rizzo and Satorre (1999) observed an increase in the time for shoot emergence with a decrease in soil moisture. When exposed to water potential of -12.8 bars, first sprouts were seen 18 d after planting, while when increasing the potential to -6.9 bars, emergence started as soon as 5 d after planting.

However, for most of the Southeast in late winter or early spring when bermudagrass rhizomes are dormant, there is frequently excessive soil moisture that prevents fieldwork, and in late spring and early summer, or early spring in Florida there is often insufficient moisture. Clearly, proper planting date is dependent on the region where the field is located. Thus, instead of date, guidance by temperature and rainfall data should be considered. Rhizomes and roots become dormant at soil temperatures below 18ºC (Halvorson and Guertin, 2003). Maximum rhizome bud germination for bermudagrass has been reported between 23 and 35°C, slow germination below 20°C, and inhibition of germination at 10°C (Horowitz, 1972a). Also, new rhizomes were formed at temperatures exceeding 15 to 20ºC. Rizzo and Satorre (1999) suggested that highly fragmented bermudagrass vegetative structures require lower temperature for sprouting. They observed that temperature required for 50% sprouting increased with the number of nodes in the rhizome (from 1 to 9).

Satorre et al. (1996) observed that buds from the vegetative structures did not sprout at temperatures below 7ºC. The rate of sprouting increased with temperatures within the range of 11 to 33ºC, and a base temperature of 7.7ºC was determined for bud sprouting of rhizome and stolons. Although the base temperature for sprouting is relatively low comparing to other species, emergence also depends on the growth of the sprouts through the soil. Then, structures distributed deeply in the soil require more thermal time than shallow planting to reach similar level of emergence. According to the same authors, the efficiency of mobilization of carbohydrate reserves was at a maximum at 20ºC and rhizomes transferred reserves more efficiently than stolons.

Owen and Maynard (2007) reviewed environmental effects on propagation by stem cuttings for several species. They found that lower air temperatures reduce the rate of shoot growth, which could deplete carbohydrate reserves and the propagule would likely die. Keeley and Thullen (1989) reported that growth of bermudagrass was improved when air and soil temperatures averaged 21 and 26ºC, respectively. Also, plants grew very little when air and soil temperatures were 11 and 14ºC. Youngner (1959) reported that *Cynodon dactylon* can grow even when exposed to nearly freezing night temperatures, as long as day temperatures are sufficiently high. When receiving 1ºC night and 21ºC day temperatures, new shoots of bermudagrass were still able to keep a growth rate of 15.5 mm day^{-1}. The author suggested that if night temperatures are below 10ºC, the day temperature must be correspondently higher. Also, he indicated that maximum temperature rather than degree-hours per day determines the amount of growth.

Vegetatively propagated bermudagrasses seem to be more tolerant than seeded bermudagrasses to freeze injury during the year of establishment. Ahring et al. (1975) observed that stands established from rhizomes or stolons usually show little or no freeze injury the following winter. On the other hand, seeded bermudagrass present an extremely high winterkill and a slow recovery the following spring in Oklahoma.

Plants need to have enough time to establish and accumulate carbohydrates to better withstand cold temperatures. Therefore, the more stolons produced before any freeze event, the better the chance the stand will survive the winter (Munshaw and Williams, 2002). Keeley and Thullen (1989) indicated that rhizomes start to be produced soon after bermudagrass emergence. Horowitz (1972a) showed that when planting from May to September, plants could form new rhizomes in less than 2 months. Therefore, even late plantings in September are still able to accumulate reserves to survive during winter. Also, he observed that in late summer and autumn, rhizomes are often found to bend upwards and to emerge as new aerial shoots.

Planting Depth

Besides planting date, another factor that affects establishment success is the sensitivity of Tifton 85 bermudagrass to planting depth. The different stratification of vegetative material in the soil profile has a strong influence on the establishment rate (Rizzo and Satorre, 1999). The depth of planting is determined by the availability of moisture and the texture of the soil. Placed too deep, the new growth may die. Placed too shallow, the rhizome may dry out without irrigation (Stichler and Bade, 2003). Burton et al. (1993) indicated that deep planting could protect the planting material from freeze. However, Phillips and Moaisi (1993) observed only a few shoots emerged from rhizomes placed below 10 cm. Rizzo and Satorre (1999) observed a linear positive relation of depth until 18 cm and time to achieve 50% emergence. Under dry land conditions, 5 to 8 cm deep is generally adequate (Burton, 2011). Under irrigation, planting should be at a depth of 4 to 5 cm with occasional rhizomes showing above ground. Stichler and Bade (2003) stated that the ideal rhizome is 12 to 15 cm long, planted with one end 5 cm deep and the other end at the soil surface.

Chamblee et al. (1989) studied several hybrid bermudagrass cultivars and noticed a delay in sprout emergence and a decrease in percentage of rhizomes sprouting as planting depth increased from 2.5 cm to 10 cm. Montesbravo et al. (1985) observed highest emergence when stolons and rhizomes were planted superficially or at 5-cm deep and emergence decreased at 10- and 15-cm deep. Another study also found a general decrease in the number of plants that emerged from the 0- to 10-cm depth (Chiles et al., 1966). Chiles et al. (1966) and Bourdôt (1984) also found that rhizome survival, emergence, and dry matter production by aerial shoots decreased and time of emergence of the first shoots was delayed with increased planting depth. Deep (7.6 cm) horizontal placement of Coastal bermudagrass in March plantings resulted in May stands of only 36%, compared with 81% from the shallow depth (3.8 cm) and 70% from the vertical orientation (Chamblee et al., 1989). Woodle (1954) noted that it is best to place rhizomes vertically so that they are able to cut across the moisture gradient. When planting during the winter, placing the material a little bit deeper may be favorable to protect from freezing. Chamblee et al. (1989) found that winter survival of ‘Tifton 44’ bermudagrass in North Carolina was markedly improved when planted horizontally at the 7.6-cm depth, compared with 3.8 cm.

Planting Rate

As with stolon planting, planting rate of rhizomes is an important factor for successful establishment. Bermudagrass can be planted at a range of rates. The faster a stand is desired, the more rhizomes should be planted. The closer the spacing, the faster the establishing grass will completely cover the area (Stichler and Bade, 2003). Mueller et al. (1993) indicated that bermudagrass is usually planted at rates of 4.5 to 5.3 m^3 ha^{-1}. Taliaferro et al. (2004) reported that planting rate of bermudagrass rhizomes varies greatly and usually ranges from 1.7 to 5.2 m^3 ha^{-1}. Recommended planting rates for rhizomes range from 1.7 to 3.5 m^3 ha^{-1} (Evers et al., 2002; Cosgrove and Collins, 2003). Although this is the rate recommended in the literature, the range is wide, and recommendations for sandy-clay loam soils with higher moisture and nutrient retention are being followed for the deep, sandy soils where most hybrid bermudagrasses are used in Florida (Newman et al., 2011). Information on establishment under these specific conditions is needed.

Summary

Tifton 85 has vegetative propagation only, planting costs are high, establishment failures are being reported and there is a call for more effective management under challenging conditions, like low moisture, low fertility and rapid desiccation. In addition, there is an increased use of Tifton 85 for grazing, particularly in Florida, and a need of planting large areas in short period of time. And there is a necessity to shorten time from planting to utilization. Information in the literature, however, is limited. Recommended rates occur over a large range and are for different field conditions. Therefore, evaluation of management practices during establishment of Tifton 85 is relevant for introduction of new pastures to succeed under deep, sandy soil conditions. Within this context, the overall objective of this research is to evaluate the effect of planting practices of Tifton 85 bermudagrass on establishment and time from planting to utilization.

To achieve this objective, three studies were conducted. The first evaluated stolon types and degree of soil cover effects on stolon growth. The second and third studies explored the effect of planting rate, one using stolons (Chapter 4) and another using rhizomes (Chapter 5).

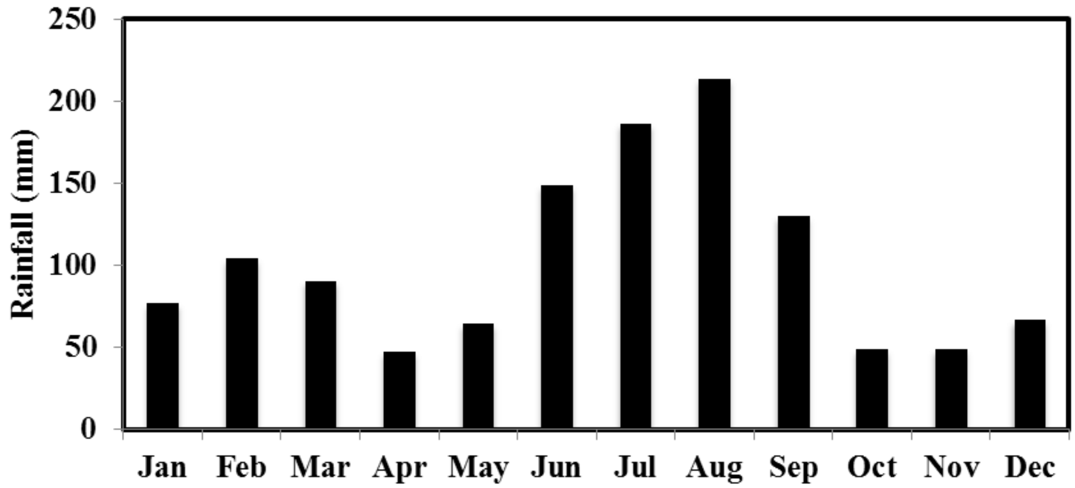

Figure 2- 1. Monthly distribution of rain throughout the year in Bronson, a north-central Florida location within the Suwannee river basin. Bars are averages of the last 9 yr at the Bronson weather station. Source: FAWN, 2011.

CHAPTER 3
STOLON PLANTING TYPE AND SOIL COVER EFFECTS ON BERMUDAGRASS ESTABLISHMENT

Stolons are above ground horizontal stems that present higher sprouting than rhizome fragments and thus tend to cover the ground quicker under optimum conditions (Fernandez, 2003). However, planting stolons under environmental stress conditions, such as planting in the deep sands of the Suwanee River basin with low fertility and moisture retention, could be a disadvantage. The higher sprouting efficiency of stolons increases competition for limited storage resources and then, if soil moisture conditions for rooting and growth are not adequate, newly formed sprouts will likely desiccate and die leading to establishment failure.

Larger cuttings are likely to root better because of increased carbohydrate reserves (Owen and Maynard, 2007). In addition, delayed emergence, lower establishment and a reduction in total plant dry weight when using small stolon fragments has also been reported (Fernandez, 2003). Therefore, strategies on harvesting nursery planting material need to be evaluated in order to enhance sprouting and emergence efficiencies and improve establishment, mainly under challenging environmental conditions. Leaving a low stubble height and avoiding excessive stolon fragmentation when harvesting planting material could be a strategy toward successful establishment.

Another factor affecting desiccation is soil cover of the planting material. By covering the whole stolon with soil, contact between planting material and soil will increase and loss of moisture will decrease, reducing the desiccation problem and avoiding loss of stolon viability. On the other hand, leaving parts of the stolon uncovered, like in studies of Greene et al. (1992) and Beaty (1966), could facilitate sprout emergence compared to totally covered, without being as prospect to desiccation as leaving all the planting material above ground.

Because stolon length and degree of soil cover can influence establishment, stolon cutting and planting practices need to be evaluated in order to improve stolon-planting efficiency. Within this context, the hypothesis of this study is that different types and lengths of stolon cuttings and extent of soil cover at planting will influence the rate and success of establishment. Therefore, the objective of this experiment is to evaluate the effects of stolon type and extent of soil cover on Tifton 85 emergence, percent cover, growth rate, and dry matter production.

Material and Methods

Study Site

This study was conducted during two seasons: from August to December 2011, and from September 2012 to May 2013. The study was located on a commercial dairy farm, Alliance Dairies, near Trenton, Gilchrist County, North Central Florida, and was planted on a prepared seedbed each year. Locations were within a 10-mile radius of each other (29° 40' 55" N, 82° 50' 43" W and 29° 34' 52" N, 82° 53' 7" W). The soil at the first site (planting of 2011) was classified as Blanton fine sand (loamy, siliceous, semiactive, thermic Grossarenic Paleudults). The second site (planting of 2012) was classified as Jonesville-Otela-Seaboard complex that consists of sandy and loamy marine deposits over limestone. Both locations are within the Suwanee River basin and differ very little in terms of physical and chemical properties. These soils are characterized as deep, sandy, well-drained, rapidly permeable sands with very low water retention capacity. Natural fertility and organic matter content are low (U.S. Dept. of Agriculture, 1984). All horizons in the profile are low in nitrogen, phosphorous, and potassium (Thompson et al., 1965). Therefore, irrigation and management practices to conserve organic matter are desirable. At the first site, soil pH was 6.7, and Mehlich 1 extractable P, K, Mg, and Ca were 55 (high), 32 (low), 50 (high), and 880 ppm in 2011, respectively. At the second site, soil pH was 5.5, Mehlich 1 extractable P, K, Mg, and Ca were 16 (medium), 28 (low), 26 (medium), and 248 ppm in 2012, respectively.

Experimental Variables and Statistical Design

Treatments were the factorial combinations of stolon type at four levels and soil cover at two levels for a total of 8 treatments. Treatments were arranged as a split-plot experiment with three replicates of a randomized complete block design. Blocks were allocated based on irrigation gradient. Stolon planting type was assigned to main plots (long stems – 3 stems with 8 nodes each; medium, upper stems – 4, 6-node stem pieces derived from the upper half of 12-node stems; medium, lower stems – 4, 6-node stem pieces derived from the bottom half of 12-node stems; and short stems – long stems cut into pieces with 3 nodes each). Soil cover, or placement of the stem in the soil was assigned to sub-plots and consisted of vegetative material that was totally covered or had the ends of the stem exposed (Figure 3-1).

Alongside, another level of stem placement in the soil was assessed using only long stems. Besides the totally covered stems with only both ends exposed, long stems with some parts under and some above ground were also used (designed as “wavy”, see diagram; Figure 3-1). This treatment was incorporated in the experiment design and compared only with same type of stolon. Therefore, this parallel assessment was based on one stolon type and three levels of soil cover. Response variables and samplings were the same as the general experiment.

Experimental Units

Each experimental unit consisted of a 4-m row corresponding to a stolon planting type by soil cover (either totally or partially covered) combination. Eight different treatment combinations in three replicates were imposed (Figure 3-1).

Field Procedures

Planting material consisted of Tifton 85 bermudagrass stolons or green stem cuttings (also called tops). Stolons with approximately 3½ months of regrowth were cut, using hand clippers, close to the ground, simulating the stubble height used in commercial practice (~3 to 5 cm). The nursery was located close to the experimental site and the planting material was fertilized in June and July with 45 kg N ha^{-1} each time (plus P, K, and micro minerals following a soil test). At planting day the planting material was clipped and kept refrigerated in iced water to preserve temperature and moisture while material was sorted. Stolons were classified as medium (6 to 8 nodes) and long (more than 8 nodes). Stolons with tillers, small pieces (< 6 cm), and thin stolons (< 0.5 cm) were discarded. Field planting was conducted in early morning or late afternoon to avoid desiccation.

Plots consisted of one 4-m row and alleyways were 1 m between treatments and 3 m between reps. Stolons were planted in the center of the plot and placed 5-8 cm deep in a trench, distributed equidistant on the 4-m row. In each plot, a different number of stolons pieces was planted depending on their node number for a total of 24 nodes per plot. Even if the stolon type differed, each experimental unit had the same total number of nodes. Trenches were dug using a hoe, simulating the action of a disk. After placing the stems into the trenches, the material was covered with soil depending on the treatment and watered immediately. Irrigation was applied using a center pivot and based on soil moisture. Water application started when volumetric water content was 7% and until it reached 10% or a maximum of 12 mm per irrigation cycle. Rainfall, evapotranspiration and air temperature are shown in Table 3-1. Planting was conducted on 11 Aug. 2011 and 18 Sept. 2012. Weed control was done using 2,4 D within the first week.

Response Variables and Sampling

During the first month after planting, emergence was evaluated every week. Number and length (cm) of new shoots of the entire plot were measured. The average length of the new shoots was calculated and the total length was the sum of all new shoots from each plot. To evaluate the rate of shoot growth (cm day^{-1}) after two weeks, the two longest stolons in each plot were selected and toothpicks were used to mark the growth length. After tillering had initiated, plant frequency percent was recorded biweekly until the end of season, when plants became dormant and stopped growing. Frequency was measured as described by Elzinga et al. (1998), using a 1- x 1-m frame divided in 25 (20 x 20 cm) counting squares, where the presence of bermudagrass was counted for the entire plot. When frequency in most of the plots was above 80% and no difference was likely to be observed among treatments, plot cover percentage recording started. Plot cover percentage was measured with the same frame, but instead of determining the presence/absence, the effective ground cover in each square was assessed. Frequency and ground cover were considered complete when percentage was above 80%.

Additionally, at the end of the season, dry matter production was evaluated. Three samples in each plot were collected, using a ring with approximately 0.17 m^2 (totaling 0.5 m^2 per plot). The material was clipped leaving 8-cm stubble height and fresh weight was measured. Samples were oven dried at 65°C until constant weight to determine dry weight.

Statistical Analysis

Data were analyzed using PROC MIXED procedures of SAS (SAS Institute Inc.). In all models, year, days after planting (DAP), stolon type, and soil cover were considered fixed effects; replicates and their interactions were modeled as random effects. When the interaction of DAP and other effects was significant, analysis was conducted within each DAP. Mean separation was further accomplished using least-square means and the PDIFF option in SAS, which gives a table of p-values for all possible pairwise comparisons. All test differences were considered significant at $P \leq 0.05$, while trends were discussed when $P \leq 0.10$. Emergence is reported for both 2011 and 2012 years. For other variables, only 2011 data are being reported.

Results and Discussion

Shoot Emergence

There were interaction effects of DAP x stolon type and DAP x soil cover; therefore, means were compared within each DAP. When analysis were performed by DAP, there were only main effects of soil cover ($P < 0.05$) and stolon type ($P < 0.05$) on number of Tifton-85 shoots starting at 13 days after planting (DAP). In 2011, plants started emerging at 6 DAP, but there was no significant difference due to degree of soil cover. This is similar to Fernandez (2003) who reported emergence after about 13 d and Montesbravo et al. (1985) who observed the highest emergence occurred 16 to 30 DAP. However, at 13 DAP, partially covered stolons presented greater number of shoots than totally covered ones (Figure 3-2). This difference became more evident on subsequent sampling dates. At 31 DAP, partially covered stolons showed 16 shoots m^{-2}, while totally covered stolons presented 7 shoots m^{-2}.

In 2012, the difference between soil cover treatments was more pronounced. In fact, the totally covered-stolons treatments did not present any emergence in any plot. On the other hand, partially covered stolons showed average of 2 shoots m^{-2} at 23 DAP. Although this is lower than the previous year, it demonstrates that the absence of shoots on all the totally covered stolons was a treatment effect.

One possible explanation may be because the stolons used for planting were visually thinner in 2012. Although we did not test the planting material, it may not have had enough reserves to emerge. In addition, in 2012 the experiment was planted about one month later. This could also have affected overall performance of all treatments in the second year and could indicate that totally covered stolons are not able to emerge when planted too late in summer.

Shoot emergence was also different among stolon types (Figure 3-3). Short stems presented greater emergence than long and upper stems at 6 DAP. However, soon after, the short stems slowed the rate of emergence and at 31 DAP the lower stems presented more shoots per square meter than long stems and tended to have more shoots than short ones ($P < 0.10$). The initial burst in emergence of short stems may be associated to stimulation of the growing points or buds. By cutting the stolons into small fragments, growth hormones were likely produced in the bud scales at the nodes, stimulating sprouting (Rechenthin, 1956). Sollenberger et al. (1990) observed that removing the apical meristem of elephantgrass resulted in early initiation of shoot growth, but measurable root growth did not begin until 2 wk after planting. Therefore, the fact that this treatment presented more than 60% shoot death at 6 wk after planting is likely related to a shortage of nutrients and water to support the initiated shoot growth.

Different results were reported by Fernandez (2003), who observed that the larger the fragment the earlier was the emergence. The later slow rate of emergence observed after 13 DAP confirms the observations reported by Dong et al. (2010) using a stoloniferous species. They observed the survival and growth of tillers of *Alternanthera philoxeroides* increased with increasing length of stolons due to the greater reserves to support initial growth.

Greater emergence from the lower section of the stem corroborates finding by Tchoundjeu and Leakey (1996). Using a woody plant, they reported a greater percentage of cuttings rooted from basal nodes rather than apical nodes. Similarly, cuttings from sub-apical positions of *Schefflera arboricola* rooted slowly and produced fewer roots than cuttings from basal regions (Hansen, 1986). Volterrani et al. (2012) indicated that starch increased considerably in older tissues and it decreased by 43% from basal to the middle node. Similarly, Greene et al. (1992) reported increased survival of vegetative cuttings of bermudagrass as age increased. However, they concluded that the primary effect of age seemed to be its relationship with length and number of nodes. Therefore, age was not directly responsible for increasing survival, but 10-wk-old cuttings were longer and had more nodes than the 2-wk ones. By virtue of having more reserves, new shoots were more likely to survive.

Average length of the new shoots had a main effect of stolon type at 6 DAP ($P < 0.05$; Table 3-2). Lower and short stems had higher average length than long and upper ones. However, this is not too meaningful, since the difference was small and no treatment showed shoots longer than 1 cm. No difference in average shoot length was observed at 13 and 20 DAP and they averaged 10 and 11 cm, respectively. Beaty (1966) observed that shoots were 5 to 7.5 cm high after 30 d incubation.

There was also an effect of stolon type on total length of new shoots ($P < 0.05$; Table 3-2). At 6 DAP, lower stems showed greater total length than long and upper ones. And at 20 DAP, lower-stem treatment presented greater total length than long and short stems. This indicates that by 20 DAP, lower section treatment had more shoots and these shoots were longer than treatments previously mentioned.

Although the difference in shoot length between 13 and 20 DAP averaged only 1 cm, by looking at the difference in total length between these samplings, it can be observed that stolons produced significant growth. The small difference for average length is due to the emergence of new shoots. There was no soil cover effect on average length (Table 3-3). However, total length was different between soil cover levels. At 6 DAP totally covered stolons showed greater total length than partially covered. This difference, however, was inverted at the next samplings, and partially covered stolons presented greater total shoot length than totally covered ones at 13 and 20 DAP.

When considering three levels of soil cover using long stems, there was no interaction between treatment and DAP. Partially covered and wavy treatments resulted in greater emergence than totally covered in both 2011 and 2012.

Shoot Node Number, Length, and Rate of Growth

There was no treatment effect on number of nodes at 30 and 43 DAP (Tables 3-4 and 3-5). At 30 DAP, the two longest shoots presented an average of five nodes, ranging from 4.4 to 6.0. After 2 additional wk, at 43 DAP, shoots had developed approximately 3.5 new nodes, averaging 8.5 nodes per shoot and ranged from 7.6 to 10.8 nodes.

The stolon type x soil cover interaction was significant for shoot length at 30 and 43 DAP (Tables 3-6 and 3-7). At 30 DAP, when totally covered, short and upper stems presented longer shoots than long-stem treatment. Lower stems did not differ from the rest. When partially covered, lower-section treatment showed longer shoots than short stems. Other treatments did not differ. Also, there was no difference between soil cover for any stolon type. At 43 DAP, when totally covered, lower and short stems presented longer shoots than long ones. When partially covered, lower-section treatment had longer shoots than short stems. This indicates that length of the longest shoots did not follow a trend and is not a good measure to compare treatments. The average of the two longest shoots ranged from 82 to 151 cm. Horowitz (1972b) observed that the longest shoots of bermudagrass measured 75 cm at 6 wk after planting. And the longest central shoots after 3 ½ months measured 128 cm. Plants in our experiment presented similar length earlier, at only one and a half months after planting. However, the author did not use Tifton 85 and the experiment was conducted in a soil with 60% clay in Israel, what could explain the smaller lengths observed in that study. Another study found that mean total shoot length at 43 DAP ranged from 3 to 26 cm (Patton et al., 2007). However, the authors averaged all the shoot lengths, while our study considered only the two longest shoots. Regarding soil cover level, partially covered presented longer shoots when using long stems. On the other hand, when using short stems, totally covered treatment had longer shoots. No differences for soil cover level were observed when using upper and lower stems.

There was an interaction of stolon type and soil cover for rate of growth (Table 3-8). When planted stems were totally covered, lower and short stems presented a growth rate measured between 2 wk in September higher than long and upper stems. When partially covered, lower stems presented higher rate than the short ones. And the rest did not differ. Partial soil cover resulted in a higher rate of growth than total cover when considering long and upper stems. Again, rate of growth was not a good variable to compare treatments. However, our experiment showed similar results to Burton et al. (1993), who indicated that shoots may grow as much as 7.5 cm d^{-1}. Also, Patton et al. (2007) observed shoot growth rate ranged from 1.7 to 11.3 mm d^{-1} when measured from 57 to 71 DAP, and Volterrani et al. (2012) reported rates from 4.9 to 38.3 mm d^{-1} when studying different turf bermudagrass species. Horowitz (1972b) observed that the rate of extension of bermudagrass in summer was only 35 cm per month after one year of growth.

Frequency

There was no interaction between DAP and other effects, but there was stolon type x soil cover interaction. Partially covered stolons had higher frequency than totally covered ones when using long and upper stems, and tended to have greater frequency when using lower and short stems ($P < 0.10$). When totally covered, lower stems showed greater frequency than upper and long ones, and longs stems shown also lower frequency than short stems. When partially covered, no differences among stolon types were observed.

When analyzing within each DAP, soil cover had a significant effect on frequency of Tifton 85 ($P < 0.05$; Figure 3-4). Partially covered stolons presented higher frequency percentage than totally covered stolons at all sampling dates. Probably, by having more emergence, as mentioned before, partially covered stolons showed well-spread plants throughout the planted area. Also, at 56 DAP, partially covered stolons had almost 80% of frequency, which we considered as a satisfactory value because it means most of the plot already presented plants. Although totally covered stolons still showed lower frequency at 98 DAP, this treatment presented 83%, which is above the threshold we consider satisfactory. Therefore, both treatments were efficient, but the differences between them are better reflected in other variables such as ground cover and dry matter production, which will be discussed later.

Mueller et al. (1992) observed that Coastal bermudagrass achieved adequate coverage when planted in 0.6-m rows, while Tifton 44 would require a row spacing of less than 0.3 m to produce the same degree of establishment of Coastal planted in 0.9-m rows. With good moisture distribution, Coastal reached 100% presence with 1.5-m row spacing. The year after establishment, however, Tifton 44 displayed greater ground cover than Coastal. In addition, in the same study, time for Coastal to reach 100% presence in 0.6-m row spacing ranged from 65 to 100 d, while Tifton 44 ranged from 80 to 95 in the best conditions and did not reach the threshold until 120 d when planted in a year with low moisture distribution (Mueller et al., 1992). This suggests that Tifton 85 presents similar establishment rate of Coastal, since all treatments showed satisfactory cover when planted in 1-m rows.

There was also a stolon type effect on bermudagrass frequency ($P < 0.05$; Figure 3-5). At 42 DAP, lower stems had greater frequency than long ones and this difference was observed until the last sampling, at 98 DAP. Other treatments did not differ. Also, lower stems reached

80% frequency earlier (at 56 DAP) than other treatments. And at 98 DAP, all treatments but long stems had surpassed this threshold. One possible explanation for the inferior performance of the long stolons is that there were only three stolons in each plot. Therefore, if one was not viable and ended up dying, one third of the material was lost. This was observed in the field, where medium stolons presented some satisfactory growth. However, some plots showed parts with the soil totally bare, indicating that at least one of the stolons was not able to emerge, reducing the overall performance of this treatment.

Although Stichler and Bade (2003) suggested that stolons of bermudagrass should be 45 to 60 cm long with at least six nodes, in this experiment, short fragments with only three nodes presented similar emergence and frequency than longer stolons (with 6 and 8 nodes). Therefore, this suggests that short stolons will not be able to root because they are not mature enough. However, if long mature stolons are cut into pieces, they can yield similar emergence results as long stolons.

When comparing levels of soil cover using long stems, no interaction of treatments and DAP was observed. Frequency within each DAP is shown in Figure 3-6. There was no difference in frequency between partially covered and wavy treatments. These treatments presented more than 90% frequency at 98 DAP and it was greater than totally covered.

Ground Cover

All types of stolons presented similar ground cover percentage at 100 DAP. Although long stems showed inferior frequency than the lower ones, these treatments were not significantly different in the ability to cover. On the other hand, there was a soil cover effect on ground cover ($P < 0.05$; Table 3-9). Partially covered stolons exhibited 90% bermudagrass cover and it was greater than totally-covered stolons, which did not reach the threshold (80%).

Similar to frequency, when comparing three levels of soil cover using long stems, partially covered and wavy showed higher ground cover than totally covered (Table 3-10). While the first two treatments presented means greater than 80%, totally covered had 44% ground cover and it was not considered satisfactory.

Herbage Dry Matter (DM) Harvested

There was only soil cover effect for DM harvested. When stolons were planted partially covered, DM harvested was 2040 kg ha^{-1}, while when totally covered treatments the average was 1040 kg ha^{-1} (Table 3-9). These values are in agreement with results from Mueller et al. (1992), who studied the establishment of two bermudagrasses in three environments. The authors found that DM production for Coastal ranged from 1160 to 2960 kg ha^{-1} and for Tifton 44 from 340 to 2980 kg ha^{-1} (Mueller et al., 1992), when planted in 0.6-m row spacing.

Because partially covered stolons presented greater emergence, frequency, and cover, this treatment provided a full canopy earlier and thus photosynthesis and growth were likely increased. Therefore, higher DM harvested was observed at the end of the season. Differently from Fernandez (2003), which showed that total plant mass was size dependent, no difference was observed among stolon types for DM. The difference the author found was probably because the dry matter was measured after only 4 wk, while in this study the harvest was after 14 wk. Then, treatments using short stems had time to compensate and catch up with other treatments.

When comparing levels of soil cover using long stems, partially covered and wavy had DM harvested greater than 1500 kg ha^{-1} and this was higher than totally covered, which showed less than 600 kg ha^{-1} (Table 3-10).

Conclusions and Implications

Partially covered bermudagrass planting material produced up to 16 shoots m^{-2} and showed more than double the shoot emergence of totally covered stolons at 31 DAP. Similar results were observed for percent frequency. When stolons were partially covered, greater frequency was observed at all sampling dates and 80% frequency was reached earlier (56 DAP). At 98 DAP, the difference was still evident, but both treatments showed satisfactory frequency. However, when bermudagrass ground cover was assessed, partially soil-covered stolons resulted in greater bermudagrass cover, and totally soil-covered stolons showed less than 70% ground cover. Dry matter harvested was almost two-fold greater for partially-covered than totally-covered stolons (2040 vs. 1040 kg ha^{-1}, respectively). When comparing three levels of cover using long stems, totally cover had the worst performance for all the response variables. Partially cover and wavy were not different, indicating that by having any part of the stem uncovered is already enough to improve the establishment. This study showed that partial coverage of stolons accelerated emergence, cover, and frequency and increased DM harvested at the end of the first growing season. Therefore, when planting, some parts of the stolons should remain uncovered to enhance establishment. This can be done with disk blades slightly angled to achieve low depth. In this manner, stems are not buried too deep and some parts will remain above ground even after rolling.

Regarding stolon type, short stems presented greater emergence at first sampling dates, but soon after they slowed their rate and at 31 DAP lower stems showed more shoots per square meter than long stems and tended to have more shoots than short ones. Planting the lower section of stolons resulted in greater frequency than long ones and this difference was observed until the last sampling, at 98 DAP. Other treatments did not differ. Stolon type had no significant effect on ground cover and DM harvested at the end of the establishment year. The two longest shoots presented an average of 5 and 8.5 nodes at 30 DAP and 43 DAP, respectively and their average length ranged from 82 to 151 at 43 DAP. The rate of growth ranged from 2.1 to 5.9 cm d^{-1} when evaluated from 30 to 43 DAP. These variables, however, were not efficient to compare stolon type and soil cover treatments. The more mature portion of the stolon, which is in the lower section, seems to provide the most viable nodes. This suggests that when cutting the material from the nursery, a low stubble height should be used.

Table 3-1. Rainfall, evapotranspiration and air temperature (2 m) for the period the experiment was in the field

Month	2011 Rainfall	2011 ET	2011 Air Temperature	2012 Rainfall	2012 ET	2012 Air Temperature
	------------mm-----------		ºC	------------mm-----------		ºC
Aug	131	140	27	209	124	27
Sept	147	105	25	168	105	26
Oct	119	78	20	39	78	22
Nov	24	53	18	1	45	16
Dec	15	39	16	138	39	16

Table 3-2. Average and total length of emerged shoots from four stolon types at different days after planting (2011)

Stolon type	Average length (cm)			Total length (cm)		
	6 DAP	13 DAP	20 DAP	6 DAP	13 DAP	20 DAP
Long	0.2 b†	11 ns	11 ns	0.3 b	53 ns	146 b
Upper	0.2 b	11	12	0.2 b	110	273 ab
Lower	0.9 a	9	10	3.9 a	110	348 a
Short	1.0 a	7	10	3.3 ab	71	183 b
Average	0.6	10	11	1.9	86	238

†Within DAP, means with same letter are not significantly different (P > 0.05). † ns – within DAP, means are not significantly different.

Table 3-3. Average and total length of emerged shoots for two soil cover treatments at different days after planting (2011)

Soil cover	Average length (cm)			Total length (cm)		
	6 DAP	13 DAP	20 DAP	6 DAP	13 DAP	20 DAP
Total	0.6 ns†	9 ns	11 ns	2.7 a	60 b	151 b
Partial	0.5	10	11	1.1 b	112 a	324 a

†Within DAP, means with same letter are not significantly different (P > 0.05).

Table 3-4. Number of nodes of the two longest stolons for four stolon types at the 30 and 43 DAP (2011)

Stolon type	30 DAP	43 DAP
Long	4.4 ns†	7.6 ns
Upper	5.3	9.4
Lower	6.0	10.8
Short	4.9	9.2

†ns – within DAP, means are not significantly different ($P > 0.05$).

Table 3-5. Number of nodes of the two longest stolons for two soil cover treatments at the 30 and 43 DAP (2011)

Soil cover	30 DAP	43 DAP
Total	5.0 ns†	8.8 ns
Partial	5.3	9.7

†ns – within DAP, means are not significantly different ($P > 0.05$).

Table 3-6. Length of the two longest shoots at 30 DAP for each treatment combination (2011)

Stolon type	Totally covered			Partially covered		
		--------------------------cm-----------------------				
Long	A†	41	b	A	58	ab
Upper	A	66	a	A	62	ab
Lower	A	62	ab	A	78	a
Short	A	67	a	A	50	b

†Means within the same row preceded by a similar uppercase letter or within columns followed by a similar lowercase letter do not differ ($P > 0.05$).

Table 3-7. Length of the two longest shoots at 43 DAP for each treatment combination (2011)

Stolon type	Totally covered			Partially covered		
	---------------------------	---	cm	---	------------------------	
Long	B†	82	b	A	122	ab
Upper	A	109	ab	A	128	ab
Lower	A	124	a	A	151	a
Short	A	137	a	B	100	b

†Means within the same row preceded by a similar uppercase letter or within columns followed by a similar lowercase letter do not differ (P > 0.05).

Table 3-8. Rate of growth of the two longest stolons measured between 30 and 43 DAP for each treatment combination (2011)

Stolon type	Totally covered			Partially covered		
	---------------------	---	cm day^{-1}	---	---------------------	
Long	B†	2.1	b	A	4.9	ab
Upper	B	3.3	b	A	5.1	ab
Lower	A	4.8	a	A	5.9	a
Short	A	5.4	a	A	3.9	b

†Means within a row preceded by a similar uppercase letter or within columns followed by a similar lowercase letter do not differ (P >0.05).

Table 3-9. Percentage of bermudagrass cover and herbage dry matter (DM) harvested for two soil cover treatments at the end of the year of establishment (100 days after planting; 2011)

Soil cover	Percentage cover	DM (kg ha^{-1})
Total	66 b†	1040 b
Partial	90 a	2040 a

†Means within a column with same letter are not significantly different (P > 0.05).

Table 3-10. Percentage of bermudagrass cover for three soil cover treatments at the end of the year of establishment (100 days after planting) using long stems (2011)

Soil cover	Percentage cover	DM (kg ha^{-1})
Total	44 b†	580 b
Partial	86 a	1840 a
Wavy	82 a	1590 a

†Means within a column with same letter are not significantly different (P > 0.05).

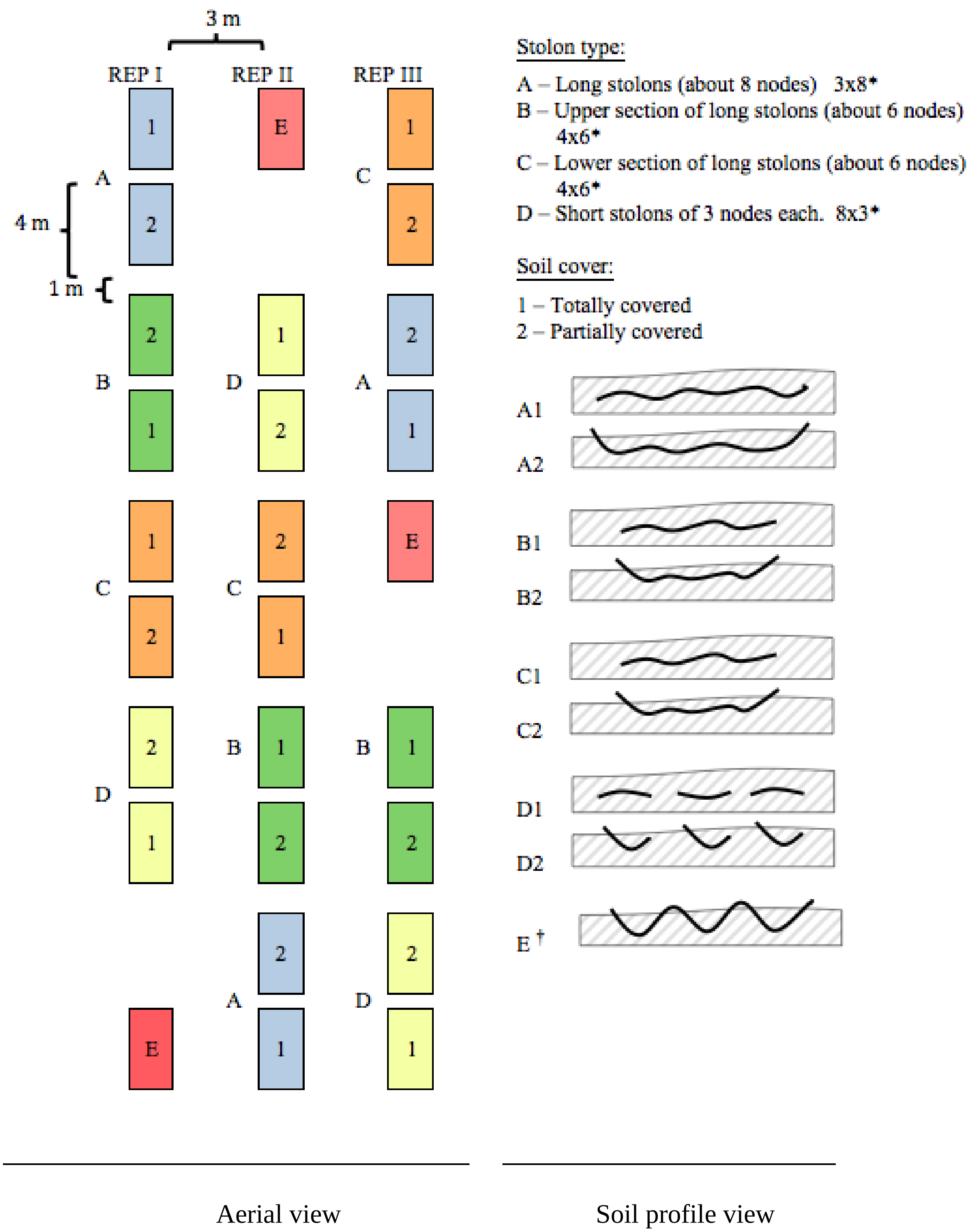

Figure 3-1. Layout of the treatments in the field. Left section shows an aerial view of plots where experimental units (stolon type x cover treatment combinations) are represented in color. Section on the right shows soil profile at 6 cm to facilitate visualization of stolon type soil cover. * = number of stolons x number of nodes † another level of soil cover, used to compare with treatments A1 and A2.

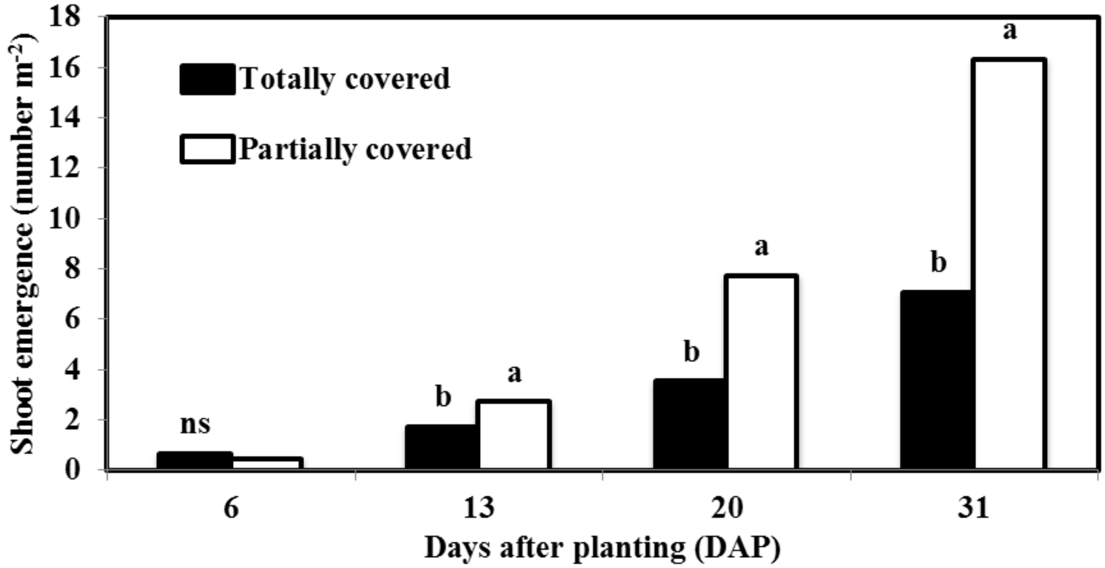

Figure 3-2. Number of shoots as affected by extent of soil cover at different days after planting (2011). Within DAP, bars with same letter are not significantly different (P > 0.05).

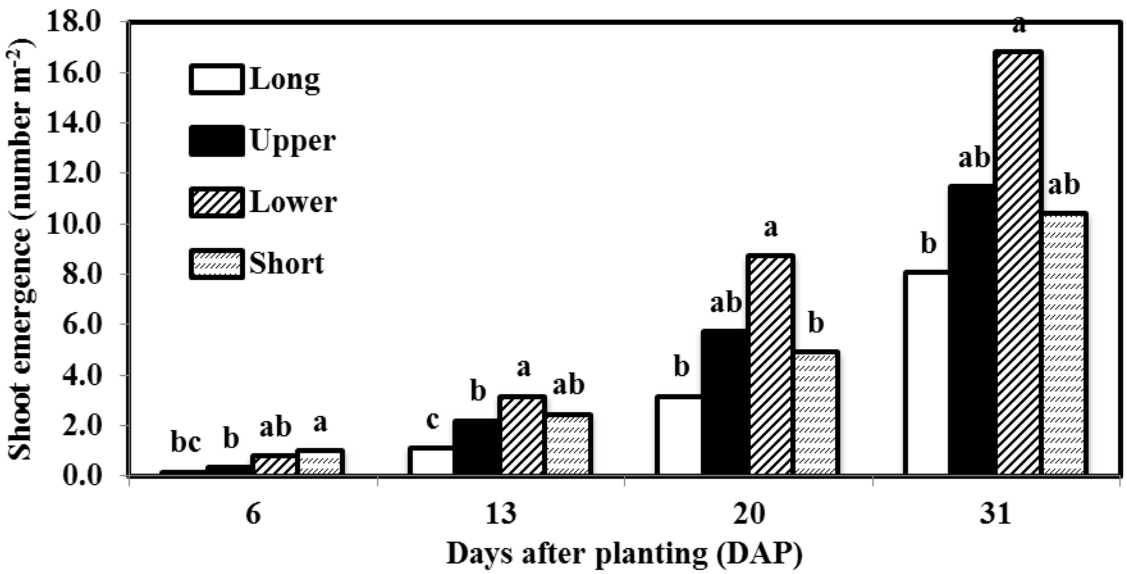

Figure 3-3. Number of shoots as affected by four stolon types at different days after planting (2011). Within DAP, bars with same letter are not significantly different (P > 0.05).

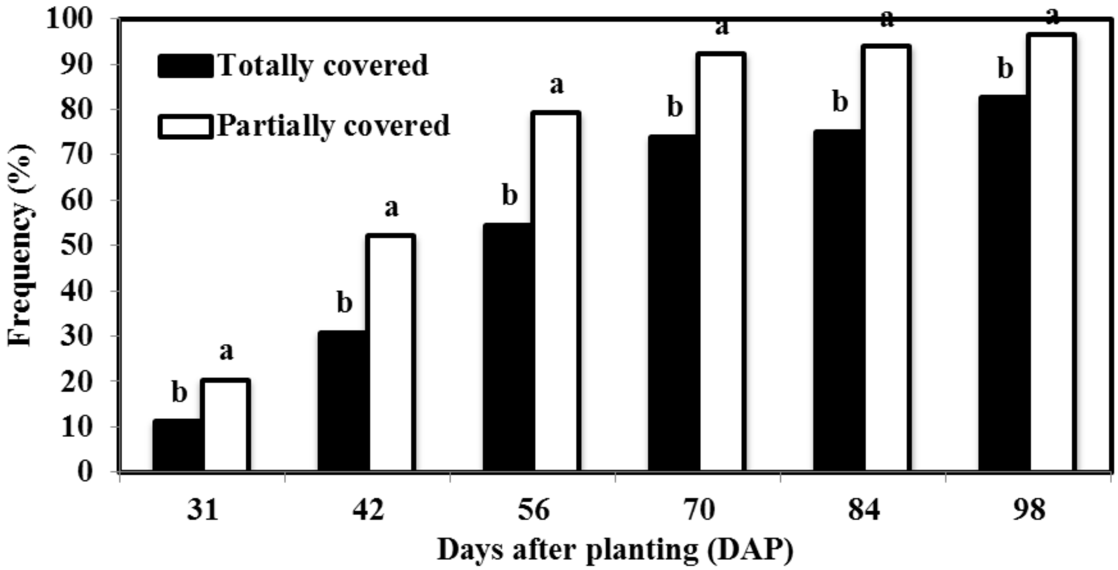

Figure 3-4. Percentage of bermudagrass frequency for two soil cover treatments averaged across stolon types at different days after planting (2011). Within DAP, bars with same letter are not significantly different (P > 0.05).

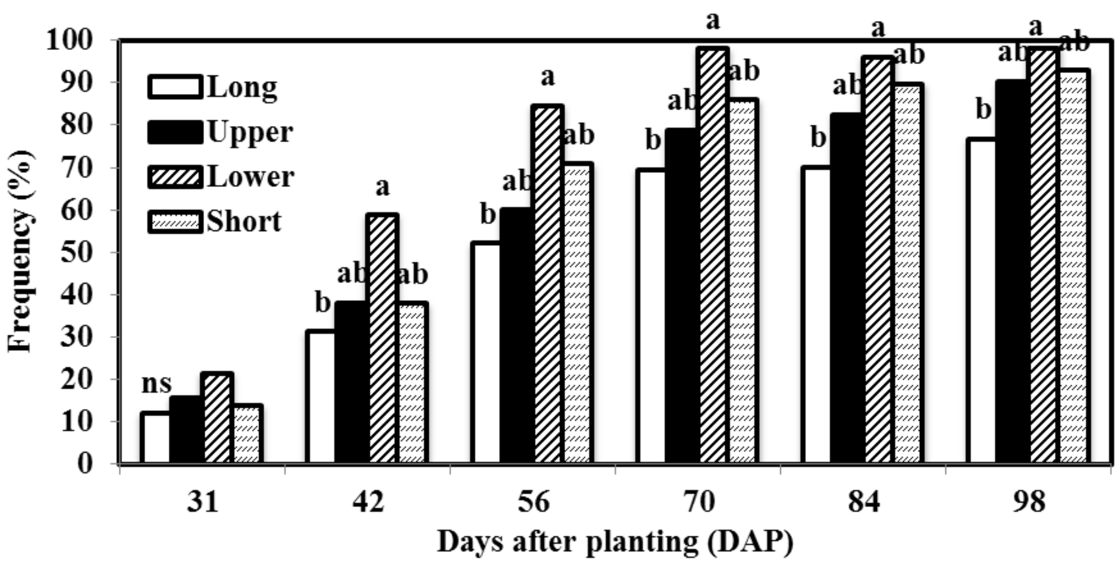

Figure 3-5. Percentage of bermudagrass frequency comparing different stolons types averaged across soil cover at different days after planting (2011). Within DAP, bars with same letter are not significantly different (P > 0.05).

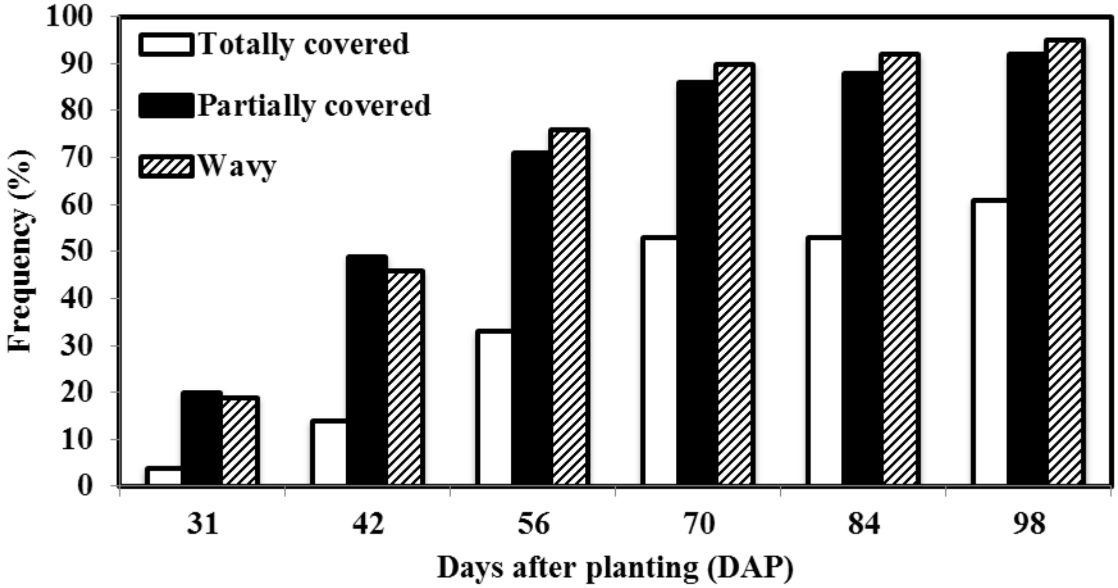

Figure 3-6. Percentage of bermudagrass frequency comparing three levels of soil cover using long stems (2011). No interaction of soil cover and DAP was observed.

CHAPTER 4
STOLON PLANTING DENSITY EFFECTS ON BERMUDAGRASS ESTABLISHMENT

Sandy soils in Florida, particularly in the Suwannee River basin, present rapid permeability and low moisture retention (Soil Survey Staff, 2013). Stolons are more susceptible to desiccation than dormant rhizomes and low survival of stolons has been reported when they were exposed to low relative humidity (Webb, 1959). When planted in coarse sands, stolons may die if soil water is limited and, in turn, the establishment will fail. Because of the prospect of desiccation, more material may be required to compensate for loss of stolons. Higher planting rates will ensure more rapid colonization and ground coverage. Therefore, when planted in late summer, higher rates may be necessary to increase number of rooted plants before freeze and improve survival during winter.

Recommended stolon planting rates cover a large range and establishment failures continue to be reported in the coarse sandy soils of north central Florida (Newman, Y.C., 2011, personal communication). Few studies exist that evaluate planting rate effects on time to established stand under deep sand conditions such as those of the Suwannee River basin that tend to favor water depletion conditions for planting material even under irrigated conditions. Although recommended rates are not always effective and higher rates may allow achievement of full ground cover faster, higher planting rate means higher establishment costs. An effective rate with minimum additional costs is required to improve establishment.

The hypothesis of this research is that higher planting rate will improve establishment and enhance cost-benefit ratio. Lower rates were also used to verify their cost-effectiveness. The objective was to quantify the effects of stolon planting rates on Tifton 85 cover and frequency, weed cover and Tifton 85 herbage mass accumulation.

Material and Methods

Study Site

This study was conducted during two seasons: from September 2011 to August 2012, and from September 2012 to June 2013. The study was located on a commercial dairy farm, Alliance Dairies, near Trenton, Gilchrist County, North Central Florida in two different locations (29° 41' 10.8” N, 82° 49' 36.7” W) and (29° 34' 52” N, 82° 53' 7” W) under irrigation. The soil at the first experimental site is classified as Bonneau fine sand (loamy, siliceous, subactive, thermic Arenic Paleudults). The second site is classified as Jonesville-Otela-Seaboard complex (sandy and loamy marine deposits over limestone). Both locations are within the Suwanee River basin and with the same characteristics previously discussed in Chapter 3, such as rapid permeability and low fertility. At the first site, soil pH was 5.7, Mehlich 1 extractable P, K, Mg, and Ca were 41 (high), 28 (low), 33 (medium), and 425 ppm in 2011, respectively. At the second site, soil pH was 5.5, Mehlich 1 extractable P, K, Mg, and Ca were 16 (medium), 28 (low), 26 (medium), and 248 ppm in 2012, respectively.

Experimental Variables and Statistical Design

The experimental variable for this 2-yr study was planting density at five levels (Very Low – 1120 kg ha^{-1}; Low – 1570 kg ha^{-1}; Medium – 2020 kg ha^{-1}; High – 2470 kg ha^{-1}; and Very High – 2920 kg ha^{-1}). The experiment was analyzed as a randomized complete block design with four replicates, for a total of 20 experimental units (Figure 4-1). Plots were 7.2 x 7.2 m (51.8 m^2) and alleyways between plots were 2.4-m wide. Planting densities were selected based on the rates likely used by producers in the Suwannee River basin area. The Low rate is similar to the recommended rate, and lower and higher rates than Low were used in order to assess their effect on cost and rate of establishment.

Field Procedures

Before planting, the soil at the experiment site was plowed to eliminate weeds. As in Experiment 1, planting material consisted of stolons or green stem cuttings planted during the summer. A planting material nursery was prepared close to the experimental site. In this nursery the bermudagrass was fertilized in June and July with 45 kg N ha^{-1} per application (plus P, K, and micro minerals following a soil test). Stolons with approximately 3 ½ months of regrowth were cut and baled wet using a small square baler (New Holland BC 5000 series). Each bale weighed approximately 35 kg to facilitate handling. Bales were transported to the experimental site soon after harvesting. Stolons were spread by hand (simulating commercial slinger broadcasting). Afterwards, stolons were incorporated using a disk followed by a roller pass to pack the soil and preserve soil moisture. Irrigation was done using a center pivot and based on soil moisture. Water application started when volumetric water content was 7% and until it reached 10% or a maximum of 12 mm per irrigation cycle. Rainfall, evapotranspiration and air temperature are shown in Table 4-1. Planting was conducted on 9 Sept. 2011 and 18 Sept. 2012. No weed control was implemented prior to first freeze. In spring, the field was sprayed on 25 May 2012 using 2.3 L ha^{-1} of GrazonNext (*aminopyralid + 2,4-D*) and on 21 March 2013 using 2.3 L ha^{-1} of Weedmaster (*dicamba + 2,4-D*). Fertilization consisted of 45 kg of N ha^{-1} soon after planting, 35 kg of N ha^{-1} in October and November and then the same amount of N every month beginning in March.

Response Variables and Sampling

The response variables measured in this study were emergence (number of shoots m^{-2}), frequency (presence/absence of plants throughout the plot) and ground cover percentage, percentage of weeds, and DM harvested. Emergence was evaluated by the number and length of shoots assessed in three 1-m x 1-m samples distributed in the plot's diagonal at 14 DAP. Shoot lengths were averaged among all shoots observed in these three samples. Total shoot length is the average of the three samplings (cm m^{-2}). After the first month, frequency and ground cover percentage were assessed biweekly until the end of the season, when plants became dormant and stopped growing. Frequency and ground cover percentage were measured with three samples distributed in the plot's diagonal and using the same approach as in previous study described in Chapter 3. Frequency and ground cover were considered complete when percentage was above 80%.

Percentage of weeds was estimated visually for the whole plot at the beginning of the following growing season in April. Dry matter (DM) harvested was first assessed in May of the year after planting, when plants were ready to be grazed and had an average height of 19 cm. A 1.2- x 7.2-m strip was harvested using a Peruzzo mower, model Canguro Normal, leaving an 8-cm stubble. Fresh weight was measured and then subsamples of approximately 500 g were taken to the oven and dried at 65°C until constant weight to determine dry weight. Also, one 0.15-m^2 quadrat per plot was clipped to an 8-cm stubble and the material was separated between Tifton 85 and weeds. Samples were dried and the ratio used to estimate total Tifton 85 dry matter harvested for the entire plot. Dry matter harvested was assessed using the same approach every 4 wk until the end of the growing season after the establishment year and cumulative DM harvested was also determined.

Statistical Analysis

Data were analyzed using PROC MIXED procedures of SAS (SAS Institute Inc.). In all models, planting density and DAP were considered fixed effect; replicates and their interactions were modeled as random effects. When the interaction of DAP and other effects was significant, analysis was conducted within each DAP. Total DM harvested was calculated as the sum of DM harvested from each harvest during the growing season. Mean separation was further accomplished using least-square means and the PDIFF option in SAS, which gives a table of p-values for all possible pairwise comparisons. All test differences were considered significant at $P \leq 0.05$, while values at $P \leq 0.10$ were further discussed as trends. Only 2011 data are being reported.

Results and Discussion

Emergence

Planting density had a significant ($P < 0.05$) effect on shoot emergence and total length (Table 4-2). Medium, high, and very high rates presented greater number of new Tifton 85 shoots than low and very low rates. As expected, increasing the amount of planting material increased emergence. There was no difference for average shoot length among planting rates. New shoots averaged 9 cm at 14 DAP, similar to what was observed for Experiment 1, where new shoots averaged 10 cm at 13 DAP. When considering the total length of shoots, again, there was a difference among planting rates. Medium, high, and very high treatments presented greater total length than low and very low rates.

Frequency

There was interaction of density and DAP. When data were analyzed within DAP, planting density affected bermudagrass frequency (Figure 4-2). At the first sampling date, very high density presented greater frequency percentage than low and very low. At 41 DAP, medium, high and very high densities reached 80% threshold frequency and were higher than low and very low. Other treatments only surpassed this threshold at 69 DAP. Later, at 83 DAP, lower densities caught up with the other treatments and no difference was observed. At 117 DAP all treatments presented close to 100% frequency, meaning that all the treatments showed plants well spread throughout the plot.

Although the experiment was planted in late summer, all the treatments presented satisfactory establishment, confirming observations of Stichler and Bade (2003) who recommend planting stolons in the southeast USA from late April through September, as long as soil moisture is sufficient. Although they indicate that planting in the late spring or early summer is associated with greater survival, because the experiment was under irrigation, all treatments had enough time to form roots and become well established before frost that occurred on 4 Jan 2012. Chambliss and Dunavin (2003) also showed that in peninsular Florida, some bermudagrasses have been successfully established from late summer and fall planting as long as the soil moisture is adequate and a relatively mild winter follows.

Bermudagrass Ground Cover

Similar results were observed on percentage of ground cover. Interaction of DAP and density was significant and then data were analyzed within DAP. Planting density had a significant ($P < 0.05$) effect on ground cover. Very low rate presented lower ground cover until 83 DAP (Figure 4-3). Higher rates reached 80% ground cover earlier than very low. Medium and very high densities reached 80% at 83 DAP and they were not different from low and high. No difference was observed at 117 DAP. Lazo et al. (1995) observed acceptable cover at 176 DAP using 2000 kg ha^{-1} and a sparse stand using 1000 kg ha^{-1}. In this study, however, even the very low rate (1120 kg ha^{-1}) achieved adequate cover at 117 DAP. Considering the days to reach a threshold of 80%, medium, high and very high planting densities reached this milestone earlier than very low and low planting densities for frequency and earlier than very low for ground cover (Figure 4-4). Very high rates reached 80% cover in about 75 d, while very low rates took 96 d to achieve the same percentage. Although they were not significantly different at the last sampling date, these 21 d in difference to reach a satisfactory cover can really make a difference, because by having more cover, weed competition is suppressed. And this, in fact, was reflected on the other responses assessed the following year.

Using information on *Cynodon* spread from turfgrass science, the study of Guertal and Evans (2006) had similar results using ‘TifEagle’ bermudagrass sprigs planted during summer in a loamy sand soil in Alabama. Time to reach 90% ground cover using turfgrass ranged from 7 to 10 wk after planting. Also, Johnson (1973) observed that ground cover was affected by planting density using ‘Tifway’ bermudagrass stolons only early in the season. At 7 and 11 wk after planting, high density presented higher ground cover than medium and low rates. However, planting rate did not influence the final establishment after 24 wk. Therefore, combining their results and our findings when planting is accomplished in spring, lower rates can still provide satisfactory ground cover by the end of the growing season.

In a study that compared different herbicides during establishment of Tifton 85 using rhizomes in Texas, lower ground cover percentages were found at 90 DAP. When controlling the weeds soon after planting, they observed maximum of 56% ground cover (Butler et al., 2006). Although they have observed relatively low percentages even when controlling weeds, the untreated control presented 2 to 5% ground cover. This suggests that under their condition and without proper weed management, establishment is decreased and comparable to using low planting rates.

Burton et al. (1993) found that Tifton 85 can completely cover the ground in less than 3 mo when it is grown in a favorable environment without weed competition. Our results agree with their findings, and in our study, the medium, high and very high planting rates presented ground cover greater than 80% at 83 DAP. The very low rate, however, took longer to achieve the same percentage and also showed more weed competition.

Bingham and Hall (1985) observed that 'Vamont' bermudagrass reached 80 to 90% ground cover at 5 to 8 wk after planting, depending the year. Also, another cultivar of bermudagrass, 'Midiron' took as long as 12 wk to achieve the same percentages. Keeley and Thullen (1989) showed that planting from May to August hastened the establishment and achieved 80% coverage of soil surface by tillers and stolons at 8 wk after planting. They also indicated that cool temperatures and shorter photoperiods considerably slowed the growth of September plantings. In our experiment, however, even planting in September, medium, high and very high presented ground cover over 80% at 55 DAP, indicating that increasing planting density could compensate the unsatisfactory environmental conditions of late planting.

Weed Cover

Very low stolon planting density presented the highest weed cover (over 20%) and was greater than all the other treatments when visually estimated in April of the following year ($P < 0.05$; Figure 4-5). Medium, high, and very high planting densities showed less than 7% weed cover. Also, when estimating weed herbage DM in May, about one third of the total DM herbage production from very low and low planting densities consisted of weeds and both presented greater weed herbage DM than medium, high and very high densities (Figure 4-6). Weeds observed included species such as cudweed (*Gnaphalium sp*.), dogfennel (*Eupatorium capillifolium*), red sorrel (*Rumex sp*.), nutsedge (*Cyperus rotundus*), and bahiagrass (*Paspalum notatum*).

Bermudagrass Herbage DM Harvested

The interaction of harvest and density was significant; therefore data were analyzed within each harvest. At the first harvest, as expected, medium, high and very high presented significantly more herbage DM than low and very low planting rates ($P < 0.05$; Figure 4-6). Very high planting density yielded almost 4700 kg ha^{-1}, while very low and low yielded 1,980 and

2270 kg ha^{-1} respectively. In a study in Texas, using plants of Tifton 85 started in pots in the greenhouse and transplanted in May 0.6-m apart within each of two rows 0.9-m wide, Evers et al. (2001) observed over 5600 kg ha^{-1} in November of the establishment year.

At second harvest, lower rate treatments caught up and no differences were observed (Figure 4-7). This result corroborates what was stated by Kays and Harper (1974), who observed the multiplication and death of tillers act together to regulate the population and to determine that the density of tillers per unit area become independent of planting density, i.e., if grown for longer periods, low planting densities are able to compensate and yield as much as higher planting densities. Considering the cumulative DM, by the end of the season, high and very high planting densities presented greater cumulative DM than very low and low with total of over 16000 kg ha^{-1} yr^{-1} (Figure 4-8). This is higher than reported by Evers et al. (2001), who showed that Tifton 85 yielded over 9000 kg ha^{-1} accumulated herbage DM in the year following establishment. However, their experiment was not under irrigation, and the cumulative rainfall from April to July was below 125 mm. Good rainfall occurred in August through October, but an extreme infestation of armyworms also restricted the growth and decreased the yield. In our study, there was a significant linear increase in cumulative DM with an increase in the planting density (Figure 4-9). The very low density (1120 kg ha^{-1}) presented the lowest cumulative DM (13050 kg ha^{-1}) and the very high (920 kg ha^{-1}) showed the greatest (16600 kg ha^{-1}).

Stolon Planting Costs

Planting material is the highest expense of total establishment costs. It is clear that depending on the planting rate used, the size of the field that can be planted will be considerably different. The approximate yield of stolons of a nursery is variable but for following calculations we will consider the planting material to be 3-mo old with an average yield of 26000 kg ha^{-1}. Considering the planting rates used in this study, with 1 ha of nursery it would be possible to plant 23 ha using very low rate (1120 kg ha^{-1}; Table 4-3). On the other hand, if very high rate (2920 kg ha^{-1}) is used, only 9 ha can be planted with the same nursery. Therefore, about 2.6 times additional land is required to plant the same amount.

Also, if a producer needs to plant an area of 100 ha, he will need a nursery of 4 ha if using very low rate or 11 ha if using very high rates. This is an increase in 160% on nursery area required. Furthermore, if the producer does not have the area required to grow a nursery, he will have to buy the material or hire somebody to do all the work and then the costs will be even higher.

The costs for planting material only are presented in Table 4-2. The price of each planting bale of Tifton 85 stolons (about 35 kg) is considered to be $4 ($0.11 kg^{-1}). Also, the price to contract someone for planting is approximately $360 ha^{-1} using a low rate of about 1600 kg ha^{-1}. Therefore, considering the economic return of each treatment in the following year and since there is no difference in DM between medium and high rates, the cost-benefit of using high rate is not favorable, since one would be paying $51.00 ha^{-1} more without having an increase in the financial return.

Conclusions and Implications

Higher planting rates presented greater bermudagrass frequency. At 41 DAP, medium, high, and very high stolon planting rates achieved 80% frequency. Other treatments reached the same value later and at 117 DAP there was no difference among rates and all treatments showed frequency close to 100%. Similar results were observed for ground cover percent. Very low planting rate presented lower ground cover up to 83 DAP and higher rates reached 80% cover earlier. No difference was observed at 117 DAP. Very high planting rates achieved 80% ground cover 21 days earlier than very low, and this difference was reflected in other responses the following year.

Very low stolon planting density showed the highest weed cover (over 20%) in April of the following year, while medium, high and very high presented less than 7%. And approximately one third of the total herbage DM of very low and low rates consisted of weeds. At the first harvest, medium, high, and very high planting rates yielded significantly more than low and very low rates. Subsequent harvests did not show difference due to planting rate, and by the end of the season, high and very high planting rates presented greater cumulative herbage DM than low and very low rates.

In summary, all the treatments presented satisfactory ground cover three months after planting. However, the higher the density, the earlier 80% ground cover and frequency were achieved. This, together with the fact that very low and low rates showed higher weed competition in spring, led to greater DM accumulation early in the following year using medium, high and very high rates. Also, cumulative DMs for very high and high planting rates were greater than low and very low rates. Considering the conditions of this study and all the response variables analyzed, medium stolon planting seems to provide a good compromise on effective establishment and cost.

Table 4-1. Rainfall, evapotranspiration and air temperature (2 m) for the period the experiment was in the field.

Year	Month	Rainfall	ET	Air Temperature
		------------------mm------------------		ºC
2011	Aug	131	140	27
	Sept	147	105	25
	Oct	119	78	20
	Nov	24	53	18
	Dec	15	39	16
2012	Jan	33	47	14
	Feb	41	60	17
	Mar	39	91	21
	Apr	26	120	22
	May	84	140	25
	Jun	301	128	26
	Jul	167	140	27
	Aug	209	124	27

Table 4-2. Shoot emergence, average and total shoot length for five planting densities at 14 DAP (2011)

Planting rate	Shoot emergence	Average length	Total length
	number m^{-2}	----------------cm------------	
Very low	13 b†	8.5 ns	108 b
Low	18 b	9.2	166 b
Medium	29 a	9.3	267 a
High	27 a	9.1	243 a
Very high	32 a	9.3	300 a

†Means within a column followed by the same letter are not significantly different ($P > 0.05$), ns – non-significant.

Table 4-3. Number of hectares that can be planted with a 1-ha nursery and cost of planting material for each planting rate using stolons

Planting rate	Rate	1 ha of nursery can plant	Cost
	kg ha^{-1}	ha	\$ ha^{-1}
Very low	1120	23	128
Low	1570	17	180
Medium	2020	13	231
High	2470	11	283
Very high	2920	9	334

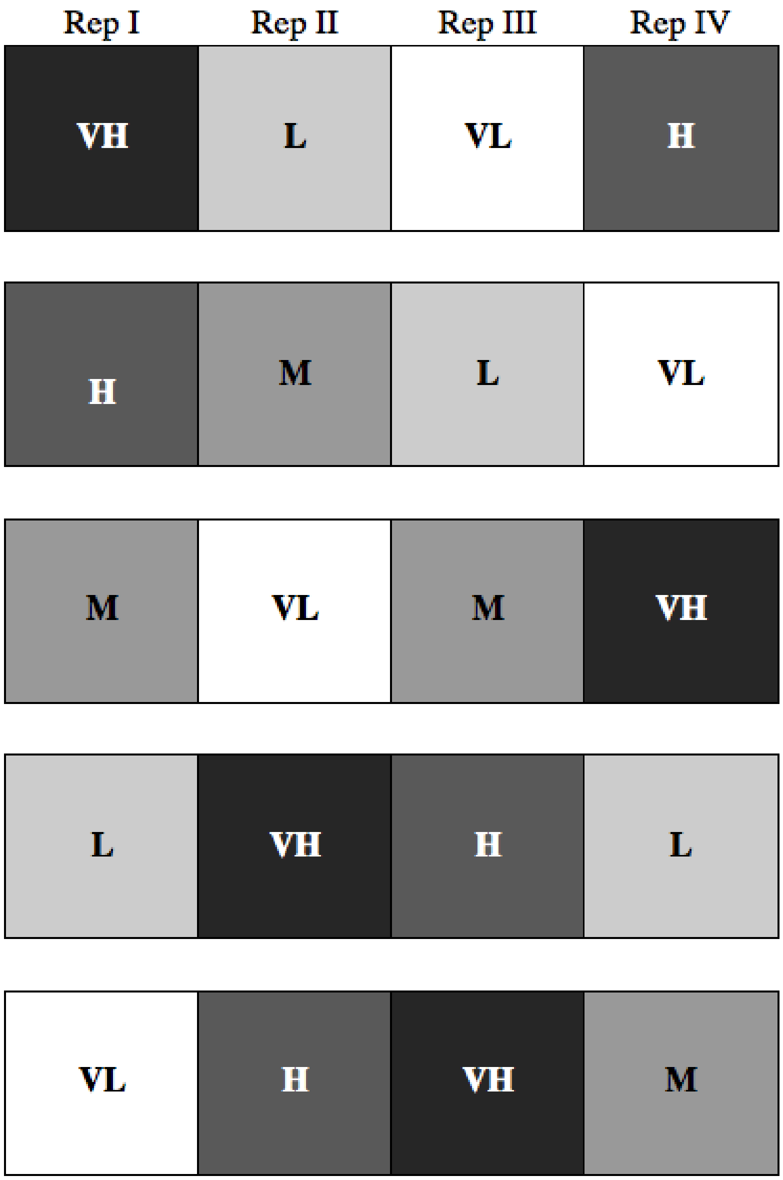

Figure 4-1. Layout of the treatments in the field. Plots size was 7.2 x 7.2 m. Stolon planting density treatments were: Very Low (VL) – 1120 kg ha^{-1}; Low (L) – 1570 kg ha^{-1}; Medium (M) – 2020 kg ha^{-1}; High (H) – 2470 kg ha^{-1}; and Very High (VH) – 2920 kg ha^{-1}

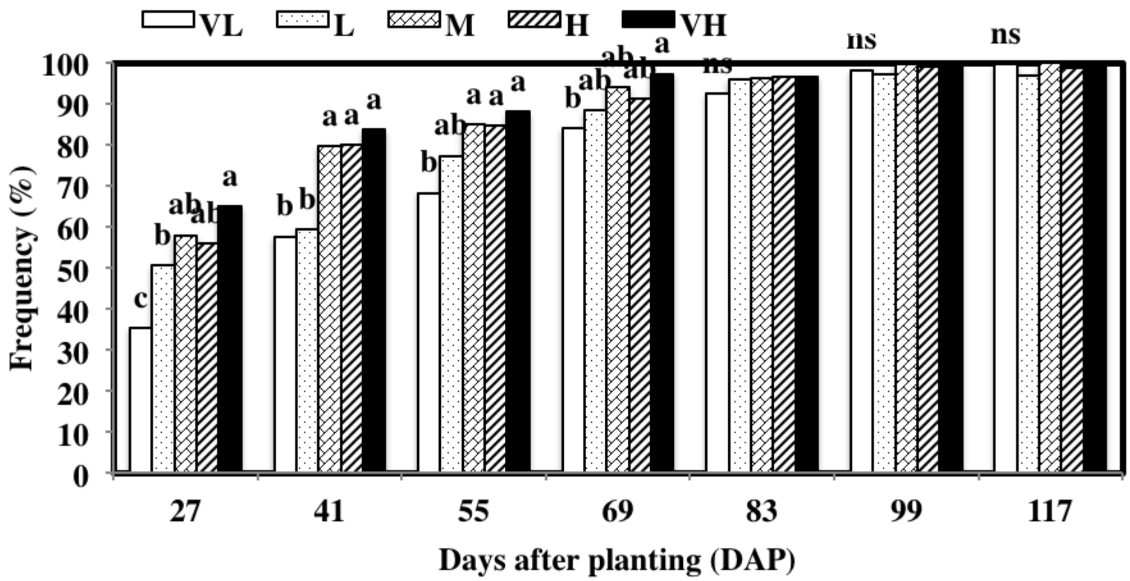

Figure 4-2. Bermudagrass frequency for five stolon planting densities at different days after planting (2011). Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Within DAP, bars with same letter are not significantly different (P > 0.05), ns – non-significant.

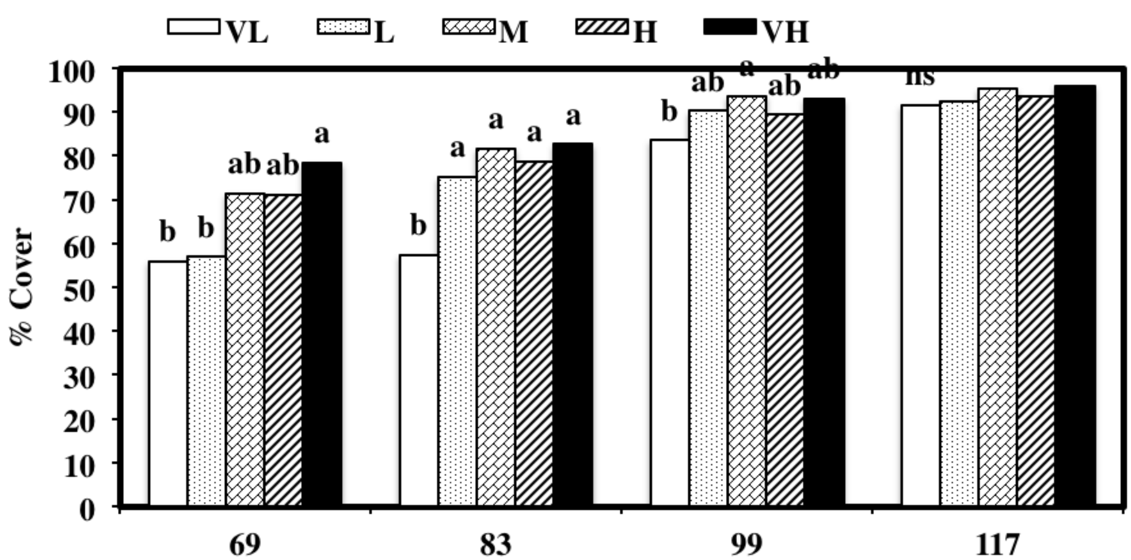

Figure 4-3. Bermudagrass ground cover for of five stolon-planting densities at different days after planting (2011). Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Within DAP, bars with same letter are not significantly different (P > 0.05), ns – non-significant.

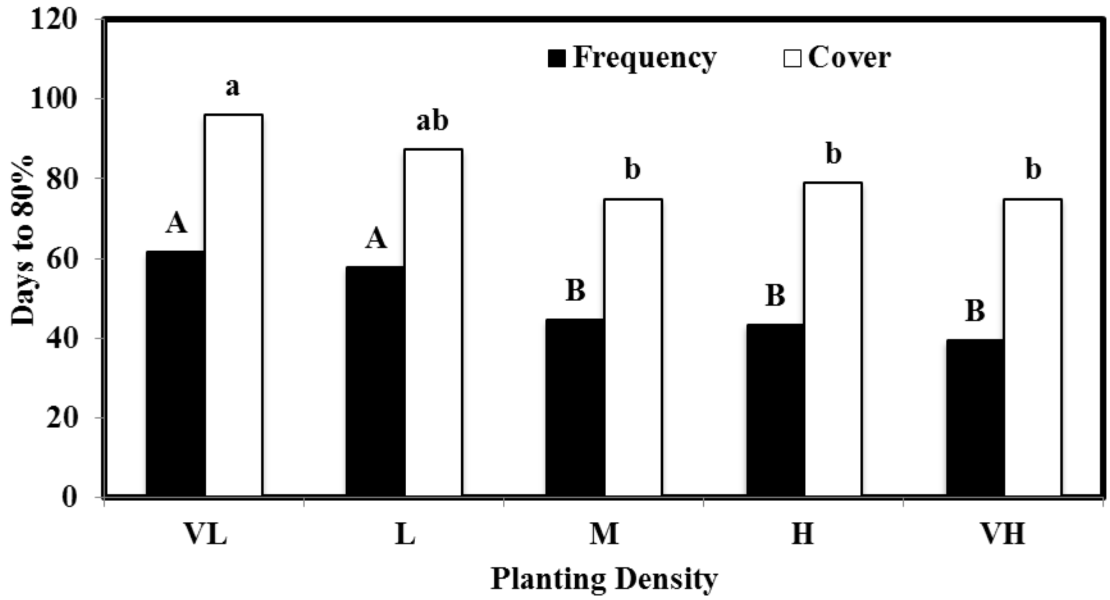

Figure 4-4. Days to reach 80% bermudagrass frequency and ground cover for five stolon planting densities (2011). Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Bars with same uppercase (frequency) letter or lowercase (cover) letter are not significantly different ($P > 0.05$).

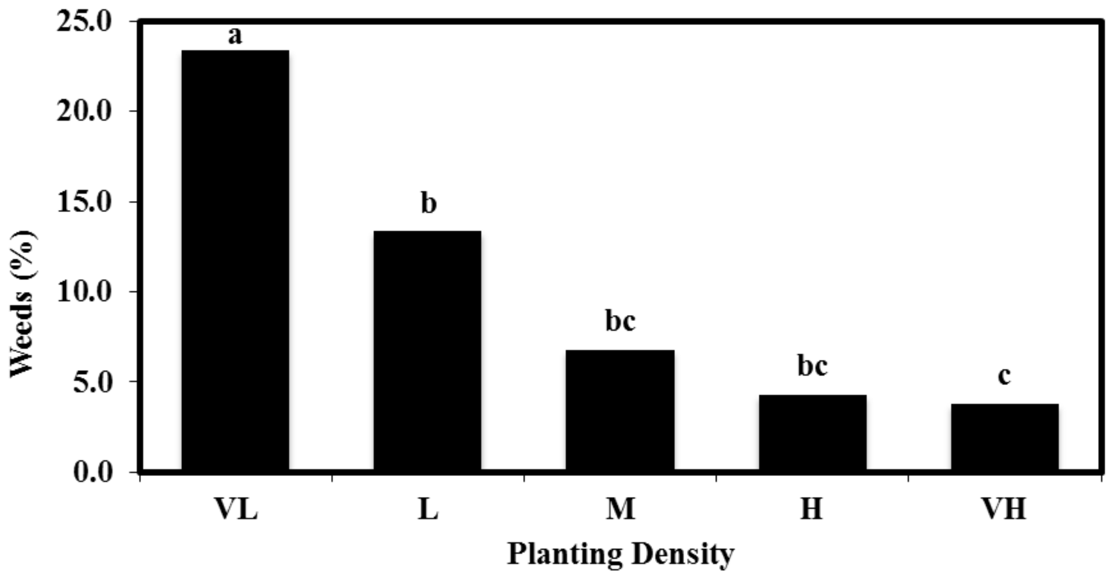

Figure 4-5. Percentage of weeds visually assessed in April 2012 in response to five=stolon-planting densities in 2011. Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Bars with same letters are not significantly different ($P > 0.05$)

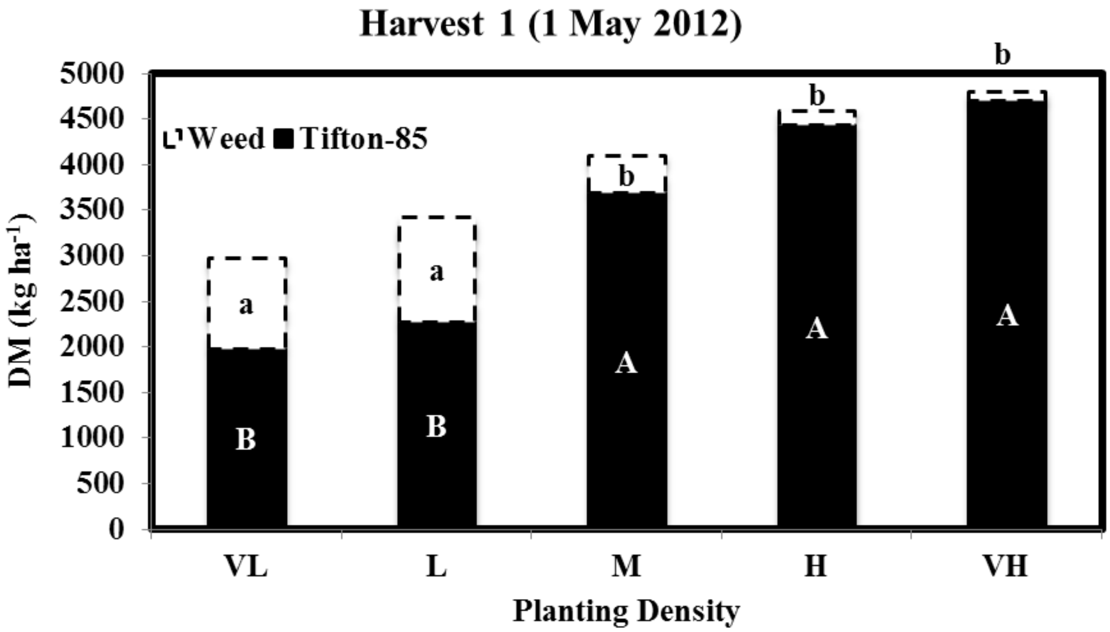

Figure 4-6. Tifton 85 and weed dry mater harvested at the first harvest in response to five stolon-planting densities in 2011. Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Bars with same uppercase (T-85) letter or lowercase (weed) letter are not significantly different (P > 0.05)

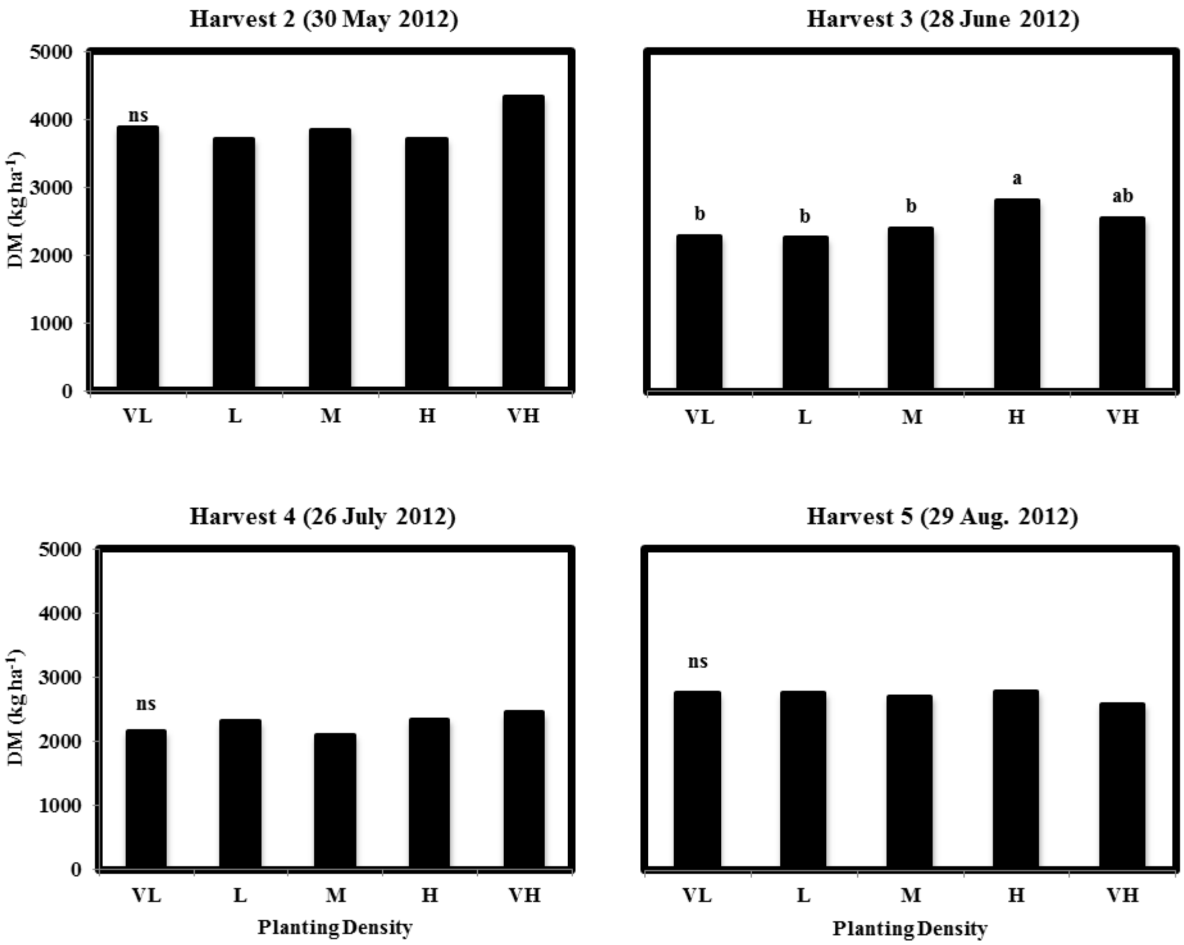

Figure 4-7. Tifton 85 dry matter harvested at the second, third, fourth, and fifth harvests of 2012 following planting using five stolon planting densities in 2011. Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. NS = means that are not significantly different ($P > 0.05$). Bars with same letter are not significantly different ($P > 0.05$), ns – non-significant.

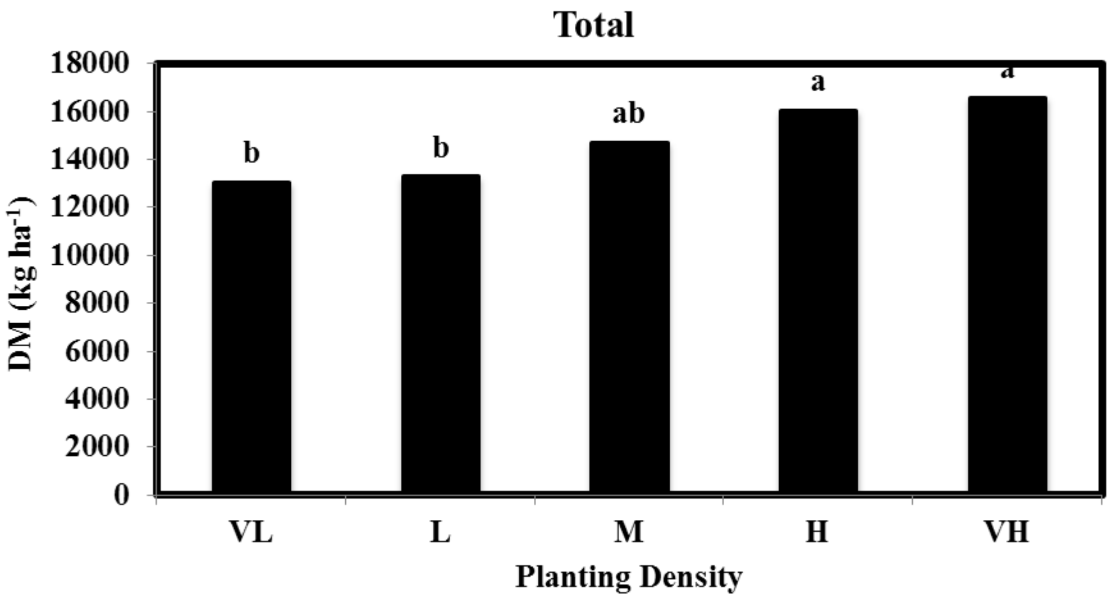

Figure 4-8. Tifton 85 cumulative dry matter harvested during the 2012 growing season in response to five stolon planting densities in 2011. Very low (VL) = 1120 kg ha^{-1}; low (L) = 1570 kg ha^{-1}; medium (M) = 2020 kg ha^{-1}; high (H) = 2470 kg ha^{-1}; and very high (VH) = 2920 kg ha^{-1}. Bars with same letters are not significantly different (P > 0.05).

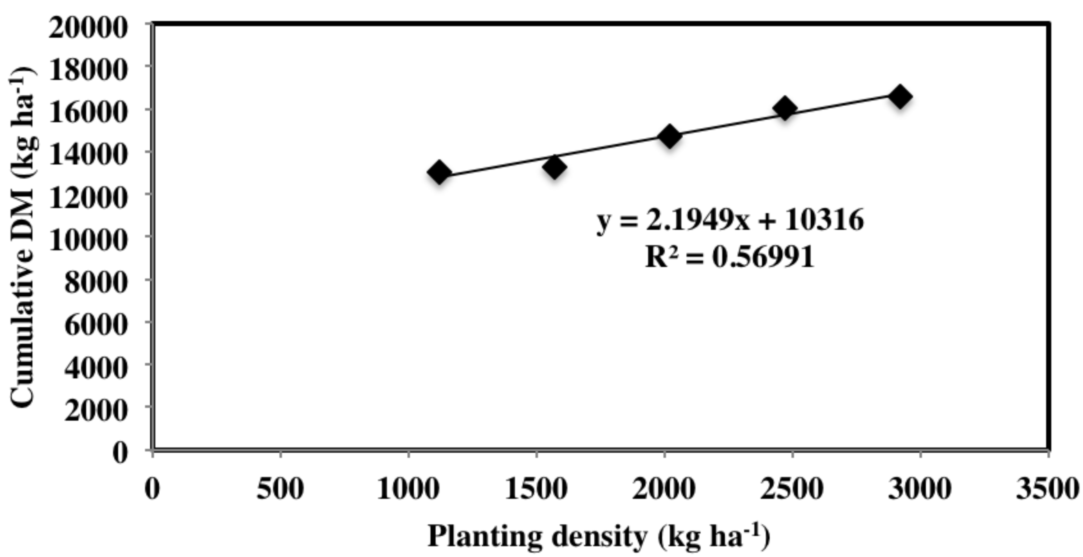

Figure 4-9. Tifton 85 cumulative dry matter harvested during the 2012 growing season in response to five stolon planting densities in 2011.

CHAPTER 5
RHIZOME PLANTING - DENSITY AND DEPTH EFFECTS ON BERMUDAGRASS ESTABLISHMENT

As in stolon planting, planting rate of rhizomes is an important factor for successful establishment. Recommended planting rates for rhizomes range from 1.7 to 3.5 m^3 ha^{-1} and are based on sandy-clay loam soils with conditions of high moisture and nutrient retention (Evers et al., 2002; Cosgrove and Collins, 2003). The faster a stand is desired, the more rhizomes should be planted (Stichler and Bade, 2003) and greater yields are expected in the first year. However, higher planting rates are only recommended if rhizomes are readily available or can be obtained at a low cost.

Another aspect to be considered when using rhizomes is planting depth. Shallow planting can increase rhizome survival, sprouting and emergence as well as ground cover and dry matter production (Chiles et al., 1966; Bourdôt, 1984; Chamblee et al., 1989). Placed too shallow, however, the rhizome may dry out without irrigation (Stichler and Bade, 2003) or be damaged by freezing (Burton et al., 1993). Although deep planting could aid in winter survival and increase moisture retention, if planted too deep the new growth may die before emerging (Stichler and Bade, 2003). In fact, Phillips and Moaisi (1993) observed only few shoots of *Cynodon dactylon* emerged from rhizomes placed below 10 cm.

Under dry land conditions, 5 to 8 cm deep is generally adequate for planting, whereas under irrigation, planting should be at a depth of 4 to 5 cm with occasional rhizomes showing above ground (Burton, 2011). Although this is the general recommendation, sandy soils with high permeability such as those in the Suwanee River basin may not hold enough moisture and thus deeper planting could be required.

Considering those conditions, the hypothesis of this study was that deep planting and higher planting rates would improve establishment of Tifton 85 in highly permeable sandy soils.

The objective was to quantify the effects of planting rates and depths on Tifton 85 frequency, ground cover and herbage mass accumulation.

Material and Methods

Experimental Site

This study was conducted during two seasons: from March to July 2012, and from March to July 2013 in North Central Florida. In 2012, the study was located on a commercial cattle farm, Quincey Cattle Co., near Chiefland, Levy County (29°30’37” N, 82°48’49” W). In 2013, the experiment was conducted on a commercial dairy farm, Alliance Dairies, near Trenton, Gilchrist County (29° 32' 12.47" N, 82° 47' 8.50" W). Both locations are within the Suwanee River basin and under irrigation. The soil at both locations is classified as Otela-Candler complex (sandy and loamy marine deposits), and with the same chemical and physical characteristics previously discussed in Chapter 3 (Soil Survey Staff, 2013). At the first site, soil pH was 6 and organic matter was 4.1 g kg^{-1}, Mehlich 3 extractable P, K, Mg, and Ca were 82 (high), 45 (low), 65 (medium), and 400 ppm in 2011, respectively. At the second site, soil pH was 6.2, Mehlich 1 extractable P, K, Mg, and Ca were 38 (optimum), 97 (medium), 65 (optimum), and 469 (optimum) in 2013, respectively.

Experimental Variables and Statistical Design

The experimental variables were three rhizome planting rates (Low - 2.6 m^3 ha^{-1}; Medium - 5.2 m^3 ha^{-1}; and High - 10.4 m^3 ha^{-1}) and two planting depths (6 and 12 cm). Treatments were arranged as random strips with four replicates, for a total of 24 experimental units. Each strip corresponded to a planting rate due to practical restriction of randomization; to guarantee the planting material amounts associated with the planting rates, the equipment requires some space before it starts dropping the amount of material that was preset. Depths were assigned to main plots and densities to sub-plots (Figure 5-1). Plots were 3 x 4.5 m (13.5 m^2).

Planting densities were selected based on the rates used by producers. The medium rate (5.2 m^3 ha^{-1}) is the most used rate. Then, lower and higher rates were added. Depths were selected based on the possible settings of the planting implements.

Field Procedures

The material consisted of dormant rhizomes, which were dug from a nursery of Tifton 85 bermudagrass on a nearby farm and kept on ice until planted later that day to preserve its viability. Rhizomes were placed (without compressing) inside a small bucket with a volume of ~22300 cm^3 (~0.66 bushel) to determine the average weight of planting material. The calculation to estimate the weight of one bushel was based on the average of 15 measurements. Rhizomes were planted using a 3-m wide Bermuda King sprig planter and followed by a roller to ensure good sprig-soil contact. Irrigation was done using a center pivot and based on soil moisture. Approximately 12 mm of water was applied when estimated volumetric water content was 7%. Rainfall, evapotranspiration and air temperature are shown in Table 5-1. Planting was conducted on 15 Mar. 2012 and 2 Mar. 2013.

Response Variables and Sampling

The response variables measured in this study were shoot emergence, bermudagrass frequency and ground cover percent, and herbage DM harvested. Emergence was evaluated by the number of new shoots in a 1- x 1-m sample quadrat placed in a fixed location in the middle of the plot. Shoots were counted weekly for 3 wk. After the first month, frequency and ground cover percentage were assessed weekly until harvest. Frequency and ground cover percentage were measured in the middle of the plot using the same approach of the previous studies, described in Chapter 3. Frequency and ground cover were considered complete when percentage was above 80%. Dry matter harvested was assessed at the beginning of July, about 4 mo after planting. Samples from two circular quadrats of 45-cm diameter, ~ 0.16-m^2 each, were hand clipped to 8-cm stubble height. Fresh weight was measured and then the samples were dried at 65°C until constant weight to determine dry weight. Total dry matter was then estimated in kg ha^{-1}.

Statistical Analysis

Emergence and herbage DM data were analyzed using PROC MIXED procedures of SAS (SAS Institute Inc.). In all models, DAP, depth, and planting density were considered fixed effects; replicates and their interactions were modeled as random effects. Mean separation was further accomplished using least-square means and the PDIFF option in SAS, which gives a table of p-values for all possible pairwise comparisons. All test differences were considered significant at $P \leq 0.05$, while values at $P \leq 0.10$ were further discussed as trends. Only 2012 data are being reported.

Frequency and ground cover percent presented a sigmoidal shape characteristic of logistic curve of growth. Values started at zero, then presented a strong increase reaching a plateau at 100%. The non-linear logistic model used is represented by the following equation:

$$Frequency = \frac{(e^{\propto})}{(1 + e^{\propto})} \tag{5-1}$$

Where,

$$\propto = Intercept + (treat\ estimate) + (DAP\ est) \times DAP + (DAP * treat\ est) \times DAP$$

The logistic regression was created using PROC GLIMMIX procedure of SAS, and the approach is described by SAS Institute Inc. (2008). The comparison of curves was performed using the ESTIMATE statement of PROC GLIMMIX.

Results and Discussion

Weight of Planting Material

The weight of one bushel was highly variable throughout the measurements. It was very dependent on the amount of sand and moisture aggregated with the rhizomes and roots. The average weight of one bushel was 6.1 kg when considering the same material (rhizome + sand) and compression used at planting. If rhizomes are stomped as is commonly done by commercial sprig sellers that value could go to 8 kg per bushel. Taliaferro et al. (2004) indicated that the amount of rhizomes in a given volume varies with degree of compaction and physical characteristics. In fact, when only the material was used, without sand, the weight of one bushel was considerably lower (data not shown). This indicates the necessity of recommendation by volume instead of mass, as is already done for rhizomes. Since the mass is highly variable and a function of the amount of sand plus planting material, by using planting rates based on volume, the variation in actual planting material tends to decrease.

Emergence

The interaction of DAP and rate was significant. When data were analyzed within each DAP, there were main effects of rate and depth on emergence of Tifton 85. First shoots started emerging about 30 DAP. Differently, Fernandez (2003) observed emergence as soon as 11 days using fragments of rhizomes. Phillips and Moaisi (1993) observed that emergence started 13 to 25 d after planting bermudagrass rhizomes in Botswana, and Montesbravo et al. (1985) observed greatest emergence occurred at 16 to 30 DAP.

Deep planting at 12 cm resulted in a greater number of shoots per square meter in all the evaluations (Figure 5-2). At 52 DAP, planting at 12 cm deep resulted in 33 shoots of Tifton 85, whereas there were only 13 shoots per m^2 for the 6-cm depth. These results are in agreement with Burton et al. (1993), which reported that deep planting could protect the planting material from freeze. On the other hand, these results are in disagreement with Phillips and Moaisi (1993), who observed only few shoots emerged from rhizomes placed below 10 cm in a sandy loam soil with 6.0% clay and 7.4% silt. The different soil type, with the presence of more clay, probably affected the emergence in that study.

At 30 DAP, the high rate of 10.4 m^3 ha^{-1} presented the greatest number of shoots, medium was second, and the low rate resulted in the lowest number (Figure 5-3). At 52 DAP, high density was still greater than the other two rates. Comparison of the results of this study with air temperature observed during the period confirms what was previously suggested in the literature. Horowitz (1972a) indicated that maximum rhizome bud germination is between 23 and 35ºC, and slow germination occurs below 20ºC. Growth of bermudagrass is improved when air temperatures average 21ºC (Keeley and Thullen, 1989). In fact, by planting in March, when the average temperature was 21ºC, germination was delayed (Figure 5-4). In May (52 DAP), when average air temperature was already 25ºC, the emergence was substantially higher. Also, if rhizomes were planted in February, the emergence would be probably slower, since the average temperature was 17ºC. In addition, Youngner (1959) reported that maximum temperature determines the amount of growth and day temperatures over 21ºC are able to promote growth even when exposed to nearly freezing night temperatures. Based on this conclusion, temperatures observed in Bronson during the entire period of the experiment were adequate for sufficient growth.

Frequency

The interaction of DAP x depth x rate was significant; therefore data were analyzed as 6 treatment combinations of rate x cover. The rate of change of frequency demonstrated a logistic behavior (Table 5-2 and Figure 5-5). Increase in frequency was slow initially but was followed by a steep increase and then a gradual slowing to reach a plateau at 100%. When comparing depths of planting within each planting rate, at low density planting at a 12-cm depth improved the frequency (Figure 5-6). The steepness of change was significantly higher for 12 cm than 6 cm when using low rate. When increasing the planting rate, however, no difference between planting depths was observed. For medium and high planting densities both depths presented similar frequency throughout the sampling dates and reached 80 or 100% at about the same time.

At 6-cm deep, high planting rate presented the greatest rate of change amongst all treatments (Figure 5-5). It also started increasing considerably earlier and at 30 DAP high rate showed 16%, while medium and low presented less than 5% even at 57 DAP. High density achieved 80% and also 100% frequency earlier than medium and low rates. Low planting rate had the worst performance and presented about 30% of frequency after 120 d. Planting deeper at 12 cm, however, did not show any difference among rates. All treatments had similar rate of increase and even low rate reached 100% frequency at 113 DAP.

When comparing the depths within each planting rate, at low density, planting at a 12-cm depth improved the frequency (Figure 5-6). The steepness of change was significantly greater for 12 than 6 cm when using the low rate. When increasing the rate, however, no differences between depths were observed. For medium and high densities both depths presented similar frequency throughout the sampling dates and reached 80 or 100% at about the same time.

Since the rhizomes are still dormant when planted, a deep planting may be advantageous because it could delay the emergence and thus protect the new shoots from adverse environmental conditions that may happen if plants were to emerge too early. According to Burton et al. (1993), deep planting could protect the planting material from freeze. However, in this experiment, the emergence was actually the opposite, with the deep planting presenting higher number of shoots initially. Probably moisture preservation and shield against desiccation deep in the soil profile contributed to increased emergence of rhizomes planted deeply compared to a more shallow depth (6 cm). Even under irrigated conditions, this deep sands soil tend to favor desiccation of planting material, since dry conditions may be observed right after irrigation is suspended. Therefore, planting at 12 cm would keep more moisture close to the rhizome and thus favor its rooting and emergence. However, moisture was not evaluated in this experiment; therefore another year is required before making solid conclusions.

Bermudagrass Ground Cover

Similar to frequency, there was interaction of DAP x depth x rate and data were analyzed as 6 treatment combinations. The rate of change of ground cover also demonstrated a logistic behavior (Table 5-3). Similar results were observed with cover. Although the low rate at the 6-cm depth presented less than 3% cover at all sampling dates and was visually inferior to the other treatments, no statistical difference could be observed (Figure 5-7). Probably because this treatment showed a nearly straight-line response that paralleled the X axis the logistic regression did not fit well and this caused the comparisons to fail. Therefore, the last sampling date was further analyzed separately using PROC MIXED and PDIFF option for mean separation, instead of comparing the curves. In fact, using this method, the differences were then observed and will be further discussed. Similar to frequency, at 12 cm, there was no difference.

The same results were observed for the depth effect (Figure 5-8). The low rate planted to a 6-cm depth resulted in less than 3% ground cover. When planted deeper, the cover was increased but it was not enough, since it never reached 80% cover. Rodriguez et al. (2001), when testing different fertilizer ratios on a high sand-content soil for bermudagrass establishment observed the time to reached 100% of ground cover ranged from 5 to 11 wk. On the other hand, treatments on this experiment took more than 14 wk to reach 100%. The rapid establishment of their experiment, however, was achieved by the high fertilization, since it was based on an N rate of 49 kg ha^{-1} wk^{-1}.

When comparing treatments at the last sampling date (106 DAP), there was an interaction between depth and rate factors (Figure 5-9). In general, the high rate presented ground cover close to 100% and it was greater than medium, which in turn was greater than low density. Also, within high and medium rates, depth was not significantly different. On the other hand, when using low planting rate, the 12-cm planting depth showed 55% cover, which was not satisfactory, but was significantly greater than the planting depth of 6 cm that presented less than 3% cover. In general, when planting material is not readily available, deep planting at 12 cm seems to improve establishment. However, another year is required. Also, rate seems to be important only when shallow planting is conducted.

Bermudagrass Herbage DM Harvested

There was no interaction of depth x rate for herbage DM harvested; therefore data were averaged within depth and rate. Herbage DM was different among rhizome planting rates and between depths about four months after planting (Table 5-4). There was a significant linear increase in herbage DM harvested with an increase in the planting rate (Figure 5-10). The low rate (2.6 m^{3} ha^{-1}) presented the lowest cumulative DM (300 kg ha^{-1}) and the high (10.4 m^{3} ha^{-1}) showed the greatest (1270 kg ha^{-1}). Medium planting rates, as expected, produced intermediate herbage DM and were different from the other treatments. For depth, deeper planting (12 cm) yielded 970 kg ha^{-1} whereas shallow planting (6 cm) produced 570 kg ha^{-1}.

Bermudagrass herbage DM production was lower than found by Keeley and Thullen (1989), who planted bermudagrass using plugs in a fine sandy loam soil in California. When planting on 1 March, oven-dry weight of culms and stolons was 1870 kg ha^{-1} about 3-mo after planting. Their methods, however, are not clear, and it seems they harvested the whole plant (above and below parts). Then, this dry weight would also be taking into consideration stolons that are close to the ground and were not harvested in this present study.

Rhizome Planting Costs

Rhizome planting material is the highest expense of total establishment costs. It is clear that depending on the planting rate used, the size of the field that can be planted will be considerably different. The approximate rhizome yield of a nursery ranges from 130 to 174 m^3 ha^{-1}. For the following calculations we will consider the average rhizomes yield to be 152 m^3 ha^{-1}. Considering planting rates used in this study, with 1 ha of nursery it would be possible to plant 58 ha using the low rate (2.6 m^3 ha^{-1}; Table 5-5). On the other hand, if the high rate (10.4 m^3 ha^{-1}) is used, only 15 ha can be planted with the same nursery. Therefore, about 3.9 times additional land is required to plant the same amount of new land.

Also, if a producer needs to plant an area of 100 ha, he will need a nursery of 1.7 ha if using low rate or 6.7 ha if using high rate. This is close to a three-fold increase (294%) on nursery area required. In addition, if the producer does not have area available to keep a nursery, he will have to buy the material or hire somebody to do all the work and then the costs will be even higher.

Considering the price of each bushel (0.035 m^3) of Tifton 85 rhizomes is $4 ($114 m^{-3}), the costs only for planting material are presented in Table 5-2. Also, the price to plant a prepared seedbed is about $185 ha^{-1}. Therefore, using a recommended rate of 2.6 to 3.3 m^3 ha^{-1}, the cost of planting, including the rhizomes, is $482 to $561 ha^{-1}. Additional costs for spraying before and after planting apply as well as disking and rolling.

Although the high rate produced more dry matter than the medium rate (Table 5-3), it yielded 70% more, while it costs about 76% more to plant. Total cost for medium and high rates, including the planting, is $775 and $1366, respectively. Therefore, high rate would be unfeasible, since it is more expensive to plant without having a significantly higher return. Moreover, since the cost is over $1300, the risk is also higher.

Considering the low rate, it is 61% cheaper than medium rate ($480 versus $775). However, the low rate produced only 40% of the dry matter yielded by medium rate. Because of this and since the medium rate showed significantly higher ground cover than low rate, low rate is not recommended for sandy soil. The medium rate provided the best cost-benefit among the rates studied.

Conclusions and Implications

Deep rhizome planting presented greater emergence than planting at 6 cm. Using high rhizome planting rate showed more shoots per square meter at 52 DAP than medium and low planting rates. For frequency, planting at 6 cm with the high planting rate resulted in greater rate of change and achieved 80% frequency earlier than medium and low rates. Low rate had the worst performance and achieved only 30% frequency at 120 DAP. When planting at 12 cm, no difference was observed among rates. Depth was only significant at low rate, where 12-cm planting presented higher frequency percent than 6-cm depth. When increasing rate, no difference was observed. Cover showed similar results as frequency. Although no difference was observed among logistic curves, when comparing treatments at the last sampling date, high planting rate presented greater ground cover than medium rate, and this one was higher than low rate. Within high and medium rates depth was not different. When using low rate, however, planting to 12 cm showed significantly higher ground cover than planting to 6 cm. For herbage DM, high rate yielded more than medium, which presented higher herbage DM than low rate. Also, deep planting at 12 cm yielded more than 6-cm depth.

In summary, planting deeper, at 12 cm, accelerates emergence, cover and increases bermudagrass herbage DM at the end of growing season. There is no difference on emergence, cover, or herbage DM between depths when using high planting rate. Medium and high rates establish faster and increase DM in the first year. But if planting material is not readily available, a deeper planting, to a 12-cm depth, seems to provide a more efficient establishment.

Table 5-1. Rainfall, evapotranspiration and air temperature (2 m) for the period the experiment was in the field in 2012

Month	Rainfall	ET	Air Temperature
	----------------------mm---------------------		ºC
Mar	39	91	21
Apr	26	120	22
May	84	140	25
Jun	301	128	26
Jul	167	140	27

Table 5-2. Logistic equations for frequency for each combination of treatment

Depth	Rate	Logistic equation
cm	$m^3\ ha^{-1}$	
6	2.6 (Low)	Freq = (EXP (-8.39+0.06*DAP)/ (1+EXP (-8.39+0.06*DAP)
6	5.2 (Medium)	Freq = (EXP (-13.84+0.18*DAP)/ (1+EXP (-13.84+0.18*DAP))
6	10.4 (High)	Freq = (EXP (-6.33+0.11*DAP) (1+EXP (-6.33+0.11*DAP))
12	2.6 (Low)	Freq = (EXP (-4.78+0.10*DAP)/ (1+EXP (-4.78+0.10*DAP))
12	5.2 (Medium)	Freq = (EXP (-8.07+0.125*DAP)/ (1+EXP (-8.07+0.125*DAP))
12	10.4 (High)	Freq = (EXP (-6.51+0.125*DAP)/ (1+EXP (-6.51+0.125*DAP)

Table 5-3. Logistic equations for ground cover for each combination of treatment

Depth	Rate	Logistic equation
cm	m^3 ha^{-1}	
6	2.6 (Low)	Cover = (EXP (-11.36+0.06*DAP))/ (1+EXP (-11.36+0.06*DAP)
6	5.2 (Medium)	Cover = (EXP (-9.83+0.10*DAP))/ (1+EXP (-9.83+0.10*DAP)
6	10.4 (High)	Cover = (EXP (-6.79+0.09*DAP))/ (1+EXP (-6.79+0.09*DAP)
12	2.6 (Low)	Cover = (EXP (-7.62+0.07*DAP))/ (1+EXP (-7.62+0.07*DAP)
12	5.2 (Medium)	Cover = (EXP (-6.47+0.08*DAP))/ (1+EXP (-6.47+0.08*DAP)
12	10.4 (High)	Cover = (EXP (-7.53+0.10*DAP))/ (1+EXP (-7.53+0.10*DAP)

Table 5-4. Average dry matter harvested (kg ha^{-1}) for each rhizome planting depth and planting rate measured 115 d after planting in 2012

Planting rate	Depth (cm)		Average	
	6	12		
m^3 ha^{-1}	------------------------kg ha^{-1}------------------------			
2.6	20	580	300	C†
5.2	510	980	750	B
10.4	1180	1350	1260	A
Average	570 b	970 a		

†Means within a row followed by the same lowercase letter or within columns followed by the same uppercase letter do not differ ($P > 0.05$).

Table 5-5. Number of hectares that can be planted with a 1-ha nursery and cost of planting material for each planting rate using rhizomes

Planting rate	Rate	1 ha of nursery can plant	Cost
	m^3 ha^{-1}	ha	\$ ha^{-1}
Low	2.6	58	295
Medium	5.2	29	590
High	10.4	15	1181

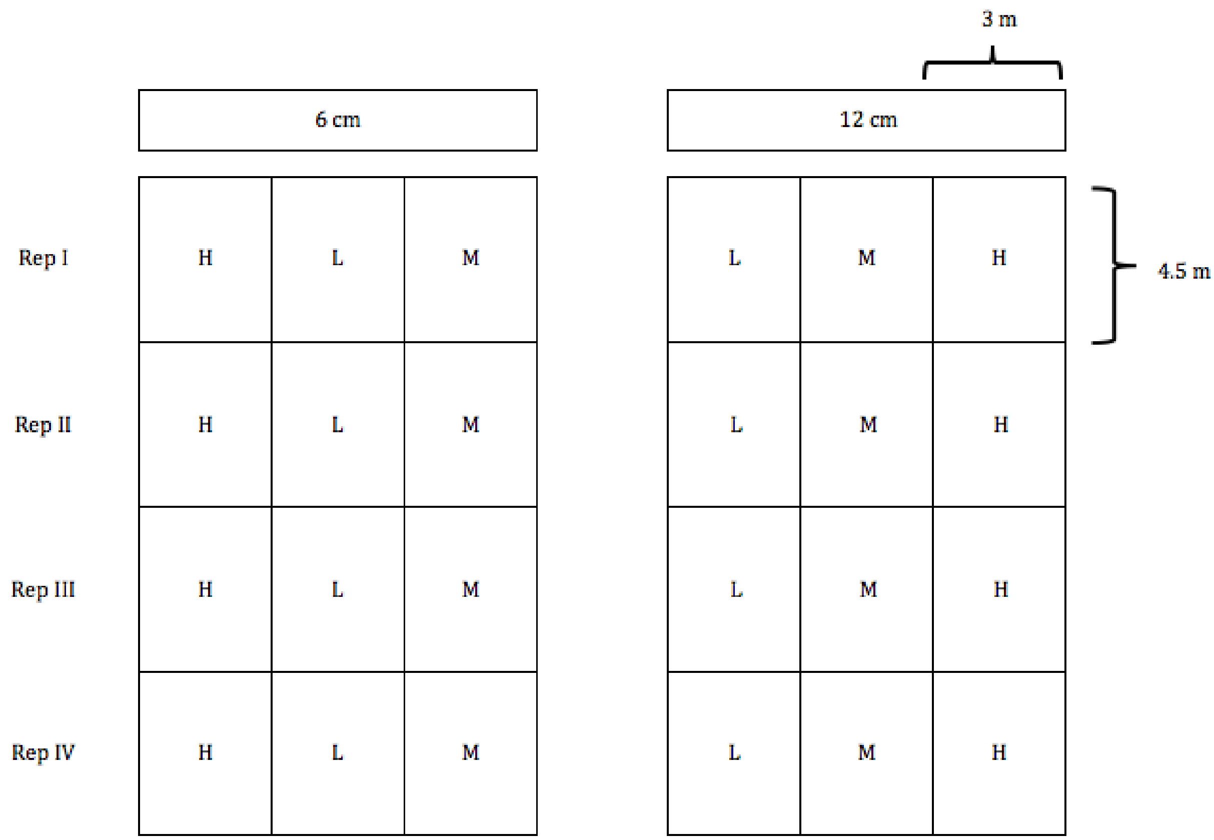

Figure 5-1. Layout of the treatments in the field. Planting density treatments were: Low (L) - 2.6 m^3 ha^{-1}; Medium (M) – 5.2 m^3 ha^{-1}; and High (H) – 10.4 m^3 ha^{-1}.

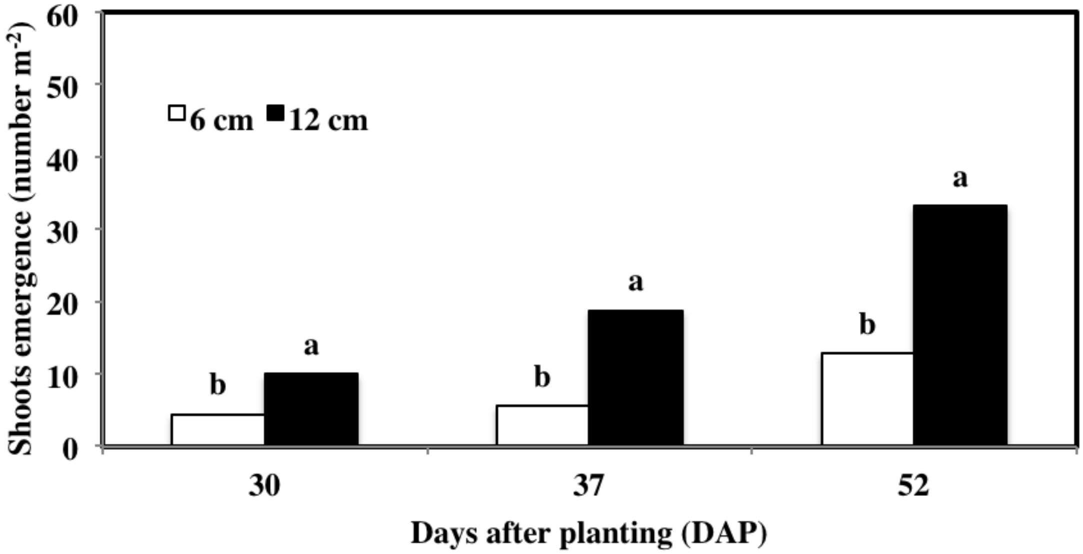

Figure 5-2. Number of Tifton 85 shoots per m^2 following planting of rhizomes at two depths (2012). Within DAP, bars with same letters are not significantly different (P > 0.05).

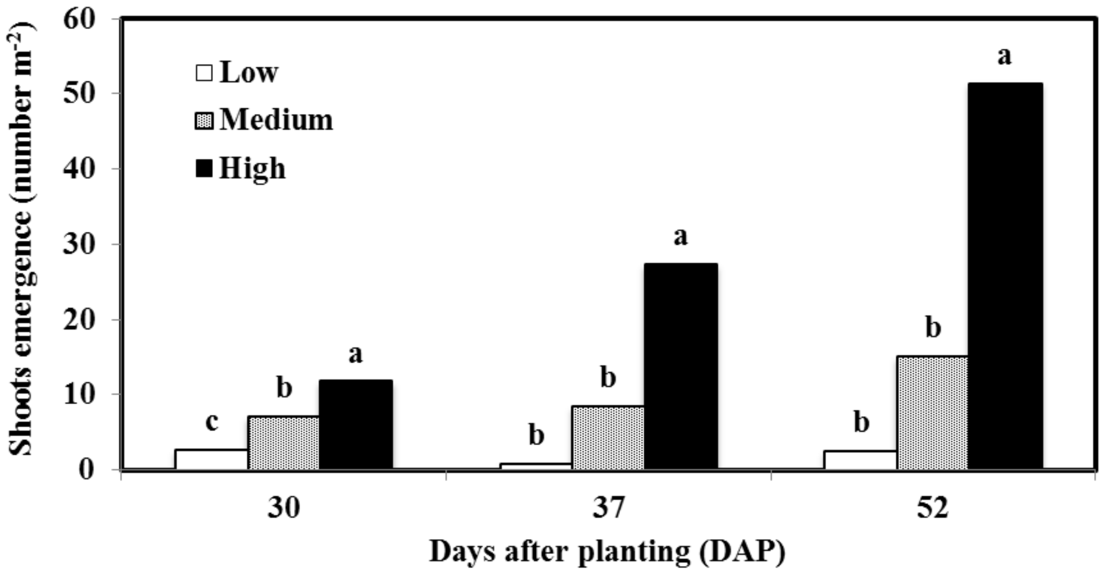

Figure 5-3. Number of Tifton 85 shoots per m^2 following planting of rhizomes at three planting rates (2012). Within DAP, bars with same letters are not significantly different (P > 0.05).

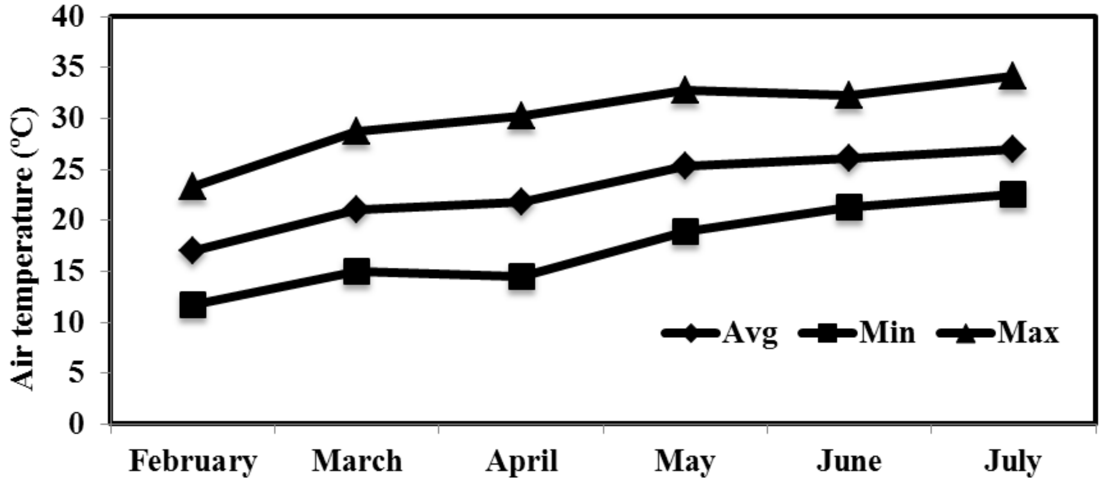

Figure 5-4. Average, minimum and maximum temperatures for the months Feb-Jul in 2012 at Bronson station (FAWN, 2013).

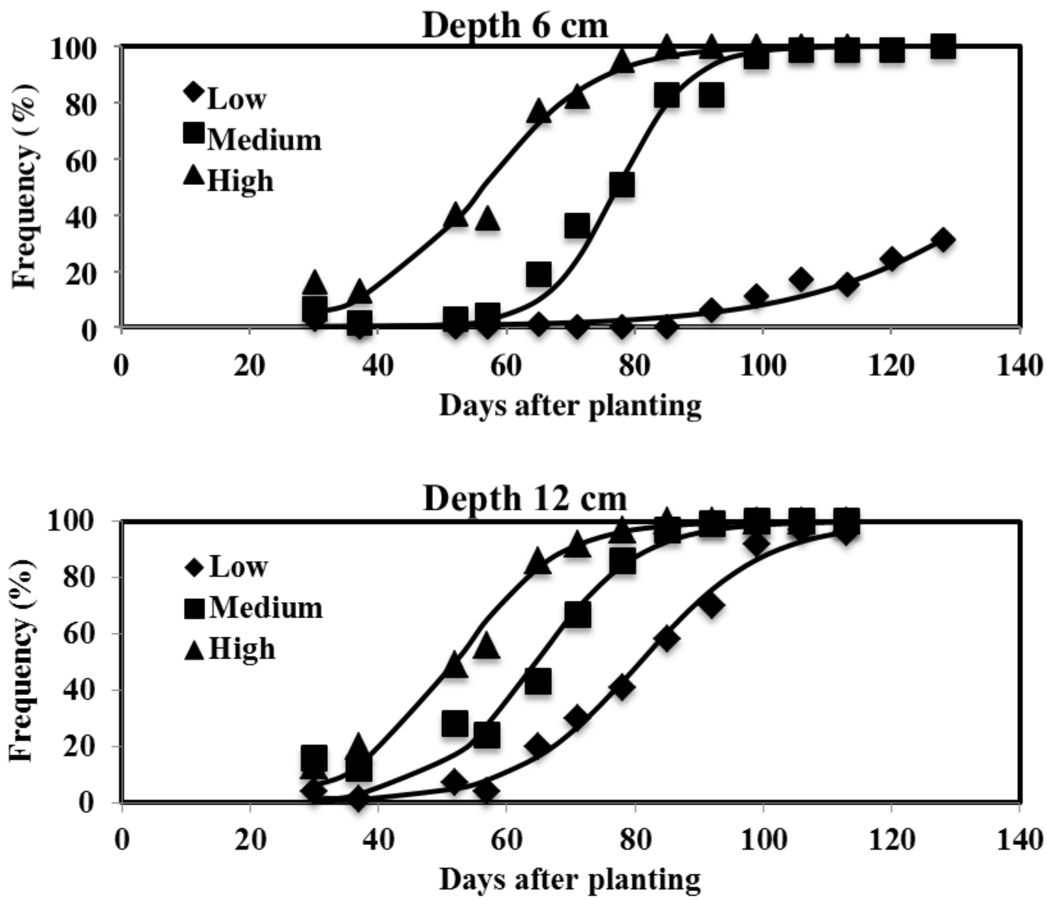

Figure 5-5. Frequency throughout time for three planting rates for each planting depth (2012).

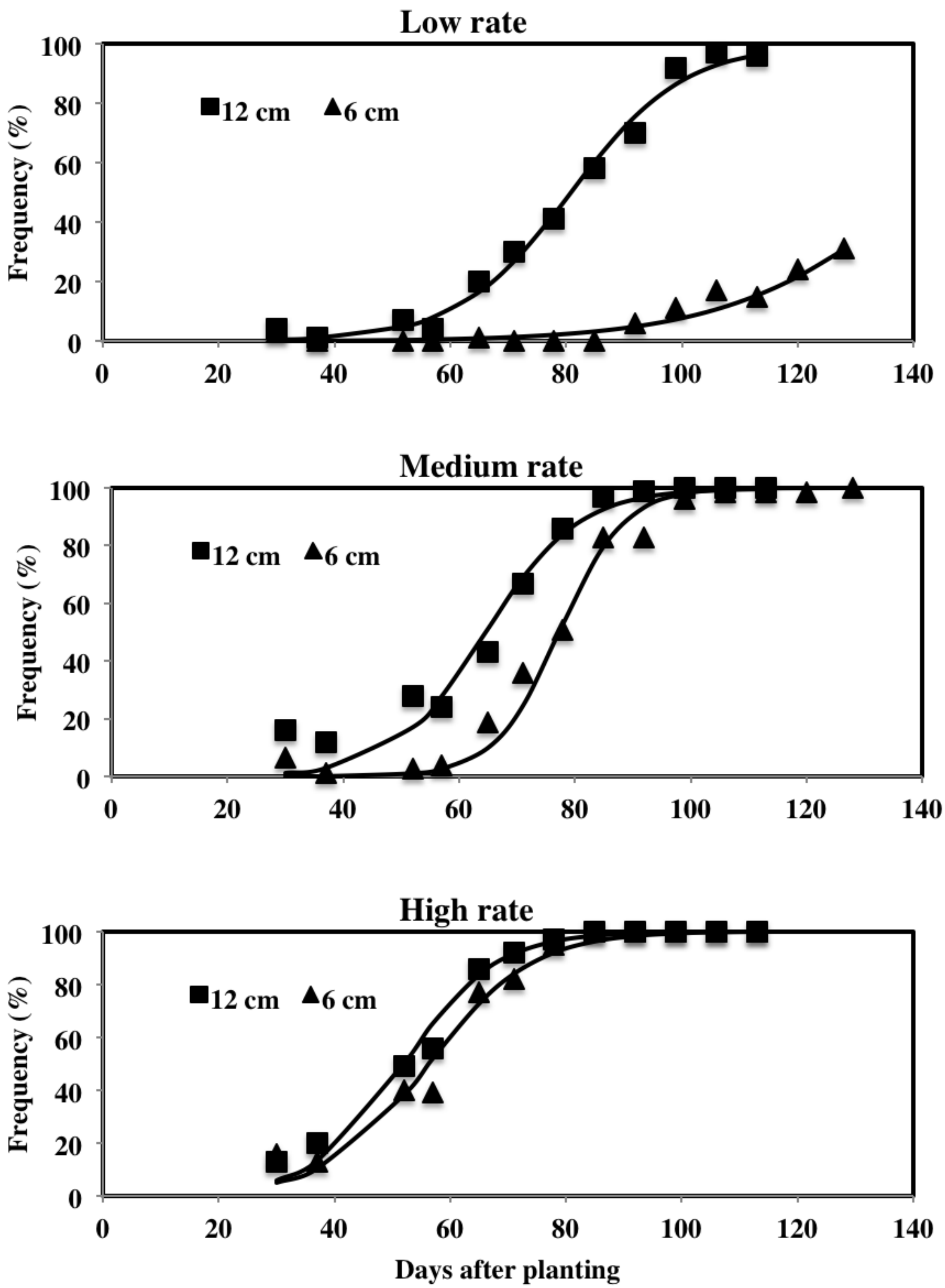

Figure 5-6. Frequency throughout time at each planting rate for two planting depths (2012).

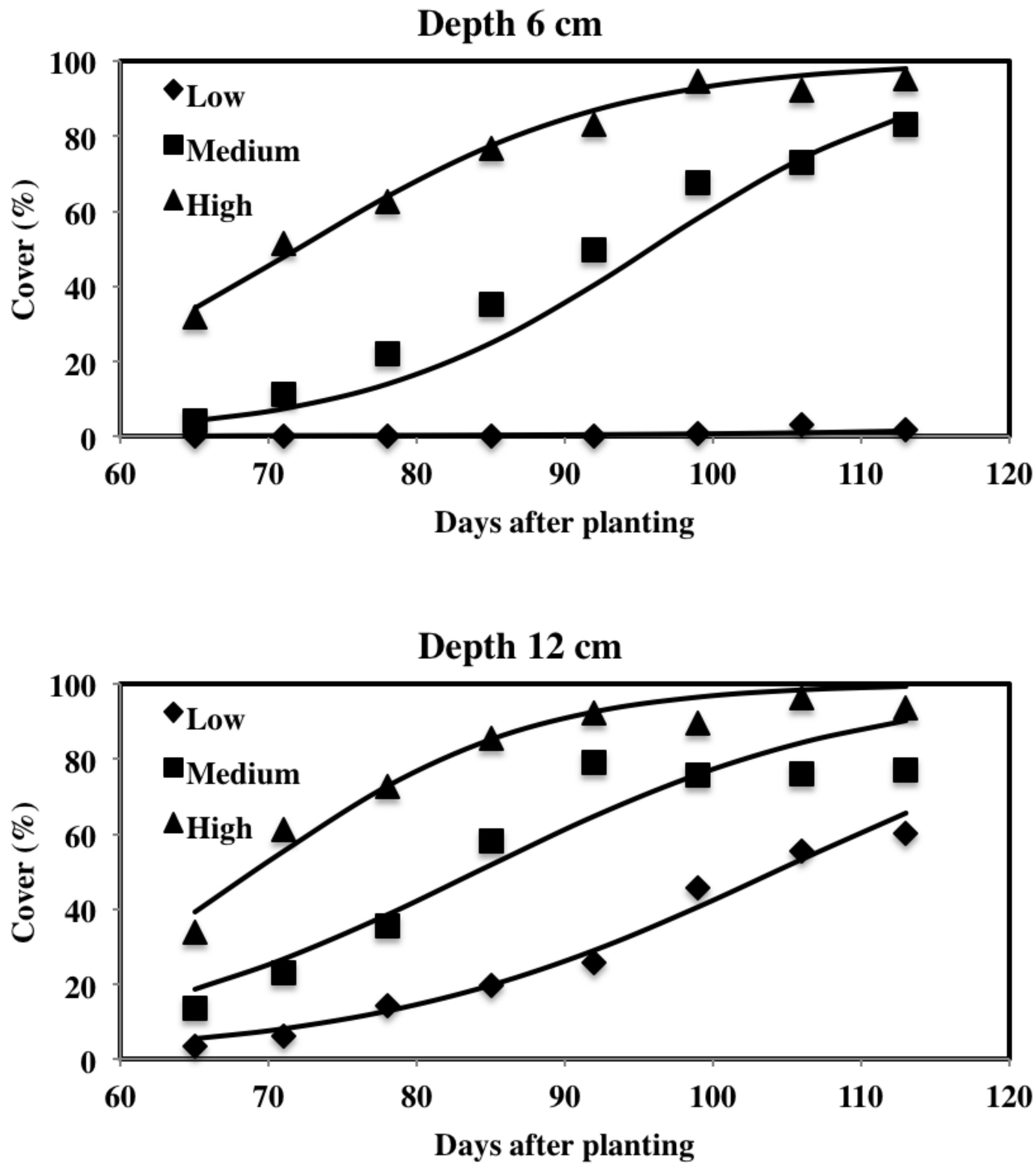

Figure 5-7. Bermudagrass ground cover throughout time for three rhizome planting rates for each planting depth (2012).

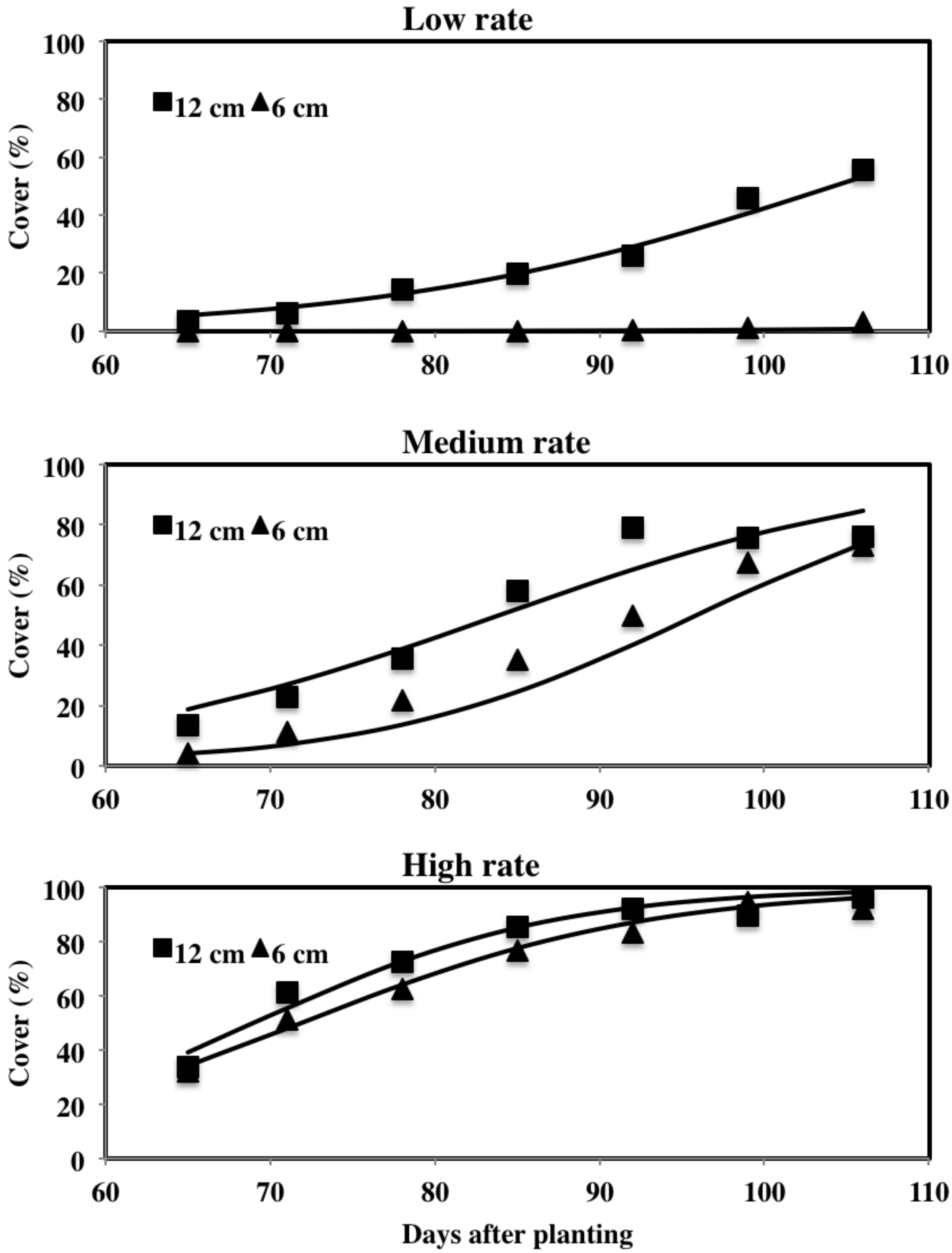

Figure 5-8. Bermudagrass ground cover throughout time at each rhizome planting rate for two planting depths (2012).

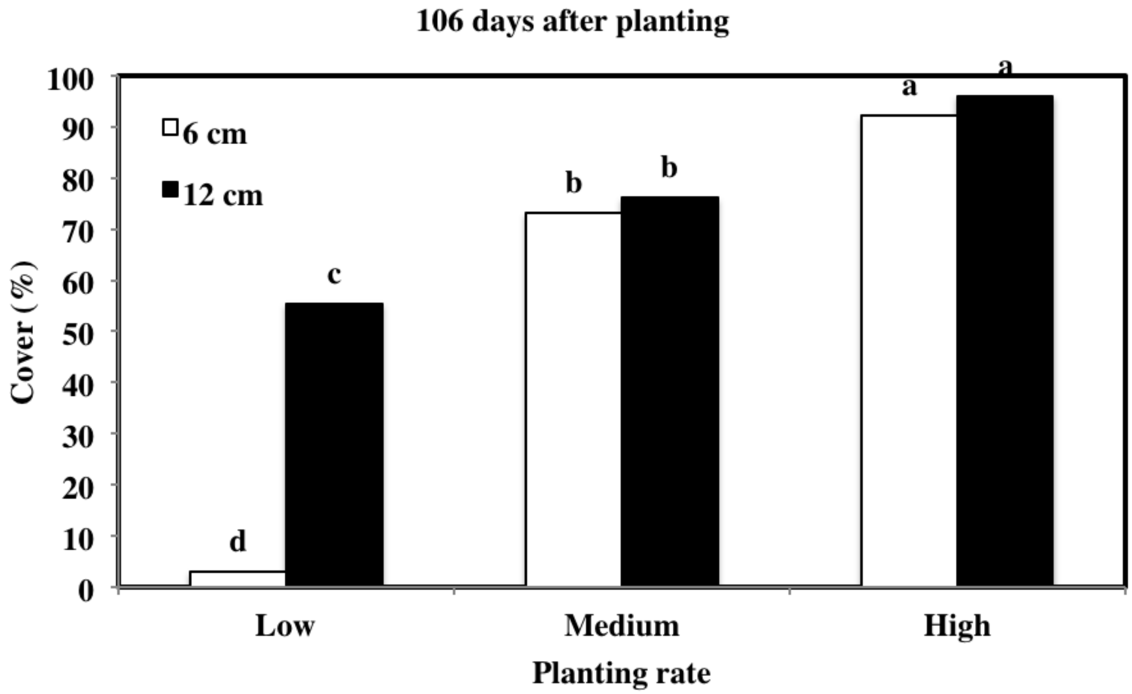

Figure 5-9. Bermudagrass ground cover at 106 days after planting for all combinations of rhizome planting depth and rate factors (2012). Bars with same letters are not significantly different (P > 0.05).

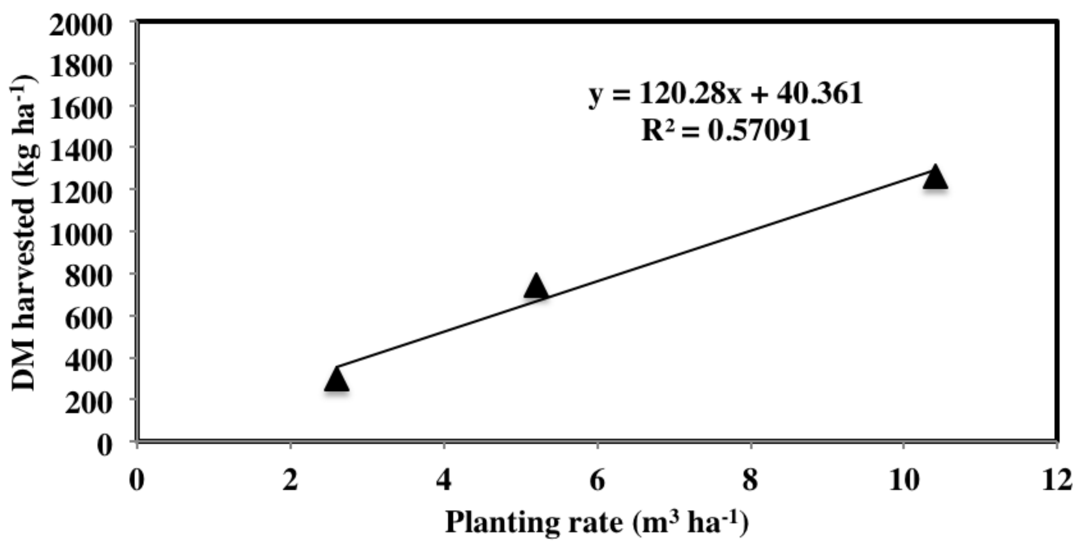

Figure 5-10. Regression for dry matter harvested (kg ha^{-1}) over planting rates measured 115 d after planting in 2012.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Bermudagrass is a highly productive warm-season grass, but must be planted by vegetative cuttings, either by stolons or rhizomes. Planting costs using vegetative propagation are high and establishment failures are being reported. The overall objective of this research was to evaluate the effect of planting practices of Tifton 85 bermudagrass to improve establishment and shorten time from planting to utilization. To enhance cost-benefit ratio and ensure more rapid ground coverage, three experiments were conducted to assess effects of stolon type and soil cover, stolon and rhizome planting rates, and planting depth using rhizomes on the establishment of Tifton 85 bermudagrass.

Stolons Type and Soil Cover

Different stolon types (long, upper half, lower half, and small stems) and two levels of soil cover (totally or partially covered) were evaluated concerning their effect on Tifton 85 establishment. Partially covered stolons, showed greater frequency in all the sampling dates and reached 80% earlier than totally covered. Also, totally covered stolons presented less than 70% ground cover at 100 DAP. Partially covered stolons yielded almost 2040 kg ha^{-1} in summer of the establishment year while totally covered ones averaged 1040 kg ha^{-1}. Therefore, planting stolons partially covered accelerates emergence, bermudagrass cover and increases herbage DM at the end of the season. Moreover, the more mature stolons, which are in the lower section provided the most viable nodes.

Stolon-Planting Rate

The effects of five stolon-planting rates (very low - 1120 kg ha^{-1}, low - 1570 kg ha^{-1}, medium - 2020 kg ha^{-1}, high - 2470 kg ha^{-1}, and very high - 2920 kg ha^{-1}) were quantified, measured as bermudagrass cover, weed cover, and bermudagrass herbage DM accumulation were quantified. Higher planting rates presented greater frequency and ground cover. At 41 DAP, medium, high and very high rates had achieved 80% frequency. Although all the treatments presented satisfactory ground cover three months after planting, the higher the density, the earlier 80% ground cover and frequency were achieved. Very low and low stolon planting rates showed higher weed competition in spring. Very high, high, and medium rates presented greater herbage DM accumulation early in the following year. Also, cumulative herbage DM for high and very high was greater than for low and very low planting rates. Medium stolon planting rate showed to be adequate.

Planting Rate and Depth Using Rhizomes

Three rhizomes planting rates (low - 2.6 m^3 ha^{-1}, medium - 5.2 m^3 ha^{-1}, and high - 10.4 m^3 ha^{-1}), were evaluated at two soil depths (6 and 12 cm). Planting deeper at 12 cm accelerates emergence, cover and increases herbage DM. This difference is more evident at low planting rate. Medium rate can be used in sandy soils, but high rate would be recommended. However, planting costs using high rates are considerably greater, without a proportional greater return.

Implications of the Research

Based on these experiments, the suggested planting rate when using stolons is approximately 2020 kg ha^{-1} and when using rhizomes is 5.2 m^3 ha^{-1}. Higher rates will promote more rapid ground coverage, but they may not be cost effective. Planting rhizomes deeper, at 12 cm, seems to improve establishment when using lower rates in sandy soils. Even under irrigated conditions, this deep-sands soil tends to favor desiccation of planting material. Another year, however, is required to confirm this finding and understand the process behind it. When planting stolons, some parts should remain uncovered to enhance establishment. Moreover, the more mature stolons, which are in the lower section, seem to provide the most viable nodes. This indicates that when cutting the material from the nursery, a low stubble height should be left to make sure the lower section, which is more mature and has the most viable nodes, will be harvested.

Comparing planting material, both stolons and rhizomes are efficient for planting, as long as recommended rates are used. The choice of one over another is specific for each case and dependent on field size, planting material availability and time of the year. In general, if the producer has his own nursery, rhizomes are recommended, since with a given nursery, larger areas can be planted. However, in certain years, with good moisture and high temperatures, stolons could be harvested twice in the same season, and then their use would be comparable to rhizomes. A disadvantage of digging rhizomes is that the nursery stock will be removed and it will not yield as much on the following year. Therefore, over a period of 3 years, stolons would yield more planting material than rhizomes. If the producer does not have a nursery and needs to buy the planting material, he should prioritize the use of stolons, since they are cheaper.

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BIOGRAPHICAL SKETCH

Matheus Baseggio was born in 1988 in Passo Fundo, Brazil. He grew up helping his father on the farm, and with all his family involved, becoming interested in agriculture was a natural progression. He went to school at Universidade de Passo Fundo, Brazil where he received his B.A. degree in Agronomy in 2010. The year before, 2009, as part of the requirements for graduation, he joined the Forage Extension Program at the Agronomy Department of the University of Florida as an intern during 4 months. While an intern, he enjoyed the exposure to dairy, beef, and hay production systems, and decided in summer of 2011 to enroll at the University of Florida to pursue graduate studies on forage management.

During his program, he represented the Agronomy department at several national and regional meetings. He has been involved with extracurricular activities and leadership roles since he was an undergraduate and continues to do so as Vice President of the Agronomy Graduate Student Association and President of the Brazilian Student Association at UF. He plans to continue contributing to the community and, upon graduation from his master’s degree, he considers keeping on the same path and pursue a PhD degree in the area of plant breeding or molecular biology.