Inclusion of legumes in low-input pasture-based systems of the U.S. Gulf Coast region may provide an alternative source of N (Thomas, 1995) and greater nutritive value forage for live-stock (Muir et al., 2011). Rhizoma peanut is a warm-season, vegetatively-propagated, perennial legume, with demonstrated persistence under management for hay, silage, grazing, and as a understory forage crop (Beltranena et al., 1981; Prine et al., 1981; Ortega-S. et al., 1992; French et al., 1994; Johnson et al., 2002). Nevertheless, to date RP has been primarily cultivated as a high value hay crop for horses (Equus caballus) and dairy cattle (Bos taurus) and is rarely used for grazing.

Factors limiting use of RP in grazed pasture include high cost, slow rate of establishment, and the need to remove the planted area from the grazing rotation during the establishment period. A technology for establishment that may have potential to address these issues is strip-planting RP into existing perennial grass pastures such as bahiagrass. Previous research has demonstrated that application of the herbicides imazapic or imazapic + 2,4-D and utilization of the planted area for hay production during the establishment year for grazed pasture have a greater effect on establishment success than seeding preparation. By season end, RP canopy cover and frequency of occurrence favored no-till (21% cover and 70% frequency) compared with the other treatments (<14% cover and 53% frequency). Weed control strategy after planting had a greater effect on establishment success than seedbed preparation. By season end, RP cover and frequency were greater for imazapic (25 and 64%, respectively) and imazapic + 2,4-D (23 and 64%, respectively) than for the control (10 and 42%, respectively) and mowing treatments (7 and 36%, respectively). Glyphosate followed by no-till planting and postemergence use of imazapic with or without 2,4-D is a viable option for reduced-cost establishment of RP in strips into bahiagrass pastures.

**ABSTRACT**

Planting rhizoma peanut (Arachis glabrata Benth.: RP) in strips into bahiagrass (Paspalum notatum Flüggé) pastures can reduce establishment cost relative to conventional techniques, but research is needed to determine the best seedbed preparation methods. The objectives were to quantify the effects of four seedbed preparation techniques: glyphosate + tillage, tillage only, glyphosate + no-till, and sod removal; and four postemergence weed control strategies: control (no herbicides, no mowing), mowing (every 28 d to 10-cm stubble height), imazapic (0.29 L ha⁻¹), and imazapic + 2,4-D amine (0.29 and 0.58 L ha⁻¹, respectively). Sprout emergence ranged from 90 to 119 m² in treatments where tillage occurred compared with 54 to 58 m² in no-till and sod removal. Nevertheless, by season end RP canopy cover and frequency of occurrence favored no-till (21% cover and 70% frequency) compared with the other treatments (<14% cover and 53% frequency). Weed control strategy after planting had a greater effect on establishment success than seedbed preparation. By season end, RP cover and frequency were greater for imazapic (25 and 64%, respectively) and imazapic + 2,4-D (23 and 64%, respectively) than for the control (10 and 42%, respectively) and mowing treatments (7 and 36%, respectively). Glyphosate followed by no-till planting and postemergence use of imazapic with or without 2,4-D is a viable option for reduced-cost establishment of RP in strips into bahiagrass pastures.

M.S. Castillo, L.E. Sollenberger, and J.A. Ferrell, Agronomy Dep., Univ. of Florida, Gainesville, FL 32611-0500; A.R. Blount and C.L. Mackowiak, North Florida Research and Education Center, Marianna, FL 32446; Chae-In Na, Dep. of Agronomy and Horticulture, Univ. of Nebraska-Lincoln, Lincoln, NE 68583-0915; M.J. Williams, USDA-NRCS, Gainesville, FL 32614. M.S. Castillo, current address: Crop Science Dep., North Carolina State Univ., Raleigh, NC 27695-7620. Received 20 June 2013. *Corresponding author (mscastil@ncsu.edu).

**Abbreviations**: PAR, photosynthetically active radiation; RP, rhizoma peanut.
maximizes RP canopy cover, frequency, and spread into the adjacent bahiagrass sod (Castillo et al., 2013a, 2013b). Currently, there is little information available regarding seedbed preparation methods in the strips where RP is to be planted and their effect on establishment responses.

Previous studies reported no planting method (no-till vs. conventional sprig planter) effect on RP establishment (Williams et al., 2002), but they noted a trend toward greater sprout emergence when soil was disturbed (i.e., rotovated, tilled) compared with no-till. Williams (1993) evaluated preplant tillage (bottom plowed and disk, disked only, and no-till) and planting date effects (winter vs. summer) on RP establishment. She reported a general ranking for RP sprout emergence of plowed and disked > disked only = no-till and recommended planting RP in a well-prepared field during winter. While these experiments provide some information on the effects of seedbed preparation before planting RP, there was significant variability from year to year in treatment response depending on weather, and none of the experiments evaluated what is now the most likely approach to be used by producers, the combination of preplant herbicide and tillage.

This experiment investigated combinations of pre-plant seedbed preparation techniques and postemergence weed control strategies on RP establishment. The specific objectives were to quantify the effect of four seedbed preparation techniques, four weed control strategies, and their interaction on establishment of ‘Florigraze’ RP planted in strips in existing ‘Pensacola’ bahiagrass sod.

MATERIALS AND METHODS

Experimental Site

The experiment was conducted during 2011 and 2012 at the University of Florida Beef Research Unit (29°43' N; 82°21' W) near Gainesville, FL. The site was chosen because of available, well-established (at least 10 yr) and uniform Pensacola bahiagrass pastures and because nearby RP pastures at this site have persisted for 30 yr, indicative of adaptation of RP to the area. The soils at the experimental site were classified as Pomona sandy siliceous, hyperthermic Aeric Haplaquods) and Myakka sands (sandy siliceous, hyperthermic Ultic Alaquods). Initial characterization of the surface soil (0 to 15 cm) indicated soil pH of 6.0 and Mehlich-1 extractable P, K, Ca, and Mg of 8, 16, 161, and 25 mg kg⁻¹, respectively. Based on soil-test recommendation, the area was fertilized after planting RP each year with 16 kg ha⁻¹ of P from triple super phosphate (440 g P₂O₅ kg⁻¹) and 60 kg ha⁻¹ of K from muriate of potash (KCl, 600 g K₂O kg⁻¹, and 500 g Cl kg⁻¹). Rainfall data for the 2 yr of the experiment and the 30-yr average are presented in Fig. 1. Total rainfall was 1029 and 1499 mm in 2011 and 2012, respectively. Greater rainfall in 2012 was due to the occurrence of Tropical Storm Debby, which brought 300 mm of rainfall in June. Last freeze events before planting in spring occurred on 14 and 5 Mar. 2011 and 2012, respectively. First freeze at the end of the growing season occurred on 14 Nov. 2011 and 26 Nov. 2012. The timing of freeze events was typical for this location.

Plating Methodology

Rhizoma peanut was planted in strips that were 4-m wide and were bounded on each side by a 1-m-wide strip of undisturbed bahiagrass sod following the approach described in Castillo et al. (2013a, 2013b). Strips were planted using a conventional three-row (0.5-m row spacing) Bermuda King sprig planter (Kingfisher, OK). Each strip accommodated a total of nine rows of RP. The first and ninth rows of planted rhizomes were 0.25 m away from the undisturbed edge of bahiagrass sod. Rows 1 through 3 and 7 through 9 were planted first so that the outermost rows could be used to estimate spread of RP into the bahiagrass sod. To fit within the 4-m-wide strip, Rows 4 through 6 were planted such that spacing was 0.25 m between Rows 3 and 4 and Rows 6 and 7. Florigraze RP rhizomes were planted at a rate of 1000 kg ha⁻¹ (packed at ~79 kg m⁻³) to approximately 5-cm depth in 5 Apr. 2011 and 25 Apr. 2012. A new area was planted each year. After planting, the plots were cultipacked to firm the seedbed and ensure adequate soil-rhizome contact. Irrigation was applied during April and May of each year such that weekly rainfall plus irrigation equaled the 30-yr average weekly rainfall (18 and 20 mm per week in April and May, respectively). Total irrigation applied in April and May 2011 was 60 and 50 mm, respectively, and in April and May 2012 was 53 and 20 mm, respectively. No further irrigation was provided to any plot after the mowing treatment was initiated in June.

Treatments and Experimental Design

Treatments were the factorial combinations of four seedbed preparation techniques and four weed control strategies applied to the strips in which RP was planted, for a total of 16 treatments. Treatments were allocated in a split-plot arrangement of a randomized complete block design and were replicated three times. The main-plot factor was seedbed preparation technique and the subplot factor was weed control strategy. The area of an experimental unit was 3-m long and 6-m wide, with a 1-m border between the lengths of the plots. The width

Figure 1. Monthly rainfall at the University of Florida Beef Research Unit, Gainesville, FL, for 2011, 2012, and the 30-yr average.
corresponded to one 4-m wide strip of RP running the length of the plot and bounded on each side by a 1-m strip of bahiagrass that also ran the length of the plot.

Seedbed preparation treatments applied to the strips before planting RP were: i) glyphosate + tillage (application of glyphosate [N-[phosphonomethyl] glycine, in the form of its potassium salt; Monsanto Company, St. Louis, MO; 6.2 kg a.i. ha\(^{-1}\)) to kill bahiagrass on 6 Oct. 2010 and 9 Oct. 2010 followed by tillage with a moldboard plow and disk during the following February before planting); ii) tillage only (bahiagrass sod tilled in February as in the previous treatment but no glyphosate applied); iii) no-till (bahiagrass sod sprayed with glyphosate in October of the year before planting as described for glyphosate + tillage and the remaining aboveground biomass mowed to 5-cm stubble height before planting RP); and iv) sod removal (bahiagrass sod was lifted with a sod-cutter to a depth of 8 cm below soil level and removed from the strip before planting RP). Seedbed preparation treatments were chosen because they represented available and commercially practical options for addressing bahiagrass competition to establishing RP and because they had the potential to create a wide range of disturbance of the bahiagrass sod.

Weed control strategies in the planted strip were: i) control (no herbicide application, nondefoliated); ii) mowing (every 28 d to 10-cm stubble height simulating a bahiagrass hay production treatment); iii) imazapic [[\(\text{E}ceil\rceil2-(4,5\text{-dihydro}-4\text{-methyl}-4\text{-[1-

\text{methyl ethyl]-5-oxo-1-\text{H-imidazol-2-yl]-5-methyl-3-pyridine carboxylic acid}}\text{; Impose; Makshteshim Agan of North America, Raleigh, NC}] applied once at a rate of 0.07 kg a.i. ha\(^{-1}\)) when grass or broadleaf weeds were 5- to 10-cm tall), and iv) imaza- pic (0.07 kg a.i. ha\(^{-1}\)) mixed with 2,4-D amine (dimethylamine salt of 2,4-dichlorophenoxyacetic acid; 2,4-D amine Weed Killer, Universal Crop Protection Alliance LLC; a.i. dimethylamine salt of 2,4-dichlorophenoxyacetic acid; 2,4-D amine Weed Killer) applied once at a rate of 0.28 kg a.i. ha\(^{-1}\)) when grass or broadleaf weeds were 5- to 10-cm tall (imazapic + 2,4-D). Herbicide was applied using a CO\(_2\)-pressurized backpack sprayer calibrated to deliver 187 L ha\(^{-1}\). The strips were sprayed using a 3.04-m-wide boom so that the bahiagrass at the edges of the strips was not sprayed. Weed-control strategies were chosen based on previous studies that demonstrated the efficacy of imazapic alone or mixed with 2,4-D amine to control weeds when strip-planting RP (Castillo et al., 2013b).

The mowing treatment was applied starting ~11 wk after planting (28 June 2011 and 5 July 2012), coinciding with the anticipated end of the sprout-emergence period, and every 28 d thereafter throughout the growing season. Timing to initiate defoliation was based on data reported by Williams (1993) and Williams et al. (1997), who indicated that sprout emergence continued for 7 wk after emergence of first sprouts. In glyphosate + tillage, tillage only, and sod removal treatments, the planted strip was not defoliated during the growing season. Only the bahiagrass bordering the planted strip was mowed to 10-cm stubble every 28 d, and this occurred at the same time as the entire plot of the mowing treatment was clipped. Herbicide clethodim \{E\rceil\rceil2-2-\{\{3\text{-chloro-2-propenyl}\}\text{oxy}i\text{mino})\text{propyl}\}5-\{\text{ethylthio}i\text{propyl}\}3\text{-hydroxy-2-cyclohexen-1-one; Select Max, Valant U.S.A. Corporation, Walnut Creek, CA}\} was spot-sprayed to control common bermudagrass [Cynodon dactylon (L.) Pers.] growing in the strips planted to RP.

**Response Variables**

**Sprout Emergence**

Subplot treatments had not yet been imposed during the sprout emergence period, thus only main plot effects were quantified. Sprout counts began at emergence and every 2 wk through 6 wk after emergence. First sprout emergence occurred ~4 wk after planting on 28 Apr. 2011 and 17 May 2012. The number of sprouts was counted at each date within three randomly located, permanently marked 20- by 50-cm quadrats per main plot, so that evaluations were done in the same place each time. The 50-cm side of the quadrat was placed parallel to the RP rows with the 20-cm side centered perpendicular to a row of RP. Total sprout emergence in a plot was calculated as the average of the three quadrats per plot and was expressed as sprouts m\(^{-2}\).

**Canopy Cover and Frequency**

Rhizoma peanut canopy cover and frequency were measured following the methodology described by Castillo et al. (2013a). In summary, a 1-m\(^2\) quadrant (0.5 × 2 m) was placed in the center of the RP strip at a permanently marked location in each experimental unit, so that canopy cover was estimated in the same area each time. The 0.5-m side of the quadrant was oriented parallel to the RP rows and was placed 1 m away from the edge of the bahiagrass sod. Thus, the area of the quadrant included a total of six rows of RP. The quadrant was divided into one-hundred 10- by 10-cm squares (five rows of 20), and canopy cover was estimated visually every 28 d by the same observer in 20 selected squares (four squares in each row of 20 squares) per quadrant and averaged to obtain an overall cover per experimental unit.

Frequency of occurrence is a measurement of the relative distribution of RP in the strip. It was determined on the same dates and at the same quadrat locations and squares that were used to estimate RP cover. Presence or absence of RP was determined and frequency was calculated as the number of cells where RP was present divided by the total number of cells counted and multiplied by 100 to express it as a percentage.

**Light Environment**

Light environment was quantified to assess the importance of shading by weeds to RP establishment. Light penetrating through a bahiagrass canopy was cited as a critical factor affecting establishment of the tropical legume jointvetch (Aeschynome americana L.) (Kalmbacher and Martin, 1983). Thus, it was of concern that weeds or grass taller than RP could affect RP establishment. Ambient light environment at the top of the RP canopy was measured 2 wk before the projected end of the shoot emergence phase (11 wk after planting; Williams, 1993; Williams et al., 1997) and every 28 d thereafter (on Day 14 of each of the 28-d regrowth periods for the mowing treatment) to represent average light environment. Measurements followed the methodology described by Castillo et al. (2013b). In summary, light environment was characterized using a Sun-Scan Canopy Analysis System (Dynamax Inc., Houston, TX) to measure transmitted photosynthetically active radiation (PAR), and incident PAR. Light environment experienced by RP plants was calculated by dividing the transmitted PAR, by incident PAR and multiplying by 100 to express it as a percentage. The average of four observations per experimental unit provided an estimate of the light environment.
Rhizoma peanut spread and canopy height were measured on all plots the day before the last clipping event of the season for the moving treatment (9 Sept. 2011 and 10 Oct. 2012). To measure spread, a transect was positioned through the center of the RP strip running the length of the each plot. At the 1- and 2-m points along the 3-m transect, a line, perpendicular to the transect, was extended on each side. Spread was defined as the distance from the outermost planted row of RP to the farthest point where identifiable RP plant parts (aboveground) were found.

Canopy height described canopy development and interaction with treatments. It was measured using a ruler to quantify the distance from the soil surface to the undisturbed height of the RP canopy. Four measurements per plot were averaged to provide estimates of spread and canopy height for each experimental unit.

Statistical Analysis
Data were analyzed as repeated measures using PROC GLIMMIX of SAS (SAS Institute, 2010). Sampling date was considered a repeated measurement with a first order autoregressive covariance structure. Year and block were considered random effects. Year was considered random because a new set of plots was established each year. Treatments were fixed effects. In the case of two- and three-factor interactions, simple effects were analyzed using the SLICE procedure of SAS. Mean separation was based on the PDIFF and SLICEDIFF procedures of LSMEANS. Plots of model residuals were used to check normality, and in the case of nonnormal distributions, data transformations were used. Square root transformation was used for canopy cover and height, natural logarithm for sprout counts, and square root of 100 minus light environment for light environment. Data are presented back-transformed and standard errors were estimated using the delta method (Weisberg, 2005; Onofri et al., 2010). Treatments were considered different when $P \leq 0.05$. A trend was discussed when $P > 0.05$ and $\leq 0.10$.

RESULTS AND DISCUSSION
Sprout Emergence
Sprout emergence was affected by seedbed preparation and sampling date. Number of sprouts $m^{-2}$, averaged across collection dates, was greater ($P < 0.05$) for glyphosate + tillage (119) than no-till (58) and sod removal (54) treatments, but not different from tillage only (90; $P = 0.27$; Fig. 2). Sprout emergence averaged 80 sprouts $m^{-2}$ at Week 4 after emergence but did not increase ($P = 0.18$) through Week 6 (88 sprouts $m^{-2}$). These results are similar to previous reports indicating that the majority of RP sprouts emerge within 6 to 7 wk regardless of preplant tillage and planting date (Williams, 1993; Williams et al., 1997). As in the current study, those authors indicated that tillage of a seedbed favored RP sprout emergence compared with no-till planting.

Fewer sprouts for no-till RP have been attributed to desiccation of rhizomes due to poor soil-rhizome contact and inadequate soil moisture under rain-fed conditions (Williams, 1993). Limited irrigation during the sprout emergence period in the current study likely minimized the worst effects of moisture constraints on RP shoot emergence. It is not obvious that above- or belowground dead material had a negative effect on sprout emergence in the no-till treatment in the current study because sprout emergence was also low in the sod removal treatment where this material was not present. Instead, the similarity of response in the sod removal and no-till treatments and the superior performance of glyphosate + tillage and tillage-only treatment suggest that tilled soil allows for more favorable rhizome placement during planting, perhaps achieving greater depth or better soil-rhizome contact.

Rhizoma Peanut Canopy Cover
There were interactions of seedbed preparation by sampling date ($P = 0.04$) and weed control by sampling date ($P < 0.01$). Seedbed preparation by sampling date interaction occurred because RP canopy cover in glyphosate + tillage, no-till, and sod removal treatments continued to increase through August ($P < 0.01$ for July vs. August for all three treatments) compared with tillage only, which plateaued in July ($P = 0.29$; Fig. 3). Analysis by sampling date showed that there were no treatment differences in June ($P = 0.23$) or July ($P = 0.13$), while treatment differences in August and September approached significance ($P = 0.06$). In August, RP cover in no-till was not different than the glyphosate + tillage treatment, but it was greater than sod-lifted and tillage only treatments. In September, no-till had greater canopy cover than the other treatments. To assess the benefit of tillage vs. no tillage in spring following glyphosate application in fall, the average of August and September sampling dates were compared for glyphosate application in fall.
+ tillage vs. no-till treatments. There was a strong trend ($P = 0.06$) for greater RP canopy cover in no-till vs. glyphosate + tillage. Thus, mowing the dead grass residue in spring to a 5-cm stubble height before planting RP in strips (no-till treatment) resulted in greater RP cover than preparing a seedbed. This is important because reducing tillage operations when planting RP in strips would lower costs of producers. When examining this response, it is interesting to note that greater RP cover for the no-till treatment occurred despite greater shoot emergence for glyphosate + tillage. Kalmbacher and Martin (1983) planted aeschynomene into bahiagrass using no-till or disking for land preparation. They observed that tillage reduced soil moisture retention vs. no-till, resulting in greater shoot death for the tillage treatment. This may have occurred after the end of the shoot emergence period of the current study and contributed to reduced RP cover in the tillage treatments.

Weed control strategy by sampling date interaction occurred because RP canopy cover remained nearly constant (~7%) throughout the growing season in the mowing treatment compared with the control that increased to ~11% in July, and imazapic and imazapic + 2,4-D treatments that increased to ~25% in August (Fig. 3). Analysis by sampling date showed no weed control strategy effect in June ($P = 0.67$), but weed control treatment was significant ($P < 0.05$) at other dates. In August and September, there was no difference in RP canopy cover between imazapic and imazapic + 2,4-D treatments, but both treatments were greater than control and mowing (Fig. 3). Canopy cover of RP of ~30% by the end of the growing season was also reported by Castillo et al. (2013b) when using imazapic and imazapic + 2,4-D in a tillage-only seedbed. Thus, regardless of seedbed preparation, application of imazapic or imazapic + 2,4-D is recommended to maximize RP cover during the year of establishment.

**Rhizoma Peanut Frequency**

Frequency of occurrence of RP followed the same pattern as canopy cover (Fig. 3). Seedbed preparation by sampling date interaction approached significance ($P = 0.08$) and

+ tillage vs. no-till treatments. There was a strong trend ($P = 0.06$) for greater RP canopy cover in no-till vs. glyphosate + tillage. Thus, mowing the dead grass residue in spring to a 5-cm stubble height before planting RP in strips (no-till treatment) resulted in greater RP cover than preparing a seedbed. This is important because reducing tillage operations when planting RP in strips would lower costs of producers. When examining this response, it is interesting to note that greater RP cover for the no-till treatment occurred despite greater shoot emergence for glyphosate + tillage. Kalmbacher and Martin (1983) planted aeschynomene into bahiagrass using no-till or disking for land preparation. They observed that tillage reduced soil moisture retention vs. no-till, resulting in greater shoot death for the tillage treatment. This may have occurred after the end of the shoot emergence period of the current study and contributed to reduced RP cover in the tillage treatments.

Weed control strategy by sampling date interaction occurred because RP canopy cover remained nearly constant (~7%) throughout the growing season in the mowing treatment compared with the control that increased to ~11% in July, and imazapic and imazapic + 2,4-D treatments that increased to ~25% in August (Fig. 3). Analysis by sampling date showed no weed control strategy effect in June ($P = 0.67$), but weed control treatment was significant ($P < 0.05$) at other dates. In August and September, there was no difference in RP canopy cover between imazapic and imazapic + 2,4-D treatments, but both treatments were greater than control and mowing (Fig. 3). Canopy cover of RP of ~30% by the end of the growing season was also reported by Castillo et al. (2013b) when using imazapic and imazapic + 2,4-D in a tillage-only seedbed. Thus, regardless of seedbed preparation, application of imazapic or imazapic + 2,4-D is recommended to maximize RP cover during the year of establishment.

**Rhizoma Peanut Frequency**

Frequency of occurrence of RP followed the same pattern as canopy cover (Fig. 3). Seedbed preparation by sampling date interaction approached significance ($P = 0.08$) and
Weed control strategy by sampling date interaction was significant ($P < 0.01$). The interaction of seedbed preparation by sampling date occurred because there were no treatment differences in June ($P = 0.24$), but there were differences at all other sampling dates ($P < 0.03$). In July, frequency of RP for sod removal was least compared with other treatments which were not different from each other. In August, only no-till was greater than sod removal ($P < 0.01$), but by September RP frequency in no-till was greater than sod removal ($P < 0.01$) and tillage only treatments ($P = 0.02$).

Weed control effects on RP frequency were significant starting in August when imazapic and imazapic + 2,4-D treatments were not different but were greater than the control or mowing, and differences remained through September (Fig. 3). In the control treatment, RP frequency increased through July ($P = 0.25$ for July vs. August comparison) while it continued to increase through September for imazapic and imazapic + 2,4-D ($P < 0.01$ for both imazapic and imazapic + 2,4-D for August vs. September sampling dates). Our results are similar to previous reports (Castillo et al., 2013b) showing RP frequency of ~70% by the end of the growing season when using imazapic and imazapic + 2,4-D for weed control.

**Light Environment**

There was interaction of seedbed preparation by weed control strategy and weed control by sampling date ($P < 0.01$ for both), and the seedbed preparation by sampling date interaction approached significance ($P = 0.06$). At the first sampling date (9 wk after planting) seedbed preparation effects were not significant. Although treatment differences were present in July and August, ambient light environment experienced by RP plants remained above 92% for all treatments until September (Fig. 4). In September, treatments segregated into pairs with lower light environment in glyphosate + tillage and tillage only ($\leq 89$) compared with no-till and sod removal (≥94%). Similarly in October, no-till and sod removal were not different ($P = 0.33$) and were ≥93%, while glyphosate + tillage and tillage were ≤85% ($P = 0.65$).

Light environment appeared to be important because greater light penetration to the level of RP was associated with greater RP cover and frequency in the no-till treatment compared with glyphosate + tillage and tillage only (Fig. 2). Poor performance of the sod removal treatment occurred in spite of similar sprout emergence (Fig. 2) and light environment (Fig. 4) to the no-till treatment and may have been related to soil factors. Rhizome placement for sod removal was ~13 cm below the original soil surface (8 cm of sod removed + 5 cm planting depth). At approximately a 15-cm depth, the E horizon begins in the Pomona and Myakka series. The E horizon is characterized as coarse textured, light colored, eluted (Villapando and Graetz, 2001), with low organic matter and water holding capacity (USDA–NRCS Soil Survey Division, 2013). It is hypothesized that poor performance of rhizomes in the sod removal treatment could be due to nutrient deficiencies or frequent dry out events due to lower water holding capacity and lower organic matter in the E horizon than in the A horizon above it (Hudson, 1994).

Weed control effects on light environment were significant starting in August when light environment was lowest in the control (89%) compared with the rest of the treatments (≥95%) (Fig. 4). The control treatment continued to have the least favorable light environment through the end of the growing season while imazapic and imazapic + 2,4-D provided the best light environment (September) or were not different from the mowing treatment (August and October) (Fig. 4). Although the light environment was generally similar to imazapic and imazapic + 2,4-D, lower canopy cover and frequency in the mowing treatment...
Table 1. Seedbed preparation technique by weed control strategy interaction effect (*P < 0.01) on incident photosynthetically active radiation (PAR) at rhizoma peanut (RP) canopy height for strip-planted RP into existing bahiagrass pasture. Data are means across 2 yr (n = 6).

<table>
<thead>
<tr>
<th>Weed control strategy</th>
<th>Glyphosate + tillage</th>
<th>Tillage only</th>
<th>No-till</th>
<th>Sod removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>82 cB†</td>
<td>80 bB</td>
<td>92 cA</td>
<td>95 aA</td>
</tr>
<tr>
<td>Mowing</td>
<td>90 bC</td>
<td>93 aB</td>
<td>96 bA</td>
<td>95 aAB</td>
</tr>
<tr>
<td>Imazapic</td>
<td>96 aA</td>
<td>95 aA</td>
<td>98 aA</td>
<td>96 aA</td>
</tr>
<tr>
<td>Imazapic + 2,4-D</td>
<td>95 aA</td>
<td>95 aA</td>
<td>96 bA</td>
<td>97 aA</td>
</tr>
</tbody>
</table>

†Means followed by the same lowercase letter within a column or uppercase letter within a row are not different (*P > 0.05).
‡Standard error of treatment mean shown in parentheses.

(Fig. 2) can be attributed to belowground competition for resources from weeds growing in the strip (Cook, 1980). Broadleaf weeds present in the strips were mainly the annuals cutleaf cherry (Physalis angulata L.), common dayflower (Commelina diffusa Burm. f.), hairy indigo (Indigofera hirsuta L.), and smooth rattlebox (Crotalaria pallida Aiton).

The effect of seedbed preparation technique on light environment also depended on weed-control strategy. Seedbed preparation technique had no effect on light environment when imazapic and imazapic + 2,4-D were used; however, seedbed preparation was important for control and mowing treatments and PAR was greater or tended to be greater for the no-till and sod removal treatments (Table 1). Weed control had no effect on light environment in sod removal (≥95%; *P = 0.34; Table 1), but for the other three seedbed preparation techniques the herbicide treatments outperformed or tended to outperform the others. Imazapic and imazapic + 2,4-D treatments also performed well when compared with a broader range of weed control strategies (Castillo et al., 2013b).

**Spread and Canopy Height**

There was a trend (*P = 0.08) for effect of seedbed preparation on RP spread. Means were 12, 9, 7, and 0 cm for glyphosate + tillage, tillage only, no-till, and sod removal, respectively. Similar low levels of spread in the establishment year following strip planting have been reported (Castillo et al., 2013a, 2013b) and are thought to be due in part to greater emphasis of establishing plants on developing rhizome mass than on aboveground lateral spread.

There was seedbed preparation by weed control strategy interaction effect (*P < 0.01) for RP canopy height. The interaction occurred because RP canopy height was not affected by weed control strategy in the sod removal treatment, but there were differences among weed control strategies for other seedbed preparation techniques (Fig. 5). In the glyphosate + tillage, tillage only, and no-till seedbed preparation treatments, RP height was greatest for the control, which was associated with the greatest shading of RP, but height varied little among mowing, imazapic, and imazapic + 2,4-D treatments. Those treatments resulted in superior light environments for RP (Fig. 2) due to frequent removal of vegetative material above 10 cm (mowing) and effective control of weeds with imazapic and imazapic + 2,4-D. The results agree with previous reports that RP demonstrates stem elongation as a light-capturing strategy in growing environments where light is limiting (Castillo et al., 2013b).

**SUMMARY AND CONCLUSIONS**

Sprout emergence of RP was favored by land preparation that included tillage. This was likely due to achievement of greater depth of rhizome placement and/or better soil-rhizome contact. In spite of the advantages of tillage for sprout emergence, there was a strong trend (*P = 0.06) for RP canopy cover to be greater for the no-till treatment (21%) than for glyphosate + tillage (14%), tillage only (14%), or sod removal (12%) treatments by September of the establishment year. Weed control strategies imazapic and imazapic + 2,4-D resulted in greater RP canopy cover and frequency than the control or mowing. Lesser light environment for establishing RP in the control treatment and greater competition with other plants in the mowing treatment likely explained this response.
Under the conditions of this experiment, glyphosate application in fall followed by no-till planting in spring provided an adequate seedbed for strip-planting RP into existing bahiagrass pastures. Postplanting control of weeds or bahiagrass with imazapic or imazapic + 2,4-D was beneficial regardless of seedbed preparation treatment, but under these conditions there was no additional benefit of imazapic + 2,4-D vs. imazapic alone.

Acknowledgments
The authors would like to express their appreciation to Richard Cone of Cone Family Farms, LLC, for providing the rhizoma peanut planting material used in the study and to Michael Durham and Dwight Thomas for excellent technical support.

References