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16. Abstract

Annual ryegrass (*Lolium multiflorum*) is not currently recommended by TxDOT as a roadside re-vegetation nurse crop because its late maturity and height are too competitive for establishing perennial or spring plant mixtures. Two available genotypes used for turf that could be seeded with perennial grasses/legumes and annual wildflowers are Panterra V and Hanamiwase. Panterra V is turf-type annual ryegrass developed for home lawns while Hanamiwase is an early maturity annual ryegrass that produces seed in February and March. Both the turf-type and early-maturing annual ryegrasses could be less competitive for nutrients, moisture, and sunlight while providing adequate cover. Appropriate warm-season perennial grasses/legumes and wildflower mixes specified by TxDOT were planted as treatments in each of four regions (Beeville, Overton, Nacogdoches, and Stephenville) to evaluate these annual ryegrass genotypes, seeding rates, and mowing influences. Additionally, similar treatments were installed at five locations in a roadway implementation trial. The turf-type and early-maturing ryegrasses proved to be both competitive and persistent when used as nurse crops for warm-season perennials with mature heights similar to the annual ryegrass varieties used in the past.

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TURF-TYPE AND EARLY MATURING ANNUAL RYEGRASS TO ESTABLISH PERENNIAL VEGETATION: TECHNICAL REPORT

by

Hennen Cummings
Tarleton State University

Roger Wittie
Tarleton State University

James P. Muir
Texas A&M AgriLife Research

John Bow
Texas A&M AgriLife Research

Raymondo Molina
Tarleton State University

Tanner Arwine
Tarleton State University

and

Michael Maurer
Stephen F. Austin University

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and the
Federal Highway Administration

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TARLETON STATE UNIVERSITY
Department of Environmental and Agricultural Management
Stephenville, Texas

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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PROJECT IMPLEMENTATION

Project objectives were to improve roadside vegetation management by determining more efficient methods to establish vegetation while maintaining adequate cover on roadside. Roadside vegetation establishment was to be achieved by planting both cool-season grass nurse crops and warm-season perennials along with wildflowers in either the spring or fall throughout Texas. The specific objectives were:

1. Identify annual ryegrass varieties that provide the best nurse crop cover for annual wildflower establishment (Task 1).
2. Identify annual ryegrass varieties that provide the best nurse crop cover for perennial, warm-season vegetation establishment (Task 1).
3. Evaluate the influence of mowing regimen and seeding rate on annual ryegrass cover and wildflower or warm-season vegetation establishment (Task 1).
4. Evaluate the influence of wildflower seeding rate when seeded in the fall with a turf-type annual ryegrass (Task 2).
5. Evaluate the influence of annual ryegrass seeding rate on warm-season perennial vegetation establishment when seeded in the fall (Task 2).
6. Evaluate whether fall seeding of warm-season perennial vegetation along with an annual ryegrass nurse crop or spring seeding of the same species into the same nurse crop provide for the establishment of target warm-season perennial vegetation (Task 2).
7. Evaluate whether results from protected-plot studies can be successfully transferred to actual right-of-ways (Task 3).

Task 1 and Task 2 were conducted at University/Research & Extension Centers in four of Texas' hardiness zones and Task 3 trials were conducted on roadway sites at five Texas locations.

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PROJECT WORK COMPLETED

RESEARCH CENTER TRIALS

First and second year trials were conducted within the protection of the Texas A&M AgriLife Research Centers (Stephenville, Overton, and Beeville) and universities (Tarleton State and Stephen F. Austin State University) as replicated plot studies on land with minimal slope and irrigation access to limit external influences. Locations from north to south were selected to represent four (see below) of six USDA Hardiness Zones found in Texas (TxDOT, 2010). Locations were selected not only for temperature (north-south) and rainfall (east-west) gradients but also on soils that best represent the region:

Locations	Soil series	Surface texture	Affiliation
Beeville	Weesatche	sandy clay loam	AgriLife Research
Nacogdoches	Nacogdoches	gravelly clay loam	SFA Equine Center
Overton	Bowie	very fine sandy loam	AgriLife Research
Stephenville	Windthorst	fine sandy loam	AgriLife Research

Experimental 12 by 6 ft (4 x 2 m) plots were established at each location, replicated four times on slopes of <1%. Analyses of variance was conducted to determine differences and a least mean square separation was implemented to separate multiple means where appropriate (SAS, 2012. The SAS System for Windows, Release 9.1. SAS Inst., Cary, NC). The statistical model for Tasks 1 and 2 considered three-way interactions first. If three-way interactions were not significant, two-way interactions were analyzed. In the case of no interactions, simple effects (for each factor) were examined. Differences at $P \leq 0.05$ were considered significant. Each location was considered a separate experiment due to inherent differences in soils, climate, slope, and most importantly, distinct TxDOT recommendations for annual wildflower and perennial grass/legume mixes.

ROADWAY TRIALS

Third-year trials (Task 3) were conducted on five TxDOT-prepared sites associated with roadway construction projects from the North and East administrative districts. Locations identified were near Hooks, Grand Saline, Bryan, Rogers, and Zephyr, Texas. A sixth location near Huntsville was originally included in the trials but removed after planting due construction interference. Trials were installed as replicated plots on sites representative of typical roadway conditions and slopes ranged from 1-3% at Grand Saline to 10-15% at Hooks and Bryan. Locations represented both temperature (north-south) and rainfall (east-west) gradients.

Locations	Surface	Slope	Affiliation
Hooks	Engineered	10-15%	TxDOT
Grand Saline	Engineered	1-3%	TxDOT
Bryan	Engineered	10-15%	TxDOT
Rogers	Engineered	5-10%	TxDOT
Zephyr	Engineered	3-5%	TxDOT

Experimental 5 x 5 m plots (16.5 x 16.5 ft) in four replicates were established at each location. Analyses of variance were conducted to determine differences and least mean square separations were implemented to separate multiple means where appropriate (SAS, 2012. The SAS System for Windows, Release 9.1. SAS Inst., Cary, NC). The statistical model for Task 3 considered interactions first. If interactions were not significant, simple model effects were analyzed. Differences at $P \leq 0.05$ were considered significant. Each location was considered a separate experiment due to inherent differences in climate, site surfaces, site preparation, background cover, and slopes.

DEPENDENT VARIABLES MEASURED FOR CENTER AND ROADWAY DEMONSTRATION TRIALS

Variable 1: Annual Ryegrass Density, Height, Senescence, and Persistence.

Seedling establishment and height were estimated in the central 9 ft^2 of every plot from mid-December through mid-May Years 1 and 2 of the first year plantings and Year 2 of the second year planting. Cool-season weedy cover was also estimated. Dates of 50% (visual estimate, average all plots) boot, flowering, and mature seed were recorded. Numbers of seed-producing inflorescences at peak seed formation for each variety were estimated. From mid-

February, plant survival (defined as number of plants with flexible, green leaves within the same 9 ft^2 area) of the variety trial were recorded up to 90% senescence. Similar observations were included for roadway trials in Year 3.

Variable 2: Wildflower Establishment and Persistence

Wildflower seedling counts, by species, were conducted mid-December through mid-May of the first year plantings and volunteer seedling counts the second year of the first year planting. Cool-season weedy forbs also were counted at this time. Date of initiation of flowering was recorded, by species, and numbers of viable inflorescences were recorded in the inner 9 ft^2. For roadway trials, only establishment during the spring was estimated.

Variable 3: Perennial Grass/Legume Establishment and Persistence

Perennial grass/legume seedling counts and heights, by target species, were conducted mid-May and mid-July following the first year plantings and second year following the first year planting. Weed species were also counted at these times. Percentage ground cover (visual rating 0-100%) and mean height measurements were recorded in mid-July both years on both first- and second-year plots. Establishment was noted for roadway trials.

Data were collected on or about 11/05, 02/14, 03/14, 04/12, 05/03, 05/19, and 07/08, and10/25 for first and second-year trials. Data for the roadway implementation was collected on or about 01/10, 02/15, 03/15, and 05/01. All trials spanned 2011-2013.

TASK 1. ANNUAL RYEGRASS VARIETY × SEEDING RATE × MOWING

The purpose of Task 1 was to evaluate the influences of annual ryegrass variety, seedling rate, and mowing regimen on establishment of wildflowers and perennial grasses/legumes. Specific objectives included:

a) Evaluate annual ryegrass varieties that function best as nurse crops for warm-season wildflower/perennial grass/legume establishment and growth.
b) Assess annual ryegrass seeding rates that combine protective cover with subsequent establishment of desired perennial plants and wildflowers.
c) Determine whether mowing affects subsequent wildflower and perennial grass establishment or on ryegrass stand senescence and persistence.

d) Assess persistence of annual wildflowers and changes in populations of volunteer annual ryegrass the following years.

Three annual ryegrass varieties, Panterra V (turf-type), Hanamiwase (early-maturing), and Gulf (standard), were compared to a no-nurse-crop control at two seeding rates and one mowing height on protected locations. Soil was tilled, roll-packed, and irrigated to allow germination of weed seed and then sprayed with RoundUp® to eliminate interfering cover. The recommended regional TxDOT wildflower and perennial grass/legume mix was planted in combination with the annual ryegrass in the fall of 2010 and 2011 in four zones (Stephenville, Beeville, Overton, and Nacogdoches). Annual ryegrass seed was broadcast at 0, 50 and 100% of breeder/distributor recommended rates (0, 24, and 48 pounds per acre [lbs/A] in year 2010 and 0, 12, and 24 lbs/A in year 2011) on 12 by 6 ft (4 by 2 m) plots along with 100% and 200% recommended seeding rates of wildflower and perennial grass/legume mixtures appropriate for the location of the trial (4 varieties X 3 rates X 4 replications = 48 plots). No irrigation was applied after seeding; germination and establishment relied strictly on precipitation received at each location. Sub-plots (6 by 6 ft [2 by 2 m]; 48 X 2 mowing heights = 96) within main plots were either mowed at 6 inches or not mowed. Data was collected using a square meter grid system. The number of live plants in ten random 15.5 in^2 (100 cm^2) was determined for each planted species. Plants were counted by species monthly, starting approximately 60 days post-seeding and through stand brown-out. Stand height, percentage ground cover, and plant health were also documented each time. After the spring mowing, plant counts were used determined the influence of mowing on ryegrass regrowth and senescence.

<u>Variety treatment</u>:

i. No ryegrass control
ii. Gulf
iii. Early maturing (Hanamiwase)
iv. Turf-Type (Panterra V)

<u>Annual ryegrass seeding rate treatments</u>

i. 0%
ii. 50% (24 lbs/A in 2010, 12 lbs/A in 2011)
iii. 100% (48 lbs/A in 2012, 24 lbs/A in 2011)

Mowing treatment

i. None
ii. 6" in spring

The field plot design included variety by seeding rate interaction on 12 by 6 ft main plots; each of these were split into two 6 by 6 ft sub-plots that received the mowing treatments. The design was a three-way factorial arranged in split-plots with four replications. One mowing height treatment was applied to half of all the plots in the spring.

Wildflowers plus legumes were planted as a mixture at an average rate of either 5 or 10 lbs/A on a pure live seed (PLS) basis.

Plants	**lbs/A**
Blackeyed Susan	1.5
Bluebonnet	20
Plains Coreopsis	2.5
Drummond Phlox	8
Evening Primrose	3
Illinois Bundleflower	2

Perennial grasses were planted as a mixture at an average rate of either 1 or 2 lbs/A on a PLS basis.

Plants	**lbs/A**
Bahiagrass	9
Bermudagrass	1.8
Blue Grama	0.9
Green Sprangletop	0.3
Little Bluestem	1
Sand Lovegrass	0.5
Sideoats Grama	2.7

Task 1 Results

Plant Count Results by Date within Location

Stephenville, 11/05/2010. There were no significant differences (*P*>0.05) among annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at both the 48 and 24 lbs/A rates for mean live plants which ranged from 45 to 49 mean live plants for 48 lbs/A and 27 to 35 mean live plants for 24 lbs/A.

Stephenville, 02/14/2011. Gulf at 48 lbs/A resulted in significantly (*P*≤0.05) more mean living plants at 40 than Hanamiwase at 27. Neither was significantly different (*P*>0.05) from Panterra V which was 34 mean live plants. There were no significant differences (*P*>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at 24 lbs/A rates for mean live plants which ranged from 24 to 26 mean live plants.

Stephenville, 05/04/2011. Hanamiwase resulted in 1 mean living plants which was significantly less (*P*≤0.05) than both Gulf at 14 and Panterra V at 12 for the 48 lbs/A rate. Similarly, Hanamiwase plots had 1.5 mean living plants which was significantly less (*P*≤0.05) than both Gulf at 14 and Panterra V at 10 for the 24 lbs/A rate.

Overton, 11/05/2010. There were no significant differences (*P*>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at both the 48 and 24 lbs/A rates for mean live plants which ranged from 60 to 79 mean live plants for 48 lbs/A and 30 to 40 mean live plants for 24 lbs/A.

Overton, 02/14/2011. Panterra V at 48 lbs/A resulted in significantly more (*P*≤0.05) mean living plants at 26 than Hanamiwase at 19. Neither was significantly different (*P*>0.05) from Gulf which averaged 24 mean live plants. There were no significant differences (*P*>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at 24 lbs/A rates for mean live plants which ranged from 10 to 15 mean live plants.

Overton, 05/04/2011. Hanamiwase plots had 3 mean living plants which was significantly less (*P*≤0.05) than both Gulf at 14 and Panterra V at 17 for the 48 lbs/A rate. Similarly, Hanamiwase plantings resulted in 5 mean living plants which was significantly less (*P*≤0.05) than both Gulf at 14 and Panterra V at 15 for the 24 lbs/A rate.

Nacogdoches, 11/05/2010. There were no significant differences (*P*>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at either the 48 and 24 lbs/A rates for mean live plants which ranged from 13 to 21 mean live plants for 48 lbs/A and 7 to 14 mean live plants for 24 lbs/A.

Nacogdoches, 02/14/2011. There were no significant differences (P>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at either the 48 and 24 lbs/A rates for mean live plants which ranged from 15 to 23 mean live plants for 48 lbs/A and 10 to 18 mean live plants for 24 lbs/A.

Nacogdoches, 05/04/2011. Hanamiwase plots had 1 mean living plants which was significantly less (P≤0.05) than both Gulf at 18 and Panterra V at 22 for the 48 lbs/A rate. Similarly, Hanamiwase was reported at 3 mean living plants which was significantly less (P≤0.05) than both Gulf at 11 and Panterra V at 17 for the 24 lbs/A rate.

Beeville, 11/05/2010. There were no significant differences (P>0.05) among annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at both the 48 and 24 lbs/A rates for mean live plants which ranged from 26 to 41 mean live plants for 48 lbs/A and 7 to 14 mean live plants for 24 lbs/A.

Beeville, 02/14/2011. Panterra V plots had 23 mean live plants at the 48 lbs/A rate which was significantly greater (P≤0.05) than Gulf which reported 17 mean live plants which was significantly greater (P≤0.05) than 10 mean live plants recorded for Hanamiwase. There were no significant differences (P>0.05) among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at the 24 lbs/A rates for mean live plants which ranged from 7 to 11 mean live plants mean live plants.

Beeville, 05/04/2011. There were no living plants among the annual ryegrass varieties Gulf, Hanamiwase, or Panterra V at either the 48 or 24 lbs/A rates.

Variety by Mowing

There were no significant differences (P>0.05) among the mean number of plants in the mowed and non-mowed Gulf, Panterra V, or Hanamiwase plots when measured in fall 2011 or spring 2012. In fall 2011, the mowing treatment had not been implemented yet; the mean number of plants ranged from 16 for Hanamiwase to 45 for Panterra V in the to be mowed subplots, and the mean number of plants ranged from 17 for Hanamiwase to 50 for Panterra V in the non-mowed subplots. In spring 2012 after mowing, the mean number of plants ranged from

10 for Hanamiwase to 39 for Panterra V in the mowed subplots, and the mean number of plants ranged from 5 for Hanamiwase to 6 for Panterra V in the non-mowed subplots.

Seeding Rate by Mowing

There were no significant differences (P>0.05) in mean living ryegrass plants in the mowed and non-mowed plots for the 0 (control), 24, and 48 lbs/A rates in fall 2011 and spring 2012. However, mowing tended to increase the number of plants in spring 2012. In fall 2011, for the 48lbs/A rate, the mean number of plants was 29 in mowed and 33 in non-mowed plots. In fall 2011 before mowing, the mean number of plants was 35 for mowed and non-mowed at the 24lbs/A rate. In spring 2012 after mowing, for the 48 lbs/A rate, the mean number of plants was 26 in mowed and 6 in non-mowed. In spring 2012, for the 24 lbs/A rate, the mean number of plants was 26 in mowed and 5 in non-mowed.

Task 1 Summary

Hanamiwase annual ryegrass produced significantly fewer (P≤0.05) mean live plants than both Gulf and Panterra at three locations. Gulf and Panterra V produced significantly greater (P≤0.05) mean live plants than Hanamiwase at one location each. These data suggest that Hanamiwase should be less competitive than Gulf or Panterra V as a nurse crop, therefore, a trial to further examine Hanamiwasse as the nurse crop was added to the project.

There were no significant differences (P>0.05) among Task 1 volunteer ryegrass counts that were conducted in Year 2 fall and spring. In fall, the numbers of mean live plants for the 48 lbs/A ranged from 19 in Hanamiwase to 48 for Panterra V, and for the 24 lbs/A, the values ranged from 18 for Hanamiwase to 48 mean live plants for Panterra V. The control plot where no ryegrass seeds were sown reported 2 volunteer annual ryegrass plants. In spring, the numbers of mean live plants for the 48 lbs/A ranged from 8 in Hanamiwase to 22 for Panterra V, and for the 24 lbs/A, the values ranged from 7 for Hanamiwase to 20 mean live plants for both Gulf and Panterra V. The control plot where no ryegrass seeds were sown reported 2 volunteer annual ryegrass plants.

Although not statistically significant (P>0.05), mowing appears to increase the number of annual ryegrass plants which is consistent with the fundamentals of turfgrass management where regular mowing increases density. Additionally, mowing may stimulate tillering while removing materials that increase mat density following the growing season. Mowing would not be recommended as a management practice to limit or reduce annual ryegrass persistence when used as a nurse crop.

TASK 2. WILDFLOWER MIXTURE SEEDING RATES × PERENNIAL GRASS/LEGUME SEEDING RATE × PLANTING SEASON.

The purpose of Task 2 was to evaluate the influences of wildflower mixture seeding rates, perennial grass/legume seeding rates, and planting season on permanent cover establishment using a single annual ryegrass variety as a nurse crop. Specific objectives included:

a) Evaluate Panterra V turf-type annual ryegrass as a nurse crop for the establishment of wildflower and perennial grasses/legumes.
b) Determine if doubling native wildflower and warm-season perennial grass/legume seeding rates aided in wildflower population establishment despite competition from Panterra V turf-type annual ryegrass.
c) Assess persistence of annual wildflowers and changes in populations of volunteer annual ryegrass the following years.

On sites already disced, roll-packed, and irrigated, initial weed flush was sprayed with Roundup®, and then over-seeded with Panterra V annual ryegrass at 100% recommended breeder rates (48 lbs/A in 2010 and 24lbs/A in 2011) across all plots. Planted plot size for this task was 18 by 6 ft (6 by 2 m). Wildflower and perennial grass mixes were seeded at 100 or 200% of the TxDOT recommended seeding rates. Trials were established in four zones (Stephenville, Beeville, Overton, and Nacogdoches). Each main plot was split into three 6 by 6 ft sub-plots that were over-seeded with the appropriate perennial grass (Item 164 in TxDOT's Standard Specifications; ftp://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf) for that region at 100 or 200% recommended seeding rates in autumn or 100% seeding rate in spring. Plots (4) were each split into sub-plots (3) and replicated (4) times for a total of 4 X 3 X 4 = 48 sub-plots at each of the four locations. Data are collected using a square meter grid system. Plants were counted monthly by species. Height, percentage ground cover, and plant health were also documented each time.

Wildflower seeding rates:

i. 100% of TxDOT recommended rate
ii. 200% of TxDOT recommended rate

Perennial grass/legume seeding rates:

i. 100% of TxDOT recommended rate
ii. 200% of TxDOT recommended rate

Planting season:

i. 7 treatments sown in autumn
ii. 3 treatments sown in spring

Wildflowers and perennial grasses/legumes used in Task 2 were similar to those included for Task 1. All were seeded according to treatment rate on a PLS basis.

Task 2 Results

In 2011, there was too much competition from Panterra V annual ryegrass for establishment of warm-season wildflowers and perennial grasses possibly due to its late maturity, height, strong matting layer, and seeding rate. Data and observation indicated that using a forage establishment rate of 24 lbs/A for Panterra V turf-type annual ryegrass was excessive as nurse crop cover. Resulting low counts for warm-season perennial grasses may have occurred due to a lack of moisture since there was a historical drought in 2011 and perhaps lack of sunlight and soil moisture due to ryegrass competition. However, control plots (no ryegrass) did not establish perennial grasses either; yet the wildflowers did germinate in these plots. There was no significant difference (P>0.05) among ryegrass varieties until spring senescence. At that time, Hanamiwase, the early-maturing type, plots had lower plant counts and were less dense than the Panterra V and Gulf annual ryegrasses. Data did indicate a significant difference (P≤0.05) between the seeding rate of 12 and 24 lbs/A, with the 12 lbs/A having lower plant counts (density). Due to the lower Hanamiwase annual ryegrass density, there was less competition for the wildflower and perennial grass/legume mix. Therefore, wildflower plant counts were greater which could lead to stronger wildflower stands the following seasons. Perhaps, Hanamiwase, the early-maturing type, at 12 lbs/A (1/2 rate) would better serve as a nurse crop than Panterra V for the establishment of warm-season wildflowers and perennial grasses, especially if mature stand height and mat-forming tendencies could be overcome.

Stem counts following spring mowing indicated that mowing increased ($P \leq 0.05$) annual ryegrass counts and delayed plant senescence. Nonetheless, Hanamiwase showed less ($P \leq 0.05$) increase in plant counts compared to Gulf and Panterra V after mowing.

Plots established in 2010 were monitored through 2012 for annual ryegrass and wildflower reestablishment. Wildflower reestablishment was poor due to competition from volunteer ryegrass, especially in Panterra V plots. Furthermore, the lodging and matting tendencies of annual ryegrass suppress new plant establishment. When the trial was replicated in 2011 using Panterra V at 24 lbs/A as a nurse crop, results were similar to 2010 where the Panterra V was too competitive and there were no significant differences ($P>0.05$) among treatments.

Based on 2010 trial results and discussions with TxDOT personnel, the complete trial was repeated at Stephenville in 2011 under more intensive management and lower weed competition. Seeding rates for Panterra V, Hanamiwase, and Gulf varieties were reduced from 24 and 48 lbs/A to 12 and 24 lbs/A (Task 1). Furthermore, new plots for Hanamiwase (early-maturing) annual ryegrass as a nurse crop were seeded at 12 lbs/A (1/2 rate) with and without supplemental irrigation to reduce environmental impacts (Task 2).

Task 2 Summary

In general, mean living annual ryegrass plants per 100 cm^2 tended to decrease from germination to senescence. Senescence of Panterra V occurred by 05/19/2011. Perennial warm-season grasses that were sown in fall 2010 or spring 2011 were not observed on 05/19/2011. Wildflower plants per square meter were reduced dramatically ($P \leq 0.05$) in plots containing a ryegrass nurse crop in 2011; however, all wildflowers were severely affected by drought in summer of 2011 and were not observed past 06/09/2011.

TASK 3. ROADWAY IMPLEMENTATION

The purpose of Task 3 was to test and demonstrate small-plot trial results, derived under supposedly more controlled environments, in public TxDOT work sites. Task 3 trials were established in autumn of the third year. Demonstration plots were installed in October 2012 by

AgriLife Center and Tarleton personnel at roadway construction locations identified by TxDOT. Demonstration plot design, installed treatments, inputs, and management practices were dependent on results from Tasks 1 and 2.

Demonstration Installation Methods

Six locations in the north and east Texas TxDOT administrative regions were identified for the roadside implementation phase (Task 3). Locations included Hooks, Grand Saline, Rogers and Zephyr in the north region with Bryan and Huntsville in the south region. Due to construction interference at the Huntsville location, it was removed from the project after planting (Fig. 1)

Trial plots 15 by 15ft (5 x 5m) were flagged and installed at each location parallel with the established roadway during the first week of October, 2012. Plot areas had been prepared for seeding per TxDOT specs, but at several locations, emergent competitive cover was suppressed by herbicide application.

Hanamiwase early-maturing annual ryegrass was seeded in replicated plots (2) at each location as a nurse crop for wildflower and perennial grass establishment. Ryegrass was seeded at 25% of a forage establishment rate (≈ 6 lb/A PLS) as one treatment, with a second treatment where ryegrass was seeded at 10% (PLS) of the total perennial seed mix. A no ryegrass control was included (Table 1).

The wildflower mixture utilized was based on TxDOT mix specification for the eco-regions represented; however, for our studies the mixture was standardized for all locations based on seed availability and cost (Table 2). The wildflower mixture seeding rate was 10 lb/A PLS.

Perennial grasses and legumes (PG/L) also were seeded in each plot for permanent cover establishment. The PG/L mixture was based on TxDOT specifications for roadway planting, but standardized for all locations. The PG/L seeding rate was 2 lb/A PLS. Mixture constituents and percentages are presented in Table 3.

Nurse crop, wildflower, and perennial grass/legume cover was evaluated on four dates post-planting, during the weeks of January 7, 2013, February 16, 2013, March 11, 2013, and May 18, 2013. Response variables observed for installed plant materials included stem counts (#/m^2), coverage (%), and average stand height (cm). Additionally, stem counts were observed for other interfering vegetation in each plot. Precipitation received at each location for the period January 2013 to May 2013 was estimated using NOAA National Climate Center data from recording stations nearest each roadway demonstration site.

Analyses of variance was conducted to determine differences and a least mean square separation was implemented to separate multiple means where appropriate (SAS, 2012. The SAS System for Windows, Release 9.1. SAS Inst., Cary, NC). The statistical model for Task 3 considered interactions first. If interactions were not significant, simple model effects were analyzed. Differences at $P \leq 0.05$ were considered significant. Each location was considered a separate experiment due to inherent differences in climate, site surfaces, site preparation, background cover, and slopes.

Task 3 Results

As expected, roadway implementation location resulted in the greatest variability for all measures. Sites near Bryan and Rogers (Figs. 31 and 32) experienced construction traffic throughout the sampling period resulting in data interference across several plots. Interfering cover was greatest at the Grand Saline site (Fig. 23), but similar across other locations. At the Bryan site, a nurse crop of wheat and oats had been seeded prior to plot installation which resulted in additional interference (Fig. 30). Therefore, responses observed became location specific.

Sampling date also accounted for a large percentage of total variability as stands became established and significant interaction ($P \leq 0.05$) was detected for location by date. Therefore, results are discussed by date within location. Replicates within location did not differ.

Seed Rate Treatments

Hanamiwase early-maturing, annual ryegrass was seeded at 25% of forage rate and at 10% of total seed mix to replicated plots at all locations. Although there were visual differences at some locations, stem counts between seeding rates did not differ statistically ($P > 0.05$) and no interactions by either location or date were detected.

Treatment within Location

1. Hooks. The Hooks site differed significantly ($P \leq 0.05$) from all other locations, producing high annual ryegrass stem counts for both treatments and with counts and coverage increasing over time. Average stem counts for the 10% and 25% rates were 127 and 89, respectively. Average stand height for this location peaked at 44" and aerial coverage peaked at 79%. Seeded wildflowers were not observed in plots until March, but stem counts increased to 172 by May. Although wildflowers were present and prevalent at this location, the early-maturing ryegrass stand hid most from view.

2. Grand Saline. The Grand Saline site differed significantly ($P \leq 0.05$) from all other locations, producing high annual ryegrass stem counts for both treatments but with counts increasing then decreasing over time. Final average stem counts for the 10% and 25% rates were similar at 150. Average stand height for this location peaked at 52" and aerial coverage peaked at 100%. Seeded wildflowers were observed in plots early, but stem counts only reached 9 by May. Although wildflowers were present, the early-maturing ryegrass stand hid most from view.

3. Bryan. The Bryan site differed significantly ($P \leq 0.05$) from both Hooks and Grand Saline but was similar ($P > 0.05$) to Rogers and Zephyr with most responses intermediate to other locations. Annual ryegrass stem counts increased then decreased over time. Final average stem counts for the 10% and 25% rates were 67 and 34, respectively. These values produced visual differences between seeding rate treatments on site, but were not statistically different ($P \leq 0.05$). Average stand height for this location only reached 8" and aerial coverage only reached 21%. These results were probably due to construction interference at this site as well as from competition due to the prior seeding of wheat and oat. Seeded wildflowers were the highest ($P \leq 0.05$) for all locations early with initial stem counts of 11 in January, rising to 35 by March, then declining to 13 by May. Because of the thinness of the cover at this site, wildflowers were easily visible. However, total stand coverage was inadequate to protect the site from erosion and some washing did occur.

4. Rogers. The Rogers site differed significantly ($P \leq 0.05$) from both Hooks and Grand Saline but was similar ($P > 0.05$) to Bryan and Zephyr with responses generally intermediate to Bryan and Zephyr. Annual ryegrass at this location was not observed until February with stem counts stable over time. Final average stem counts for the 10% and 25% rates were 29 and 18, respectively. These values also produced visual differences between seeding rate treatments on site, but were not statistically different ($P \leq 0.05$). Average stand height for this location only reached 12" and aerial coverage only reached 24%. These results were probably due to construction interference at this site as well. Seeded wildflowers steadily increased over time rising to 27 by March, then declining to 22 by May. Because of the thinness of the cover at this site, wildflowers were easily visible. However, total stand coverage was inadequate to protect the site from erosion and some washing did occur.

5. Zephyr. The Zephyr site differed significantly ($P \leq 0.05$) from both Hooks and Grand Saline but was similar ($P > 0.05$) to Bryan and Zephyr but with numerical responses generally lower than Bryan and Zephyr. Annual ryegrass at this location was not observed until February with high initial stem counts but with counts declining over time. In February, stem counts averaged 54, but by May, average stem counts for the 10% and 25% rates were 6 and 0, respectively. Average stand height for this location only reached 4" but aerial coverage reached 39%. This location was the driest of all and results reflect that condition. Seeded wildflowers were present by February and counts remained stable over time averaging 10 by May. Because of the thinness of the cover at this site, wildflowers were easily visible. However, total stand coverage was inadequate to protect the site from erosion and some washing did occur.

Task 3 Summary

Although six sites were initially selected for this task, data from one was ineffective leaving four northern sites and a single southern site. In general, ryegrass germination and initial establishment (February) was adequate but climatic conditions (low soil moisture and high temperatures) and construction traffic resulted in quick stand depletions in most locations by May. In the best location (Grand Saline), ryegrass aerial coverage reached 100% while in the worse (Zephyr for climate and Bryan due to construction traffic), it only reached 39 and 21%, respectively. Wildflower germination, establishment and subsequent stand depletion followed a similar pattern although established seedlings persisted longer (into May) than did the ryegrass. These numbers at best were in the 100's per m^2 (10.8 ft^2) early in the season and in the 10's late in the season, inadequate for good aerial coverage and soil stability in most locations. With greater protection from construction traffic and better climatic conditions in different years, results would likely improve.

TASK 4. ANALYZE DATA AND PROVIDE REPORTS AS REQUIRED.

All data collected for Tasks 1-3 were analyzed as noted above. Semiannual reports and project summary meetings were conducted between project and TxDOT personnel periodically throughout the project period.

TASK 5. DEVELOP AN INSTRUCTION GUIDELINE ON UTILIZING RYEGRASS AS A NURSE CROP FOR SEEDING WARM-SEASON PERENNIALS AND FALL-SEEDED WILDFLOWERS.

Based on the results of all tasks, the use of Panterra V (turf-type) and/or Hanamiwase (early-maturing) as a nurse crop for establishment of permanent, perennial roadway cover could not be recommended. Therefore, *Task 5: Development of an Instruction Guideline* was removed as a requirement for this project.

PROJECT SUMMARY

This project compared Hanamiwase, an early maturing annual ryegrass, and Panterra V, a turf-type annual ryegrass, to Gulf annual ryegrass for use as a nurse crop to establish annual wildflowers and perennial grasses/legumes in spring and fall plantings at four locations (Task 1 and 2). Results from that work were utilized to design and install plantings on road shoulders in north and east Texas (Task 3). Gulf's and Panterra V's heights, late maturities, mat layers, and volunteer plants the following seasons were too competitive for use as a nurse crop. More wildflowers and perennial grasses established when using Hanamiwase due to its less competitive stand and earlier maturing habit; however, Hanamiwase seeding rates that may allow for desired vegetation establishment would not satisfactorily prevent erosion on road shoulders. None of the annual grasses evaluated were truly dwarf in stature. Based on results from these studies, the use of the Panterra V or Hanamiwase varieties of annual ryegrass as a nurse crop for wildflower and perennial grass establishment is not recommended. Perhaps development of new annual ryegrass varieties or perennial ryegrass and fine fescue would serve better as a nurse crop if seeded at less-competitive, yet erosion preventative, rates.

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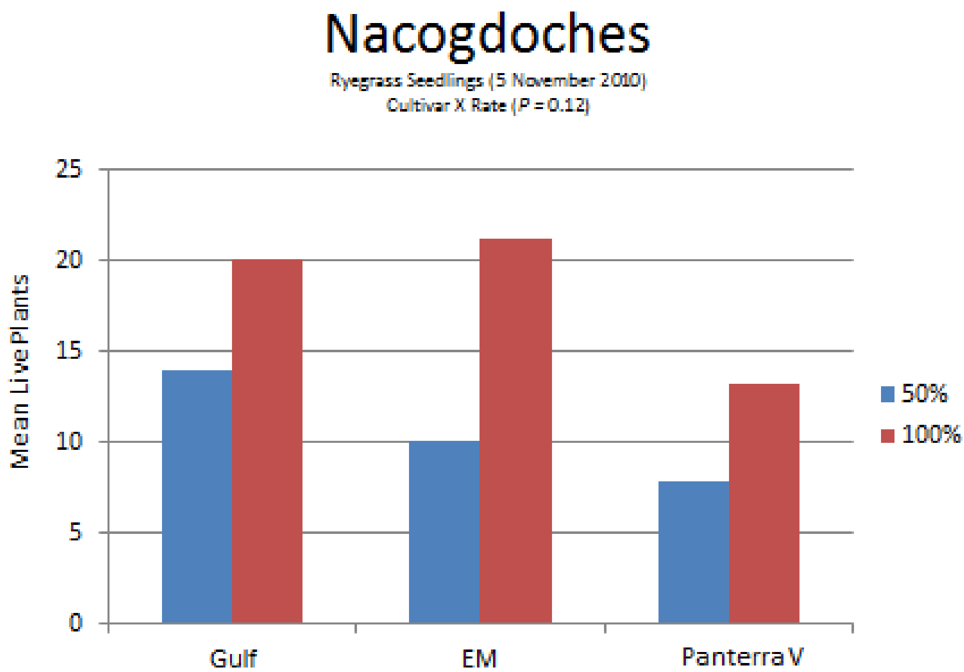
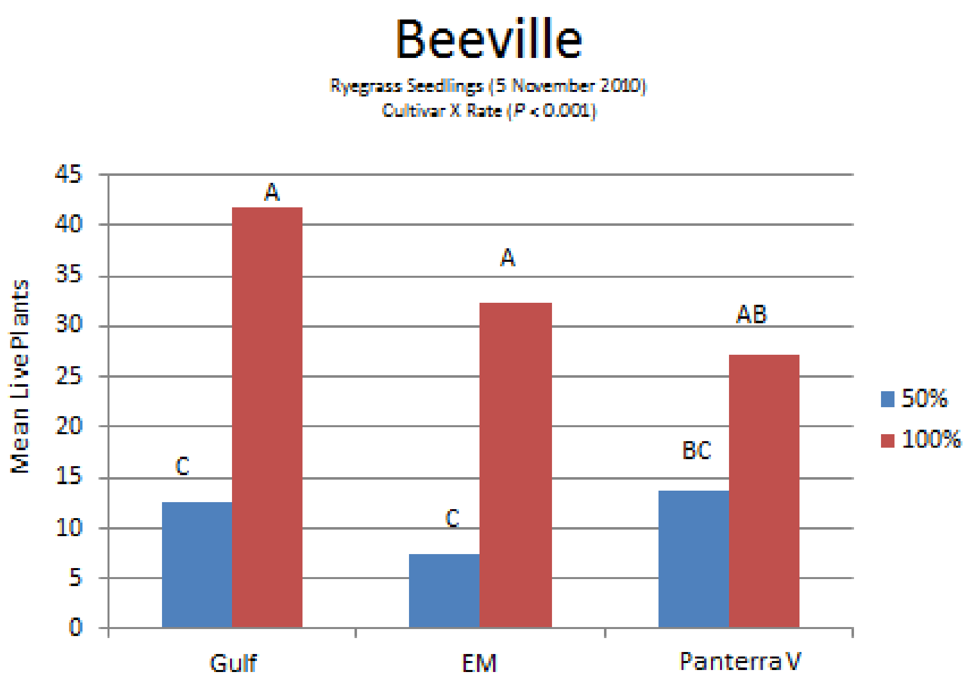
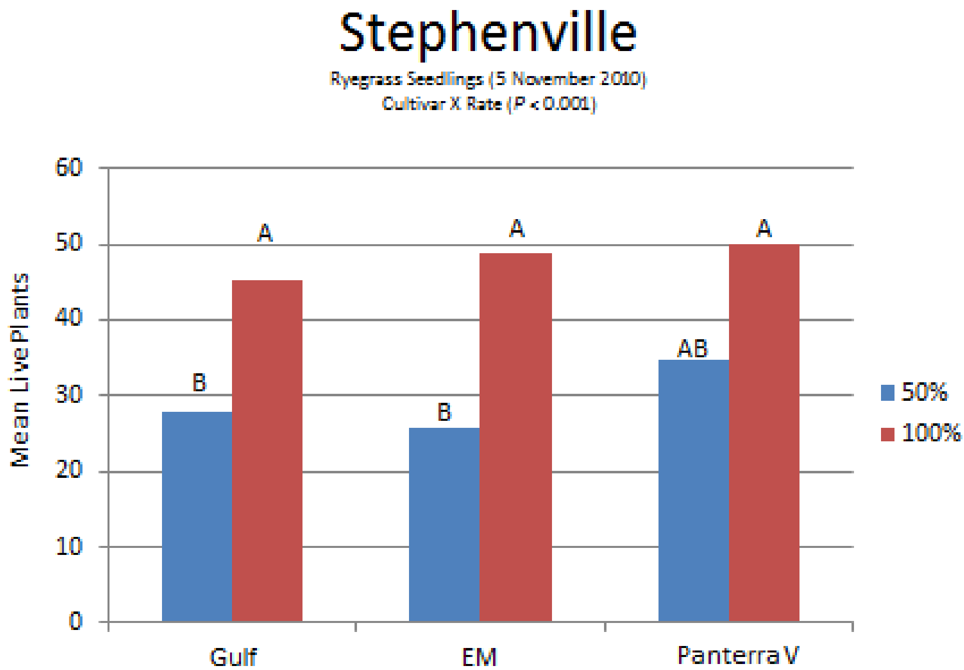
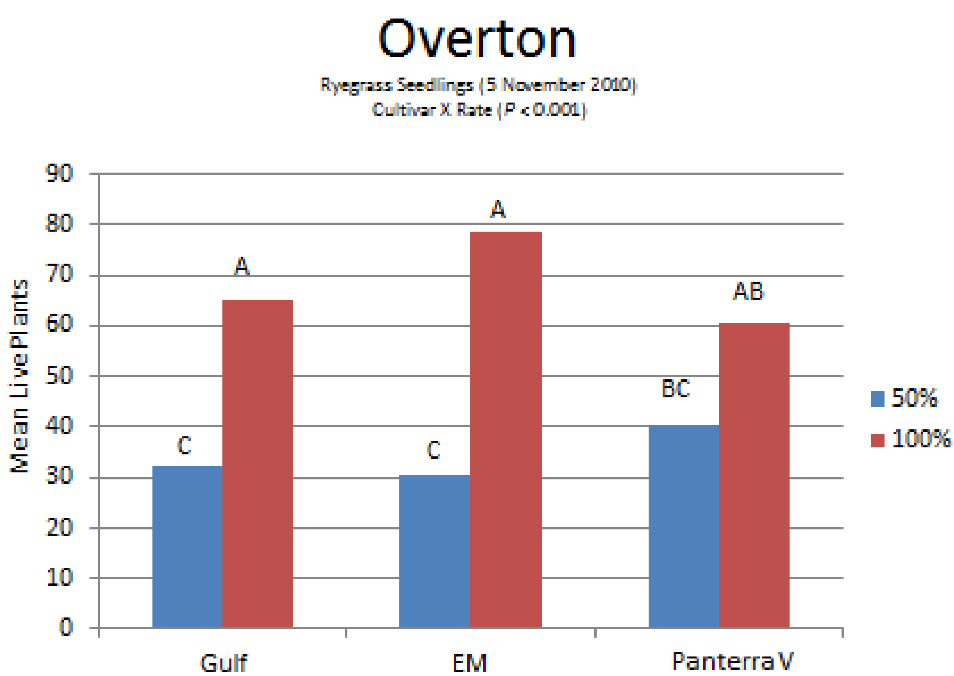
TABLES, GRAPHS, AND PHOTOGRAPHS

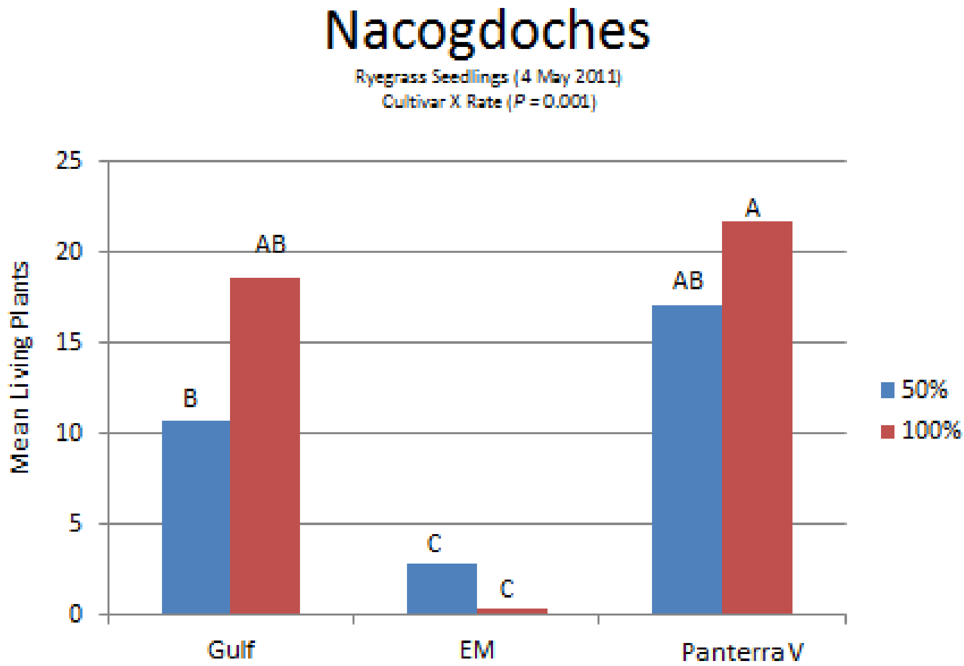
TASK 1 – CULTIVAR × RATE × MOW

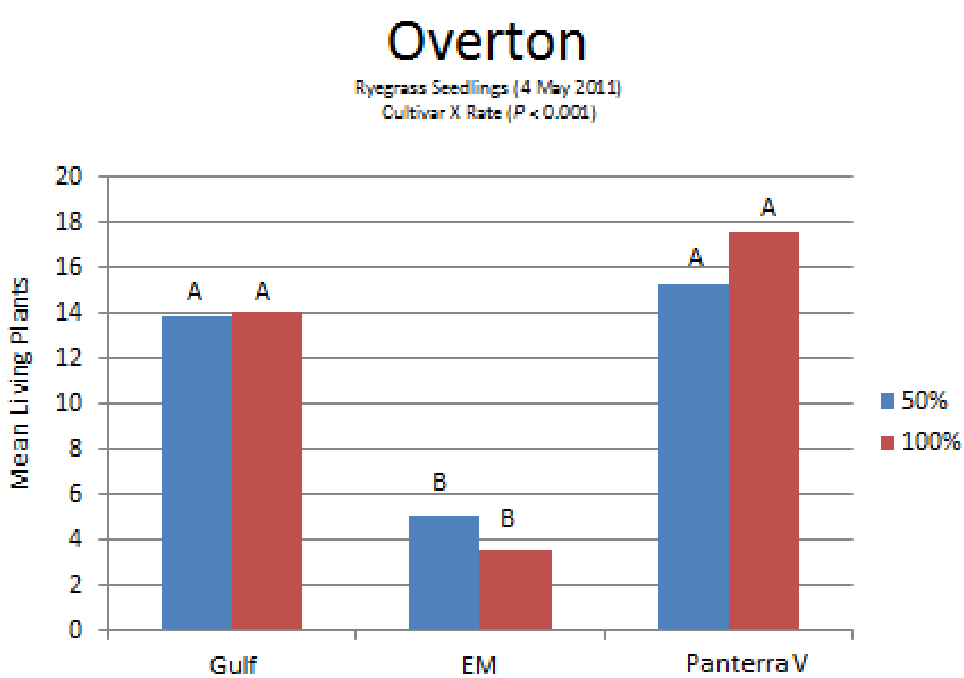


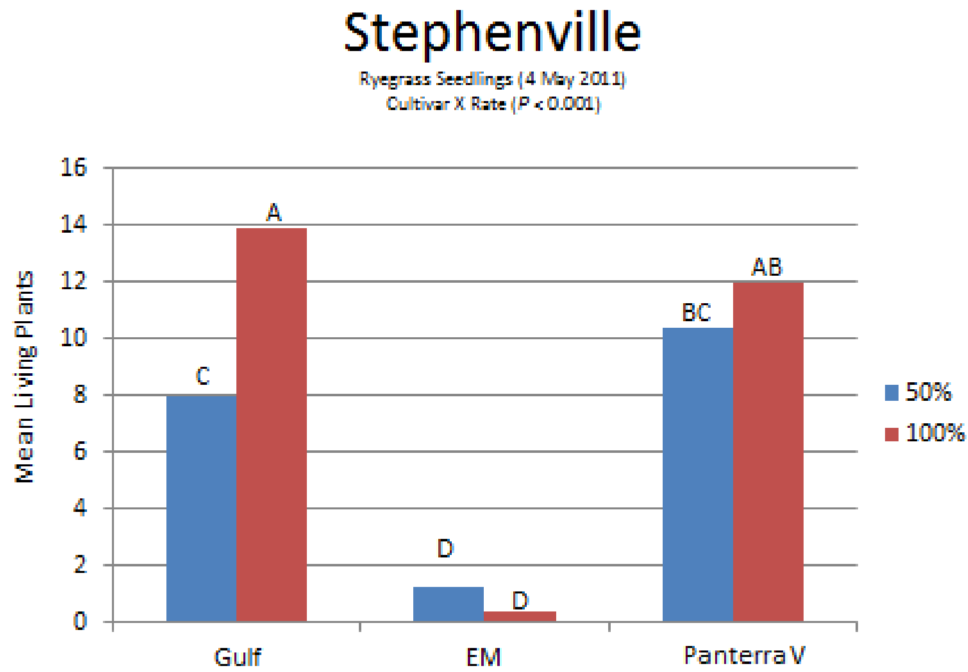


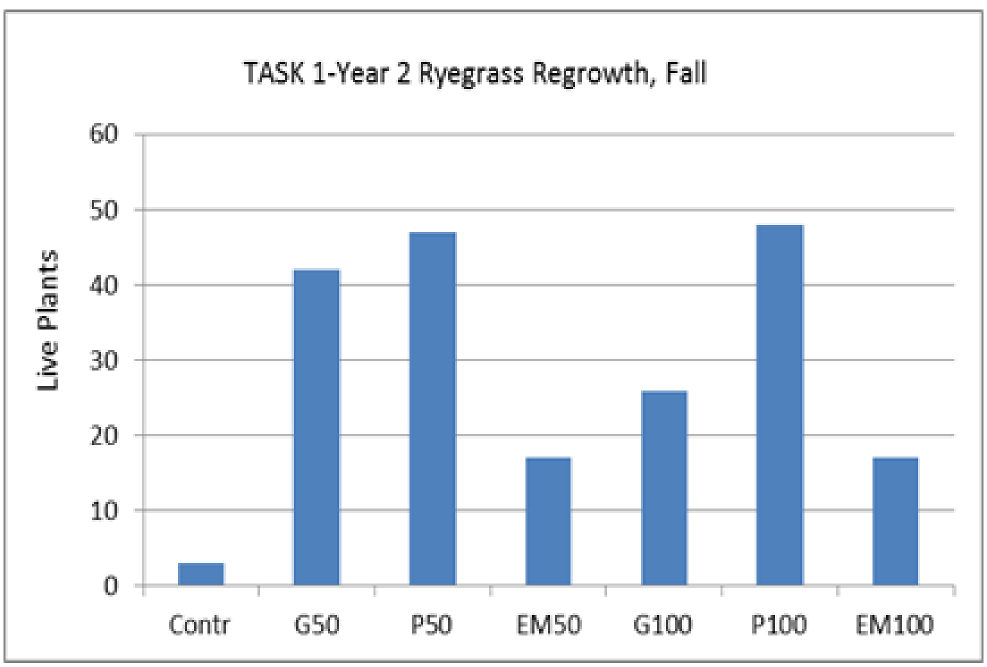

Stephenville
Ryegrass Seedlings (5 November 2010)
Cultivar X Rate (P < 0.001)
Mean Live Plants
60
50
40
30
20
10
0
A
A
A
B
B
AB
Gulf
EM
Panterra V
50%
100%

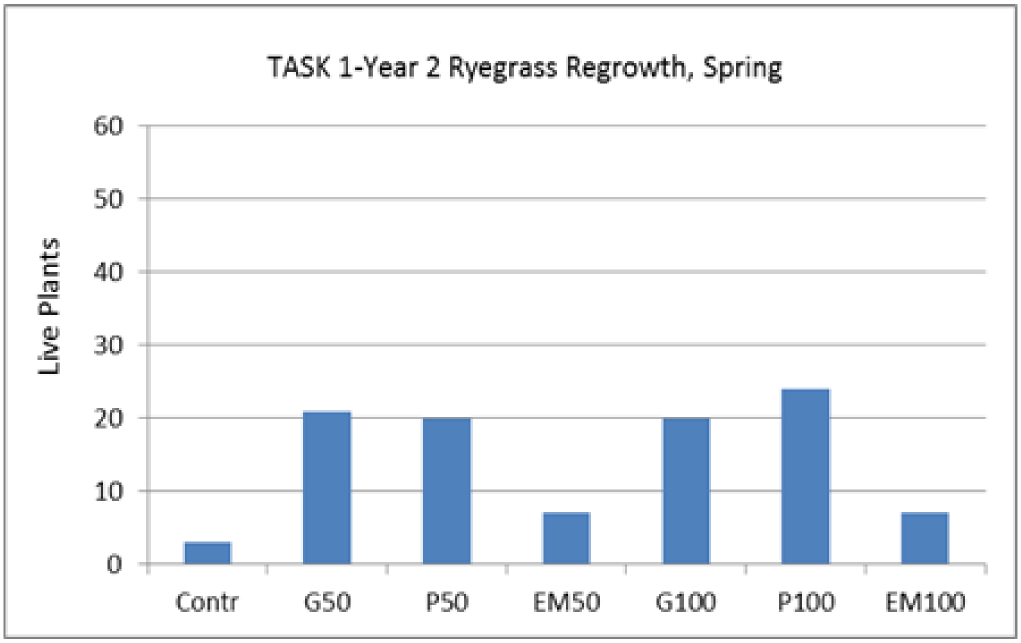

Overton
Ryegrass Seedlings (5 November 2010)
Cultivar X Rate (P < 0.001)
Mean Live Plants
90
80
70
60
50
40
30
20
10
0
A
A
AB
C
C
BC
Gulf
EM
Panterra V
50%
100%

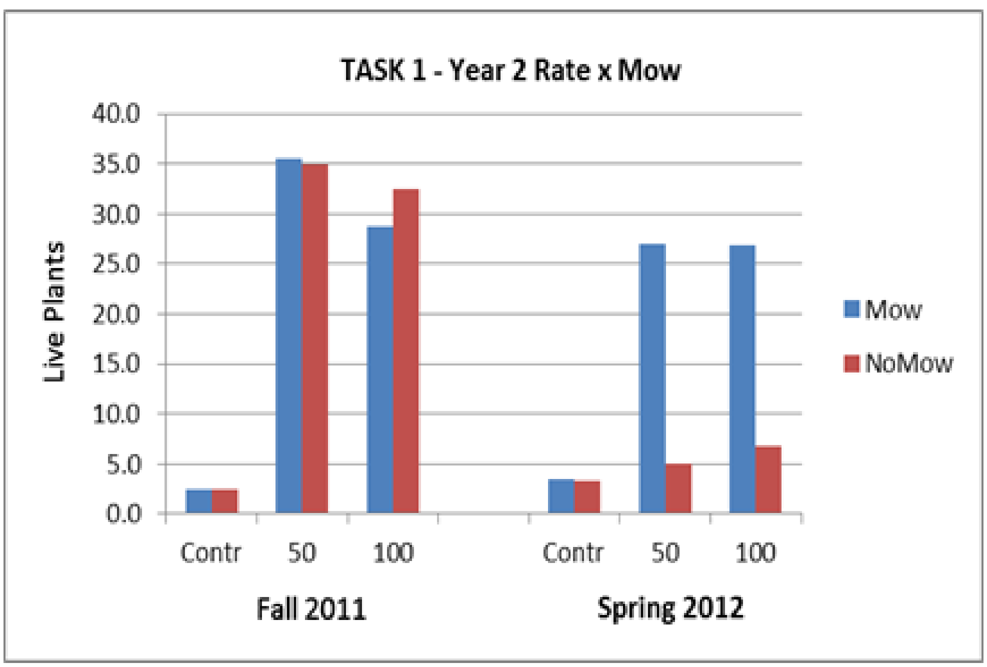

Nacogdoches
Ryegrass Seedlings (4 May 2011)
Cultivar X Rate (P = 0.001)
Mean Living Plants
25
20
15
10
5
0
B
AB
C
C
AB
A
Gulf
EM
Panterra V
50%
100%

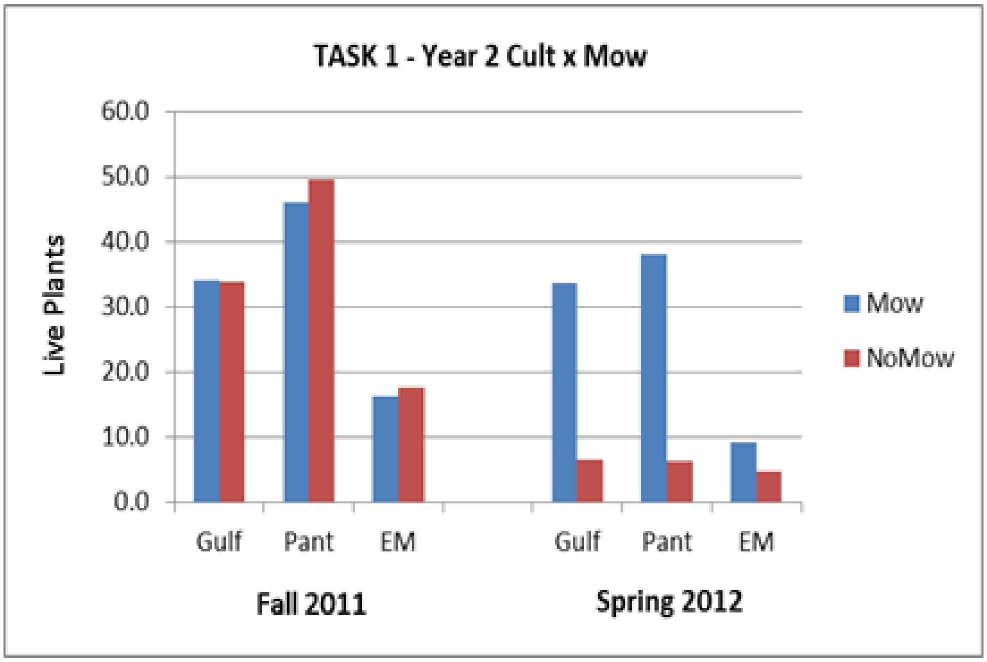

Overton
Ryegrass Seedlings (4 May 2011)
Cultivar X Rate (P < 0.001)
Mean Living Plants
20
18
16
14
12
10
8
6
4
2
0
A
A
B
B
A
A
Gulf
EM
Panterra V
50%
100%


Stephenville
Ryegrass Seedlings (4 May 2011)
Cultivar X Rate (P < 0.001)
Mean Living Plants
16
14
12
10
8
6
4
2
0
A
C
D
D
BC
AB
Gulf
EM
Panterra V
50%
100%

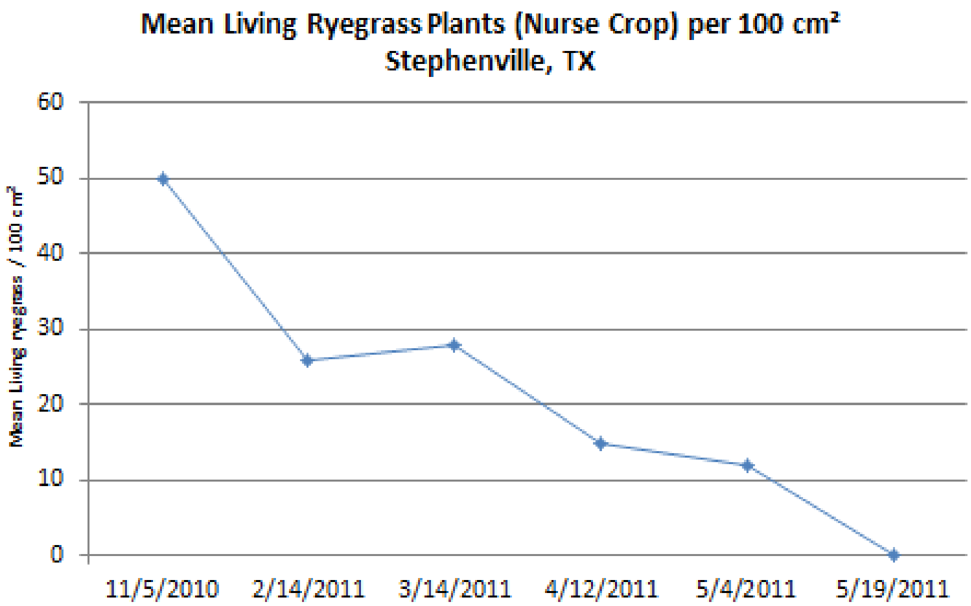

TASK 1-Year 2 Ryegrass Regrowth, Fall
Live Plants
60
50
40
30
20
10
0
Contr
G50
P50
EM50
G100
P100
EM100

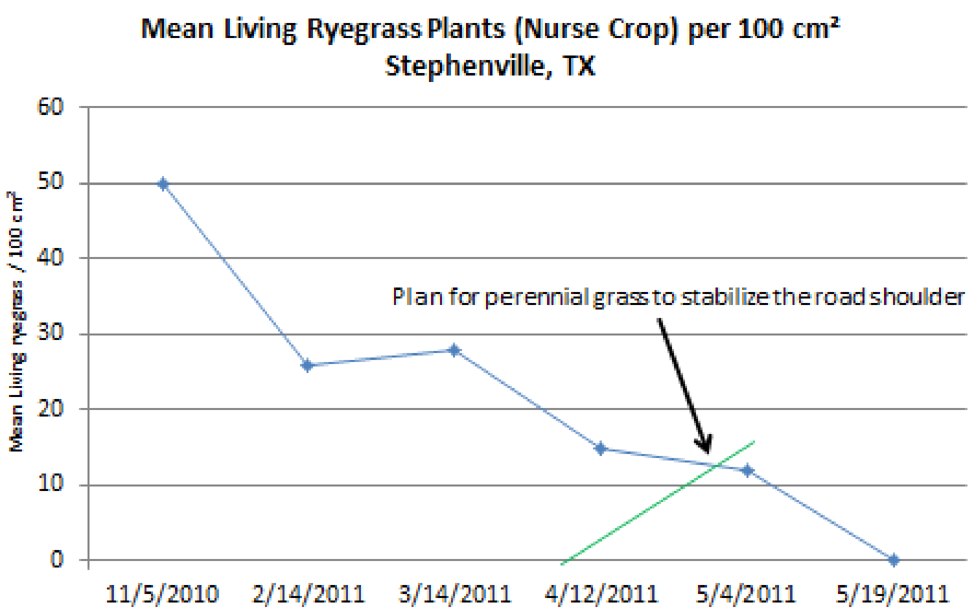

TASK 1-Year 2 Ryegrass Regrowth, Spring
Live Plants
60
50
40
30
20
10
0
Contr
G50
P50
EM50
G100
P100
EM100


TASK 1 - Year 2 Rate x Mow
Live Plants
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Contr
50
100
Contr
50
100
Fall 2011
Spring 2012
Mow
NoMow

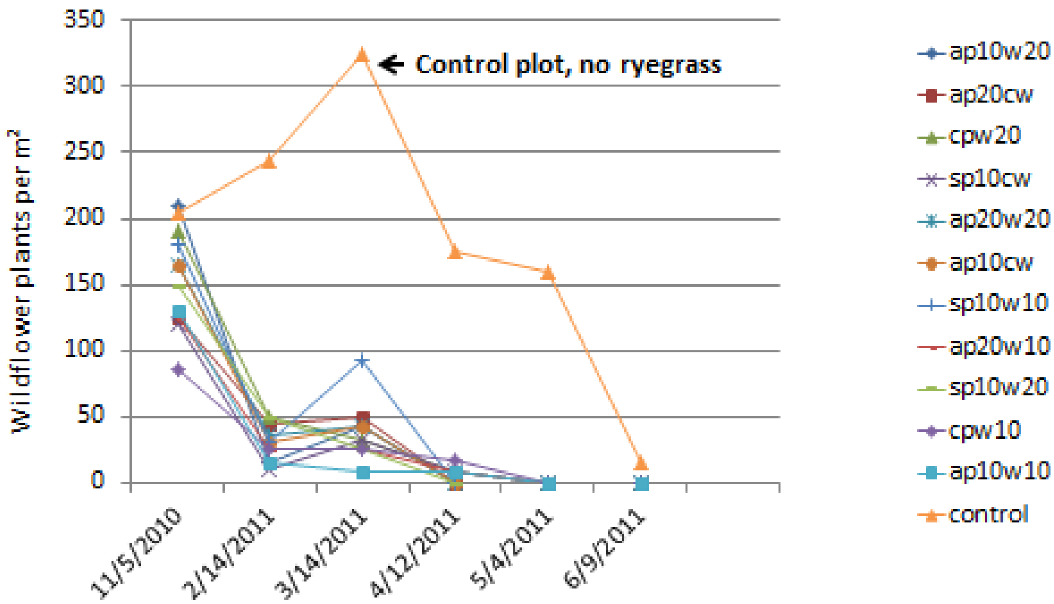

TASK 1 - Year 2 Cult x Mow
Live Plants
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Gulf
Pant
EM
Gulf
Pant
EM
Fall 2011
Spring 2012
Mow
NoMow

TASK 2 – WILDFLOWER MIX SEEDING RATE × PERENNIAL GRASS/LEGUME SEEDING RATE

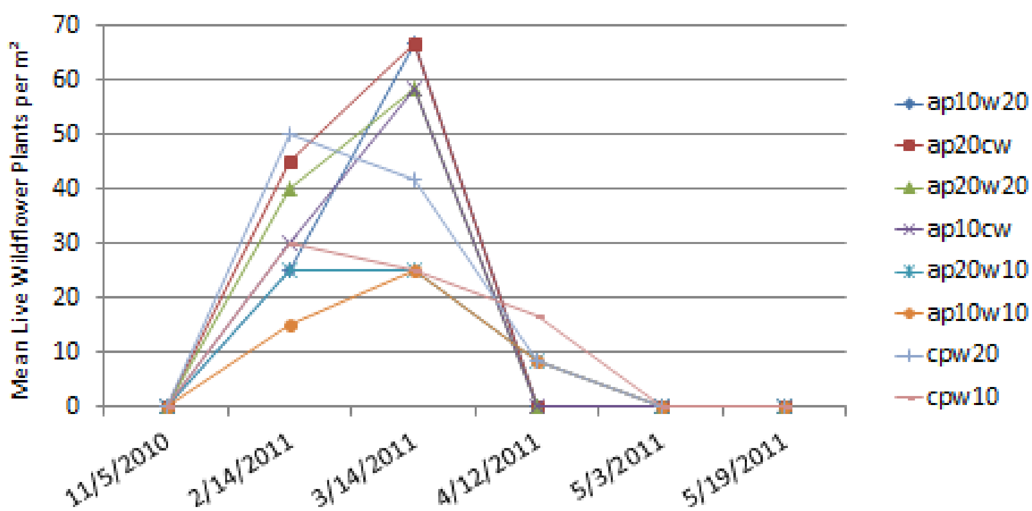




Wildflower Plant Count per Square Meter, Stephenville, Texas



Wildflowers with Autumn Planted Perennials



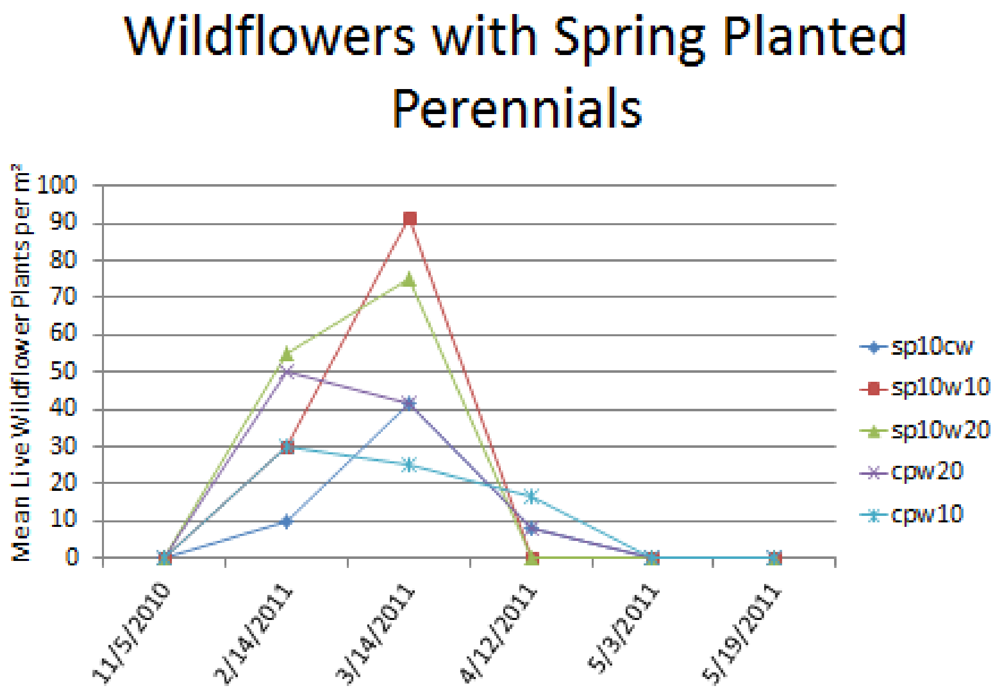


Figure 1. Panterra V annual ryegrass matting (Year 1, Nacogdoches, Texas).

Figure 2. Seeded wildflowers within Panterra V canopy (Year 1, Stephenville, Texas).

Figure 3. Panterra V annual ryegrass second year cover (Stephenville, Texas).


Figure 4. Panterra V stand cover seeded at 12 lb/A (Stephenville, Texas).

Figure 5. Hanamiwase early-maturing annual ryegrass seeded at 12 lb/A (Stephenville, Texas)

TASK 3 – ROADWAY IMPLEMENTATION

Table 1. Nurse crop, wildflower, and perennial grass/legume seeding plot plan for roadway implementation, 2012-13.

103 100% WF/PG NO NURSE CROP	203 100% WF/PG NO NURSE CROP	303 100%WF/PG NO NURSE CROP	403 100%WF/PG NO NURSE CROP
102 100%WF/PG NURSE CROP @ 10% OF TOTAL MIX	202 100%WF/PG NURSE CROP @ 10% OF TOTAL MIX	302 100% WF/PG NURSE CROP @ 10% OF TOTAL MIX	402 100% WF/PG NURSE CROP @ 10% OF TOTAL MIX
101 100% WF/PG NURSE CROP @ 25% OF FORAGE RATE	201 100% WF/PG NURSE CROP @ 25% OF FORAGE RATE	301 100% WF/PG NURSE CROP @ 25% OF FORAGE RATE	401 100% WF/PG NURSE CROP @ 25% OF FORAGE RATE

Table 2. Wildflower seed mixtures utilized for 0-6620 roadway implementation, 2012-13.

Species	Locations	Percent of Mix	PLS lbs per Acre
Bluebonnet (*L. texensis*)	All	40%	20
Drummond Phlox (*P. drummondii*)	All	8%	8
Pink Primrose (*O. speciosa*)	All	4%	2
Black-eyed Susan *(R. hirta)*	All	3%	2
Prairie Verbena (V. bipinnitifida)	All	6%	6
Lance-leaf Coreopsis (*C. lanceolata*)	North	8%	10
Plains Coreopsis (*C. tinctoria*)	South	3%	2

Table 3. Perennial grass/legume mixture utilized for 0-6620 roadway implementation, 2012-13.

Species	Locations	Percent of Mix	PLS lbs per Acre
Little Bluestem (*S. scoparium*)	All	4%	1.0
Blue grama (*B. gracilis*)	All	9%	0.9
Sideoats grama (*B. curtipendula*)	All	7%	2.7
Bahiagrass *(P. notatum)*	All	21%	9.0
Bermudagrass (*C. dactylon*)	All	45%	1.8
Green Sprangletop (*L. dubia*)	All	2%	0.3
Sand lovegrass (*E. trichodes*)	All	9%	0.5
Illinois Bundleflower (*D. illinoensis)*	All	3%	2.0

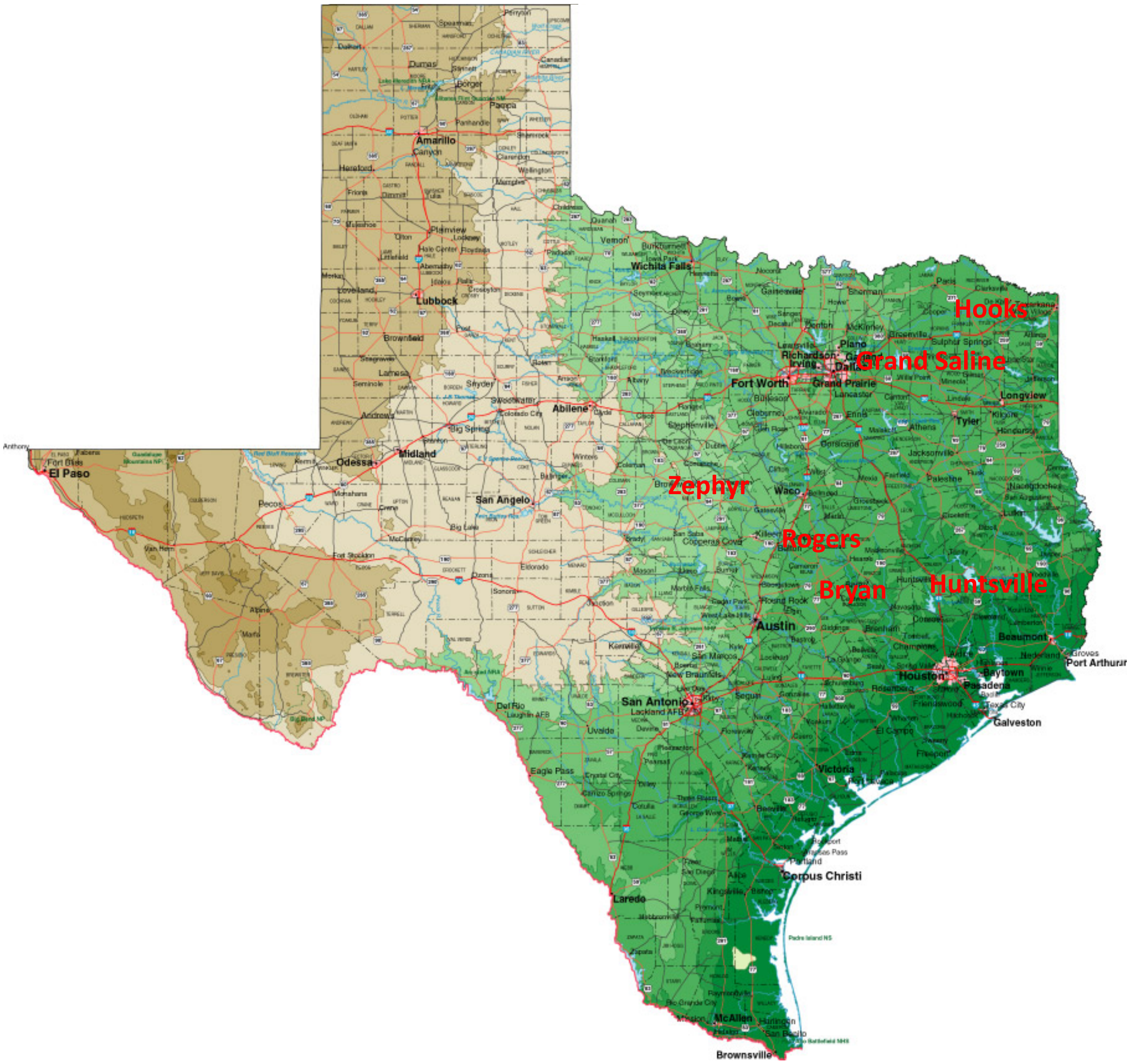


Figure 6. TxDOT-selected locations for the 2012-13 roadside implementations (Task 3).

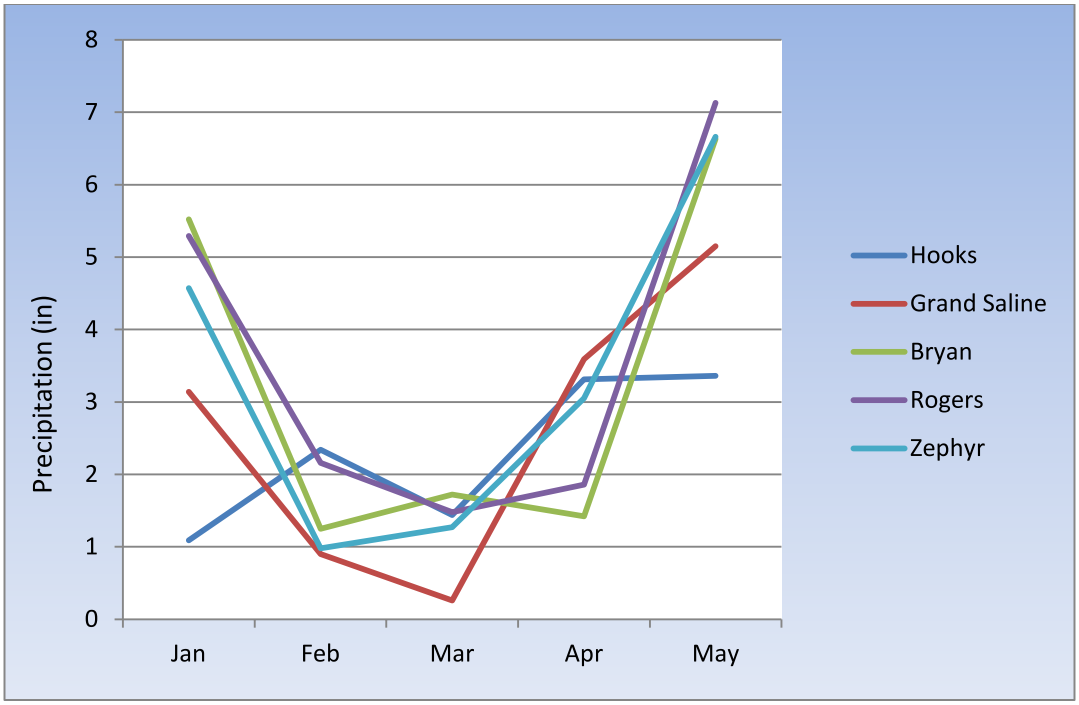


Figure 7. Precipitation across roadway demonstration locations, 2013.

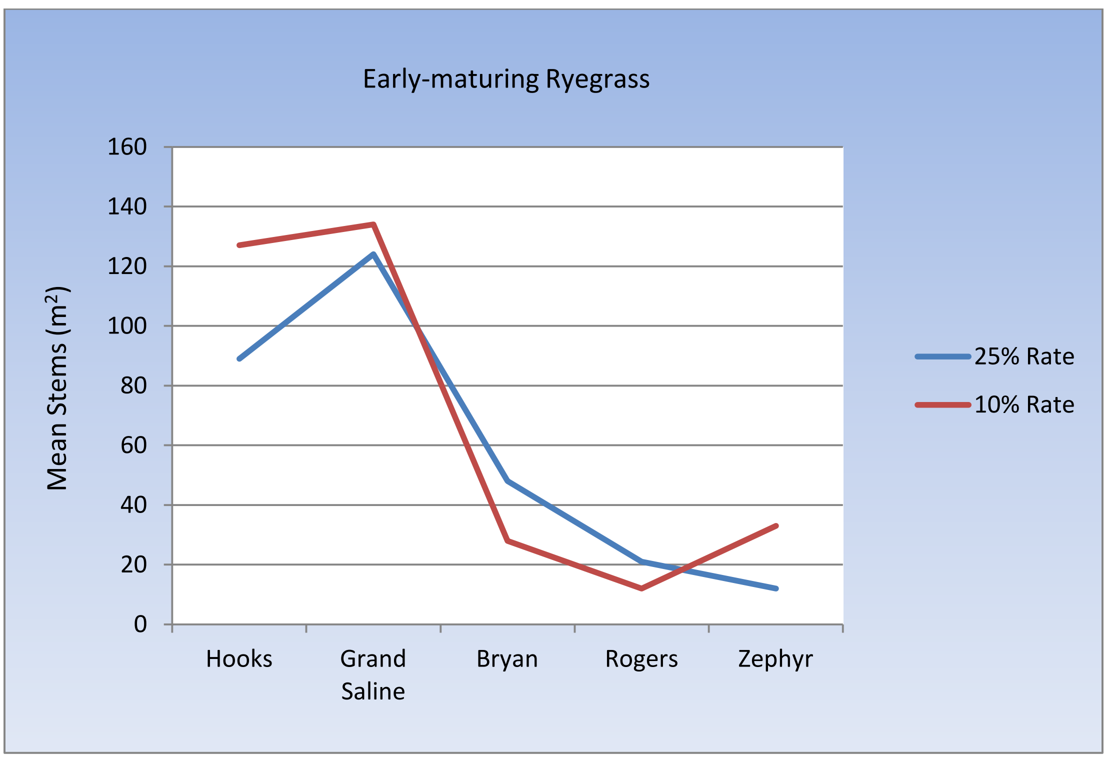


Figure 8. Early-maturing ryegrass stem count across locations, 2013.

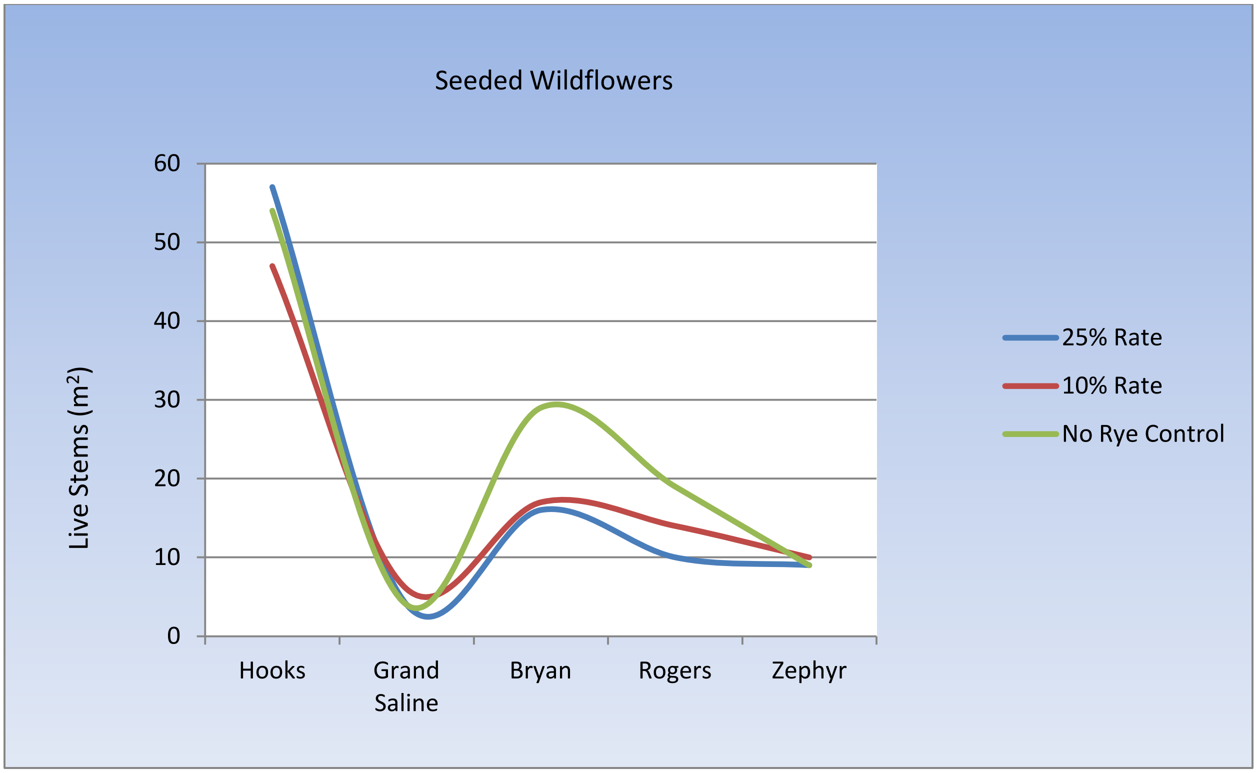


Figure 9. Wildflower stem counts by locations, 2013.

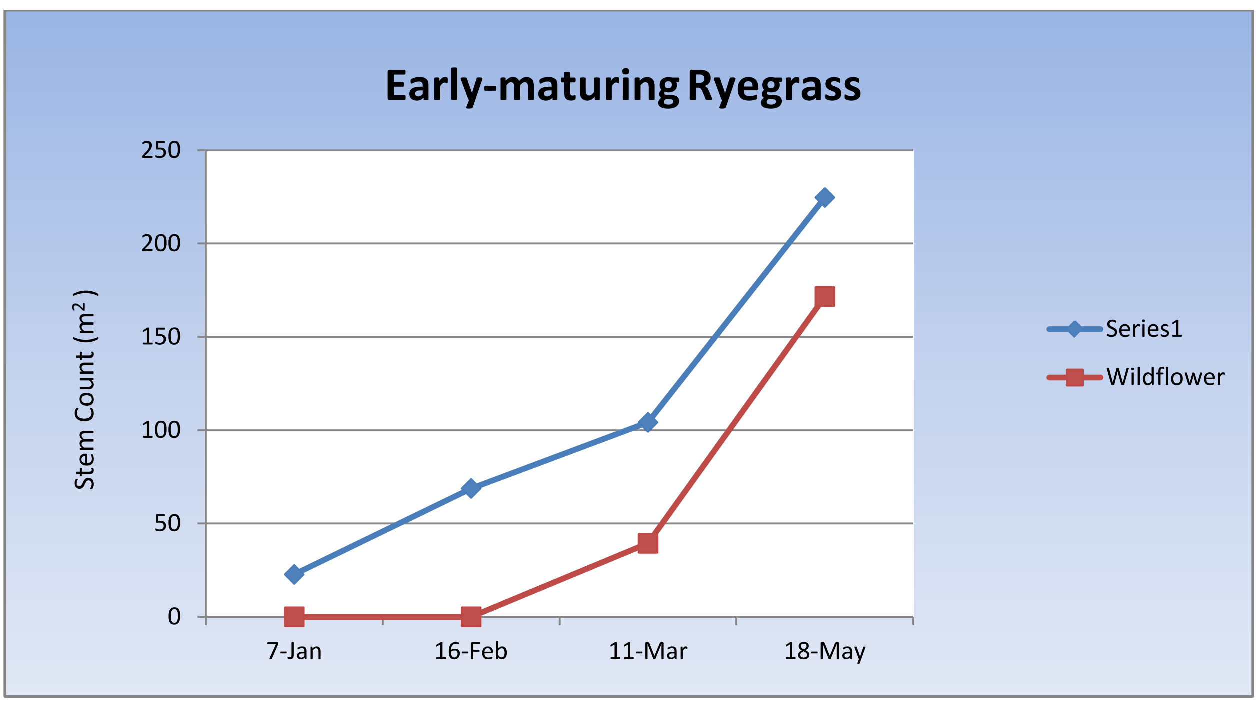


Figure 10. Response of early-maturing ryegrass and seeded wildflowers at Hooks, Texas 2013.

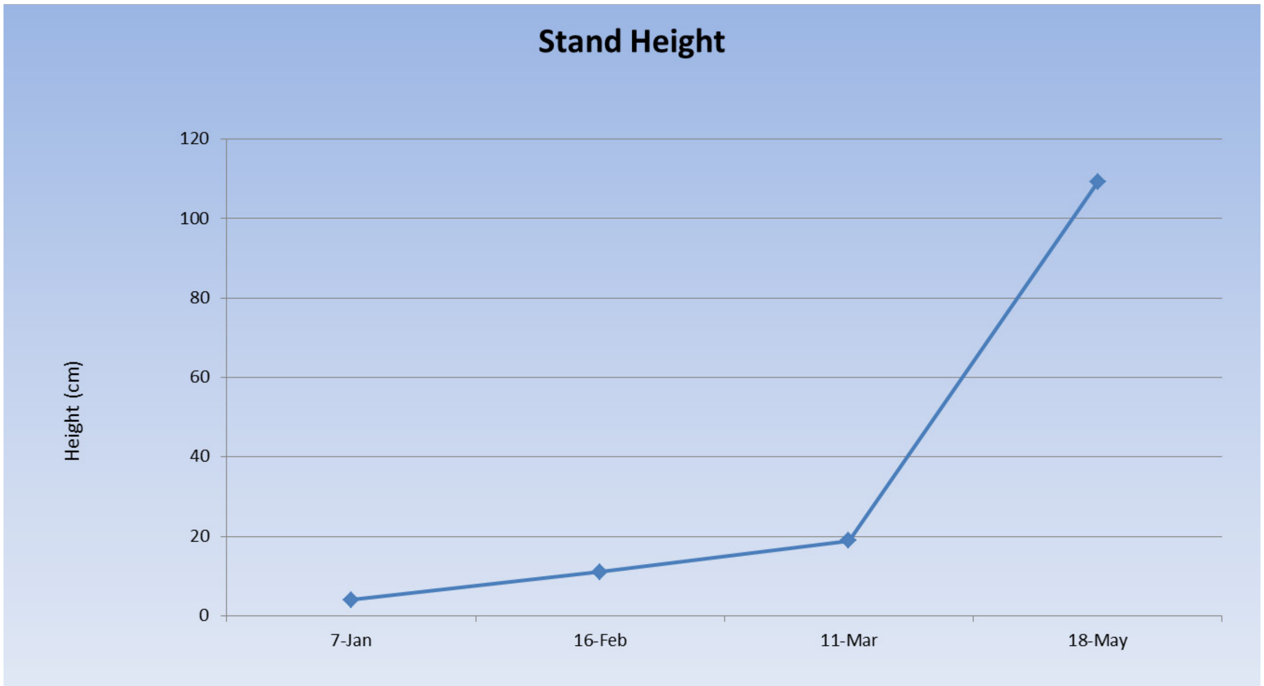


Figure 11. Early-maturing ryegrass stand height accumulation at Hooks, Texas 2013.

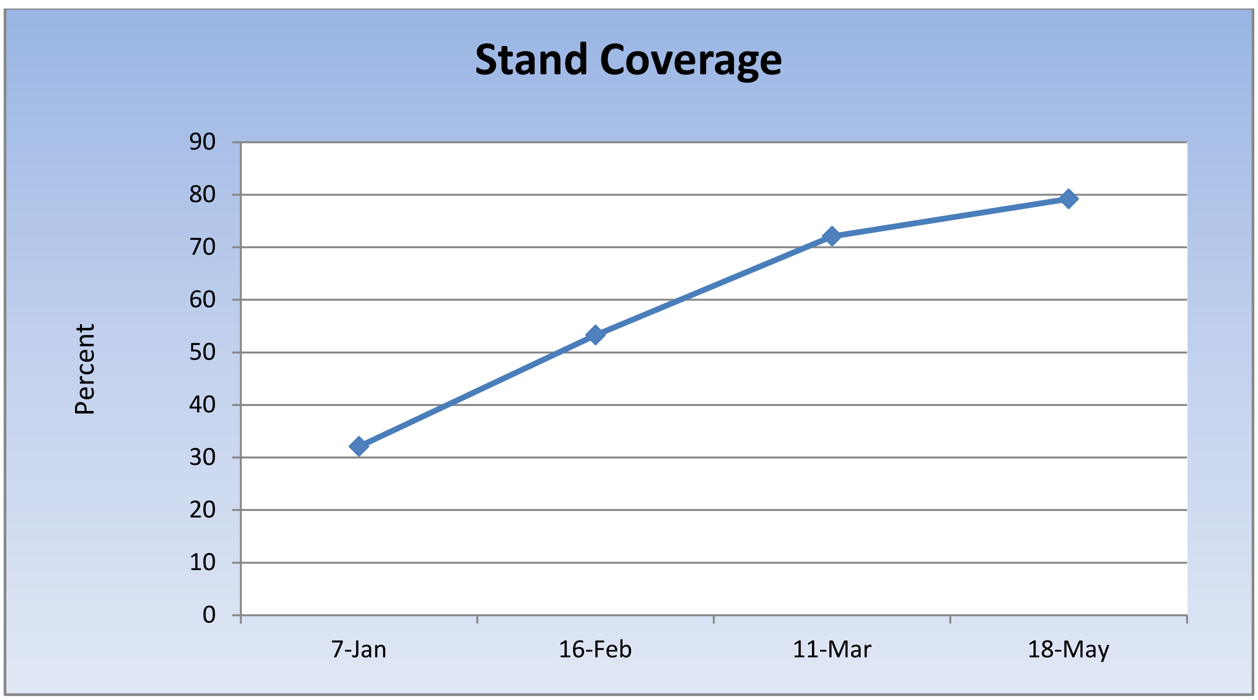


Figure 12. Accumulated aerial coverage for Hooks, Texas 2013.

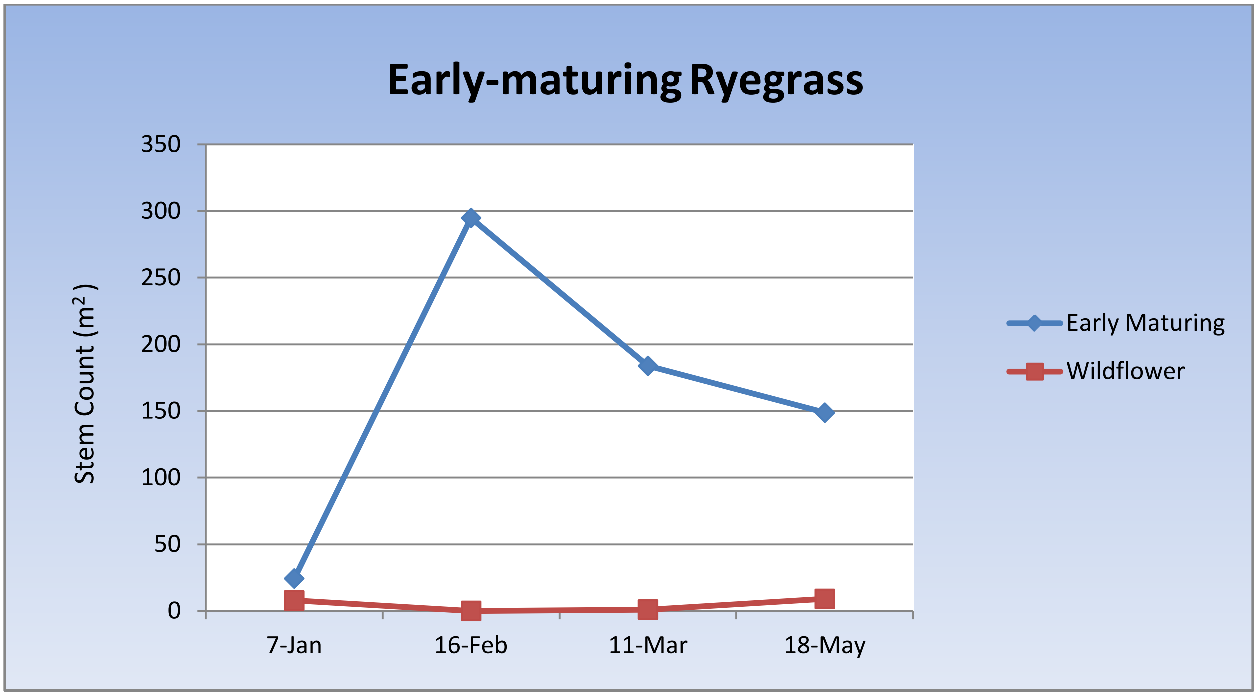


Figure 13. Response of early-maturing ryegrass and seeded wildflowers at Grand Saline, Texas 2013.

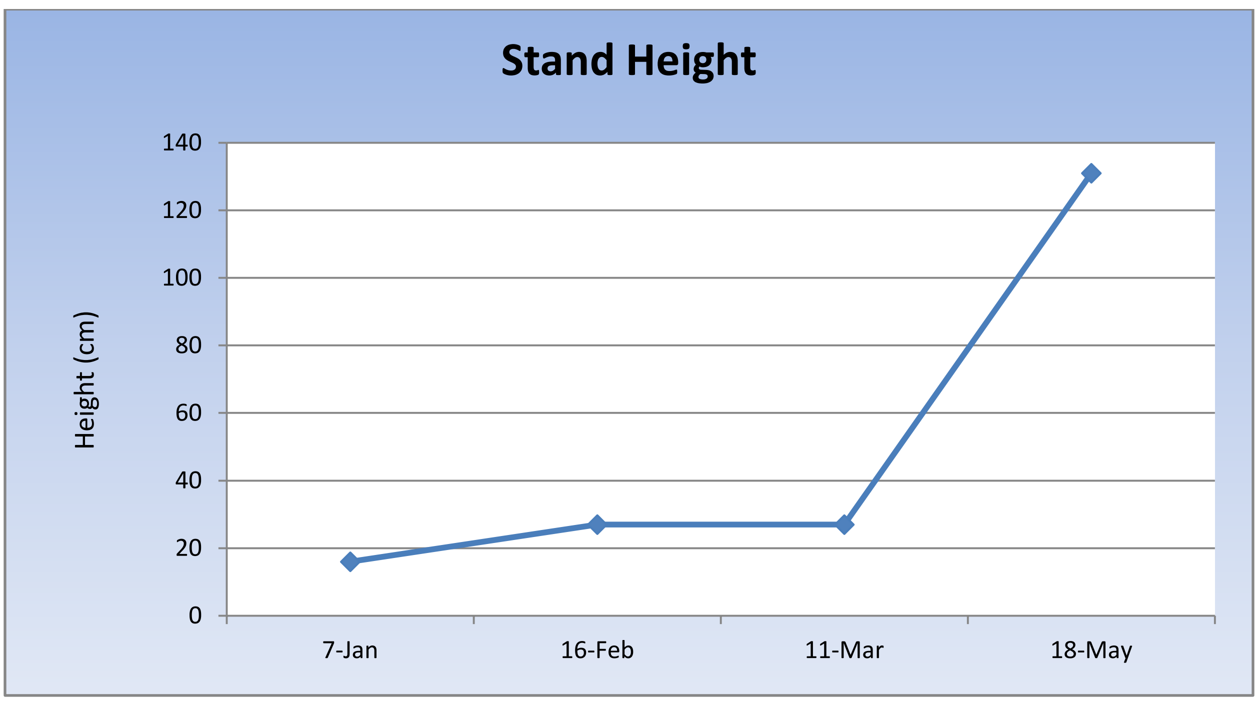


Figure 14. Early-maturing ryegrass stand height accumulation at Grand Saline, Texas 2013.

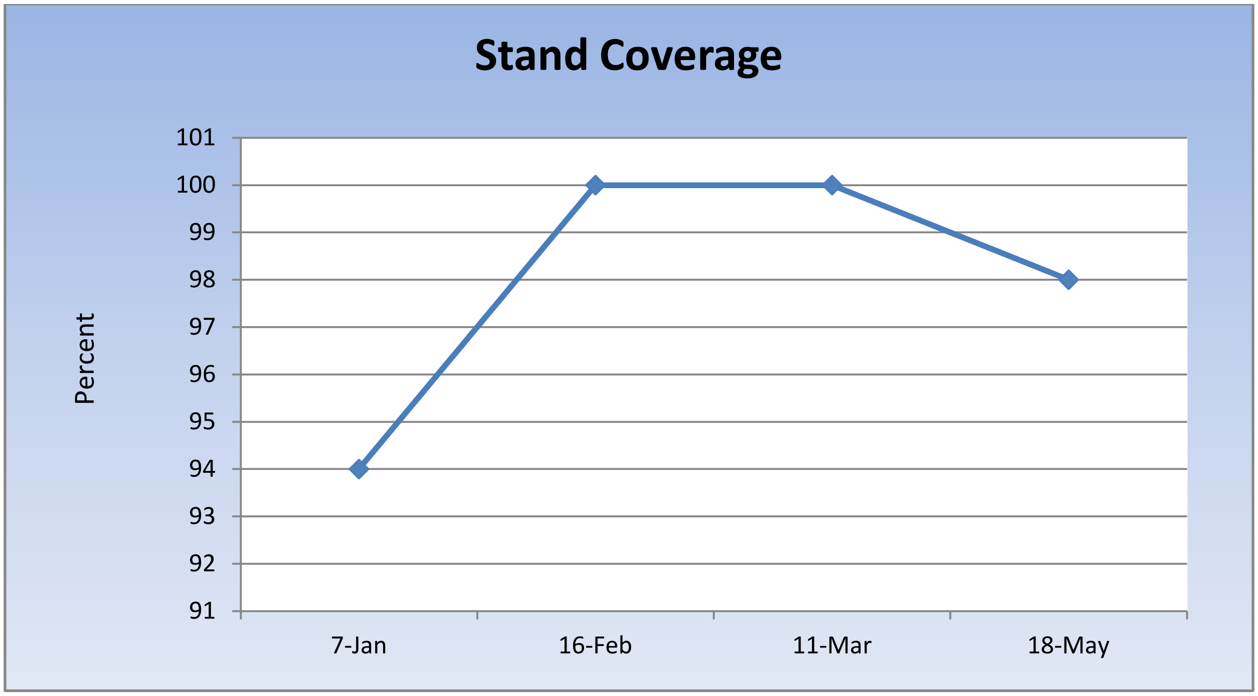


Figure 15. Accumulated aerial coverage at Grand Saline, Texas 2013.

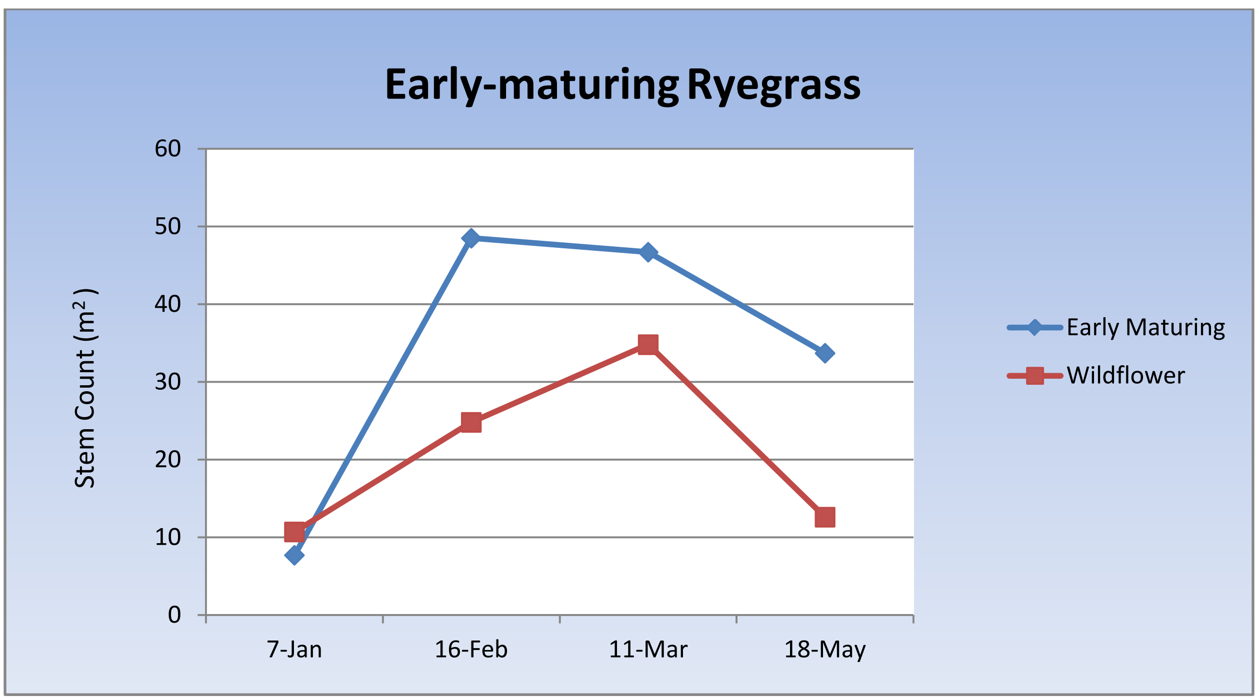


Figure 16. Response of early-maturing ryegrass and seeded wildflowers at Bryan, Texas 2013.

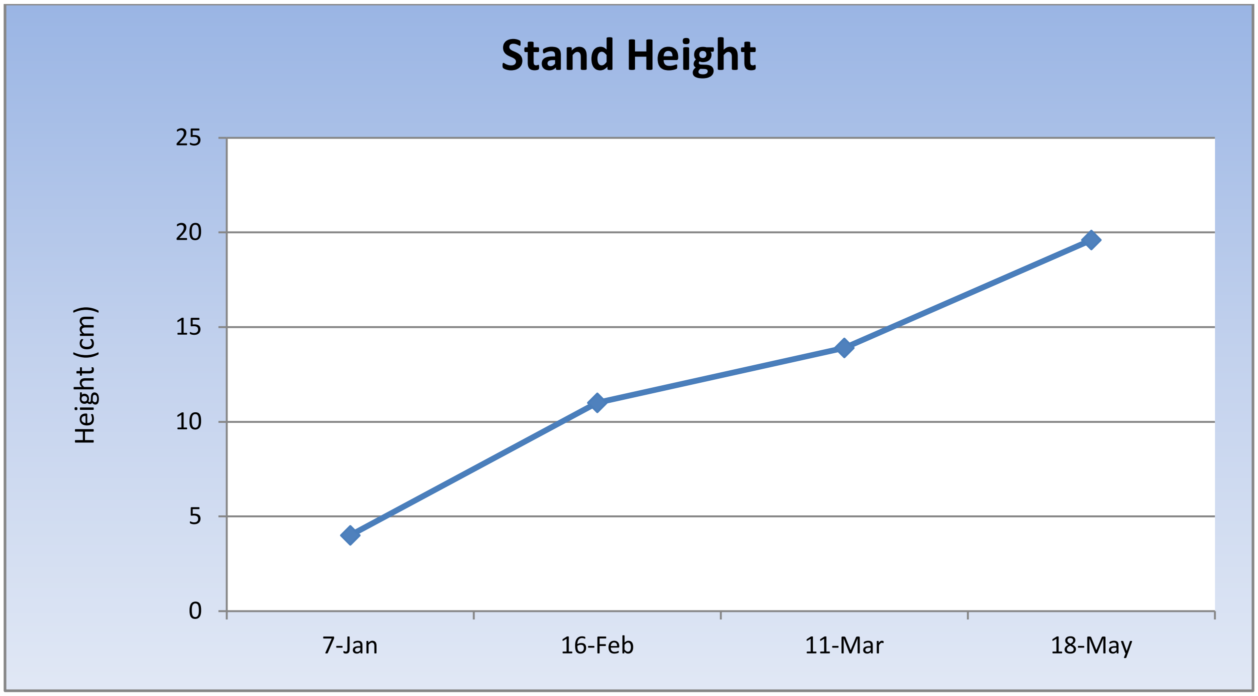


Figure 17. Early-maturing ryegrass stand height accumulation at Bryan, Texas 2013.

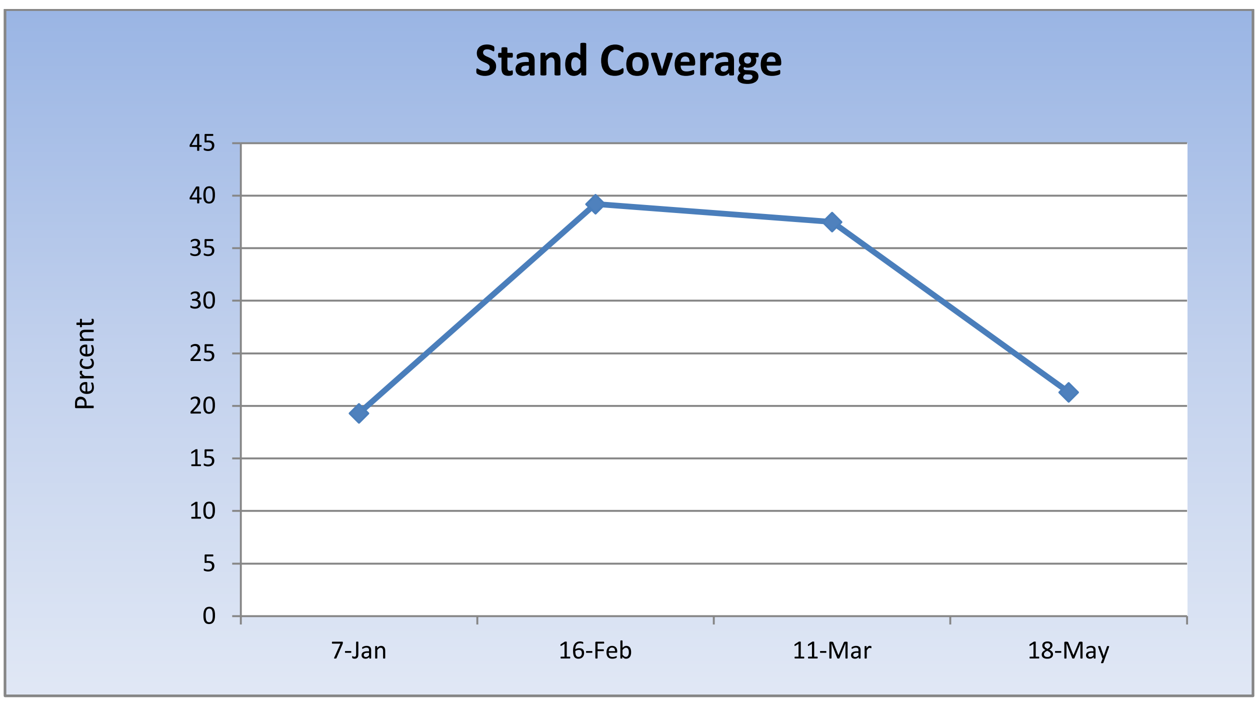


Figure 18. Accumulated aerial coverage at Bryan, Texas 2013.

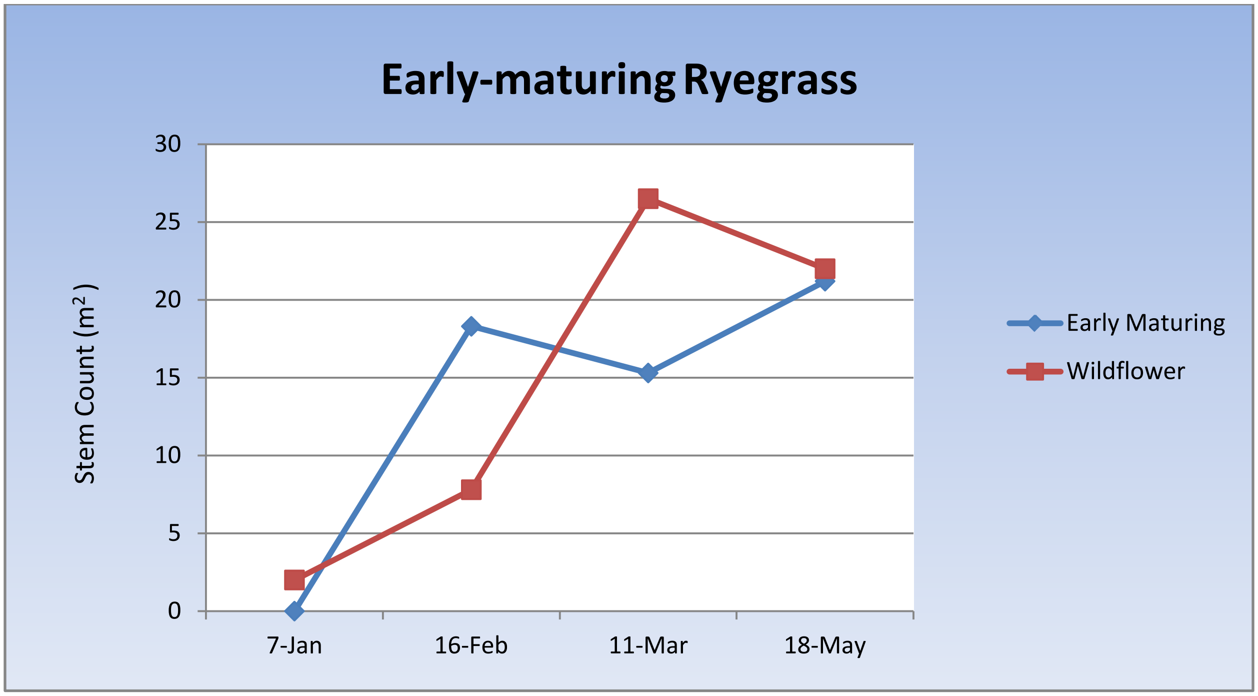


Figure 19. Response of early-maturing ryegrass and seeded wildflowers at Rogers, Texas 2013.

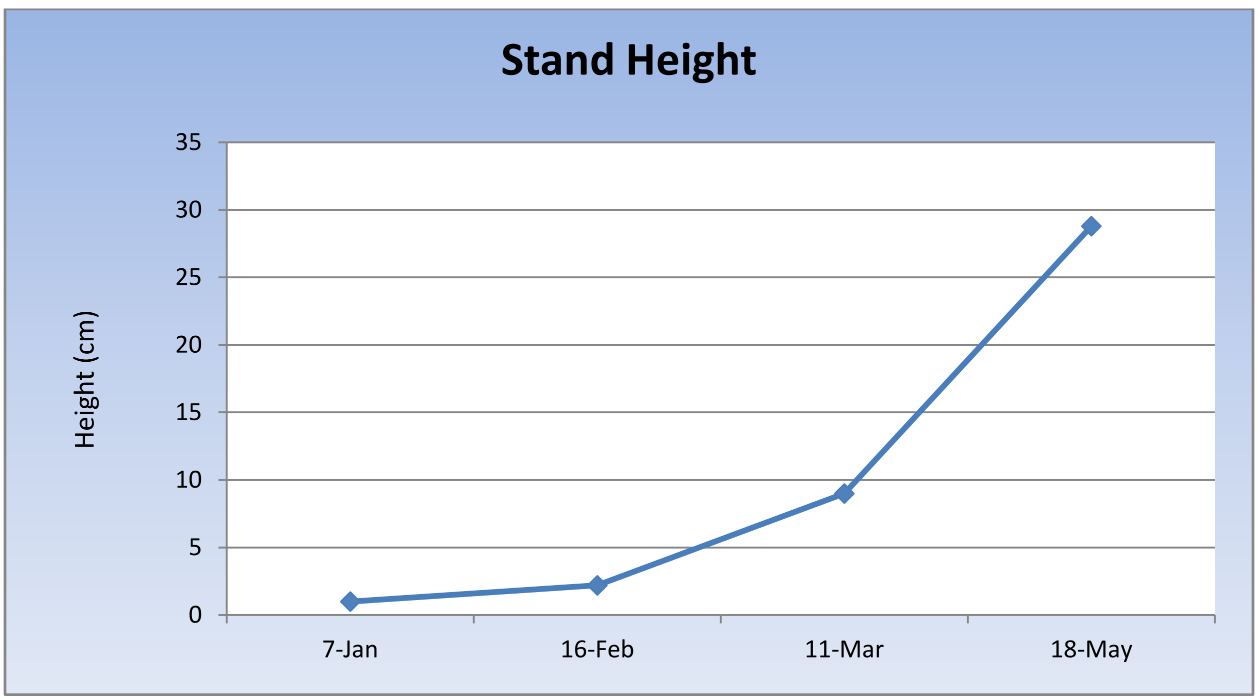


Figure 20. Early-maturing ryegrass stand height accumulation at Rogers, Texas 2013.

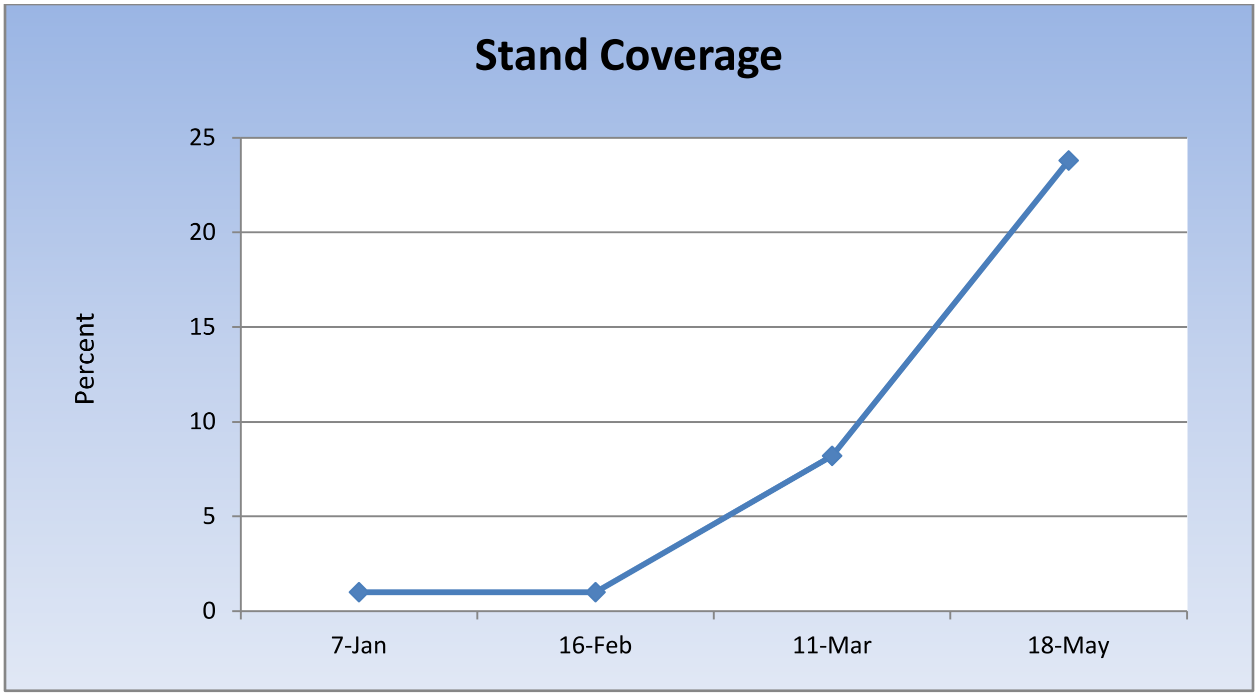


Figure 21. Accumulated aerial coverage at Rogers, Texas 2013.

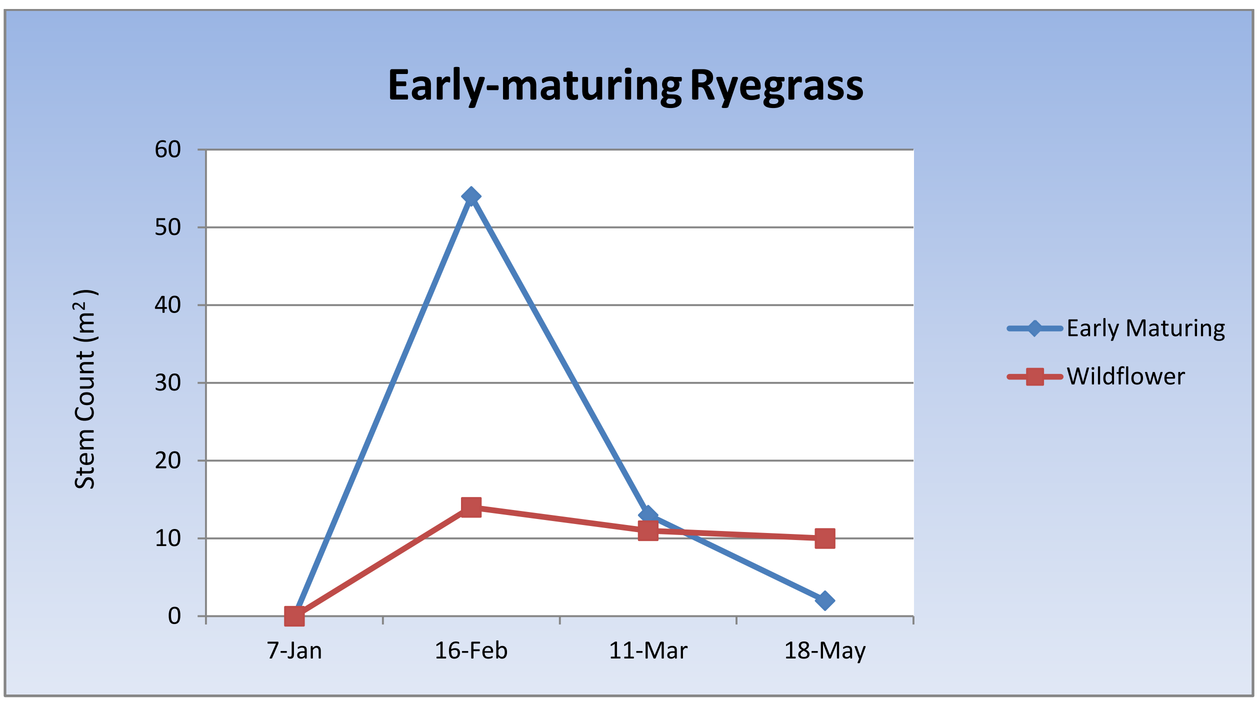


Figure 22. Response of early-maturing ryegrass and seeded wildflowers at Zephyr, Texas 2013.

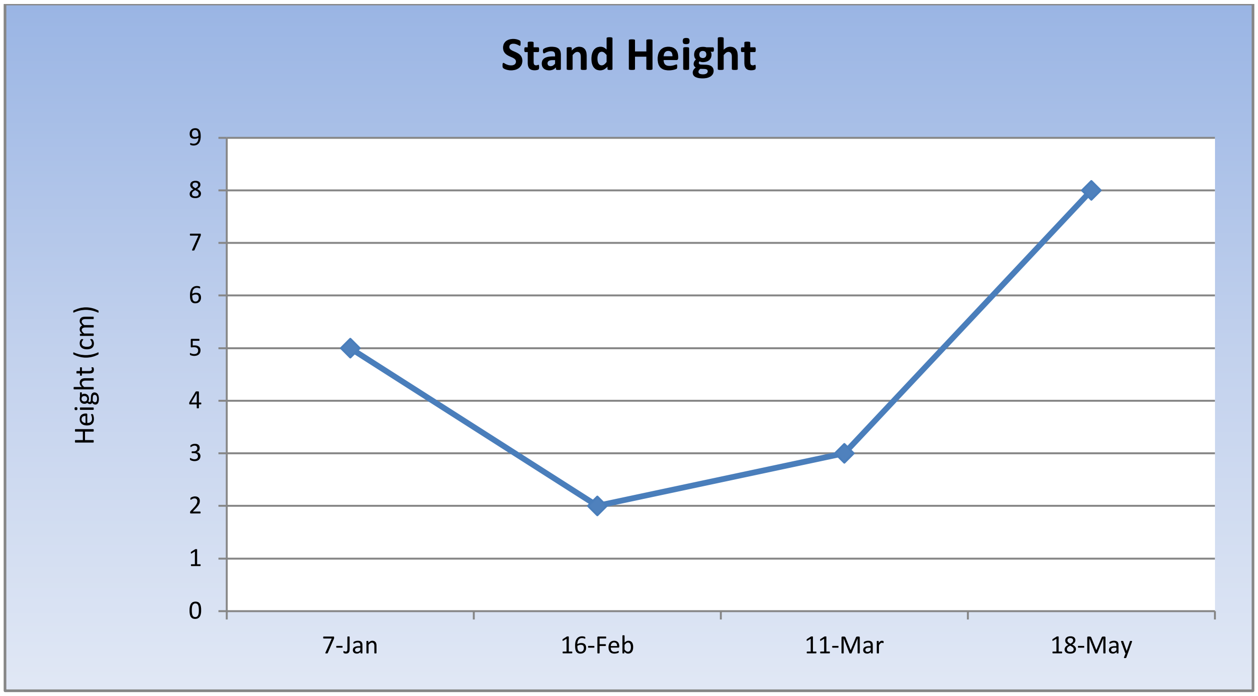


Figure 23. Early-maturing ryegrass stand height accumulation at Zephyr, Texas 2013.

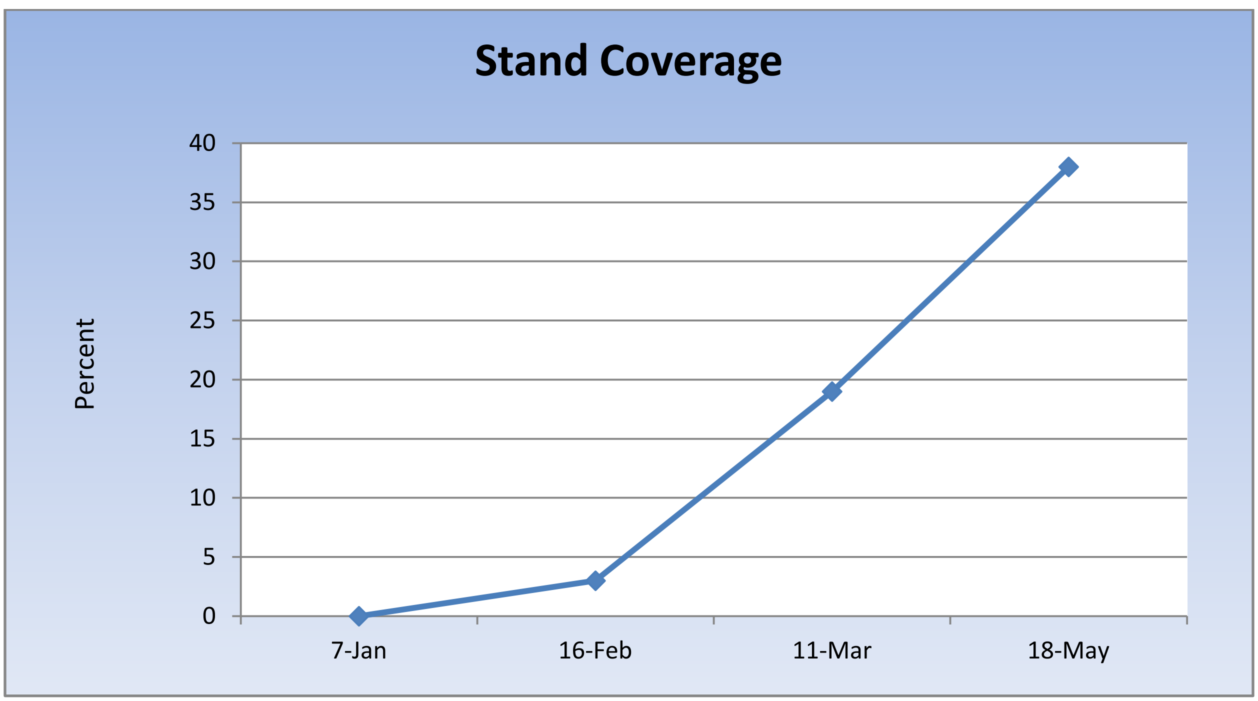


Figure 24. Accumulated aerial coverage at Rogers, Texas 2013.

Figure 25. Prepared site at Hooks, Texas in October 2012.

Figure 26. Plot coverage at Hooks, Texas in May 2013.

Figure 27. Prepared site at Grand Saline, Texas in October 2012.

Figure 28. Plot coverage at Grand Saline in May 2013.

Figure 29. Prepared site at Zephyr, Texas in October 2012.

Figure 30. Plot coverage at Zephyr, Texas in May 2013.

Figure 31. Prepared site at Bryan, Texas in October 2012.

Figure 32. Plot coverage at Bryan, Texas in May 2013.

Figure 33. Prepared site at Rogers, Texas in October 2012.

Figure 34. Plot coverage at Rogers, Texas in May 2013.

Figure 35. Seeded cover interference at Bryan, Texas.

Figure 36. Construction traffic interference at Bryan, Texas.

Figure 37. Construction traffic interference at Rogers, Texas.