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Evaluation of Methods for the Restoration of Native Grasslands on Abandoned Center Pivots in the Sandsage Prairies of Southwestern Kansas

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EVALUATION OF METHODS FOR THE RESTORATION OF NATIVE

GRASSLANDS ON ABANDONED CENTER PIVOTS

IN THE SANDSAGE PRAIRIES

OF SOUTHWEST

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ABSTRACT

Throughout southwestern Kansas thousands of acres of native grassland have been converted to cropland for agricultural use, reducing native prairie by over 60% in the sandsage prairie. Due to low precipitation and arid conditions, much of these croplands are irrigated by center pivot irrigation systems fed by the Ogallala Aquifer. These fields are abandoned when the aquifers dry up, resulting in erosion of the unused farmland. Conservation programs such as the Conservation Reserve Enhancement Program (CREP) were established to address this problem but have been unsuccessful in restoring native grasslands in abandoned croplands in southwestern Kansas. We hypothesized that insect larvae infestation could be instrumental in the lack of vegetation establishment success. To address this, we investigated whether insecticide use would result in higher seedling survival and plant cover of native grasses. Using a custom seed mixture, we planted three strip plots in an abandoned center pivot located in Kearny County, Kansas and measured seed establishment and canopy cover in two transects per strip plot. The strip plots were divided into halves, with one half sprayed with insecticide and the other half used as a control. We found marginally significant difference in average median seed counts between unsprayed and sprayed plots, with sprayed plots having greater seedling counts. We also found significant difference in Total Plant cover and Planted Grass cover, with more Total Plant cover and Planted Grass cover in sprayed plots. We found that Pivot soil had greater amounts of carbon than Native soil. In 2020, we planted a total of three new strip plots in two new sites in Kearny County, Kansas, with the intent to evaluate which of three different frames worked better for seed counting – A small frame (20 cm x 50 cm), a larger frame (one m x one m), and a three-meter tract of seed row. We found a significant difference between the three frame types, but only the small frame was shown to be inferior to the other two types

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INTRODUCTION

Grasslands of the Great Plains have become fragmented and are more susceptible to erosion from human development. This development impacts the populations of many flora and fauna found throughout the Great Plains states, including grassland birds, reptiles and amphibians, and mammals (Herkert, 1994; Greer et al. 2016). In the Great Plains, the main alteration of land comes from urban development and agriculture to grow crops, a trend that started as settlers from the eastern states moved west in the 1800's (Smith, 1981).

Agricultural production increased in the High Plains region of Kansas (FIG.1) in the 1950's with the advent of irrigation systems. Such developments include center pivot irrigation systems, which were able to take advantage of aquifers to water crops. Central pivots were installed all over the High Plains region, converting large tracts of native grasslands into cropland in this area. Many of these pivots are still used today. A 2008 Farm and Ranch Irrigation Survey found that 1,039,355 ha (2,568,303 acres) of total cropland were irrigated in Kansas (FRIS, 2008) with many of these pivots occurring in the High Plains region. The expansion of irrigated land has resulted in the conversion of native ecosystems throughout Kansas and the Great Plains to grow crops such as wheat and maize.

One ecosystem in Kansas that has experienced large amounts of native grassland loss due to center pivot irrigation is the sandsage prairie, which is located in the southwestern corner of the state (Kuchler, 1974). Due to the sandy soils and propensity to drought, sandsage prairies are not suited to farming unless fitted with a center pivot irrigation system (Sexson, 1980). Center pivots in the sandsage prairie of Kansas make use of the Ogallala aquifer that extends throughout much of the Great plains. Throughout southwestern Kansas thousands of acres of native grassland have been converted to cropland for agricultural use, reducing native prairie from 547,773 ha to 207,509 ha by 1978 in the sandsage prairie (Sexson, 1980). Once the wells that feed these center pivots dry up or become too depleted, the land becomes useless for farming. As a result, former crop fields are left abandoned and neglected by landowners. Consequently, many acres of land sit vacant and become barren sand dunes that cause ecological and economic issues (FIG. 2).

Programs such as the Conservation Reserve Enhancement Program (CREP) attempt to mitigate and reverse the process of desertification by attempting to restore high quality native grass cover to former farmlands. Landowners that enroll their land in the CREP are awarded a cost share to plant native grasses and paid to maintain these native grasses on their properties (U.S. Department of Agriculture, 2020 https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index#). The CREP and others like it (i.e., Conservation Reserve Program (CRP)) have worked well in other parts of Kansas and even throughout the Great Plains, but unfortunately are not as effective in the sandsage regions of western Kansas. The reasons for the lack of effectiveness are unknown as research on how native plants germinate, establish, and grow in sandsage prairies is minimal when compared to the numerous publications available about other dryland systems (Wilson et al., 2010; Pabian et al., 2013).

A proposed modification to current CREP plantings is to keep the soil moist during the first few weeks after planting which could increase the likelihood of seed germination and survival, leading to greater stand establishment (Wilson and Briske, 1979). Grasses such as blue gramma (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) have been shown to require at least 2 days of moist soil for successful germination (Frasier, 1984). Moisture in the soil remains important even after germination, as a long drought period could cause seedlings to perish or be torn apart by blowing dry sand. Currently, there is no requirement for irrigation in the CREP other than the land must legally and physically be capable of being irrigated (U.S. Department of Agriculture, 2020 https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index#). Use of irrigation is left to the judgement of the landowners, resulting in inconsistent use in restoration projects. Irrigating the soil before sowing and during germination could potentially improve the odds of raising a successful stand of native grass.

Soil temperature may be another important factor for seed germination. Research shows that temperatures of 18℃ are more effective in stimulating germination (Knipe, 1967; Stubbendieck and McCully, 1976; Wilson and Briske 1979). However, under current CREP methods, the deadline to sow seeds is April 15, usually before the soil has reached these optimum temperatures (U.S. Department of Agriculture, 2020 https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-enhancement/index#). Plantings may be occurring too early to allow for proper germination to establish stable grass stands. Lack of success may be due to soil that is not warm enough for germination. Planting grass seed after May 1 could potentially help propagate higher seed survivability, by allowing soil temperatures to reach desirable levels and reduce the time for seed to be exposed or buried too deep from shifting soils or be predated upon before germination.

Another factor to consider for restoration success is predation of seedlings from insects or their larvae. The relationship between insect predation and seedling establishment is not well understood, at least concerning native grass restoration (Archer, 1991). However, a study found that underground insect herbivory reduced recruitment of Common vetch (*Vicia sativa* L.) from 88% to 52% if either the hypocotyl or radicle were partially or fully consumed (Gange et al., 1991). Other research has pointed to ant species being capable of harvesting seeds before germination (Campbell, 1973) and that insects predated more on seeds than mammals did (Linabury et al., 2019), impacting and hindering germination and establishment of seedlings. It is likely that spraying for insects when the grasses begin to sprout may help them withstand herbivory or seed predation by insects, leading to a larger stand of native grasses (Campbell, 1973).

Soil nutrient content is another factor potentially impacting restoration success. The histories of many center pivots involve tilling the soil before sowing, which has often been a cause of soil erosion (Gadermaier et al., 2021). Tilling and other modern agriculture practices may alter the nutrient content of the soil from its original form, in particular when it comes to soil carbon, phosphorus, and nitrogen (Lal and Kimble, 1997; Govaerts et al., 2006). Farmers looking for high crop yields can also deplete the nutrient components of the soil over time (Murugappan et al., 2007), as well as affect the pH of the soil (Keres et al., 2020). To counteract the loss of nutrient content in the soil, farmers use fertilizers, also resulting in changes to the nutrient composition. It is possible that these changes in nutrient content may affect the survivorship of grass seedlings and restoration efforts. Determining how different these changes are may help with improving seed germination and survivorship.

We wanted to investigate the methodology for measuring seed counts. Not much literature exists on how to conduct seed counts. We initially decided to use small Daubenmire frames (20 cm x 50 cm) for our study. However, we had the chance to compare these small Daubenmire frames with larger frames (1m x 1m), which cover more area and allow for more chance for finding seedlings. We also wanted to determine the effectiveness of surveying three-meter tract of seed row (3 m frame) as a possible method for conducting seed counts. To conduct seed counts, three meters of a seed for would be marked and surveyed in place of a normal transect point. This method would also cover more ground than the small frame, potentially reducing variability between transect points. Determining the effectiveness of these different frames may allow for more accurate surveys and data in future studies.

The objectives for this study were three-fold. The first objective was to determine the influence of insecticide use on native plant seedling survival. We hypothesized that use of insecticide would increase the establishment (2-3 leaf stage) of native plants, as well increase canopy cover of planted native grasses and forbs. The second objective was to evaluate numerous soil nutrient properties for potential differences that may act as mechanisms preventing successful grass establishment. We hypothesized that pivot soil that has been tilled for numerous years would have lower amounts of soil nutrient components than native, untilled soil. The final objective was to determine the effectiveness (ability to reduce variability between counts) of three different survey frame sizes for conducting seedling counts in the field. We expected that 20 cm x 50 cm Daubenmire frames (small frames) would have more variability between counts than the other two frame types – the one m x one m frame (large frames) and a three-meter tract of seed row (3 m frame) – and therefore be less effective overall. We also hypothesized that the larger frames would have the least variability of the three frame types.

METHODS

Study Area

The study area was located in Kearny County, Kansas in T26S R35W NE ¼ section 15-26-35, 30 km (18.64 miles) south-southwest of Garden City, Kansas. The area is dominated by sandy soil, and has an arid, dry climate. Summers can reach well above 32℃, and winters as low as -6℃. It is common to see trace amounts of snow during winter. The area is in a dry region, receiving on average 518 cm (7 in) of rain annually, with winds being very prominent on most days (Kansas Geological Survey, 2017 http://www.kgs.ku.edu/Publications/Bulletins/34/04_clim.html#:~:text=Precipitation,17%20inches%20at%20the%20west). The center pivot is approximately 52 ha (128.5 acres) in size and is fed by an aquifer, which is the main source of water for irrigation. The center pivot had originally been used for growing corn and wheat and was planted to corn the year before drilling of native grasses occurred. The property was enrolled into CREP by a landowner wanting to restore the center pivot (currently in agriculture) to native grasslands before the initiation of the experiment. Special approval was obtained from USDA to alter current CREP protocol and prior to initiation of the experiment.

Setup and Study Design

The center pivot was divided into four quarters, (NE, SE, NW, and SW). The SW quarter was not used due to complications in timing of sowing and spraying. We planted three rectangular strip plots 50 m wide x 240 m long, from 19 May-11 June 2019 (FIG. 3) with a custom seed mix of native grasses and forbs (APPENDIX A). Strip plots were planted approximately 2 weeks apart to separate seedling counting periods. We focused on insecticide use as our one independent variable to test in relation to conventional CREP methodology and "new" methodology (TABLE 1) due to budget constraints. We divided each strip plot horizontally into two even strips, with each strip given a different spraying treatment. We treated the southern half of each plot with insecticide, with spraying occurring within 24 hours of sowing the seed. A four-wheeler mounted sprayer with a 12-foot boom was used to apply Warrior II© (by Syngenta) (broad base crop insecticide) at the manufacture's recommended rate. The northern half of each plot was left untreated (control). In order to keep planting soil temperature balanced between treatments, we planted both strips in a plot at the same time corresponding to a soil temperature of 18.3 °C (65 °F) or greater. Each plot received the same amount of water, provided by the center pivot on site (not quantified). Each quarter was watered for 10 days after planting.

Seed Count for Spraying Experiment

Daubenmire frames (20 cm x 50 cm) were used to determine seedling germination and survival (Daubenmire, 1956). A transect was established down the center of each treatment strip, where six permanent frames were evenly distributed throughout the transect, each labeled 1-6, roughly 30 m apart. This resulted in 12 frames per rectangular plot (6 per treatment). To ensure consistent frame location, GPS coordinates were taken at each frame and corners of each frame were also marked with flags. Each frame was surveyed for seedlings daily for 12 consecutive days starting two days after seed was sown. We recorded the total number of seedlings present each day. We marked new seedlings with toothpicks, and we used a different color of toothpick for each day. If a seedling was found dead or went missing, we recorded it and removed the toothpick. The data used for analysis was the number of grass seedlings that survived to day 12. After 12 days (2-3 leaf stage) seedlings are large enough that survival after insect herbivory is likely. Surveys were conducted from May 2019 to July 2019.

Canopy Cover for Spraying Experiment

The same transects used for seed counting were used for assessing canopy cover. A 1 m x 1 m frame was used to collect canopy cover data on each of the transect points where seedling counts occurred. A modification of the Daubenmire Cover Class Method (Daubenmire, 1959) was used to assess cover. The functional groups for which cover was assessed included total canopy cover, bare ground, planted grass cover, planted forb cover, canopy cover of weedy grasses (not in seed mix), and canopy cover of weedy forbs (not in seed mix). Canopy cover was estimated in 10% increments (i.e., 0, >0-10, >10-20 etc.). Cover surveys were conducted in September of 2019 at peak biomass for warm-season grasses.

Soil analysis

Sixteen soil samples were taken in September 2019 in order to compare soil nutrient characteristics between native (untilled) soils and center pivot (tilled) soils. In total, eight samples were from tilled soils (within the center pivot), and eight samples were from untilled soils (outside the center pivot in the unplowed corners). Collection sites were randomly selected and spread across each of the land uses as much as possible. A hand trowel was used to collect soil from the top 20cm at each location. Soil was placed in quart freezer bag and stored at 4 ℃ until shipping. Samples were analyzed by Kansas State University's Water and Forage Testing Lab (Manhattan, KS). Factors assessed were amount of Nitrogen (percentage), Total Organic Matter (percentage), pH, Sikora pH, Organic Matter – Loss on Ignition (OM LOI) (percentage), and Total Phosphorus (ppm).

Frame Size Evaluation

Based on preliminary results from summer 2019 and lack of literature on seedling counting methods it was decided there was a need to evaluate multiple frame sizes for their effectiveness (reduced variability) between seedling counts. In summer 2020, three new plots 40 m wide x 160 m long where sown in two sites near the 2019 study site. The first site (referred to as "Pete," in reference to the owner of the land) was a former center pivot located directly west 1.6 km (1 mile) of the 2019 pivot, across Road AA in Kearny County, located 29.5 km (18.33 miles) south-southwest of Garden City, Kansas (T26S R35W NW ¼ section 14). In May 2020 two rectangular plots were sown 100m apart with the same custom seed mix as the 2019 plantings within the "Pete" site (plots were referred to as "Pete 1" and "Pete 2," respectively). A wire fence was erected around the planting sites to keep cattle from grazing on the seedlings. Site two (referred to as "Oasis") was located 25.84 km (16.06 miles) south-southwest of Garden City, Kansas (T26S R35W NW ¼ section 1). Only one plot was sown within the Oasis site. As the only independent variable tested was the size of the frame; differences in sites were not of concern. All plots where watered equally and sprayed in entirety.

Three transects were established within each plot with transects being spaced 1 m apart (FIG. 4). This minimized the variability between transects while preventing excessive trampling in any one area by conducting all three frames on one transect. Along each transect, six points were chosen to survey each spaced 20 m apart. Points were marked using a GPS and marked with flags in each corner. On one of the three transects a 20 cm x 50 cm metal Daubenmire frame was used to conduct seedling counts just as they were used in the 2019 field season. These frames were referred as Small Frames (SF). On a different transect we used 1 m x 1 m frame, which was referred to as Large Frames (LF) to conduct seedling counts. On the final transect a three-meter long segment of a seed row was counted for each point. These were referred to 3M frames (3M). Frame size was randomly assigned to a transect within each plot. Each frame within a transect was separated by six meters. As in the 2019 season, seedlings were counted every day for 12 days with new seedlings being marked with a toothpick. Data used in analysis was number of seedlings alive on day 12.

Statistics

All tests were performed using the statistical program R version 4.0.2 (R Core Team, 2020). In order to test seed survivability, the number of seedlings found at day 12 with a subplot's corresponding counterpart was averaged for each transect. For example, transect point 1 of each transect line was averaged with transect point 1 of each of the other two transect lines. Seed survivability from the 2019 season was tested for normality using a Shapiro-Wilks test and for equal variance using an F-test. The data passed the Shapiro-Wilks normality test (Unsprayed: W = 0.93, p-value = 0.55; Sprayed: W = 0.93, p-value = 0.55), but failed the test for equal variance (F = 12.52, df = 5, p-value = 0.015). The data was assessed using a right-tailed Mann-Whitney U test with an alpha level of 0.05.

Canopy cover from the 2019 season was tested for normality using a Shapiro-Wilks test and for equal variance using an F-test for all six cover categories (TABLE 2). The data for total plant coverage passed the assumptions for normality but failed equal variance and were assessed using a right-tailed Mann-Whitney U test at an alpha of 0.05. The data for bare ground met the assumptions of normality and equal variance and were assessed using a Two-sample T-test with an alpha of 0.05. The data for planted grass coverage failed the assumptions for normality and passed for equal variance and were assessed using a right-tailed Mann-Whitney U test at an alpha of 0.05. The data for planted forbs coverage failed the assumption for normality and passed for equal variance and were assessed using a right-tailed Mann-Whitney U test at an alpha of 0.05. The data for weedy grasses met the assumptions of normality and equal variance and were assessed using a Two-sample T-test with an alpha of 0.05. The data for weedy forbs cover failed the assumption for normality and passed for equal variance and were assessed using a right-tailed Mann-Whitney U test at an alpha of 0.05.

Soil samples were tested for normality using a Shapiro-Wilks test and for equal variance using an F-test for all six variables (TABLE 3). The data for total organic carbon failed the Shapiro-Wilks test and passed the equal variance test. Total organic carbon was assessed using a two-tailed Mann-Whitney U test at an alpha of 0.05. The date for Nitrogen passed both for normality and equal variance and were tested using a Two-sample T-test at alpha for 0.05. The date for pH passed both for normality and equal variance and were tested using a Two-sample T-test at alpha for 0.05. The data for Sikora pH failed for normality and passed for equal variance and were tested using a two-tailed Mann-Whitney U test at alpha for 0.05. The data for organic matter – loss on ignition (OM LOI) passed both for normality and equal variance and were tested using a Two-sample T-test at alpha for 0.05. The data for total phosphorus passed both for normality and equal variance and were tested using a Two-sample T-Test at an alpha of 0.05.

To analyze frame comparison data, we averaged the six points of each transect line (single frame size) together, and then subtracted the individual frame value from the transect average for each frame size. We then took the absolute value from each result. Frame comparisons were tested for normality using a Shapiro-Wilks test and for equal variance using a Levene's test. The data failed the normality test (Small Frame: $W = 0.7$, p-value = 7.462e-05; Large frame: $W = 0.93$, p-value = 0.16; 3-Meter Frame: $W = 0.71$, p-value < 0.001) and the Levene's test ($Df = 2$, F value = 6.2, $Pr(>F) = 0.0039$). The data was assessed with a Kruskal Wallis One-Way Analysis of Variance test at an alpha level of 0.05. A Kruskal Wallis Multiple Comparison test was performed afterwards at an alpha level of 0.05.

RESULTS

Seedling Survival

Our analysis found marginally significantly higher seed counts in sprayed plots compared to unsprayed plots (W = 27.5, p-value = 0.07) (FIG. 5). The Median seed count for unsprayed plots was 1.17 and the median seed count for sprayed plots was 2.5.

Canopy Cover

Our results found significantly more total plant canopy cover in sprayed plots than in unsprayed plots (W = 34.5, p-value = 0.005) (FIG. 6). The median cover for unsprayed plots was 51.5% and the median cover for sprayed plots was 75%.

We found significantly more bare ground in unsprayed plots compared to sprayed plots (t = -4.17, df = 10, p-value = 0.0019) (FIG. 7). Unsprayed plots had a mean bare ground of 43.7% and sprayed plots had a mean bare ground of 23.8%.

We found significantly higher planted grass canopy cover in sprayed plots than in unsprayed plots (W = 29, p-value = 0.045) (FIG.8). The median planted grass cover for unsprayed plots was 4% and the median cover for sprayed plots was 9%.

There was no significant difference in planted forb canopy coverage (W = 21, p-value = 0.34) (FIG.8) The median coverage for unsprayed plots was 5.0% and median cover for sprayed plots was 8.0%.

We found that sprayed plots did not have higher canopy cover of weedy grass (t = 1.63, df = 10, p-value = 0.13) compared to unsprayed plots. Unsprayed plots had a mean of 14.7% and sprayed plots had a mean of 25.3%.

We found that sprayed plots did not have higher canopy cover of weedy forbs (W = 13, p-value = 0.82) compared to unsprayed plots. The median cover for unsprayed plots was 45% and the median cover for sprayed plots was 43.5%.

Soil analysis

We found marginally significantly higher amounts of nitrogen in pivot soil samples compared to native soil samples ($t = -2.09$, $df = 14$, p-value = 0.055) (TABLE 4). There was no significant difference between total organic carbon in native and pivot soil samples ($W = 15$, p-value = 0.083) (TABLE 4). No significant differences were found in pH ($t = 1.1364$, $df = 14$, p-value = 0.28) (TABLE 4). There was no significant difference between Sikora pH in native and pivot soil samples ($W = 41.5$, p-value = 0.29) (TABLE 4). We found significantly higher amounts of organic matter in pivot soils compared to native soils ($t = -2.38$, $df = 14$, p-value = 0.032) (TABLE 4). No significant differences were found in Phosphorus content ($t = -1.52$, $df = 14$, p-value = 0.15) (TABLE 4).

Frame comparison

There was a significant difference in count variability between the three different frame types in counting seedlings ($\chi 2 = 22.85$, $df = 2$, p-value < 0.001) (FIG. 9). We found a significant difference between large frames (LF) and three-meter sections (3M) when compared to small frames (SF), but not when compared to each other (TABLE 5). The data suggests that of the three frame types, small frames were the least effective for conducting seedling counts. The median seedling count for SF was 0. The median seedling count for LF was 17. The median seedling count for 3M was 5.

DISCUSSION

Insecticide effectiveness

Our evidence found that plots sprayed with insecticide showed only marginally higher seed germination compared to unsprayed plots, contrary to our hypothesis. We found that sprayed plots had higher percentages of Total Plant Canopy Coverage and Planted Grass Canopy Coverage, and that unsprayed plots had more bare ground than sprayed plots, aligning with our hypothesis.

A study focusing on sunflower (*Helianthus annuus* L.) and sorghum (*Sorghum bicolor* (L.) Moench) showed that insecticide use after planting may help with seedling survival and plant establishment (Radford and Allsopp, 1987). Their experiment additionally looked at alternative methods of applying insecticides, including pre-soaking seeds, seed dressing, and water injection into the soil, finding that all methods generally worked equally as well as broadcast spraying. However, Radford and Allsopp (1987) also applied a press wheel in their experiments along with their insecticide treatments. Although we did not look into soil compaction as a method for decreasing seed predation by insects, Radford and Allsopp (1987) noted that soil compaction helped reduced the impact of insects.

We also found that planted grass cover was higher in sprayed plots than in unsprayed plots. This suggests that insecticide use may be a reliable tool to use in establishing stands of native grass on abandoned center pivots in the sandsage prairie. However, other previous studies have shown mixed results. McKenna et. al. (1990) recommended carbofuran and atrazine at 1.1 kg a.i. ha1 to help with the establishment of switchgrass (*Panicum virgatum* L.) and Caucasian bluestem (*Bothriochloa bladhii* (Retz.) S.T. Blake). These tests were conducted in Blacksburg, Virginia, a place with more humid grasslands than Southwestern Kansas, which may have influenced the results. The insecticide Triazophos, tested by Standell and Clements (1994), found that insecticides did little in helping white clover (*Trifolium repens* L.) establish in their experiments.

Soil Composition

Our results show that there were few differences between pivot soil samples and native soil samples in much of the factors that we tested. Of the differences that we did find, we found that pivot soil samples had significantly higher amount of organic matter and marginally higher amounts of nitrogen compared to native soils.

Loss Of Ignition (LOI) was chosen to measure organic matter as it is more accurate when compared to Water-Oxidation (WO). The advantage LOI has to WO, is the WO runs the risk of incomplete oxidation (Hoogsteen et al., 2015). This requires corrections to take place, which can vary depending on the type of soil tested. Because only physical destruction takes place, LOI is more accurate in measuring organic matter present in samples. However, LOI has a lack of standard protocol that makes this method prone to variability in results between studies. Temperature at which the samples are baked, the mass of the samples, the duration the samples are put in the oven, and the type of oven used, may sway the results a sample gives (Hoogsteen et al., 2015). This was evident more so for soils containing clay, as such soils are subject to structural water loss while in the oven and may affect results. Hoogsteen et al., (2015) suggested using a corrective factor when dealing with clay samples to avoid overestimating Soil Organic Matter (SOM). As the samples taken were predominantly sandy, we do not expect that this to affect our results.

The pivot site has a history of tilling prior to its enrollment into the CREP. Tilling has been associated with loss of C in soils (Lai 2004), so the results seem paradoxical. A possible factor are weedy plants that currently have a large presence in the seed bank of the pivot. Weedy and invasive species have been shown to be more effective in nutrient-poor soils than native plant species (Sardans et al., 2017). Weedy and invasive plant species in nutrient-poor soils are capable of more effective resorption of nutrients than their native counterparts, corelating with studies that show invasive species can change the soil nutrient composition of an area (Sardans et al., 2017). The foliage from former crops grown in the pivot as well as nonnative flora such as Russian thistle (Salsola kali L.) and weedy grasses could be producing more biomass that is eventually decomposed into the soil, replenishing lost nutrients such as nitrogen and increasing organic matter within the pivot. Dryland systems like the sandsage prairies are susceptible to high winds that, combined with desertification, can decrease soil organic carbon found within the soil (Lai, 2004). Many dryland systems are also low in soil organic carbon, making up only 0.5% or less of soil makeup by weight (Lai, 2004). Loss of carbon in dryland soils such as sandsage prairies limits plant growth and biomass production. This reduction in plant growth may lead to even more erosion and desertification, creating a feedback loop. As there are less plants to anchor the soil in place, the soil is displaced by high winds to surrounding fields, exacerbating the problem. Soil samples were only collected from one center pivot site, and results may not be indicative of the sandsage systema as a whole. More research and soil analysis between farmland and unfarmed soils in the sandsage region is needed. Investigations into true (no agriculture influence) native prairies are also needed to get a clear picture on how farming has impacted soils in the region.

Frame Comparison

This study found that of the three different frame types, smaller frames were not as effective (reducing variability between counts) for seedling counts than either the large frames or the three-meter frames. It is our recommendation that any future research into the topic should avoid using small Daubenmire frames for seedling counts. Frequently, the small frames resulted in not finding any seedlings in one frame while the other two frame types contained numerous (8+) seedlings. This variability in counts makes determining statistical differences challenging. Both of the other frame types (LF and 3M) had the advantage of covering more area, increasing the chance of finding and marking at least a few seedlings. The two larger frames reduced 0 counts and resulted in reduced variability in counts between frames. Large frames were found to be more effective in areas where seed rows could not be easily identified. Three-meter sections are best used when seed rows are easily identified, and as such are best set out within 24 hours of sowing. However, we cannot say conclusively that one frame type was more effective than the other when comparing the LF to the 3 m frame. Lack of methodology on determining seed survival counts in the field also make comparing the two frame types inconclusive.

Factors for Future Research

While timing of sowing and water usage were not analyzed in our research, we recommend that future research evaluate these topics. The CREP does not require irrigation of plots for restoration. Watering seedlings may potentially increase establishment of native plants (Wilson and Briske, 1979). Canopy coverage may also help in facilitating higher rate of seedling survival. A study found that subcanopy soil (soil found under the canopy cover of other trees) had more soil moisture than inter-canopy soil (soil that was found between canopy cover of trees) (D'Odorico et al., 2007). Access to greater amounts of water within the soil allowed for seedlings to take root within the subcanopy soils. The study focused on woody canopy cover in the savanna ecosystem in the Kalahari region, but there is a possibility that the same may hold true in ecosystems with sagebrush or tall grasses acting as the canopy such as in the sandsage prairie. Similarly, Johnston (1962) found that water infiltration rates increased as plant cover increased in a grassland system. This is important as moisture is a limiting factor in many arid environments for plant growth, as plants use water sources that are most easily accessible to them – annual plants limited to surface water contents, and forbs and shrubs using deeper soil moisture (Nippert and Knapp, 2007). Timing planting of seeds to match the point where soil temperatures reach over 18℃ constantly may likewise increase seed germination and produce a healthier stand of native grasses (Knipe, 1967). Evaluation of planting timing was originally part of this study but was not able to be assessed due to complications. We suspect that the implementation of these alternative methods may increase the chances of seed germination and survival, resulting in greater restoration success.

Microorganisms are an important part to soil and soil nutrient dynamics. Plants interact with a fraction of these microorganisms usually to each other's benefit (Nihorimbere et al., 2011). These organisms can help the plant grow and provide plants nutrients that it might otherwise not get on their own. We did not investigate the presence and makeup of the microbiome that exists within the sandsage prairie; however, the microbiome does have an impact on soil nutrient composition and seedling survivability. Soil health can be assessed by examining the biodiversity of the microbiome that is present in the soil, giving us an indicator of how healthy a soil system is (Chaparro, 2012). The composition of the microbiome can also be important for restoration success, not only in increasing establishment, but in also increasing species diversity and richness in a given restoration area (Koziol et al., 2018). Many Arbuscular Mycorrhizal Fungi (AMF) and other microbes are sensitive to anthropogenic practices such as tillage, resulting in soils with an altered microbiome makeup in farmlands when compared to native prairies (Koziol et al., 2018). Inoculating soils with native microbes such as native AMF combined with other restoration practices may help speed up grassland restoration projects and increase overall success.

Importance

The sandsage prairie is a unique ecosystem, home to many species of small mammals, birds, and reptiles (Sexson, 1980). Species like pronghorn (*Antilocapra americana*) (Sexson and Choate, 1981), lesser prairie chicken (*Tympanuchus pallidicinctus*) (Jensen et. al., 2000), swift fox (*Vulpes volex*), burrowing owl (*Athene cunicularia*) (Klute et. al., 2007), lark sparrow (*Chondestes grammacus*), sage sphinx moth (*Lintneria ermitoides*), the Texas horned lizard (*Phrynosoma cornutum*) rely on the sandsage prairies for food and shelter. The Lesser prairie chicken, listed as vulnerable under the International Union for Conservation of Nature's Red List of Threatened Species has been one of the most affected species by the loss of the sandsage prairies – The sandsage prairies once made up more than half of the Lesser Prairie Chicken's habitat, now it makes up the least (McDonald et al. 2014). At one point there was an estimated 547,773 ha (1,353,000 acres) of sandsage prairie in the state of Kansas. As of 1980, 344,130 ha of sandsage prairie were found to be converted into center pivots (Sexson, 1980). The Short-eared owl (*Asio flammeus*) a species native to the area is considered a species in need of conservation (SINC) in the state of Kansas (Kansas Department of Wildlife, Parks, and Tourism https://ksoutdoors.com/Services/Threatened-and-Endangered-Wildlife/All-Threatened-and-Endangered-Species/Short-eared-Owl). Nesting in prairies, marshes, and farmlands, the species has been rare in the state since the 1930s. The need for restoring these hectares of lost sandsage prairies is eminent, recreating habitat for many native fauna in Kansas, as well as reducing the ecologic and economic concerns associated with erosion and desertification of this unique ecosystem.

Conclusion

We found marginal evidence supporting our hypothesis that insecticides may increase seed count and seed survivability in the sandsage prairies. However, we found stronger evidence that insecticides may increase Total Plant Canopy Cover and Planted Grass Canopy Coverage for restoring the sandsage prairies. We found no significant difference in soil composition between native soil and pivot soils except in Organic Matter and Nitrogen. We found that pivot soils had significantly higher concentration of organic matter than native soils, as well as marginally higher amounts of nitrogen than native soils. We found that small Daubenmire frames performed the least effective, compared to large frames and three-meter frames in terms of variability.

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Table 1--Comparison of standard CREP methodology to Alternative methodology in terms of timing, insecticide use, and water usage. This experiment primarily focuses on insecticide use, but timing and water usage are important to note as well.

Variable	Standard CREP Methodology	Alternative Methodology
Time of planting	Before 15 April (Conventional timing)	May to June (soil = 18℃) (Designated timing)
Insecticide	None used	Insecticides used within 24 - 48 hours after planting
Water usage	Dependent on the landowner	Use of pivot for the first 10 days after planting

TABLE 2--Normality and equal variance test results for canopy coverage data taken from the center pivot in Kearny County Kansas, in September 2019. Data sets that failed either the test were later assessed with Mann-Whitney U test. Data sets that passed both normality and equal variance were assessed with Two-Sample T-Tests. * indicated a failed result.

	Normality (Shapiro-wilks test)				Equal variance (F-test)				Total result	Assessed with
Canopy Coverage	Treatment	*W*	*p-value*	Result	*F*	*df*	*p-value*	Result		
Total Plant Coverage	Unsprayed	0.89132	0.3252	Pass	0.12669	5	0.04064*	Fail	Fail	Mann-Whitney U
	Sprayed	0.89777	0.3609	Pass						
Bare Ground	Unsprayed	0.82473	0.09693	Pass	0.68636	5	0.6897	Pass	Pass	Two-Sample T-Test
	Sprayed	0.79385	0.0517	Pass						
Weedy Grasses	Unsprayed	0.95326	0.7666	Pass	1.6759	5	0.5847	Pass	Pass	Two-Sample T-Test
	Sprayed	0.83906	0.1281	Pass						
Weedy Forbs	Unsprayed	0.78933	0.04702*	Fail	1.3298	5	0.7621	Pass	Fail	Mann-Whitney U
	Sprayed	0.90382	0.397	Pass						
Planted Grass	Unsprayed	0.80249	0.06187	Pass	8.7687	5	0.03251	Pass	Fail	Mann-Whitney U
	Sprayed	0.7618	0.02592*	Fail						
Planted Forbs	Unsprayed	0.76252	0.02634*	Fail	0.26464	5	0.1709	Pass	Fail	Mann-Whitney U
	Sprayed	0.84969	0.1565	Pass						

TABLE 3--Normality and equal variance test results for soil sample data taken from the center pivot in Kearny County Kansas, in September 2019. Data sets that failed either test were later assessed with Mann-Whitney U test. Data sets that passed both normality and equal variance were assessed with Two-Sample T-Tests. * indicated a failed result.

	Normality (Shapiro-wilks test)				Equal variance (F-test)				Total result	Assessed with
Soil samples	Treatment	*W*	*p-value*	Result	*F*	*df*	*p-value*	Result		
Total Organic Carbon	Native	0.80714	0.03412*	Fail	2.5915	7	0.2323	Pass	Fail	Mann-Whitney U
	Pivot	0.9229	0.4538	Pass						
Nitrogen	Native	0.92543	0.4754	Pass	1.0361	7	0.9639	Pass	Pass	Two-Sample T-Test
	Pivot	0.85263	0.1013	Pass						
pH	Native	0.91058	0.3582	Pass	0.83729	7	0.8208	Pass	Pass	Two-Sample T-Test
	Pivot	0.88407	0.2059	Pass						
Sikora pH	Native	0.81042	0.03697*	Fail	0.82143	7	0.8019	Pass	Fail	Mann-Whitney U
	Pivot	0.82721	0.05552	pass						
Organic Matter – Loss of Ignition	Native	0.87835	0.1816	Pass	3.5704	7	0.115	Pass	Pass	Two-Sample T-Test
	Pivot	0.89036	0.2359	Pass						
Phosphorus	Native	0.87981	0.1875	Pass	0.43563	7	0.2952	Pass	Pass	Two-Sample T-Test
	Pivot	0.86242	0.1269	Pass						

TABLE 4-- Two-sample T-test results for native and pivot soil samples collected in the Center Pivot in Kearny County Kansas, on 29 September 2019. Soil nutrient composition was tested for Nitrogen, pH, Organic matter, and Phosphorus. The only significant find was for Organic Matter – Loss on Ignition (OM LOI).

	t	df	p-value
Nitrogen (%)	-2.0909	14	0.05525**
pH	1.1364	14	0.2748
OM LOI (%)	-2.3779	14	0.0322*
Total P ppm	-1.5157	14	0.1519

* Significant difference

** Marginally significant difference

TABLE 5-- Multiple Comparison test showing the differences between the three frame types (Small Frame, Large Frame, 3M frame) tested across three sites in Kearny County KS.

	Obs. Dif	Critical.dif	Difference
3M-LF	6.888889	12.55414	False
3M-SF	17.388889	12.55414	True*
LF-SF	24.277778	12.55414	True*

*indicates significant difference

FIG. 1--Biomes of Kansas. Map taken from the Kansas Historical Society.

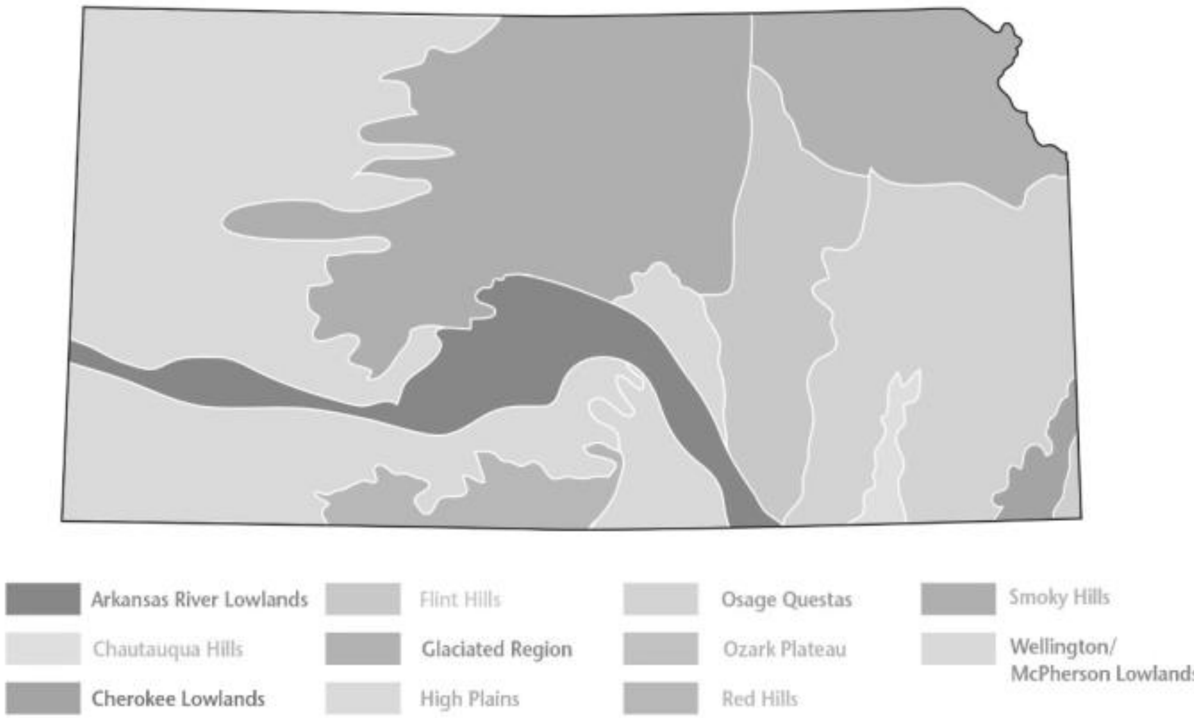


FIG. 2--Picture of sand blowing across a county road in Finney County, Kansas. The source of the sand is from an abandoned center pivot, illustrating the need to improve current restoration efforts. Picture was taken on 17 May 2018.

FIG. 3--Diagram of the center pivot experimental design for a Center Pivot in Kearny County, Kansas, in 2019. Legend coded to distinguish treatments (gray = sprayed with insecticide and white no spraying). The 2019 dates show time when the three plots were sown.

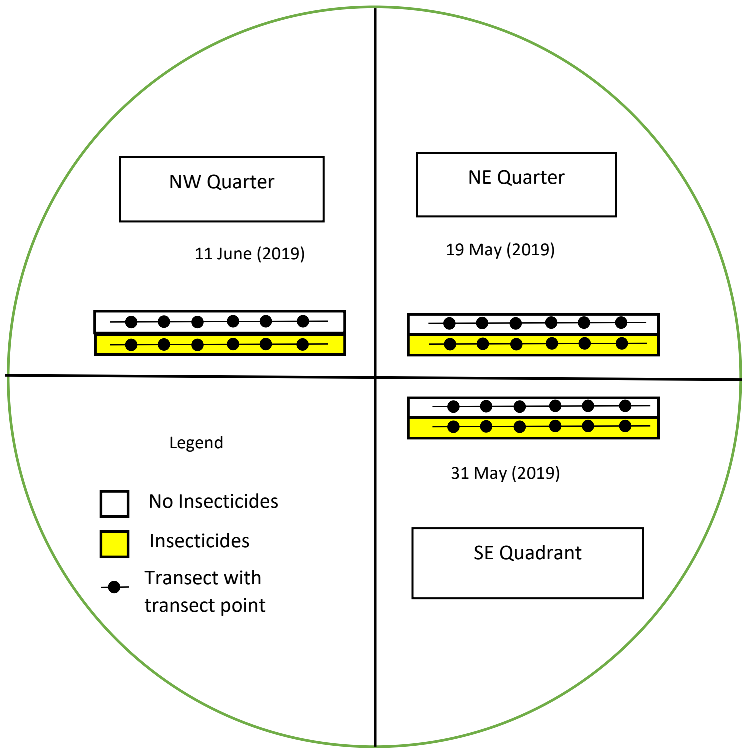


FIG. 4--Diagram of transects taken in each plot sown in fields in Kearny County Kansas in 2020. Each transect was separated by one meter apart. Each transect was sampled by six transect points. Rectangle represents a 3M frame transect point. Black circle represents a Large Frame transect point. White circle represents a Small Frame transect point. Each transect point was separated by 20m.

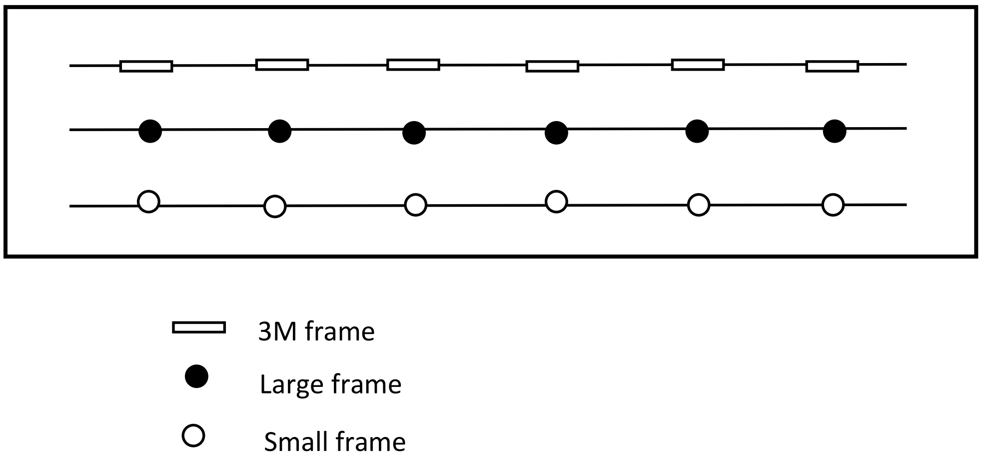


FIG. 5--Average Seed count at unsprayed and sprayed plots sown in a Center Pivot in Kearny County, Kansas, in 2019. Seed counts were conducted from 19 May to 29 June 2019. Results show that a higher average of seeds in sprayed plots than in unsprayed plots.

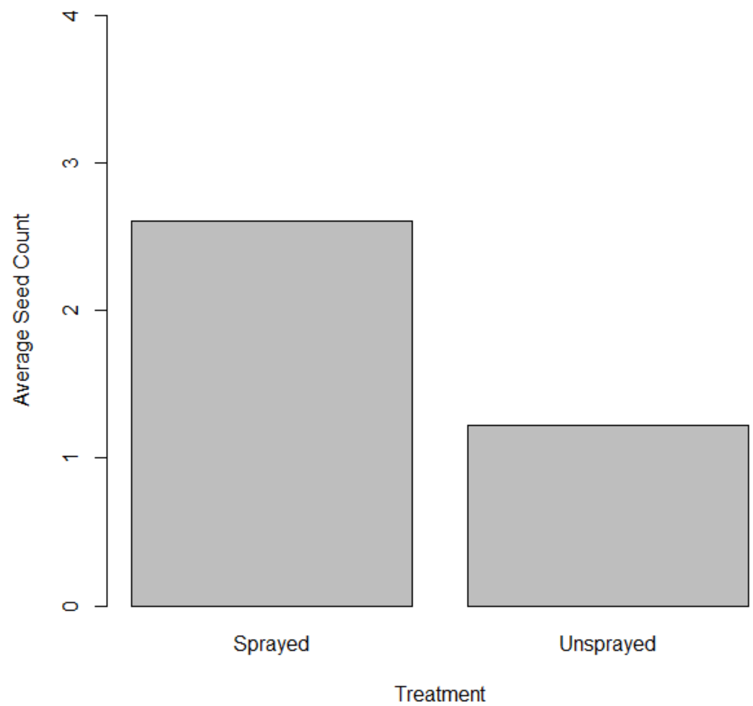


FIG. 6--Graph depicting the number of frames of a given cover class of Total Plant coverage between unsprayed plots and sprayed plots sown in a Center Pivot in Kearny County, Kansas,in 2019. We found a higher frequency of high plant coverage in the sprayed plots compared to the unsprayed plots.

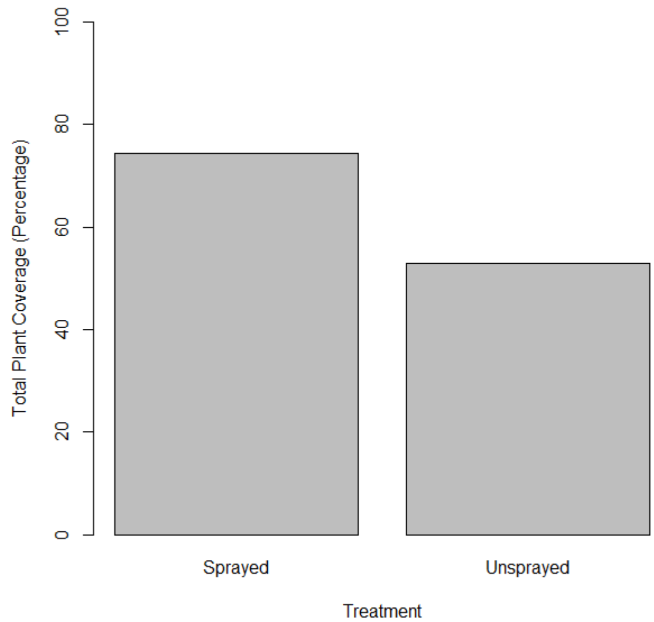


FIG. 7--Bare ground percentage comparison between unsprayed plots and sprayed plots sown in a Center Pivot in Kearny County, Kansas, 2019. Overall, there was more bare ground in the unsprayed plots compared to the sprayed plots.

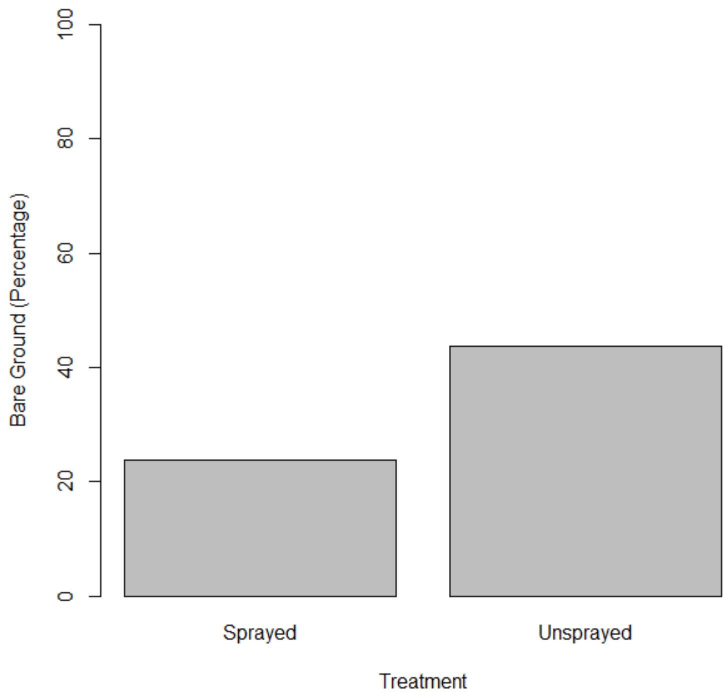
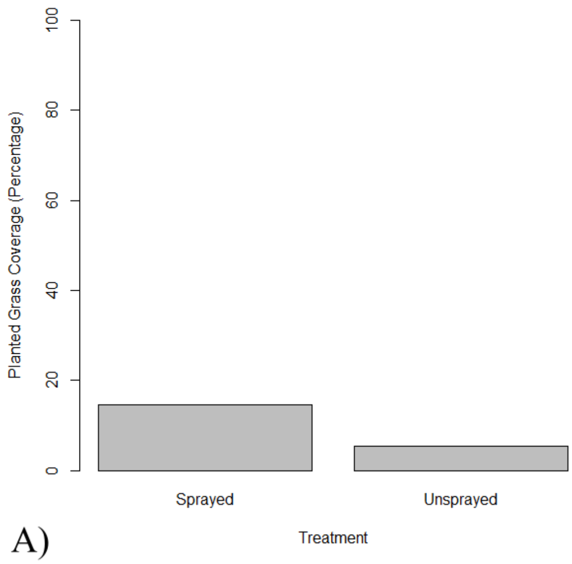
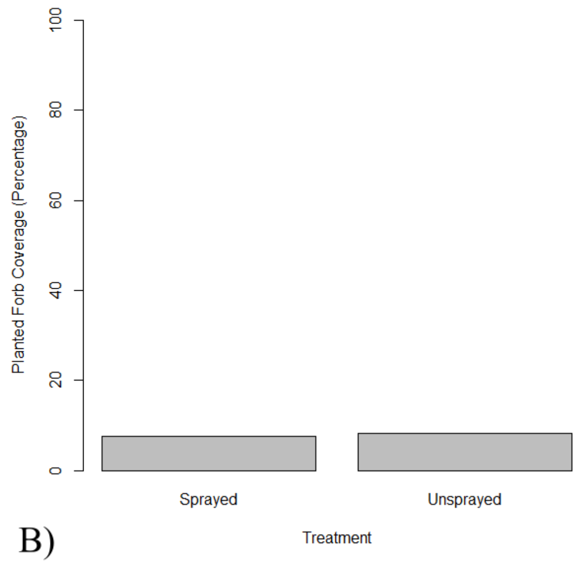


FIG. 8-- Planted Grass Canopy coverage and Planted Forb Canopy coverage comparison of unsprayed and sprayed plots sown in a Center Pivot in Kearny County, Kansas, in 2019. A) shows canopy coverage for Planted Grass, B) shows canopy coverage for Planted forbs.

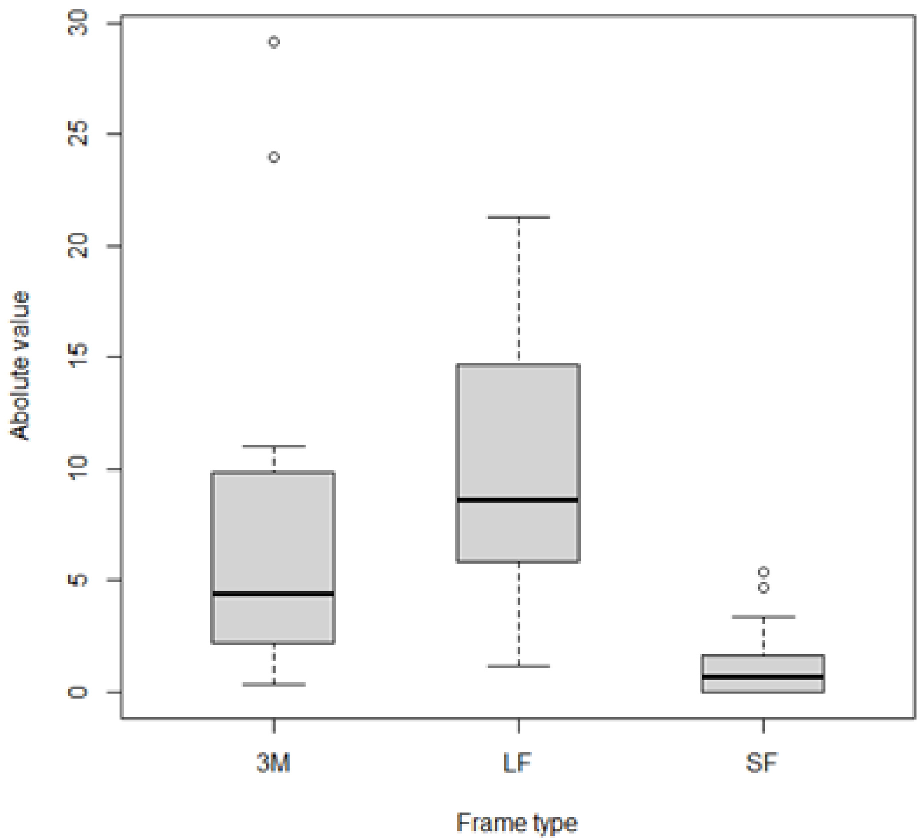


A)



B)

FIG. 9--Seed count comparison between three different frame types in three plots in Kearny County, Kansas, in 2020. There was not significant difference between the 3M and LF frames, but there was such a difference on small frames.



APPENDIX A.--List of plant species and varieties included in the seed mix that was planted in a Center Pivot plot in Kearny County, Kansas, on May and June, 2019. These plant species native to southwest Kansas are well suited to surviving the dry conditions of the region.

Species Included in Seed Mix			
Plant Type	Species, Variety	Acre rate	Pounds of Live Seed
Grasses	Blue Grama, Lovington *Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	0.08	10.3
	Little Bluestem, Cimarron *Schizochyrium scoparium* (Michx.) Nash	0.4	51.48
	Sand Bluestem, Chet *Andropogon Hallii* Hack.	0.9	115.83
	Sand Dropseed, KS/CO Origin *Sporobolous crypandrus* (Torr.) A. Gray	0.002	0.26
	Sand Lovegrass, Bend *Erogrostis trichodes* (Nutt.) Alph. Wood	0.028	36.04
	Sideoats Grama, El Reno *Bouteloua curtipedula* (Michx.) Torr.	0.6	77.22
	Switchgrass, Blackwell *Panicum virgatum* L.	0.3	38.61
	Western Wheatgrass, Barton *Pascopyrium smithii* (Rydb.) Á. Löve	0.1	12.87
	Yellow Indiangrass, Cheyenne *Sorghastrum nutans* (L.) Nash	0.6	77.22
	Needle and Thread *Hesperostipa comate* (Trin. & Rupr.) Barkworth	0.5	64.35
Forbs	Alfalfa, Cimarron *Medicago sativa* L.	0.08	10.3
	Annual Sunflower *Helianthus annuus* L.	0.186	23.94
	Illinois Bundleflower (Prairie Mimosa) *Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald	0.16	20.59
	Indian Blanket, Annual (Annual Galillardia, Firewheel) *Gaillardia pulchella* Foug.	0.04	5.15
	Maximillian Sunflower *Helianthus maximiliani* Schrad.	0.05	6.44
	Plains Coreopsis *Coreopis tinctorial* Nutt.	0.006	0.777
	Purple Prairie Clover *Dalea purpurea* Vent.	0.06	7.72
	Showy Partridge Pea *Chamaecrista fasciculata* (Michx.) Greene	0.14	18.02
	Upright Prairie Coneflower (Mexican Hat) *Ratibida collumnifera* (Nutt.) Woot. & Standl.	0.03	3.86
	White Prairie Clover *Dalea candida* Michx. ex Willd.	0.06	7.72
	White Yarrow *Achillea millefolium* L.	0.003	0.39

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