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# Effects of Planting Method on Enhanced Stand Establishment and Subsequent Performance of Forage Native Warm-Season Grasses

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**Abstract**

To develop strategies for successful establishment of forage native warm-season grasses (NWSGs) in southeastern USA, early agronomic performance of transplanted and seeded stands of big bluestem (BB, *Andropogon gerardii* Vitman), eastern gamagrass (GG, *Tripsacum dactyloides* L.), indiangrass [IG, *Sorghastrum nutans* (L.). Nash], and switchgrass (SG, *Panicum virgatum* L.) were compared. In early June, about 6-week old high tunnel grown seedlings were transplanted to assigned clean seedbeds. Plant spacing (cm) was 30-within and 45-between rows. Seeded plots received ≥ 11 kg seeds $ha^{-1}$ planted at ≤ 2 cm deep in 45-cm wide rows, a month after transplanting to match rainfall availability. As needed, tall-growing broadleaf weeds were removed physically by cutting with a hand hoe. Plants were allowed uninterrupted first year growth with no fertilizer applied. Early in the following spring, dead standing biomass was mowed down to allow the emerging tillers more access to sunlight. During the second and third year after planting, plots were machine harvested twice between July and September for yield assessment. Percentage ground covered by plant material and species basal diameters were also recorded. Data were analyzed as a randomized complete block design for effects of planting method, species, and stand age. Except for GG, transplanting resulted in greater (>3,000 kg DM $ha^{-1}$) forage yield and more so during the second harvest year. Total second year yields were similar for BB and GG and averaged 9,600 and 6,300 kg DM $ha^{-1}$ for transplanted and seeded, respectively. Indiangrass and SG yields (kg DM $ha^{-1}$) were 11,500 and 8,300 and 13,000 and 10,000 for transplanted and seeded plots, respectively. The NWSG ground cover was greater in the transplanted than seeded plots, while the reverse was true for weed cover. Data indicate that, in less than two years, transplanting under comparable growing conditions can produce harvest-ready uniform NWSG stands in weed infested areas. For practical recommendations, however, data on comparable responses of transplanted vs seeded stands to actual grazing at a similar timing is necessary.

**Keywords:** Native warm-season grass, establishment, transplant, forage yield, basal diameter, cover, defoliation

## 1. Introduction

### *1.1 Summer Forage Shortages*

In Virginia, as in most other southeastern states of America, inability of introduced warm-season forage grasses (IWSGs) to withstand the July-August dry spell causes summer forage shortages and can potentially impact the productivity of ruminant livestock. Besides their inability to withstand the summer droughty conditions, the productivity of these introduced warm-season forages such as bermudagrass (*Cynodon dactylon* (L), bahiagrass (*Paspalum notatum* Flueggé), and *P. dilatatum* Poir.) is dependent on rainfall distribution and application of external fertilizers. This is partly so because their root systems are usually too shallow to access the receding moisture front at deep soil profiles during dry periods. Livestock producers are, therefore, forced to sustain their animals on costly hay and concentrate feeds, which negatively impact their profit margins. Unfortunately, this reliance on purchased hay somehow eliminates the producers' control over the quality and composition of feeds in use, thus making it even harder for those interested in organic production. This makes forage systems composed of plant species adapted to a diversity of growing conditions more likely to support year-round forage-based ruminant production.

### *1.2 Advantages of Native Warm-Season Forage Grasses*

Unlike IWSG, native warm-season grasses (NWSGs) are relatively more drought tolerant, less dependent on fertilizers, and usually remain vegetative longer into the summer dry-spell (Kiss et al., 2007; Mulkey et al., 2008). So, incorporating NWSGs into the pasture systems will most likely improve summer forage production and availability in the region. For over a decade now, the mid-south and southeastern regions of the US have seen a growing interest in NWSGs mainly due to their superior summer forage potential (Angima et al., 2009; Temu et al., 2014a), wildlife habitat quality features (Temu et al., 2014b), and low-input demand. Of the NWSGs, big bluestem (BB, *Andropogon gerardii* Vitman), eastern gamagrass (GG, *Tripsacum dactyloides* L.), indiangrass [IG, *Sorghastrum nutans* (L.). Nash], and switchgrass (SG, *Panicum virgatum* L.) are the most favored (Vogel, 2000; Jones et al., 2007). These NWSGs grow notably better than the IWSGs owing to their superior morphological and physiological adaptations. Once well established, most NWSGs are able to exploit large soil volumes for moisture and nutrients owing to their deep and extensive root systems (Huang, 2000). They are also able to sustain high photosynthetic activity during hot and dry summer months due to their $C_4$ photosynthetic pathway. This ability to sustain growth under harsh growing conditions may explain the observed high annual yields of 2637 kg ha$^{-1}$ for unfertilized BB, IG, and SG (Mulkey et al., 2008), and 8472 kg ha$^{-1}$ from mixed stands of BB, IG, and LB (Temu et al., 2014a). In another study, SG yield of 8000 kg ha$^{-1}$ is reported with 55% of it being obtained in July and August (Jung et al., 1985).

Being tall-growing, NWSGs make even better pastures for goats, which prefer feeding from tall-, over short-growing plants. On these tall grasses, goats are also less likely to pick gastrointestinal nematode (GIN) eggs off the ground. Like in other hot humid environments, GINs have a tremendous economic impact on small ruminant production in the southeastern US. Usually, GINs reduce animal performance and losses in production of up to 50% have been reported in sheep (Sykes, 1994). Therefore, the potential contribution of NWSG pastures towards reduced GIN loads in grazing small ruminants, cannot be over emphasized. In addition, NWSG stands, because of their bunch-like structure, have voids close to the ground that make room for legumes, which improve the forage nutritive value. In pastures, legumes also improve soil fertility through biological nitrogen fixation and increase the crude protein concentration of the forage biomass (Muir et al., 2011).

Besides forage production, NWSGs because of their growth characteristics; tall growing, open canopy structure, wider canopy cover, and relatively smaller basal area (White et al., 2005; Harper & Moorman, 2006) offer good wildlife habitats. Their compatibility with non-grass species also supports the formation of diverse plant communities that allows for a broader wildlife food base. For grassland birds and small mammals, voids among tall grasses facilitate movement through the stand and with upward of 20% bare ground which is good for visibility and access to food (Lusk et al., 2006; Jones et al., 2007; Temu et al., 2015). Most NWSG pastures have multiple ecological benefits. For example, in a typical NWSG forage stand, northern bobwhites retain vigilance to predators, visibility to foods on the ground, easy mobility, and concealment while foraging under the canopy.

### *1.3 Slow Adoption of Native Warm-Season Forage Grasses*

Despite their beneficial attributes, incorporation of NWSGs into pasture systems is still very slow, in the Southeast, mainly because they are costly and difficult to establish. They usually exhibit poor germination, low seedling vigor that easily succumb to competitive annual weeds, and could be at least two years before you have a reasonable stand. Unfortunately, low seedling vigor during seeded establishment of NWSGs is not avoidable because their initial resource allocation favors root system development at the expense of vegetative growth. This differential resource allocation also accounts for poor initial NWSG ground coverage in seeded stands, which without timely weed control and gap-fillings, gives way to poor initial stands and undesirable plant species encroachment into the pasture. However, once well stablished, NWSGs do preferentially channel resources towards above-ground growth, which is a good forage attribute.

Strategies for achieving faster establishment of thick NWSG stands without costly weed control and/or gape-filling measures will likely improve their standing as alternative summer forage resources. Unlike their seeded counterparts, transplanted NWSGs have been found to attain maturity and produce seeds within the first year, (Goedhart & Warne, 2006). However, there is paucity of information about their initial ground coverage and readiness for forage harvesting. This study, therefore, was designed to evaluate the use of seedling transplants as a strategy for achieving faster establishment of the selected four NWSGs with respect to their early establishment ground cover and forage yield during the second year of production.

## 2. Materials and Methods

### *2.1 Location and Field Preparations*

The study was conducted at Virginia State University's research farm (Randolph Farm) located in Chesterfield county, Virginia at 37° 13" 43' N; 77° 26" 22' W, and 45 m above sea level. The soils at the farm are Bourne series fine sandy loam (mixed, semiactive, thermic Typic Fragiudults). The area has a 20 year June, July, and

August average precipitation of 92, 113, and 121 mm with day temperatures of 30.2, 32.1, and 31.2 °C, respectively (Satellite N.O.A.A., 2013). Prior to starting the experiment, the field had been under rotational corn-soybean row-cropping for several years. In mid-May, the field was first sprayed with a broad spectrum herbicide, Glyphosate {N-(phosphonomethyl) glycine}, to kill the cover crop and later disk plowed and harrowed repeatedly to produce a fine seedbed.

*2.2 Seedling Preparation and Planting*

For about 5-6 weeks starting late April, degradable paper strip cups (5×5 cm top, 2×2 cm bottom and 5 cm deep), arranged in perforated flats on polyethylene lined table tops were seeded with BB, GG, IG, and SG and kept moist. Seedlings were allowed to grow in a high tunnel. In early June, 64, 6×7 m plots were marked and randomly assigned to BB, GG, IG, and SG in a randomized complete block design (RCBD). Two days after a heavy rainfall in mid-June, seedlings of each species were transplanted into pre-assigned plots, spaced 30 cm within and 45 cm between rows, using a tractor operated seedling planter. The planting was such that seedlings were upright with their entire root mass completely covered with at least an inch thick layer of soil. Missing and improperly placed seedlings were manually replaced and corrected immediately after planting. Following the return of summer rains in mid-July, about six weeks after transplanting, a control plot for each species and in each block (replication) was seed-drilled at about 2 cm depth for comparison. Ernst Conservation Seeds, Inc. high seed rate recommendations for establishing a forage stand were followed.

*2.3 Field Management*

Because there was no rainfall for over a month after transplanting and fields were not irrigated, some poorly covered seedlings died. Following the return of summer rains in mid-July, a little over a month after transplanting, dead seedlings were immediately replaced. Later in the season, broadleaf weeds were manually removed by cutting as needed, using a hand hoe and throughout the study to minimize their competitiveness against the native grass seedlings. For the remainder of the season, plants grew uninterrupted and no fertilizer was applied. In late March of 2013, the standing dead biomass accumulated since being planted was mowed down so that the new growth could have ample access to solar radiation.

*2.4 Forage Yield Measurements*

During the second year after planting, 1.5 m wide strips were harvested twice from July to September, to assess (kg DM $ha^{-1}$) during the first year (Year1) of production. A CIBUS F Plot Forage Harvester (Winterstaiger Ag, Dimmelstrasse, Austria) equipped with a Harvestmaster weighing system (Juniper Systems, Inc, USA) with a 0.01 kg accuracy was used to determine fresh plot weights. Cutting height was set at 18 cm. From each plot harvest, a representative forage sample was collected and transported in plastic bags to a field laboratory, where it was weighed before and after drying to a constant weight at 65 °C in a forced-air oven to determine percentage moisture content. The sample moisture content values were used to convert the respective fresh plot weights into dry matter, with which per hectare yield estimates (kg DM $ha^{-1}$) were calculated. Forage yields during the second year (Year2) of production were obtained similar to that of year1. However, respective harvest dates differed by about 1-2 weeks due to weather.

*2.5 Cover Estimates*

In vegetation survey, ground cover is defined as the percentage of material other than bare ground covering the land surface (Anderson, 1986). In the current study, visual estimates of the proportion of land surface covered by the vertical projection of above ground plant parts were recorded, a day or two before harvest. These assessments were made towards the end of May for the two years. During 2013, the first year in production, proportions of ground area covered by the native grasses, weeds, and litter, within a 1-m square quadrat, were recorded. For faster area estimation, the quadrat-sides were painted in alternate10-cm color bands such that a 10×10-cm cell represented a 1% cover. All dead plant parts found recumbent on the ground surface, including those still attached to the mother plant, were considered litter. Generally, the stands had no bare ground patches and, therefore, there were no records for the same. In each plot, three randomly placed quadrats were sampled. During the second year in production (2014), six basal diameter readings of the native grass stubbles, the cross-sectional area of plants near the ground, as indicators of respective basal cover, were recorded along a line transect across the rows. Two diameter readings were recorded within each of three 1-m line segments at least a meter apart and excluding the outermost rows.

*2.6 Design and Data Analysis*

The data were subjected to analysis of variance (ANOVA) as a RCBD with planting method, years in production, and species as fixed effects. Means were compared by the Fisher's Least Significant Difference test at $\alpha = .05$.

During the data analyses, the first and second cuts were combined into respective year total yields. The plot yield data were organized by number of years in production and analyzed for effects of planting method and species. The latter compared species yields within the first or second year in production to their same-established-method counterparts. Yields were also separately compared between planting methods within years in production. To assess treatment effects on stand establishment, yield ratios obtained by expressing the first-year yields as proportions of their respective second-year values were also compared. The cover and basal diameter data, however, were pooled across years in production for the analyses.

## 3. Results and Discussion

### *3.1 Effects of Planting Method*

During the 2012 summer months, the study area experienced severe droughty conditions that impacted survival of the seedling transplants. In fact monthly rainfall totals were only about 45 and 66 mm in June and August, respectively, and although the July total was significantly greater (205 mm), it was still poorly distributed (Satellite N.O.A.A., 2013). Results of forage yield by the NWSG stands during the first and second year in production are summarized in Table 1. Throughout the section and unless otherwise indicated, mean differences have been declared not significant when $P > .05$. There were significant planting method × year and/or species interactions in the yield rankings, so results are presented separately by species and year. During the first year in production, both first and second harvest yields for each species were consistently greater ($P < .01$) from the transplanted than their matching seeded plots. At the second harvest, for example, the percent yield differences ranged from slightly below 40 for SG to nearly 60 for BB and IG. During the second year, first harvest trends in the corresponding yield ranks and the percentage differences due to planting method were more or less sustained, but not in the second harvest, except for BB. Second-harvest yields for the other three species were not statistically different and only averaged 29 units for GG, < 20 for the rest, and even as low as 10 for IG. However, total yields remained significantly greater from the transplanted ($P < .02$) than the seeded plots.

These yield differences were partly attributable to the growing advantage the transplants had over the seeded plants. A greater seedling survival in the transplanted plots, which translated into greater initial plant population density, also contributed to their resulting better yields, somewhat agreeing with an earlier report on GG (Springer et al., 2003). Similar results regarding greater forage biomass from transplanted grasses compared to seeded ones have also been reported (Houser, 1983; Borman, et al., 1991). While the seeded NWSGs had their root development phase amidst severe weed completion, the transplants established their root systems ahead of weeds emergence. In terms of number of years after planting, first and second year yields are comparable for BB and SG. Although the values were below the reported averages of 7.7 and 9.2 kg DM $ha^{-1}$, respectively, for the two species (Propheter et al., 2010). The noted yield differences may also be due to the fact that fertilizers were not applied in this study unlike that reported by Propheter et al. (2010) which received 168 to 180 kg N $ha^{-1}$ as urea. However, even without fertilizers, total yields in the current study from transplants were still notably greater than those reported earlier. These results suggest that the performance of newly established NWSG stands may be limited more by weed challenges rather than soil fertility and that the growing advantage associated with transplanting would more or less guarantee success.

### *3.2 Effects of Species on Forage Yield*

For each harvest and years in production, there were significant species yield differences. While a planting method × harvest order interaction was not detected, significant harvest order × year interactions were. Therefore, results of species yield ranking for each harvest event and or their combinations are described separately. Throughout the study, mean SG yield values were greater than those of other species, although not always significantly so. For example, mean second harvest yield for SG was only statistically greater than that of BB during the first and second year, and greater than GG but not different from that of IG during the second year (Table 1). In each year, however, mean total forage yield for SG, was significantly greater than that of any other species ($P < .02$). For the transplanted SG, respective total yields, during the first and second year, were 10,452 and 13,474 kg DM $ha^{-1}$. Although these yields were on the lower end of reported five-year averages of 10.4 to 19.1 Mg $ha^{-1}$ in the Southeast (Fike et al., 2006), that may be attributable to differences in number of harvests per year and the use of fertilizers. Yields in year 1 were similar for transplants and seeded IG, BB, and GG plots, averaging 3955 kg DM $ha^{-1}$ (Seeded) and 7870 kg DM $ha^{-1}$ (transplants). However, during the second year, IG had higher biomass, but with relatively narrower yield differences between seeded and transplanted SG plots than the other species.

To some extent, the observed relatively narrow SG yield differences due to planting methods suggest that aggressive tillering ability for the performer variety enabled the seeded stands to quickly minimize the potential effects of their initial stand density on biomass production. This also indicates that, among the four NWSGs, SG establishment was less susceptible to weed competition, and therefore, under comparable growing conditions, the productivity of fall-seeded new stands of similar varieties may benefit more from careful early defoliation management that promotes tillering than it might with intensive weed control alone. Defoliation usually favors the growth of auxiliary tillers through improved light environment (Assuero & Tognetti, 2010) and the removal of the reproductive tillers'' apical dominance (Richards, et al., 1988; Briske and Richards, 1995; Tomlinson and O'connor, 2004). However, when deciding on appropriate defoliation strategies, species differences in response to defoliation as in the case of SG in the current study should be taken into consideration.

### *3.3 Effects of Years in Production on Forage Yield*

While first harvest yields for each species, within a planting method, showed no significant differences due to number of years in production, the corresponding second harvests and total yields were consistently greater during the second than the first year. However, while it was not unusual for yields of the second year stands to surpass their respective first-year performances (Cornelius, 1946), total yields during these harvest years were notably greater from transplanted- than seeded plots indicating that transplanting favored faster stand establishment. These faster stand establishments would also explain the notable yield increase of the second year stands relative to their first year performance. While the second-year seeded plot-yields were as much as 118% higher than their first-year values, respective yield increase for the transplants was only 45%. This notable closeness of transplanted first year stand performance to their second year values was also consistent with the enormously greater percentages of native grass ground cover observed (Table 2). However, the fact that second year yields, for each planting, exceeded their respective first year records indicates the importance of careful initial defoliation management for newly established NWSG stands to attain higher forage potentials in future.

Table 1. Effects of planting method on forage yields (kg DM $ha^{-1}$) from pure stands of four native warm-season grasses[†] during the first (Year1) and second (Year2) year of production recorded in 2013 and 2014, respectively

| Species/Method | Yield (harvest order and total) by year of production | | | | | | |
|---|---|---|---|---|---|---|---|
| | First cut | | Second cut | | Total | | Yield increase[‡] |
| | Year1 | Year2 | Year1 | Year2 | Year1 | Year2 | |
| | ---------------kg DM $ha^{-1}$--------------- | | | | | | % |
| Big Bluestem | | | | | | | |
| Seeded | $3587^{b}_{Ba}$[¶] | $3694^{b}_{BCa}$ | $432^{b}_{Bb}$ | $3274^{b}_{Ba}$ | $4019^{b}_{Bb}$ | $6968^{b}_{Ca}$ | 73 |
| Transplanted | $6962^{a}_{Ba}$ | $5842^{a}_{BCa}$ | $999^{a}_{Bb}$ | $4058^{a}_{Ba}$ | $7961^{a}_{Bb}$ | $9900^{a}_{Ca}$ | 24 |
| P>α[§] | <.01 | .02 | <.01 | 0.04 | <.01 | .01 | |
| Eastern gamagrass | | | | | | | |
| Seeded | $3227^{b}_{Ba}$ | $2680^{b}_{Ca}$ | $790^{b}_{Ab}$ | $3035^{a}_{Ba}$ | $4017^{b}_{Ba}$ | $5716^{b}_{Ca}$ | 42 |
| Transplanted | $6198^{a}_{Ba}$ | $4994^{a}_{Cb}$ | $1522^{a}_{Ab}$ | $4260^{a}_{Ba}$ | $7720^{a}_{Ba}$ | $9254^{a}_{Ca}$ | 20 |
| P>α | <.01 | <.01 | <.01 | .12 | <.01 | .01 | |
| Indiangrass | | | | | | | |
| Seeded | $3205^{b}_{Ba}$ | $3441^{b}_{Ba}$ | $625^{b}_{Ab}$ | $4910^{a}_{Aa}$ | $3830^{b}_{Bb}$ | $8350^{b}_{Ba}$ | 118 |
| Transplanted | $6410^{a}_{Ba}$ | $6068^{a}_{Ba}$ | $1518^{a}_{Ab}$ | $5402^{a}_{Aa}$ | $7928^{a}_{Bb}$ | $11470^{a}_{Ba}$ | 45 |
| P>α | <.01 | <.01 | <.01 | .31 | .01 | .01 | |
| Switchgrass | | | | | | | |
| Seeded | $5408^{b}_{Aa}$ | $5355^{b}_{Aa}$ | $975^{b}_{Ab}$ | $4969^{a}_{Aa}$ | $6383^{b}_{Ab}$ | $10324^{b}_{Aa}$ | 61 |
| Transplanted | $8875^{a}_{Aa}$ | $7624^{a}_{Aa}$ | $1576^{a}_{Ab}$ | $5850^{a}_{Aa}$ | $10452^{a}_{Ab}$ | $13474^{a}_{Aa}$ | 29 |
| P>α | <.01 | .02 | <.01 | .08 | .01 | .01 | |

[†]Big bluestem (*Andropogon gerardii*), eastern gamagras (*Tripsacum dactyloides*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). [‡]The difference between Year1 and Year2 total yields as a percentage of the total in Year2. [¶]Means followed by the same letter, superscript for paired planting methods, or same subscript (uppercase for species, within a column and lowercase for paired year1&2, within a row), are not significantly different at α = .05. [§]Probability of mean difference between planting methods for the respective species.

There was also a significant difference in how the first and second harvest yields compared, within the first and second harvest year. During the first year, the yields were greater at the first- than the second harvest by a range of 75 to 88% while values for their counterparts during the second year were only ≤ 30%. In fact, for seeded GG and IG, yields were even greater at the second- than first harvest. These yield differences are attributable to changes in the proportions of weed biomass in the harvested material and crown expansion. While the first harvests in year1 included significant proportions of annual weed biomass, their proportions in the second harvest were negligible. The native grasses regrowth had a growing advantage over weeds and could exploit larger soil volumes for moisture and nutrients to quickly outcompete the weeds. Additionally, growth of perenials in the second year were from bigger crowns and started well before most weed seeds could even germinate and that minimized their proportions of the latter in the harvested biomass.

*3.4 Effects of Planting Methods on Ground Cover*

Treatment differences in stand establishment were also reflected in visual estimates of the proportions of ground covered by live or fallen dead vegetation parts. Table 2 summarizes results on means of ground cover values for the NWSGs, weeds, and litter, during the first year in production. Significant planting method × species interactions were detected and so results of mean comparisons, for the native grasses are discussed separately. Percentage ground cover by the NWSGs was greater in transplanted plots than their seeded counterparts (*P* < .01). While NWSGs cover for all transplants ranged from 58 to 93%, it is only seeded SG that had values within this range (Table 2). Other species show values of 42% (BB and IG), and 6 (GG). Again, except for SG, values for the proportions of ground covered by weeds were greater in seeded plots, ranging 51 - 94%. Weed cover values in transplanted plots were only about 30% for IG and < 10 for BB and GG. Among the seeded plots, values for ground cover by litter were ≤ 7% except for GG which had no litter, but the highest cover of weeds. Except for SG where litter cover was comparable for both planting methods (5%), the cover by litter was greater in all transplanted plots than their seeded counterparts in other species and values averaged 13%, significantly greater than in SG.

Table 2. Effects of species and planting method[†] on mean early-summer percentage ground cover by live vegetation and litter (visual estimates) for four native warm-season grasses[‡] during the first year in production, 2013

| Species/Method | Ground cover[‡‡] | | |
|---|---|---|---|
| | Native grass | Weeds | litter |
| Big Bluestem | -------------------------%----------------------- | | |
| Seeded | $40^{b}_{AB}$[§] | $57^{a}_{BC}$ | $3^{b}_{BC}$ |
| Transplanted | $81^{a}_{AB}$ | $7^{b}_{B}$ | $12^{a}_{AB}$ |
| *P* >Fα[#] | <.01 | <.01 | .05 |
| Gamagrass | | | |
| Seeded | $6^{b}_{C}$ | $94^{a}_{A}$ | $0^{b}_{C}$ |
| Transplanted | $77^{a}_{B}$ | $8^{b}_{B}$ | $15^{a}_{A}$ |
| *P* >Fα | <.01 | <.01 | .01 |
| Indiangrass | | | |
| Seeded | $43^{b}_{B}$ | $51^{a}_{B}$ | $6^{b}_{AB}$ |
| Transplanted | $58^{a}_{C}$ | $29^{b}_{A}$ | $13^{a}_{A}$ |
| *P* >Fα | <.01 | <.01 | 0.18 |
| Switchgrass | | | |
| Seeded | $66^{b}_{A}$ | $27^{a}_{C}$ | $7^{a}_{A}$ |
| Transplanted | $93^{a}_{A}$ | $2^{b}_{B}$ | $5^{b}_{B}$ |
| *P* >Fα | <.01 | <.01 | .04 |

[†]Six week-old seedlings, raised in a high tunnel, were transplanted by machine in June onto rain-soaked, disked fine seedbeds with seeds of the same species being drilled at 1-2 cm depth in matching plots later in the summer. [‡] Big bluestem (*Andropogon gerardii*), eastern gamagras (*Tripsacum dactyloides*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). [‡‡]Proportions of ground covered by a vertical projection of plant parts of the native grass, all other live plants (weeds), or dead fallen plant material. [§]Within a column means followed by the same letter, superscript for species or subscript for planting method, do not differ significantly at α =.05. [#]Probability of mean difference between planting methods by species.

The observed superiority of the transplanted plots over the seeded ones in native grass cover was indicative of a greater population of fast growing tillers that outcompeted the weeds. Thus the anticipated growth advantage that transplants would have over weeds was actually achieved and that resulted in their dominance during the recovery, similar to earlier findings (Borman et al., 1991). The results also indicate that the transplanted stands were better prepared for recovery spring-growth with greater numbers of dormant tillers and energy reserves in their crowns. This demonstrated better performance of the transplanted stands compared to their seeded counterparts is also partly attributable to their age differences since the transplants were at least 6 weeks old at planting and it took over a month for the control plots to be seeded. There was no attempt to eliminate this age difference since fall planting is actually a common practice to avoid severe weed competition. Similar reports on better performance of transplanted native grass stands than their seeded counterparts also exist (Brown & Johnston, 1976). Having greater proportions of litter in the transplanted plots was actually consistent with their exhibited robust growth that resulted with relatively more forage yields (Table 1) and senescent leaves as indicated by litter cover (Table 2).

### *3.5 Effects of Species and Planting Method on Basal Diameters*

When subsequent stand recovery growth from the preceding harvest regimes were compared based on early-spring basal diameters, differences due to planting method and species were detected (Table 3). Basal diameters in the transplanted plots exceeded their seeded counterparts by up to 8 cm for GG plots and about 4 cm for the other species. Among the transplanted NWSG stands, mean basal diameter was greater for GG (19 cm) than any other species (*P* < .01), the least being 13 cm for BB, but with no difference between IG and SG. In the seeded plots, values were still the least for BB (9 cm), but not statistically different from GG (11) and all other differences were only numeric (*P* > .05). Specific differences in basal diameter could result from variable competitive abilities of the native grass species against the already established weeds similar to earlier observations (Schmidt et al., 2008). While the current data still indicate that transplanting may be a better establishment method to direct seeding for the NWSGs, results further showed that upon successful establishment, GG will produce a thicker stand relatively sooner while BB may suffer weed competition longer.

Table 3. Effects of species and planting method[†] on early-spring basal diameters and early-summer ground cover of native warm-season grasses[‡] in pure stands during the second year in production, 2014

| Method | Big Bluestem | Gamagrass | Indiangrass | Switchgrass | *P* >Fα[‡‡] |
|---|---|---|---|---|---|
| | Basal diameter[§] | | | | |
| | ------------------------------ cm ---------------------------- | | | | |
| Seeded | 9bB[¶] | 11bAB | 12bA | 13bA | .01 |
| Transplanted | 13aC | 19aA | 17aB | 16aB | <.01 |
| *P* >Fα | <.01 | 0.01 | .02 | <.01 | |
| | Ground cover[#] | | | | |
| | ------------------------------% ---------------------------- | | | | |
| Seeded | 49bB | 23bC | 46bB | 64bA | <.01 |
| Transplanted | 93aA | 92aA | 77aB | 96aA | <.01 |
| *P* >Fα | <.01 | <.01 | <.01 | <.01 | |

[†]Six week-old seedlings raised in a high tunnel, were transplanted by machine, in June, onto rain-soaked, pre-tilled and leveled fine seedbeds and seeds of the same species drilled at 1-2 cm depth in earmarked matching plots later in the summer. [‡]Big bluestem (*Andropogon gerardii*), eastern gamagras (*Tripsacum dactyloides*), indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). [‡‡]Probability of difference between means of planting methods, within species. [¶]Means of paired planting methods followed by the same letter lowercase letter, within column, or those of species followed by the same uppercase letter, within row, are not significantly different at α = .05. [§]Average of six diameters of the sprouting native warm-season grass crowns along a perpendicular transect across rows. [#] Late-May visual estimates of the proportion of land surface covered by the vertical projection above ground plant parts of the native warm-season grasses.

### *3.6 Effects of Species and Planting Method on Ground Cover*

During 2014, the second year in production, visual estimates of early-summer percentage ground cover also showed the effects of planting method and species. In ground cover, the transplanted plots outnumbered their seeded counterparts by 30-60 units (Table 3). The fact that the transplanted stands sustained superiority over their seeded counterparts suggests that the growth advantage they had at planting was sustained into the second year. This difference in performance was partly more attributable to inability of the seeded stands to suppress the already established annual weed populations. Thus the annual weeds retained their competitive advantage over resources, which may have impacted the rate at which the seeded bunches expanded. Faster establishment of transplanted grasses over their seeded counterparts have also been reported (Hauser, 1983). In the current study, however, mean differences in the transplanted plots were only significant between IG (77) and all others, which nearly averaged 94 ($P < .01$). Among the seeded plots, percentage ground cover was greater for SG (64) than any other species and was the least for GG (23). Comparable percent cover was exhibited by BB and IG whose values averaged at 47% (Table 3).

## 4. Conclusions

The observed narrower differences between the first and second year forage yields from transplanted plots demonstrate the reliability of seedling transplants in achieving enhanced establishment of NWSG stands in less than two years. The results also show that, under similar growing conditions, the forage productivity for transplanted SG stands may not remain superior over their seeded counterparts beyond three growing cycles. The demonstrated greater weed suppression in the transplanted NWSG stands compared to their seeded counterparts has implications on costs for weed control and forage quality attributes associated with the proportions of undesirable species in pastures. For the studied NWSGs, transplanting has shown ability to alter species rankings in relative growth response of their newly established stands to defoliation. There is a need to establish whether the demonstrated ability of transplanted NWSG stands to suppress weeds could be sustained if fertilizers were applied. There is also a need to establish how transplanting may affect species performance during establishment of mixed NWSG stands.

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## References

Anderson, E. W. (1986). A guide for estimating cover. *Rangelands*, 236-238.

Angima, S. D., Kallenbach, R. L., & Riggs, W. W. (2009). Optimizing hay yield under lower nitrogen rates for selected warm-season forages. *J Integr Biosci, 7*, 1-6.

Borman, M. M., Krueger, W. C., & Johnson, D. E. (1991). Effects of Established Perennial Grasses on Yields of Associated Annual Weeds. *J. Range Manage, 44*(4), 318-322. http://doi.org/10.2307/4002390

Briske, D. D., & Richards, J. H. (1995). Plant responses to defoliation: a physiological, morphological and demographic evaluation. *Wildland plants: physiological ecology and developmental morphology. Society for Range Management, Denver, CO*, (pp. 635-710).

Brown, R. W., & Johnston, R. S. (1976). *Revegetation of an alpine mine disturbance: Beartooth Plateau, Montana* (Vol. 206). Intermountain Forest & Range Experiment Station.

Cornelius, D. R. (1946). Establishment of Some True Prairie Species Following Reseeding. *Ecology, 27*(1), 1-12. http://doi.org/10.2307/1931012

Ernst Conservation Seeds, Inc. (n.d.). Native Warm-season Grasses for High Quality Biomass Forage, Including Livestock Bedding & Mushroom Compost. Retrieved from http://www.ernstseed.com/files/documents/native_warm.pdf

Fike, J. H., Parrish, D. J., Wolf, D. D., Balasko, J. A., Green, J. T., Rasnake, M., & Reynolds, J. H. (2006). Long-term yield potential for switchgrass for biofuel systems. *Biomass Bioenergy, 30*, 198-206. http://doi.org/10.1016/j.biombioe.2005.10.006

Goedhart, J., & Warners, D. (2006). Assessment of prairie pot transplants as a restoration tool. Piece Cedar Creek Institute Biology Dept, Calvin College Grand Rapids, Michigan. Retrieved from http://www.cedarcreekinstitute.org/sites/default/files/Calvin%20 %20Jennifer%20Goedhart%20and%20David%20Warners.pdf

Harper, C. A., & Moorman, C. E. (2006, October). Qualifying native warm-season grasses and early succession habitat. In *11th Triennial National Wildlife & Fisheries Extension Specialists Conference (2006)* (p. 10).

Hauser, V. L. (1983). Grass establishment by bandoleer transplants, and germinated seeds. American Society of Agricultural and Biological Engineers. *ASAE, 26*(1), 0074-0078.

Huang, B. (2000). Role of root morphological and physiological characteristics in drought resistance of plants (pp. 39-64). In R. Wilkinson (ed.) *Plant-environment interactions*. Marcel Dekker, Inc. New York, NY. http://dx.doi.org/10.1201/9780824746568.ch2

Jones, J., Coggin, D. S., Cummins, J. L., & Hill, J. (2007). *Restoring and Managing Native Prairies*. A Handbook for Mississippi Landowners. Wildlife Mississippi. Starkville, MS.

Jung, G. A., Griffin, J. L., Kocher, R. E., Shaffer, J. A., & Gross, C. F. (1985). Performance of switchgrass and bluestem cultivars mixed with cool-season species. *Agron. J., 77*, 846-850. http://dx.doi.org/10.2134/agronj1985.00021962007700060005x

Kiss, Z., Fieldsend, A. F., & Wolf, D. D. (2007). Yield of switchgrass (*Panicum virgatum* L.) as influenced by cutting management. *Acta Agron. Hungar., 55*, 227-233. http://dx.doi.org/10.1556/AAgr.55.2007.2.10

Lusk, J. J., Smith, S. G., Fuhlendorf, S. D., & Guthery, F. S. (2006). Factors Influencing Northern Bobwhite Nest-Site Selection and Fate. *Journal of Wildlife Management, 70*, 564-571. http://dx.doi.org/10.2193/0022-541X(2006)70[564:FINBNS]2.0.CO;2

Muir, J. P., Pitman, W. D., & Foster, J. L. (2011). Sustainable, low-input, warm-season, grass-legume grassland mixtures: mission (nearly) impossible?. *J. Grass and Forage Sci., 66*, 301-315. http://dx.doi.org/10.1111/j.1365-2494.2011.00806.x

Mulkey, V. R., Owens, V. N., & Lee, D. K. (2008). Management of warm-season grass mixtures for biomass production in South Dakota USA. *Bioresource Technology, 99*, 609-617. http://dx.doi.org/10.1016/j.biortech.2006.12.035

Page, H. N., & Bork, E. W. (2005). Effect of planting season, bunchgrass species, and neighbor control on the success of transplants for grassland restoration. *Restoration Ecology, 13*(4), 651-658. http://dx.doi.org/10.1111/j.1526-100X.2005.00083.x

Propheter, J. L., Staggenborg, S. A., Wu, X., & Wang, D. (2010). Performance of annual and perennial biofuel crops: yield during the first two years. *Agron. J, 102*(2), 806-814. http://dx.doi.org/10.2134/agronj2009.0301

Richards, J. H., Mueller, R. J., & Mott, J. J. (1988). Tillering in tussock grasses in relation to defoliation and apical bud removal. *Annals of Botany, 62*(2), 173-179.

Schmidt, C. D., Hickman, K. R., Channell, R., Harmoney, K., & Stark, W. (2008). Competitive abilities of native grasses and non-native (Bothriochloa spp.) grasses. *Plant Ecology, 197*(1), 69-80. http://dx.doi.org/10.1007/s11258-007-9361-2

Satellite, N. O. A. A. (2013). Information Service. National Climatic Data Center. *US Dept of Commerce*.

Sykes, A. R. (1994). Parasitism and production in farm animals. *Anim. Prod., 59*, 155-172. http://dx.doi.org/10.1017/S0003356100007649

Temu, V. W., Baldwin, B. S., Reddy, K. R., & Riffell, S. K. (2015). Harvesting Effects on Species Composition and Distribution of Cover Attributes in Mixed Native Warm-Season Grass Stands. *Environments, 2*(2), 167-185. http://dx.doi.org/10.3390/environments2020167

Temu, V. W., Baldwin, B. S., Reddy, K. R., Riffell, S. K., & Burger, L. W. (2014b). Wildlife habitat quality (sward structure and ground cover) response of mixed native warm-season grasses to harvesting. *Environments, 1*(1), 75-91. http://dx.doi.org/10.3390/environments1010075

Temu, V. W., Rude, B. J., & Baldwin, B. S. (2014a). Yield response of native warm-season forage grasses to harvest intervals and durations in mixed stands. *Agron., 4*, 90-107. http://dx.doi.org/10.3390/agronomy4010090

Tomlinson, K. W., & O'connor, T. G. (2004). Control of tiller recruitment in bunchgrasses: uniting physiology and ecology. *Functional Ecology, 18*(4), 489-496.

Vogel, K. P. (2000). Improving warm-season forage grasses using selection, breeding, and biotechnology. *Native warm-season grasses: research trends and issues*, (nativewarmseaso), 83-106. http://dx.doi.org/10.1111/j.0269-8463.2004.00873.x

White, B., Graham, P., & Pierce, R. A. II. (2005). Missouri Bobwhite Quail. Habitat Appraisal Guide: Assessing your farm's potential for bobwhites featuring a revised habitat appraisal tool (pp. 13-14). University of Missouri Extension MP902.