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Effects of Planting Method and Seeding Rate on Forage Production and Nutritive Value of Annual Ryegrass

Abstract

Annual ryegrass (*Lolium multiflorum* L.) is an important annual cool-season grass to the cow-calf and stocker cattle industry in the southern USA. It is hypothesized that the annual ryegrass establishment method and seeding rate could impact forage production. In a two-year study, two strategies were implemented to determine annual ryegrass establishment and forage production. The study was conducted at Mississippi State University across two growing seasons [Season 1 (2016/2017) and Season 2 (2017/2018)] in a randomized complete block design in a split-plot arrangement. The main plots consisted of two planting methods (broadcast and drill) in a prepared seed bed and the sub-plots were six seeding rates [20, 25, 30, 35, 40, and 50 lb pure live seed (PLS) per acre (ac^{-1})]. The study was harvested twice in Season 1 and four times in Season 2. Data collected included biomass production, leaf area index (LAI), and forage nutritive value. Biomass production was not affected by planting methods or seeding rates. Mean harvest biomass decreased when LAI was greater than 3.5. Crude protein (CP), acid detergent fiber (ADF), and neutral detergent fiber (NDF) were mainly affected by harvest dates across seasons. Partial economic analysis indicated that an increase in seed rate increased the cost of annual ryegrass per ton of dry matter. Data suggests that seeding rates between 20 and 30 lb PLS ac^{-1} were sufficient to sustain annual ryegrass productivity during the growing season while being economically viable.

Keywords: annual ryegrass, seeding rate, establishment, biomass, nutritive value.

Abbreviations: PLS = pure live seed; N = nitrogen; S1 = season 1 (2016/2017); S2 = season 2 (2017/2018); DM = dry matter; LAI = leaf area index; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; IVTDMD = *in vitro* dry matter digestibility; WSC = water-soluble carbohydrates; LSD = least significant difference.

Introduction

Production of annual ryegrass (*Lolium multiflorum* L.) is an important part of winter grazing and reducing hay supplementation in the southern USA. Annual ryegrass is usually established in a prepared seed bed or overseeded in perennial warm-season pastures such as bahiagrass (*Paspalum notatum* Flueggé) and bermudagrass (*Cynodon dactylon* L.) by using a drill or broadcasting the seed. Several performance characteristics such as rapid establishment, weed suppression, response to nitrogen fertilization, high biomass production, excellent nutritive value and palatability, long growing season, tolerance to a wide range of soil types, and persistence under close grazing make annual ryegrass the desirable cool-season forage among livestock producers (Jung et al., 1996; Nelson et al., 1991).

In Mississippi, annual ryegrass can produce an average of 5,629 pounds (lb) of dry matter (DM) per acre (ac^{-1}) (Lemus, 2018). Methods of the establishment of annual ryegrass and seeding rates could affect annual forage production in the southern USA. Chastain et al. (2017) studied the effects of tillage and establishment systems on “Gulf’ annual ryegrass seed production using six different systems. The systems included:

(1) continuous conventional tillage (CT),
(2) continuous no-till (NT),
(3) NT/CT cycle alternate year tillage (NT/CT),
(4) volunteer/CT cycle alternate year tillage (Vol/CT),
(5) burn and NT/CT cycle alternate year tillage (Burn +NT/CT), and
(5) volunteer/NT/CT cycle with tillage every third year (Vol/NT/CT).

They indicated that increasing tillage frequency from zero in NT to once every other year in NT/CT boosted yields that were equivalent to CT. Vendramini et al. (2012) reported that annual ryegrass planted in a prepared seedbed along with a glyphosate application produced greater biomass than annual ryegrass (‘Prine’) broadcast seeded in glyphosate-treated bahiagrass stands. Evers (2012) indicated that disking before drilling or broadcasting annual ryegrass (‘TAM 90’), was the most productive method on a ‘Coastal’ bermudagrass hay meadow.

The potential advantage of seeding annual ryegrass in the autumn is earlier germination which allows for the utilization of moisture during the winter months and plant development under cooler air temperatures. Traditional seeding rates for annual ryegrass can range from 20 (Chambliss, 1999) to 25 lb pure live seed (PLS) ac^{-1} (Bryn et al., 1991). Evers (2012) reported that first-harvest yields were achieved with broadcasting than drilling when seeding rates were increased above 25 lb PLS ac^{-1} due to increase seed-to-soil contact and less competition with residue at germination. Although increasing seeding rates to 50 to 100 lb PLS ac^{-1} can increase early season forage production (Bryn et al., 1991; Chambliss, 1999); however, the cost of livestock gain for season production might not be economically sustainable seeding rates above 25 lb PLS ac^{-1}.

A common practice has been to recommend higher seeding rates of ryegrass when broadcasting when compared to drilling under the assumption that a lower percentage of seeds will germinate when exposed to less favorable climatic conditions and predators (e.g. birds; Evers, 2012). It is hypothesized that the annual ryegrass establishment method and seeding rate impact forage production. The objective of this study was to evaluate annual ryegrass production and nutritive value using different methods of annual ryegrass establishment and seeding rates.

Materials and Methods

The study was conducted at the Henry H. Leveck Animal Research Farm at Mississippi State University in a Marietta fine sandy loam (fine-loamy, siliceous, active, thermic Fluvaquenti Eutrudepts) during 2016-2017 (Season 1) and 2017-2018 (Season 2) annual ryegrass growing season (fall-spring). The experimental design was a randomized complete block in a split-plot arrangement replicated three times. The main plot was two planting methods (broadcast and drill) in a conventional prepared seed bed. The subplots were six seeding rates of 'Marshall' annual ryegrass established at 20, 25, 30, 35, 40, and 50 lb PLS ac^{-1}. Plots were 6 ft x 10 ft and fertilized with 100 lb N ac^{-1} in split applications using urea ammonium sulfate (33-0-0-18S). The first N application was applied when plants reached a height of two inches after emergence and the second application of 50 lb N ac^{-1} was applied after the first harvest. Phosphorus (P) and potassium (K) were applied based on soil test recommendations. The study was established on November 20, 2016, and October 20, 2017. The 2016 planting was delayed due to drought conditions. Therefore, there were two harvests in 2017 (March 22 and April 18) and four harvests in 2018 (January 31, March 23, April 13, and May 7).

Before each harvest, leaf area index (LAI) was measured using a line quantum sensor (LI-2000; Li-Cor, Lincoln, NE). The plots were then harvested to a three-inch stubble with a self-propel Cub Cadet mower equipped with a bagging system when 50% of the plots reached 12 to 15 inches tall (vegetative to early boot stage). Plot was biomass was weighed and a forage subsample sample was dried at 140 °F in a forced-air oven for 72 h for dry matter biomass determination. Forage subsample was ground to pass through a 1-mm screen using a Wiley mill (Thomas Scientific, Swedesboro, NJ) for nutritive analysis. Samples were analyzed for crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in vitro* dry matter digestibility at 48h (IVTDMD), and water-soluble carbohydrates (WSC) using a Foss DS2500 near infra-red reflectance spectroscopy (NIRS) instrument (Foss North America, Eden Prairie, MN). The analysis was conducted using the 2018 grass hay equation developed by the NIRS Forage and Feed Testing Consortium (Berea, KY).

Data were analyzed using harvest frequency as a repeated measure for each of the dependent variables. Data were further analyzed in the PROC GLIMMIX of SAS and the least significant difference was used to determine treatment differences at $\alpha = 0.05$. A correlational analysis was conducted between mean harvest biomass and LAI using PROC CORR in SAS.

Results and Discussion

Weather conditions

Total precipitation was 20% and 5% lower during Seasons 1 (S1) and 2 (S2), respectively (Table 1). During S1, a drought extended from August to October causing a delay in planting the study. Monthly precipitation was below the 30-yr normal for most of S1 (NOAA, 2022). Monthly precipitation was 43% above normal during the planting in S2 and then declined by 50 and 80% in November and December, respectively, during early annual ryegrass growth. March of S2 experienced higher precipitation with 95% above normal. The mean growing season temperature stayed slightly above normal for S1 and S2. The monthly temperature stayed above normal from October to April for S1. Although S2 followed a similar trend, January and April experienced cooler temperatures than normal. Since growing degree days (GDD) are related to temperature, a similar pattern of increase in GDD was observed for S1 and S2.

Biomass production

No differences in mean harvest biomass were observed in S1 across establishment or seeding rate. On the other hand, during S2, there was a planting method by harvest interaction ($P = 0.0008$). Drilling the annual ryegrass provided a 20% yield increase during the first harvest, while the yield benefits of broadcasting the seed were not observed until the second and third harvests (Figure 4). Broadcasting the seed provided a 5% and 20% yield advantage over drilling during the second and third harvest of S2.

Seasonal biomass production was significantly different among years ($P < 0.001$). Season 2 growing season had a 72% greater biomass (2,355 vs. 4,059 lb DM ac^{-1}) production compared to Season 1. Lower yields in Season 1 could be related to drought conditions from August to October of 2016 (Table 1) that delayed planting and establishment of annual ryegrass. This also delayed harvest intervals in the spring of 2017. No significant differences were observed among the planting methods (broadcast and drill, Figure 2) in a conventional prepared seed bed or the seeding rates (Figure 1). However, this might not be the case when using these methods in a perennial warm-season sod where the annual ryegrass stands can be increased by increasing seeding rates (Evers, 2012). Evers et al. (1993) indicated that broadcasting annual ryegrass seed provided a more uniform distribution of seed which delayed competition among annual ryegrass seedlings which does not occur when planting with a row with a drill.

This current study indicates that there is no advantage to seeding rates above 25 lb ac^{-1}. The seed cost in 2016 was \$0.55 lb^{-1} and \$0.66 lb^{-1} in 2017, respectively. A partial comparative analysis in seed cost alone indicates a loss of \$10.24 in Season 1 and \$11.40 in Season 2 per ton of dry matter produced at 50 lb PLS ac^{-1} seeding rate compared to the recommended 25 lb PLS ac^{-1} since there was no yield advantage (Figure 3).

Table 1. Weather conditions (precipitation, temperature, and growing degree days) during two annual ryegrass growing seasons at Starkville, MS along with the 30-year normal for each parameter (NOAA, 2023).

	Month								
	------------------------------- *Precipitation (in)* --------------------------------								
Season	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Total/Mean**
2016/2017	0.04	3.45	4.61	5.30	3.41	4.72	4.24	6.07	31.8
2017/2018	4.85	2.19	1.13	5.47	2.03	10.33	5.61	5.93	37.5
30-yr	3.40	4.61	5.50	5.21	5.90	5.31	5.38	4.30	39.6
	------------------------------ *Temperature (°F)* -------------------------------								
2016/2017	70.0	57.7	48.0	51.9	54.2	58.0	67.1	69.9	59.6
2017/2018	66.0	55.0	46.3	38.0	54.0	55.3	58.2	76.2	56.1
30-yr	63.5	53.0	45.7	43.2	46.6	54.9	62.6	71.1	55.1
	------------------------------------- *GDD** ---------------------------------------								
2016/2017	626	264	112	13	108	289	434	631	2477
2017/2018	512	200	89	210	167	313	523	604	2618
30-yr	433	162	71	53	73	230	396	659	2077

*Growing degree days (GDD) base 50.

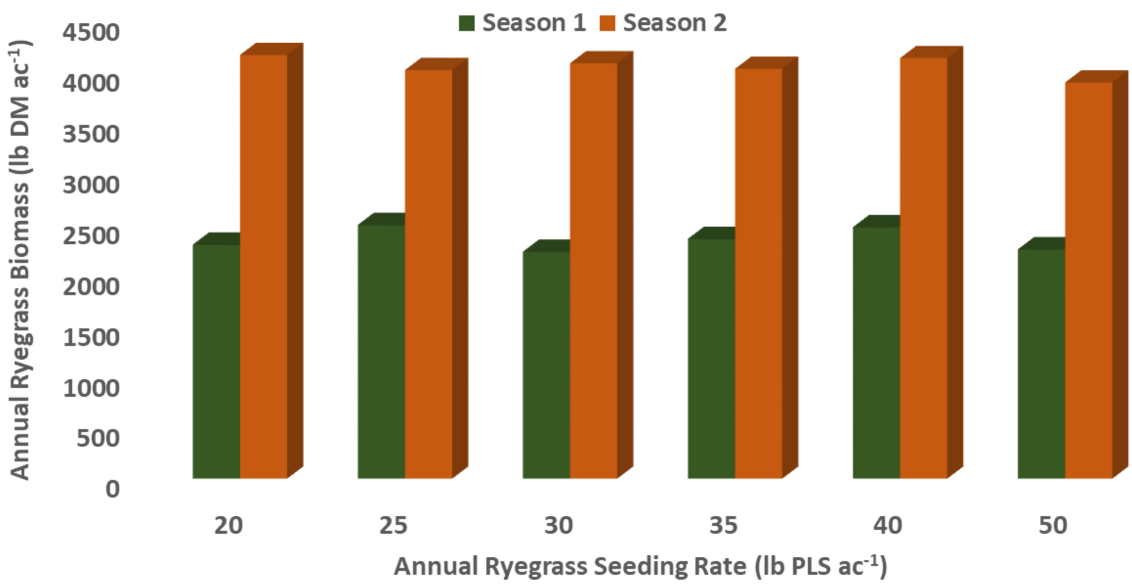

Figure 1. Seasonal biomass distribution for annual ryegrass established at six different seeding rates across two seasons in Starkville, MS. PLS = pure live seed. DM = dry matter.

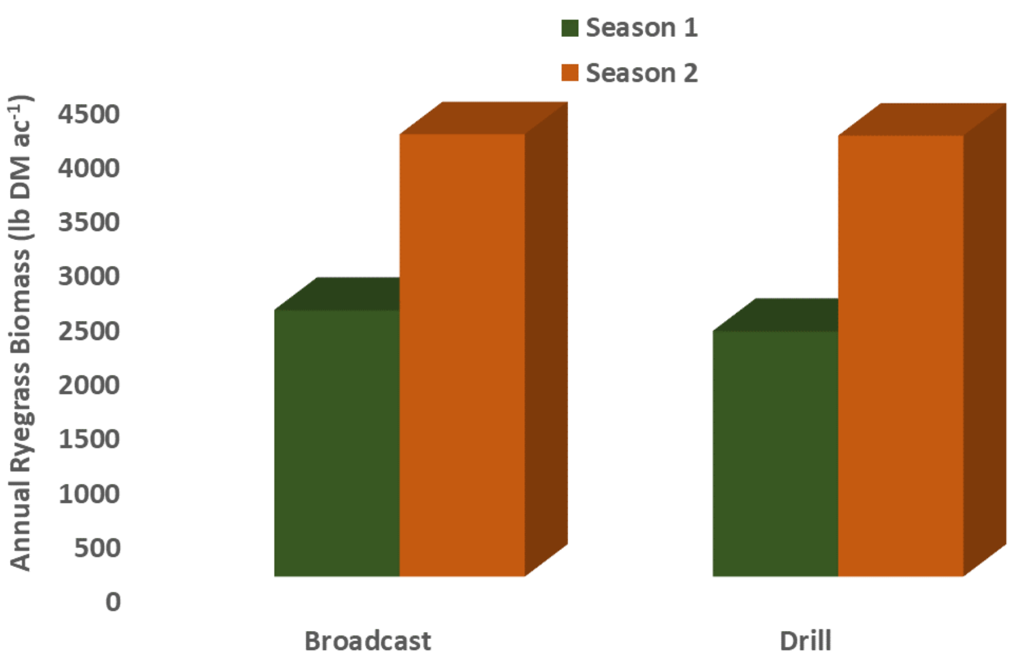

Figure 2. Seasonal biomass production of annual ryegrass across two establishment methods in Starkville, MS. DM =dry matter.

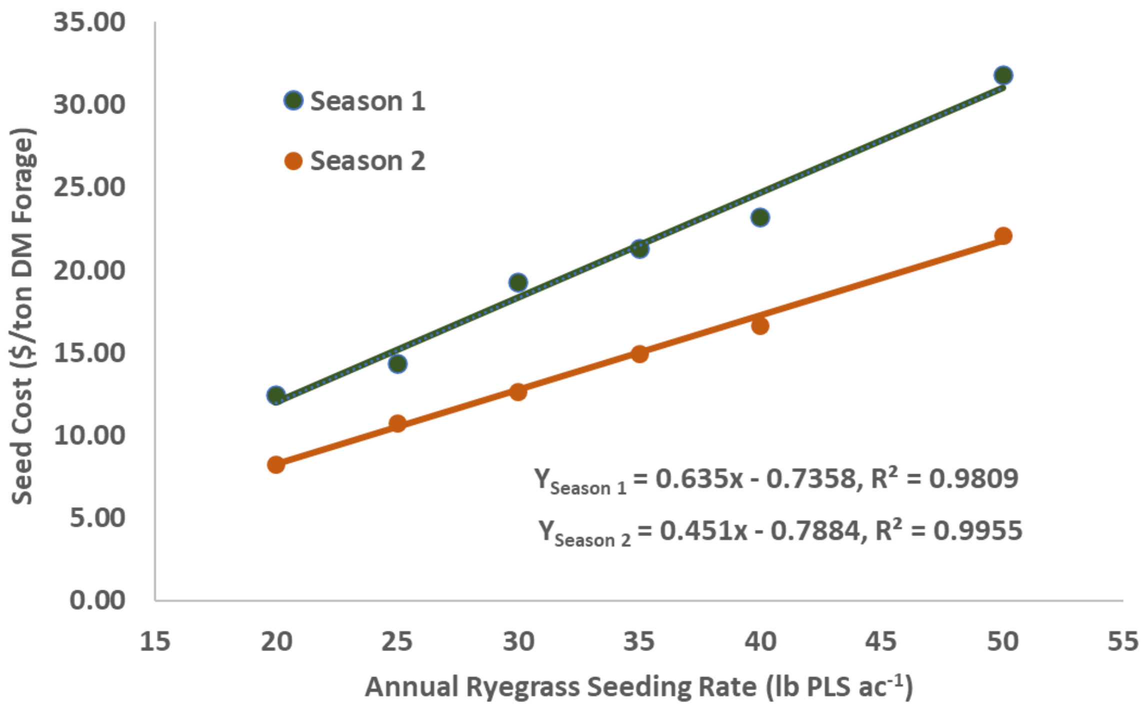

Figure 3. Partial seed cost per ton of annual ryegrass biomass production across six seeding rates in Starkville, MS. Cost was estimated based on the seed cost across two growing seasons. PLS = pure live seed. DM = dry matter.

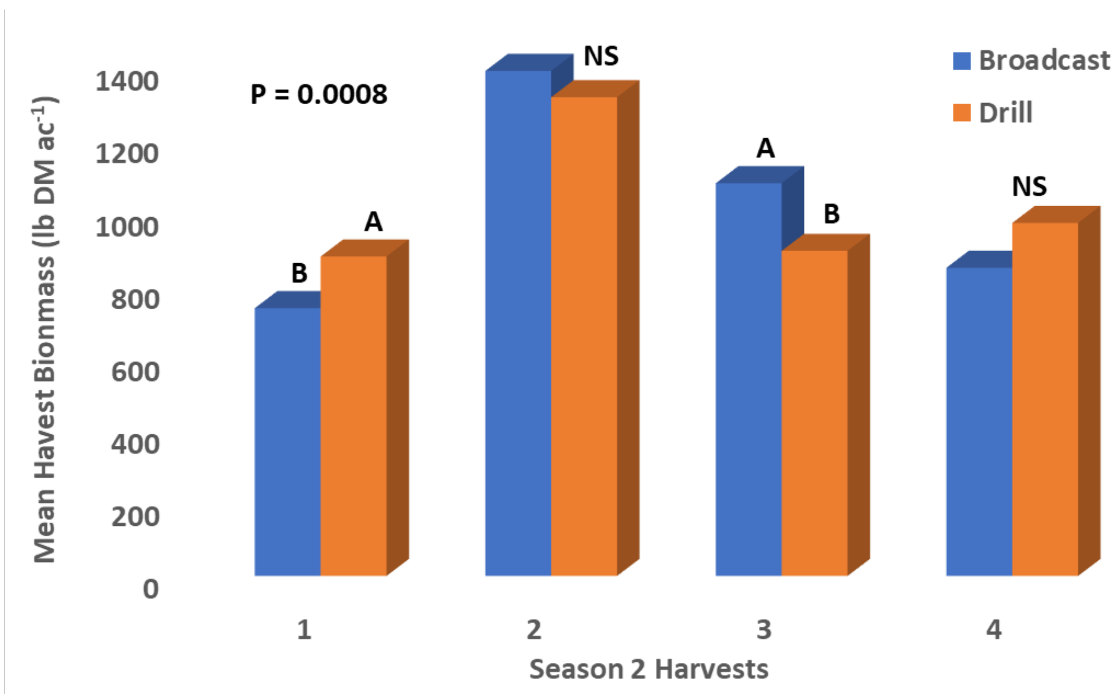

Figure 4. Influence of planting method and harvest date on mean harvest dry matter (DM) biomass (P = 0.008) at Starkville, MS during the 2017/2018 (S2) growing season. Letters are for mean comparison within a harvest date. DM, dry matter.

Leaf area index (LAI)

During Season 1, LAI was significantly affected by the planting method (P =0.0034) and harvest date (P = 0.0014). The first harvest of S1 had a 17% greater LAI than the second harvest. This could be related to maturity and a decline in leaf:stem ratio towards the end of the growing season. The plots that were broadcasted also had a 17% increase in LAI compared to those that were drilled. In S2, there was an establishment by harvest interaction (P = 0.0001; Figure 5). There was a decline in LAI with harvest as the season progressed, and broadcasting the seed had a 10% increase in LAI compared to drilling. We speculate that these differences in planting methods could be related to reduced interrow competition created by the drill. A relationship between LAI and mean harvest biomass across two seasons indicated that an LAI of 3.5 had a peak biomass production (Figure 6). A phenotypic variation in leaf area between diploid and tetraploid might yield differences due to tiller numbers since tetraploids do not tiller as aggressively as diploids and form a naturally sparse stand that could provide justification for higher seeding rates (Olson et al., 2021).

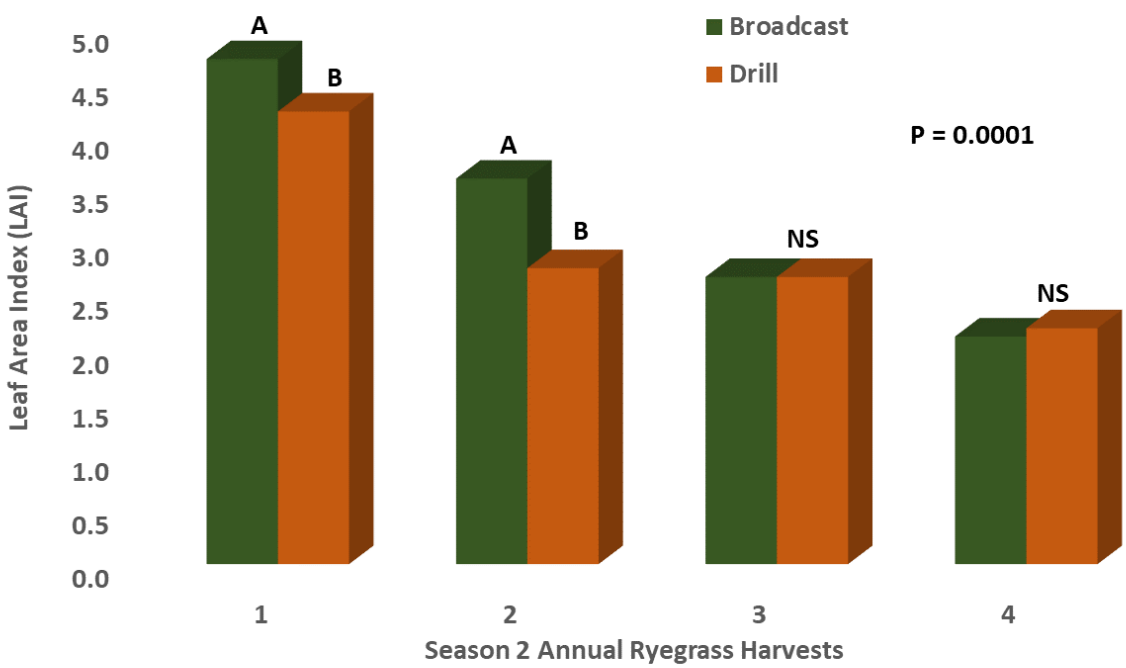

Figure 5. Influence of planting method on leaf area index (LAI; P= 0.001) of annual ryegrass at Starkville, MS during the 2017/2018 growing season (S2). Letters are for mean comparison of planting methods within a harvest date.

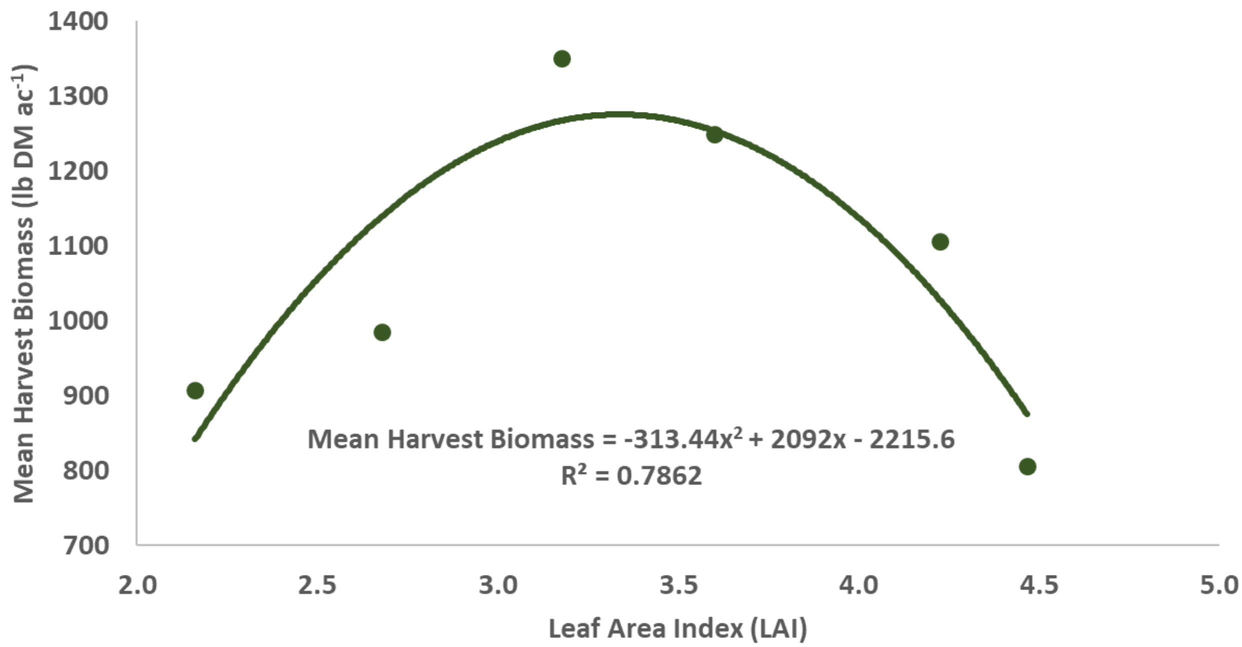

Figure 6. Relationship between mean harvest biomass and leaf area index (LAI) across seven harvests for two annual ryegrass seasons in Starkville, MS. DM = dry matter.

Nutritive value

Nutritive value parameters were mainly influenced by harvest date, rather than planting method and seeding rates during S1 and S2 (Table 2). There was a decline in CP as the season progressed which was related to a decrease in leaf:stem ratio creating an increase in fiber concentration and a decrease in digestibility (IVTDMD). During S2, there was a sharp decline in CP due to excessive rain in March (Table 1) which limited nutrient uptake, utilization, and efficiency due to resulting in losses (Guo and Chen, 2022). There was a fluctuation in WSC concentrations during S2 that could have been created by energy allocation to growth (Jensen et al., 2014). There was a significant effect of the planting method on CP ($P = 0.0009$) and WSC ($P < 0.0001$) during S1 where broadcasting the seed had a 10% increase in CP and a 92% increase in WSC compared to drilling, respectively.

Table 2. Influence of harvest date on crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro dry matter digestibility (IVTDMD), and water-soluble carbohydrates (WSC) of annual ryegrass at Starkville, MS. Letters are for comparison of a nutritive value parameter within a season and among harvests.

			Nutritive Value Parameter			
Season	**Harvest**	**CP**	**ADF**	**NDF**	**IVTDMD**	**WSC**
		------------------------- *% Dry Matter (DM)* -------------------------				
1	1	19.1a	19.5b	38.1b	92.6a	12.7
	2	11.9b	26.5a	48.5a	87.2b	13.2
	P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	NS*
2	1	22.0a	24.1d	44.5c	86.1b	6.6c
	2	8.6d	26.7b	38.6d	84.5c	16.4a
	3	14.0b	32.1a	49.5a	82.9d	7.9c
	4	12.4c	25.1c	47.1b	87.1a	12.7b
	P-value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

*No significant difference.

Conclusions

Although there were no differences in seeding rates, the seeding rates in this study did not account for seed size. Recent research has shown wide variation in PLS density of annual ryegrass varieties when planted at a constant seed weight per unit area (Venuto *et al.*, 2002). Diploid cultivars typically produce smaller seeds than traditional tetraploid cultivars and a seed lot for a specific cultivar can change from one year to another depending on environmental conditions during annual ryegrass seed filling and maturation. The cultivar used in this study (Marshall) has a great grazing and cold tolerance and provides consistent forage production compared to other cultivars (Lemus, 2018). This research also demonstrated that the effect of planting annual ryegrass above 20 to 30 lb PLS ac^{-1} did not have subsequent overall yield and could have an economically negative effect in cost of establishment and subsequently in cost of grazing. This range of seeding rates depending on the establishment method could affect early grazing potential while high seeding rates could create competition for resources and reduce tiller development and subsequently reduce biomass production. Although having tillage can reduce competition from weeds and summer grasses residue, the use of a drill did not increase ryegrass production compared to broadcasting. This means that establishment method could be affected by the amount of residue at the soil surface, soil type, date of planting, and moisture availability. Further studies are needed to compare both early and late diploid and tetraploid cultivars under different seeding rates, establishment methods, and fertility regimes.

Conflict of Interest

The author declares that there is no conflict of interest.

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