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Seasonal Mass, Performance under Grazing, and Animal Preference for Irrigated Winter Cereal Forages under Continuous Stocking in a Semiarid, Subtropical Region

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Abstract: Winter annual cereal forages perform well in semiarid, subtropical regions forming, a significant component of livestock operations for autumn through spring stocker cattle (*Bos taurus*) backgrounding in either grazeout or graze-grain systems; however, little information is available about their relative seasonal productivity and animal preference. Seasonal growth and regrowth under grazing and grazing preference of oat (*Avena sativa*), rye (*Secale cereale*), triticale (×*Triticosecale rimpaui* Wittm.), and wheat (*Triticum aestivum*) were compared over two years at New Mexico State University's Rex E. Kirksey Agricultural Science Center at Tucumcari. Seasonlong (Nov–Apr) average forage dry matter yield was rye > oat > wheat > triticale (5.03, 4.44, 3.58, and 2.79 Mg ha^{-1}, respectively; $p < 0.0001$). Rye also had greater average monthly growth than the other cereals, among which there was no difference (1.58, 1.05, 0.96, and 0.85 Mg ha^{-1} mo^{-1} for rye, oat, wheat, and triticale, respectively; $p < 0.0331$). Growth of ungrazed cereals was reduced in mid-winter and regrowth of grazed forage did not equal removal by growing cattle. When given a preference and allowed to deplete available forage, growing cattle preferred oat followed by rye, then wheat and triticale. Regrowth of grazed forage did not differ among cereals.

Keywords: grazing preference; oat; rye; triticale; wheat; winter cereal forages

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1. Introduction

The demand for available forage for livestock production is increasing in semiarid, subtropical regions [1], including the US Southern Great Plains (SGP) and Southern High Plains (SHP) [2,3]. The SGP and SHP are characterized by limited and erratic precipitation and high summer temperatures, as well as early autumn freezes [4], typical of semiarid, subtropical regions. When environmental conditions limit production of perennial forage crops, annual species can be effectively used [5]. Winter annual cereal forages perform well in semiarid, subtropical regions [6,7] where they form a significant component of livestock operations for autumn through spring backgrounding of stocker cattle (*Bos taurus*) in either grazeout or graze-grain systems [8–10], which fits well with spring through autumn grazing of perennial cool-season pastures [11] and annual and perennial warm-season pastures [12–14]. Currently used winter cereals for pasture include oat (*Avena sativa*) [8], rye (*Secale cereale*) [3], triticale [×*Triticosecale* Wittm. ex A. Camus (*Secale* × *Triticum*)] [8,15], and wheat (*Triticum aestivum*) [3,8,9].

The literature is scant for information comparing the seasonal productivity of winter cereal forages under grazing, particularly in the SGP and SHP, however, such information is needed to assist cattle growers in deciding which species to use. Hence, the objective of this research was to compare seasonal productivity of the currently used winter cereals with and without grazing in a subtropical, semiarid region, as well as animal preference among the cereals.

2. Materials and Methods

Two identical studies were conducted over two years at the New Mexico State University Rex E. Kirksey Agricultural Science Center at Tucumcari, NM, USA (35°12′0.5″ N, 103°41′12.0″ W; elev. 1247 masl). The soils were Canez (Fine-loamy, mixed, thermic Ustollic Haplargid), Quay (Fine-silty, mixed, superactive, thermic Ustic Haplocalcids), and Redona (Fine-loamy, mixed, superactive, thermic Ustic Calciargids) fine sandy loams. The test area had been in permanent perennial cool- and warm-season grass pastures for 10 year that had been furrow-irrigated. The climate in the region is semiarid, subtropical, continental, characterized by cool, dry winters and warm, moist summers. Approximately 83% of the precipitation occurs as intermittent, relatively intense rainfall events from April through October [4]. Weather data were collected from a National Weather Service cooperative station located within 1 km of the study area (Table 1).

Table 1. Monthly mean air temperatures and total precipitation at Tucumcari, NM, USA, during two winter cereal forage growing seasons and the long-term (1905–2020) means. Cereals were sown on approximately 24 August each year.

Year	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Annual
						Mean temperature, °C							
1	23.3	26.7	26.1	21.1	15.6	12.2	5.0	6.7	9.4	10.6	16.1	22.2	18.5
2	24.4	27.8	28.3	23.9	15.0	5.0	2.2	1.7	6.7	8.3	17.2	18.9	15.0
Long-term mean	20.9	23.7	22.5	18.4	11.3	3.1	−3.7	−2.7	−0.08	4.7	9.0	15.5	14.5
						Total precipitation, mm							
1	44	14	59	50	17	1	21	3	0	45	19	22	295
2	30	57	7	2	97	11	21	17	24	67	3	72	408
Long-term mean	47	66	68	39	34	17	16	10	13	19	27	48	399

Furrows from the previous crops each year had remained intact sufficiently for uniform irrigation distribution. In late July of each year, prior to plowing, the field was irrigated to soften the soil. The field was prepared into a conventional seedbed and formed into beds on 101.6-cm centers for furrow irrigation through siphon tubes. The irrigation source was surface water supplied via canal by the local irrigation conservancy district. Oat (cv. Walken; considered a 'winter' type oat with good cold tolerance), rye (cv. Elbon), triticale (cv. Wintri; an early released variety), and beardless wheat (VNS) were sown between 23 and 25 August each year, in 0.97 ha plots using a conventional grain drill with 20-cm row spacing. There were two randomized complete blocks (pastures), but a different randomization was used in the second year. Seeding rates for cereal forages were 36, 63, 56, and 67 kg ha^{-1} for oat, rye, triticale, and wheat, respectively, or 87 L ha^{-1} for each species. After planting, the field was irrigated to promote germination. In mid-October, 56 kg N ha^{-1} as urea (46-0-0) was broadcast and another irrigation was applied. All irrigations were of sufficient duration to completely soak the beds to the center for their full length, which is anticipated to bring the surface 45 cm to field capacity. While all cereals established excellent stands in Year 1, by the time grazing was initiated in Year 2, stands were not as good, being visually rated at 83, 82, <5, and 66% ground cover for oat, rye, triticale, and wheat, respectively. The very poor stand establishment by triticale in Year 2 was attributed to seed quality, although that was not verified.

The test area was encompassed by previously existing woven wire fence. A single-strand electrified cross fence was installed to divide the replicates (pastures) and cattle had equal access to all plots within the replicate with no cross fences within the replicate. An alley had been previously constructed at one end of each pasture to facilitate cattle movement and provide a centralized area for cattle watering and provision of mineral supplement [Hi-Pro Beef Range Mineral (Hi-Pro Feeds, LLC, Brentwood, TN, USA)]. Grazing was initiated in mid-November each year and ceased in early April of the following year. Thirty recently weaned, predominantly British × continental mixed-breed steers (212 ± 14 kg LW and 187 ± 13 kg LW in Years 1 and 2, respectively) from NMSU's Corona Range and Livestock Research Center were divided into two groups of equal weight and turned in to continuously graze the pasture replicates. All animal handling and experimental procedures were in accordance with guidelines set by the New Mexico State University Institutional Animal Care and Use Committee with no special requirement because these animals were used in a typical agricultural setting with no treatments applied directly to the animals.

Two permanent 4.88 m × 4.88 m exclosures were erected in each plot prior to the initiation of grazing. Near each permanent exclosure, but far enough away to allow free movement of cattle, another exclosure (1.55-m diameter) was also installed. One set of exclosures was located in the northern half of each plot and one in the southern half. In mid-November of each year (16 November Year 1 and 15 November Year 2), and every 28 days thereafter, three samples were collected from each exclosure set. One sample was collected from a new area within each permanent exclosure as cumulative growth, one from a grazed area near each permanent exclosure but far enough away to avoid the trampling effect of steers scratching on the exclosure to determine available forage, and one from within the smaller exclosure. Each month the smaller exclosure was moved to a new area that represented the available forage surrounding the permanent exclosure. New growth of accumulated forage during the previous 28 days was calculated as the difference between the current and previous months' accumulated forage collected from within the permanent exclosures. Regrowth 28-d after grazing was calculated as the difference between the previous month's availability and the current month's small exclosure yield.

For each sample, all the forage within a 0.30 × 101.6-cm quadrat was hand-clipped to ground level. Placement of the exclosures and quadrats was such that a representative cross-section of the furrow-bed continuum was obtained in each sample. Samples were bagged and dried for 48 h at 65 °C to determine dry matter (DM) yield. Data from the two exclosure sets were averaged for each plot for statistical analyses.

Coincident with clipping dates, steers were weighed following a 16-h fast with water available. Liveweight data will not be presented as it was used solely to ensure that steer gain was not sacrificed due to limited forage availability. Beginning with the second week after the initiation of grazing, nearly daily throughout each test period, steer head counts by cereal species were made during morning and afternoon grazing sessions to determine the cereals within each replicate pasture that were being grazed by steers to evaluate grazing preference. Steers in the alley were not included and percentage of steers grazing each species within a pasture was averaged for each week.

Forage yield data were subjected to the mixed procedure of SAS [16] to test the main effects of year, date, and cereal and all possible interactions. Replicate was identified as unique within year and considered random. All differences reported are significant at $p \leq 0.05$. When an interaction was significant for yield variables, protected least significant differences were used to determine where differences occurred using the PDMIX800 macro [17]. Grazing preference data were analyzed as split plot repeated measurements over weeks 2 to 19 for the year and cereal main effects and the year × cereal interaction.

3. Results and Discussion

Main effect means for sampling date and cereal and results of statistical analysis are presented in Table 2 for all forage DM yield variables. Despite the reduced yield in Year 2, the main effect of year was not significant for any variable; however, date and the year × date interactions were significant for all variables, the latter of which include the effect of reduced yields in Year 2. The year × date interaction for accumulated DM yield is presented in Figure 1. Differences existed between years for all dates. The interaction was caused by a greater increase in yield from November to December in Year 1 than in Year 2. The likely cause of this was differences in climatic factors between the two years. Weather data for Years 1 and 2 and the long-term average are presented in Table 1. August, through October of both years were warmer than average and increased temperature persisted through April in Year 1. While the autumn through winter period of Year 2 was also warmer than average, the differences were not as great as they were in Year 1 from

November through February (Table 1). Precipitation was also near average in August and September of Year 1, which, coupled with warmer temperatures, promoted early growth of the cereals. Otherwise, precipitation was well-below average for the remainder of the season in Year 1 (Table 1). Precipitation was average for Year 2, but not well-distributed for winter cereal forage production (Table 1). That, coupled with greater temperatures, in August and September were not as conducive for winter cereal establishment and growth [18] as was Year 1, despite irrigation applied at planting and in October. In addition, November through March temperatures in Year 2 were considerably colder than Year 1 (Table 1), likely limiting late fall/winter growth (Figure 1).

Table 2. Dry matter yield (Mg ha^{-1}) and results of statistical analyses of winter cereal pastures at Tucumcari, NM, USA. Values are the lsmeans of two years and two replicates for the date × cereal interaction.

Effect	Ungrazed Forage				Grazed Forage			
	Cumulative		28-d New Growth [1]		Available		28-d Regrowth [2]	
Date								
14 November	1.89	D [3]	—		1.98	ABC	—	
15 December	3.10	C	1.23	B	2.23	A	0.75	B
10 January	3.42	C	0.34	C	2.21	A	−0.08	CD
7 February	3.40	C	0.00	C	1.71	C	−0.47	D
7 March	4.62	B	1.24	B	1.86	BC	0.23	C
4 April	7.33	A	2.73	A	2.06	AB	2.03	A
SED [4]	0.28		0.28		0.15		0.22	
Cereal								
Oat	4.44	B	1.05	B	1.26	C	0.30	
Rye	5.03	A	1.58	A	2.57	A	0.68	
Triticale	2.79	D	0.85	B	1.74	B	0.46	
Wheat	3.58	C	0.96	B	2.46	A	0.52	
SED	0.23		0.25		0.13		0.19	
			p-values					
Year (Y)	0.2915		0.8745		0.3070		0.2315	
Date (D)	<0.0001		<0.0001		0.0101		<0.0001	
Y × D	0.0089		0.0020		<0.0001		<0.0001	
Cereal (C)	<0.0001		0.0331		<0.0001		0.2880	
Y × C	0.0111		0.6377		<0.0001		0.2969	
D × C	0.0022		0.1046		0.0014		0.1614	
Y × D × C	0.5989		0.5913		0.0020		0.3248	

[1] 28-d new growth represents the difference between the current and previous months' measurements for accumulated (ungrazed) growth within permanently set exclosures. [2] 28-d regrowth represents the difference between the current month's yield within exclosures moved each month and the previous month's grazed yield. [3] Means within a column and either date or cereal followed by similar letters are not significantly different based on a 5% LSD. [4] SED signifies the standard error of the difference between means within an effect and column.

The year × cereal interaction for accumulated yield (Table 2) occurred because of a difference in magnitude among sampling dates between years among cereals. In Year 1, oat and rye had equal, but greater yields than both triticale and wheat (5.81, 6.17, 4.43, and 4.45 Mg ha^{-1} for oat, rye, triticale, and wheat yields in Year 1, respectively, SED = 0.32). In Year 2, yields of all cereals were reduced with rye having greater yields than all others and triticale yielding less than oat and wheat (2.67, 3.39, 1.00, and 2.36 Mg ha^{-1} for oat, rye, triticale, and wheat yields in Year 2, respectively, SED = 0.32). This is best explained by the significant year × date interaction for new growth of accumulated yield (Table 2; Figure 2), as well as the poor stand establishment by triticale in Year 2. Ungrazed growth of all cereals from November to December in Year 1 reflects the same interaction for cumulative growth (Figure 1).

Greater precipitation during August and September of Year 1 than in Year 2 (Table 1) likely caused this. Otherwise, there was no difference between years until the 28-d period from March to April, when Year 2 had greater growth (Figure 2). Above average precipitation from January through March in Year 2 (Table 1) likely promoted spring growth that year (Table 2), rather than temperature differences as described by Griggs [15]. While new growth of ungrazed cereals in April of Year 2 was greater than in April of Year 1 (Figure 2), spring precipitation may not be able to overcome less than optimum growth conditions in autumn to maximize yields of cereals.

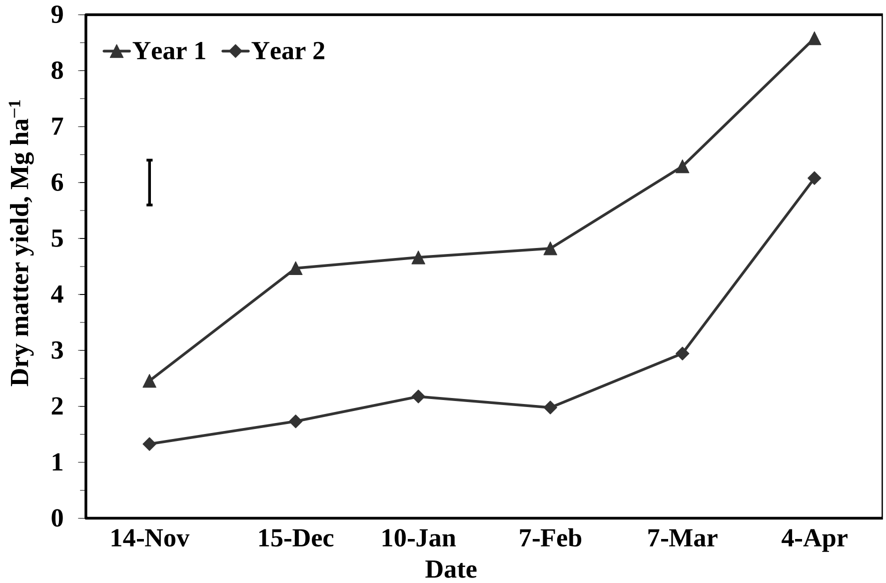

Figure 1. The year × date interaction for average accumulated forage of winter cereals (oat, rye, triticale, and wheat) sampled monthly in two autumn through spring seasons at Tucumcari, NM, USA. Values are the means of two replicates. The bar represents the 5% LSD for the year × date interaction.

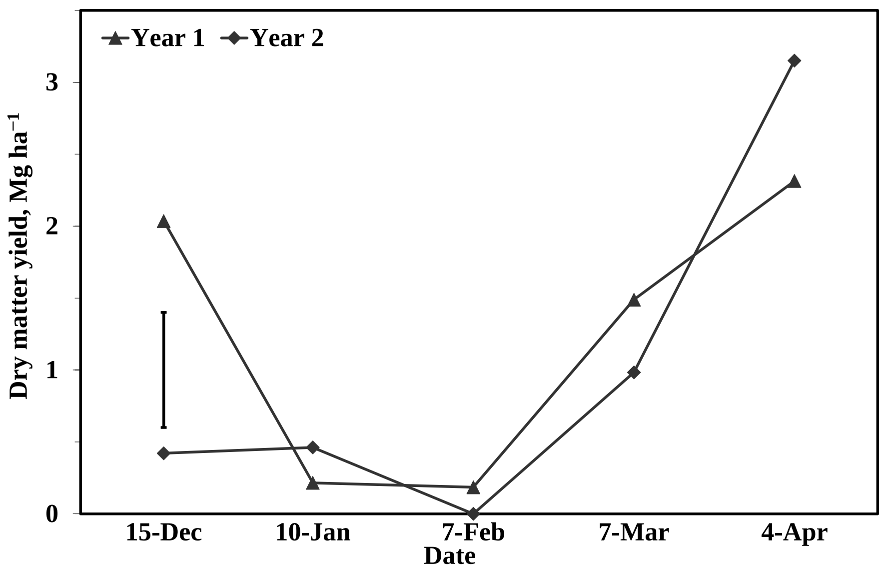

Figure 2. The year × date interaction for new growth of ungrazed forage of winter cereals (oat, rye, triticale, and wheat) sampled monthly in two autumn through spring seasons at Tucumcari, NM, USA. Values are the means of two replicates. The bar represents the 5% LSD for the year × date interaction.

Lauriault and Kirksey [2] found that the ability to irrigate to promote germination and again in mid-October increases forage DM yield in the spring of cereals in less than optimum precipitation years in the Southern High Plains, but even then, yields would not equal those of more frequently irrigated cereals with more optimum precipitation [8].

Figure 3 shows the date × cereal interaction for accumulated yield. Oat and rye consistently outyielded triticale every month while wheat was usually intermediate, being not different from any other cereal until after all species had begun rapid growth in February after which oat and rye were greater and different from each other.

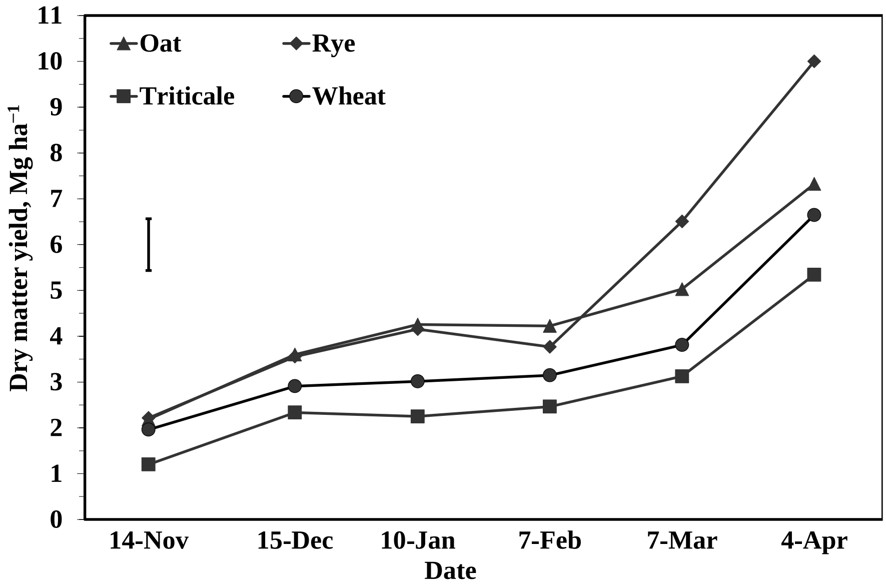

Figure 3. The date × cereal interaction for accumulated forage of winter cereals sampled monthly in two autumn through spring seasons at Tucumcari, NM, USA. Values are the means of two years and two replicates. The bar represents the 5% LSD for the date × cereal interaction.

Mean annual yields of the monocultures measured in early April in the present study (7.0 Mg ha^{-1}; calculated from Figure 1) were consistent with those for the same species measured elsewhere [6,19,20] and greater than those measured at the present study location by Lauriault and Kirksey [2] for monoculture cereals harvested at boot stage for hay (8 and 25 April and 2 and 10 May, on average, for rye, wheat, triticale, and oat, respectively). In other research at this location, harvesting winter cereals in early April when cattle would be moved from winter cereals to perennial pastures [11] presents an opportunity for continued growth of all cereals for harvest as hay or silage to increase in economic returns from the same seeding (data not collected in the present study, but 1.17, 2.34, and 0.45 Mg ha^{-1} were harvested from 1–2 additional cuttings between early April and the end of May for rye, triticale, and wheat respectively; Leonard Lauriault and Mark Marsalis, unpublished data). Marsalis et al. [21] and Niece et al. [22] show that triticale and wheat typically produce more DM than cereal rye when allowed to mature to boot stage later in the spring. Chapko et al. [20], Collins et al. [23], and Rao et al. [7] all found that forage yields of small grains were depressed by moisture stress. Delaying grazing of those species allows them to accumulate greater forage prior to spring [9]. Lauriault et al. [14] reported that pearl millet (*Pennisetum glaucum* (L.) R. Br.) can be grazed through the frost-prone autumn period without concern for Prussic Acid toxicity [24], which is a concern when using sorghum (*Sorghum bicolor* and *S. bicolor* × *S. sudanense* (Piper) Stapf.) forages [25]. Using other available forages and even dormant native grass pastures for early autumn grazing would allow for delayed grazing of winter cereals for increased forage accumulation [13].

Irrigation water via canal is generally not available from late October through mid- to late April at this location. By mid-April (Julian date 105), most cereal species in this region have begun elongation of reproductive tillers and future forage production is limited, although there is generally a yield increase due to seed production if the crop is to be harvested as the soft dough stage for silage. In areas where water is available year round or as early 1 March, producers have the opportunity to promote spring growth, as did the precipitation in Year 2 (Figure 2). The availability of water for spring irrigation should also provide the opportunity for cereals to benefit from a spring fertilizer application [19,23,26].

Lauriault and Kirksey [2] reported a difference between years in yields of annual cereal rye, winter wheat, and triticale forage due to the amount of growing season (September through April) precipitation and Marsalis et al. [8] attributed differences over years in cereal forage yields to environmental and total water applied, as did Rao et al. [7].

Marsalis et al. [8], 100 km to the south of Tucumcari, reported triticale yields of 10.78 Mg ha^{-1} for three varieties over five years and 9.20 Mg ha^{-1} for four winter wheat varieties over four years. In addition, newer, improved triticale varieties tested at the same location (Clovis, NM, USA) now consistently yield over 11 Mg ha^{-1} (range: 11.0 to 16.5 Mg ha^{-1}) [22]. Environmental differences between study sites, particularly warmer temperatures for later autumn and spring growth (Table 2), combined with the availability of winter irrigation using groundwater, likely led to these differences. Griggs [15] reported greater spring yields by cereals in a year with warmer February and March temperatures.

Available forage data are shown in Figure 4 as a year × date × species interaction. In Year 1, available forage on each date and the distribution patterns of rye, triticale, and wheat were similar with rye occasionally out-yielding triticale until April when availability of rye declined. While rye generally completes its life cycle in April at this location [2,8], removing animals in April would allow for the accumulation of forage by oat, triticale, or wheat for harvest as hay or silage. Oat availability declined from November through February when it became and remained near zero thereafter. This is reflective of the animal preference data for which the cereal species and all interactions including species were significant. The year × species and year × week × species data are shown in Table 3. With unlimited available forage in Year 1, animals selectively grazed the oat until it became limited and then they grazed rye more heavily, but also keeping the oat grazed down, all the while avoiding the wheat and triticale when possible (Table 3; Figure 4). Availability remained limited in Year 2 with no difference among oat, rye, and wheat and triticale having less availability than rye on every date, except in February leading cattle to spend more time on the rye and keep the oat and wheat grazed down. Triticale availability was always limited in Year 2 due to the thin stand, although plants were tall enough to be grazed when other cereals were limited in availability (Table 3; Figure 4).

The year × week × species interaction for animal preference (Table 3) was exacerbated by regrowth of the cereals, particularly in Year 2 (Figure 5). Although not statistically analyzed, comparing new growth of accumulated forage (Figure 2) with regrowth of grazed forage (Figure 5) indicates nearly equal growth from November to December in Year 1 whether or not the cereals were grazed. From December January, little growth occurred for ungrazed cereals (Figure 2), but grazed cereals (Figure 5) appear to have produced greater yields. From January to February, little growth occurred again for ungrazed cereals and none took place for grazed cereals (Figures 2 and 5). Grazing in spring led to reduced regrowth compared to ungrazed cereals in Year 1, which may have been associated with low precipitation from November through February (Table 1) and the inability to irrigate after October. In Year 2, poor initial stands, coupled with low winter precipitation, cooler temperatures, and grazing, led to zero regrowth of grazed cereals until precipitation increased during the typical period of rapid growth beginning in March (Figure 5; Table 1). By April, monthly regrowth of grazed cereals nearly equaled that of ungrazed cereals in Year 2 when spring precipitation was greater than in Year 1 (Figures 2 and 5; Table 1). Despite differences between years among dates in cereal forage availability (Table 2; Figure 4) and the interactions for grazing preference (Table 3), the main effect of cereal was significant for grazing preference such that oat > wheat = rye > triticale (29, 22, 21, and 14%, respectively; SED = 3).

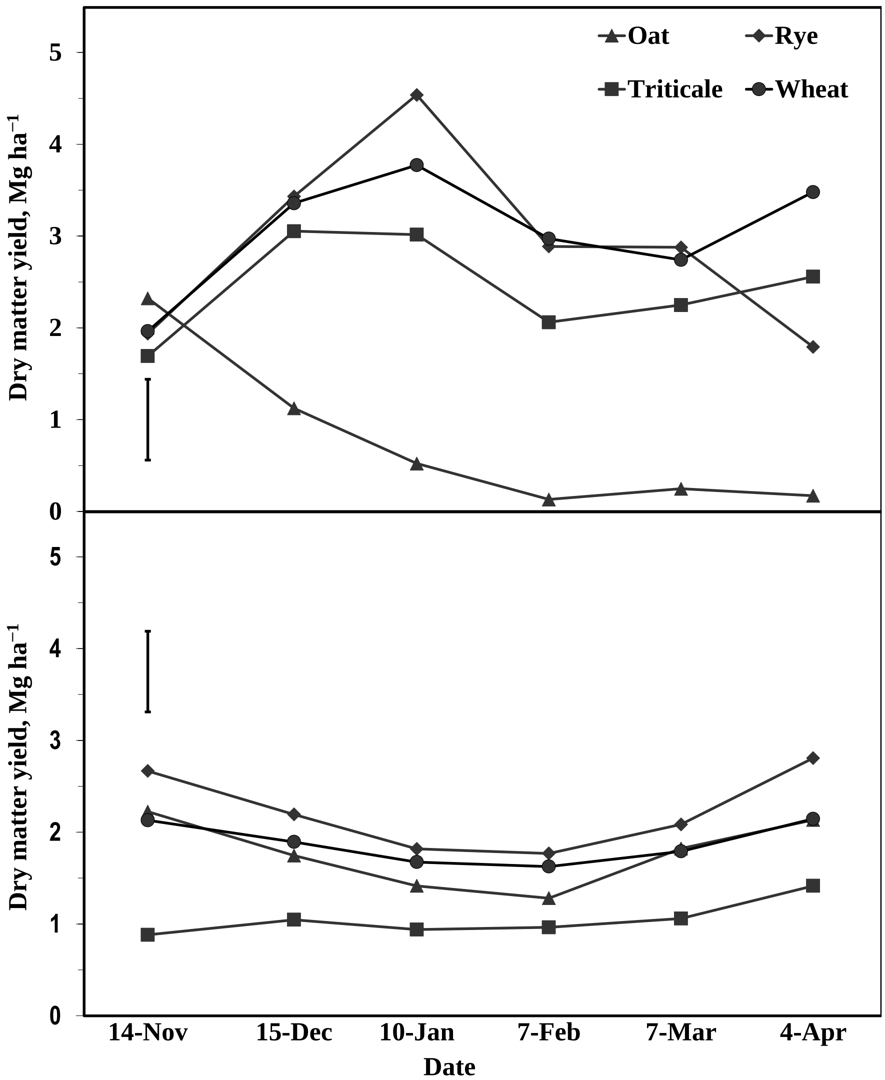

Figure 4. The year × date × cereal interaction for available forage of winter cereals sampled monthly in two autumn through spring seasons at Tucumcari, NM, USA. Values are the means of two replicates. The bar represents the 5% LSD for the year × date × cereal interaction.

Table 3. The year × cereal and year × week × cereal interactions ($p < 0.0023$ and $p < 0.0002$, respectively) for the 7-day average percent of cattle grazing winter cereals at Tucumcari, NM, USA. Values are the means of two replicates. The least significant difference between year × week × cereal means is 31, while for the year × cereal interaction (annual average) it is 8 [1].

	Year 1				Year 2			
Week	**Oat**	**Rye**	**Triticale**	**Wheat**	**Oat**	**Rye**	**Triticale**	**Wheat**
21 November	65	4	0	8	13	7	6	61
1 December	68	4	4	2	20	5	26	25
8 December	46	8	16	9	10	17	25	22
15 December	58	4	13	15	0	16	0	21
22 December	29	22	9	27	30	0	22	19
5 January	43	16	7	22	20	0	0	50
12 January	35	29	6	12	9	36	0	21
19 January	60	14	4	13	17	5	29	17
26 January	46	11	12	7	9	26	10	13
2 February	24	16	13	14	10	4	23	15
7 February	29	41	7	11	5	10	25	35

Table 3. *Cont.*

Week	Year 1				Year 2			
	Oat	Rye	Triticale	Wheat	Oat	Rye	Triticale	Wheat
16 February	38	26	3	11	1	11	33	19
23 February	14	51	11	5	33	8	6	21
2 March	10	60	7	6	14	18	3	23
9 March	14	53	15	5	6	16	13	34
16 March	12	28	14	21	30	7	11	13
30 March	31	14	15	10	16	15	17	16
3 April	42	20	20	4	11	21	0	52
Annual average	39A	23B	10C	11C	19B	19B	19B	34A

[1] Annual average means followed by a similar letter are not significantly different based on a 5% LSD.

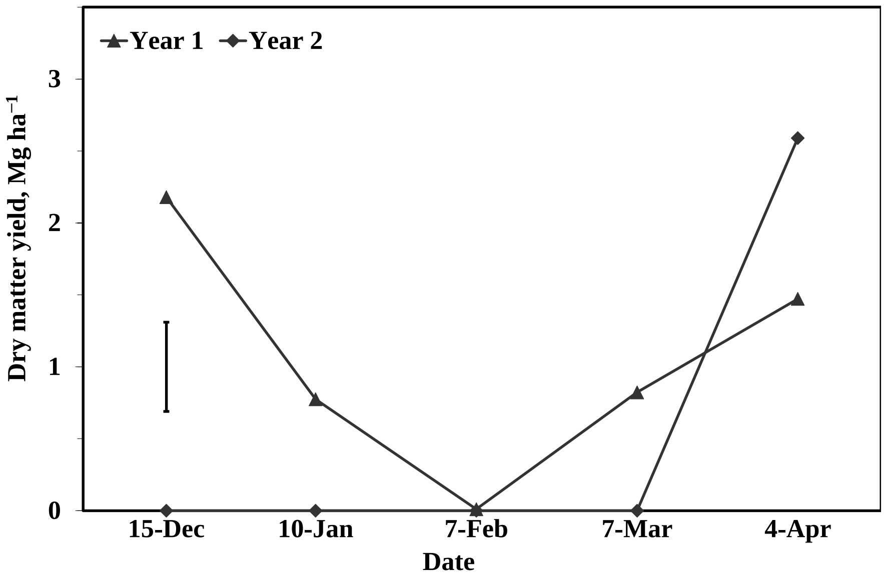

Figure 5. The year × date interaction for regrowth of winter cereals (oat, rye, triticale, and wheat) during the first month since grazed in two autumn through spring seasons at Tucumcari, NM, USA. Values are the means of two replicates. The bar represents the 5% LSD for the year × date interaction.

4. Conclusions

Very little difference existed among cereals in the autumn and winter growth periods; however, rye had greater forage accumulation in the spring (up to early April) than the other cereals and oat was greater than triticale with wheat being intermediate. When given a preference, growing cattle preferred oat followed by rye, then wheat and triticale. Regrowth of grazed forage did not differ among cereals.

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Institutional Review Board Statement: All animal handling and experimental procedures were in accordance with guidelines set by the New Mexico State University Institutional Animal Care and Use Committee, although specific approval for this study was not needed when the study was conducted because no procedures were used that were beyond typical animal production practices (i.e., surgery, unapproved pharmaceuticals, etc.).

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available upon reasonable request from the authors.

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