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Evaluation of Different Fall Dormancy-Rating Alfalfa Cultivars for Forage Yield in a Semiarid Environment

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Abstract: Alfalfa is one of the most important, nutritive, and high yielding forage legumes planted across the US. Fall dormancy in alfalfa influences forage yield characteristics and the plants persistence mostly under the cold and temperate climate. The objective of this study was to evaluate alfalfa cultivars with different fall dormancy-ratings for their forage yield at each cut and the annual forage yield. Two sets of 24 alfalfa cultivars were evaluated in a field experiment conducted at the Agricultural Science Center at Farmington, NM. The first set of 24 cultivars was planted late fall 2007 at seeding rate of 22.4 kg ha^{-1} and managed for the 2007–2011 period and the second set was planted late fall 2009 and managed during the 2009–2013 period. Average forage yield varied with years from 7.6 to 2.9 Mg ha^{-1}, 6.8 to 4.3 Mg ha^{-1}, 9.2 to 4.2 Mg ha^{-1}, and 7.9 to 3.2 Mg ha^{-1} during the 1st, 2nd, 3rd, and 4th alfalfa cut, respectively. The results showed no statistical differences between the moderately dormant, dormant, and the non-dormant alfalfa cultivars while they showed higher forage yield than the very dormant and semi-dormant alfalfa cultivars. There was a decreasing trend in forage yield from the first cut to the fourth cut in each growing season. However, the very dormant cultivars showed the lowest forage yield. Alfalfa forage yield decreased from the cut 1 to the cut 4 which represented on average 33, 29, 22, and 16% of the annual yield. The semi-dormant cultivars obtained the lowest forage yield at the first and second cutting while there was no difference between the cultivars for the third and fourth harvests. Average forage yields per harvest were 5.7, 5.9, 6.0, 5.5, and 5.9 Mg ha^{-1} for the very dormant, dormant, moderately dormant, semi-dormant, and non-dormant alfalfa cultivars, respectively. Annual forage yield varied with alfalfa fall dormancy-ratings and ranged from 15.5 to 29.9 Mg ha^{-1} with the highest forage yield achieved during the third years of the production. The moderately dormant and the non-dormant cultivars showed the highest yield during the first harvest year while the very dormant cultivars and dormant cultivars had the lowest forage yield. Alfalfa cultivars with a fall dormancy range 4–5 may be considered for alfalfa production in northwest New Mexico however, the good agricultural practices (conservation tillage, fertilizer management based on soil residual available nutrient and crop requirement, recommended planting rate, weed and pest management, irrigation scheduling to match crop evapotranspiration) should be the most important to maximize alfalfa forage yield in the southwest US.

Keywords: alfalfa; fall dormancy; forage yield; semiarid climate; high elevation

1. Introduction

Alfalfa (*Medicago sativa* L.) is one of the widest grown perennial forage crops in the world with high nutritive value and is preferred by livestock compared to grasses [1]. Alfalfa is well-regarded

for providing high-quality forage with high protein content and nutritive value [2]. It offers additional advantages as it widely adapts to different climates, has good biological nitrogen fixation capacity and produces high biomass yield with exceptional nutritive value [3–6]. Fall dormancy is defined as the reduction in shoot growth in the autumn due to decreasing day length and air temperatures [7].

Fall dormancy is considered an adaptation trait to different climatic conditions [8]. The more dormant the cultivar is less forage yield it produces but has better longevity [9]. Alfalfa genotypes are grouped in 11 classes called fall dormancy-ratings (FD) according to their ability to survive throughout winter and regrowth. These fall dormancy classes are: very dormant (FD 1, 2), dormant (FD 3, 4), moderately dormant (FD 5), semi-dormant (FD 6, 7), non-dormant (FD 8, 9), and very non-dormant (FD10, 11) [7]. Brummer et al. [10] and Lauriault et al. [11] described other fall dormancy-rating as fall dormant (FD 1–3), semi-fall dormant (FD 4–6), non-fall dormant (FD 7–9), and extremely non-fall dormant (FD 10–11). Photoperiodism and air temperature in fall and throughout winter determine alfalfa fall dormancy which is related to plant growth, biomass accumulation and abiotic stresses tolerance of the alfalfa plant [7,12–15]. Fall dormant alfalfa cultivars go dormant the earliest, have reduced shoot elongation in the fall and survive better throughout winter, whereas extremely non-fall dormant cultivars continue to grow, have the tallest plant height in the fall, and generally do not have good survival over the winter [16,17].

Alfalfa forage productivity is impacted by its fall dormancy-rating that has correlation with forage nutritive value, plant survival, root characteristics, and persistence [8,18–24]. Efforts have been made to improve alfalfa forage yield with improvement in the first/second harvests of newly released varieties and yield improvement is dependent on identification of the genes controlling yield and yield components such as canopy height, herbage, stubble, stem population, which is quite complex due to the involvement of several genes in the agronomic traits like forage yield [25,26]. Moreover, Arshad et al. [27] and Lei et al. [28] reported that drought tolerance in alfalfa is a key challenge in improving its productivity. Forage yield of alfalfa could be tremendously affected by salinity [29–33]. Li and Su [34] reported alfalfa annual forage yield as function of irrigation amount and which varied from 11.7 to 18.6 Mg ha^{-1} in China with increasing trend in seasonal irrigation [35,36]. Bolger and Matches [37] reported alfalfa first cut yield to be 41–46% of the annual yield while Li and Su [34] indicated the first cut yield as 35–50% of the annual forage yield as function of irrigation rates. Cavero et al. [38] reported that the maximum alfalfa forage yield was lower the first year (17 Mg ha^{-1}) than in the two following years (20–22 Mg ha^{-1}).

Alfalfa is the second most important crop gown across New Mexico State after pecans with total harvested area of 76,890 ha with a total production of 950,000 Mg corresponding to a value of $171 million in 2017 [39]. Alfalfa hay is the most important hay in the San Juan county as it was $162 per Mg while other hay was $139 per Mg in 2016 [40]. Alfalfa average yield in New Mexico State is 11.4 Mg ha^{-1} and its average yield in San Juan county was 10.6 Mg ha^{-1} in 2016. San Juan county is the largest alfalfa producing county of the State of New Mexico with alfalfa harvested area of 9308 ha. It is therefore important to improve alfalfa forage yield to increase hay production and promote the dairy industry across the San Juan county and the neighboring counties. Local adaptation coupled with high yield potential are the main sustainability traits for a wide adoption of alfalfa varieties and on-farm evaluation of fall dormancy categories might provide information on cultivar adaptation with good agronomic performance in correlation to fall dormancy-rating and persistence. With regard to the importance of alfalfa in New Mexico high desert environment, this research aims to investigate forage yield of different fall dormancy-rating alfalfa cultivars under late summer planting at the high desert region of the Colorado Plateau of the US.

2. Materials and Methods

2.1. Study Area

This study was conducted at the New Mexico State University (NMSU) Agricultural Science Center at Farmington (36.69°, 108.31°, elev. 1720 m) during the 2007–2013 period. The soil type at the

study site is Doak fine sandy loam. Climatic variables [minimum temperature (Tmin), maximum temperature (Tmax), average temperature (Tmean), and precipitation] were collected daily from an automated weather station installed at the study site and summarized in Figure 1. The long-term average annual Tmax and Tmin at the site are 17.2 and 2.2 °C, respectively and the long-term average annual precipitation is 216 mm.

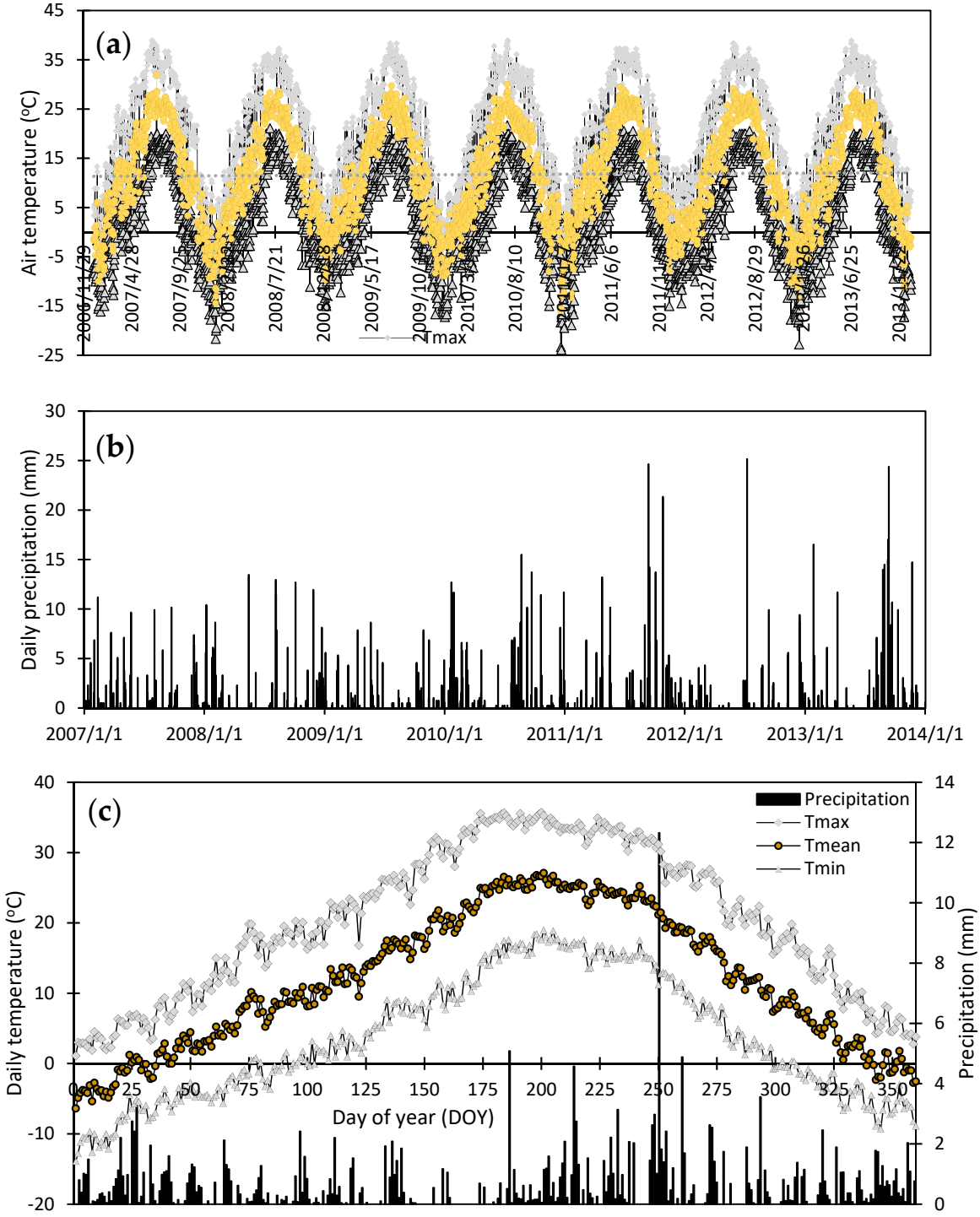

Figure 1. Evolution of the (**a**) maximum, minimum, and mean air temperatures, (**b**) precipitation during the 2007–2013 period, and (**c**) the 2007–2013 average maximum, minimum, and mean air temperatures, and daily precipitation.

2.2. Crop Management

Two sets of 24 selected alfalfa cultivars were planted in fall 2007 and fall 2009 at the seeding rate of 22.4 kg ha^{-1} (Table 1). Some well-known alfalfa varieties such as African Common, Ameristand, Archer II, Dona Ana, Legend, Malone, NM Common, Ranger, Wilson, and Lahontan were used across both plantings, but not all in each planting. Alfalfa cultivars were arranged in a randomized complete block design with four replications. Plot size was 1.2 m × 4.9 m. Plots were irrigated three times a week through a solid set sprinkler irrigation system. Irrigation depth was estimated by the FAO reference evapotranspiration and crop coefficient method [41]. Preplant fertilizer was applied before both plantings and a combination of ammonium nitrate, potassium chloride, triple superphosphate and zinc sulfate was used. The applied nutrient units rates were 11.2-52-61-3.4-6.7 for N-P_2O_5-K_2O-S-Zn in 2007 and 11.2-58.5-67.3 for N-P_2O_5-K_2O in 2009. Alfalfa forage was harvested each time when alfalfa plants visually reached 10% flowering stage. Each plot was combine harvested using a self-propelled harvester Almaco SPFH85001 (Almaco, Nevada, Iowa) with provided the plot fresh weight. A sample was collected from the harvested fresh biomass and the plot sample was forced-air oven dried at 72 °C up to a constant weight (about 13% standard moisture content). The plot dry weight was estimated from the sample dry weight and moisture content. Plot yield was determined from the plot dry weight which was extrapolated to Mg ha^{-1}.

Table 1. Alfalfa cultivars and the associated fall dormancy level used in the 2007–2011 and 2009–2013 experiments.

2007–2011		2009–2013	
Alfalfa Cultivars	**Fall Dormancy** *	**Alfalfa Cultivars**	**Fall Dormancy** *
Mountaineer 2.0	5	Mountaineer 2.0	5
54V09	4	4S417	4
Masterpiece	4	SW435	4
PGI459	4	HybriForce 2400	4
FSG 528SF	5	Lahontan	4
CW 95026	5	63Q105	3
Grandstand	4	HybriForce 2420/wet	4
Wilson	6	Dura 843	8
A-5225	N/A	Artesian Sunrise	7
African Common	N/A	AmeriStand 201 + Z	2
NM0306	7	WL440HQ	6
Ranger	3	Maxi-Graze GT	2
AmeriStand 407TQ	4	Rugged	3
Integra 8400	4	Malone	7
NM0307	7	LegenDairy 5.0	3
Medalist	4	Ranger	3
Dona Ana	7	Velvet	2
Legend	4	6422Q	4
AmeriStand 444NT	4	WL363HQ	5
Archer ll	5	Dona Ana	7
NM0313	N/A	NM Common	N/A
Archer III	5	SW6330	6
WL343HQ	4	African Common	N/A
NM Common	N/A	Wilson	6

* (1,2 = very dormant, 3,4 = dormant, 5 = moderately dormant, 6,7 = semi dormant. 8,9 = non-dormant, 10,11 = very non-dormant). N/A = not applicable.

2.3. Statistical Analysis

Cultivars with the same fall dormancy rating were combined and forage yield was averaged by fall dormancy rating range. Three factors were considered in this study: fall dormancy-rating range,

cut (harvest time) and the production year (the three independent variables) and the dependent variable is the forage yield. With the assumption of normal distribution of forage yield data set with independence of observations and homogenous variances, the data was tested using Bartlett's test and the probability was greater than 0.05, which confirms our assumption of homogeneity of variances. Three-way analysis of variance (ANOVA) was performed to analyze the main effects of these three factors and their interactions using the statistical SAS software [42]. The mean forage yields were cross-paired and compared using Fisher's protected least significance difference (LSD) test at the 95% level of probability to identify significant differences between alfalfa fall dormancy ratings for forage yield relative to the cut period and production years.

3. Results and Discussion

3.1. Weather Conditions During the Study Period

During the study period, maximum temperature varied from −10 to 39 °C, the minimum temperature varied from −23 to 26 °C and the daily average temperature varied from −16 to 32 °C (Figure 1a). The highest temperatures were registered late June–late July or early August and the coldest temperatures were registered in late December–early January. With alfalfa base temperature of 5 °C [43], alfalfa plants were physiologically active by the end of February throughout late spring, summer and early fall and went dormant mid-November as the daily mean temperature dropped below the base temperature (5 °C). Average annual thermal unit accumulated was 1292 °C that allowed four cut and four regrowth cycles of alfalfa. Annual precipitation was 169, 183, 120, 258, 209, and 121 mm in 2007, 2008, 2009, 2010, 2011, and 2013, respectively (Figure 1b), and averaged 215 mm a year of which only 41 mm occurred during the period of mid-October to mid-April when the irrigation system is off at the study site putting the plants under severe drought conditions (Figure 1c). With the limited annual precipitation, irrigation is therefore recommended as alfalfa production could not be possible under rainfed conditions at the study site.

3.2. Trend in Alfalfa Forage Yield Per Cut

The results of the 2007–2011 experiment ANOVA revealed non-significant effect Fall dormancy-rating on alfalfa forage yield at each cut ($p = 0.2445$) while the year and cut showed highly significant effect on alfalfa forage yield (Table 2). The interaction of fall dormancy-rating and alfalfa cut was significant like the interaction year and cut while the interaction of fall dormancy-rating and year was not significant ($p = 0.6277$) ($LSD_{0.05} = 0.17$). The highest forage yield at each cut was obtained in in the third year of production 2010 (6.40 Mg/ha) followed by second year of production 2009 (5.91 Mg/ha) and the fourth year of production 2011 (5.63 Mg/ha) ($LSD_{0.05} = 0.19$). The lowest yield was obtained in 2008 (4.55 Mg/ha) which was the first year of production. Overall, the first cut showed the highest yield (7.19 Mg/ha) followed by the second (6.47 Mg/ha), third (4.94 Mg/ha), and fourth cut (3.88 Mg/ha).

The analysis of the 2009–2013 experiment data showed that all three simple factors such alfalfa fall dormancy-rating, production year, and alfalfa cut were highly significant and their interactions except the fall dormancy-rating-production year and the cut ($p = 0.3393$) (Table 3). The moderately dormant, dormant, and non-dormant ratings showed statistically similarly high forage yield while the very dormant and the semi dormant ratings showed the lowest forage yield ($LSD_{0.05} = 0.17$). Like the 2007–2011 experiment, the third year of production (2012) registered the highest forage yield at each cut followed by the second year of production (2011), the fourth year (2013), and first year of production. However, the third year of production which showed the highest forge yield at each cut, all other productions years showed statistically similar forage yield ($LSD_{0.05} = 0.15$). On average, alfalfa forage yield significantly decreased from the first cut to fourth cut during each production year.

There were no significant differences between the alfalfa dormancy-ratings in terms of forage yield at each alfalfa cut. Forage yields averaged 7.3, 6.5, 4.9, and 3.8 Mg ha^{-1} for the 1st, 2nd, 3rd, and 4th cut for the 2007–2011 experiment and 7.9, 6.8, 4.9, and 3.7 Mg ha^{-1} for the 2009–2013 experiment.

On average alfalfa forage yield during the 1st, 2nd, 3rd and 4th cut represented 33, 29, 22 and 16% of the annual yield. However, the semi-dormant alfalfa cultivars showed the lowest forage yield at the first cut and the very dormant cultivars showed the lowest forage yield at the fourth cut. Alfalfa forage yield decreased from the cut 1 to the cut 4 (Figures 2–4). Average forage yield varied with years and varied from 7.6 to 2.9 Mg ha^{-1}, 6.8 to 4.3 Mg ha^{-1}, 9.2 to 4.2 Mg ha^{-1}, and 7.9 to 3.2 Mg ha^{-1} during the 1st, 2nd, 3rd, and 4th cut for all cuts (Figures 2–4). The highest yields were obtained during the third year of forage harvest. Over the four-year 2009–2013 experiment, average forage yields were 5.7, 5.9, 6.0, 5.5, and 5.9 Mg ha^{-1} for the very dormant, dormant, moderately dormant, semi-dormant, and non-dormant alfalfa cultivars, respectively, and 5.6, 5.7 and 5.6 Mg ha^{-1} for the very dormant, dormant and moderately dormant alfalfa cultivars, respectively, for the 2007–2011 experiment. The four-year pooled data for each experiment showed that the semi-dormant cultivars obtained the lowest forage yield at the first and second cutting while there were no significant differences between the cultivars in terms of forage yield for the third and fourth harvests (Figure 3). The results of this study agreed with Liu et al. [44] who found no significant difference in above ground biomass production among alfalfa cultivars with different fall dormancy-ratings. Fall dormancy might have little effect on forage yield under the current study conditions as reported by Liu et al. [44]. Similar results were reported by Malinowski et al. [45] who indicated that alfalfa productivity is not related to fall dormancy under a supplementary irrigation production system in a semiarid and sub-humid environment of the southern Great Plains. The drought conditions during the off season from late October to early April when the irrigation water is off at the research site and the hardness of winter at high elevation might have resulted in the induction of drought-related dormancy in all cultivars regardless of their fall dormancy-ratings [46]. In contrast, other studies demonstrated that non-dormant alfalfa cultivars showed lower yield compared to dormant cultivars [11,47]. Fransen et al. [48] reported that the first cutting usually represents 35–38% of the alfalfa annual forage yield. Volenec et al. [25] reported that there was not improvement in alfalfa first and second cut forage yields however, the yield of the fourth cut had shown some increasing trend due to the reduction in fall dormancy.

Table 2. Summary of the analysis of variance (Three-way ANOVA) of the 2007–2011 experiment.

Source	df	Tyoe III SS	MS	F	P	Signif.
Blocs	3	0.45	0.14	0.6606	0.5776	ns
Main Effects						
Fall Dormancy Rating	2	0.64	0.32	1.4227	0.2445	ns
Year	3	88.36	29.45	130.1497	0.0000	***
Cut	3	320.56	106.87	472.1979	0.0000	***
Interaction						
Fall Dormancy Rating × Year	6	0.99	0.16	0.7281	0.6277	ns
Fall Dormancy Rating × Cut	6	3.18	0.53	2.3382	0.0349	*
Year × Cut	6	150.79	16.75	74.0308	0.0000	***
Fall Dormancy Rating × Year × Cut	18	3.37	0.19	0.8266	0.6667	ns
Error	141	31.91	0.23			
Total	191	600.28				
Model	50	568.37	11.37	50.2285	0.0000	***
R^2 = SSmodel/SStotal = 0.94684108657						
Root MSerror = sqrt(MSerror) = 0.47572495221						
Mean Y = 5.62207288767						
Coefficient of Variation = (Root MSerror)/abs(Mean Y) × 100% = 8.4617358%						

Significance: ns = non-significant; * = significant at p value = 0.05; *** = significant at p value = 0.001.

Table 3. Summary of the analysis of variance (Three-way ANOVA) of the 2009–2013 experiment.

Source	df	Tyoe III SS	MS	F	P	Signif.
Blocs	3	2.17	0.72	3.156	0.0255	*
Main Effects						
Fall Dormancy Rating	4	6.43	1.61	7.006	0.0000	***
Year	3	55.74	18.58	80.973	0.0000	***
Cut	3	702.93	234.31	1021.078	0.0000	***
Interaction						
Fall Dormancy Rating × Year	12	9.06	0.76	3.291	0.0002	***
Fall Dormancy Rating × Cut	12	8.62	0.72	3.132	0.0004	***
Year × Cut	9	70.48	7.83	34.127	0.0000	***
Fall Dormancy Rating × Year × Cut	36	9.02	0.25	1.0924	0.3393	ns
Error	237	54.39	0.23			
Total	319	918.85				
Model	82	864.47	10.54	45.9413	0.0000	***

R^2 = SSmodel/SStotal = 0.94081195029

Root MSerror = sqrt(MSerror) = 0.47903329536

Mean Y = 5.2991597581

Coefficient of Variation = (Root MSerror)/abs(Mean Y) × 100% = 9.0397972%

Significance: ns = non-significant; * = significant at p value = 0.05; *** = significant at p value = 0.001.

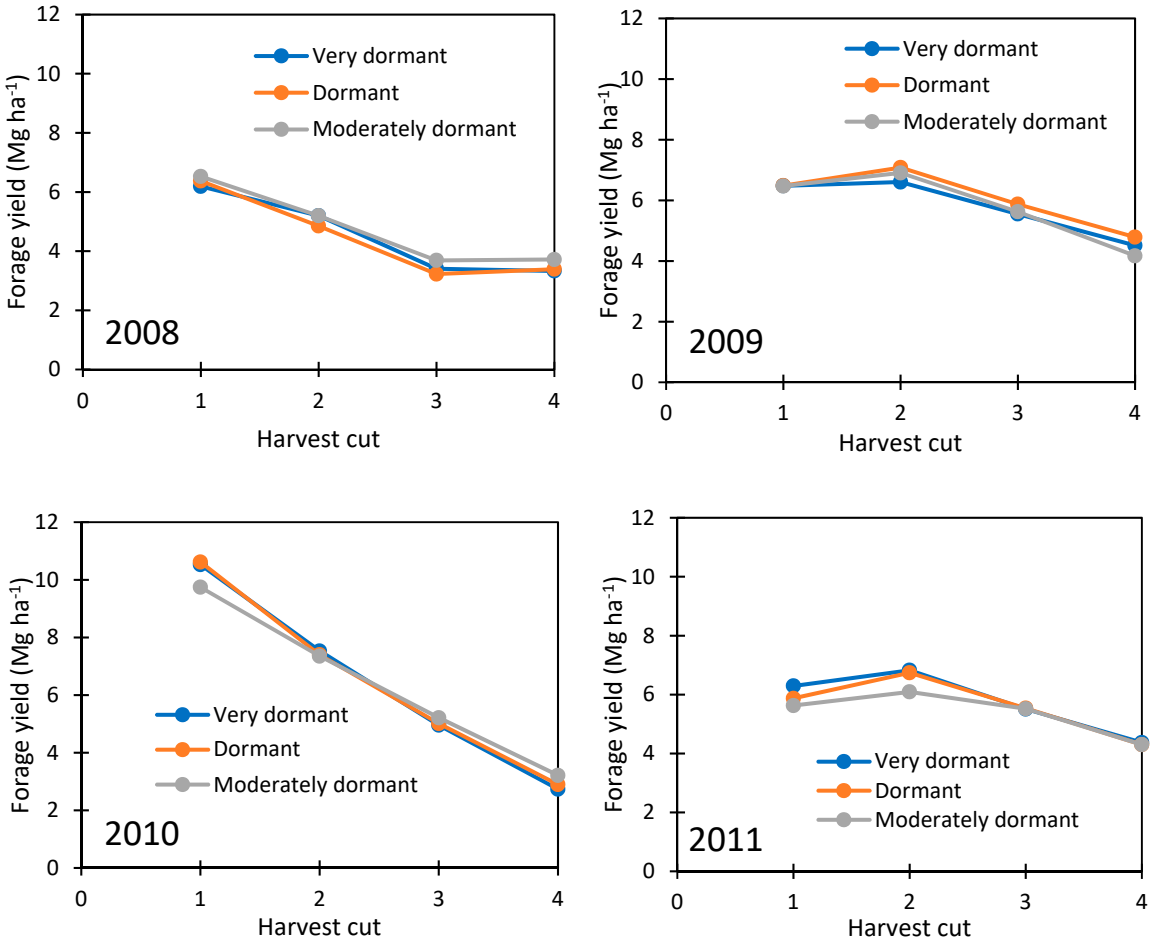

Figure 2. Average forage yield per harvest of the very dormant, dormant, moderately dormant alfalfa cultivars during 2008, 2009, 2010, and 2011.

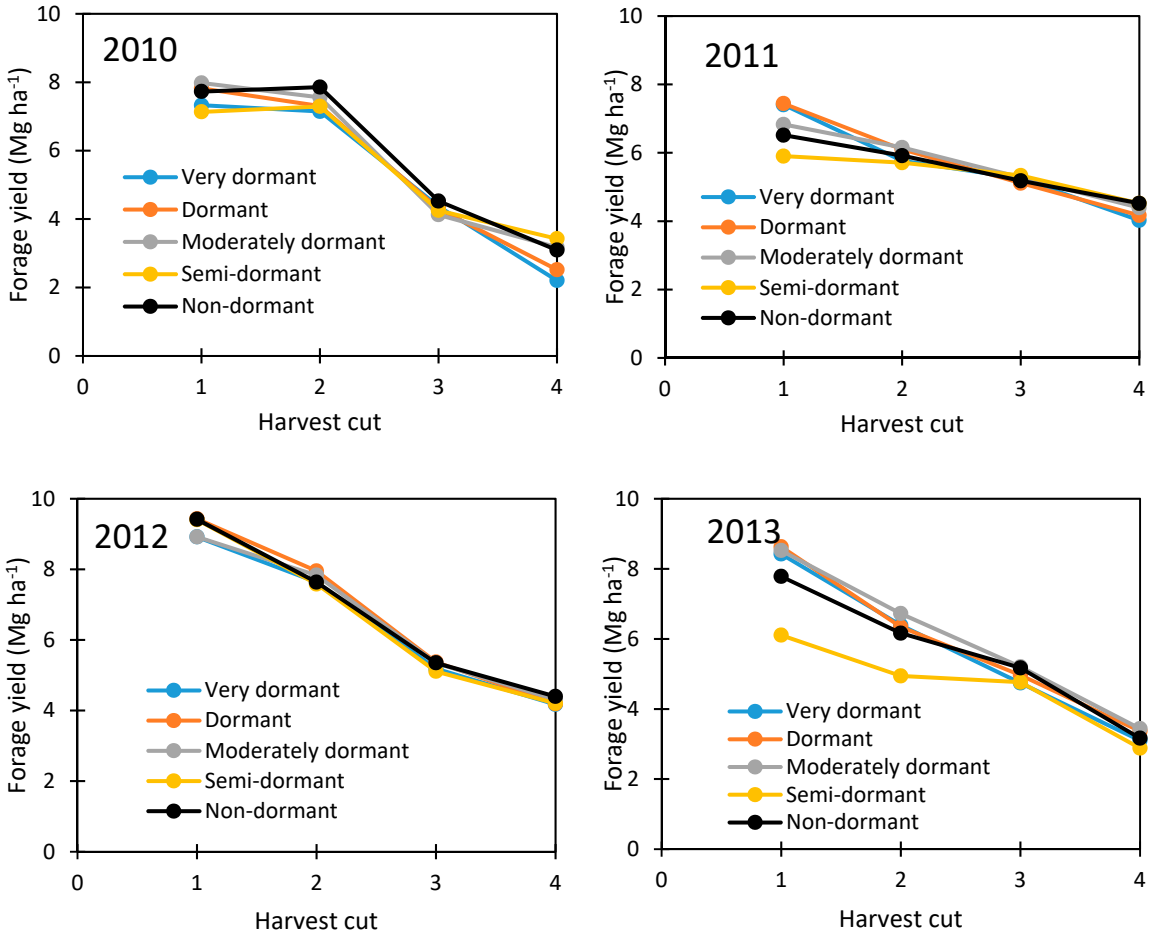

Figure 3. Average forage yield per harvest of the very dormant, dormant, moderately dormant, semi-dormant, non-dormant alfalfa cultivars during 2010, 2011, 2012, and 2013.

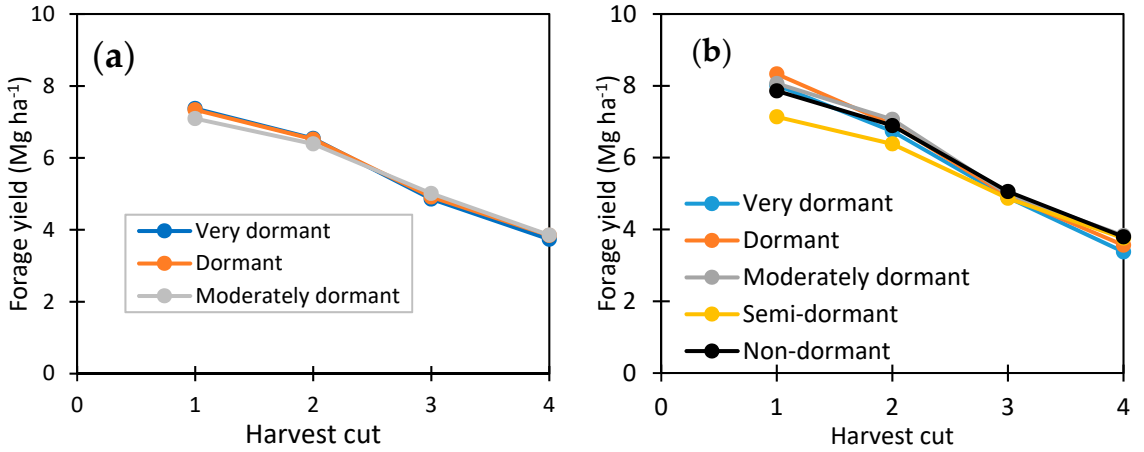

Figure 4. Average forage yield per harvest of the (**a**) very dormant, dormant, moderately dormant alfalfa cultivars for 2007–2011 and (**b**) very dormant, dormant, moderately dormant, semi-dormant, non-dormant alfalfa cultivars during 2009–2013 experiments.

3.3. Alfalfa Annual Forage Yield as Function of Fall Dormancy-Rating

Annual forage yield varied with cultivars and fall dormancy and ranged from 15.5 to 22.5, from 20.2 to 25.7, from 21.7 to 27.9, and from 19.2 to 22.9 Mg ha^{-1} in 2008, 2009, 2010, and 2011 for the 2007–2011 experiment and from 21.6 to 23.2, from 21.1 to 24.1, from 23.6 to 29.9, from 16.0 to 25.7 Mg ha^{-1} in 2010, 2011, 2012, and 2013 for the 2009–2013 experiment (Figure 5). The coefficient of variation was

less than 10% in both experimentations and there were significant differences between alfalfa cultivars in terms of forage yield in all years except the first year of harvest for both experiments (Figure 5). The moderately dormant and the non-dormant cultivars showed the highest yield during the first harvest year while the very dormant cultivars and dormant cultivars had the lowest forage yield. During the second, third, and fourth year, the semi dormant cultivars obtained the lowest forage yield (Figure 5). Overall, the average annual forage yield for the 2007–2011 and 2009–2013 experiments showed that alfalfa cultivar Mountaineer 2.0, 4S417, SW435, HybriForce 2400, and Lahontan with fall dormancy-rating range [4,5] yielded the highest for the 2007-2011 experiment while other cultivars within the same fall dormancy-rating range such as Archer II, Archer III, and WL343HQ are among the lowest yielding cultivars (Table 4). Similarly, for the 2009–2013 experiment, Mountaineer 2.0, 4S417, SW435, HybriForce 2400, and Lahonton with fall dormancy-rating range [4,5] were the high yielding cultivars. Alfalfa cultivars 6422Q and WL363HQ within the same fall dormancy-rating were among the low yielding cultivars (Table 5).

The reported yield data in this study are higher than some of the reported yield data in the literature. Pembleton et al. [49] reported lower irrigated alfalfa annual forage yield than the present study which varied from 14.63 to 15.74 Mg ha^{-1} in Australia. Attram et al. [50] reported very low yield of four alfalfa cultivars with maximum annual yield of 6.77 Mg ha^{-1} in southern Alberta (Canada) while Dill et al. [51] reported annual alfalfa yields ranging from 8.4 to 15.6 Mg ha^{-1} in the same region. Bolger and Matches [37] reported alfalfa yield of 20.70 Mg ha^{-1}. Grimes et al. [52] reported that irrigated alfalfa cultivars CUF 101, Moapa 69, and WL 318 can yield as high as 26.3 Mg ha^{-1} in the San Joaquin Valley of California. Lipson [53] reported 0.5% increase in seasonal forage yield a year using 114 alfalfa cultivars over a 30-year experiment while Holland and Bingham [54] reported 0.18% increase in seasonal forage yield from 3-year experiment with 12 alfalfa cultivars in Wisconsin. Winter survival might play tremendous role in the alfalfa yield in consecutive years mostly under the semiarid dry climate of the north western region of New Mexico and similar regions. Wang et al. [47] reported that the greatest average annual forage yield of 24.4 Mg ha^{-1} was achieved with 'Runner' (FD2), while the smallest yields were found in 'Defi' (FD5) with no statistical difference in annual forage yields of varieties among FD ratings 3 and 5–9 from the evaluation of 42 varieties of eight fall dormancy-ratings (2–9). They pointed out the importance of early season management to achieve great annual total forage yields rather than considering fall dormancy-ratings as the main criteria for alfalfa variety choice and adoption in temperate regions. However, Rimi et al. [55] found non-dormant alfalfa cultivars with the highest forage yield (18.2 Mg ha^{-1}) followed by less non-dormant cultivars (17.1 Mg ha^{-1}) and very non-dormant cultivars (16.9 Mg ha^{-1}) in the Po Valley, Italy. Pembleton et al. [56] also reported the superior yield performance of fall dormant alfalfa cultivars compared with non-fall dormant cultivars in the cool and temperate region of Australia.

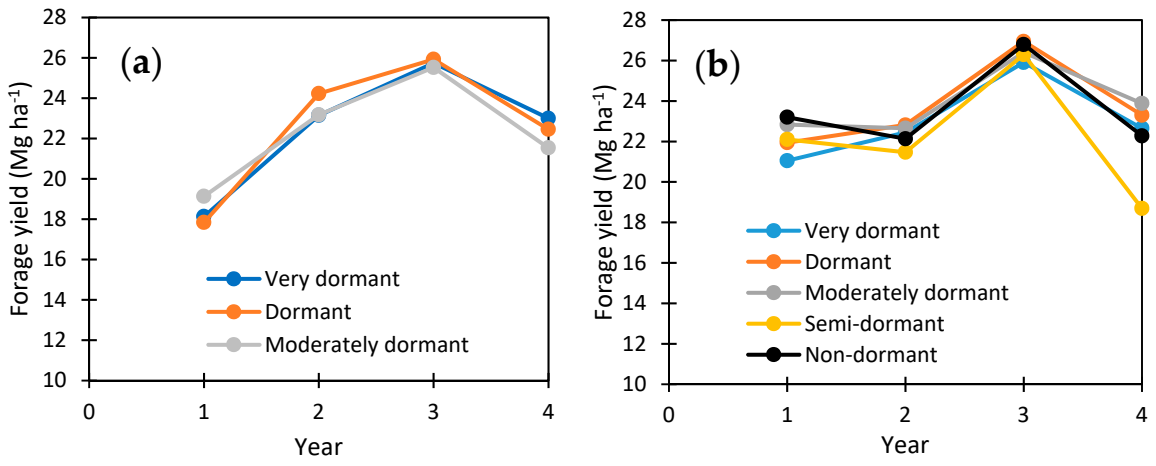

Figure 5. Average annual forage yield of the (**a**) very dormant, dormant, and moderately dormant alfalfa cultivars for 2007–2011 and (**b**) very dormant, dormant, moderately dormant, semi-dormant, non-dormant alfalfa cultivars during 2009–2013 experiments.

Table 4. Alfalfa cultivar forage yield (Mg ha^{-1}) for the 2007–2011 experiment.

Alfalfa Cultivars	Fall Dormancy	2008	2009	2010	2011	Average
Mountaineer 2.0	5	22.5	25.7	27.9	22.9	24.7
54V09	4	22.5	25.7	26.9	22.8	24.5
Masterpiece	4	20.5	25.7	27.2	23.5	24.3
PGI459	4	19.0	23.7	26.8	25.5	23.7
FSG 528SF	5	19.1	26.1	26.5	22.5	23.5
CW 95026	5	19.5	24.5	25.9	24.1	23.5
Grandstand	4	18.4	22.5	26.1	24.8	23.0
Wilson	6	21.0	22.8	25.7	22.2	22.9
A-5225	N/A	17.5	23.8	26.3	23.6	22.8
African Common	N/A	19.3	23.3	23.1	23.1	22.2
NM0306	7	19.0	24.2	25.7	19.9	22.2
Ranger	3	18.5	23.2	25.0	21.7	22.1
AmeriStand 407TQ	4	19.8	22.7	24.4	21.5	22.1
Integra 8400	4	16.7	22.2	25.9	23.0	21.9
NM0307	7	15.5	23.2	23.9	24.8	21.9
Medalist	4	16.0	22.3	24.7	24.2	21.8
Dona Ana	7	17.3	23.5	25.4	20.9	21.8
Legend	4	13.5	22.6	26.8	24.1	21.7
AmeriStand 444NT	4	16.1	23.1	25.9	21.6	21.7
Archer ll	5	16.1	23.7	23.5	21.7	21.2
NM0313	N/A	18.2	21.5	22.3	21.4	20.8
Archer III	5	13.9	21.8	25.5	21.7	20.7
WL343HQ	4	18.3	20.8	23.4	20.2	20.7
NM Common	N/A	15.5	20.2	21.8	19.3	19.2
Average		18.1	23.3	25.3	22.6	22.3
LSD.05		5.7	0.5	2.8	3.4	2.5
CV%		21.8	6.9	8.0	10.6	8.07
P		0.1186	<0.0001	0.0019	0.0270	0.0072
Significant		ns	***	**	*	**

Significance: ns = non-significant; * = significant at p value = 0.05; ** = significant at p value = 0.01; *** = significant at p value = 0.001.

Table 5. Alfalfa cultivar forage yield (Mg ha^{-1}) for the 2009–2013 experiment.

Alfalfa Cultivars	Fall Dormancy	2010	2011	2012	2013	Average
Mountaineer 2.0	5	23.2	24.1	28.7	25.7	25.4
4S417	4	22.9	23.3	29.9	24.1	25.0
SW435	4	22.1	23.8	28.5	25.5	25.0
HybriForce 2400	4	22.9	23.2	28.6	24.6	24.8
Lahontan	4	23.6	25.0	27.8	21.4	24.5
63Q105	3	21.3	22.9	27.5	25.0	24.2
HybriForce 2420/wet	4	21.9	23.0	27.9	23.4	24.1
Dura 843	8	23.2	22.1	26.8	21.9	23.5
Artesian Sunrise	7	22.7	21.1	28.5	21.5	23.4
AmeriStand 201 + Z	2	21.0	23.2	26.8	22.2	23.3
WL440HQ	6	22.0	22.0	26.8	21.1	23.0
Maxi-Graze GT	2	20.4	22.1	26.3	23.0	22.9
Rugged	3	21.2	21.7	26.4	22.4	22.9
Malone	7	21.6	22.0	27.7	19.4	22.7
LegenDairy 5.0	3	22.1	22.1	25.0	21.2	22.6
Ranger	3	21.5	22.1	25.3	21.3	22.6

Velvet	2	21.7	22.0	24.6	21.6	22.5
6422Q	4	20.7	21.6	25.2	22.2	22.4
WL363HQ	5	22.4	21.2	24.1	21.2	22.2
Dona Ana	7	22.2	22.1	25.7	18.2	22.1
NM Common	N/A	22.2	22.4	24.7	17.0	21.6
SW6330	6	22.3	21.1	25.8	16.6	21.4
African Common	N/A	22.7	22.0	23.6	16.6	21.2
Wilson	6	21.6	21.1	23.9	16.0	20.7
Average		22.1	22.4	26.5	21.4	23.7
LSD.05		1.9	2.1	3.2	2.9	1.9
CV %		6.24	6.83	8.50	9.47	5.83
p Value		0.1390	0.0469	0.0031	<0.0001	<0.0001
Significant		ns	*	**	***	***

Significance: ns = non-significant; * = significant at *p* value = 0.05; ** = significant at *p* value = 0.01; *** = significant at *p* value = 0.001.

4. Conclusions

This study evaluated different fall dormancy-rating alfalfa cultivars for their forage yield at each cut in two experiments. The results showed no statistical differences between the moderately dormant, dormant, and the non-dormant alfalfa cultivars while they showed higher forage yield than the very dormant and semi-dormant alfalfa cultivars. There was a decreasing trend in forage yield from the first cut to the fourth cut. Annual forage yield significantly increased from the first year to the third year of production and decreased in the fourth year of the production. All fall dormancy-ratings showed statistically similar annual forage yields however, the semi dormant cultivars obtained the lowest forage yield. In light of this study, alfalfa cultivars choice should not only focus on the fall dormancy-rating however, the dormant (FD 3, 4) and moderately dormant (FD 5) alfalfa cultivars may be appropriate for the high desert region of the Colorado Plateau of the US. Thus, Mountaineer 2.0, 54V09, Masterpiece, 4S417, SW435, and HybriForce 2400 could be considered by producers within the study region.

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