Journal of Animal and Veterinary Advances 12 (19): 1498-1503, 2013
ISSN: 1680-5593

Different Fall Dormancy Levels No Effected on Yields of Alfalfa in Northeast China

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Abstract: Due to the relationship between Fall Dormancy (FD) and the yield potential of alfalfa, varieties with contrasting FD levels has not been determined in the Northeast regions with cold Winters. This study was conducted with 17 varieties of five FD levels (2-6) over 3 consecutive years to determine the relationship of annual total Dry Matter (DM) yields with FD levels. The results showed that all the five FD varieties survived over the Winter without any persistency problems during the three production years. The greatest average DM yield of 7.93 Mg/ha/year was achieved with Runner (FD2) while the smallest yields were found in Defi (FD5). There were no differences in annual DM yields of varieties among FD levels 2-5. DM yields for some of the dormant, semidormant and non-dormant varieties were also the greatest and notable yield differences ($p<0.05$) were found among the same FD varieties whereas overall annual total DM yields were not correlated with FD levels. The data suggest that different fall dormancy levels no effected on yields of alfalfa in Northeast China and FD level should not be used as the main criteria for alfalfa variety improvement and/or introduction of new varieties in the cold regions such as Northeast China.

Key words: Alfalfa varieties, fall dormancy levels, DM yield, FD varieties, Runner

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is an important crop in China and its demand is expected to reach 1 million ton each year for dairy industry between 2010 and 2020 (Li *et al*., 2010). Therefore, it is imperative to breed more alfalfa cultivars with wider adaptabilities. However, Fall Dormancy (FD) is very important factor due to different geographic regions. Fall dormancy plays an important role in variety adaptation to particular regions associated with Winter survival and according to FD ratings, it is commonly classified into three groups: dormant (FD 1-3), semi-fall dormant (FD 4-6) and non-dormant cultivars (FD≥6) (Barnes *et al*., 1979). It is well known that dormant cultivars produce short and prostrate shoots in Autumn, exhibit slow stem elongation after Summer harvest and possess high Winter hardiness (Dhont *et al*., 2002; Haagenson *et al*., 2003b). In contrast, non-dormant cultivars grow vigorously in Autumn, forming long erect shoots and resume rapid shoot elongation after cutting in Summer and Autumn (Brummer *et al*., 2000; Haagenson *et al*., 2003a).

Due to the importance of FD in alfalfa adaptation and productivity, FD level is often used as the first index of selecting alfalfa varieties (Fairey *et al*., 1996). Especially, in recent years with fast development in animal husbandry, the areas of alfalfa production have expanded rapidly in China, many alfalfa varieties have been introduced into China from the United States and Canada. The concept of FD level was also accepted by the Chinese Scientific Community, Forage Production Board and the general alfalfa producers. So, the FD level of a new variety must be determined before its approval and characterization of FD levels has also become the first criteria in alfalfa variety of China. However, for FD level, much research has been conducted in the United States (Cunningham *et al*., 2001; Haagenson *et al*., 2003a, b) and few in China. There were a few studies reporting on DM yield differences among limited varieties with different FD levels (Zang *et al*., 2005), a possible relationship between FD and Autumn herbage yield (Leep *et al*., 2001) and association between FD and the non-structural carbohydrates accumulation in alfalfa roots and shoot in the Spring (Dhont *et al*., 2002). While some studies show the importance of early growth in production of alfalfa (Wang *et al*., 2004, 2005). There has been no attempt to establish the link between FD levels and annual yields. The objectives in this study were:

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- Determine DM yield differences among five FD levels of 17 foreign-originated varieties in comparison with a local variety
- Assess if there was a quantitative relationship between annual DM yields and FD levels
- If there were differences in DM yield among varieties of the same FD level

Such information is to better understanding of alfalfa variety adaptation in relation to FD in Northeast China.

MATERIALS AND METHODS

Experimental conditions: The field experiments were carried out at the Frigid Forage Research Station located in Shuihua region. The research station has an altitude of 160 m, longitude of 125°58' and latitude of 46°32'N in Songnen Plain, Northeast China (Chen *et al*., 2010). The climate is classifed as a typical chillness semi-wetness monsoon environment. The annual mean air temperature is 5.3°C with a maximum temperature of 31.2°C in July and a minimum temperature of -25.2°C in January. Average annual accumulated heat units (above 10°C) are 2,760°C. The average annual precipitation is 469.7 mm of which about 75% falls between June and August and the average annual free water evaporation is about 950 mm. The experiments were seeded on May 1, 2008 and crops grew for 2 years until 2011. The climate variables (rainfall, maximum and minimum temperatures) were recorded daily and are reported as average monthly data in Fig. 1.

Experimental design: The study was conducted by a randomized complete block design with four replications. The 17 varieties were introduced from overseas varieties while Zhaodong was the only local variety whose FD levels ranged from 2-6 (Table 1). FD levels for each variety were provided by the breeding company. Each plot is 3 m long and 2 m wide with inter-row spacing of 15 cm, seeded by hand on May 1, 2008 uniformly. Seeding rate was 15 kg ha^{-1} (the seeding rate used for individual varieties was adjusted by seed purity and germination rate to achieve the target population density of 200 plants/m^2). After seeding, the plot surface was pressed using a corrugated roller. Open perimeter area outside of the experiment was reserved to protect the experimental rows from interferential damage. No fertilizer or irrigation was applied during the experimental periods. Plots were hand-weeded during the growing period whenever necessary for proper weed control. In addition, the experiments were carried out for 3 consecutive years (2009-2011).

Table 1: Variety name, source of origin, their Fall Dormancy (FD) levels and overall average annual dry matter yield of alfalfa used in the field experiment conducted in Northeast, China from 2009-2011

Varieties	Breeding country	FD level†	Average yield (Mg/ha/year)
CW201	United States	2	6.87^{b}
Runner	United States	2	7.94^{a}
WL-252HQ	Canada	2	6.78^{b}
CW300	United States	2	6.68^{b}
Zhaodong	China	2	5.41^{e}
CW301	United States	3	4.95^{f}
WL-323HQ	United States	3	6.48^{c}
Alfaking	United States	3	7.09^{b}
WL-323	United States	4	5.47^{d}
WL-323ML	United States	4	7.62^{a}
Goldenkey	United States	4	7.66^{a}
Durango	Canada	5	6.12^{cd}
Defi	Canada	5	4.63^{f}
Derby	Australia	5	5.47^{e}
Sitel	France	5	6.12^{c}
Sanditi	France	5	6.29^{c}
CW675	United States	6	5.73^{d}
WL-414	United States	6	6.35^{e}

†FD level is calculated according to the criterion of Barnes *et al*. (1979). Different letters between rows are statistically different at p<0.05 and same letters between rows are not statistically different at p<0.05

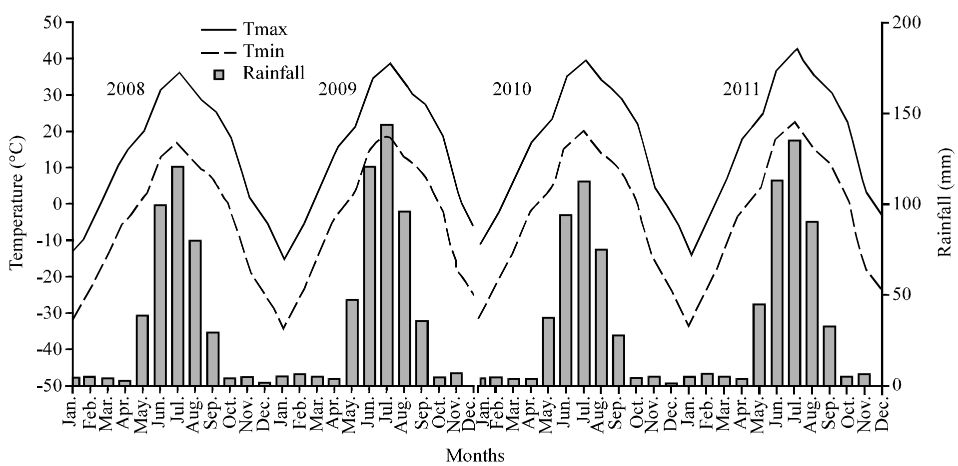

Fig. 1: Monthly maximum and minimum temperatures and total rainfall for 2008 and 2011 in Northeast, China

Observations and equipment: The over Winter survival rate was calculated depending on number of plants (in early November 2008 and again in later April 2009) in one randomly selected row per plot which were counted according to the following equation:

$$\text{Survival rate (\%)} = \frac{\text{Plant numbers in April 2009}}{\text{Plant numbers in November 2008}} \times 100$$

The alfalfa plants usually started to grow at near the end of April each year. DM yield of each variety was cut at early blooming stage and was determined for each plot with three cuts per year. Cutting frequencies occurred during a 120 days period of each year where the first cut took place in late May to early June and the third cut at the mid to the end of July. The final cut for all varieties took place in mid-october each year.

During experimental period there were 3 shoot regrowth cycles for the 18 varieties differed in FD levels from 2-6 but the average difference in blossom occurrence within a year was only 2 days with extremes of up to 4 days. At each sampling, plants from a 2 by 2 m area in each plot were cut at approximately, 5 cm above the ground. After cut, a 300 g sample of green herbage was collected from each plot at each harvest to weigh and then oven dry at 65°C to determine DM concentration. The DM yield was calculated and reported on a zero water basis.

Data analyses: Because FD level and variety are nested factors, two separate (one for FD level, the other for variety) ANOVA were performed on DM yield data each year. Similarly, pooled ANOVAs across years were run separately for FD level and variety factors. Due to a lack of normality, some data were square root transformed as appropriate prior to analysis. Where F-tests were significant ($p<0.05$), LSD was calculated to compare the means. All data were assessed for homogeneity of variance and normality and statistical analyses were performed using Statistical Computer Software SAS (SAS, 2002).

RESULTS

Over Winter survival rate comparisons among different FD levels: After the first Winter, number of plants were measured in early November 2008 and again in later April 2009. Almost all the varieties tested had nearly perfect over Winter survival rates while two varieties had slightly lower survival rates of 96 and 98%, respectively. In consecutive years (2009-2011), all varieties appeared normal and stand persistent without visible gaps of missing plants in any plots.

DM yield comparisons among different FD levels: During the 3 production years, the temperature profile during the 3 years trial was similar to the 30 years average with the highest temperature (25-28°C) recorded in July and August and the lowest just below 0°C recorded in December and January. The average of total annual rainfalls was about 500 mm not much different from the prior 30 year average. Generally, the rainfalls were mainly recorded between June and August during the growing seasons from year to year (Fig. 1). These weather variations were part of the reasons of annual total DM yield differences of the same varieties and the interaction (year x variety) on DM yields as presented.

Overall, the 17 varieties differed greatly in the average annual total DM yields (Table 1). In growing seasons, average forage yields of 17 varieties showed significantly in experiment ranged from 4.63-7.94 Mg/ha/year. The greatest total DM yields were produced by Runner (FD2), followed by Goldenkey (FD5) and WL-323ML (FD4) while the smallest yields were found in Defi, a semidormant variety (FD5) and CW301 another dormant variety (FD3) (Table 1).

Over a 3 years average DM yields which differed among the 3 production years for all FD levels (Table 2). In 2009 year the effect of FD on Alfalfa DM yields was observed significantly ($p \leq 0.05$) because the FD2 varieties and FD4 varieties had greater DM yields (6.53 and 6.47 Mg/ha/year, respectively) when compared to FD3 varieties (6.17 Mg/ha/year), FD4 varieties (6.11 Mg/ha/year) and FD5 varieties (6.04 Mg/ha/year) while in 2010 year the effect of FD levels on Alfalfa DM yields show coincident with the above results where FD2 varieties and FD4 varieties had more DM yields (5.71 and 5.71 Mg/ha/year, respectively) than FD6 varieties (6.04 Mg/ha/year) with FD3 varieties and FD5 varieties being intermediate (5.51 and 5.51 Mg/ha/year, respectively). In 2011, FD2 varieties and FD4 varieties had more DM yields (6.90 and 7.10 Mg/ha/year, respectively) than FD3 varieties (6.60 Mg/ha/year), FD5 varieties (6.63 Mg/ha/year) and FD6 varieties (6.73 Mg/ha/year). Across the 3 years, FD2 and FD4 varieties produced the greatest annual total DM yields, 5.5 and 6.1%,

Table 2: Dry Matter (DM) yields of each Fall Dormancy (FD) level varieties in a field experiment conducted in Northeast, China from 2009-2011

	Mg/ha/year			
FD	2009	2010	2011	Average
2	6.53^{a}	5.71^{a}	6.90^{a}	6.38^{a}
3	6.17^{b}	5.51^{b}	6.60^{b}	6.09^{a}
4	6.47^{a}	5.71^{a}	7.10^{a}	6.42^{a}
5	6.11^{b}	5.51^{b}	6.63^{b}	6.08^{a}
6	6.04^{c}	5.38^{c}	6.73^{b}	6.05^{a}

Different letters between rows are statistically different at $p<0.05$ and same letters between rows are not statistically different at $p<0.05$

Table 3: Dry Matter (DM) yields of alfalfa at each cutting averaged across all varieties in Northeast, China from 2009-2011

	Mg/ha/year			
Years	First cutting	Second cutting	Third cutting	Total yield
2009	4.33[a†]	2.34[a]	0.03[b]	6.69[a]
2010	3.81[b]	2.19[b]	0.09[b]	6.09[b]
2011	4.13[a]	2.39[a]	0.23[a]	6.74[a]

Table 4: Dry Matter (DM) yields of Fall Dormancy (FD) varieties in Northeast, China from 2009-2011

	Mg/ha/year		
Varieties	2009	2010	2011
FD2			
CW201	6.26[b†]	5.99[b]	8.35[b]
Runner	8.05[a]	8.12[a]	8.66[a]
WL-252HQ	6.18[bc]	5.91[b]	8.24[bc]
CW300	6.09[c]	5.82[b]	8.12[c]
Zhaodong	4.93[d]	4.71[c]	6.58[d]
FD3			
CW301	4.52[c]	4.32[c]	6.02[c]
WL-323HQ	5.91[b]	5.65[b]	7.88[b]
Alfaking	6.47[a]	6.18[a]	8.63[a]
FD4			
WL-323	4.99[b]	4.76[b]	6.65[b]
WL-323ML	6.95[a]	6.64[a]	9.26[a]
Goldenkey	6.98[a]	6.67[a]	9.31[a]
FD5			
Durango	5.58[a]	5.33[a]	7.44[a]
Defi	4.22[c]	4.03[c]	5.63[c]
Derby	4.99[bc]	4.76[bc]	6.65[b]
Sitel	5.58[a]	5.33[a]	7.44[a]
Sanditi	5.73[a]	5.48[a]	7.64[a]
FD6			
CW675	5.23[a]	5.00[a]	6.97[a]
WL-414	5.80[a]	5.54[a]	7.73[a]

†Different letters between rows are statistically different at $p<0.05$ and same letters between rows are not statistically different at $p<0.05$

respectively greater than those of FD6 varieties. Analysis of the overall data showed a very weak non-significant negative correlation between FD levels and annual total DM yields (r = -0.11). There was no interaction (year x FD). Overall, considering of weather condition (Fig. 1), there exist year effect with DM yields of >6.09 Mg/ha/year in 2009 and 2011 which are greater ($p<0.05$) than the other year (2010) (Table 3). Among the 3 years, the total DM yield in 2010 was the lowest (6.09 Mg/ha/year).

DM yield comparisons within the same FD level: Among the five FD levels, ANOVA showed that varieties of the same FD level differed greatly ($p<0.05$) in DM yields each year (Table 4). Within a FD level 2, the four alfalfa varieties of FD2 differed greatly ($p<0.05$) in DM yields from 2009 to 2011. For example, Runner had an average annual total DM yield of 7.94 Mg/ha/year, the greatest among all varieties while Zhaodong, in the same FD level, produced the lowest yield (5.41 Mg/ha/year). Similarly, CW201, another FD2 variety also produced greater ($p<0.05$) DM yields than that of Zhaodong in the three production years. On the contrary, varieties CW300, introduced from United States had 15.87% lower DM yields than Runner. Within a FD level 3, the three alfalfa varieties of FD3 differed greatly ($p<0.05$) in DM yields from 2009-2011 (Table 4). DM yields for Alfaking differed significantly by up to 30.2% than the low yielding varieties CW301 with varieties WL-323HQ being intermediate. Within a FD level 4, the three alfalfa varieties of FD4 differed greatly ($p<0.05$) in DM yields from 2009 to 2011 (Table 4). DM yields for Goldenkey and WL-323ML differed significantly by up to 28.5 and 28.2%, respectively than the low yielding varieties WL-323 with Goldenkey and WL-323ML being nonsignificant different. Within a FD level 5, the five alfalfa varieties of FD5 differed greatly ($p<0.05$) in DM yields from 2009-2011 (Table 4). DM yields for Sanditi differed significantly by up to 26.4% than the low yielding varieties Defi, with the others being nonsignificant different. Within a FD level 6, the two alfalfa varieties of FD6 were non-significant different in DM yields each year (Table 4).

In 3 production years, there was notable difference in the stability of DM yields among the same FD level varieties. For example, Runner a stable variety, produced in all the 3 years, great yields of 8.05 Mg ha^{-1} in 2009, 8.12 Mg ha^{-1} in 2010 and 8.66 Mg ha^{-1} in 2011, respectively whereas Goldenkey and WL-323 was an unstable variety with up to 28% differences in annual total DM yields.

DISCUSSION

Alfalfa (*Medicago sativa* L.) is an important hay crop in the world whose forage yield was thought to be associated with variety Fall Dormancy (FD) levels. This finding is consistent with those of similar studies on alfalfa yield in the United States (Smith, 1961; Barnes *et al*., 1979) and in the British Columbia (Stout and Hall, 1989). At the same time, several studies illustrated the relationship between FD and autumn forage yield in which emphasis is given to the importance of non-FD varieties in temperate regions where all alfalfa varieties with various FD types were able to grow. Recently, this finding is consistent with those of some Chinese studies (An *et al*., 2003; Li and Zhu, 2005; Wang *et al*., 2005) which showed that there appeared not to be an established relationship between FD levels and annual herbage yields in temperate regions. The study with 17 varieties with FD levels from 2-6 in Northeast China with cold climate provided solid evidence to support their claim. In fact, with cold climate in the regions of Northeast China, Winter survival of alfalfa crop is very important for the initial year of establishment. In the study, all 17 alfalfa varieties with five FD levels overwintered safely in the 1st year (2008) with survival rates >96% and there appeared to be no problem for any of the varieties in the subsequent years (2009 and 2010). Considering of the high Winter survival rate in this study, there appeared to be associated with overall warm Winter temperatures in 2009, although, extreme temperatures in January reached -30°C.

In this study, two key points was found. The first one was that non-significant correlation between annual DM yields and variety FD levels so that FD level should not be used as the main index for selecting alfalfa varieties in Northeast of China. The second one was that significant differences existed in DM yields among varieties with the same FD level from the data which implyed that varieties with more DM yield potentials are much more important than FD in some regions with cold climate which is in contrast with the current wisdom in the literature that FD level is the primary criteria for choosing alfalfa varieties in any production regions.

Through 3 years of yield, the magnitude of DM yield differences among most varieties tested in the research were approximate or similar with greater DM yields in the 3rd year (2011) than in the 1st year (2009) and the lowest in the 2nd year (2010). This trend of productivity across years was similar to that reported by Nie and Yan (2005) with one exception that in their study, there was little difference in variety yields in the 2nd production year which was greater than that of the 1st year. The weather in the second growing season in the study deviated markedly from the long-term average with higher rainfall and below normal mean daily air temperatures and less sunshine hours, leading to lower DM yields in year 2010. Among the three production years, the weather conditions played an important role in this structure change in alfalfa forage production. Likely, the general conclusions were made by Dhont *et al*. (2002) from North American studies where primary concerns in alfalfa production are to prepare the crop for over wintering which were highlighted in the study for the importance of early season management to achieve annual total yields in the Northeast region. In this study, annual DM yield was up to 63% in the first cut and up to 30% of the total annual yield for the second cuts. Therefore, in the cold region, effective management practices for alfalfa production should be focused on the early period (May to July) and it is of crucial importance to increase herbage yields in the first cut each year.

CONCLUSION

All the tested varieties were able to survive the Winter although their FD levels ranged from 2-6. There was no correlation between FD levels and total annual DM yields but differences in DM yields were found among different varieties within each FD level. Consequently, special attention should be paid to improve variety yield potential rather than variety FD levels. Different fall dormancy levels no effected on yields of alfalfa in Northeast China and FD level should not be considered as the sole and main index for selecting suitable varieties of alfalfa in the cold regions such as in Northeast China and other regions with similar climate.

ACKNOWLEDGEMENTS

Researchers thank colleagues of Institute of Pratacultural Science for their support and assistance to field study and thank Prof. Hua-Ping Zhou referees for their valuable comments on this manuscript. This project was financially supported by the key project of National Science and Technology Planning as part of the eleventh 5 Years Plan.

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