Yield Evaluation of Seventeen Lucerne Cultivars in the Beijing Area of China

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Abstract

Both high dry matter yield and good quality of lucerne (*Medicago sativa* L.) are important for hay production. From 2001 to 2007, a field study was conducted to evaluate the dry matter yield of seventeen cultivars in the Beijing area, China, and to determine the most suitable cultivars for this area. Seventeen lucerne cultivars were sown in late March of 2001 and were harvested for hay four times in each subsequent year. The results showed that, averaged across the six years, the top three cultivars with the highest annual dry matter yield were 'Germany' (16.9 t/ha), 'Baoding' (16.3 t/ha) and 'Zhongmu No.1' (15.7 t/ha), respectively. These cultivars were also the three with the greatest plant heights and dry matter yields at the first harvest. Yields varied between years, with the third year being the highest and the sixth, the lowest. Across all six years, the fourth harvest was the lowest yielding and had the lowest leaf to stem ratio whilst the first harvest had the highest yield and plant height and the second harvest, the highest ratio of leaf to stem. 'Germany' and 'Zhongmu No.1' had high persistence and resistance to disease and insects.

Keywords: Cultivars, Dry matter yield, Lucerne, Plant height, Resistance

1. Introduction

Lucerne (*Medicago sativa* L.) is an important forage crop that has high yield, high nutritional value and adaptability (Geng 1995; Chen & Xu 2001; Yang 2003). In recent years, the expanding intensive livestock systems have resulted in a large demand for forage in China. However, grassland sown to lucerne was about 2.6×10^6 ha and produced 25×10^6 t hay, far lower than the actual demand, and this has led to an increase in the price of lucerne forage (Han 1999; Wang 2005). A program titled "Returning degraded land or marginal land to forest or grass", similar to the Conservation Reserve Program in USA, was initiated across China in 1999 to conserve soil and water resources in areas prone to erosion. Lucerne was widely cultivated as a soil cover or as windbreaks in arid and semi-arid areas of northern China. Thus, the area devoted to forage production of lucerne has increased steadily in last ten years, which has stimulated interest in the factors that limit lucerne forage production.

Since 2000, many lucerne cultivars have been introduced into Beijing area, northeastern China. However, little information is available on the forage yield and the resistance of these cultivars to disease and insects in the local

environment, which limited the forage production of lucerne. In this study, seventeen lucerne cultivars were tested over six consecutive years. The main objective was to determine the adaptability of these lucerne cultivars and select the best ones for forage production in this area. The second objective was to provide information for lucerne breeding in the Beijing area.

2. Materaials and Methods

The field study was conducted at the Animal Science Institute, Chinese Academy of Agricultural Sciences, located in Beijing, northeastern China (latitude 39°57′N, longitude 116°18′E), from 2001 to 2007. The area has a warm temperate semi-moist continental climate. The mean air temperature is 11.5°C. The mean rainfall is about 600 mm, over 70% of which falls from June to October. Soil at the site is an eluvial cinnamon soil. Chemical characteristics of the soil (0-60 cm) are listed in Table 1. The previous crop was corn (*Zea mays*). The residual was ploughed and the field was prepared for sowing.

The experiment used a randomised complete block design with three replications. Seventeen lucerne cultivars included 'Germany', 'Algonquin', 'Gold Empress', 'Vernal', 'Farmer's Treasure', 'Sanditi', 'Defy', 'WL232', 'CW300', 'CW323', 'CW400', 'CW1351', '4RR', 'Zhongmu No.1', 'Ao Han' and 'Baoding'. The sources of the seventeen cultivars are shown in Table 1. The trial was sown in March of 2001. Individual plot size was 2.5 m by 4 m. The trial was drilled at a seeding rate of 15 kg/ha, a seeding depth of 2 cm and a between-row spacing of 60 cm. In each year, the experimental field was irrigated in November at a rate of 90 mm. No fertiliser was applied. Weeds were controlled with hand hoeing as needed

2.1 Data collection

2.1.1 Yield measurement

Lucerne was harvested at 25% flowering (between early flowering and full flowering stage), four times each year from 2002 to 2007. Table 2 presents each harvesting date for the six years. At each harvest, fresh weights were determined by hand harvesting the whole plot, and sub-samples (1 kg) were then dried at 60°C to obtain a constant dry weight. The dry matter yield (DMY) was calculated on a dry-weight basis. Annual yield was the summation of the DMY of four harvests in the same calendar year.

2.1.2 Plant height and ratio of leaf to stem

Before harvesting, plant heights were determined by taking measurements on 10 stems selected randomly in each plot. In 2007, another sample (10 stems) per plot were clipped, dried and separated into leaves and stems for estimating the percentage ratio of leaf to stem as follows.

Ratio of leaf to stem =(Leaf weight/(Leaf weight+Stem weight))*100%

The differences among the four harvests were also tested for dry matter yield, plant height and leaf/stem ratio.

2.1.3 Insect pests

Plots were rated for *Odontothrips lati* Haliday damage using the rating score of 1 to 3, where 1 is slight injury with crimpling evident on less than 25% of leaves, 2 is moderate crimpling on 25% to 75% of leaves, and 3 is severe crimpling on more than 75% of leaves.

2.1.4 Evaluation of diseases

Several leaf diseases were often observed together in the same plant. Consequently, we computed the disease index by lesion area not by disease species.

The first evaluation occurred on 20th July of 2005, and the second was on 9th August of 2005. Twenty plants were randomly selected from each plot and five stems of each plant were tested. The plants were rated using a 0 to 5 scale, where 0 denotes no infected stems and 5 denotes when all stems are 100% infected.

Disease index was estimated as follows. Y =((the number of disease plants×scale of disease)/ (the number of investigated plants × maximum score))*100.

In April of 2007 and 2009, the numbers of plants per plot were recorded and were used to calculate the number of plants per square meter.

2.1.5 Statistical analysis

Mean separations for 17 cultivars and four harvests were performed using Fisher's protected LSD test at a $P \leq 0.05$ significance level. These analysis procedures were performed using the MIXED procedure of the SPSS statistical software package (SPSS 2000).

3. Results

3.1 Dry matter yield

Averaged across six years, annual DMY of seventeen cultivars were quite variable, ranging from 10.1 to 16.9 t/ha (Figure 1). The three cultivars with the highest mean annual DMYs were 'Germany' (16.9 t/ha), 'Baoding' (16.3 t/ha) and Zhongmu No.1 (15.7 t/ha), respectively; these cultivars were not significantly different (P<0.05). The cultivars with the lowest mean annual DMYs were 'Gold Empress' (10.8 t/ha), 'Vernal' (10.6 t/ha) and 'Farmer's Treasure' (10.1 t/ha), respectively; no significant differences were observed among these cultivars. There were significant differences in DMY among four harvests averaged across six years (Table 3) (P<0.05). For all 17 cultivars, the first harvest resulted in the highest DMY and the fourth harvest, the lowest, and there was a decreasing trend in DMY from the first to the fourth harvest. The top three cultivars with the highest DMY of the first harvest were 'Germany' (6.5 t/ha), 'Baoding' (7.0 t/ha) and 'Zhongmu No.1' (6.7 t/ha), which were the same as those with the highest mean annual DMY. Similarly, the cultivars with the lowest mean annual DMY also had the lowest values of the first harvest.

This experiment showed wide variation for DMY among six years of the study (Table 4). The highest annual DMY were obtained in 2003 for all cultivars, except for 'AoHan', 'WL232' and 'Gold Empress'. From 2005 to 2007, the annual DMY of 17 cultivars except 'Sanditi' 'Vernal' and 'Defy' decreased year by year, and for seven cultivars, the annual DMY of 2007 were lower than those of 2002.

3.2 Plant height and ratio of leaf to stem

There were significant differences in plant height among four harvests averaged across 6 years (Table 5) (P<0.05). For all seventeen cultivars, the first harvest resulted in the highest plant height and the fourth harvest, the lowest. Furthermore, there were no significant differences between the second and third harvests for twelve cultivars.

Averaged across four harvests, the similar trends were shown in plant height those were demonstrated in DMY. The two cultivars ('Vernal' and 'Farmer's Treasure') with the lowest means of plant height also produced the lowest DMY (Figure 2).

Significant differences in the ratio of leaf to stem were also detected among four harvests averaged across six years (Table 6) (P<0.05). Generally, the highest and lowest values were obtained with the second and fourth harvest for all cultivars, respectively. In each harvest, the two cultivars, 'Farmer's Treasure' and 'Sanditi', resulted in the highest two ratios of leaf to stem in number.

3.3 Insect pests and diseases

The two cultivars with the lowest *Odontothrips lati* Haliday damage scores were 'Germany' and 'Zhongmu No.1', while 'Sanditi', 'Defy' and 'Farmer's Treasure' had the highest scores (Table 7). Based on the comparision of two tests, the disease index increased as the stand developed from 20 July to 9 August in 2005. The three cultivars with the highest disease index were 'WL 232', 'CW 323' and 'Defy'.

In the sixth harvest year, the plant densities of seventeen cultivars were tested, reflecting the stand longevity and persistence of these cultivars in the local environment. 'Germany' exhibited the highest plant densities among seventeen cultivars in two evaluations. In April 2007 the plant densities of 'CW400', 'CW300', 'Zhongmu No.1' and 'Baoding' exceeded 70 plants/m^2. From 2007 to 2009, the plant densities of all seventeen cultivars decreased by more than 10%.

4. Discussion

Many researches have reported significant differences in dry matter yield of lucerne among different harvest times (Jefferson & Gossen 1992; Llovera & Ferran 1998). In this study, seventeen cultivars were harvested by mowing four times a year in six consecutive years. Averaged across six years , the DMY of the first harvest were consistently the highest among four harvests, accounting for 37 % of the mean annual DMY. The second, for 26 %; the third, for 22 %; the fourth, for 15 %. These findings are in agreement with other studies that suggest that the DMY of the first harvest forms about 40% of annual DMY, and the DMY of each harvest decreases from the first to third or fourth harvest (Hoy et al . 2002; Yang et al. 2005; Lu & Yu 2006). So selections based on the DMY in the first harvest will help to select plants or populations with high annual DMY in lucerne breeding and introduction (Zang et al. 2005)

Furthermore, it is important to determine the fluctuation of annual DMY and stand longevity for lucerne hay production. Some studies testing the DMY over many years indicated that lucerne exhibited high DMY at its third and fourth years (Qiao 1990; Luo et al. 2001; Cao 2002)**.** In our experiment, the significant differences

were detected in annual DMY among six harvesting years when no irrigation and fertilisation were applied. Fourteen of seventeen lucerne cultivars produced the highest annual DMY in the second harvest year, while two other cultivars ('WL232' and 'Gold Empresss') did so in the third harvest year. After the fourth harvest year, the annual DMY of 15 cultivars decreased year by year, and for 9 cultivars, the annual DMY of 2007 were lower than those of 2002. On the whole, the lucerne cultivars could be harvested for hay production for five or six years in Beijing area, with the highest annual DMY in the second harvest year.

Plant height and the ratio of leaf to stem are important criteria for lucerne forage production (Frakes et al. 1961; George et al. 1964; Davis et al. 1966; Li 1997;). Using one lucerne cultivar ('Zhongmu No.1') for three harvests a year in Beijing, Yang et al. (2005) found that the first harvest gave the maximum plant height during the study, and the plant height of the second harvest was significantly lower than the first and third harvest. These results are consistent with the findings of our experiment that for 17 cultivars, the plant heights of the first harvest were the highest among four harvests. The ratio of leaf to stem is strongly correlated to the palatability and quality of lucerne forage (Liu et al. 2008). Some researches have showed that the ratio of leaf to stem decreased from the budding stage to flowering stage, and primarily responded after the early flowering stage (Basu & Poushinsky 1978; Yi & Peng 1993; Wang 2004). Our study indicated that the second harvest had the highest ratio of leaf to stem and the fourth had the lowest when lucerne was harvested four times a year in the Beijing area.

During the past five decades, breeding efforts have resulted in nearly all currently marketed lucerne cultivars having high resistance to a wide variety of important diseases and insects (AOSCA 2002). Consequently, it is very important to evaluate if the resistance holds in the Beijing area for in lucerne production and breeding. There were three main insect pests of lucerne in the Beijing area: *Odontothrips lati*, *Adelphocoris lineolatus* and *Tettigoniella viridis* with *Odontothrips lati* being the most damaging. The effects of *Odontothrips lati* result in a large decrease in DMY and quality of lucerne hay, so the cultivars with high resistance to *Odontothrips lati* such as 'Germany' and 'Zhongmu No.1' are recommended for planting in the Beijing area. Weekly monitoring of fields is recommended from June to August when *Odontothrips lati* damage becomes serious. From the investigation of the disease resistance of 23 lucerne cultivars in the Beijing area, Zhang et al. (2003) found that all cultivars were influenced by root diseases such as fusarum root rot complex, rhizoctonia rot, pythium root rot and sclerotinia rot. However, few root diseases were detected in this study, and leaf diseases became the major factor affecting lucerne. Furthermore, the leaf diseases mainly occurred in July, August and September, and several leaf diseases often were observed together in the same plant.

5. Conclusion

Averaged across the six years, cultivar 'Germany', 'Baoding' and 'Zhongmu No.1' had high annual dry matter yield. 'Germany' and 'Zhongmu No.1' also had high persistence and resistance to disease and insects. So these two cultivars are suitable to be recommended for planting in the Beijing area.

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Table 1. The sources of seventeen lucerne cultivars

Cultivar	**Source**	**Cultivar**	**Source**	**Cultivar**	**Source**
'Algonquin'	Canada	'Zhongmu No.1'	China	'Vernal'	USA
'Germany'	Germany	'Sanditi'	Holand	'CW300'	USA
'CW1351'	USA	'Defy'	Holand	'4RR'	USA
'AoHan'	China	'WL232'	USA	'CW323'	USA
'Victoria'	USA	'Gold Empress'	USA	'CW400'	USA
'Baoding'	China	'Farmer's Treasure'	USA		

Table 2. Dates of harvesting in six years

Year	Harvest 1	Harvest 2	Harvest 3	Harvest 4
2002	24 May	2 July	6 Aug.	16 Oct.
2003	27 May	3 July	14 Sept.	13 Oct.
2004	18 May	27 June	21 Aug.	13 Oct.
2005	18 May	2 June	30 July	20 Sept.
2006	18 May	22 June	28 July	22 Sept.
2007	18 May	22 June	1 Aug.	24 Sept.

Table 3. Dry matter herbage yield (t/ha) of 17 lucerne cultivars in the different cutting times. Values are means with stand errors. A lower case letter means significant difference ($P < 0.05$) down the column

Cultivar	Harvest 1	Harvest 2	Harvest 3	Harvest 4
'Algonquin'	4.1±0.0^a	2.7±0.1^b	2.6 ±0.1^b	1.6±0.0^c
'Germany'	6.5 ±0.6^a	4.6 ±0.3^b	3.6±0.0^c	2.2±0.0^d
'CW1351'	5.6 ±0.2^a	3.3 ±0.1^b	2.9 ±0.1^b	2.0 ±0.0^c
'AoHan'	5.9 ±0.7^a	2.8 ±0.2^b	2.6 ±0.2^b	1.8 ±0.1^c
'Victoria'	5.4 ±0.2^a	3.6 ±0.2^b	3.2 ±0.2^b	2.1 ±0.1^c
'Baoding'	7.0 ±0.1^a	4.0 ±0.1^b	3.1±0.0^c	2.3±0.0^d
'Zhongmu No.1'	6.7 ±0.1^a	3.6 ±0.1^b	3.1 ±0.1^b	2.2 ±0.0^c
'Sanditi'	4.4 ±0.0^a	2.8 ±0.2^b	2.7 ±0.1^b	1.6 ±0.1^c
'Defy'	4.9 ±0.1^a	3.1 ±0.2^b	2.9 ±0.1^b	1.7 ±0.1^c
'WL232'	4.6 ±0.3^a	3.7 ±0.2^b	3.1±0.2^c	2.1±0.1^d
'Gold Empress'	4.0 ±0.2^a	2.7 ±0.1^b	2.4±0.1^b	1.7 ±0.0^c
'Farmer's Treasure'	3.9 ±0.4^a	2.4 ±0.3^b	2.2±0.2^b	1.6 ±0.1^c
'Vernal'	3.9 ±0.3^a	2.8 ±0.1^b	2.3±0.1^b	1.7 ±0.1^c
'CW300'	5.1 ±0.5^a	3.8 ±0.5^b	3.2±0.3^c	2.2±0.1^d
'4RR'	5.0 ±0.1^a	3.3 ±0.1^b	3.0 ±0.0^b	2.1 ±0.0^c
'CW323'	4.5 ±0.3^a	3.4 ±0.3^b	2.7±0.2^c	1.9±0.0^d
'CW400'	5.3 ±0.4^a	3.8 ±0.4^b	3.1±0.1^c	2.2±0.0^d
Average	5.1±0.2^a	3.3±0.1^b	2.9±0.1^c	2.0±0.0^d

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Table 4. Dry matter herbage yield (t/ha) of 17 lucerne cultivars in the different years. Values are means with stand errors. A lower case letter means significant difference ($P < 0.05$) down the column

Cultivar	2002	2003	2004	2005	2006	2007
'Algonquin'	12.0±0.2^{ab}	13.5±0.9^{a}	13.0±1.0^{a}	10.3±0.5^{bc}	9.9±0.2^{bc}	9.4±0.8^{c}
'Germany'	16.8±1.9^{b}	19.5±1.2^{a}	18.8±0.3^{ab}	16.6±1.3^{b}	16.5±0.6^{b}	12.2±0.7^{c}
'CW1351'	13.3±0.2^{c}	17.0±0.6^{a}	16.2±0.4^{ab}	14.0±0.6 ^{bc}	13.6±0.8^{c}	10.3±0.8^{d}
'AoHan'	16.1±1.6^{a}	15.6±1.7^{a}	14.6±1.1^{ab}	12.5±1.1^{bc}	12.2±1.2^{c}	10.6±0.6^{c}
'Victoria'	14.5±0.3^{b}	17.6±0.9^{a}	16.5±0.2^{ab}	14.8±1.1^{b}	14.1±1.3^{b}	11.1±0.9^{c}
'Baoding'	18.2±0.5^{a}	18.3±0.9^{a}	17.8±0.7^{a}	16.9±0.2^{a}	16.0±0.1^{a}	12.9±0.4^{b}
'Zhongmu No.1'	16.5±0.4^{ab}	18.3±0.4^{a}	17.6±0.5^{ab}	16.4±0.4^{ab}	15.4±0.2^{b}	12.3±0.5^{c}
'Sanditi'	7.7±0.5^{c}	14.2±0.8^{a}	13.2±0.3^{a}	11.7±0.5^{ab}	12.6±0.4^{ab}	10.6±0.6^{b}
'Defy'	11.3±1.2^{cd}	16.0±0.7^{a}	14.5±1.4^{ab}	12.4±1.1^{bc}	13.3±0.5^{bc}	9.1±0.4^{d}
'WL232'	11.0±0.8^{b}	15.3±1.1^{a}	15.8±0.8^{a}	15.1±1.0^{a}	14.7±1.4^{a}	11.2±0.3^{b}
'Gold Empress'	7.0±0.4^{c}	13.1±0.8^{a}	13.3±0.1^{a}	12.5±0.5^{a}	11.1±0.2^{ab}	9.4±1.2^{b}
'Farmer's Treasure'	7.2±0.8^{d}	14.0±1.2^{a}	12.7±1.1^{ab}	11.4±1.1^{bc}	10.0±1.2^{c}	7.4±0.6^{d}
'Vernal'	6.6±1.5^{c}	13.0±1.0^{a}	12.7±0.3^{a}	11.2±0.2^{ab}	11.3±0.5^{ab}	9.4±1.0^{b}
'CW300'	8.9±0.8^{d}	17.8±1.8^{a}	17.6±1.7^{a}	16.3±1.5^{ab}	14.6±2.2^{bc}	12.7±0.8^{c}
'4RR'	9.2±0.3^{d}	16.8±0.7^{a}	15.4±0.9^{a}b	15.6±0.2^{ab}	13.3±0.2^{bc}	12.5±0.7^{c}
'CW323'	6.1±0.1^{d}	16.0±0.7^{a}	15.6±1.0^{ab}	15.6±0.9^{ab}	13.2±1.2^{b}	10.8±0.8^{c}
'CW400'	9.2±0.6^{d}	18.4±1.5^{a}	17.2±2.1^{a}b	16.5±1.0^{ab}	14.7±1.4^{bc}	13.2±0.2^{c}
Average	11.3±1.8^{e}	16.1±1.0^{a}	15.4±1.0^{b}	14.1±1.0^{c}	13.3±1.0^{d}	10.9±0.8^{e}

Table 5. Plant height (cm) of 17 lucerne cultivars in the different cutting times. Values are means with stand errors. A lower case letter means significant difference ($P < 0.05$) down the column

Cultivar	Harvest 1	Harvest 2	Harvest 3	Harvest 4
'Algonquin'	73.0±1.5^{a}	58.1±2.2^{c}	66.6±0.7^{b}	30.5±0.6^{d}
'Germany'	90.6 ±2.1^{a}	78.1±1.1^{b}	72.1±5.7^{c}	38.5±1.4^{d}
'CW1351'	79.1 ±2.0^{a}	67.0 ±2.4^{b}	70.0 ±2.3^{b}	32.0±1.1^{c}
'AoHan'	84.5±3.7^{a}	57.9 ±1.2^{b}	56.9 ±1.3^{b}	26.4 ±0.8^{c}
'Victoria'	86.4 ±1.3^{a}	72.3 ±2.1^{b}	74.0 ±0.4^{b}	35.3 ±0.6^{c}
'Baoding'	96.3 ±2.0^{a}	74.3 ±1.6^{b}	71.4 ±0.3^{b}	35.5 ±0.9^{c}
'Zhongmu No.1'	98.4±0.7^{a}	72.0 ±3.9^{b}	69.0 ±5.1^{b}	37.1 ±0.6^{c}
'Sanditi'	80.3 ±1.6^{a}	65.5±0.9^{c}	72.8 ±1.1^{b}	36.7±0.5^{d}
'Defy'	79.8 ±1.9^{a}	69.2 ±0.7^{b}	71.5 ±1.9^{b}	35.5 ±0.7^{c}
'WL232'	75.2 ±1.2^{a}	67.7 ±0.3^{b}	71.2±0.3^{ab}	34.0 ±0.1^{c}
'Gold Empress'	76.8 ±1.1^{a}	62.1 ±1.9^{c}	68.7 ±0.9^{b}	33.3±0.5^{d}
'Farmer's treasure'	71.0 ±1.9^{a}	60.0 ±2.6^{b}	65.1±0.5^{b}	31.2 ±1.1^{c}
'Vernal'	67.8 ±3.6^{a}	61.2 ±1.0^{b}	67.0±0.6^{a}	30.9±0.9^{c}
'CW300'	74.9 ±2.8^{a}	64.9 ±2.0^{b}	70.7±1.9^{a}	34.5 ±1.3^{c}
'4RR'	75.6 ±2.1^{a}	65.5 ±1.3^{b}	72.0±0.3^{a}	36.1 ±0.5^{c}
'CW323'	76.8 ±1.6^{a}	67.6 ±1.8^{b}	70.6±1.9^{b}	34.9 ±0.4^{c}
'CW400'	79.7 ±3.3^{a}	69.2 ±1.5^{c}	74.5±0.5^{b}	36.8 ±0.7^{c}
Average	80.4 ±4.4^{a}	66.6 ±3.1^{c}	69.6 ±2.6^{b}	34.1 ±1.6^{d}

Table 6. Ratio of leaf to stem of 17 cultivars in the different cutting times. Values are means with stand errors. A lower case letter means significant difference ($P < 0.05$) down the column

Cultivar	Harvest 1	Harvest 2	Harvest 3	Harvest 4
'Algonquin'	48.0 ±0.5^{b}	50.7 ±1.0^{a}	46.8 ±0.6^{bc}	46.0±0.9^{c}
'Germany'	50.5 ±1.0^{b}	52.8±1.2^{a}	48.7±1.9^{c}	47.7±2.0^{c}
'CW1351'	46.5±1.0^{b}	49.5±0.5^{a}	44.7±0.8^{c}	43.3±0.8^{c}
'AoHan'	50.0±0.5^{b}	51.7±0.6^{a}	48.5±0.9^{bc}	47.2±1.0^{c}
'Victoria'	46.0±0.5^{b}	49.3±0.8^{a}	44.5±0.5^{bc}	43.8±0.6^{c}
'Baoding'	49.3±0.8^{b}	51.8±1.6^{a}	48.0±0.9^{bc}	46.5±0.5^{c}
'Zhongmu No.1'	50.0±0.5^{b}	53.0±1.3^{a}	48.3±0.8^{c}	46.5±0.9^{d}
'Sanditi'	50.5±1.0^{b}	53.2±1.5^{a}	49.5±1.0^{bc}	48.2±1.3^{c}
'Defy'	46.5±0.5^{b}	48.7±1.0^{a}	45.0±0.5^{bc}	43.7±0.6^{c}
'WL232'	47.7±0.8^{b}	49.7±0.3^{a}	45.3±0.8^{c}	44.0±0.9^{c}
'Gold Empress'	49.3±0.8^{b}	51.7±0.8^{a}	47.5±0.9^{c}	46.7±1.0^{c}
'Farmer's Treasure'	52.5±1.0^{b}	55.0±0.9^{a}	50.5±1.5^{c}	49.2±1.8^{c}
'Vernal'	49.0±0.5^{b}	51.8±1.2^{a}	46.7±0.6^{c}	45.3±0.8^{c}
'CW300'	46.0±0.5^{b}	49.7±0.3^{a}	43.3±1.6^{c}	41.8±1.3^{c}
'4RR'	49.0±0.5^{b}	51.8±1.5^{a}	47.7±0.3^{bc}	46.7±0.8^{c}
'CW323'	47.5±0.5^{b}	50.5±1.0^{a}	45.5±0.0^{c}	44.2±0.8^{c}
'CW400'	45.0±0.5^{b}	49.3±0.8^{a}	43.8±1.3^{bc}	43.3±1.2^{c}
Average	48.4±0.3^{b}	51.2±0.3^{a}	46.7±0.3^{c}	45.5±0.3^{d}

Table 7. Density and rating for disease and insect pest tolerance of seventeen lucerne cultivars.

Cultivar	Plants/m^2		Scores of *Odontothrips lati* Haliday damage	Disease index	
	April 2007	April 2009		20 July 20	9 August 2005
'Algonquin'	5.2	3.2	3	32.3	49.8
'Germany'	9.5	8.2	1	30.6	51.3
'CW1351'	6.5	5.6	2	32.6	71.4
'AoHan'	6.8	5.2	1.3	9.8	73.8
'Victoria'	6.5	5.7	1.7	40.1	75.3
'Baoding'	7.2	5.1	2.5	28.1	58.0
'Zhongmu No.1'	7.0	4.1	1	23.1	60.3
'Sanditi'	6.1	4.6	2.7	25.6	69.5
'Defy'	6.2	3.4	2.7	51.2	78.3
'WL232'	6.5	5.0	1.3	55.3	88.4
'Gold Empress'	5.0	3.2	1.5	36.7	72.4
'Farmer's Treasure'	4.6	3.2	2.7	31.4	63.2
'Vernal'	5.0	3.6	1.6	35.8	75.3
'CW300'	7.5	5.2	1.5	34.8	77.3
'4RR'	6.8	5.1	2	23.2	70.5
'CW323'	6.3	4.6	2	56.1	81.3
'CW400'	7.6	6.4	2	28.0	75.6

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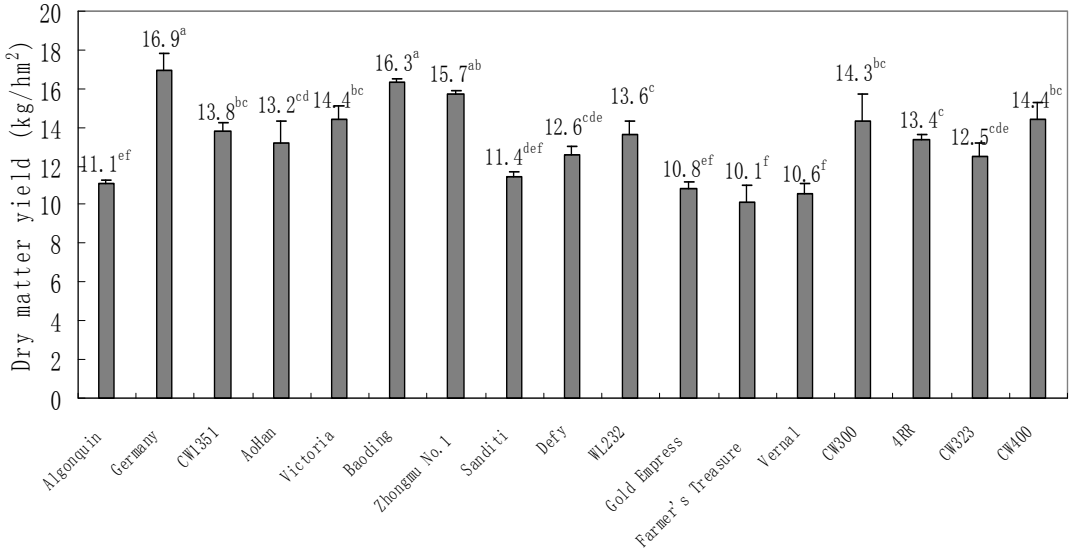

Figure 1. Annual dry matter yield of seventeen cultivars averaged across six years. Means are represented by bars with stand errors. Different lower case letters indicate significance at the 0.05 probability level

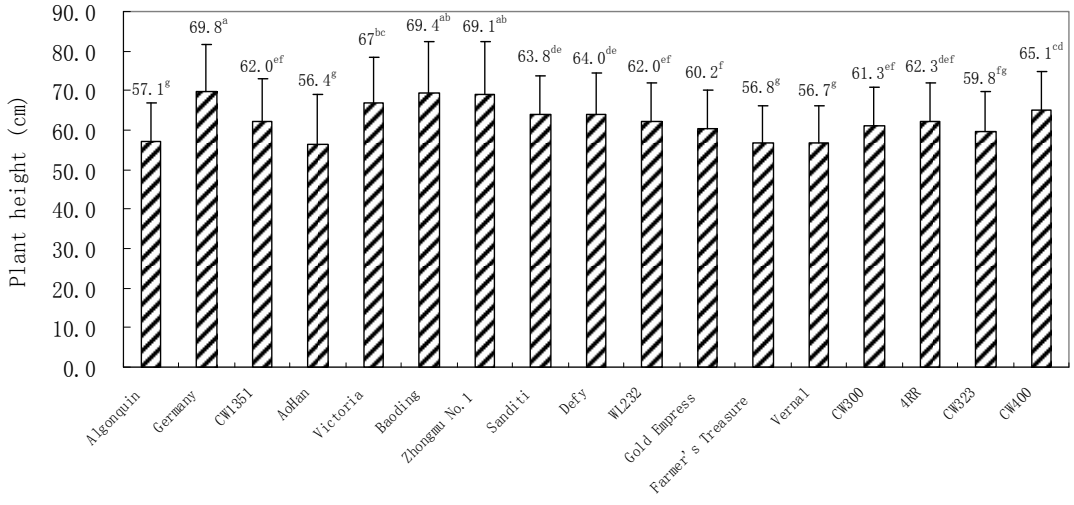

Figure 2. Plant heights of seventeen cultivars averaged across four harvests. Means are represented by bars with stand errors. Different lower case letters indicate significance at the 0.05 probability level