Productivity of vetches (*Vicia* spp.) under alpine grassland conditions in China

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Abstract

Improved lines each of common vetch (*Vicia sativa)*, woolly-pod vetch (*V. villosa*) and narbon vetch (*V. narbonensis*) obtained from the International Center for Agricultural Research in the Dry Areas (ICARDA) were evaluated for seed and forage production at 4 sites in the alpine grassland of China. Annual mean rainfall and temperature ranges were 253–661 mm and 1.4–3.6°C, respectively. Differences in productivity were found between the 3 vetch species and between the lines within each species. Nine common vetch and 4 narbon vetch lines produced seeds. Common vetch lines 2505, 2556, 2560 and 2566 and narbon vetch line 2561 were identified as having the necessary potential for seed and forage production in China's alpine grasslands.

Introduction

Alpine grasslands account for more than 30% of the total grassland area in China and are the major source of feed for yak and Tibetan sheep kept by millions of poor farmers in the region. They mainly occur on the Qinghai-Tibet Plateau at more than 2500 m above sea level, where annual temperature averages less than 5°C. The productivity of these alpine grasslands has declined recently due to over-grazing (Ren *et al*. 2000). Nan (2005) recommended integrating grassland grazing with the use of sown pastures and forage legumes to provide hay for winter and early-spring feeding as one way of reducing the grazing pressure and improving livestock productivity in the region. However, due to low temperatures and short growing periods found in the alpine grassland areas, perennial forage legumes cannot survive, and annual legumes cannot produce sufficient seeds when planted there. Therefore, studies have been conducted in an attempt to introduce or develop perennial forage legume cultivars that are adapted to alpine conditions. These included studies on: germplasm evaluation (Yan 1990); the breeding of cold-tolerant cultivars through hybridisation of existing genetic resources (Cao *et al*. 1991); and the development of cultural practices which would protect sown forage legume pastures from winter and spring damage (Cui *et al*. 1997; Sun and Gui 2001). However, these efforts have met with little or no success.

Common vetch (*Vicia sativa*) is an important annual forage legume which is grown both in China (Wang and Ren 1989) and other parts of the world (Abd El-Moneim and Ryan 2004). In China, smallholder crop-livestock farmers on the Loess Plateau sow common vetch for livestock feed and soil conservation purposes (Li 1984; Wu 1993), while herders in the alpine grassland areas grow vetch in association with oats (*Avena sativa*) for hay (Ma and Han 2001). Most of the locally available vetch cultivars cannot produce seed under these conditions. However, the *Vicia* species found elsewhere in the world exhibit considerable diversity, and this could be explored to find seed-producing material suitable for China. West Asia and north Africa (WANA), for example, are the centres of origin and primary diversity for *Vicia* species (Robertson *et al*. 1996), and many species can be found in the world's largest collection of forage legumes, which is held by the International Centre for Agricultural Research in the Dry Areas (ICARDA). ICARDA also runs

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an active *Vicia* improvement program (Abd El-Moneim 1993; Abd El-Moneim and Ryan 2004). Promising lines of common vetch, narbon vetch (*V. narbonensis*) and woolly-pod vetch (*V. villosa* ssp. *dasycarpa*) selected for cold and drought tolerance, were therefore introduced to China from ICARDA's collection and evaluated under the alpine grassland conditions found in the country. This paper reports the results of a 4-year study that assessed the seed and forage yields of these lines at 4 sites in China.

Materials and methods

Experimental sites

Two experiments were conducted at 4 sites in the alpine grassland area of Gansu Province, China during the period 1998–2002. The climate and edaphic conditions found at the experimental sites are presented in Table 1.

Experimental treatments and design

Experiment 1. Nine lines of common vetch (2486, 2505, 2556, 2558, 2560, 2566, 2604, 2616 and 2628) and 10 each of narbon vetch (2378, 2381, 2386, 2388, 2391, 2461, 2465, 2469, 2470 and 2561) and woolly-pod vetch (2432, 2438, 2439, 2442, 2445, 2450, 2451, 2452, 2457 and 2562) were evaluated in 1998 and 1999 in Xiahe, Tibetan Autonomous County using a randomised complete block design with 4 replicates at each site. Plots were 2 × 2 m, and 1-m wide paths were located between replicates, while plots within a replicate were separated by 0.5 m paths. Seeds were sown by hand, in rows 0.25 m apart at 75 kg/ha for common vetch and 60 kg/ha for woolly-pod and narbon vetch. Sowing dates varied between 22 April and 15 May each year, when the air temperature was constantly higher than 5°C at each site. Plots were hand-weeded and no fertiliser was applied. Whole plots were harvested between 15 and 26 September each year at all sites. At harvest, all mature pods were hand-picked, air-dried, threshed, and the weight of seeds was subsequently recorded. The remaining herbage including the immature pods was cut to ground level with a sickle and weighed to estimate forage yield. Sub-samples (500 g) were oven-dried at 90°C for 24 hours to allow an estimate of dry matter (DM) to be made.

Experiment 2. Four common vetch lines (2505, 2556, 2560 and 2566), selected from Experiment 1 on the basis of days to maturity and yield of seed and fodder, were evaluated at Xiahe, Maqu, Luqu and Sunan counties in 2001 and 2002. The experimental design and methods used were similar to those used in Experiment 1.

Statistical analysis

Data were analysed using the General Linear Models (GLM) procedures (SAS 1987). In Experiment 1, seed and forage yield data for common vetch were pooled over both years because there was no significant year × line interaction. The model for Experiment 2 included site, line and year as well as their interactions.

Results

Experiment 1

Common vetch. Forage and seed yield varied significantly ($P<0.05$) among lines, with lines

Table 1. Summary of climatic and soil (0-10 cm depth) characteristics of the experimental sites, Gansu Province, China.

Item	Xiahe	Luqu	Maqu	Sunan
Location	35°12′N, 102°31′E	34°35′N, 102°30′E	34°43′N, 101°44′E	38°48′N, 99°36′E
Elevation (m)	3000	3100	3470	2700
Mean daily temperature (°C)	2.6	2.3	1.4	3.6
Mean annual rainfall (mm)	444	612	616	253
Soil type	Chernozem	Chernozem	Sierozem	Castanozem
Organic carbon (g/kg)	42	52	45	40
Available nutrients				
• Nitrogen (g/kg)	23.4	23.6	23.4	25.0
• Phosphorus (mg/kg)	7.5	10.5	12.8	12.8
• Potassium (g/kg)	17.5	17.5	19.1	Not available

2556, 2560, 2566 and 2604 yielding more than 6t/ha DM (Figure 1). Lines 2505 and 2628 produced more than 1 t/ha seed over the 2-year study period. Based on data on days to maturity and yield of forage and seed, lines 2505, 2556, 2560 and 2566 were selected for further studies at 3 additional sites in 2001 and 2002.

Narbon vetch. In 1998, forage DM yield of the narbon vetch lines varied significantly (P<0.05), from 2.89 t/ha in line 2386 to 5.15 t/ha in line 2561 (Figure 2a). Only 4 of the 10 lines produced seeds, the yield of which ranged from 0.32 t/ha in line 2465 to 0.82 t/ha in line 2561. In 1999, forage yield of the 4 lines which had produced seed in

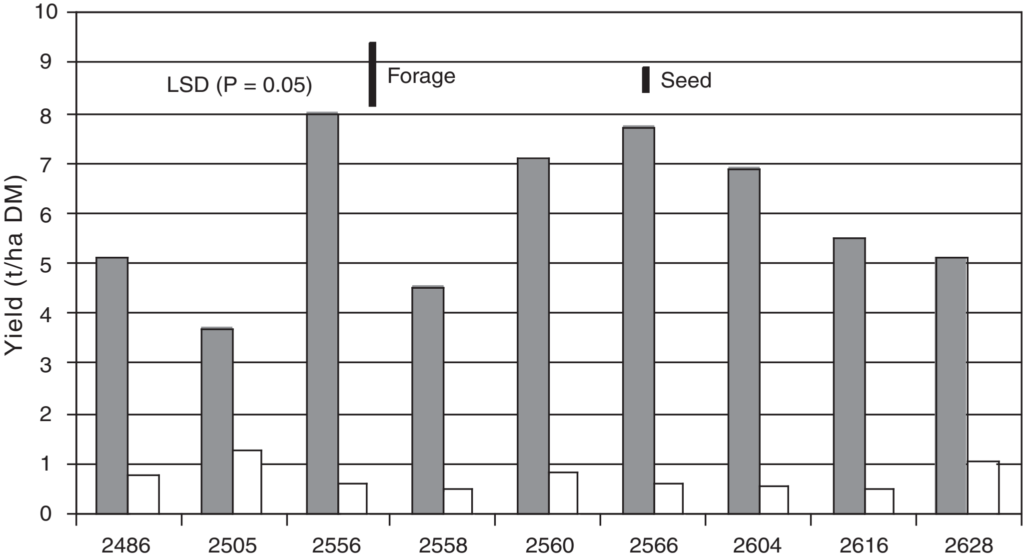

Figure 1. Average forage (shaded bars) and seed (white bars) yields of common vetch (*Vicia sativa*) lines at Xiahe County, Gansu Province, China in 1998 and 1999.

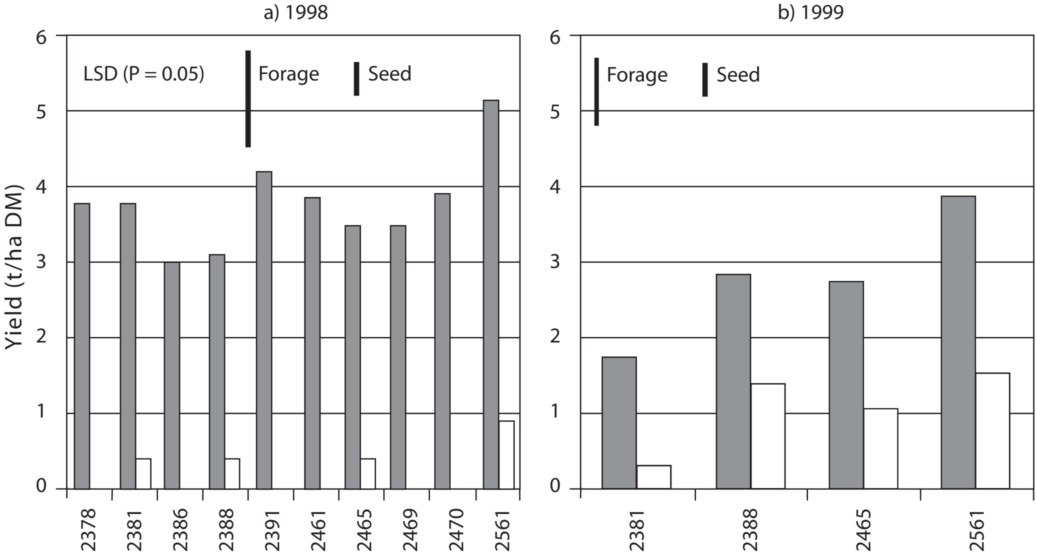

Figure 2. Forage (shaded bars) and seed (white bars) yields by narbon vetch (*Vicia narbonensis*) lines at Xiahe County, Gansu Province, China in 1998 and 1999.

1998 declined by 10–54% (Figure 2b); by contrast, the seed yield of lines 2561, 2465 and 2388 increased by 85, 240 and 282%, respectively.

Woolly-pod vetch. All lines produced more than 8 t/ha DM in 1998 with lines 2439, 2451, 2452 and 2562 producing more than 10 t/ha DM (Figure 3). None of the lines produced seed in 1998, and because seed production was a major selection criterion, the trial on woolly-pod vetch was terminated after the first year.

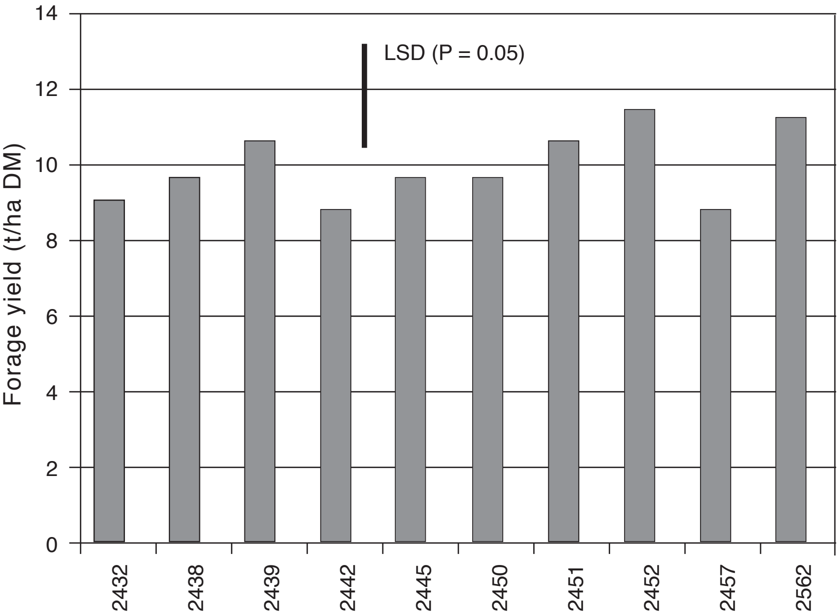

Figure 3. Average forage yields of woolly-pod vetch (*Vicia villosa* ssp. *dasycarpa*) lines at Xiahe County, Gansu Province, China in 1998.

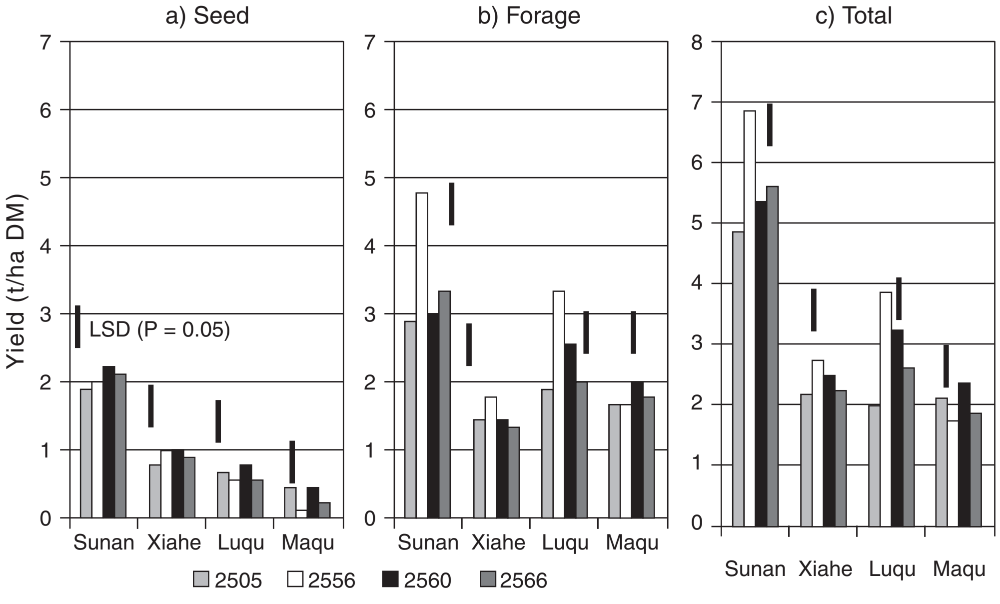

Figure 4. Seed, forage and total yields of common vetch (*Vicia sativa*) lines at 4 sites in Gansu Province, China in 2001 and 2002.

Experiment 2

Average seed, forage and total yields of the 4 promising common vetch lines sown at each of the trial sites in 2001–2002 are shown in Figure 4. While line 2560 produced the highest seed yields at Sunan, Xiahe and Luqu (Figure 4a), the differences were not significant (P>0.05). Overall, seed yields were higher at Sunan than at the other 3 sites. Forage yields were higher in line 2556 than in the other 3 lines at Sunan and Luqu (P<0.05) and Xiahe (P>0.05). As for seed yield, forage yield at Sunan was generally higher than at the other sites. Total yield at Sunan exceeded that at the other sites and total yield of line 2556 was higher than that of the other lines at Sunan and Luqu (P<0.05).

Discussion

This is the first report of a systematic evaluation of *Vicia* species lines grown under alpine grassland conditions in China. In agreement with other studies (Abd El-Moneim *et al*. 1990; ICARDA 2000), forage and seed yield varied significantly between the lines of narbon vetch and woolly-pod vetch grown at Xiahe (Experiment 1), and common vetch in Xiahe, Sunan, Luqu and Maqu. Of the 3 species evaluated at Xiahe (Experiment 1), woolly-pod vetch produced more forage than common vetch and narbon vetch. Similar results have been reported for comparative trials of woolly-pod vetch and common vetch under rain-fed conditions on the Loess Plateau (Wu 1993) and under irrigation on the Northern Plain (Zhang *et al*. 1992) in China, and also for the 3 species in WANA (Abd El-Moneim 1992).

Previous research in Xiahe and other regions with similar environmental conditions revealed that common vetch was not well adapted to alpine grasslands (Yan 1990). By contrast, this study showed common vetch to be the most promising species because all 9 lines tested produced seeds and a substantial amount of forage at Xiahe, and lines 2560, 2556 and 2566 produced a total biomass of more than 4 t/ha at Sunan and 2 t/ha at Xiahe and Luqu. This reflects great diversity in both adaptation and productivity of common vetch. The seed and forage production of the common vetch lines at Sunan were significantly higher than at the other sites (Figure 4) partly because Sunan has a relatively higher mean temperature (Table 1) and possibly longer daylight than the other sites. Furthermore, the climatic conditions at Sunan are more representative of the conditions in the WANA region, where the lines were developed.

The overall objective of ICARDA's vetch breeding program is to develop and disseminate genotypes adapted to areas with annual rainfall ranging from 233–504 mm and absolute minimum temperature from 5.8 to 9.9°C (Abd El-Moneim and Ryan 2004). The mean annual rainfall at the experimental sites used in the current study (253–661 mm) was similar to that in ICARDA's target regions in which the lines were developed. However, the mean temperature at the sites (1.4–3.6°C, Table 1) was far colder than the target range. The seed and forage yields of the various vetch lines in our study show that some lines selected by ICARDA are obviously adapted to regions with relatively lower temperatures than those found in WANA.

With high seedling vigour, rapid winter growth and high yields of seed and straw (Abd El-Moneim and Cocks 1988; ICARDA 2000), narbon vetch is probably one of the most attractive annual forage legumes for the dry areas. To our knowledge, this is the first report from China on the evaluation of narbon vetch as a forage legume. Four of the 10 lines studied flowered at Xiahe, suggesting that it would be possible to select genotypes adapted to alpine grassland conditions. Among the lines studied, line 2561 appeared to have great potential in the crop-livestock production system in China.

The failure of woolly-pod vetch lines to produce seeds at Xiahe, supports the conclusion of Abd El-Moneim (1992) that woolly-pod vetch is poorly adapted to alpine grassland conditions. However, it may fit into Chinese farming systems in areas in which the growth period is longer and the mean temperature is higher than in Xiahe.

This study has identified lines of common vetch (2505, 2556, 2560 and 2566) and narbon vetch (2561) that have potential for seed and forage production in the alpine grasslands of China. Further studies are warranted in order to integrate the promising lines into the smallholder crop-livestock farming systems found there.

Acknowledgements

The project was jointly supported by the Science and Technology Department of Gansu Province, China and the International Centre for Agricultural Research in the Dry Areas (ICARDA). The senior author thanks Professor Fernand Lambein for his encouragement.

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(Received for publication September 9, 2005; accepted February 20, 2006)