Legumes for cropping systems in the Democratic Peoples Republic of Korea

Jeffrey Evans[1], Edwin Wolfe[2], Mun Yun-Guk[3], Ri Yong-Jo[4] and Kim Tong-Ryul[3]

[1]NSW Agriculture, Agricultural Institute, PMB, Wagga Wagga, NSW 2650 Australia
[2]Charles Sturt University, Farrer Centre, Locked Bag 588, Wagga Wagga, NSW 2678 Australia
[3]Kim Il Sung University, Pyongyang, DPRK
[4]Pyongyang Agricultural University, Pyongyang, DPRK

Abstract

Over the last decade in the Democratic Peoples Republic of Korea (DPRK), the yields of the staple crops rice and maize declined to less than half of their known potential (8 t/ha). Insufficient application of fertiliser, soil erosion (maize) and extreme climatic events (drought, flooding, high winds) were responsible, at least in part, for the decline. Current production is constrained by low soil fertility and tenuous domestic supplies of fertiliser, particularly nitrogen. Even when supplemented with international donations, the supply of nitrogen fertiliser is inadequate to achieve food self-sufficiency. In an effort to produce sustainable, higher yielding crops, we are seeking to introduce legumes into rice and maize cropping systems to produce nitrogen, organic matter and soil stabilisation benefits to soils in the DPRK. To avoid competing with staple grains during the late May to September (summer) growing season, the legume phase ideally will be based on green manure legumes that are sown in autumn, survive winter temperatures as low as -20^{o}C and grow productively in spring. After severe winters, it may be necessary to re-establish the legume phase post-winter. In 2002, over 400 legumes of diverse genera and species, mostly sourced from cold climate regions, were established in hill plots at Pyongyang, DPRK. There were 2 sowing dates prior to winter and 2 sowing dates post winter. In this preliminary investigation, all legumes were grown with adequate mineral fertiliser. On the basis of observations in spring for apparent winter survival, biomass and ground cover, 25 accessions were rated as potentially promising/highly promising for autumn sowing and 42 for post-winter sowing.

Media summary

Several legumes from Australian collections survived the severe winter in North Korea, and may be suitable for use in rotations to improve the production of rice and maize.

Key Words

Legumes, rice, maize, Democratic Peoples Republic of Korea

Introduction

Rice and maize are the major grain crops produced in the DPRK. A decade ago the yields of these staple crops approached 8 t/ha (Michalk and Mueller 2003), with production supported by fertiliser, machinery and energy inputs from local and imported sources. However, this support has declined significantly as a result of economic difficulties faced by the country since the early 1990s. Subsequent efforts to maintain yield levels led to the over-exploitation of DPRK soils, resulting in the further loss of soil nutrients, loss of soil stability and soil erosion. According to the DPRK Ministry of Agriculture (cited by Michalk and Mueller 2003), only 30% of soils in the agricultural provinces are classed as ‘good’ (soil organic matter content >2% and a maize yield potential of 3-6 t/ha). A further 30-40% of soils are considered ‘degraded’ (soil organic matter <1%, maize yield potential <1.5 t/ha). These soils also have low exchangeable cation capacity (<6 meq/100 g) and base saturation (<20%), and inadequate available phosphorus (5-10 mg/kg). According to statistics collected by UNDP and the FAO/World Food Program (Michalk and Mueller 2003), current average yields of rice and maize are around 2 to 3 t/ha. These yields are inadequate to provide for the food and nutritional needs of the domestic population, with annual deficits in grain production of 1.5 to 2 Mt [FAO/WFP Crop Mission 2001; Bulletins on the DPRK Situation, United Nations Office for the Coordination of Humanitarian Affairs (OCHA)].

Insufficient fertiliser is one of the main constraints to higher grain yields. Domestic production of granulated urea is now less than a third of its production in 1995 because of fuel deficiencies. Thus, 'aid' fertiliser is regularly sought, which in some seasons can be as much as 400,000 t urea and 220,000 t of NPK (source: OCHA Bulletins). Food supply in the DPRK therefore relies on tenuous, international donations of fertiliser and grain.

In 2000, the Australian Centre for International Agricultural Research (ACIAR) evaluated and reported on the situation for cropping systems in DPRK (RA Fischer, pers. comm.). In May-June 2001 in Australia, ACIAR sponsored a short course in soil management for 8 DPRK soil scientists and agronomists. This initiative led on to a collaborative project between the scientists in DPRK and Australia during 2002-2004, a project that is funded by ACIAR and focussed on building scientific capacity to develop sustainable systems for rice and maize production through the use of legume green manures and minimum tillage. Current experiments in DPRK comprise (1) a search for potentially suitable legumes, capable of surviving the harsh winter and then producing herbage and fixing N in spring, (2) cropping experiments with winter/spring legumes and minimum tillage in rice paddy and hillside (maize) locations at 2 sites near Pyongyang in the central western grain region, and (3) tillage, cover and soil loss investigations in the maize culture system. In this report is described a preliminary evaluation in DPRK of the winter survival and spring growth of a diverse range of forage legumes.

Legume evaluation

Essential for a legume phase in DPRK rice- and maize-based production systems are green manure legumes that fit into the calendar for grain production during the summer cropping season (May-September). Ideally, the legumes would be established in September/October after the grain harvest and then, prior to rice transplanting or maize sowing in May/June, the green material could be grazed, desiccated or incorporated with soil. Hence, suitable legumes must be adapted to survive low winter temperatures, which in January at Pyongyang average -8^{o}C (mean) and -12^{o}C (daily minimum) and which frequently fall to minima as low as -20^{o}C and beyond in most seasons. After severe winters, the post-winter re-establishment of a legume phase may be necessary, in which case rapid spring growth will be important. Average precipitation over the late autumn-spring period (October – April) in Pyongyang is 208 mm, including snowfall.

We therefore sought to screen a range of legume genotypes, available from the Australian *Trifolium* and *Medicago* Genetic Resource Centres located in Perth and Adelaide, respectively. The legumes were selected primarily on the basis of (1) their collection from cold sites (>1000 m altitude) and (2) seed availability. The resultant 437 legumes comprised the following genera (species) and genotypes: *Astragalus* spp. (15) 26, *Coronilla* sp. (1) 1, *Dorycnium* spp. (3) 12, *Erophaca* sp. (1) 1, *Hedysarum* sp. (1) 1, *Hippocrepis* sp. (1) 1, *Hosackia* sp. (1) 1, *Hymenocarpus* sp. (1) 4, *Lathyrus* spp. (2) 2, *Lens* sp. (1) 1, *Lotus* spp. (11) 18, *Lupinus* sp. (1) 1, *Medicago* spp. (28) 84, *Onobrychis* sp. (1) 1, *Ononis* sp. (1) 1, *Ornithopus* spp. (3) 3, *Pisum* sp. (1) 2, *Scorpiurus* spp. (3) 4, *Securigera* spp. (2) 2, *Tetragonolobus* spp. (3) 4, *Trifolium* spp. (57) 234, *Trigonella* spp. (11) 13 and *Vicia* spp. (13) 20. In some cases the same species was sourced from different geographical locations, and some of the species comprised sub-species. A few genotypes did not originate from altitudes >1000 m. A detailed list of the legumes is available on request.

The site of the investigation was in a field at the Pyongyang Agricultural University. All seed was scarified and then each legume was sown separately in the centre of a 'hill plot' (20 cm x 20 cm, 0.18 g/plot) on each of 4 occasions: 25 September 2002 and 9 October 2002 (pre-winter); 6 March 2003 and 14 March 2003 (post-winter). The legumes were randomised to 'hill plot' locations on a 20 cm grid. The layout was the same for each of the sowing times (blocks) and no replication was used within sowing dates. All legumes were grown with complete fertiliser (Thrive^{TM}) because an effective inoculant was not known for all species. The Thrive fertiliser (27% N, 5.5% P and 9% K) was dissolved in water and applied at a rate of 0.4g per 'hill plot' (10g/m^2).

On 30 April 2003, each of the 'hill plots' was scored by a team of 3 persons for winter survival (first 2 sowings, scale 0 = no survival to 5 = good survival), biomass production (all sowings, 0 = no biomass to

10 = excellent level of green biomass) and ground cover (all sowings, 0 = no material to 5 = excellent cover, spreading beyond 400 cm^2). Without cutting, the hill plots sown on 6 and 14 March were re-assessed for biomass and cover on 1 June.

Results

Of the 437 legumes sown on four occasions, 8 failed to produce biomass from any sowing; presumably the seed of these was not viable. A further 46 genotypes produced biomass from only one of the sowing times. At the other extreme, 25 genotypes were adjudged ‘highly promising’ or ‘promising’ on the basis of their good survival from both pre-winter sowings and their overall biomass and cover ratings in spring. These legumes are shown with their country of origin in Table 1.

Table 1. **Score evaluation (30 April 2003) of legumes sown on 25 September 2002**

Legume (genotype no.)	Origin	Survival 0-5	Spring biomass 0-10	Cover 0-5
	Highly promising			
Astragalus vogelii (389)	Ethiopia	5	10	5
Medicago crassipes (401)	Turkey	5	10	5
Medicago sativa *(227)*	Russia	5	10	5
Medicago sativa (333)	Afghanistan	5	10	5
Medicago sativa (421)	Russia	5	10	5
Medicago sativa (422)[+]	China	5	10	5
Medicago sativa (423)	China	5	10	5
Medicago sativa (398)	China	5	10	3
Medicago sativa (438)	Australia	5	10	3
	Promising			
Medicago phrygia (400)[+]	Turkey	5	7.5	5
Medicago fischeriana (321)	Turkey	5	7.5	3

Medicago fischeriana (393)	Turkey	5	7.5	3
Medicago rigidula (253)	Turkey	5	7.5	3
Medicago rigidula (297)[+]	Iran	5	7.5	3
Medicago sativa (228)	Russia	5	7.5	3
Medicago sativa (229)	China	5	7.5	3
Medicago sativa (235)	Russia	5	7.5	3
Medicago sativa (244)	Iran	5	7.5	3
Medicago sativa (245)	Russia	5	7.5	3
Medicago sativa (416)[+]	Australia	4	7.5	3
Medicago sativa (424)	Romania	4	7.5	3
Trifolium michelianum (403)[+]	Turkey	4	7.5	3
Medicago arcuata (320)	Iran	4	5	2
Lotus corniculatus (436)[+]	USSR	4	5	2
Trifolium resupinatum (402)[+]	Unknown	2	2.5	1

Notes: The *Lotus* accession (#436) was included in the short-list for further winter testing, in spite of its failure to survive from the late (October) sowing. The overall winter-spring performance of the *Trifolium resupinatum* genotype #402 was not particularly good but it was classed as the best of the rest of the Trifolium accessions. The 7 genotypes marked [+] were rated 'promising/highly promising' when sown not only pre-winter but also post-winter.

For the post-winter sowings, 42 genotypes were classed as 'highly promising' or 'promising' on the basis of good biomass ratings and adequate cover ratings at 30 April and 1 June. These genotypes included *Medicago sativa* 4, other *Medicago* 13, *Trifolium* 14, *Vicia* 5, *Trigonella* 2 and 1 representative from *Hymenocarpus*, *Pisum*, *Lotus* and *Onobrychis*.

Discussion

A range of forage legumes is needed for the variety of climates, soils and agricultural niches in DPRK. During the 2002-2003 season, the winter survival and spring productivity of several accessions, notably from the *Medicago* genus were excellent results. The winter-hardiness of at least some lines of

Astragalus spp., *Medicago sativa* and annual *Medicago* spp. such as *rigidula* was expected, since the cold tolerance of these genotypes in the Northern Hemisphere is appreciated scientifically and commercially (Bennett and Cocks 1999; Maxted and Bennett 2001). Only one line of hairy vetch (*Vicia villosa*), a species that is used as a winter hardy legume in China and in DPRK, was included in the group that were tested. This line and 19 other *Vicia* genotypes did not survive the winter conditions that were experienced but, in green manure experiments conducted in DPRK, the team successfully used a commercial hairy vetch line from China during 2002/03 and 2003/04. The poor over-winter performance of the bulk of the *Trifolium* genotypes in 2002/03 was disappointing but expected on the basis of previous experience with clovers in DPRK.

Hardy and productive lines of *Medicago sativa* may be less suited than comparable *Medicago* annual species to the role of a single-season green manure crop. Lucerne/alfalfa is vigorous and difficult to kill in summer (Davies and Peoples 2003) whereas annuals are less likely to compete with the subsequent crop and they could regenerate naturally. However, many of the DPRK soils may be too acid to support a healthy *Medicago-Rhizobium* symbiosis, and genotypes that are both winter hardy and acid-tolerant are potentially valuable. This latter need justified the inclusion of two *Trifolium* genotypes (#402, 403) and a *Lotus* accession (#436) in the short-list for further testing. As a result of this preliminary assessment, all of the lines listed in Table 1 were selected for re-evaluation in DPRK. Unfortunately the seed arrived too late to sow in a replicated experiment during the 2003/04 winter, and that experiment will be conducted in 2005/06. However, sufficient seed was available to sow a single replicate. The results from that replicate confirmed the winter hardiness and spring vigour of several genotypes of *Medicago* species.

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