BREEDING BETTER LUCERNES FOR THE CROPPING ZONE OF EASTERN AUSTRALIA

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Abstract

Lucerne-based rotations are the key to sustainable farming systems in the cropping zone. A cohort of lines were bred from a range of sources using recurrent selection for persistence and pest and disease resistance. Of these lines, Y8622 was identified from trials across NSW as a new persistent lucerne to replace the aphid-susceptible cultivar Hunter River. Y8622 averaged 130 percent of the site mean plant frequency after four years across ten rainfed sites and was the only lucerne to consistently persist better than the site mean in all sites. Additional lines are being bred and evaluated specifically to increase productivity and N-fixation and to provide greater suitability for their use in both short and longer term crop rotations. New on-farm trials will foster co-learning networks between farmers and researchers and improve the adoption of lucerne-based rotations. This will help reduce land degradation in the cropping zone of eastern Australia and improve both grain yield and protein.

Key words: Lucerne, pastures, rotations, breeding

Declining soil fertility and land degradation has put at risk the viability and profitability of the grains industry (6). Wheat yield potentials in the northern region alone have declined by as much as 50% and grain protein levels have fallen from 16-17% to 8-10% (3). ?Many soils cropped for 20-70 years in this region have also lost 20-45% of their organic carbon and nitrogen (2).

Lucerne pastures are the key to sustainable cropping systems for many soils. Only lucerne-based rotations can reliably deliver soil N in excess of crop removal, minimise disruption to soil aggregates, and optimise soil water use. For example, lucerne can fix between 50 and 463 kg of N/ha/yr (10). Lucerne pastures also disrupt crop insect and disease cycles, increase soil organic matter, and improve soil structure (1). Holford (8) has demonstrated that wheat sown in rotation with lucerne generally produced greater yields and higher protein levels than after continuous wheat in the northern cropp-ing zone. The Warra experiment in Queensland also showed that lucerne-based pastures significantly increased farm profitability (4).

Both NSW Agriculture and the GRDC have recogn-ised a need to develop better lucerne-based rotations as the key component of sustainable cropping systems. ?Meetings between research providers, the GRDC, and grower groups have culminated in a major new lucerne program involving NSW Agriculture (NSWA), the Queensland Department of Primary Industries (QDPI), and the CRC for Tropical Plant Pathology (CRCTPP) at the University of Queensland. This new program is breeding better lucernes for rainfed pastures while also developing and encouraging better methods of using and integrating these pastures within cropping systems. ?

Materials and Methods

Although the "Better lucernes for crop rotations" project has only recently commenced, since 1986 the NSW lucerne program has sought to improve the survival and long-term productivity of lucerne for rainfed pastures in the wheat/sheep belt in NSW. In particular, the program aimed to breed an improved semi-winter-dormant lucerne to replace the aphid-susceptible cultivar, 'Hunter River' in rainfed pastures. ?A large number of new lines were bred from four germplasm pools using recurrent phenotypic selection among and within half-sib families for pest and disease resistance and persistence in rainfed trials. The original four germplasm pools included (1) Hunter River clones selected along the Lachlan River by F. Hely, CSIRO, for superior persistence under dryland grazing, (2) re-selected populations derived from clones of 'B' and 'C' breeding lines bred by I. Kaehne of the SA Lucerne Program in 1984, (3) re-selected versions of "M" breed-ing lines, also from SA, and incorporating elite germ-plasm from Iraq, Spain, and

Algeria selected for grazing tolerance and persistence under harsh conditions, and (4) several synthetics derived from persistent clones of cultivars in five earlier trials in NSW. All lines derived from each germplasm pool were sown as pure stands in rainfed trials throughout NSW - in 1988 at Yanco (YD88) and Tamworth (TD88), and in 1992 at Narrabri (ND92), Walgett (WD92), Tamworth (TD92), Purle-waugh (PD92), Dubbo (DD92), Condobolin (CD92), Temora (TM92), and Yanco (YD92).

All trials were grazed according to local management decisions, and not necessarily in a strict rotation. All trials also experienced widespread and lengthy drought periods, particularly in 1994. Forage dry matter yield was measured at strategic times during the four year life of each trial. Stand density (ie. plant survival) after four years in each site was measured on the basis of two counts of the frequency (presence or absence) of lucerne crowns in 100 squares, each 10 cm^2. Total yield and stand density data were then expressed relative to the mean of each site.

Results

Aquarius is a highly winter-active cultivar bred by NSWA for high rainfall and irrigated conditions. Nevertheless, as shown in Tables 1 and 2, this cultivar generally performed better than other highly-winter active cultivars and yielded and persisted as well as the successful winter-active cultivar Aurora across most of the low rainfall sites. Aquarius is the first lucerne with high resistance to Phytophthora root rot and it is possible that its healthy root systems may give it an advantage over other highly winter-active cultivars in storing energy for regrowth (high yield) and in retrieving water during drought (good survival). This proposal will be examined in further studies.

The winter-active cultivar Genesis was recently released by NSWA as a general purpose cultivar for rainfed and irrigated sites. This broadly-adapted cultivar was the only cultivar in the 1988 and 1992-sown trials to combine the desired characteristics of relatively high yield and good persistence across most sites (Tables 1 and 2). These data suggest that Genesis will provide a generally superior alternative to other winter-active cultivars such as Aurora and Trifecta in rainfed pastures. Nevertheless, for unknown reasons, Genesis failed to persist in trials at Dubbo and Condobolin.

Breeding line Y8622 was unique among all lines and cultivars in maintaining high relative plant frequencies for at least four years in all trials in which it was tested (Table 1). The relative survival of line Y8622 across sites suggests it is broadly adapted to a wide range of environmental and managerial conditions. Not only did it consistently rank among the top few lines and cultivars in persistence in each trial, line Y8622 also fulfilled the major breeding objective by persisting as well as or better than the well adapted cultivar, Hunter River in eight of the ten trials.

Generally, better persistence in lucerne is often gained at the expense of yielding ability. Nevertheless, yields of line Y8622 were generally equivalent to the site mean for most trials in which it was tested (Table 2). It generally out-yielded Hunter River and matched the yield performance of successful cultivars such as P581 and Aurora. However, as only strategic cuts could be made, care must be taken in interpreting the total yield performance of lines and cultivars from the limited cuts taken in some sites. Its performance under irrigation at Tamworth (data not shown) confirms that the total yields of line Y8622 will generally be less than those of more active types where cutting/grazing is extended into the cooler months. However, semi-dormant lucernes such as line Y8622 have higher leaf to stem weight ratios and greater fodder quality than more winter-active types.

Line Y8622 is currently being commercialised as a new semi-winter-dormant lucerne with excellent persistence and good productivity in rainfed pastures. It succeeds in providing a superior alternative to the persistent, but aphid-susceptible cultivar, Hunter River. Line Y8622, as a semi-dormant cultivar, will also complement previous cultivars released from the NSW lucerne breeding program. It will provide a generally better option than these and other cultivars, particularly when dense plant stands need to be maintained for at least three years under more marginal conditions and/or when grazing management is less than ideal. Line Y8622 will be named in conjunction with the selected commercial partner and protected under PBR legislation.

Table 1: Stand density after four years for breeding line Y8622 and a subset of nine standard cultivars expressed as a percentage of the respective site mean of all entries in rainfed trials sown in 1988 & 1992.

CULTIVAR	1988-sown trials		1992-sown trials								
	YD88	TD88	ND92	WD92	TD92	PD92	DD92	CD92	TM92	YD92	Mean
Line Y8622	123	136	125	115	160	106	155	127	133	123	130.3
Hunter River	114	134	100	126	155	114	150	103	125	100	122.1
P581	66	98	113	88	97	92	90	78	135	94	95.1
P L52	-	-	112	87	71	93	130	83	138	102	102.0
WL S. Special	74	102	90	83	122	89	83	84	85	114	92.6
Aurora	108	111	63	126	60	94	76	91	113	103	94.5
Trifecta	102	99	108	85	71	95	79	81	63	91	87.4
Genesis	112	128	134	135	122	112	83	65	125	110	112.6
Aquarius	-	119	89	103	95	98	79	86	107	105	97.9
Cuf101	56	62	39	89	48	75	61	99	116	79	72.4
Site mean	29.2	30.1	8.2	16.4	19.0	23.7	16.3	18.6	10.8	42.4	
Trial age (months)	56	46	49	57	52	48	49	48	48	52	

Table 2: Total dry matter yield of breeding line Y8622 and a subset of nine standard cultivars expressed as a percentage of the respective site mean of all entries in rainfed trials sown in 1988 & 1992.

CULTIVAR	1988-sown trials		1992-sown trials								
	YD88	TD88	ND92	WD92	TD92	PD92	DD92	CD92	TM92	YD92	Mean
Line Y8622	101	81	98	116	111	102	105	108	102	96	102.0
Hunter River	95	91	79	97	86	94	100	92	103	77	91.4
P581	85	100	114	93	105	90	91	92	80	96	94.6
P L52	-	-	95	85	98	100	110	82	81	122	96.6
WL S. Special	89	103	95	93	96	99	101	108	89	112	98.5
Aurora	95	93	107	117	92	92	90	96	98	108	98.8
Trifecta	93	109	89	103	97	100	90	79	97	113	97.0
Genesis	113	109	103	120	106	105	98	100	128	111	109.3
Aquarius	-	105	96	117	108	109	113	97	114	122	109.0
Cuf101	95	116	96	111	88	101	110	124	106	100	104.7
Site mean ($t.ha^{-1}.cut^{-1}$)	1.23	1.23	0.83	0.64	1.21	1.53	0.92	0.48	0.45	0.58	
Number of cuts	6	16	3	8	4	9	3	6	8	18	

Discussion

Line Y8622 will provide a persistent new lucerne for marginal areas of the cropping zone. However, benefits to cropping systems are also often related to lucerne productivity and its proportion within the pasture phase (5). Other specific characteristics of the variety and its use will also affect relative contributions. Our new lucerne project is firstly attempting to identify and prioritise the key biotic and abiotic limitations to lucerne productivity and survival in the cropping zone. There may also be opportunities for improving N-fixation by breeding lucernes with specific morphological or physiological traits (10). The successful adoption and integration of these new lucernes in crop rotations also require additional breeding objectives to be prioritised. ?These include: (a) greater seed yields to minimise seed price to growers, (b) easier establishment, (c) ability to maintain density for desired rotations, (d) greater tolerance to waterlogging, drought, and extensive grazing, (e) better resistance to pests and diseases, (f) improved compatibility with companion species, especially perennial grasses, (g) more successful removal options (eg. perhaps herbicide susceptibility), and (h) greater general adaptation to the cropping zone.

Initially, a set of 60 "probe" lines and cultivars, including advanced breeding material, has been sown in twelve sites in southern NSW, northern NSW and southern QLD. All sites are being regularly monitored for forage yield, changes in lucerne persistence, disease/ pest epiphytotics, and other challenges. Automatic weather stations will help clarify the environmental and/ or physiological basis for differences in performance among lines. This will help prioritise breeding object-ives and ensure better lucernes are bred and recommend-ed for all target zones.

Despite many demonstrations of its value in crop rotations, lucerne has previously not been widely adopt-ed in the northern zone (9). The new project will encour-age farmers to work with researchers in a collaborative framework to both identify their major limitations with lucerne rotations and then to address these limitations using strategic experiments by the project team and/or as collaborative on-farm R&D led by focus groups. Specific experiments are being undertaken in eco-physiology, plant pathology, and weed management. For example, the QDPI are investigating associations between root morphology and waterlogging tolerance, the CRCTPP are determining the inheritance of resist-ance to a range of important pathogens, QDPI and NSWA weeds agronomists are examining herbicide bio-degradability and its effects on lucerne establish-ment, and NSWA researchers are describing the effects of grazing management on lucerne hydrology, product-ion, persistence, and N-fixation. Collaborative on-farm studies will be determined in association with group networks, but may aim to (a) reduce risks of establish-ment failure, particularly under minimum-tillage systems, difficult environments, and/or under cover crops (b) develop improved pasture mixtures based on lucerne, (c) improve the timing and methods of terminating a lucerne ley, and (d) develop methods to optimise and maintain the benefits of lucerne rotations to crop yield and protein. This environment of co-learning between growers and researchers, together with specific new lucerne cultivars such as line Y8622, will promote the development and adoption of better lucerne rotations and improved cropping systems in the northern grains region.

Conclusions

(1) A range of new lucernes were bred using recurrent selection within and among four major populations to replace the aphid-susceptible cultivar, Hunter River.

(2) Line Y8622 has proven to be persistent and productive after four years in rainfed trials across the NSW wheatbelt and is being commercialised as a new semi-winter-dormant cultivar.

(3) Additional objectives for breeding improved lucernes for cropping systems in eastern Australia are being defined using a cohort of 60 lines and cultivars and a network of on-farm experiments across the north-ern grains region.

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References

1. Baldock, J.O., Higgs, R.L., Paulson, W.H., Jakobs, J.A., and Schrader, W.D. 1981. Agron. J. 73, 885-890.

2. Dalal, R.C. and Mayer, R.J. 1986. Aust. J. Soil Res. 24, 265-279.

3. Dalal, R.C., Strong, W.M., Weston, E.J., and Gaffney, J. 1991. Trop. Grass. 25, 173-180.

4. Dalal, R.C., Strong, W.M., Weston, E.J., Cahill, M.J., Gaffney, J., Cooper, J.E., Lehane, K.J., and King, A.J. 1996. Proc. 8th Aust. Agron. Conf.. Toowoomba, pp. 181-184.

5. Ellington, A., Rowland, I.C., Schultz, J.E. 1992. In "Transfer of biologically fixed nitrogen to wheat." Edited by J.F. Angus. GRDC, Canberra. pp. 85-91.

6. Hamblin, A. and Kyneur, G. 1993. In "Trends in wheat yields and soil fertility in Australia". DPIE & Bureau of Resource Sciences, Canberra. pp. 34.

7. Heichel, G.H., Barnes, D.K., Vance, C.P., and Henjum, K.I. 1984. Crop Sci. 24, 811-815.

8. Holford, I.C.R.1980. Aust. J. Agric. Res. 31, 239-250.

9. Reeve, I., Lees, J., Price, I., and O'Donnell, L. 1995. In "Evaluation of the 1992-93 promotional campaign".The Rural Development Centre, Armidale. pp. 22.

10. Vance, C.P., Heichel, G.H., and Phillips, D.A. 1988. In "Alfalfa and alfalfa improvement." Edited by A.A. Hanson. Am. Soc. of Agron., Madison, Wis, USA. pp. 229-258.