PERENNIALS FOR ACID SOILS:

PERENNIALS IN THE PIPELINE - NEW CULTIVARS FOR ACID SOILS

Rex Oram

Principal Research Scientist
Division of Plant, CSIRO, CANBERRA ACT 2601

Abstract: *In recent years, the increasing acidity of light soils has increased the popularity of acid tolerant pasture plants such as Porto cocksfoot and Maku lotus at the expense of sensitive species, especially phalaris and lucerne. This trend will continue, but enough lime must be applied to balance losses removed from farms to produce, and to prevent the pH declining below the point where even tolerant species lose productivity. The newer cultivars are listed - Grasslands Wana and Kara cocksfoot, Yatsyn 1 and Brumby perennial ryegrass, AU Triumph tall fescue, Holdfast phalaris, Black Mountain secale, Consol African lovegrass, and wallaby grasses and other natives. The lower nutritive value of cocksfoot relative to other grasses is exemplified. The future prospects for obtaining improved cultivars of these grasses and of white clover, lotus, lucerne and other legumes are discussed. A case is made for greater emphasis on breeding rather than overseas collecting and testing. However, more collection should be done in poorly explored areas eg. Chile, South Africa and California, and in Australia itself. Genetic resources need to be maintained for trading with overseas gene banks.*

The general increase in acidity in the lighter soils of the Tablelands and Slopes of New South Wales is bringing about a gradual change in the species and cultivars used in sown pastures. As the pH falls below 4.5 (in calcium chloride solution), compounds containing the toxic metals aluminium and manganese are dissolved, and plants may also be injured by a different set of root diseases and nutrient deficiencies. Low pH itself also damages some plants. In the districts most affected by pH decline, sensitive plants like lucerne can no longer be grown without liming. But liming is expensive, and lime penetrates very slowly into undisturbed soils, so one alternative is to grow less sensitive species. Some progress is being made in the search for acid- tolerant crop and pasture plants. In this paper, the development of tolerant perennial pasture plants will be reviewed but first it must be emphasized that resistant plants alone are not the answer to soil acidification, because:-

(1) tolerant cultivars on acid soils rarely yield as much as tolerant or sensitive cultivars on non-acid soils. The loss of productivity may be large enough to render the grazing operation unprofitable. And,

(2) more alkalis than acids are removed in the products sold off the farm, especially hay and grains (Helyar *et al.*, 1988), and so the soil gradually acidifies, even if alkalis are not washed out of the root zone by rainwater.

Therefore, the best approach seems to be to use enough lime to balance the export of alkalis and to maintain the soil pH above the critical point below which even tolerant species progressively lose productivity. About 50- 200 kg/ha of lime are usually needed each year.

RECENT CULTIVARS

GRASSES

Standard Cultivar

Porto cocksfoot and Haifa white clover have been sown extensively on neutral to moderately acid soils in the higher rainfall districts in the last decade. Various perennial ryegrass cultivars and Demeter tall fescue also tolerate some acidity. Ellett, Nui and Kangaroo Valley ryegrasses have remained popular. These cultivars have been the standards for the last decade or more, against which the newer introductions, selections and bred lines have been judged.

New Cultivars

Cocksfoot: Grasslands Wana cocksfoot, bred by the former DSIR in New Zealand, appears to be higher yielding than Porto in some parts of Victoria (Clark *et al.*, 1990), but not in an early trial at Gumble in the Orange district (Orchard, 1989). However, it is recommended for the tablelands of N.S.W. Grasslands Kara cocksfoot is more erect, and is designed for cattle pastures rather than sheep pastures. Like Wana, it also failed to persist beyond the third winter at Gumble.

Although cocksfoot is the best grass for many districts with acid soils, it must be borne in mind that the nutritive value of cocksfoot is less than that of the other common grasses such as ryegrass, phalaris and tall fescue. Animal production commonly is about 10% less on cocksfoot than on other grasses in Europe, U.S.A., Australia and elsewhere. A recent demonstration of this general rule is provided by a grazing experiment being conducted at Taralga by my colleagues in the CSIRO Division of Plant Industry, Allan Axelsen, Mike Freer and John Donnelly (pers. comm.). Table 1 shows the liveweight gain of weaner sheep on a mixture of Porto and Currie cocks-foots, Kangaroo Valley perennial ryegrass, or Black Mountain secale, each grown with Haifa white clover. The cocksfoot stands contained less white clover than other grass- clover mixtures. These differences would have contributed to the poorer animal production on cocksfoot, as would the lower nutritive value of the cocksfoot herbage. The soil at this site is too acid to support the growth of phalaris, but with adequate superphosphate (1500 kg/ha), can be made highly productive with acid-tolerant species even without an initial application of lime. Animal production from the whole trial area is about ten times higher than that from the surrounding sub clover-based pasture, which receives only small dressings of superphosphate.

Table 1: Comparison of the productivity of sheep grazing perennial ryegrass, secale, and cocksfoot at Taralga, NSW.

	Stocking rate (wethers/ ha)	Wool weight (kg/ha)		Weight gain (kg/ha)	
		1989	1990	1989	1990
Secale	10.0	56	56	226	290
(Black Mountain)	12.5	68	73	236	338
	15.0	91	89	372	405
	17.5	107	100	422	438
Ryegrass	10.0	69	55	324	260
(Kangaroo Valley)	12.5	70	74	264	325
	15.0	84	86	278	345
	17.5	93	98	352	403
Cocksfoot	10.0	50	47	186	220
(Porto & Currie)	12.5	64	54	223	213
	15.0	75	68	269	360
	17.5	74	61	191	298

Despite the lower nutritive value of cocksfoot, it will still be the most suitable grass for some districts. DSIR breeding lines are being tested extensively in Victoria in cooperation with the Department of Agriculture (DAV; Clark *et al.*, 1990). Some of these also appear promising in a cooperative trial on an acid soil near Bendigo (Oram, R.N. and Taylor, J., unpublished), and some may be released by DRIR/DAV in the next few years.

Perennial ryegrass: Yatsyn 1 and Brumby have been bred by private companies in New Zealand and Victoria, respectively. New DSIR selections are under test by the Victorian Department, but so far, none of these seems to be specifically adapted to acid soils. The next step in the improvement of perennial ryegrass seems likely to be the replacement of the present widespread endophytic fungus, which protects the plant against insect attack but also causes ryegrass staggers in stock, by another endophyte which is non-toxic to stock, but which still protects the plant against insects. A joint program between DAV and NSW Agriculture and Fisheries is designed to make selections from Kangaroo Valley for high rainfall areas. These new lines will possibly also have tolerance to acid soil conditions.

Tall fescue: AU Triumph has greater seedling vigour than the highly variable Demeter. Triumph also performs well in later years. The early- flowering, erect cultivar Melik, was released many years ago, but seed is not yet available commercially. Melik tolerates waterlogging and acidity, but is fairly easily damaged by grazing during stem growth. It is not clear whether the original cultivar or a further selection, or neither, will be put on the market. Again, DAV has had some promising results with new DSIR breeding lines (Clark *et al.*, 1990).

Phalaris: is one of the most sensitive perennial grasses to excess aluminium in acid soils (Culvenor *et al.* 1986), but variation does exist, and selection for moderate resistance is possible. The new cultivar, Holdfast, results from two generations of selection for the ability to grow roots at very high aluminium concentrations (10 parts per million) in a hydroponics system. The cultivar also has been selected for productivity and survival at Canberra and Temora. It is somewhat like Sirosa and Sirolan, but holds most ripe seeds in its heads, so reducing seed cost. Holdfast has proven to be more productive than Sirosa on an acid yellow podsolic soil near Canberra. The topsoil had been limed and given 500 kg/ha superphosphate, but the 10-20 cm soil layer was still highly acid (pH in calcium chloride solution 4.0-4.6) and high in extractable aluminium (2.9- 17.1 parts per million). Holdfast and Sirosa yielded 0.76 and 0.45 t/ha dry matter in June of the second year (1990), and Holdfast has persisted better into 1991. By contrast, Holdfast has been inferior to Sirosa and Australian on a strongly acid soil near Benalla, and similar to Sirosa on a less acid, shallow soil near Bendigo. Holdfast is being tested more widely in 1991, and seed will be marketed in 1992.

The next phalaris cultivar to be released is an early-flowering one to replace Sirocco with a seed-retaining type. Still later, the cross of Australian by Uneta should give a seed-retaining Australian type with better herbage and seed yields than Uneta. Also in 7- 8 years, a more acid-tolerant cultivar should be completed. The extra acid tolerance comes from *Phalaris arundinacea*, which also is more water- logging tolerant and spreads laterally faster than any *P. aquatica*. However, *P. arundinacea* is not drought tolerant and is unpalatable on fertile soils in summer. The first generation hybrid is fairly sterile, so gene transfer by backcrossing into *P. aquatica* is not easy, but is being accomplished (Oram *et al.*, 1990). Over 200 families are under test on acid soils in A.C.T., Vic. and W.A. Only a few are clearly superior to Holdfast, so several more generations of selection are needed to produce the required cultivar. It is hoped that a winter-active, acid-tolerant phalaris with fast lateral spread will be persistent for long periods, but manageable by grazing. If the phalaris stand is too thick, it could be thinned out by heavy grazing in spring, or if it is too thin, the stand could be thickened up by more lenient spring grazing.

Secale: is a perennial form of ryecorn with extremely good tolerance to soil acidity. However, it needs well-drained, light soils and enough summer rainfall to maintain white clover. Its herbage is highly palatable, and better wool production has been obtained from it than from other grasses in the Upper Shoalhaven (Myers *et al.*, 1985). At Taralga, wool production on secale equals that on perennial ryegrass (Table 1). Secale is a short- term perennial, but successfully regenerates from seed around Omeo, Victoria. Secale also shows promise in warmer areas of S.A. and W.A., and new cultivars may be selected for such areas with more Mediterranean climates.

African lovegrass: is highly tolerant of acidity. It prefers light soils, and can persist even on deep sands at Narrandera. The only cultivar available so far, Consol, is highly regarded on acid sands in the Coonabarabran area, where it combines well with serradella to produce good yields of herbage, and to suppress weeds such as spiny burr grass (*Cenchrus* spp.) (Johnston and Cregan, 1979).

Despite the presence of weedy, unpalatable forms in the tablelands, further releases of palatable, productive, acid- tolerant forms seem to be warranted. These may be the best competitors to use against the weedy forms. Only fully apomictic, palatable genotypes should be released. These will breed true through the seed, and, if they pollinate the weedy forms, more palatable hybrids will result. If the greenhouse effect gives the Tablelands more summer rain, but with a more erratic incidence, summer growing, drought tolerant pasture plants such as African lovegrass will become more successful.

Native grasses such as *Microlaena stipoides* (weeping grass), and at least some populations of *Danthonia richardsonii* (wallaby grass), are acid tolerant. The release by NSW Agriculture and Fisheries of some *Danthonia* selections is scheduled for the next few years, and the solution of the seed-harvesting problem in other species hopefully will lead to their domestication in the coming decades. Some of these can produce green herbage throughout the year, but they also are drought tolerant, a combination not found in introduced species.

LEGUMES

White clover: Genetic resources are being collected and evaluated at Glen Innes, and breeding programs have started at Tatura, Vic., for salt tolerance and at Hamilton, Vic., for better performance across southern Victoria. There seems to be no direct attempt to select for greater acid soil tolerance in Australia or New Zealand, but this will happen automatically whenever an extensive collection is evaluated on acid soils. The extent of variation is not known, but can be assumed to be fairly high, so eventually more tolerant cultivars should become available.

Other perennial clovers: Caucasian clover (*Trifolium ambiguum*) includes populations which are acid tolerant (Oram, 1990). This species establishes very slowly, but then is highly persistent; it will be used more extensively in the wetter and colder parts of the Tablelands. The existing cultivars are adequate, especially Monaro. Other perennial clovers, *eg.* strawberry, deserve attention.

***Lotus pedunculatus*:** is extremely tolerant of acidity and can cope with low soil phosphorus, and some salinity and waterlogging. Cultivar Maku therefore has become very popular on acid, sandy soils near the coast of south- eastern Australia. Naturalised forms are also common, and spread onto the Tablelands in places (*eg.* Braidwood) when successive summers are wet.

N.S.W. Agriculture and Fisheries is considering releasing a Portuguese line with earlier flowering and better seed set in northern N.S.W. and Qld, where Maku flowers sparsely, and fails to build up a reserve of seeds in the soil. The early line complements Maku in growth rhythm to some extent, but is high in tannins (Kelman and Tanner, 1990). This will not be a problem unless the new line becomes dominant in a pasture, in which case, the digestibility of the whole diet of the stock will be reduced, and their performance will fall off. A breeding program is getting under way in Canberra to grasp this and some of the other opportunities for genetic improvement which are already apparent in various lotus species (Schachtman and Kelman, 1991).

Lucerne: is sensitive to both aluminium and manganese in acid soils, and also the rhizobia are not tolerant of low pH. Rhizobia from the more tolerant annual *Medicago murex* could solve the latter problem. Many efforts to eliminate the aluminium and manganese sensitivity have been made, but have been unsuccessful. However, lucerne is so valuable that additional efforts are warranted. Currently, genetic engineering and molecular biology are being explored. Attempts are now being made, in CSIRO, Canberra, to transfer the genes for acid tolerance from murex and burr medics to lucerne by fusing the cells, and then growing hybrid cells into callus and plantlets in tissue culture. Probably we can only expect minor advances at first, but these should then be built on to eventually breed an acid tolerant form.

Other legumes like cicer milkvetch (*Astragalus cicer*) are strongly persistent, but not particularly acid tolerant. Winter dormancy also is unfavourable in Australia, but these and other weaknesses might be overcome in future breeding projects.

FUTURE COLLECTION, SELECTION AND BREEDING

The genetic resources of most overseas populations of our major pasture plants have now been fairly well explored, *eg.* sub clover, perennial ryegrass, phalaris. However, even in these species, new pockets of useful variation have been found in recent years, *eg.* Sardinia for winter- active, but late- maturing sub clover, and USSR for early-flowering *Lotus corniculatus* and many other types likely to be useful in special niches in Australia (Reed and Dear, 1990). It would take a massive effort to chronicle all the future possibilities, and I cannot attempt it here. But I believe some generalities can be made:-

(1) More progress will be made by breeding than by collecting and testing wild material, especially as major steps are made for the domestication of our pasture species. The Uneta/Holdfast system of seed retention is such a step in phalaris - it is impossible to find seed- retaining populations in the wild. Since the trait is so important for reducing seed prices, virtually all future cultivars will result from crossing and selection. Such breeding programs are expensive and long term, *eg.* $1 million and 10-12 years per cultivar, yet the benefits are usually several times greater. However, these programs are becoming cheaper than overseas collecting missions, which in future will be increasingly unproductive of new cultivars. It is becoming necessary to cross- breed and artificially mutate native grass and legumes too, in order to remove toxins and spines, and to prevent seed shedding.

(2) Some overseas collecting and introduction of foreign lines should continue. For example, there has been little effort placed on collecting in South Africa, Chile, Argentina and California, where the climates are similar to our own. The Mediterranean area and southern Europe have supplied the majority of our pasture plants, but we certainly can get more than capeweed from South Africa! Southern Russia still seems a worthwhile source of salt tolerance, at least (Reed and Dear, 1990).

(3) Much of the genetic resources to be used in Australia in future will be obtained from overseas gene-banks, *eg.* in the U.S. Department of Agriculture system. We must reciprocate, and therefore must maintain our overseas collections, but also we must collect, propagate and domesticate our native grasses and legumes, both to exchange with overseas breeders, and to use in our own breeding programs.

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