



DEPARTMENT OF AGRICULTURE, SOUTH AUSTRALIA

Agronomy Branch Report

BREEDING PERENNIAL GRASSES FOR SOUTH
AUSTRALIA - WITH SPECIAL REFERENCE
TO FESTUCA ARUNDINACES Schreb.
(TALL FESCUE)

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BREEDING PERENNIAL GRASSES FOR SOUTH AUSTRALIA - WITH SPECIAL
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I. FOREWARD

I have recently embarked on a perennial grass breeding programme with Festuca arundinacea Schreb. (Tall fescue). This report reviews the role of perennial grasses in South Australia, highlighting the deficiencies of existing grass species, and the potential superiority of Tall fescue. Details are outlined of how improvements can be achieved through this breeding programme.

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II. INTRODUCTION

In the high rainfall zones of southern Australia (> 500mm) perennial grasses are the major component of many pastures. It is generally recognized, although rarely substantiated by critical evidence, that they significantly contribute to pasture productivity because they possess the following attributes:-

- (1) The growing period is longer than that of annuals. They can utilize rain too light to germinate annuals in autumn, as well as exploiting deeply percolating water beyond the root zone of annuals in the late spring and summer.
- (2) The total annual production of perennials is greater than annuals.
- (3) They add stability to a pasture - preventing the invasion of nutritionally inferior "weedy" species, particularly thistles and capeweed.
- (4) Some perennials have an ability to respond to summer rains - offsetting to some extent the deficiencies in pasture production during the summer months.

Through the establishment and maintenance of more productive and nutritious perennial pastures, the efficiency of animal production should be improved. Cultivars that are easily established, are productive and nutritious and persist indefinitely would assist in reducing costs of animal production to a minimum.

At present in southern Australia almost all improved pastures are based on introduced plants. This is because the indigenous pasture plants in Australia are generally unproductive, low in nutritive value for much of the year, susceptible to overgrazing and adapted to low fertility soils. Through both planned and accidental plant introduction in association with other agronomic advances, particularly the use of fertilizers, pasture productivity has been improved to a remarkable extent. However, the results of pasture plant breeding have only more recently begun to have an impact in Australia.

The relative importance of direct plant introduction, and the results of pasture plant breeding on pasture improvement has now changed. The majority of herbage plant cultivars released now are the product of plant breeding programmes, rather than direct plant introductions. This is because of the extensive testing of the great range of plant introductions that has been carried out over the last two decades. The possibility of a new introduction being incorporated directly into the agricultural scene is diminishing as collections of natural ecotypes become more complete, and the level of sophistication demanded of a new cultivar increases. However, plant introduc-

tion must continue; but its main function will be more as a source of genetic variation for use in breeding work.

In view of the long term nature of pasture plant breeding programmes, objectives should anticipate requirements of animal production systems in the future - as well as overcoming present deficiencies of our pasture plants. e.g. Grass may be grown in monoculture, using large quantities of Nitrogen fertilizers as it already is in Western Europe and North America. Conservation practices may increase in importance in animal production enterprises, to the extent of "zero grazing". Changes, particularly those involved with an increase in the degree of intensity of production will require cultivars different from those of today. Breeding programmes such as this one offer the means by which such requirements may be met.

Successful breeding programmes are those that have objectives clearly defined. With cereals this is relatively simple to do as there are few end uses. With grasses there is a great range of uses to which they can be put. e.g. A particular grass variety may be grown with or without companion grasses or clovers, at high or low levels of fertility, used for both grazing and cutting, made into silage or hay, and fed to cattle, or sheep, at all levels of production potential.

Therefore it is especially important that objectives are soundly formulated and based not only on the priorities of improvement but also on the genetic variation that is known to exist within the species.

III. PERENNIAL GRASS CULTIVARS USED IN SOUTH AUSTRALIA

A brief description of the perennial grass cultivars presently available will now follow. These descriptions have been obtained in general from the Australian Herbage Plant Register (1967). Emphasis will be placed on pointing out both attributes and deficiencies.

(1) Phalaris tuberosa cv. Australian

This is undoubtedly the most valuable and versatile grass available at present. It has wide adaptability, is extremely drought tolerant, is persistent even under heavy grazing, it responds quickly to the first autumn rains and it makes vigorous growth during autumn and spring. Its main limitations are:-

- (a) the problem of establishment - seedling vigour is poor even under the best possible soil conditions, rendering seedlings very sensitive to competition.
- (b) it is not fully responsive to summer rains - being partially summer dormant.
- (c) it contains toxins which cause phalaris staggers and the "sudden death syndrome".
- (d) its seed shattering characteristic resulting in low yields of poor quality seed.
- (e) low quality of dry residues.

A great deal of breeding research has been concentrated on this species by Drs. J.R. McWilliam and R.N. Oram of the C.S.I.R.O. in Canberra and Wagga. Attempts to overcome its major limitations have been made through plant introduction, hybridization and selection.

Cultivars that have been produced are:-

(a) Sirocco phalaris

This is a direct introduction selected from material from Morocco (Neal-Smith 1955). Its characteristics are: vigorous winter growth, drought tolerance, rapid seedling growth and it flowers about a week earlier than Australian phalaris. Its seed production and seed retention characteristics are comparable with "Australian".

(b) Siro seedmaster

This is a selection from within the Australian commer-

cial type obtained from Argentina. The heritability for seed retention in Phalaris tuberosa is high (McWilliam 1963), hence selection for seed retention gave marked response. The inflorescences are much shorter, more compact, and rigid due to the closer packing of the individual spikelets. The strain is not substantially different from the commercial strain with respect to maturity, growth habit, appearance and seasonal herbage yield.

(c) Siro 1146 Hybrid Phalaris

This variety has yet to be released, although in extensive trials it has performed excellently. It is an F1 hybrid between P. tuberosa and P. arundinacea. Using a self incompatible selection of P. tuberosa (cv. Seedmaster) as the female parent, hybrid seed is produced by intergrowing rows of the 2 species. The growth of the hybrid is superior to that of the parents, combining the best seasonal growth characteristics of both parents. Its superiority is most pronounced in autumn and summer - the summer growth component coming from the P. arundinacea parent. (McWilliam 1962). The present high cost of seed due to the special seed production technique is probably the main factor restricting the release of this new variety. Special management techniques are required when grazing this cultivar. Sheep losses from toxic poisoning can be quite severe if cobalt bullets have not been administered. Also the stocking rate must be adjusted to prevent the grass becoming rank and unpalatable. (MacKay, 1972).

Work is being concentrated on developing a variety low in the levels of the toxic alkaloids. The possibility of producing an agronomically acceptable cultivar with this special characteristic is considered good. (Oram, 1970).

(2) Dactylis glomerata (Cocksfoot)

The main variety in commercial use in South Australia is "Currie" an introduction from Algeria. It has good drought resistance, surviving substantially hot rainless summers to a lower limit of 350-400 mm. It is more productive in summer and autumn than phalaris because it responds more quickly when rain falls. It requires good drainage - not persisting - on sites subject to inundation, particularly if it continues for some weeks. It does not stand up to hard continuous grazing as well as phalaris, but is a good alternative for those graziers who fearing "staggers" are reluctant to introduced phalaris. A major limitation of Dactylis glomerata is the poor digestibility of all commercial cultivars. Digestibility studies continually

show this species to be at least 5 units lower in digestibility compared with perennial ryegrasses, although recent work has shown that it is possible to select more digestible lines (W.P.B.S. Rep. 1968). There are other cultivars of this species available locally but they are not widely used in South Australia.

"Berber" and "Kasbah" have been selected from Mediterranean material at the Waite Institute, but seed has not been produced in commercial quantities. Both cultivars are extremely summer dormant, responding little to summer rain or irrigation and most likely would persist in low rainfall, short growing season areas, better than "Currie".

"S26" and "S143" bred at Aberystwyth, Wales, are used in irrigation mixtures to some extent.

"Brignoles" - N.S.W.

"Grasslands Apanui" - New Zealand

"Cressy" - Tasmania

(3) Lolium perenne (perennial ryegrass)

This species has received a good deal of attention by breeders overseas, because of its wide recognition as a desirable component of pastures. The species generally has both good digestibility and productivity. Many cultivars are available but the main one in commercial use in South Australia is "Victorian"; this term is used to cover a range of ecotypes found in various parts of that state. It is recommended in South Australia for the more fertile heavier soils in districts receiving more than 600mm of rain a year. Winter production is low, but it makes good growth in autumn and spring. Generally its lack of persistence on anything but the really heavy soils, make Lolium perenne unsatisfactory for the long term pasture proposition in South Australia.

A relatively new cultivar of Lolium perenne that has been developed at the Waite Institute is "Medea". It originated from selections from within some Algerian introductions. It characteristically remains dormant during the summer, not responding to summer rains, while autumn and winter production is greater than that of "Victorian". (Cade, 1969). The little experimental evaluation that has been carried out with "Medea" in South Australia, has revealed several deficiencies. In a grazing experiment on Kangaroo Island, "Medea" has been found not to always behave as a true perennial. In some seasons it has behaved in the

same way as an annual, setting seed before the death of all plants in summer. Also the body weights gains and wool production of wethers grazing "Medea" have been significantly less than wethers grazing "Victorian" - despite equivalent levels of forage availability. This may indicate some problem in the nutritional qualities of the plant (Gibson 1972). A further deficiency is its poor seed producing potential compared with other perennial ryegrass cultivars (Higgs 1972).

Other cultivars available but not widely sown are:-

Grasslands Ariki	}	New Zealand
Grasslands Ruanui		
Tasdale	}	Tasmania
Tasmanian No. 1		
Kangaroo Valley Early)	}	N.S.W.
Kangaroo Valley Late)		
Mt. Alma)	South Australia

(4) Festuca arundinacea (Tall fescue)

The main cultivar in commercial use in Australia is "Demeter". This is a direct introduction into Australia from France, but it is said to have originated in Morocco. (CPI 1499,1931). Its growth rhythm suggests however it is non-Mediterranean in origin. Neal-Smith (1969) considers it is probably a hybrid with intragression through contact with the Northern European summer growing material. This would explain its capacity for summer growth and its relative winter inactivity compared with Mediterranean ecotypes.

Demeter fescue is best adapted to temperate regions with greater than 600 mm rainfall per year. It responds well to summer rains and is more productive than Australian Phalaris in mild winters (Hilder 1965). It has a longer effective growing season than either phalaris or the rye-grasses and seems better adapted to areas with adequate summer and autumn rainfall. Hilder concluded from his studies at Armidale that Demeter fescue was not suited particularly to Mediterranean type environments. He based this conclusion on its lack of summer dormancy and its inability to survive prolonged periods of drought.

Tall fescue has the ability to flourish under a wide range of soil conditions. It does well in waterlogged conditions, tolerates soil salinity and succeeds in

both acid and alkaline soils. Adaptation to such a wide range of conditions indicates there is great scope within South Australia for increased acreage to be sown with this species.

In areas receiving greater than 600mm of rainfall annually in South Australia, Demeter fescue is rapidly gaining in popularity. Its ability both to flourish in poor acid sands where no species other than fog grass previously persisted, and to respond to summer rains or irrigation to provide good summer feed, are the principal reasons for this.

Another cultivar of Tall fescue that only recently has been released is Melik. It is a direct introduction from Israel (CPI 15301). It is outstanding in its winter growth is an erect growing type of relatively early maturity, and is adapted to regions of long dry summers. It has a growth rhythm typically of a cultivar with Mediterranean origins (Bailey & Rogers 1965). The potentiality of this new cultivar in South Australian agriculture is unknown at this stage. Indications that it could be valuable come from trials on Kangaroo Island by E.J. Crawford where it performed much better than Demeter under cutting.

A cultivar from Oregon, U.S.A. called "Alta" has recently been grown in the lower South-East of South Australia to some extent. It has yet to be evaluated in comparison with Demeter in South Australia. Trials at Armidale, New South Wales indicated it had a very similar growth rhythm to Demeter and was equally productive. It was however less frost resistant in winter than Demeter (Hilder 1963).

From this short review of the most common perennial grass cultivars grown in South Australia, it is evident that while each has a role to play in pastural productivity of the higher rainfall zones of the state, none is without limitations. Improvement in the seasonal distribution of growth and attainment of high quality herbage are two aspects which are considered most important. As there is material available via which such improvements can be achieved (as will be described in the next section of this report) a breeding programme is entirely justified.

IV FESTUCA ARUNDINACEA (SCHREB.) - TALL FESCUE

The area of natural distribution of Tall fescue is through Europe and temperate Asia extending to western Siberia and North Africa. Through the influence of man this distribution has been extended to parts of North America, South America, South Africa, Australia and New Zealand. As with most cross pollinated species, a large number of distinct ecotypes of tall fescue have developed, each adapted physiologically to the climate of its habitat. Man has exploited this variation by using direct introductions for agricultural purposes, and in a few cases developing new cultivars through breeding.

Today it is a particularly important species in the United States, and a number of cultivars have been developed there through purposeful selection.

In the U.K. also, it has a definite but limited use. Its popularity is restricted because it is very slow to develop as a seedling, and under some U.K. conditions the mouths of grazing animals are severely lacerated. Crop growth rate studies in a phytotron at the Welsh Plant Breeding Station, Aberystwyth have shown that under suitable light conditions and with adequate nutrients, the crop growth rate of Tall fescue is rarely matched by other grass species. These studies indicated it has perhaps a greater biological potential than ryegrass (Hunt and Cooper 1970). Tall fescue is particularly gaining in popularity for harvesting systems which require repeated cuts throughout the growing season. Throughout the world there are more than 25 commercial cultivars now available. With few exceptions these are of non-Mediterranean origins with a characteristic summer growth component and relatively little activity during winter.

e.g.	<u>Country of Origin</u>		<u>Cultivars</u>
	U.S.A.	6	Alta, Fawn, Goar, Kenmont, Kentucky 31, Kenwell
	U.K.	4	S170, McGillsmith Early, English Tall Evergreen, Gartons Own Leafy
	France	6	Festival, Lironde, Ludion, Manade, Clarine, Ludelle
	Poland	3	Pulawska, Grebabwska, Stef
	Italy	2	Grombaldia, Djbel Aboid
	Netherlands	2	Festal, Mottal
	Australia	2	Demeter, Melik
	Sweden	1	Bakafall
	Yugoslavia	1	Brudzynski
	Germany	1	Geinsheim
	USSR	1	Sakhalinskaja

As was indicated earlier, part of the natural distribution of Tall fescue includes North Africa. However, with the exception of the Australian cultivars Melik and Demeter, all other cultivars originate from material from central and Northern Europe. As one would expect the truly Mediterranean ecotypes are characterized by winter production, poor frost tolerance and an ability to survive summer drought through dormancy. The material of central and Northern European origin is characterized by summer production, poor survival under drought conditions, winter dormancy and associated frost tolerance.

In Australia the seasonal productivity and general agronomic performance of some Tall fescue ecotypes and varieties have been examined by several people. Neal-Smith and Wright (1969) at Canberra, Bailey and Rogers (1965) at Kojonup in W.A., Hilder (1963) and Schiller (1972) at Armidale, N.S.W. and Crawford (1971) on Kangaroo Island. The Mediterranean ecotypes were found to be 2-3 times more productive during winter, and more persistent than the locally recommended cultivar "Demeter". The non-Mediterranean cultivars were more productive in the summer months than the Mediterranean ecotypes, but in the winter had a relatively lower growth rate associated with a greater resist-

ance to frosts. These differences in growth patterns have prompted the suggestion that through hybridization between contrasting ecotypes, followed by careful selection, it should be possible to produce a variety with the most desirable combination of growth characteristics.

The difference in growth rhythm between the two sources of material, particularly the winter production aspect, has been studied on a physiological basis by many workers in the U.K. e.g. Chatterjee (1961), Robson and Jewiss (1968), Thomas and Lazenby (1968), Frame et al (1970), Blacklow and McGuire (1971). They examined the seasonal growth pattern of a number of North African selections in comparison with their local varieties - especially Sl70 which was developed at the Welsh Plant Breeding Station, Aberystwyth. In all cases the North African ecotypes were found to be more productive in the winter than Sl70 (even up to 5 times more productive. (Robson, 1967). There is general agreement that this greater winter production is due to an inherently greater physiological efficiency. The North African ecotypes were found to have a greater leaf area ratio, and at times a greater net assimilation rate resulting in a greater relative growth rate during these months. It was also found that in winter the North African ecotypes produced more tillers than Sl70, while in summer the reverse was true. Robson (1968) has shown that the main environmental factor controlling the seasonal differences in growth between Sl70 and North African material was temperature - not short days or light intensity. When the North African material was increasing in leaf area in the winter months, Sl70 was no longer increasing in leaf area, but was accumulating soluble carbohydrates and a greater resistance to injury by below zero temperatures. A definite inverse relationship between the ability of varieties to survive low temperatures and their ability to grow rapidly during winter was noticed.

All these physiological observations were made in the U.K. which experiences winters much more severe than ours. This lack of winter hardiness of the North African ecotypes would not be an important limitation when grown in our mild Mediterranean type environment. Cold tolerance is a characteristic which is not particularly relevant in this environment. It is apparent however that this greater growth during the winter by these North African varieties has genetic origins. It should be possible through the use of this genetic material to improve the winter growth of "Demeter". An important aspect of this winter productivity of Mediterranean ecotypes is that it is only realized with an ample supply of Nitrogen (Schiller 1972, Green 1963, 1964, Chatterjee 1961). Under these conditions the difference in growth rate between the Mediterranean and Temperate ecotypes has been recorded to be as great as 10 kg d.m./ha/day during the winter months (Schiller 1972).

There are other characteristics where useful variability between lines of Festuca arundinacea have been noticed.

a. Persistence:

Bailey and Rogers (1965) and Neal-Smith and Wright (1969) have both recorded greater persistence characteristics from material of Mediterranean origin. This particularly is in reference to its summer dormancy characteristic ensuring survival through the summer. Variation in the rhizomatous nature of the tufts of Tall fescue - one of the attributes that is important in determining the persistence qualities of a plant - has been reported by Niqueux and Arnaud (1967) from a collection of French ecotypes.

b. Inflorescence characters:

Bean (1969) has reported that all inflorescence characters are subject to genetic or genetic x environmental control. The characters most likely to show response to selection are seed weight per inflorescence and seed fertility. This shows that improvement in the seed production capabilities of the plant is therefore possible.

c. Response to Nitrogen:

Large differences between varieties in their response to Nitrogen were recorded by Frame et al (1970). In general the lowest yielders gave the lowest response. Hence selection for high yield would presumably exclude any lines that were less responsive to Nitrogen applications.

Further variation exists in the nutritive value between different lines of Tall fescue. This complex problem of quality I will endeavour to explain in the next section. However, it is clearly evident that there is a good deal of intraspecific variation on which to base a comprehensive breeding programme.

V. FORAGE QUALITY

In Australia the current animal production grazing system means pasturage must provide the great proportion of the animal's diet. It must therefore provide energy, protein and minerals at all times of the year in quantities sufficient for good animal production, while remaining free of deleterious or toxic components.

The nutritive value of a grass must be an important consideration in any plant improvement programme. Assessment of this can in part be done by determining the intake of digestible organic matter of the forage. This will approximate closely with the metabolisable energy of that forage (Alderman 1966). The protein content of green growing herbage is usually more than sufficient for animal production (Jones 1972), and hence now this parameter is rarely used as an indicator of nutritive quality. It is now widely recognised that digestibility and intake characteristics are usually more important determinants of quality. Minerals on the other hand are often in short supply in grasses, even under good soil fertility conditions. It is thought that the beneficial effect of including a legume to an all grass diet may in part be due to an increase in the mineral intake (Davies et al 1967).

Laboratory procedures that accurately predict the most important quality determinants, viz., digestibility and voluntary intake have been developed. (Tilley and Terry, 1963) (VanSoest, 1971) (Bailey & Jones, 1971). Refinement of these techniques is continuing to make them suitable for evaluating large numbers of lines as is necessary in a breeding programme.

There is no doubt that there is often a relationship between digestibility and intake (Minson et al 1964). The less digestible the fodder the greater the volume of material within the rumen and hence a proportionate reduction in voluntary intake, i.e. Voluntary intake depends on the extent of rumen fill (Raymond, 1969).

In cases where this relationship holds, selection on the basis of high digestibility also will select for high voluntary intake, and hence voluntary intake of digestible dry matter. However, deviations from this general relationship often have been found. Different varieties with the same digestibility have been found to differ in voluntary intake. (Osbourn et al 1966).

The fact that this relationship does not always hold indicates that it would be unwise to base selections in a plant breeding programme solely on digestibility results. Both intake and digestibility are important. This is further confirmed by Walters (1971) who worked with varieties within a species. He demonstrated that considerable variation existed

between varieties within a species, in voluntary intake at similar levels of digestibility, and in the rate of change in intake per unit change of digestibility. The relationship of digestibility and intake are he concludes more a characteristic of the variety rather than the species.

With reference to Tall fescue, Van Soest (1964) showed that with the particular variety he studied (at different levels of maturity and hence different digestibilities) voluntary intake in fact varied inversely with digestibility. This unusual result he states may be due to the "presence of a toxic factor in the juice of the plant". Bryon *et al* (1970) also found a lack of relationship between voluntary intake and digestibility with Tall fescue. He concluded that digestibility alone is not a good measure of its nutritive value. This all emphasizes how important it is that both factors be measured to assess the nutritive value of the plant.

These complications in assessing quality have led to a proposal by Minson (1968). This in essence states, "When screening lines for quality at first a laboratory method is used. The in vitro digestibility technique (Tilley and Terry 1963) is suggested as suitable for this. The most promising selections are more vigorously screened for quality by a measurement of the voluntary intake of digestible energy with pen fed wethers. The final evaluation with the very best selections is based on the results of grazing trials with both sheep and cattle."

This suggestion of Minson's however would not be practical for the very large number of lines involved in a breeding programme. In time it is hoped that refined techniques will become available which will enable the plant breeder to accurately characterize herbage quality in the laboratory and hence more rapid progress should be possible.

It is now well established that the digestibility of plant material depends greatly on its age. The lignification of the plant's cell walls when it changes from the vegetative stage to the flowering stage is a major reason for the decline in digestibility after maturity. Consequently if any selection is to be based on in vitro digestibility results it is important that the comparisons be made when the plants are at similar stages of maturity. Otherwise one may be simply selecting for late maturity rather than greater digestibility.

The rate of decline in digestibility after flowering is also an important consideration. Radcliffe and Cochrane (1970) found Demeter fescue to have a much slower rate of decline in digestibility than many other species - Phalaris, Cocksfoot, Bromegrass, Annual Ryegrass. Digestibility was maintained after maturity through the continued production of new tillers which offset the lower digestibility of the maturing older tillers. This attri-

bute is extremely valuable as it helps to overcome in part the quality deficiency of pastures early in summer.

A general comment on the selection for increased digestibility is I feel necessary. It is important from the aspect of excluding all lines within a breeding programme, which are substantially lower than an acceptable level (say 70%). Advances above this level would I suggest have little bearing on animal productivity, as the general digestibility of a pasture is often so much more affected by management (especially stocking rate) than by the genotype of the pasture's components. Hence so long as one is dealing with material known to be of adequate nutritional value, selection for exceptional digestibility is perhaps of limited value.

A further consideration in relation to quality concerns herbage toxicity. With reference to Tall fescue a non-infectious disease known as "fescue-foot" has been observed in cattle grazing rank, coarse fescue growing in marshy areas (Cunningham 1949). After ten to fourteen days of continuous grazing on Tall fescue, a lameness associated with swelling and localized areas of heat, can develop in the hind legs. This is followed by hardening of the skin, the extremities become cold and numb, leading to gangrene, and death can be the eventual outcome (Cowan 1956). There are two published reports of this condition developing among cattle grazing fescue in Australia and New Zealand (Pulsford 1950). (Cunningham 1949). In New Zealand Tall fescue gained the reputation as a particularly undesirable weedy species, because of many cases of cattle deaths attributed to "Fescue-foot". In the Millicent district, the condition is reported to be not uncommon among cattle grazing a local strain of Tall fescue, called "Williams grass".

A number of workers have isolated alkaloids from Tall fescue in an effort to determine the causative agent (Gentry 1969), Yates and Tookey (1965). The predominant one present was perloline which is also found in many of the ryegrasses. Its concentration was found to vary throughout the growing season and increase with application of nitrogen. Bush (1970) found that perloline inhibits in vitro cellulose digestion by microorganisms of rumen fluid. However digestion of purified cellulose was more sensitive to perloline than was the digestion of cellulose in leaf tissue. It has been suggested that some of the reports of poor performance of cattle and sheep grazing Tall fescue may be related to the effect of perloline in the digestion by rumen micro-organisms.

Yates and Tookey have isolated another alkaloid from Tall fescue and named it Festucine. However administration of pure isolates of this alkaloid to young heifers has failed to induce the toxic symptoms characteristic of "fescue-foot".

More recently Tookey et al (1972) have isolated toxins

from the fungus Fusarium tricinctum which has been found on toxic pastures of Tall fescue in the U.S.A. The toxic compound produced from the fungus when injected intramuscularly into heifers produced some of the symptoms of "Fescue-foot". However there is still doubt as to the part Tall fescue grass plays in this disease. It may be that the disease is associated with Tall fescue in the U.S.A. simply because the grass is commonly used in winter pasture - winter being the period when the disease has been noticed to be most prevalent.

It does appear however that there must be an interaction between the fungus - grass - animal and environment for the disease to become evident.

The nutritional problems cited here are not apparent in S.A. with the cultivar of Festuca arundinacea "Demeter". Numerous cases have been noted where farmers are "very pleased" with the growth of their animals (cattle and sheep) on Demeter fescue pastures - and even on pure stands used for certified seed production (Fairbrother 1969).

VI. METHODS USED IN PERENNIAL GRASS BREEDING

(1) Intraspecific hybridization:

This approach involves the pooling of all the useful variation from a wide range of ecotypes within the species and from this broadly based gene pool resynthesizing by recombination and selection the best combination of desirable traits in a single synthetic variety.

With cross pollinated species such as Tall fescue there have developed a large number of distinct ecotypes each adapted physiologically to the climate of their habitats. Consequently there would be a great wealth of genetic variation with which to work in a breeding programme. Of course its success depends on the cross fertility of the different ecotypes, and on the breeder's ability to manipulate the maturity of the different lines by adjusting daylength and temperature to synchronize flowering.

As far as Tall fescue is concerned, however, there appear at this stage to be several barriers to this intraspecific hybridization approach. While the majority of Tall fescue ecotypes and varieties are hexaploid (42 chromosomes), it is known that many of the ecotypes with origins in Morocco are decaploid (70 chromosomes) (Welsh Pl. Br. Sta. Rep. (1969)). This difference is likely to restrict in some way the amount of hybridization possible. However, as there is a vast range of hexaploid ecotypes from a large array of countries, this limitation should prove of little consequence. The more significant barrier is the fact that while many hybridizations between distinct geographic races have been achieved, in the majority of cases the progeny have been sterile. (Breese 1963). The plants have had completely non dehiscent anthers which were almost entirely devoid of pollen grains. Breese points out that if some female fertility in the hybrid can be found, backcrossing to either of the parents could be a successful approach. The point, however, is clear; namely that through isolation for long periods of time the different races have developed genetically along divergent paths - causing the inter-ecotypic sterility. This problem although an important and significant one should not be unsurmountable, particularly if a large collection of genetic material is obtained. The probability of complete sterility between distinct races must then surely be lessened.

The intraspecific hybridization approach is I feel a very practicable one through which relatively rapid success should be attainable. It has been used in Canberra with Phalaris tuberosa - and a very promising potential replacement for Australian phalaris has been produced (McWilliam, 1969).

(2) Interspecific hybridization:

This involves the hybridization between two species within the one genus. The aim is to transfer individual characters from one to another. Because the two parents are different species the hybrid between them is most likely to be sterile. Consequently in an effort to produce a fertile hybrid the technique of doubling the chromosome number of the hybrid is a useful approach. The hope is that the resultant amphidiploid will behave the same way as a diploid, having meiotic stability and subsequent fertility. However, as one would expect the constituent chromosomes of the two parents often arise from mutual origins, i.e. some chromosomes are homoeologous. When this occurs some multivalents occur at meiosis rendering the hybrid sterile. The amphidiploid does not behave exactly as a diploid because of some homoeology between chromosomes from the different species.

With the genus Festuca mild success has been achieved with hybrids between F. arundinacea and F. pratensis (Hertzch 1966). These plants although sterile grew unusually well and were extremely robust. Doubling the chromosome number of the parents was carried out to get an amphidiploid fertile hybrid. This approach appears to have some practical value, as the hybrids are fertile to some extent, but are found lacking in certain agronomic characteristics. However, as combinations have been made with relatively few parents no conclusions as to the prospects of this approach can be made. Parents with different genetic backgrounds, from different ecological niches, might produce better growing hybrids. It is important to point out that the production of many amphidiploids through interspecific hybridization is just the beginning of the breeding programme. From there on further hybridizations and selections will have to be done as with conventional breeding programmes to obtain the desirable combination of characters within the one line.

(3) F1 Hybrids:

If fertility of the final product is unimportant, the production of amphidiploids may be unnecessary. In this case one relies on the high specific combining ability between the two parents to produce the superior hybrid. The two individual genotypes which in combination produce this exceptional product, must be propagated vegetatively in large numbers for the production of worthwhile quantities of hybrid seed. The use of this hybrid vigour phenomenon can involve either crossing ecotypes within a species with contrasting distributions (Knight 1966) or hybridizing closely related species. This latter approach has been successfully adopted by McWilliam with Phalaris. An interspecific hybrid between P. tuberosa and P. arundinacea called Siro 1146 has been produced (McWilliam 1962). This hybrid combines the desirable parts of the growth rhythms of the two parents. Production of hybrid seed involves growing the

two species in alternate rows, using genotypes selected for their high specific combining ability. The female parent in this case is P. tuberosa and the male parent is P. arundinacea. The seed is of course harvested from the rows containing P. tuberosa.

If two interfertile populations have a high combining ability the problem of hybrid seed production is less complicated and expensive (Foster 1971). The two populations must be largely self sterile, cross fertilized species. With the two populations bulked in equal proportions, one would expect in the seed resulting, 50% inter populational hybrids and 25% intra populational progenies from within each parent population. By altering the initial relative proportions of the two populations the amount of hybrid seed can be proportionately increased. The main factor affecting the inter populational F1 hybrid content of the seed product is the coincidence of flowering patterns. It has been shown by Foster, that growing the mixtures of F1 hybrid seed along with the parental seed in bulk in the ratio of 2:1:1 does not cause any reduction in the productivity compared with a pure stand of the hybrid. The hybrids tend to compete out the parent populations (hybrid vigour) and eventually dominate the grass component of the sward.

As with the artificial production of allopolyploids through interspecific hybridization, it is also important in the production of F1 hybrids that a large array of hybrids be formed from a wide range of backgrounds. Stebbins (1956) has concluded that there is no way of predicting the results to be expected from any particular hybridization. Consequently this stresses the importance that a large variety of crosses be carried out.

(4) Intergenic hybridization:

The problems associated with interspecific hybridization also apply to intergeneric hybridization to some extent. In the latter case we can probably assume that the genetic similarity between the two species is less great than with two species within the same genus - and consequently the artificially produced allopolyploid is more likely to behave like a diploid and be fertile. However, the more two species are unrelated, the greater is the possibility that infertility of the hybrid may result from an upset caused by the 2 genomes in the one cytoplasm. In general the most successful controlled hybrids have been produced between species which are genetically closely related.

The genera Lolium and Festuca are fairly closely related cytogenetically although not apparently morphologically. Many intergeneric hybrids have been made between these 2 genera. The aim has been to combine the palatability and ease of

The result gave plants which were stable meiotically and showed greater seedling vigour, dry matter yield and palatability than four Tall fescue varieties.

Other species also have been used in this intergeneric approach. Usually the parents are altered to autotetraploids before hybridization, to avoid the necessity of colchicine treatment on the F1 hybrid (Hertzch 1966).

e.g. L. multiflorum (4x) x Festuca pratensis (4x)

L. perenne (4x) x F. pratensis (4x)

L. perenne (4x) x F. arundinacea (12x)

(L. multiflorum x L. perenne) x F. pratensis (4x)

As with interspecific hybridization the problem of obtaining intergeneric hybrids is only the beginning of the programme. To obtain new species with the desirable combination of attributes from the parental species requires the formation of a large number of hybrids, followed by further hybridization and selection. Because of the complications there would seem to be little justification for adopting the intergeneric hybridization approach unless the intraspecific variability had been fully exploited. However, it is possible that the long term benefits of these investigations may be in the form of quite dramatic results - the new species may have outstanding effects on agricultural production. A counter argument to this revolutionary new species concept is that one may be attempting to produce a superseded form of a contemporary allopolyploid that has not survived through the natural selection process. Hence it is argued that rather than advancing one is regressing. However, these artificially produced allopolyploids could succeed today under the influence of man's agronomic practises where they could not succeed in nature when originally evolved.

In the final analyses each individual plant breeder must decide which approach offers the greatest possibility for success on the basis of

- (a) his resources both genetic and physical (financial).
- (b) his objectives.
- (c) the length of time to be assigned to the cause.

(5) Inbreeding

Most of the forage grass species exhibit a wide range in self incompatibility, from plants that are completely self incompatible to those that are completely or almost completely self fertile. Hence it is possible to get some seed from enforced self pollination from most species. However, the

theoretical value of this approach is considered extremely doubtful.

The aim in this scheme is to obtain maximum benefits from the phenomenon of hybrid vigour. Inbreeding brings about homozygosity. In those cases where many genes control particular character, e.g. yield, it should be possible theoretically to get all the dominant genes in the homozygous condition. Crossing two of these presumably outstanding inbreds should produce a particularly vigorous hybrid.

However, the isolation of the most favourable combination of genes from a foundation plant under the standard selfing procedure depends on the effectiveness of selection during the selfing process. Considering the small populations usually grown in each progeny generation, the hindrances to recombination imposed by linkage, and the limited effectiveness of visual selection, it seems most unlikely that the potential ceiling set by the genotype of the foundation plant would ever be achieved in an inbred line developed by selfing. In fact inbreeding is a very inefficient process. It does not give new combinations of genes, it just gives homozygosity. It causes a rapid decline of variability because genes become fixed (either dominant or recessive). The probability of obtaining outstanding inbreds depend on (1) the proportion of superior genotypes in the heterozygous source material from which the inbreds were isolated and (2) the effectiveness of selection in increasing the frequency of desirable genes or gene combinations during the inbreeding process.

Due to the considerable doubt about the effectiveness of this technique it is rarely used. However, Buckner (1960) has been able to produce a number of inbred lines of Tall fescue and suggests this to be a satisfactory procedure for breeding new varieties. The palatability and agronomic performance of polycross progenies and synthetics of inbred lines, was his basis for suggesting that selection within inbred lines was a worthwhile approach.

(6) Polyploidy

This approach has been used with quite significant success - particularly with species that are diploid to start with e.g. the ryegrasses ($2n = 14$). Doubling the chromosome number simply by the application of colchicine to germinating seeds has brought about the production of autotetraploids. However, those autotetraploids that have been released were produced only after a programme of hybridization and selection at the tetraploid level. The raw autopolyploids commonly had a slower growth rate, genetic instability, reduced fertility and a lower dry matter content than their diploid parents. Their advantages are a greater seed size with associated greater seedling vigour and larger cell size contributing to larger plant yield. This

greater green matter yield more than compensates for the lower dry matter percentage in comparison with the diploid. Some tetraploids also have been found to have a higher digestibility and nutritive value, (Dent and Aldrich 1963), and greater soluble carbohydrate content.

Interest in this approach to ryegrass varietal improvement originated from the release of tetraploid varieties from the Netherlands (Western Wolths ryegrasses - Wit (1958)). Since then a number of reports on breeding and performance of tetraploids have been published from several countries (Barclay and Vartha - New Zealand, Ahloowulia-Ireland).

Due to the already polyploid nature of F. arundinacea this approach is unsuitable. Excessively large chromosome numbers cause physiological instability - thus restricting this technique to species with low diploid chromosome numbers.

Another problem is that there is no way of predicting the value of a polyploid from the performance of the diploid. Poor performing diploids may in fact produce the better polyploids. However, only a small proportion of diploids will yield a polyploid of potential value. Newly produced artificial polyploids are rarely if ever of economic value; they must be adapted to the needs of the breeder by means of selection and testing first as so newly produced hybrids. Hence this approach as with intergeneric/specific hybridization takes longer than conventional hybridization and selection.

Many consider that the true value of artificially inducing polyploidy with colchicine lies in overcoming barriers to interspecific transfers of genes. That is, it is of greatest value in the production of stable allopolyploids from the sterile products of interspecific and intergeneric hybridization. This is based on the relatively small amount of success with autotetraploids, and the unpredictability of the polyploid from the performance of the diploid progenitor.

This concludes the brief regime of grass plant breeding approaches used today. In relation to Tall fescue the great concentration of work revolves around the interspecific/generic hybridization approach - with the ultimate aim being the production of an entirely new species. Before such an involved programme with all its inherent complications is considered, the intraspecific variation that exists should be examined. There is no doubt that so far the most successful breeding programmes are those that have exploited this type of variation.

VII. THE PROPOSED TALL FESCUE BREEDING PROGRAMME

Objectives:

- (i) To develop a persistent cultivar of Festuca arundinacea of high nutritive value which has a seasonal growth pattern closely matching the requirements of the grazing animal. This can be done by combining into a single synthetic cultivar the winter growing ability and drought tolerance of Mediterranean ecotypes with the spring summer and greater total yield potential of temperate lines.
- (ii) To develop a cultivar of Festuca arundinacea that is adapted to a more intensive form of agricultural production.

These objectives have been formulated on the basis of the known genetic variation that exists within the species, and the attributes considered desirable for a perennial grass both now and what is predicted will be necessary in the future.

The desirable attributes of the ideal cultivar to fulfill objective (i) are listed below:-

- (i) Persistence - In view of the costs of pasture renovation a plant whose life span is at least a decade is essential.
- (ii) Drought tolerance - Survival through the summer is essential to be consistent with the persistence requirement. An ability to respond to summer rains is also desirable as during the summer period there is both a quantity and quality deficiency in our present pastures.
- (iii) Winter activity - The lack of winter production from our present perennial grass cultivars greatly effects animal productivity, unless conserved fodder is distributed.
- (iv) Late maturity coupled with a slow rate of decline in digestibility after maturity would ensure there would be material of adequate nutritional value well into summer.
- (v) Satisfactory spring production - Seasonal distribution of yield is considered more important than total yield. Consequently if the spring component of growth is at least adequate, this would be satisfactory.
- (vi) Compatible with an adapted legume component.
- (vii) Of satisfactory quality - absence of toxic compounds
- possessing a high voluntary intake of digestible dry matter.

- (viii) Seedling vigour.
- (ix) Capable of high seed yields.
- (x) Resistant to diseases and insects.

The ideal cultivar to fulfill objective (ii) would need to possess many of the attributes already described. However, the following would also be required.

- (i) Responsive to nitrogen.
- (ii) Resistant to frequent cutting.
- (iii) Adapted to a monoculture situation.

Collection of Material:

Material has been acquired mainly by correspondence from a large range of ecological niches as well as all commercial cultivars, so as to form a broad genetic basis to the programme. This has been made possible through the Commonwealth Plant Introduction Section of the C.S.I.R.O. in Canberra, Dr. Ron Knight of the Waite Agricultural Research Institute and from the response of breeders overseas to specific request for seed samples of established cultivars. All commercial cultivars have temperate origins - viz. France, U.S.A., U.K., The Netherlands and Germany; while the majority of Mediterranean lines have been obtained from expeditions to this region by various parties (Neal-Smith, Grassland Research Institute-Hurley, and others) especially to Tunisia, France, Portugal and Morocco.

Due to small seed quantities collected originally, and low seed viability following long storage, many of the natural ecotype introductions have been non viable, or have produced only a few plants. This has stressed the importance of adequate seed storage and maintenance facilities if the full benefit of these collecting expeditions is to be obtained.

Seed Multiplication:

This step has been necessary to realistically evaluate material in swards in the environment for which the plant is destined.

Due to the lack of a pollen proof glasshouse facility seed multiplication is extremely difficult, time consuming and inefficient. To achieve pollen isolation between lines it has been necessary to spacially separate them in the field at Northfield Research Centre. In 1972 this operation was carried out with more than 100 lines with a moderate degree of success, as far as seed production is concerned, but with no direct knowledge of the level of crossing between lines.

Assessment of Introductions

This was commenced in the Adelaide Hills at Woodside in Autumn 1973. The trial has been designed so that information on the following characteristics can be obtained, from small swards (1 metre x 3 metres).

1. Seasonal yield
2. Total potential yield
3. Responsiveness to Nitrogen
4. Resistance to frequent cutting
5. Seedling vigour
6. Persistence
7. Nutritive value by laboratory techniques

This information should indicate which areas in the breeding programme should be concentrated upon, as well as revealing whether any introductions are so outstanding as to have the potential for immediate use by farmers and to indicate likely parental lines for recombination.

Hybridization

The criteria on which to base selection of parental lines for recombination have been formulated to ensure the maximum assortment of genes within the population.

Selection will be based on:-

- wide diversity of origins and hence growth rhythms.
- wide diversity of morphological types.
- the published performance and characteristics of lines.
- the intuitive appeal of lines based on their performance in pots at Northfield Research Centre.
- the performance of lines in swards grown in the Adelaide Hills (when information becomes available).

Hybridization will take place in two ways:-

- (1) Pair crosses between selected lines in isolation without emasculation in the glasshouse → F1 families.
- (2) Establishment of polycrosses in the field on the Northfield Research Centre → Half sib F1 families (i.e. Random ♂ parentage, common ♀ parentage).

Four polycrosses have been constructed in 1973.

- (1) A polycross with a wide genetic base (8 Mediterranean lines, 8 temperate cultivars)
- (2) A polycross with a narrow genetic base (4 Mediterranean lines, 5 temperate cultivars)
- (3) A polycross consisting of lines which originated from temperate regions (10 cultivars)
- (4) A polycross consisting of lines which originated from Mediterranean regions (9 ecotypes)

A wide cross section of the genetic variation available has been included in these blocks.

Assessment of Hybrids

The F1 families (from the pair crosses) and F1 half-sib families (from the polycrosses) will be planted as seedling in boxes in the glasshouse.

Selection will then be based on seedling vigour, and first year autumn and winter growth. Equal numbers of outstanding genotypes from each family will be selected to be placed in a further recombination block, to give further assortment of genes. A random selection of genotypes from all F1 groups will also be carried out to form a base population containing hopefully the entire genetic variability available.

Recombination

Polycross blocks will be set up in the field containing the selected genotypes.

- (1) Equal representation of genotypes from the F1 families.
- (2) Random selection of genotypes from both the F1 families and half-sib F1 families.
- (3-6) Equal representation of genotypes from the half-sib F1 families resulting from the four polycrosses.

After inter pollination seed would be bulked within each polycross. This large quantity of F2 seed would then form the base populations on which individual plant selection would be carried out. This second recombination should ensure a thorough mixing of genes throughout the population and remove any unfavourable linkage combinations.

Individual Selection

All seed from the polycross would be germinated in petri

dishes in an incubator. Those 10% outstanding in seedling vigour would be grown outdoors in boxes and selection would be based on autumn growth. These F2's would be transplanted into the field, in the environment for which the plant is finally destined. They would go through further series of selection sieves for first year winter growth, growth habit, flowering time and seed retention. Plants passing through the final screening would be removed from the field prior to flowering and recombined in all combinations in isolation to produce a large number of F3 families.

Development of a Synthetic Variety

A synthetic variety is a population produced by hybridizing in all possible combinations a number of selected genotypes; and which is thereafter maintained and multiplied by random mating in isolation (Breese 1972). It originally would contain between 6 and 10 outstanding genotypes.

There are 2 contrasting approaches for developing a synthetic at this stage.

- (1) Phenotypic selection from the F2 or F3 populations.

Apparently superior plants from the F2 or F3 population would be placed together to form the base population of the synthetic. Selection here would be purely subjective, based on morphological uniformity, coincidence of maturity and general attractiveness.

- (2) Progeny testing of the F2 elite genotypes with the F3 families in swards.

This assessment of the general combining ability of the elite F2 plants, enables outstanding genotypes as determined by the sward performance of their F3 families, to be placed together to form the base populations of the synthetic.

After recombination of these base populations, sufficient seed would be available to enable them to be evaluated in swards over a number of environments, for those characteristics as detailed in the original objectives. For instance digestibility and intake laboratory analyses would be carried out with this material. Further evaluation under grazing would be necessary before the final release of any synthetic.

The heritabilities of the characters under examination determine the relative rates of improvement by individual phenotypic selection and progeny testing. Only in the case where the heritability of the character is low will a progeny test give a better result

than direct phenotypic selection. Morley and Heinrichs (1960) have estimated the heritability has to be as low as 10% before inclusion of a progeny test will give better results in annual improvement compared with phenotypic selection alone. The heritability of forage yield may be of this order, consequently in this case, progeny testing may be worthwhile. However, if the heritability is too low, no amount of progeny testing could produce useful improvements. Then so little of the final phenotypic variation of that character is contributed to by the genotype, that selection of any nature would be worthless.

Conversely if the heritability of the character is relatively high, valuable advances may be made more quickly simply by basing selection on the phenotype itself. The loss of time due to the extra generation necessary to perform a progeny test, may in this case in fact reduce the rate of response to selection.

In the long term, both selection systems could run concurrently as has been suggested for this programme. It is envisaged however that the most rapid improvements would be obtained from phenotypic selection alone - bypassing the extra generation required for a progeny test.

Summary of Breeding Programme

<u>Operation</u>	<u>Comments</u>
1. Collection of seed material:	Wide diversity of origins. Mediterranean ecotypes, Temperate cultivars.
2. Establishment of nursery:	Preliminary evaluation as spaced plants.
3. Seed multiplication:	Spacial isolation in field. Crossatron.
4. Assessment of introductions in swards:	This evaluation to be carried out concurrently with rest of programme.
5. Recombination of selected lines:	Pair crosses in glasshouse → full-sib families Polycross blocks in field → half-sib families.
6. Assessment and selection of F1's:	Selection based on; seedling vigour, 1st year autumn and winter production, morphology yield potential.
7. Recombination of F1's:	Polycrosses in field
8. Individual selection of F2's:	Selection based on: seedling vigour 1st year autumn and winter production, seed production potential, morphology, general attractiveness.
9. Recombination of outstanding F2's:	Pair crosses in isolation in glasshouse or crossatron.
10. F3 families evaluated in swards:	Cutting trial, assessment based on seasonal productivity, response to Nitrogen fertilizer, laboratory analysis of quality.
11. Phenotypic selection of outstanding F3's:	Selection based on; seedling vigour, 1st year autumn and winter production, seed production potential morphology uniformity, synchronisation of flowering.
12. Recombination of outstanding F3's:	6-10 genotypes allowed to interpollinate at random to produce the basic synthetics.

13. Recombination of outstanding F2's:

The constituents of these polycrosses would be determined from the results of the F3 families in swards. These would be further basic synthetic populations.

14. Evaluation of basic synthetic populations:

Laboratory analysis for quality. Sward evaluation over a number of environments and years.

15. Seed multiplication of outstanding lines:

Selection based on the achievement or otherwise of original objectives.

16. Evaluation of superior lines in grazing experiments.

17. Release of new cultivar.

RECOMMENDATIONS

- (1) That approval of the basic philosophy behind a perennial grass breeding programme be accepted, in light of the evidence presented in this review. Realisation of the value of such a programme and commitment to its cause will ensure the successful fulfilment of its potential.
- (2) That it be recognized that any dividends that would result from this avenue of research cannot be achieved without investment. A modern, efficient and productive plant breeding programme relies heavily on the provision of facilities and resources for it to be successful.
- (3) That effort be devoted to obtaining financial support for this programme.

Specific items which need urgent attention are:-

- (a) A crossatron: This is a modified glasshouse designed to facilitate the cross pollination of groups of plants under conditions which are free from contaminating pollen. Seed multiplication plays a vital role in the breeding of any cross pollinated species. Efficient seed multiplication equipment will ensure that sufficient seed of advanced lines and introductions can be produced, so that adequate evaluation of lines can be carried out over a number of environments.
- (b) Support staff: In view of the large amount of field and glasshouse work involved in this programme, it is essential that labour assistance be obtained.
- (c) Laboratory facilities: Access to adequate laboratory facilities must become available if the important quality aspects of advanced lines and introductions are to be investigated.

CONCLUSION

The introduction of perennial grasses to the pasture system has contributed to a general increase in animal productivity in the past (McWilliam 1969, Hutton 1971). The development of improved varieties as outlined in this report would further enhance the productivity of pastures.

There is ample evidence to suggest that sufficient genetic variation exists within the species Festuca arundinacea on which to base a successful breeding programme. If the known major characteristics are considered together, such as, the widespread adaptability of the local cultivar "Demeter", the greater winter yield potential of Mediterranean ecotypes, the greater spring and summer producing capabilities of the temperate lines, and that the achievable growth rate of this species is rarely matched by other temperate grasses (Hunt and Cooper 1967) it is clear why success is so confidently predicted.

This potential cannot be realised unless supporting staff and facilities are made available.

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