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Report of the Meeting of the Fodder Crops Section

Aberystwyth, Wales; UK. 13-16 September 1982

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Preface

Following the wishes expressed at the previous meeting in Ghent, the Welsh Plant Breeding Station kindly accepted to organize the 1982 meeting of the Eucarpia Fodder Crops Section. The conference, which was held in the Biology Lecture Theatre of the University College of Wales, Aberystwyth, was attended by participants from 15 European and Middle East countries. The main theme for discussion was "The utilization of genetic resources in fodder crop breeding".

Genetic variation or variability is what the plant breeder depends on to face the increasing demand for better and more distinct varieties. Through mutation and recombination, variability has accumulated in plants during thousands of years. However, the present rapid change in land management and cultivation techniques may lead to the loss of valuable material. In recent years, fodder plant breeders have become more aware of the need to save old local varieties as well as wild ecotypes. As more good land will be necessary to produce crops for human nutrition, production of fodder plants may be intensified in rather marginal regions. Genetic material, which has no interest at the moment, may be useful in the breeding of varieties for more marginal conditions such as high altitudes, dry land and poor soil. For these reasons every potential genetic resource should be taken into consideration. Storage alone of genetic material in a gene bank is however not sufficient. Another major task must be to acquire more knowledge about the characteristics of valuable wild material in relation to its adaptation to various management systems. Finally, we have to know how to exploit these resources in a breeding program by appropriate breeding procedures.

All these questions, which require exchange of information and material as well as co-operation with international agencies, gave the canvas of our three sessions:

(1) Creation and exploitation of novel genetic resources and the scope for genetic exchange

(2) Evaluation of genetic resources

(3) Utilization of genetic resources in breeding programs

The papers presented during the meeting are included in this report.

A visit was also organized to the Welsh Plant Breeding Station, where staff members demonstrated the experimentation in progress.

In the name of all participants, I should like to express my great appreciation to the organizing committee headed by Professor J.P.Cooper. I am especially indebted to Dr M.Hayward, who took charge of most of the administrative work and accepted to act as the editor of these proceedings.

S.Badoux
President of the Eucarpia
Fodder Crops Section

WELCOME ADDRESS TO EUCARPIA FODDER CROP SECTION

MEETING AT ABERYSTWYTH, SEPTEMBER 1982

E.L.Breese

Deputy Director, Welsh Plant Breeding Station, Aberystwyth

Mr President, fellow members and associates of the EUCARPIA Fodder Crop Section, it is my great pleasure to welcome you back to Aberystwyth after an interval of almost 14 years. In doing so it is customary, and my privilege in the unavoidable absence of Professor Cooper who sends his apologies, to briefly describe something of the interests and activities of the host institute as a setting for the conference. But I shall be brief because there will be further opportunity on Wednesday afternoon when you visit our Headquarters at Gogerddan.

The Welsh Plant Breeding Station is a research department of the University College of Wales at Aberystwyth and it is thus fitting that you are lodged, and that the meetings are held in the College itself. The Station is proud of its links with the University and we have active co-operative programmes with other Departments, especially the Department of Agricultural Botany; - indeed for many of the earlier years the Director of the Station was Professor of Agricultural Botany. We are however, completely financed by a grant-in-aid from the Agricultural Research Council (ARC) and are one of 30 Institutes supported by this Council. Our responsibilities are to carry out research in plant breeding methods and techniques, and in relevant scientific disciplines, and to use these techniques for the development of improved crop varieties. We concentrate on those crops which are important for livestock farming systems in the west and north of Britain, principally on the herbage grasses and clover, but also on oats and barley.

Following a rationalization of programmes among ARC Institutes a few years ago, we now have a responsibility for breeding grasses and clovers for the whole of Britain, while the Plant Breeding Institute, Cambridge concentrates more on cereals and on arable crops of the south east, and the Scottish Crop Research Institute concentrates on potatoes and arable forages, including the brassicae.

The target for our herbage plant breeding activities in this country is to produce improved varieties (i) for the two million or so hectares of temporary grass, (ii) as a reseeding option for the improvement of the permanent grass which includes some five million ha of lowland and five to six million ha of hills and uplands. All this covers a wide range of dairy, sheep and beef enterprises. In this programme we have a natural affinity and shared interests with two other sister institutes, - the Grassland Research Institute, Hurley, and the Hill Farming Research Organisation in Scotland.

In seeking to improve breeding methods and produce improved varieties at the Welsh Plant Breeding Station, work on research and development is organised into ten departments. The three operational Breeding Departments, concerned with herbage grasses, herbage legumes and arable crops respectively, are responsible for variety production but also carry out cyto-genetic research leading to improved breeding methodology. In the latter they are closely supported by the Cytology Department who study chromosome relationships between different grass and cereal species with a view to genetic manipulation through interspecific hybridization and polyploidy.

Four other Departments are discipline-oriented, and concentrate on translating ruminant animal requirements into plant characteristics, particularly to provide more effective selection criteria and screening methods in the breeding programmes. Thus the Developmental Genetics Department is concerned with identifying those morphological or physiological features which determine the efficiency of the grass or legume crop in converting the environmental inputs of light energy, water and soil nutrients into high quality animal food; the Plant Biochemistry Department is concerned with the biochemical basis of plant growth and development; the Chemistry Department studies the physical and chemical constitution of the plants in relation to nutritive value; and the Pathology Department is concerned with loss through disease and with the mechanisms of disease resistance.

The two remaining Departments are concerned with commercial seed production and utilization of potential varietes. The Seed Production Department has the responsibility for the initial multiplication of the Station bred varieties, and also carries out research on factors affecting seed production. Of course ultimately the variety is only as good as its management and the potentials and defects of new and potential varieties are considered by our Agronomy Department in relation to realistic management systems. We believe this to be a positive approach to crop and management improvement and contrasts with much current grassland research and its pre-occupation with existing permanent pastures. While the latter approach can offer rapid advances in some less well developed grassland areas through the application of known technology and practice, it is limited (i) by the rate of ecological change in the native sward and (ii) the yield and nutritive value of the naturally occurring final components which are selected for survival rather than production. As such it fails to take into account the full genetic resources and potentials of the crop and the way these may lead to future developments in grassland technology and husbandry; - which is the theme of this conference. And by the grassland crop I include with the grasses the very significant role that the legumes can play in leading to low cost nutritious food for enhanced animal production.

I have always taken great pleasure in belonging to the Forage Crop Section of EUCARPIA. I believe it is one of the best forums I know for forthright discussion between researchers and practical breeders. At our annual conferences we have never failed to co-operate in tackling and trying to solve the many problems, genetic and agronomic, which confront us in breeding better varieties in those most difficult of all crops - the forages in general and the herbage grasses and clovers in particular. The presented papers form a 'public address' system for voicing varied interests and points of view. The real value of this meeting lies in discussion and debate, both at formal meetings and informally in the evenings. This Section has a strong tradition of such active participation by all its members, - we hope that the Aberystwyth environment will help maintain, - indeed foster, that tradition.

Finally, I would like to pay tribute to Dr Michael Hayward who, as Secretary of the Organising Committee, has borne the brunt of the work in arranging this meeting.

NEW COMBINATIONS OF CHARACTERS IN GRASSES: THE NEED, THE RESOURCES AND SCOPE FOR GENETIC EXCHANGE

E.L. Breese

Welsh Plant Breeding Station, Aberystwyth.

BREEDING TARGETS

Grass is a complex crop and before considering available genetic resources and the way we can exploit these, we need to specify our breeding targets in realistic and balanced terms. In agriculture the crop has value only as a source of low cost feed for ruminant animals, so improvement has to be closely associated with the needs of ruminant livestock systems. In genetically adjusting the crop to suit these systems, factors affecting utilization by the animal are at least as important as the total annual dry matter yield of the crop. Such factors are seasonal distribution of yield and nutritive quality. They also include tolerance of low winter temperatures and of water stress, resistance to diseases and pests, all of which affect consistency of yield and quality as well as modify the innate persistency of the genotype. All these factors have to be related to the farming system, intensive dairy or extensive beef and sheep, and all are profoundly influenced by management for conservation or grazing. We need also to bear in mind that management flexibility is of the highest importance in the practical farm situation.

The ultimate value of a sward can only be measured in terms of animal products but this is a difficult and costly process. At Aberystwyth a multi-discipline approach has been adopted in seeking to translate animal requirements into more specific plant characteristics than are indicated by the factors broadly categorized above, and which may be more effectively used as selection criteria. In this approach we have sought to elucidate the relationship between photosynthetic efficiency and utilizable yield under different environmental constraints, thus identifying those factors which are important for sward growth and quality. These provide not only selection criteria and screening techniques for breeding programmes, but also for the evaluation of the improved variety. In addition they provide guides to the kind of descriptors and descriptor states which are most useful to breeders in labelling germplasm collections. Other papers in this meeting will deal with some of these aspects in more detail.

NATURAL GENETIC RESOURCES

The species

A number of grass species can flourish under the conditions of improved fertility and relatively heavy grazing pressures which are required for high animal production. In Britain, perennial ryegrass is well adapted to the grazed situation on most soils, and is unsurpassed in terms of yield and acceptability to the grazing animal. It is however, less well adapted to yield and persist under conservation managements, and here Italian ryegrass for short term leys, and tall fescue for longer term leys, merit closer consideration. Improved forms of cocksfoot are better suited to light, dry land while red fescue has potentiality for upland areas (Munro, Davies & Morgan, 1973). No single grass species can provide the ideal sward under all, or even a few, farm systems, and for maximum flexibility the breeder is presented with the problem of producing co-adapted varieties for use in mixtures, or developing new and novel hybrid combinations. We shall return to this later.

Ecotypic variation

Most grassland species are outbreeding and many have a widespread distribution. They all reveal a vast array of adaptations to various combinations of climatic, edaphic and biotic factors. Adaptation to a particular ecological niche rarely involves response to a single environmental factor or incurs a single physiological or morphological change: rather it depends on the co-ordination of very many physiological processes in securing growth and the full reproductive cycle, with due regard to a whole complex of environmental factors. Differences of significance to the plant populations therefore tend to be quantitative rather than qualitative, depending on the fine adjustment of many genes or gene sets. We shall return later to the complexity of gene action and interaction in determining phenotypic expression, and the limitations this may impose, or at least the problems it may pose, in the exploitation of the new technologies now being developed in the field of genetic engineering.

Many present day varieties are based on ecological adaptations. Breeders have effectively exploited the rich resources of naturally occurring ecotypes and have made the most productive of these generally available for grassland improvement by reseeding, or to fit into ley farming systems.

Inevitably the laws of diminishing returns apply to a continuing search for ecotypes which will be superior to varieties in current use, and it is now only very occasionally that plant prospecting of this sort will turn up 'pure gold' collections which can be released as commercial cultivars with a minimum of further selection for agronomic performance and, of course, for uniformity and stability. Most often the better collections will be raw materials ('crude ores') with specific valuable traits which have to be extracted and forged into new varieties by hybridization and selection.

Natural pastures still offer an unique wealth of germplasm, but this resource is being increasingly eroded by changing agricultural patterns. Foreseeing this some years ago, we set up a Plant Introduction Unit at the WPBS, charged with co-ordinating the collection of grasses and clovers and with their evaluation, classification, description and maintenance, and over the years we have systematically prospected and collected through temperate grasslands in Eurasia, guided by basic principles of adaptation to climatic edaphic and biotic complexes (Davies et al., 1973). At the same time our collections have been augmented through a system of seed exchange with other collection centres.

Our earlier quests were for an extended season of growth and we were able to obtain very early spring growing, or even winter growing ecotypes of ryegrass or cocksfoot from southern latitudes. Too often these populations were cold sensitive and in severe winter were killed out. More recently we have discovered a revolutionary combination of early spring growth and winter hardiness in a persistent pasture type of perennial ryegrass from the lower Swiss Alps. Among other more useful discoveries are an unusual tillering capacity in cocksfoot from N.Spain and a resultant greater persistence under grazing and also new potentials for summer growth in Italian ryegrass from N.Italy.

I take this opportunity to emphasize that the successful outcome of many of our plant collection expeditions would not have been possible without effective liaison with scientists and breeders in the collection areas. I would like to record our gratitude to these associates, some of whom are at this meeting today. It is also my view that future breeders and germplasm conservationists will have much to owe to these early forms of international co-operation, operating at the practical and individual and hence often at the most effective level.

Genetic architecture and scope for selection within populations

These grass species have efficient incompatibility genes (Cornish *et al.*, 1979a,b) which enforce outbreeding and thus preserve a high degree of genetic variability in both natural populations and derived varieties. The variability is in the free and the heterozygous potential state.

Just how great this variability can be for quantitative characters is well illustrated by the selection experiments of Cooper (1959) with perennial ryegrass. Working with two populations (i) a short lived, hay-type, old commercial variety (Irish) and (ii) a persistent pasture ecotype (Kent Indigenous), he selected for early and late flowering. Response was rapid in both populations and divergence considerable before the directional selection resulted in a loss of fertility and a consequent brake on further response. Because of the correlation between the date of heading and the degree of tillering, reproductive modes (asexual v. sexual) were simultaneously affected. As a consequence predominantly 'sexual', relatively short lived types were obtained from Kent ryegrass, and predominantly asexual, more persistent lines were obtained from Irish, - and vice versa.

These experiments were among the first to illustrate the vast amount of potential genetic variation that exists within single populations of these outbreeding grasses, indeed within very small samples of plants since Cooper obtained good response from as low as four basic individuals per population. In general the outcome of the selection was presaged by the classical work of Mather & Harrison (1949) using Drosophila as an experimental organism. But the extent and nature of the response, particularly the correlated responses in other characters, provide an insight into the genetical structure of the populations. This reflects past selection histories and thus affords a better understanding of the evolution of L.perenne, which in turn provides guidance on breeding strategies and tactics.

Over the years evidence has accumulated to demonstrate the large scope for selection within populations, or in crosses between populations for a wide range of physiological characters, - for factors affecting nutritive quality, water stress, cold tolerance and disease resistance (for review see Cooper & Breese, 1971; Wilson, 1981; Breese, 1983) and Dr Wilson will be speaking on these aspects later in this meeting. Again it is important to note that in almost all instances (with the possible exception of disease resistance), the characters useful in agriculture or in ecological adaptation are quantitative, controlled by many interacting genes. All too often selection for one character engenders correlated response in other characters because of complex linkage relationships as well as through pleiotropic effects of the same genes, - all of which pose problems of multitrait selection if we are to obtain improved synthetic varieties which are at linkage equilibria and hence stable enough for seed multiplication without loss of the primary selected characters.

Somatic variability

I would like to deal here with another dimension of variability which may become amenable to adjustment by the breeder. In doing so I shall first refer to experiments on selecting within clones (individual genotypes) of ryegrass, carried out some years ago by myself and colleagues (Breese, Hayward & Thomas, 1965). This involved selecting for slow and fast tillering rates within individual clones grown from seed deriving from different populations. In some clones responses were obtained, and since no obvious chromosomal effects were noted this was thought to involve changes in the plasmon, possibly of the mitochondria or the chloroplasts which are now known to have their own self-replicating DNA coding for a number of genes affecting regulatory enzymes. The effects were only noted in a few clones, particularly those deriving from persistent populations. In later experiments, however, similar changes could be evoked in shorter lived *L.multiflorum* clones, although with greater difficulty.

By using *L.multiflorum* seed which had been stored for nine years (in open containers at approximately 0°C) we were able to demonstrate a different kind of somatic instability. One of the clones had an atypical leaf morphology and general appearance which later somatically segregated in a qualitative manner to give more normal as well as abnormal phenotypes. As we might guess the 'abnormal' phenotype was aneuploid with two extra chromosomes plus a centric fragment, and the somatic segregation was associated with a loss of one or more of the extra chromosomes.

It is tempting to suggest that these somatic instabilities observed some 20 years ago are the 'tip of an iceberg' of the so-called 'somaclonal' variability which has been revealed by modern tissue and cell culture techniques (Larkin & Scowcroft, 1981) and which Dr Dale will be considering in a later paper at this meeting. At that time we considered the gradual changes mediated by possible plasmon heterogeneity to have adaptive significance, and to be potentially of significance to breeding programmes (Breese *et al.*, 1965).

It is clear that in the outbreeding *Lolium* spp. there is wide genetic diversity at the species and ecotype level and large amounts of genetic variability within ecotypes at the nuclear and perhaps the plasmon levels. Adaptation is fairly widespread climatically and on the more fertile soils. But there is one predominant pattern of adaptation that has been suggested (Breese, 1973) as the major cause of differentiation within the genera: that is adaptation to the grazing animal. In its train has come changes not only in the physiology and morphology of the populations but also in genetic architecture. Thus plants adapted to increasing defoliation by grazing have short, prostrate leaves and are high tillering, leading to a predominantly asexual (vegetative) mode of reproduction: the antitheses in morphology, physiology and sward geometry of the predominantly sexually-reproduced, shorter lived populations found under infrequent defoliation. Accompanying the physiological changes have come changes in the dominance and interactive properties of the genes, and in their linkage characteristics as measured by chiasmata frequency and distribution, also perhaps differences in the role of the plasmon (Breese, 1973). We could list many other generalised contrasts. The reason for these changes and their full implications for breeding are beyond the scope of this paper and have been discussed elsewhere (Breese & Hayward, 1972; Breese, 1973). But I draw attention to the limited degree of speciation and consequent barriers to genetic exchange; so that genes, for instance for disease resistance, can easily be transferred from one species to another by conventional hybridization and backcrossing programmes.

INTERSPECIFIC HYBRIDS

During evolution natural ecotypes and species of the grasses have become fairly narrowly adapted to only part of the spectrum of farm management conditions. They have become spacialists. In practise the specialists have become too specialized and a greater management flexibility is sought through the use of unstable mechanical mixtures of varieties or species. These are designed variously to ensure long season growth, nutritional complementation and even to provide for better combined grazing and conservation potentialities. An alternative approach is to genetically combine these diverse characteristics in a common nucleus through the production of hybrids. The extent that we are able to do so depends first on a balanced complementation of characters between the parent lines, secondly on the dominance and interactive relationships of the genes. Jointly these will determine the specific combining abilities of the parents with respect to adaptability.

Ryegrass hybrids

Italian and perennial ryegrass offer a most useful complementation of characters. But the critical element here is the extent to which the genes of a hybrid nucleus can find expression to provide greater versatility under the grazed situation on the one hand and conservation systems on the other; diverse situations which call for opposing and mutually exclusive foliage morphologies and sward geometries. Conceptually it requires alternative pathways of development mediated by some suitably triggered dominance switch mechanism.

First let us consider the possibilities for producing commercial quantities of hybrid seed. The species cross easily to produce fully fertile F_1s which are, of course, genetically unstable. Opportunities exist for producing commercial quantities of F_1 seed through the use of incompatible clones or of male sterility. Both methods have problems which may add to the cost of the F_1 seed, but the latter method has been used in the Netherlands to produce a potential hybrid variety (J. Joordens, pers.comm.). An alternative method is through allopolyploidy (Stebbins, 1956).

The use of ploidy

These basic diploid species (2n = 14) were both early candidates for the production of artificial autotetraploids (4n = 28) by colchicine treatment (Wit, 1958), and a number of varieties have been commercialized. Their main features compared with diploids are (i) a larger cell size bringing about reduced fibre and increased water soluble carbohydrate contents, - leading to improved palatability, digestibility and feeding value (Castle & Watson, 1971; Alder, 1968), (ii) a slower rate of tillering so that they tend to be less persistent particularly under grazing. Otherwise these autotetraploids generally reflect the adaptational properties of the diploids from which they derive. The field has been reviewed by Van Bogaert (1975).

The synthetic autotetraploids can be used as a basis for the production of tetraploid hybrids (allopolyploids) between the species (Breese *et al.*, 1975). Although the chromosome sets are not markedly differentiated there is cytological evidence to suggest preferential pairing (Clarke & Thomas, 1976; Lewis, 1980), which has been shown by the use of allozymes as chromosome markers to be of the order of 32% (Breese & Thomas, 1978), although this may vary and so offers scope for selection (Breese et al., 1981).

It was calculated that tetrasomic inheritance, hopefully reinforced by a degree of preferential pairing would maximize heterozygosity relative to disomy and thus preserve hybrid combinations during generations of seed multiplication to commercial quantities (Breese et al., 1981). This has largely been realised and a number of commercial hybrids have now been produced which combine useful features from both parent species. The method involves controlled pair crossing of individual clones (genotypes) from existing tetraploid varieties or newly induced tetraploid populations, followed by the selection of individual F_1 families for fertility, stability and agronomic performance. In some of the selected hybrids the dominance of the Italian ryegrass parent is apparent up to the heading phase when there is a switch more to the dominance of the perennial parent during recovery growth. This developmentally induced switch affects the canopy structure of the sward to give more flexible management for silage cuts together with early and late grazing. Selected hybrids have good seasonal growth patterns, are highly palatable and have digestibility and intake characters which match or exceed Italian ryegrass (Walters & Evans, 1978). Good winter hardiness, tolerance of drought and resistance to some diseases have been built in.

Future prospects

The hybrids thus lend hope that we can combine a plastic response to controllable (management) variables with low sensitivity to uncontrollable (environmental) variables. These primary hybrids are single crosses between selected pairs of clones from the two parental species. Thus although hybridity is maximized between homoeologous chromosomes it is minimal between homologous chromosomes. Clearly the technique offers scope for the production of a wide range of such hybrids that are still better adapted to grazing/conservation conditions. It allows rapid selection at the diploid level for complementary genotypes and uniting these in relatively stable tetraploids. (This technique could also be used for stabilizing hybrids within the species, although without the advantages of preferential pairing in improving stability).

However the tetraploid state offers the possibility of a second dimension of hybridity in the interspecific crosses, that between chromosome homologues of the same species, thus providing further opportunities for enhancing heterosis and extending adaptability. This course, however, requires a fundamental re-appraisal of the relations between chromosomes, and the consequent segregational properties when more than two alleles at a locus are involved. For tetrasomy, if we consider seven loci, it can be shown that only 37% of a population at equilibrium is heterozygous for all four possible alleles at even one locus, and only a very small proportion is simultaneously fully hybrids for even three loci (Breese *et al.*, 1981). It can also be shown that no contrived mating system can maximize hybridity beyond 44%. Thus by intercrossing our primary hybrids we can effectively create a new hybrid tetraploid ryegrass species of the status of 4x *Dactylis glomerata* or lucerne. But to fully exploit secondary hybridity and continue to add more accurately to genotypic flexibility we require a more precise control of homologous chromosome pairing leading to amphidiploidy; either by the selection of pairing control genes already present in the diploid species as indicated by previous studies (Breese *et al.*, 1981), or by introducing pairing control genes from related polyploid fescue species and this will be discussed by Thomas & Morgan later in this symposium. We can expect that in the process there would be a reduction in the very high level of aneuploidy present in the allotetraploids, which at present is of the same level as that found in intraspecific autotetraploids.

Intergeneric hybrids

A number of *Lolium* and *Festuca* species are sufficiently closely related to allow hybridization with varying degrees of difficulty. Of these species, the ryegrasses show useful degrees of complementation in agronomic characters with diploid meadow fescue and hexaploid tall fescue. Although ryegrass x meadow fescue hybrids are sterile at the diploid level, fertility is stored to some extent in induced allotetraploids (Lewis, 1972). A number of these hybrids have been produced and show useful complementation for late summer growth and good drought and winter hardiness (Lewis _et al._, 1973). Although markedly superior to meadow fescue, the hybrids have not so far matched the ryegrass parents or ryegrass hybrids under intensive UK conditions, but show promise under more extreme winter cold and summer drought. There is scope for improving both the fertility and the genetic stability of these hybrids.

Next to the ryegrass hybrids, the combination of tall fescue and Italian ryegrass appears to offer the best complementation of characters, particularly for a persistent conservation crop. F_1 hybrids are sterile but the chromosome doubled octaploid ($2n = 56$) is fertile (Lewis, 1966). Incomplete control of homologous chromosome pairing, however, leads to chromosome loss and subsequent genetic instability which has so far limited the development of this hybrid. In both this and other ryegrass/fescue hybrids, the allopolyploid can be used as a genetic bridge to transfer genes or gene combinations between the parent species (Buckner _et al._, 1977).

CONCLUSION

It is apparent that there is a wealth of genetic variability for the improvement of grass species. Within the ryegrass species there is wide scope for selection both of nuclear genes and perhaps of extranuclear elements. There is relatively easy access to the recruitment of genes and genetic material from related fescue species, and, especially through the use of allopolyploidy, a means to expand the versatility as well as the general adaptability of the grass crop.

In polyploid breeding, whether for combining genomes or for genetic transfer, the limits are initially set by the number of sexual hybrids which can be obtained. The crossability of the species varies markedly between different genotypes of the donor species as well as between species. The development of tissue culture techniques for embryo culture and ultimately somatic hybridization offers hope of overcoming some of these obstacles and Dr Dale will be mentioning these later in this meeting. These open up new vistas of genetic manipulation.

A new term 'genetic engineering', has crept into our vocabulary, which involves technologically sophisticated, even awe-inspiring methods for what is conceptually simple, i.e. moving genes over greater distances than was possible by sexual means. This concept is perhaps dangerously simple, - liable to raise over-optimism or over-sceptism. Thus to what extent can we usefully identify and manipulate genes at the molecular level, especially in eukaryotes? I quote from a commentary paper given at the 2nd Kew Chromosome Conference (John, 1982):

> 'While it is true that all actions and interactions in any biological system are ultimately traceable to molecular matters, it is equally true that many of these interactions are so remote from the initial molecular events which underlie them - as to make an assessment of the one in terms of the other not only impracticable but essentially meaningless. In biology, it is clear that the whole is indeed greater than the parts'.

Certainly new advances in the technology of genetic manipulation will provide new tools and add new dimensions in the field of plant breeding. But ultimately the breeders task is the organization and orchestration of assemblies of genes in harmonious combinations, and in this we must come back to biometrical considerations, multitrait selections and meaningful evaluation techniques.

REFERENCES

Alder, F.E. (1968). Comparison of diploid and tetraploid ryegrasses in animal-production experiments. J.Br.Grassld Soc. 23, 310-316.

Breese, E.L. (1973). Genetic architecture and adaptation in grasses with special reference to Lolium. In: Quantitative Inheritance, Polymorphisms, Selection and Environment. Int.Meeting, Bologna 1972. pp.78-83.

Breese, E.L. (1983). Exploitation of genetic resources through breeding : Lolium species. In: Proc.Symp. on Genetic Resources of Forage Plants. (Bray, R.A. & McIvor, J.G., eds). Melbourne:CSIRO (in press).

Breese, E.L. & Hayward, M.D. (1972). The genetic basis of present breeding methods in forage crops. Euphytica 21, 324-336.

Breese, E.L., Hayward, M.D. & Thomas, A.C. (1965). Somatic selection in perennial ryegrass. Heredity 20, 367-379.

Breese, E.L., Lewis, E.J. & Evans, G.M. (1981). Interspecies hybrids and polyploidy. Phil.Trans.R.Soc.Lond. Ser.B 292, pp.487-497.

Breese, E.L., Stephens, D.E. & Thomas, A.C. (1975). Tetraploid ryegrasses:allopolyploidy in action. Rep.Fodder Crops Section, EUCARPIA, Zurich 1975, pp.46-49.

Breese, E.L. & Thomas, A.C. (1978). Uniformity and stability of Lolium multiflorum x L.perenne allotetraploids. Proc.8th Cong. of Eucarpia, Madrid 1977, pp.155-159.

Buckner, R.C., Burrus, P.B. & Bush, L.P. (1977). Registration of 'Kenhy' tall fescue. Crop Sci. 17, 672-673.

Castle, M.E. & Watson, J.N. (1971). A comparison between a diploid and tetraploid ryegrass for milk production. J.agric. Sci., Camb. 77, 69-76.

Clarke, J. & Thomas, H. (1976). L.perenne x L.multiflorum amphiploids. Rep.Welsh Pl.Breed.Stn for 1975, p.59.

Cooper, J.P. (1959). Selection and population structure in Lolium. III. Selection for date of ear emergence. Heredity 13, 461-479.

Cooper, J.P. & Breese, E.L. (1971). Plant breeding : forage grasses and legumes. In: Potential Crop Production. (Wareing, P.F. & Cooper, J.P., eds). pp.295-218. Heinemann, London.

Cornish, M.A., Hayward, M.D. & Lawrence, M.J. (1979a). Self incompatibility in ryegrass. I. Genetic control in diploid *Lolium perenne* L. *Heredity* 43, 95-106.

Cornish, M.A., Hayward, M.D. & Lawrence, M.J. (1979b). Self incompatibility in ryegrass. II. The joint segregation of S and Z in *Lolium perenne* L. *Heredity* 43, 129-136.

Davies, W.E., Tyler, B.F., Borrill, M., Cooper, J.P., Thomas, H. & Breese, E.L. (1973). Plant introduction at the Welsh Plant Breeding Station. Rep.Welsh Pl.Breed.Stn for 1972, pp.143-162.

John, B. (1982). A sceptical cytologist in a molecular wonderland. Proc.2nd Kew Chromosome Conference (in press).

Larkin, P.J. & Scowcroft, W.R. (1981). Somaclonal variation - a novel source of variability from cell cultures for plant improvement. Theor.appl.Genet. 60, 197-214.

Lewis, E.J. (1966). The production and manipulation of new breeding material in *Lolium/Festuca*. In: Proc.10th Int.Grassld Cong., Helsinki. (Hill, A.G.G., ed.). pp.688-693. Helsinki: Finnish Grassland Association.

Lewis, E.J. (1972). Production of Festuca/Lolium hybrids. Rep.Welsh Pl.Breed.Stn for 1971, p.20.

Lewis, E.J. (1980). Chromosome pairing in tetraploid hybrids between Lolium perenne and L.multiflorum. Theor.appl. Genet. 58, 137-143.

Lewis, E.J., Tyler, B.F. & Chorlton, K.H. (1973). Development of Lolium/Festuca hybrids. Rep.Welsh Pl.Breed.Stn for 1972, pp.34-37.

Mather, K. & Harrison, B.J. (1949). The manifold effect of selection. Heredity 3, 1-52, 131-162.

Munro, J.M.M., Davies, D.A. & Morgan, T.E.H. (1973). Research on pasture improvement potential at Pant-y-dwr Hill Centre. Rep.Welsh Pl.Breed.Stn for 1972, pp.209-228.

Stebbins, G.L. (956). Artificial polyploidy as a tool in plant breeding. In: Genetics in Plant Breeding (Brookhaven Symposia in Biology, vol. 9). pp.37-52. New York: Brookhaven National Laboratory.

van Bogaert, G. (1975). A comparison between colchicine induced tetraploid and diploid cultivars of Lolium species. Rep.Fodder Crops Section Eucarpia. Zurich 1975. pp.61-73.

Walters, R.J.K. & Evans, E.M. (1978). Herbage quality. Rep.Welsh Pl.Breed.Stn for 1977, pp.55-57.

Wilson, D. (1981). Breeding for morphological and physiological traits. In: Plant Breeding II. (Frey, K.J., ed.). pp.233-290. Iowa State University.

Wit, F. (1958). Tetraploid Italian ryegrass (Lolium multiflorum Lam.). Euphytica 7, 47-58.

SELFING EFFECT ON S_1 GENERATION OF *DACTYLIS GLOMERATA* MEASURED IN COMPETITIVE CONDITIONS

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The aim of our breeding programme in cocksfoot is to build synthetic varieties suitable for cutting and high performance under irrigated conditions.

We adopted the same method of breeding pointed out for lucerne, an autotetraploid plant like cocksfoot (Rotili, 1970, 1976; Rotili *et al*., 1978). This method is based on the use of selfing combined with selection in competitive conditions.

MATERIAL AND METHODS

Two cultivars, differing in origin and adaptation, were chosen as parental populations. They were:

Dora - derived by mass selection from material collected in the Lodi country, and

Montpellier - selected in the South of France.

For each population, 4000 plants were studied in glasshouse, in concrete boxes having the useful sizes of 150 x 25 x 40 cm. The density was 40 plants per linear metre, about 300 plants per square metre.

Dry matter yield and earliness per plant were determined. After 8 cuttings, selection was practised for plants exceeding the mean by two standard deviations. These plants were cloned. After cloning, the plants were polycrossed and self-fertilized.

The S_0 and S_1 families were studied in glasshouse, at the same density as for the parental populations.

The results of the first six cuttings, concerning the dry matter yield for parental populations, S_0 and S_1 progenies, are presented in this note.

The experiment included 133 S_0 progenies and 32 S_1 progenies (Table 1). Each progeny was represented in total by 126 plants in 6 replications. Each parental population was represented by 336 plants. The distance between the cuttings was 25 - 28 days.

RESULTS AND DISCUSSION

The Table 2 shows the data concerning the forage yield, averaged over 6 cuttings. The two populations are not different, neither for mean values nor for variability between the families. The selection seems to have been more efficient in cv. Dora than in cv. Montpellier.

In Table 3 the data of inbreeding depression obtained for cocksfoot are compared with those obtained for lucerne. In the same growing conditions, and with the same number of cuttings, the loss in vigour is on average 20.5% in cocksfoot vs 28% in lucerene. This difference should be explained by the fact that lucerne is more susceptible than cocksfoot to the effect of frequent cutting.

How may we explain such a loss in vigour? Many authors have shown, with different autotetraploid species, a loss in vigour more rapid than that expected from the coefficient of inbreeding. In other words, the coefficient of inbreeding is not sufficient to completely explain the experimental results; other hypotheses giving a greater weight to the heterozygous structure (for example tetragenic structure) are considered more satisfactory (Berninger, 1967; Busbice & Wilsie, 1966; Gallais & Guy, 1970).

On the basis of numerous results obtained with lucerne (Rotili, 1970; Rotili, Zannone & Gnocchi, 1980) and of these first results for cocksfoot, the hypothesis till now considered do not allow a satisfactory explanation. We know that at the experimental level we obtained every degree of loss in vigour we want, by varying the experimental conditions, such as density, or cutting regime, or arrangement of the progenies in the field, and so on. Furthermore, the response is variable through the cuttings, which means, that the inbreeding depression increases with the increasing number of cuttings. Consequently, the average value of the inbreeding depression depends upon the number of cuttings we make: if 3 or 6, or 10 or 15, as it is usual with perennial plants like lucerne and cocksfoot. This situation is well represented in Figure 1 for lucerne and cocksfoot.

In Table 4 the data of inbreeding depression with their range of variation are averaged over six cuttings. the variability in the loss of vigour is very high in both cultivars. This variability could be explained by many factors: either a variability in the level of heterozygosity of the parental material, or variability of the effects of genes controlling the root reserve cumulation or the capacity of regrowth. Besides, the cutting regime (as for instance the frequent cutting, operated at the same time for all the material) emphasizes the differences between the progenies.

In Figure 2 we reported the percentages of mortality at the sixth cutting. We observe that in both cultivars the mortality increases in S_1. This can be explained chiefly by the fact that, concerning the root reserve restoration, the self-progenies are, on average, later than the cross-progenies.

CONCLUSION

The chief meaning of these results is that in Dactylis glomerata we observed general responses to the selfing, in competitive conditions, similar to those we obtained in lucerne. We consider this fact highly positive. But, obviously, a judgement on the efficacy of selfing in the cocksfoot breeding may be made only at the end of the programme.

REFERENCES

Berninger, E. 1967. Contribution à l'étude des modalités d'expression de l'hétérosis chez les autotétraploides. Ann.Amélior.Plantes 17, 93-104.

Busbice, T.H. & Wilsie, C.P. 1966. Inbreeding depression and heterosis in autotetraploids with application to Medicago sativa L. Euphytica 15, 52-67.

Gallais, A. & Guy, P. 1970. Use of heterosis in breeding autotetraploids. Eucarpia Fodder Crops Section Meeting, Lusignan, September 1970.

Rotili, P. 1970. Selfing effects on S_2 and S_3 generation in *Medicago sativa* L. Eucarpia Fodder Crop Section Meeting, Lusignan, September 1970.

Rotili, P. 1976. Performance of diallel crosses and second generation synthetics of alfalfa derived from partly inbred parents. I. Forage yield. *Crop Sci*. 16, 246-251.

Rotili, P., Zannone, L. & Gnocchi, G. 1980. Effects of inbreeding on vigour of alfalfa measured in competitive and frequent cutting conditions. Eucarpia Fodder Crops Section Meeting, Perugia, September 1979.

TABLE 1. MATERIAL UNDER STUDY IN GREENHOUSE, IN CONCRETE BOXES 150x25x40 CM. DENSITY OF 300 PLANTS PER SQUARE METRE.

CULTIVAR	GENERATION	NUMBER OF PROGENIES	NUMBER OF PLANTS
DORA	PARENTAL POPULATION	---	336
	S_0 PROGENIES	64	8064
	S_1 PROGENIES	16	1816
MONTPELLIER	PARENTAL POPULATION	---	336
	S_0 PROGENIES	69	8694
	S_1 PROGENIES	14	1764

TABLE 2. DRY MATTER YIELD (G/BOX) IN COMPETITIVE CONDITION (40 PLANTS PER LINEAR METRE). AVERAGE OF 6 CUTS. (32 FAMILIES S_0 AND 32 FAMILIES S_1)

	DORA		MONTPELLIER	
	MEAN	σ	MEAN	σ
S_0 FAMILIES	22.5	2.1	21.1	2.9
S_1 FAMILIES	18.5	3.4	16.2	3.2
PARENTAL POP.	17.62		19.08	

TABLE 3. COMPARISON COCKSFOOT vs. LUCERNE FOR INBREEDING EFFECT IN S_1 FAMILIES. AVERAGES OF 6 CUTTINGS IN COMPETITIVE CONDITIONS. (S_0 =100)

COCKSFOOT		LUCERNE	
DORA	MONT.	LEO.	CANT.
82	77	72	72

TABLE 4. INBREEDING DEPRESSION IN TWO CULTIVARS AT HIGH DENSITY (40 PLANTS PER LINEAR METRE) AND UNDER FREQUENT CUTTING REGIME. AVERAGE OF 6 CUTTINGS.

	CULTIVAR	
	DORA	MONTPELLIER
MEAN DEPRESSION	-18	-23
RANGE OF VARIATION	-4 TO -37	-5 TO -47

FIGURE 1. DRY MATTER YIELD. SELFING EFFECTS IN S_1 FAMILIES THROUGH 6 CUTTINGS. (S_0=100)

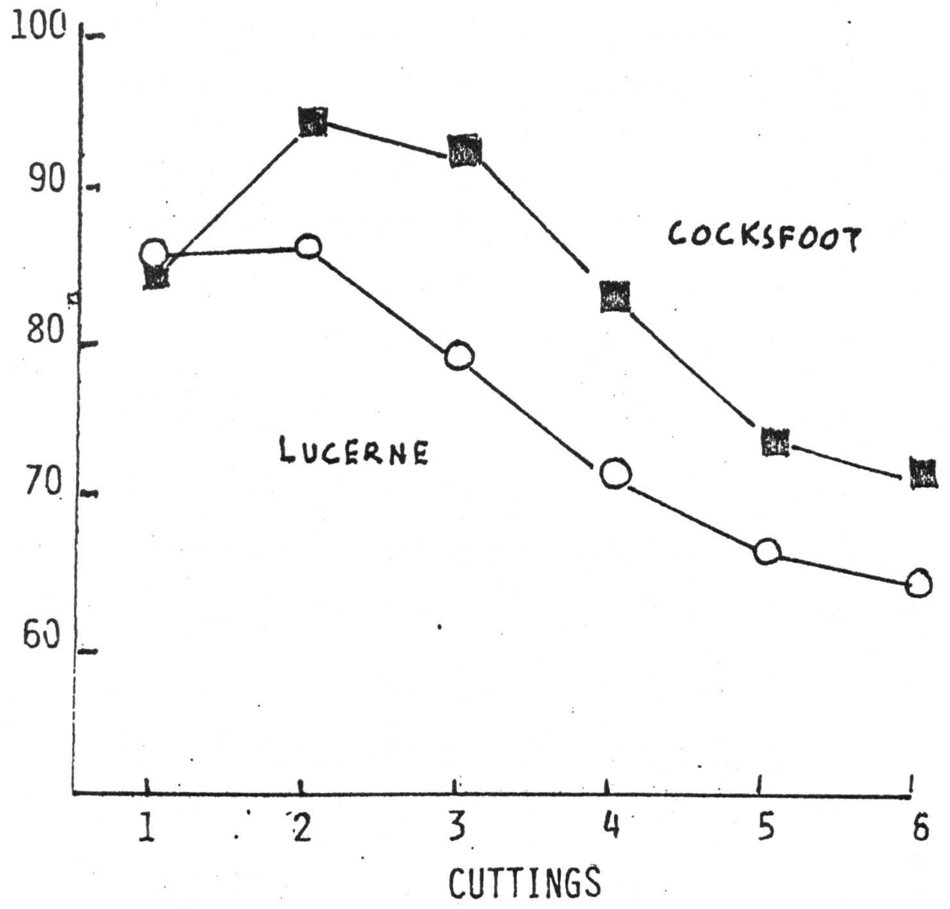
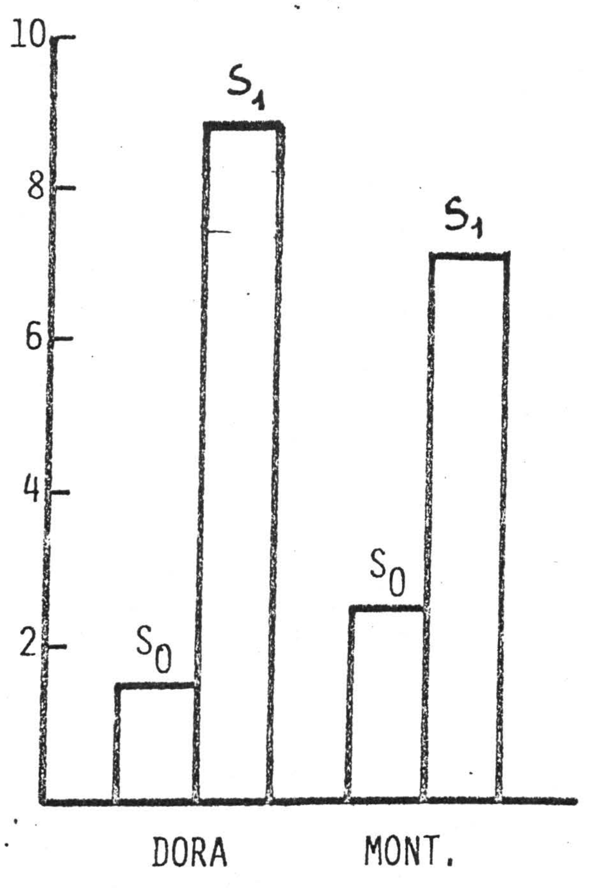


FIGURE 2. PERCENTAGE OF MORTALITY AT THE 6 CUTTINGS.



THE DEGREE OF SELF-FERTILITY IN LOLIUM PERENNE POPULATIONS

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SUMMARY

Plants from 33 european cultivars have been selfed and seed set was determined on 5 spikes per plant in the S_o- and S_1-generation. According to the different populations 2 - 45 % of the plants set no seeds. This was increased to 15 - 7o % in S_1. Regarding the number of plants yielding more than 1oo selfed seeds, great differences (S_o: 1 - 26 %, S_1: o - 21 %) between the cultivars could be observed. Giving the seed set data as a histogram, the shape of the distribution differs between populations and indicates a varying degree of self-fertility. Self-fertility is discussed with regard to breeding methods.

INTRODUCTION

Lolium perenne is a windpollinated crossfertilizer containing a system of incompatibility, which has been confirmed by the recent work of CORNISH et al (1979). Therefore, in practical plant breeding, perennial ryegrass is considered to be self-sterile. Since the detection of cytoplasmic male sterility (NITZSCHE, 1971) the way for breeding hybrids has been opened. To exploit the full amount of heterosis possible, the development of inbred lines would be needed. A number of published works, summarized in table 1, show, that a certain degree of self-fertility is present in L. perenne. All of these data are based on selfing of heterozygous S_o-plants. Besides UTZ and OETTLER (1978), JONES and JENABZADEH (1981) reported results of self-fertility in inbred generations. The present study is part of a hybrid breeding program and will show

i) the degree of self-fertility in the base populations and

ii) give an idea about the chance of developing inbred lines.

Table 1: Self-fertility in Lolium perenne

author	year	self-fertility (%) max.	(av.)
Frandsen	1917	11	
Gregor	1928	32	(3)
Jenkin	1931	35	
Troll	1931	15	
Nilsson	1934	35	(7)
Beddows et al.	1962	5	(3)
Foster & Wright	197o	31	(2)
Lewis	197o	17	(4)
Bean & Yok-Hwa	1972	14	(2)
		7	(2)
		58	(11)
Matzk	1974	2	
Utz & Oettler	1978	25	(8)

MATERIALS AND METHODS

Seedlings from 33 populations (see table 2) were grown in the glasshouse and transplanted to the field in September 1976. The following year, in each of the populations about 1oo unselected plants (space planted) have been selfed. Bagging was done by enclosing 5 spikes per plant in a paper bag prior to athesis. Seed set was determined by counting the number of seeds per bag, i.e. per plant. Soon after harvest S_1-plants were grown, planted to the field and bagging was done the following year. According to the seed set in the base populations, the number of S_1-families (lines) differed widely. As far as possible, a line consisted of 1o plants. Selfing was done on suitable plants only, which means that within-family selection took place.

RESULTS

The number of plants in the different base populations setting selfed seeds ranged from 55 to 98 %, i.e. 2 to 45 % hand no seed set. The seed set data for the 33 populations are given in table 2. For better comparison with the figures given by UTZ and OETTLER, who investigated 8 cultivars, seed set is given as per cent of plants having o,1 to 5o and more than 5o selfed seeds. (It has to be mentioned, that their S_1 and S_2 refer to the generation of the seed, i.e. the S_1-data are the seed set on S_o-plants.)

Like UTZ and OETTLER, a heavy increase of plants setting no seeds (15 to 7o %) could be observed in the first generation inbred lines. In the class from 1 to 5o seeds per plant the range was 46 to 9o and 28 to 66 % of the plants in S_o and S_1, respectively. From the point of view of self-fertility the last column is the most interesting. The number of plants yielding more than 5o selfed seeds (i.e. more than 1o seeds per spike) differed greatly (7 to 43 % in S_o and 2 to 26 % in S_1). While the number of plants with zero seed set was higher in all populations in S_1 as compared to S_o, this was not true for the class with more than 5o seeds per plant. In 24 of the populations high seed set was reduced, 6 showed no great difference, and in only 3 of them, seed set in S_1 was increased.

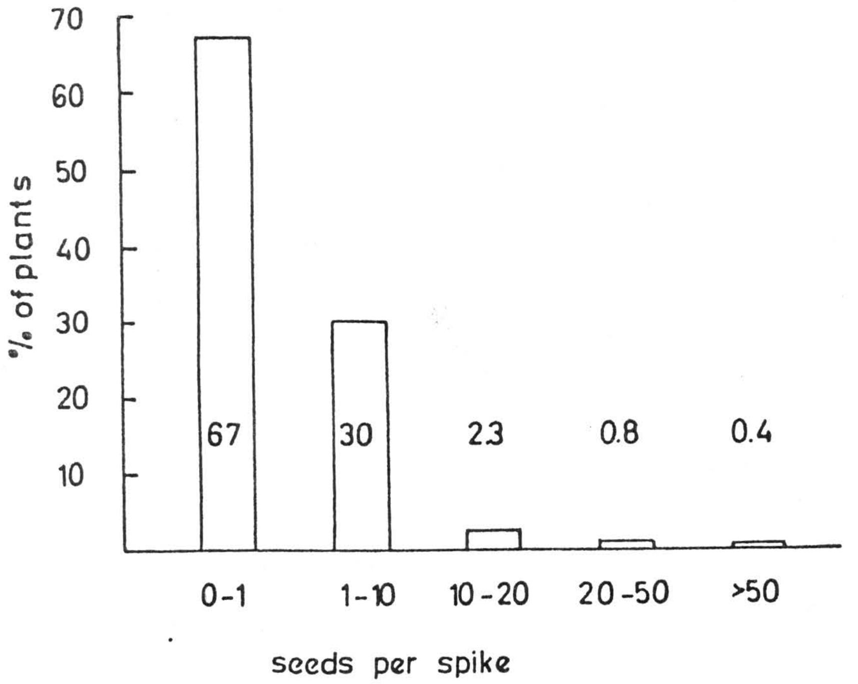
Because the figures in table 2 give only a rough picture, 3 examples will be taken to study the distribution of seed set in more detail. For populations, KELLER (1948) has suggested to present the data in the form of a histogram. The type of frequency distribution indicates whether a population is self-fertile or self-sterile. The latter showing a non-normal or skewed distribution.

To illustrate this, the data from CORKILL (1956) are given as a histogram (see fig. 1). From the shape of the distribution it is quite obvious, that this material was highly self-sterile.

Table 2: Per cent of selfed plants with o,1 - 5o and more than 5o selfed seeds

No.	Cultivar		S_o o	S_o 1 - 5o	S_o 5o	S_1 o	S_1 1 - 5o	S_1 5o
1	Liperlo	D	7	82	21	25	55	2o
2	Limedia	D	3	7o	27	25	53	22
3	Lilope	D	6	76	18	4o	5o	1o
4	NFG	D	15	73	7	47	42	11
5	Verna	D	4	77	19	15	66	19
6	Animo	D	12	74	14	41	49	1o
7	Premo	D	4	84	12	22	64	14
8	Morenne	D	5	63	32	43	46	11
9	Melino	B	5	73	22	25	58	17
1o	Borvi	DK	25	65	1o	51	43	6
11	Odin	DK	4	74	22	3o	61	9
12	Lenta	DK	2	9o	8	39	52	9
13	72-1o-1	DK	4	79	17	29	6o	11
14	Brian	DK	1o	83	7	34	54	12
15	Tripera	DK	9	79	12	39	49	12
16	Elrond	DK	25	62	13	69	27	4
17	Pippin	DK	11	61	28	58	39	3
18	Albi	DK	13	68	19	48	46	6
19	Real	F	45	46	9	7o	28	2
2o	S 321	GB	7	72	21	4o	51	9
21	Hubal	NL	14	75	11	46	46	8
22	Caprice	NL	7	74	19	56	42	2
23	Combi	NL	8	81	11	58	39	3
24	Endura	NL	7	68	25	59	38	3
25	Cropper	NL	6	62	32	29	45	26
26	Talbot	NL	4	74	22	35	57	8
27	Wendy	NL	13	71	16	63	33	4
28	Houba	NL	9	79	12	39	48	13
29	Splendor	NL	5	52	43	36	55	9
3o	Hora	NL	11	79	1o	61	36	3
31	Viva	S	4	77	19	39	44	17
32	Svea	S	7	76	17	45	48	7
33	Viris	S	3	86	11	43	53	4
	average		9,5	73	17,8	42,4	47,8	9,8

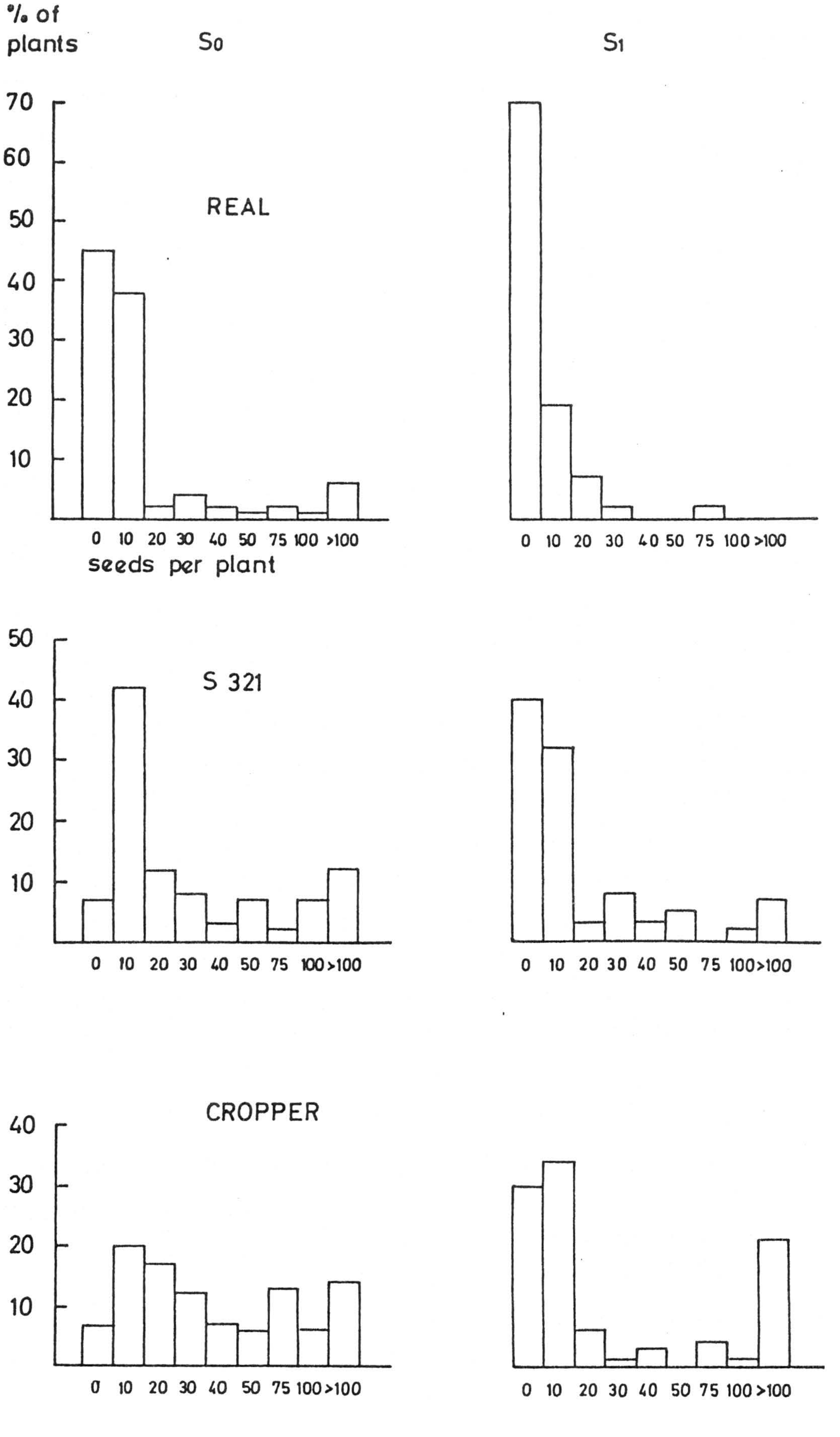
Fig.1: Seed set after selfing in L. perenne (n=487)
(after CORKILL,1956)



Most of the populations under study show a similar pattern. Figure 2 gives the histograms from the cultivars Real, S 321 and Cropper for the two selfing generations. Comparing the histograms with the one after CORKILL, it has to be mentioned, that a separate zero class is given and that Real was the only base population where most of the plants fell into this class. In all other cases, the highest number of plants yielded 1 to 1o seeds. Though, having a higher amount of seed set, the shape of the histogram indicates, that S 321 is highly self-sterile. The last 3 classes give a somewhat wrong picture insofar as the size of the class is greater. Both histograms for the Cropper-plants differ greatly from the other two and indicate a much higher degree of self-fertility.

Besides Cropper with 14 % of the plants, yielding more than 1oo seeds, Morenne and Pippin had 18 % and Splendor even 26 % of the S_o-plants in this class.
In the S_1-generation, Cropper had highest seed set with 21 %, followed by Limedia with 18 % and Liperlo and Verna 16 % of the plants with more than 1oo seeds per plant.

Fig. 2: Distribution of seed set in 2 generations of 3 cultivars



DISCUSSION

In the literature the results of selfing studies are reported in a different manner: seed weight, seeds per floret, seeds per 1oo spikelets, seeds per inflorescence, seeds per cm of inflorescence or as per cent of cross-fertilized seeds. Seeds per floret seems to be the most exact basis. But, one has to bear in mind, that the full potential of seed set is never reached. In crossing experiments it could be shown by TROLL (1931), NILLSSON (1934) and BEDDOWS et al. (1962) that only 65, 75 and 68 % of the florets set seeds.

Refering to the data in table 2 and fig. 2, it is arbitrary to take more than 5o or more than 1oo selfed seeds per plant as the degree of self-fertility. In both cases, the highest figures are still within the range of self-fertility given by others (see table 1). Most of the selfing studies have been done on a limited number of single genotypes and not on whole populations, as it was done here. Therefore, the most important result of this study are the relative differences between populations, indicating, that a different frequency of self-fertility genes is present. Or, looking from the other side onto the problem, that there are great differences in the efficiency of the incompatibility system. From the investigations of FOSTER and WRIGHT it is well known, that environment can modiefy the selfing results to a high degree. The recent work of JONES and JENABZADEH shows the pattern how seggregation of self-fertility takes place and that it would be usefull to self more than 1 plant per S_1-family to improve selection for self-fertility. Allready JENKIN (1931) demonstrated, that self-fertility can be improved by recurrent selection.

According to the data from UTZ and OETTLER one can expect to obtain 5 to 1o % of homozygous inbred lines. Having in mind, that during the course of breeding, selection for other characters than self-fertility is practiced, too. This means, that one has to start with a large base population.

SELF-FERTILITY and BREEDING METHODS

Regarding panmictic populations, a high degree of heterozygosity is wanted. An effectiv system of incompatibility would avoid selfing and thus inbreeding depression. As pointed out by CORNISH et al., it is quite important that the base plants of a synthetic variety are both highly selfincompatible and cross-compatible to the other components. From the point of view of synthetic-prediction and response to selection, S_1-testing would be favourable (WRIGHT, 198o). Practical experiences have shown, that in general, 1o plants per clone in isolation, but under open pollination conditions, will suffice, to give enough seeds for field plot experimentation.

A next step would be, to interpollinate an S_1-family. This was already done by WITTE (1915) in Sweden to create new varieties.

Before the detection of male-sterile perennial rye-grass, self-fertile inbred lines did not have any direct value in practical breeding. The results presented in rye by GEIGER and SCHNELL (197o) and our own experiences in L. perenne show, that the rate of outcrossing is not high enough to create synthetic varieties on the basis of self-fertile inbred lines. Hybrid breeding programs have been started in several places, but information is still lacking.

REFERENCES

BEAN, E.W. a. CHEN YOK-HWA — 1972: An analysis of the growth of inbred progeny of Lolium. J. agric. Sci., Camb. 79: 147-153

BEDDOWS, A.R., E.L. BREESE a. B. LEWIS — 1962: The genetic assessment of heterozygous breeding material by means of a diallel cross. Part I. Heredity 17: 5o1-512

CORKILL, L. — 1956: The basis of synthetic strains of cross-pollinated grasses. Proc. 7th Int. Grassl. Congr. p. 427-438

CORNISH, M.A., M.D. HAYWARD a. J.J. LAWRENCE — 1979/198o: Self-incompatibility in rye-grass. I-IV. Heredity 43: 95-1o6, 129-136. Heredity 44: 55 - 62, 333-34o

FOSTER, C.A. a. C.E. WRIGHT — 197o: Variation in the expression of self-fertility in Lolium perenne L. Euphytica 19: 61-7o

FRANDSEN, H.N. — 1917: Die Befruchtungsverhältnisse bei Gras und Klee in ihrer Beziehung zur Züchtung. Z. Pflanzenzüchtung 5: 1-3o

GEIGER, H.H. a. F.W. Schnell — 197o: Die Züchtung von Roggensorten aus Inzuchtlinien. I. Selbstungsanteile aus Polycross-Nachkommenschaften. TAG 4o: 3o5-311

GREGOR — 1928. cit. b. JENKIN (1931)

JENKIN, T.J. — 1931: Self-fertility in perennial rye-grass. WPBS-Ser. H. No. 12: 1oo-119

JONES, R.N., a. P. JENABZADEH — 1981: Variation in self-fertility, flowering time and inflorescence production in inbred Lolium perenne L. J. agric. Sci., Camb. 96: 521-537

KELLER, W. — 1948: Interpretation of self-fertility in grasses by frequency-distribution. J. Amer. Soc. Agron. 4o: 894-9oo

LEWIS, J. — 197o: Reproductive growth in Lolium. I. Evaluation of genetic differences within an established variety by means of a diallel cross. Euphytica 19: 47o-479

MATZK, F. — 1974: Selbstfertilität, Inzuchtdepression und kreuzungstechnische Experimente bei Lolium. Arch. Züchtungsforschung, 4 (2): 141-151

NILSSON, F. 1934: Studies in fertility and inbreeding in some herbage grasses.
Hereditas 19: 1-162

TROLL, H.-J. 1931: Untersuchungen über Selbststerilität und Selbstfertilität bei Gräsern.
Z. f. Züchtung, Reihe A Pflanzenzüchtung, Bd. 16: 1o5-136

UTZ, H.F. a. G. OETTLER 1978: Performance of inbred lines and their top crosses in perennial rye-grass.
Z. Pflanzenzüchtung 8o: 223-229

WITTE, H. 1915: cit. b. LUNDQUIST (1963): Self-incompatibility and the breeding of herbage grasses. In: Recent Plant Breeding Research, Svalöf 1946-1961

WRIGHT, A.J. 198o: The expected efficiencies of half-sib, testcross and S_1 progeny testing methods in single population improvement.
Heredity 45: 361-376

EUCARPÍA FODDER CROPS SECTION MEETING

ABERYSTWYTH 1982

POLYMORPHISM AS A GENETIC RESOURCE IN COCKSFOOT

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Three aspects of the available genetic resources are developed:

1) Genetic diversity at different taxonomic levels: polymorphism has been investigated for more than fifty populations of the autotetraploid group; frequencies have been estimated for several loci, data are presented only for a locus coding for a glutamate-oxalo-acetate transaminase; the allelic distributions have been compared:

a) at a large scale, for populations ranging from those of North Western Europe (Scotland) to North Africa (200 alleles per population were analysed on average),

b) at a small scale, along a transect exhibiting a clinal variation for water availability, this transect is located in Southern France;

2) Functional diversity:-

a) for responses of gas exchange to drought: a study of these mechanisms has been made in parallel with the analysis of genotypic variation; several characteristics are specific to extreme populations (stomatal density, osmotic potential, ...),

b) for nutrient competitive abilities, measured in terms of producer and associate effects and of characteristics of the roots;

3) Demographic diversity for survival in:-

a) contrasting levels of disturbance,

b) in competition, in relation with the changing environment along a succession, mainly in terms of panicles/individual.

In conclusion, two examples are given of combining genetics (polymorphism) and demography, to approach the genotype-phenotype interface. The two cases concern an investigation of the relationships between diversity (for a set of systems) and vigour. Both in natural populations and in controlled material under experimental conditions, a positive relationship is more evident for one specified locus than for a global approach of the whole genotype.

Genetic resources must be considered not only for their direct use in breeding, but also as a means of clarifying some "accepted" relationships that allow one to confront the theory of controlled selection with the reality of nature.

FREQUENCY OF SPONTANEOUS POLYPLOIDS IN *LOLIUM PERENNE* AND *FESTUCA PRATENSIS*

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Perennial ryegrass (*Lolium perenne* L.) and meadow fescue (*Festuca pratensis* Huds.) are important species of fodder grasses occurring in nature as diploids with the chromosome number 2n=14. In breeding mostly diploid forms are used, though attempts have been made to use also autotetraploid colchicine-induced forms.

Until now, there have been little data concerning the frequency of spontaneous polyploids in *L.perenne* and *F.pratensis* and there are no data concerning breeding value of such polyploids.

Müntzing (1937, 1938) paid attention to the fact that in grasses caryopses with twin embryos may be a source of spontaneous polyploids and sometimes haploids as well. When performing a cytological analysis of 105 twin seedlings of *L.perenne*, he found four triploid plants. In the case of *F.pratensis*, he found one triploid plants out of 34 studied twin seedlings. However, in the both species Müntzing found neither tetraploids nor haploids.

In our studies we searched for spontaneous polyploids analysing the chromosome number in twin plants selected from diploid cultivars of perennial ryegrass and meadow fescue. Caryopses with twin embryos could be selected during seed germination. Twin seedlings were separated and single plants were planted into the pots filled with soil and placed in a glasshouse.

These plants were analysed for the somatic chromosome number in the root tips.

Lolium perenne

Caryopses with twin embryos were selected from five Polish diploid cultivars of perennial ryegrass: Górczanski, Nadmorski, Arka, Lux and Gazon. Percentage of caryopses with twin embryos in these varieties ranged from 0.07 to 0.17 with an average of 0.11 for species.

Totally we examined the chromosome number in 1447 twin plants of L.perenne. Results of cytological analyses are summarized in Table 1.

In the case of L.perenne, out of 1447 studied twin plants 2 were haploids (0.14%), 37 triploids (2.56%) and one tetraploid (0.07%). The remaining twin plants were diploid. Another plant in twin pairs with a haploid and a polyploid was always diploid and, therefore, twin pairs had a heteroploid character.

The spontaneous tetraploid of L.perenne is fertile, this plant produced pollen, stainable to 79%.

All triploids are partially fertile, the seed setting in these plants under open mutual pollination ranged from 0.4 to 35.8%, whereas in isolated spikes it ranged from 0.0 to 1.8%.

Haploid plants of L.perenne were propagated vegetatively in the form of clones. They reached the earing and flowering stage. The vigour of haploids is distinctly reduced, however these plants can be cloned without difficulty.

Festuca pratensis

Our studies concerned the following four Polish diploid cultivars of meadow fescue: Nakielska, Skrzeszowicka, Pulawska and Motycka. We found that the percentage of caryopses with twin embryos in these varieties was about 0.07.

In F.pratensis we analysed the chromosome number in 1271 twin plants and found: 44 triploids (3.46%), 6 tetraploids (0.47%) and one pentaploid (0.08%). The remaining twin plants were diploid (Table 1).

In F.pratensis, like in L.perenne, polyploids in twin pairs were always accompanied by diploids.

All six spontaneous tetraploids are fertile. Pollen viability of these plants ranged from 70.0 to 95.0% and the seed-set under open mutual pollination was sufficient. Comparing the progeny of spontaneous tetraploids with colchitetraploids of meadow fescue (cv. Westa), we noticed that spontaneous tetraploids display a higher tillering capacity and a lower 1000-seed weight. These characters may be of interest, if spontaneous tetraploids are eventually used in breeding.

Among spontaneous triploids of F.pratensis there occurs completely sterile (with indehiscent anthers), as well as partially fertile plants, the last group being larger. Triploids display great variation of morphological characters, particularly with respect to the leaf breadth, culm thickness, plant height and tillering capacity.

Pentaploid seedling of F.pratensis perished at the three-leaf stage because of strong chlorophyll defects.

CONCLUSIONS

1. Among twin plants of L.perenne, haploid, triploid and tetraploid plants have been found.
2. Among twin plants of F.pratensis, triploid, tetraploid and pentaploid plants have been found, but there were no haploid plants.
3. Among spontaneous polyploids of the both studied species, triploid plants displayed the greatest frequency.
4. The frequeny of spontaneous tetraploids was higher in F.pratensis than in L.perenne.
5. It seems that spontaneous tetraploids of F.pratensis may constitute an interesting initial material for breeding, since they distinguish by a relatively high tillering capacity.

REFERENCES

Müntzing, A. 1937. Polyploidy from twin seedlings. Cytologia Fujii Jubilee Volume pp.211-227.

Müntzing, A. 1938. Note on heteroploid twin plants from eleven genera. Hereditas 24, 487-491.

Table 1. Results of cytological analyses of twin plants of diploid *Lolium perenne* and *Festuca pratensis*

Species	No. of tested plants	Number and frequency of cytotypes				
		Haploid x=7	Diploid 2x=14	Triploid 3x=21	Tetraploid 4x=28	Pentaploid 5x=35
Lolium perenne	1447 100%	2 0.14%	1407 97.23%	37 2.56%	1 0.07%	- -
Festuca pratensis	1271 100%	- -	1220 95.99%	44 3.46%	6 0.47%	1 0.08%

GENETIC VARIATION AND CONTROL OF CHROMOSOME PAIRING IN NATURAL AND SYNTHETIC ALLOPOLYPLOIDS IN LOLIUM/FESTUCA

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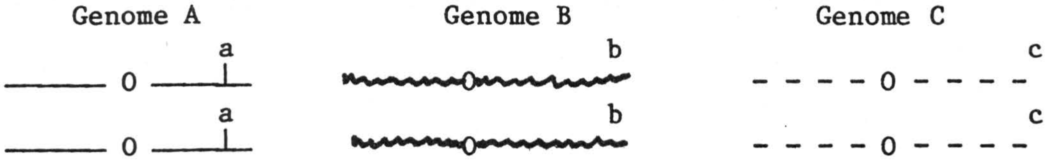
A large proportion of cultivated crop species are allopolyploids and their origin can be traced back to hybrids between diploid progenitors, followed by natural doubling of the chromosome number, or the chance fusion of two unreduced gametes. The majority of these natural allopolyploid species have a regular bivalent forming meiosis and disomic inheritance. Chromosome pairing is restricted to homologous pairs and the corresponding chromosomes of the constituent genomes do not form chiasmate associations.

The discovery that colchicine could induce polyploidy by disturbing the mitotic cycle in primordial cells, resulting in the doubling of the chromosome number, has provided the plant breeder with the means to produce polyploids (see review Dewey, 1980). A number of amphidiploids have been produced in an attempt to combine the complementary attributes of two species in a single breeding entity. However, instability arising from irregular meiotic behaviour has often limited the commercial exploitation of amphidiploids as cultivars.

Within the genus Festuca the species form a polyploid series from diploid to decaploid with a basic chromosome number of seven. All the polyploid species have regular diploid-like meiosis. What is the nature of the regular bivalent pairing? This has been studied in some detail in the hexaploid species

Festuca arundinacea, which is of allopolyploid origin combining the chromosome complements of three diploid progenitors. It is reasonable to assume that bivalent pairing reflects complete preferential pairing in this species, i.e. chromosome pairing is confined to the identical pairs (homologues) derived from the one progenitor and that the corresponding chromosomes derived from the three diploid progenitors (homoeologues) do not pair. It is possible to test this assumption by a simple genetic test to establish the mode of inheritance in the species. This is illustrated diagramatically as folows:



Assuming that a plant is triallelic and that the three loci are located on homoeologous chromosomes of the constituent genomes, and that chromosome pairing is restricted to homologous pairs i.e. preferential chromosome pairing, all the gametes produced would be abc. On selfing the triallelic genotype all the progeny would be phenotypically identical to the parent (abc). If on the other hand the six equivalent chromosomes paired at random as bivalents seven gametic genotypes, aab, aac, abb, cbb, bcc, acc and abc would be produced and on selfing four possible phenotypes ab, ac, bc and abc. The multiple co-dominant alleles of the isoenzyme phosphoglucoisomerase-2, in which all the above phenotypes can be identified, provides a suitable system for testing the mode of inheritance in tall fescue. Lewis et al. (1979), using this electrophoretic technique, have shown unequivocally that the mode of inheritance in tall fescue is disomic, confirming that bivalent pairing is completely preferential.

When the plant breeder produces synthetic amphidiploids combining the genomes of two diploid species the ideal situation would be to achieve regular meiotic behaviour comparable to natural polyploids. However, preferential pairing is incomplete in most synthetic amphiploids and this leads to the dissipation of favourable gene combinations due to inter-genomic chromosome pairing.

The Lolium multiflorum x L.perenne amphiploid is an example of such a synthetic amphidiploid. Although the number of multivalents in the amphidiploid is lower than in the auto-tetraploids of both parental species their presence is proof of inter-genomic chromosome pairing. This does have an effect on the segregation ratios observed using isoenzyme variants of p.g.i. Breese and Thomas (1977) and Lewis (personal communicaion) have clearly shown that the ratios obtained deviate from the expectation assuming disomic inheritance. If chromosome pairing was completely preferential in the amphi-diploid, in which the L.perenne and L.multiflorum genomes were marked by different alleles, the segregation ratios obtained by intercrossing or selfing such genotypes would be in agreement with expectation based on disomic inheritance. Since it is possible to calculate the expected ratios assuming disomic and tetrasomic inheritance the segregation ratios obtained can be used to calculate the level of preferential pairing (Breese et al., 1981). As expected from the cytological data the values obtained fall between the expected ratios for disomic and tetrasomic inheritance.

Although in the L.perenne x L.multiflorum tetraploid hybrid preferential pairing is incomplete it is sufficient to arrest the breaking down of intergenomic gene combinations for the number of generations required to multiply the seed stocks for the development of commercial cultivars. The production of tetraploid cultivars has been successful. However, the complete diploidisation of the amphidiploids would make the task of the plant breeder easier since the integrity of the component genomes would be preserved indefinitely. What are the prospects of the breeder achieving this goal using the variation available?

Lewis (1980) has demonstrated plant to plant variation in the level of preferential pairing achieved in L.multiflorum x L.perenne (4x) hybrids. The possibility of selecting for higher levels of preferential pairing in the tetraploid hybrids is being explored.

Evans (1982) has reported the existence of genes in genotypes of L.perenne which reduce homoeologous chromosome pairing in interspecific hybrids with L.temulentum. The incorporation of these pairing genes in synthetic amphidiploids between L.perenne and L.multiflorum may stabilise the meiotic behaviour of the amphidiploid.

In the Festuca polyploid species complete preferential pairing has been achieved during the course of the evolution of these species. Evidence, that the diploid-like chromosome pairing in these natural polyploid species is genetically controlled, is emerging from a collaborative study with Dr Martin Borrill on the cytotaxonomy of the Festucae. The best understood genetic control mechanism of the diploidisation of a polyploid species is the effect of the Ph locus on chromosome 5B of wheat (Riley and Chapman, 1958). It is of interest to compare the characteristic features of the meiotic behaviour of wheat and tall fescue.

Wheat	Tall fescue
. 21_{II} at metaphase	. 21_{II} at metaphase
. disomic inheritance	. disomic inheritance
. minimal chromosome pairing in the haploid due to the presence of chromosome 5B	. homoeologous chromosome pair at meiosis in the haploid

In wheat the presence of the Ph gene prevents homoeologous chromosomes from pairing in the haploid when the opportunity for preferential pairing is removed. In the nulli-haploid, in which chromosome 5B is deleted, homoeologous chromosomes pair. The main difference between wheat and tall fescue is that homoeologous chromosome pairing takes place in the tall fescue haploid. Jauhar (1975) proposed that the control system in tall fescue was only effective when the genes controlling diploid-like behaviour, i.e. genes with comparable effect to the Ph gene in wheat, were present as a double dose. In the haploid plant the reduction of the pairing genes to the hemizygous state leads to a breakdown in the control resulting in the pairing of homoeologous chromosomes. Data from our studies of chromosome pairing in a range of species hybrids in the Festuca can in general be interpreted by the presence of such a control system in the polyploid species.

Can the pairing genes in polyploid Festuca species be transferred into Lolium species? In hybrids between Lolium species and polyploid Festuca species chiasmata associations are formed between the Lolium and Festuca chromosomes. The introgression of characters from one species into the other should be accomplished. We have started a programme at the WPBS to explore the possibility of introducing the 'pairing genes' into autopolyploid L.multiflorum by means of a backcrossing programme. These genes are effective in discriminating between chromosomes, which are not grossly differentiated in structure. In the L.perenne x L.multiflorum amphidiploid there is clear cut evidence for a tendency towards preferential pairing, which is a reflection of some differentiation between the chromosomes of the parental species. The introduction of such 'pairing genes' from the natural polyploids should achieve the complete diploidisation of these amphidiploids.

Exploiting the variation within our collections of diploid and polyploid species in the Festuca/Lolium complex, in respect of genotypic effects on chromosome pairing, should lead to an improvement in the stability of the amphidiploids. The challenge to the breeder and cytogeneticist is to achieve a comparable level of stability through regular meiotic behaviour to that found in natural polyploids.

REFERENCES

Breese, E.L. & Thomas, A.C. (1977). Monitoring chromosome segregation in Lolium multiflorum x L.perenne amphiploids. Rep.Welsh Pl.Breed.Stn for 1976, pp.29-32.

Breese, E.L., Lewis, E.J. & Evans, G.M. (1981). Interspecies hybrids and polyploids. Phil.Trans.R.Soc.Lond.B292, pp.487-497/

Dewey, D.R. (1980). Some application and misapplication of induced polyploidy to plant breeding. In: Polyploidy: Biological Relevance (W.H. Lewis, ed.). pp.445-466. New York, Plenum.

Evans, G.M. (1982). Fertility and stability of induced polyploid. Proceedings of the Second Kew Chromosome Conference (in press).

Jauhar, P.P. (1975). Genetic control of diploid-like meiosis in hexaploid tall fescue. Nature(Lond.) 245, 595-597.

Lewis, E.J., Humphreys, M.W. & Caton, M.P. (1980). Disomic inheritance in Festuca arundinacea Schreb. Pflanzenzuchtg. 84, 335-341.

Lewis, E.J. (1980). Chromosome pairing in tetraploid hybrids between Lolium multiflorum and L.perenne. Theor.appl. Genet. 58, 137-143.

Riley, R. & Chapman, V. (1958). Genetic control of the cytologically diploid behaviour in hexaploid wheat. Nature 182, 713-715.

THE USE OF SECALE CEREALE X SECALE MONTANUM HYBRIDS FOR THE IMPROVEMENT OF FORAGE RYE

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Introduction

In the U.K. cultivated rye (Secale cereale) has ceased to be considered a major cereal crop. Nevertheless it is still widely grown on lighter soils where it will give a reasonable yield and where other cereals such as wheat and barley will not flourish. Winter rye is also a very useful early spring forage crop for which purpose it is grown specifically in many areas and on many types of soils. Its capacity to put on green leaf at low temperature, low light intensities and short daylength is superior to the other cereals and the major grasses such as Italian and perennial ryegrass. As a consequence of growing rye solely for forage, varieties have been bred specifically for this purpose; examples are Rheidol, Lovaspatonai and Greenfold. These varieties have been developed in the main from central European grain rye and are consequently derived from a relatively narrow genetic base. Furthermore attributes of grain rye such as reduced tillering and upright habit are not the ideal for a forage crop where high tillering and a slightly more prostrate habit are more desirable. These characteristics are found in the wild perennial rye species Secale montanum which is widely distributed throughout the Mediterranean basin and the Middle East (Evans, 1976). The work of Pfahler (1968) provided some evidence that S. cereale x S. montanum hybrids showed considerable capacity of recovery from defoliation with the consequence that the total forage production of the hybrids over a period of time compared very favourably with the standard S. cereale cultivars. The present report describes a programme aimed at assessing the potential of S. montanum x S. cereale hybrids as breeding material for the improvement of forage rye for U.K. conditions.

The Material

A series of S. montanum ecotypes obtained from the U.S.D.A. Plant Introduction Service were crossed with S. cereale cv. Rheidol bred by the Welsh Plant Breeding Station. No attempt was made to assess the parental S. montanum ecotypes prior to crossing. These stocks therefore represented a range of types but all being strongly perennial.

Assessment of the F1 hybrids

The initial assessment of the F1 material was based on single row plots of 10 spaced plants using a randomised block design with four replicates. Plots were harvested three times during March and April and the yields expressed in terms of dry matter. These are given in Table 1 with the values expressed relative to the S. cereale cultivar Rheidol.

TABLE 1. Yields of spaced plants (Dry Matter).

	Early (2 cuts)	Late (1 cut)	Total
S. cereale cv. Rheidol	25	75	100
* I 104 (Iran)	3	22	25
Rh x I 104	7	75	82
I 108 (Turkey)	3	30	33
Rh x I 108	14	114	128
I 109 (Hungary)	6	71	77
Rh x I 109	24	164	188
I 110 (Hungary)	12	97	109
Rh x I 110	24	134	158
I 113 (Iran)	2	25	27
Rh x I 113	16	110	126
I 118 (Turkey)	2	22	24
Rh x I 118	11	120	131
I 119 (Turkey)	5	59	64
Rh x I 119	18	160	178

* All the I lines are S. montanum.

All the S. montanum lines with the exception of I 110 from Hungary yielded significantly less dry matter than the check variety Rheidol and this was particularly evident in the more important early cuts. It was only in the very late cut that some of the lines matched the yield of Rheidol. However, although most of the Rheidol x S. montanum hybrids also did not compare favourably with Rheidol in early spring growth both Rheidol x I 109 and Rheidol x I 110 showed a great deal of promise. The higher yields of several of the hybrids at the third cut is a clear reflection of their lateness of growth in spring. While the second cut had removed many of the elongating tillers of Rheidol the later growing hybrids were still of a prostrate habit.

Assessment of the dry matter yield of the best F1 hybrids together with an additional entry, Rheidol x I 105, was repeated using small plots instead of spaced plants. Under these conditions only Rheidol x I 110 and the new entry Rheidol x I 105 compared favourably with Rheidol at the first cut although neither outyielded it. Bearing in mind that the S. montanum lines had not been subjected, as far as was known at least, to any selection the performance of some of the hybrids in matching the S. cereale control variety in early spring growth and even surpassing it in capacity to recover after defoliation was taken as sufficient evidence to warrant a limited programme of selection.

Breeding Strategy

Several different options are available for combining the attributes of two separate species into a single stable and fertile product. The exact method used will of course be conditioned by several factors, the most important being the fertility of the hybrid, the nature of the breeding objectives and the phenotypic variability generated in advanced generations of the hybrid population. In the first place the possibility of obtaining a reasonably stable and fertile population by recurrent selection within segregating diploid hybrid population has to be considered. A reasonable level of fertility in the F1 hybrid which moreover can be increased by selection and maintained at a high level through advanced generations of seed propagation is essential. Success will then depend on being able to 'fix' certain required characters in the population bearing in mind that there will inevitably be considerable segregation in the F2 and subsequent generations which will tend to dissipate any hybrid advantage. In this context the nature of the breeding objectives in relation to the differences between the parental species will be an important consideration.

Alternatively the creation of allotetraploids as a method of reducing genetic deterioration might be considered. This was favoured by Breese and his co-workers for creating genetically stable hybrids of Lolium multiflorum x Lolium perenne (Breese et al. 1975). This method is also the only one available if the diploid F1 is sterile; tetraploidy usually restores fertility to such hybrids. However, although polyploidy serves to reduce the rate of hybrid deterioration, it nevertheless introduces other complications such as chromosome instability in the form of aneuploidy and also where diploid hybrids are completely fertile, that of lower fertility. Finally, where only relatively few of the properties of one of the species are required a programme involving one or two backcrosses followed by recurrent selection might be the most appropriate. It is unlikely that polyploidy would have to be superimposed on such a programme.

Recurrent Selection

Programmes of selection which could best be described as recurrent selection for general combining ability were carried out separately on two diploid segregating hybrid populations, three tetraploids and a single composite population of diploid backcrosses to S. cereale. Details are given in Table 2.

TABLE 2. Lines used for recurrent selection

Diploid hybrids -	Rheidol x I 105		
-	Rheidol x I 110		
Tetraploid hybrids -	Rheidol x I 109		
	Rheidol x I 110		
	Rheidol x I 113		
Diploid composite of backcrosses - Composite.			
-	Rheidol x (Rh x I 105)	*Lovaspatonai	x (Rh x I 105)
	x (Rh x I 109)		x (Rh x I 109)
	x (Rh x I 110)		x (Rh x I 110)
	x (Rh x I 113)		x (Rh x I 113)
	x (Rh x I 119)		x (Rh x I 119)
	x Lovaspatonai		x Rheidol

* S. cereale cultivar

In proceeding in this manner it had to be borne in mind that the diploid F1 hybrids would only be partly fertile. It was known that the karyotype of S. cereale differed from that of S. montanum by two reciprocal translocations involving three pairs of chromosomes and that the diploid hybrids would be structurally heterozygous (Riley, 1955; Khush and Stebbins, 1961; Khush, 1962). The only viable gametes produced by these F1's would be those containing either the S. cereale or the S. montanum arrangement of these three chromosomes; intermediate types would contain large deletions or additions. However it was believed that selection for full fertility together with selection for a specific agronomic type would result in one of the parental arrangements being 'fixed' in the homozygous state throughout the population. It is inevitable in this type of selection plan that one of the parental types will be favoured and it is implicit that even starting from a straight diploid hybrid the end product will be a 'segmental backcross'. It was also realised that the structural heterozygosity of these hybrid populations could also cause complications at the tetraploid level if the degree of homoeologous chromosome association at meiosis was high. The advantages of tetraploidy in conserving hybridity would then be outweighed by severe problems of infertility due to disturbed chromosome segregation resulting from complicated chromosome configurations at metaphase one of meiosis.

The recurrent selection programme adopted for each of the six populations was essentially as follows. Initially one hundred plants were selected by visual observation from a population of 1000 spaced F2 (or equivalent) plants, and transplanted into an isolated polycross block in late spring. All the semisterile plants were removed before harvest and a single head collected separately from each of the fertile plants. The remaining heads were bulk harvested for use in check plots. Seed from the single head samples were sown as progeny rows of single plants some three to four weeks after harvest (late August/early September). The aim was to establish progeny rows containing 25 plants spaced 10 cms apart with 30 cms between rows and with similarly structured check rows of Rheidol every seventh entry. The progeny rows were evaluated in late March/early April by means of a single cut harvest of green forage and the results expressed relative to the mean of the neighbouring two Rheidol rows. The best four plants from the best 25 rows were then immediately transplanted into an isolated polycross block and the whole procedure repeated as in the previous year. The remnant seed from all the polycross blocks together with Rheidol were sown in small replicated plots at a seed rate comparable to that used for commercial forage rye production. Again these plots were harvested in late March early April through a single cut of forage. However unlike the progeny rows the dry matter content of these samples were also determined.

Results

The tetraploid populations were dropped from the programme at a very early stage. The fertility level of both Rh x I 109 and Rh x I 113 was so low as to make a meaningful assessment of the forage yield of the progeny impossible. On the other hand although the fertility of Rh x I 110 (4x) was adequate its yield of green forage was inferior to its diploid counterpart and to the check variety Rheidol.

The dry matter yield of the remaining diploid populations expressed relative to Rheidol are given in Table 3. These values were obtained from the small replicated field plots in each generation. The data for Rh x I 110 is incomplete as it was dropped from the programme on account of its very weak straw which made it very susceptible to breakage at the 'neck'.

TABLE 3. Dry matter yield of selected lines (small plots).

	1979	1980	1981	1982
Rheidol	100	100	100	100
Composite	103	105	117*	127*
Rh x I105	88	111	104	106
Rh x I110	87	82	105	-

* Significantly higher than Rheidol.

It is clear from the data in Table 3 that progress has been made in increasing the forage yield of both the remaining two lines i.e. the Composite and Rh x I 105 populations. However the yield of the latter is still not significantly greater than the check variety Rheidol. On the other hand the dry matter yield of the Composite population in early spring has been higher than that of Rheidol over the last two cycles of selection. This has been achieved through a slight increase in tillering capacity and a marginal improvement in earliness of growth.

Both the Composite and Rh x I 105 lines are now fully fertile. Cytological analysis of all 100 plants in the Rh x I 105 polycross block in 1981 showed that none were heterozygous for the translocations. It is highly likely that the S. cereale chromosome arrangement has been 'fixed' in both lines.

Conclusion

This programme has shown that the use of 'wild' relatives of cultivated species has some value in specific instances. However it is highly likely that in the short term only a small degree of introgression can be tolerated. Of the two lines retained in this particular programme there is no doubt that the Rh x I 105 exhibits the most S. montanum traits. The superior Composite line is clearly a S. cereale type although there is some evidence that some introgression of S. montanum genes did occur.

Finally the use of several cycles of recurrent selection for general combining ability appears to have been a very efficient method of achieving progress in an annual outbreeding forage crop of this type where selected plants could be isolated prior to pollination. It might be worth considering such a scheme for short lived perennials such as Lolium multiflorum intended for conservation purposes. Each cycle in such a programme would have to be of at least two years duration.

REFERENCES

BREESE, E.L., STEPHENS, D.E. and THOMAS, A.C., 1975: Tetraploid hybrid ryegrasses:- Allopolyploidy in action. In: 'Ploidy in Fodder Plants', Report of Fodder Crops Section Meeting of Eucarpia, Zurich 1975, p 46-49.

EVANS, G.M., 1976: Rye. In 'Evolution of Crop Plants', Ed. N.W. Simmonds, p. 108-111.

KHUSH, G.S., 1963: Cytogenetics and evolutionary studies in Secale. II. Interrelationships of wild species. Evolution 16, 484-496.

KHUSH, G.S. and STEBBINS, G.L., 1961: Cytogenetic and Evolutionary studies in Secale. 1. Some new data on the ancestry of S. cereale. American J. Bot. 48, 721-730.

PFALER, P.L., 1968: Heterosis and homeostasis in Secale montanum. Guss. x Secale cereale L. hybrids. Vegetative growth and development. Crop Sci. 6, 663-666.

RILEY, R., 1955: The cytogenetics of the differences between some Secale species. J. Agric. Sci. 46, 277-283.

EXPLOITING GENETIC VARIATION IN PHYSIOLOGICAL PROCESSES TO INCREASE YIELD IN GRASSES

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Evaluation of forage grass breeding material is usually based on characteristics which can be readily scored on spaced plants growing in the field. However, it is often difficult to equate individual plant yield under these conditions with that which may be expected within a well managed crop or with the potential inherent in the genotype. For this reason, more sophisticated selection criteria are being developed which are based on an increased understanding of the physiological bases of yield. These have to take account of several other important agronomic features of the crop. Firstly, 'yield' has both quality and quantity components which influence the animal end-product. Secondly, most of the photosynthetic system is repeatedly removed at harvests during the growing season, so that immediate investment of photosynthate into non-harvestable reserves must always be sufficient to ensure adequate recovery, regrowth and persistence in difficult conditions. Thirdly, the proportion of the crop which is actually harvested (the 'harvest index') is variable and usually large - about 60% or more in a healthy well grown perennial ryegrass crop (Alberda, 1968). Scope for increasing harvestable yield by adjusting the harvest index is therefore slight and the best prospects for improving yield seem to be in increasing total dry matter, or biomass production (Robson, 1981; Wilson, 1981).

This paper discusses these prospects and the possibilities of combining high dry matter yields with other long-term yield objectives such as persistence and nutritive value.

BIOMASS PRODUCTION

By definition, genetic increase in total dry matter can only be obtained by increasing crop net carbon fixation. Clearly this requires significant additive genetic variation in factors influencing photosynthesis and/or respiration. These may take the form of readily identifiable morphological or developmental features which can influence the gas exchange activities of the crop through their effect on the structure of the canopy, and hence the light environment within it. They may also be the more fundamental physiological or biochemical characteristics affecting the photosynthetic capacity of individual leaves or respiratory activities of plant tissues. It is now clear that useful variation does exist for many such morphological and physiological traits. However, for any to be useful in practical plant breeding it is essential that the full agronomic consequences of selection be determined. Such preliminary assessment has, so far, only been conducted for a few well defined characteristics but others hold promise.

Light interception and distribution

In grass, as in other crops, the basic climatic limitation to production is the seasonal input of light energy, although other environmental constraints can limit its conversion. However, the rate of development of the light intercepting canopy is closely dependent on temperature (Mitchell, 1953;

Peacock, 1976) and in temperate climates low temperature restricts annual yield by its effect on length of the growing season. Where winters are mild annual yields might be increased by exploiting variation in the capacity to expand leaf at low temperature (Eagles, this volume). This apart, the possibility of increasing yields by developing varieties which intercept more of the incoming radiation seems largely confined to selecting types with particular growth habits. Not that growth habits are always fixed. For example, existing varieties tend to change from prostrate to erect as the crop grows denser. Perennial x Italian ryegrass tetraploid hybrids often appear to retain the erect form of the Italian parent until after flowering but subsequently adopt the more prostrate habit of the perennial (Breese, personal communication).

Variation in canopy morphology influences crop photosynthesis both through immediate effects on current photosynthesis and through longer term effects arising from changes in the environment, particularly light, within the crop in which plants and leaves develop (below). The scope for modifying plant habit and structure by selection is considerable. For example, Rhodes (1973, 1975) has clearly demonstrated that it is a relatively simple matter in temperate grasses to shift population canopy structure toward almost any desired type by recurrent selection for certain leaf and stem morphological characteristics at the seedling stage. However, in practice the possibilities of yield improvement in this way can be limited to particular management situations and even by relationships between forage quality and leaf or stem structure.

A prostrate leaf arrangement leads to earlier development of a closed canopy and therefore more effective light interception and faster growth after harvest than occurs with more erect leaves. However, the latter is more effective in later stages of crop development since it allows light to be distributed over a larger leaf area. This leads to more efficient conversion, higher maximum leaf area index (L_{max}) and therefore greater crop photosynthesis and potential dry matter yield (Cooper & Breese, 1971). However, the extent of these relationships change with time of day, weather, season and stage of crop development. Breeding for higher L_{max} in this way is likely to have more effect on potential dry matter yield in sunny than cloudy climates. Nevertheless, even in maritime W.Britain increases of up to 30% in annual dry matter yield of infrequently cut plots have been achieved in perennial ryegrass by recurrent selection for long erect leaves (Rhodes, 1972, 1973, 1975). Even so, with frequent defoliation a short-leaved more prostrate type appeared to have greatest yield (Rhodes, 1973). Clearly, under either close frequent grazing, or a purely conservation system, a general purpose variety is unlikely to have as high a potential yield as one specifically adapted to the system. For grass crops which can be managed to allow repeated development of high L_{max} considerable improvements in potential yield can be made by breeding for canopy characters.

Morphology and economic yield

In practice, efficient continuous production of forage must take account of crop maintenance requirements which may not always be compatible with those for high current yields. Canopy structure may also affect economic yield by influencing both the availability of feed above defoliation height and its nutritive characteristics. Fractions such as lignin which might lend rigidity to leaves, so improving light interception are waste products to the animal. Even cellulose is only slowly digested. Therefore, more erect leaves might be nutritionally less useful than lax leaves (Selim, 1976). Even so, in both ryegrass (Rhodes, personal communication) and cocksfoot this possibility has been avoided. For example, erect and lax-leaved selections from Cambria cocksfoot have displayed no consistent difference in *in vitro* digestibility, cellulose content or water soluble carbohydrate levels, yet greater yields have been produced by the erect selection (Table 1). If high quality can be combined with erect habit then more complete harvesting might result from the improved presentation (Jackson, 1974). However if this leads to reduced leaf area after defoliation then regrowth could be slow and persistency poor.

For these reasons it is often difficult to predict the long-term effects of changes in canopy structure on economic yield. These can only be determined by experimental selection programmes.

Photosynthetic potential of individual leaves

Young fully expanded leaves of north temperate grasses developed in favourable light and temperature conditions usually display maximum rates of light-saturated photosynthesis (P_{max}) of around 30-35 mg CO_2 dm^{-2} h^{-1}. However, in practice very few leaves in a vegetative grass crop come close to this. In most swards, leaves seem capable of fixing carbon at maximum rates varying widely about an average of 10-15 mg CO_2 dm^{-2} h^{-1}, even when brightly illuminated. There appears to be two main reasons for this discrepancy, one is leaf ageing and the other is unfavourable environmental conditions during leaf development. It is important therefore to determine if it is possible to mitigate the effects of these by breeding or indeed whether P_{max} can be raised.

Maximum efficiency

Appreciable genetic variation has been detected within temperate grass species in both P_{max} per unit leaf area (Wallace, Ozbun & Munger, 1972; Wilson, 1973) and the temperature response of photosynthesis (McWilliam, 1978). However, selection for rapid P_{max} or related characters has not led to greater crop dry matter production (Wilson & Cooper, 1970; Moss & Musgrave, 1971; Hart, Pearce, Chatterton, Carlson, Barnes & Hanson, 1978) and genetic variation in P_{max} can even be negatively correlated with yield (Wilson, 1981). The reason for this lack of effect may be because of other compensatory changes such as an inverse correlation between P_{max} per unit leaf area, or unit leaf volume, and leaf size (Wilson, 1981). The possibilities of increasing yield by selecting for P_{max} expressed on some other basis such as unit cell remain to be determined, although even if this were effective quite large changes would be required to produce any significant effect on crop photosynthesis (Monteith, 1977).

Leaf ageing

As leaves age their photosynthetic potential declines. Although the age at which this decline begins, and its rate, seems to vary both between and within species (Wilson, 1981) the significance of this variation for yield of the grass crop is probably slight. Because of shading, older leaves may only intercept 10% of the incoming light within a closed canopy (Leafe, 1972) even when they are still capable of usefully high rates of light-saturated photosynthesis (Woledge, 1972). Even if selection for greater leaf longevity were to delay leaf detachment, and therefore loss of yield, such leaves may well respire more carbon than they gained by photosynthesis.

Photosynthetic adaptability

The potential photosynthetic activity of a leaf can be greatly modified by the light and temperature conditions under which it developed. Low light intensity and extremes of temperature during expansion lead to reduced photosynthetic potential (Wilson, 1973; Woledge, 1978). Within a vegetative grass crop many leaves, and even whole plants, may develop in, and therefore adapt to shaded poor light conditions yet subsequently be exposed to high light intensity. The number of leaves with reduced P_{max} for this reason increases as the crop becomes more dense. Over an extended growth period this effect alone may lead to a reduction of about 30% in crop photosynthesis and largely accounts for the reduced photosynthetic capacity of vegetative compared with erect flowering swards (Robson, 1973).

However, it may well be possible to select genotypes better able to produce leaves with greater photosynthetic adaptability. These would be more suited to resisting the depressant effects of increasing crop density on their capacity to fix carbon. It is known that the range of adjustment of photosynthesis to growth conditions is genetically variable within important grass species (Wilson, 1973). In perennial ryegrass considerable variation has already been detected in the extent to which potential photosynthesis is depressed by growing leaves in low light intensity or higher temperature (Table 2). Fortunately, this variation in adaptability in forage grasses does not seem to be regularly associated with variation in leaf morphology (Wilson & Cooper, 1969). Improved photosynthetic adaptability might therefore be achieved within a background of any derived canopy structure.

<u>Respiratory losses</u>

Substantial losses of carbon can occur in temperate grasses as a result of CO_2 evolution in the light (photorespiration) and subsequent to fixation in the dark (dark respiration). The possibility of increasing yielding capacity by breeding to reduce these losses has attracted much attention (Wilson, 1981). However, so far it is only dark respiration which has shown much promise in this direction. The extent to which photorespiration might be beneficially reduced in C_3 grasses is not at all clear.

Even so, half or more of the carbon initially fixed by photosynthesis in grass crops can be lost through dark respiration (Robson, 1973). Attempts have been made to partition these losses between those associated with the synthesis of new tissue, 'growth' respiration, and those concerned with the maintenance of existing tissue (McCree, 1970; Penning de Vries, 1972). It is this 'maintenance' component which seems to display genetic variation and has recently proved to be amenable to selection in perennial ryegrass (Wilson, 1975, 1982). The amount of carbon lost in maintenance associated respiration can be greater than that associated with growth in the long term and it now seems clear that some genotypes are more 'efficient' than others in this respect.

Estimates of maintenance respiration can be made by enclosing mature tissue (leaves or roots) in the dark and measuring subsequent 'steady-state' CO_2 evolution or O_2 uptake. Using this technique it has proved possible by simple intra-varietal mass selection to produce populations of perennial ryegrass with consistently slower rates of 'maintenance' respiration than the original variety, S.23. The response to selection ($h^2 \propto 0.50$) occurred almost entirely in the first cycle (Wilson, 1982). Slow respiration populations from this programme have consistently outyielded the original variety in the field by amounts of up to 13% annually and around 20% in mid to late summer in Wales (Wilson & Jones, 1982). The precise advantage seems to depend on season and management in a way which has yet to be defined. The possibility that there may be some agronomically deleterious effect of the selection cannot yet be excluded but there has been no evidence of this over four years of field trials. Why then do fast respiration genotypes continue to exist within grass populations? One possibility has been suggested by experiments of Robson, Stern & Davidson (1982) who have shown that the superiority of slower respiration material declines as swards become progressively nitrogen deficient. Nitrogen is often in short supply in agricultural grasslands and there may therefore be litte significant disadvantage to inefficient use of carbon in these circumstances.

From the breeding viewpoint it is also fortunate that slow respiration does not seem to be necessarily related to forage quality (Wilson & Jones, 1982) or to canopy characteristics, and initial larger-scale screening suggests the existence of significant inter-population variation in the characters.

CONCLUSIONS

In forage grasses, useful genetic variability appears to exist for physiological and morphological characteristics which are associated with crop yielding capacity. These include, a) canopy traits, b) 'maintenance' respiration, c) photosynthetic adaptability of individual leaves, d) growth response to temperature, and e) dry matter digestibility. However, to be of value in practical breeding the agronomic consequences of selecting for yield-related characteristics need to be assessed beforehand.

REFERENCES

Alberda, Th. (1968). Dry matter production and light interception of crop surfaces. IV. Maximum herbage production as compared with predicted values. Neth.J.agric.Sci.16,142-153.

Cooper, J.P. & Breese, E.L. (1971). Canopy structure, light-interception and potential production in forage grasses. Rep.Welsh Pl.Breed.Stn for 1970, pp.57-69.

Hart, R.H., Pearce, R.B., Chatterton, N.J., Carlson, G.E., Barnes, D.K. & Hanson, C.H. (1978). Alfalfa yield, specific leaf weight, CO_2 exchange rate and morphology. Crop Sci. 18, 649-653.

Jackson, D.K. (1974), Efficiency in grass production for grazing. Rep.Welsh Pl.Breed.Stn for 1973, pp.111-116.

Leafe, E.L. (1972). Micro-environment, carbon dioxide exchange and growth in grass swards. In: Crop processes in controlled environments (Rees, A.R., Cockshull, K.E., Hand, D.W. & Hurd, R.G. eds). pp.157-174. Academic Press, London.

McCree, K.J. (1970). An equation for the rate of respiration of white clover plants grown under controlled conditions. In: Prediction and measurement of photosynthetic productivity (Setlick, I. ed.). pp.221-230. Centre for Agricultural Publishing

McWilliam, J.R. (1978). Response of pasture plants to temperature. In: Plant relations in pastures (J.R. Wilson, ed.). pp.17-34. CSIRO, Melbourne, Australia.

Mitchell, K.J. (1953). Influence of light and temperature on the growth of ryegrass (Lolium spp.). Physiol.Plant 6, 21-46.

Monteith, J.L. (1977). Climate and the efficiency of crop production in Britain. Phil.Trans.Roy.Soc.London B 271, pp.277-294.

Moss, D.N. & Musgrave, R.B. (1971). Photosynthesis and crop production. Adv.Agron. 23, 317-336.

Peacock, J.M. (1976). Temperature and leaf growth in four grass species. J.appl.Ecol. 13, 225-232.

Penning de Vries, F.W.T. (1972). Respiration and growth. In: Crop Processes in Controlled Environments (Rees, A.R., Cockshull, K.E., Hand, D.W. & Hurd, R.G. eds). pp.327-348. Academic Press, London.

Rhodes, I. (1972). Yield, leaf area index and photosynthetic rate in some perennial ryegrass selections. J.agric.Sci. 78, 509-511.

Rhodes, I. (1973). Relationship between canopy structure and productivity in herbage grasses and its implications for plant breeding. Herb.Abstr. 43, 129-133.

Rhodes, I. (1975). The relationship between productivity and some components of canopy structure in ryegrass (Lolium spp.). IV. Canopy characters and their relationship with sward yields in some intra-population selection. J.agric. Sci. 84, 345-351.

Robson, M.J. (1973). The growth and development of simulated swards of perennial ryegrass. II. Carbon assimilation and respiration in a seedling sward. Ann.Bot. 37, 501-518.

Robson, M.J. (1981). Potential production - what is it and can we increase it? In: Plant Physiology and Herbage Production (Wright, C.E. ed.). pp.5-18. Occ.Symp.Brit. Grassld Soc., Nottingham.

Robson, M.J., Stern, W.R. & Davidson, I.A. (1982). Yielding ability in pure swards and mixtures of lines of perennial ryegrass with contrasting rates of 'mature tissue' respiration. In: Efficient Grassland Farming. 9th Meeting of the European Grassland Federation, Reading 1982 (in press).

Selim, O.I. (1976). Variation in leaf anatomy in relation to nutritive value of Festuca arundinacea Schreb. and other temperate grasses. Ph.D. Thesis, Univ.Coll.Wales, Aberystwyth.

Wallace, D.H., Ozbun, J.L. & Munger, J.M. (1972). Physiological genetics of crop yield. Adv.Agron. 24, 97-146.

Wilson, D. (1973). Physiology of light utilization by swards. In: Chemistry and Biochemistry of Herbage (Butler, G.W. & Bailey, R.W. eds). Vol. 2, pp.57-101. Academic Press, London.

Wilson, D. (1975). Variation in leaf respiration in relation to growth and photosynthesis of Lolium. Ann.appl.Biol. 80, 323-328.

Wilson, D. (1981). Breeding for morphological and physiological traits. In: Plant Breeding II (Frey, K.J. ed.). pp.233-290. Iowa State University Press, Ames, Iowa.

Wilson, D. (1982). Response to selection for dark respiration rate of mature leaves in Lolium perenne and its effects on growth of young plants and simulated swards. Ann.Bot. 49, 303-312.

Wilson, D. & Cooper, J.P. (1969). Effect of light intensity during growth on leaf anatomy and subsequent light-saturated photosynthesis among contrasting *Lolium* genotypes. *New Phytol*. 68, 1125-1135.

Wilson, D. & Cooper, J.P. (1970). Effect of selection for mesophyll cell size on growth and assimilation in *Lolium perenne* L. *New Phytol*. 69, 233-245.

Wilson, D. & Jones, J.G. (1982). Effect of selection for dark respiration rate of mature leaves on crop yields of *Lolium perenne* cv. S.23. *Ann.Bot*. 49, 313-320.

Woledge, J. (1972). The effect of shading on the photosynthetic rate and longevity of grass leaves. *Ann.Bot*. 36, 551-561.

Woledge, J. (1978). The effect of shading during vegetative and reproductive growth on the photosynthetic capacity of leaves in a grass sward. *Ann.Bot*. 42, 1085-1089.

Table 1. Yield, quality and disease rating of plots of *Dactylis glomerata* selections with contrasting habit. Ex. cv. Cambria. Six cut conservation management in 1980.

Cutting date	Leaf habit	Dry wt (kg ha^{-1})	IVDMD	WSC	Cellulose	Spring mildew
21 May	Erect	4423	61.7	4.2	28.6	-
		*	**		*	
	Lax	3850	59.4	4.2	29.7	+
16 July	Erect	2235	75.0	10.5	25.9	.
		*		*		
	Lax	2141	75.1	8.5	26.0	.
24 Sept	Erect	1004	72.5	4.3	25.6	.
	Lax	1048	72.9	4.7	25.6	.
Annual yield	Erect	13149	-	-	-	-
	Lax	12093	-	-	-	-

*P < 0.05

Table 2. Percentage depression of subsequent light-saturated rate of leaf photosynthesis (P_{max}) at 15°C as a result of growth at lower light intensity (22 W m^{-2} compared with 50 W m^{-2}) or high temperature (25°C compared with 15°C). Contrasting genotypes of *Lolium perenne*

Genotype origin	Environmental variant	
	Low light	High temperature
Sweden (Viris)	12	48
Germany (Steinacher)	19	31
Netherlands (Vertas hybrid)	22	34
Lithuania (Veya)	43	17
Canada (Norlea)	50	40
C.Spain (ecotype)	62	27
Significance of G x E interaction	***	***

***P < 0.001

GRASS AND CLOVER IDEOTYPES FOR IMPROVED MIXTURE YIELD

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White clover (*Trifolium repens* L.) is invariably grown in mixture with a grass, and red clover (*Trifolium pratense* L.) is often grown in such conditions. In the breeding of improved varieties of these species, for whatever management or environment, a primary objective must be their compatibility with the associate grass.

The pragmatic approach of selecting grass and clover material, which may be co-adapted, from the same location can prove useful in achieving this goal, particularly in the short term (Evans & Hill, in this volume). However, any improved compatibility obtained using this procedure is not necessarily associated with high mixture yield.

The complementary approach described in this paper involves the design of compatible and productive grass and clover ideotypes based on physiological and agronomic information, and represents the first phase of a programme to produce grass and clover varieties showing both spatial and temporal compatibility and specifically designed for mixture growth.

EXPERIMENTAL

Basically the contributions of grass and clover to mixture yield under any management or environment are dependent on their *yielding ability* (as measured in monoculture) and the degree of competitive enhancement or suppression of this yielding ability, resulting from differences in the competitive abilities of the components. Thus, in theory differences in the botanical composition of swards under various managements/environments or with different varieties can arise through differences in yielding ability and competitive ability alone or in combination.

Since yielding ability and competitive ability may be unrelated or even negatively related parameters (Table 1), it is essential that their effects on sward composition are quantified and the characters controlling them are elucidated, thus providing information for the formulation of ideotypes.

For the purpose of these experiments it is relevant to quantify the competitive suppression/enhancement by expressing the yield of a mixture component as a proportion of its yield from a similar area of ground in monoculture. Expressed as natural logarithms positive values indicate competitive enhancement and negative values competitive suppression.

The experiments described in this paper illustrate the genetic variation which exists in yielding ability and competitive ability and some of the characters associated with these parameters. Finally simple ideotypes of both grasses and clovers are described and their effects on the total yields of grass-clover mixtures discussed.

Red clover (Trifolium pratense)

Experiments have been carried out using two diploid varieties, Lakeland and Sabtoron and their respective tetraploid derivatives Minuet and Norseman. These varieties were grown in monoculture and in 50:50 mixtures with each of four grasses: *Phleum pratense* (S.48), *Lolium perenne* (S.24), *L.multiflorum* x *L.perenne* 4x (Sabrina) and *Festuca arundinacea* (S.170). The swards were subjected to two defoliation frequencies: viz. 3 week and 6 week cutting. Detailed reports of these studies have been presented elsewhere Ngah (1980), Rhodes & Ngah (1983).

a) Yielding ability

Large differences existed between varieties in spaced plant yield and morphological characters (Table 2), but no differences existed in sward yielding ability (Table 3) until the third year when persistency became a major factor.

b) Competitive suppression/enhancement

Considerable variation existed between varieties with, in general, Norseman showing the greatest and Lakeland the least enhancement, or least and greatest suppression respectively (Table 4).

The associate grass had a marked effect on the clover yield in mixture, with the ranking of the grasses changing dramatically from year to year (Table 5).

c) Mixture yield

Whilst most mixtures showed partial or complete complementation (Hill & Shimamoto, 1973), some mixtures exhibited over complementation resuting in their yields being greater than their highest yielding monoculture. This transgressive yield only occurred in mixtures with perennial ryegrass or tall fescue as the associate grass.

d) Characters associated with yielding ability and competitive ability

Whilst no differences existed in yielding ability between varieties, studies on the patterns of regrowth revealed a decline in the crop growth rate of Lakeland, Minuet and Sabtoron beyond certain leaf areas. Norseman, in contrast, exhibited a linear increase in crop growth rate throughout the period and at LAI values greater than in the other varieties. Thus Norseman with its tall open habit and large leaves may have a higher yield potential which would only be expressed under less frequent defoliation. The contrasting pattern of regrowth of the other tetraploid variety Minuet, may be related to its dense packing of leaves with a consequent higher light extinction coefficient. In addition it appears that Minuet diverts a greater proportion of its assimilatory products to root production at the expense of harvestable yield (Table 2). The superior yielding ability of Lakeland in spaced plant conditions is probably related to its greater number of shoots giving increased lateral spread and occupancy of a larger ground area.

Differences in competitive ability, with Norseman being most and Lakeland least aggressive, were maintained throughout the experiment. High competitive ability was associated with a faster rate of seedling root elongation, greater mature plant root weight, taller stature and larger leaves (Table 2).

The high competitive ability of Minuet, the other tetraploid may be in part related to its dense growth habit, in which a similar leaf area to Norseman was held on a smaller structural framework. This growth habit would ensure effective shading, particularly of the shorter grasses.

White clover - ryegrass mixtures

a) Competitive ability

Marked variation exists both between varieties and natural populations and has often been attributed to differences in stature characteristics such as petiole length and leaflet size. However these relationships have generally only been found during the establishment phase of a sward (Table 6) or with annual clovers such as *Trifolium subterraneum* (Black, 1960). The results in Table 6 clearly demonstrate the competitive advantage resulting from long petioles/large leaflets where the clover is in competition with tall grass, during the establishment year.

However, in situations where survival and regeneration are dependent upon the vegetative plant, competitive ability after the establishment year is related to many and more complex physiological characters, with a resultant change in the ranking of varieties for this parameter. For instance, the tall variety Sabeda showed greater competitive suppression than the short variety S.184 under infrequent cutting in the first full harvest year (i.e. after the first winter) (Table 7). The main factor reducing the contribution of S.184 under infrequent cutting was its lower yielding ability.

These changes in the relative competitive abilities of tall and short clovers have been attributed in part to the small amount of stolon, fewer growing points and possibly lower reserve status of the stolon in the tall types (Rhodes, 1981). Such features appear to result in less growth in early spring at a time when grass growth is rapid and they also render tall varieties more vulnerable to catastrophic damage from winter conditions and predators. Other more subtle characters may be involved in this relationship. For instance it has beeen shown that, within a group of large leaved varieties, yield in a mixture, in the second year is negatively related to internode length (D.R. Evans, pers.comm.).

Under more frequent defoliation systems, little is known about the characters governing competitive ability, although stature has been demonstrated to be unimportant (e.g. Table 6) and a dense stolonferous habit is desirable. In such a management system where average leaf area index is low, the rate of individual leaf photosynthesis may be important and characters associated with root competitive ability will assume greater relative importance.

b) Yielding ability

Because white clover is not grown agriculturally as a monoculture, few reliable reports of variation in yielding ability are available, and often yields include weed grasses such as *Poa*.

However, substantial differences in apparent (i.e. harvested yield) have been recorded, with interactions between varieties and defoliation frequencies. Despite these differences in harvested yield, in a limited range of varieties of very contrasting morphology, little difference has been found in aerial biomass. The differences in harvested yield were due to differences in harvest index (Rhodes & Harris, 1979).

Generally, tall varieties have a higher yielding ability under infrequent cutting with the shorter varieties often more productive, but not universally so under frequent cutting.

c) Effects of associate grass

Little attention has been given in previous studies to the effects of differences in grass morphology on clover yield or total mixture yield. Initial studies showed that subtle differences between grass varieties and selection lines had marked effects on the degree of competitive enhancement/ suppression of clovers with long leaves; erect grasses generally permitting better clover growth (Rhodes & Harris, 1979; Rhodes *et al.*, 1979).

More recent studies, using selection lines of ryegrass developed from within varieties, have substantiated the earlier findings and emphasized the beneficial effect of upright growth habit in grasses.

It is worth noting however, that under severe winter conditions winter damage to clovers may be greater in mixtures with upright open grasses (Rhodes, 1981). However, such effects may not be evident in the majority of winters in the United Kingdom.

CONCLUSIONS

The type of studies described in this paper provide information for the development of simple morphological grass and clover ideotypes, to which more subtle physiological characters can be added, as information becomes available. They can similarly be developed for other environments or managements involving such features as water, nutrient, light and temperature stresses.

With regard to white clover, the most important forage legume in the United Kingdom, it appears that tall stature of the clover may be associated with high harvestable yield and competitive ability in the establishment year, in managements with a high average LAI. However, in many varieties this stature may have been achieved at the expense of stolon development, and competitive ability may decline in subsequent years.

Our recent studies have shown that it is possible to develop lines from within varieties which show considerable increases in stolon development but are accompanied by relatively little loss of plant stature. These lines are currently undergoing field trials to quantify associated changes in yielding ability and competitive ability.

Of course, if as seems likely more emphasis is given in agricultural practice to continuous grazing managements with concomitant low sward LAI then a different morphotype of clover is required with a densely stoloniferous habit and shorter stature. It can also be argued that for some extreme situations, very small statured clovers are required, which avoid defoliation and remain purely to transfer nitrogen to the grass component of the association.

It terms of temporal compatibility it is clear that temperature limitations to early spring growth are more pronounced for white clover than grass. This can reduce the clover production *per se* as well as placing it at a competitive disadvantage. Preliminary work of Mytton & Hughes (1980) suggests that poor growth of clover at low temperatures is primarily a function of the clover plant *per se* rather than a nitrogen limitation imposed by poor fixation from *Rhizobium*. However, there are also indications of some problems with fixation at low temperatures. Studies are being undertaken into the existence of variation in the growth of white clover at low temperatures and its incorporation into basic morphological ideotypes.

The desirable features for an associate grass appear to be some of those which confer a high yielding ability in monoculture conditions (Rhodes & Mee, 1980) i.e. long leaves and an upright open habit of growth. A recent development in this field is the finding that not only do such grasses permit better clover growth in the mixture, but that their inclusion can result in an increase in the total yield of the mixture, by as much as 25% (Rhodes & Ngah, 1983). A further development of this work will involve the evaluation of mixtures comprising both the newly developed grass and clover morphological ideotypes.

REFERENCES

Black, J.N. (1960). The significance of petiole length, leaf area and light interception in competition between strains of subterranean clover (*Trifolium subterraneum* L.) grown in swards. *Aust.J.agric.Res.* 9, 39-52

Hill, J. & Shimamoto, Y. (1973). Methods of analysing competition with special reference to herbage plants. I. Establishment. J.agric.Sci., Camb. 81, 77-89.

Mytton, L. & Hughes, D.M. (1980). Symbiotic nitrogen fixation at low temperatures. Rep.Welsh Pl.Breed.Stn for 1979, pp.54-56.

Ngah, A.W. (1980). Variation in response to defoliation and competition in *Trifolium pratense*. PhD Thesis, University of Wales.

Rhodes, Ian (1981). The physiological basis of variation in the yield of grass/clover mixtures. In: Plant Physiology and Herbage Production. (Wright, C.E., ed.). pp.149-161. British Grassland Society Occasional Symposium No. 13

Rhodes, I. & Harris, W. (1979). The nature and basis of differences in sward composition and yield in ryegrass white clover mixtures. In: Changes in Sward Composition and Productivity. (Charles, A.H. & Haggar, R.J., eds). pp.55-60. British Grassland Society Occasional Symposium No. 10.

Rhodes, I. & Mee, S.S. (1980). Changes in dry matter yield associated with selection for canopy characters in ryegrass. Grass and Forage Sci. 35, 35-39.

Rhodes, Ian & Ngah, A.W. (1983). Yielding ability and competitive ability of forage legumes under contrasting defoliation regimes. In: The Physiology Genetics and Nodulation of Temperate Legumes. (Jones, D. Gareth & Davies, D. Roy, eds). Association of Applied Biologists (in press).

Rhodes, I., Harris, W. & Mee, S.S. (1979). Crop morphology, canopy structure, yielding ability and competitive ability. Rep.Welsh Pl.Breed.Stn for 1978, pp.159-161.

Table 1. Yielding ability and competitive enhancement/ suppression* of some clover populations (frequent cutting)

	Yielding ability ($g\ m^{-2}$)	Competitive enhancement/suppression
S.184	755	-0.10
S.100	558	-0.03
Menna	650	-0.13
Olwen	621	-0.25
Ac 32	660	0.11
Blanca	772	-0.04
Ac 3420	562	0.22
Ac 3434	587	0.16
LSD P = 0.05	118	

$$^{*}\log_e \frac{\text{mixture yield}}{\text{monoculture yield}}$$

Table 2. Some morphological features of four red clover varieties

	Sabtoron	Norseman	Lakeland	Minuet	LSD P=0.05
Petiole length (cm)	14.9	18.8	16.3	16.8	2.3
Area of leaflets (cm^2)	23	35	30	33	7
Length of long root (cm) (60 days)	41	50	38	43	7
Number of lateral root/plant (60 days)	65	49	79	49	11
Weight of roots in sward (g)	13.0	17.7	17.9	21.0	4.2
Root/shoot ratio	0.14	0.18	0.17	0.23	0.05
Number of shoots/plant					
(a) Frequent cutting	7.2	7.4	10.8	8.3	3.1
(b) Infrequent cutting	14.4	11.6	19.4	14.3	

(from Rhodes & Ngah, 1983)

Table 3. Dry matter yield of four red clover varieties

	Spaced plants (g)		Sward (g m^{-2})	
	Frequent	Infrequent	Frequent	Infrequent
Sabtoron	15.1	31.4	1034	1605
Norseman	14.8	31.0	1016	1576
Lakeland	19.3	35.6	863	1450
Minuet	16.2	33.2	983	1632
LSD P = 0.05 between varieties within cutting frequencies	2.4		N.S.	

(from Rhodes & Ngah, 1983)

Table 4. Competitive enhancement/suppression of red clover varieties

	Frequent cutting	Infrequent cutting
Sabtoron	-0.25	0.16
Norseman	0.00	0.27
Lakeland	-0.76	-0.20
Minuet	-0.10	0.23

(from Rhodes & Ngah, 1983)

Table 5. Competitive enhancement/suppression of red clover (means of four varieties) grown with four associate grasses

	Frequent cutting		Infrequent cutting	
	1979	1980	1979	1980
Asssociate grass				
P.pratense (S.48)	0.42	-0.54	0.92	0.15
F.arundinacea (S.170)	0.22	-1.70	0.67	-0.54
L.perenne x L.multiflorum (Sabrina)(4x)	0.14	0.48	0.15	1.13
L.perenne (S.24)	-0.08	-0.76	0.29	0.10

Table 6. Enhancement/suppression of white clovers grown with four grasses

	Sixth leaf length of grass (mm)	14 day cutting		28 day cutting	
		S.184	Sabeda	S.184	Sabeda
Associate grass					
L.perenne x *L.multiflorum*	423	-0.32	-0.24	-0.82	0.29
L.perenne x *L.multiflorum*	305	-0.16	-0.06	-0.54	-0.12
L.perenne	289	0.00	-0.29	-0.36	0.05
L.perenne	192	0.17	0.19	0.34	0.36

S.184 short petioles small leaves
Sabeda long petioles large leaves

Table 7. Yielding ability and competitive suppression of two white clover varieties

	Yielding ability ($g\ m^{-2}$)		Competitive suppression	
	Frequent	Infrequent	Frequent	Infrequent
Sabeda (large leaves)	793	765	-0.31	-0.69
S.184 (small leaves)	720	621	-0.42	-0.38
LSD P=0.05	92			

(from Rhodes & Ngah, 1983)

CO-ADAPTATION AND ITS ROLE IN IMPROVING THE PERFORMANCE OF WHITE CLOVER/PERENNIAL RYEGRASS MIXTURES

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For most of the forage legumes grown in UK agriculture, annual seed usage has declined drastically since the early 1960s. The one notable exception to the trend is white clover (*Trifolium repens*), whose usage over this period has fallen by only 25%. Consequently it is currently the most widely grown forage legume in UK agriculture. Apart from crops grown for seed, white clover is grown in mixtures with a grass companion. During the productive lifetime of such mixtures the components will be exposed to both intra- and inter-specific competition, the effects of which will determine the contribution made by each component to the productivity of the mixture as a whole.

At present the objective of forage breeding programmes can be stated simply as the production of improved varieties of grasses or clovers. But in the present context is this enough? The farmer after all grows a mixed grass/clover sward. Is it not therefore more appropriate to re-define the objective as the production of improved grass/clover mixtures? We will not attempt to minimize the difficulties attendant upon such a course of action; they will indeed be formidable. But if improved mixture productivity is deemed to be a worthwhile breeding objective then there is no feasible alternative. Such an objective requires that the components of the intended mixture are grown and evaluated in each other's presence so that they can exert mutual selection pressure upon each other. They become, in other words, adapted to each other's presence or co-adapted.

In attempting to incorporate the essential features of co-adaptation into a breeding programme one can take either a medium or long term view. The former enlists the help of natural selection and can hopefully be used to shed light on the process of co-adaptation itself and hence assist with the longer term approach of actually breeding compatible mixture components.

The experiment to be described here is essentially an exploratory experiment designed to compare the productivity of supposedly co-adapted and non-adapted white clover/perennial ryegrass mixtures.

THE EXPERIMENT

Five co-adapted pairs of white clover/perennial ryegrass populations were included in this experiment (Table 1). The first four of these were taken from naturally occurring pastures which have no history of ploughing and re-seeding. The fifth - Menna/Ajax - was collected from a pasture in S.England which had been established some seven years earlier. Two additional non-adapted perennial ryegrasses were included as controls, namely S.23 and Ba 9462, this latter having been selected for erectness of growth habit and leaf length.

The experiment was established in 1980 as a split plot with four replicates. Main plots were provided by the three grass groups, that is co-adapted, S.23 and Ba 9462, whilst the five clover populations supplied the sub-plots. Thus each replicate contained 15 mixture plots which had been sown with its allotted mixture at a rate equivalent to 3 and 12 kg/ha of clover and grass respectively. Phosphorus, potassium and lime were applied in the seed bed, whilst additional P and K has been supplied annually in the spring.

RESULTS AND DISCUSSION

Table 2 shows the total dry matter production of the 15 mixtures, each subdivided into its two components for 1981, the first harvest year. These figures are based on 3 cuts. There is not much to choose between the three grass groups as regards total (grass plus clover) productivity. However, it is noteworthy that both the highest and the lowest yielding mixtures occur in the co-adapted group. Turning to the clover yields it can be seen that without exception the contribution of these five populations to the mixtures is greatest when it is grown with a grass collected from the same locality (Table 3). Equally without exception their contributions are lowest when grown with S.23. From the analysis of the clover data shown in Table 4 it can be seen that highly significant differences exist between the dry matter yields of the 15 mixtures. Partitioning this item further indicates that these differences are attributable to grass companion and clover population, there being no evidence of a significant interaction between the two effects at this stage. Finally, differences between grass companion can be shown to be due primarily to the contrast between adapted and non-adapted.

Meanwhile, what has been happening to the grass component in the mixture? From what was said earlier it should be clear that the gains made by the clovers in the co-adapted mixtures have largely been at the expense of the grass component. Only in the Menna/Ajax mixture have both components apparently benefitted from the association (Table 2). If, however, we look at the second years' results to date, and these cover the major part of the growing season, then an interesting picture begins to emerge. The dry matter productivity of the grass is now as high in the co-adapted mixtures as in the non-adapted mixtures (Table 5). Given the continued high productivity of the clovers in such mixtures, this means that the total productivity (grass and clover) is now generally higher for a particular clover population in its co-adapted mixture. It is tempting to suggest that the nitrogen fixed by symbiosis in the first year is now being cycled to the grass and that the co-adapted mixtures have an advantage because of their higher clover content in the first year. In addition one notes that, for an individual clover population, mixtures with S.23 have the lowest total yield. One must remember though that the first year's results relate only to the latter half of the growing season, hence the lower productivity in that year.

In discussing these results it must be said that this experiment is limited in its scope and objectives. Nevertheless, the results do suggest that co-adaptation has a role to play in improving the productivity of grass/white clover mixtures. We need, however, to understand the process of co-adaptation better: how quickly it operates, or perhaps how quickly it can be made to operate; whether we can shorten the process by identifying 'ideotypes' which are likely to be co-adapted; the role of the environment and management in modifying its effects, and so on. In this context it is worth noting that Ajax, the grass collected with Menna, was re-selected from S.23 for improved performance and persistency under an intensive grazing management. Subsequently, however, it failed to meet the legal requirements of distinctness from S.23 and consequently was not granted plant breeder's rights. The evidence from this experiment so far suggests that Menna may have succeeded in distinguishing Ajax from S.23 where man-made tests, including isozyme tests, have failed.

One point in conclusion is that co-adaptation should not be equated automatically with high productivity. Here, for example, the co-adapted mixture with Ac 3441 gave the lowest combined yield of all in the first harvest year. This is hardly surprising, since a mixture collected 1,600 m up in the Swiss Alps would not be expected to be high yielding when grown at sea level in a cool, maritime environment. Under such circumstances artificial selection will be required to supplement that already exerted by nature.

Table 1. Origin of the five co-adapted clover/grass populations

Population	Country of origin	Altitude (m.a.s.l.)
Ac 3441	Switzerland	1,600
Ac 3160	Italy	700
4512-13-14aCo	Switzerland	340
Ac 3449-53	France	300
Menna	England	100

Table 2. Total dry matter yield (kg ha^{-1}) (1st harvest year)

Clover population	Grass companion	Clover yield	Grass yield	Total yield
Ac 3441	S.23	80	3514	3594
	Ba 9462	214	3444	3658
	Co-adapted	410	2156	2566
Ac 3160		361	3522	3883
		732	3200	3932
		1402	2837	4239
4512-13-14aCo		282	3493	3775
		470	3466	3936
		635	3010	3645
Ac 3449-53		335	3561	3896
		704	3447	4151
		784	2372	3156
Menna		331	3413	3744
		782	3362	4144
		924	3792	4716

Table 3. Clover dry matter yield (kg ha^{-1}) (1st harvest year)

	S.23	Ba 9462	Co-adapted	Mean
Ac 3441	80	214	410	235
Ac 3160	361	732	1402	832
4512-13-14aCo	282	470	635	462
Ac 3449-53	335	704	784	608
Menna	331	782	924	699
Mean	278	580	831	563

Table 4. Analysis of clover dry matter yield

Item	df	MS
1. Clover mixtures	14	456,189***
(a) Grass companion	2	1,533,055***
(i) Adapted v non-adapted	1	2,151,773***
(b) Clover varieties	4	616,814***
(c) (a) x (b)	8	106,661
2. Reps	3	72,025
3. Error	42	101,443

*** - $P < 0.001$

Table 5. Total dry matter yield (kg ha^{-1}) (2nd harvest year to date - total of first four cuts)

Clover population	Grass companion	Clover yield	Grass yield	Total yield
Ac 3441	S.23	601	1749	2350
	Ba 9462	2588	2239	4827
	Co-adapted	3684	3164	6848
Ac 3160		4865	2063	6928
		6489	2887	9376
		6966	2919	9885
4512-13-14aCo		4499	2305	6804
		5347	2506	7853
		6028	3102	9130
Ac 3449-53		4342	2409	6751
		5388	2930	8318
		5928	3149	9077
Menna		5150	2107	7257
		6132	2654	8786
		6555	2582	9137

FORAGE YIELD OF POLYCROSS PROGENIES OF LUCERNE DERIVED FROM PARTLY INBRED PARENTS

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The general scheme of breeding adopted at the Forage Crop Institute in Lodi is presented in Figure 1.

Two aspects have to be underlined: firstly, the utilization of interplant competition during all the phases of breeding; secondly, the utilization of two generations of selfing.

Why did we decide to use the interplant competition? The answer may be summarized as it follows.

The direct breeding for the yield in lucerne, is considered to have given till now results not signficantly different from the old cultivars.

Some colleagues affirmed that we failed till now in direct breeding for yield. Such an assertion is perhaps too drastic. Indeed, we select for some well defined objectives (as for instance cultivars suitable for irrigation or industrial exploitation) but these cultivars are mostly utilized in conditions, and for uses, which are different from the previously defined objectives. In this case, the responsibility of their failure must be ascribed not to the breeding but to the erroneous management of the cultivars. In any case, it is well evident that, beside the very good results of the breeding for disease resistance and quality (bringing an indirect improvement of yield), direct breeding for yield has given only modest results.

In our opinion, this occurs chiefly because the selection is usually done in experimental conditions different from the field. In general, the breeders pay more attention to the criteria of selection than to the way of using them. Usually, the selection and the progeny test are made with spaced plants. We believe that such a method is one of the most responsible factors for the poor results till now obtained.

The terms of the question are the following.

From the farmer's practical point of view, an individual plant of lucerne has no interest, because the exploitation concerns not an individual plant but the lucerne crop as a whole. The problem is therefore to know if the spacing method is more or less efficient than the method by which the individual plants are considered as members of a given type of plant society.

In order to solve such a problem, we have studied, during several years and in many experiments, the lucerne crop from the point of view of the regulation mechanisms of the canopy structure. In such a way, we were able to define a lucerne crop model and, in view of it, a plant ideotype suitable for the improvement of the lucerne canopy as a whole (Rotili, 1979; Rotili & Zannone, 1975; Rotili, Zannone & Jacquard, 1976).

Our last searches on the canopy evolution under an intensive management system, detected a high positive correlation between resistance to cutting (at the first flowers) and interplant homogeneity for some physiological characteristics; for example, time and capacity of regrowth, velocity of growth, earliness in flowering.

At the end of such work we concluded that the breeding method based on interplant competition seems to increase the efficacy of selection, because it enables us to appreciate the plant modelled by the canopy and by the management techniques, that means in conditions as nearest as possible to the actual agronomic situation.

The breeding carried out at the Lodi Forage Crop Institute is based on this working hypothesis. The objective of our breeding programme is the constitution of cultivars for the Northern and Central Italy irrigated plains, and therefore for intensive management systems.

Why a phase of selfing? For at least two reasons. Firstly, a rich and well organized agriculture system can control the major part of natural environment factors. In these conditions, the effects of artificial factors introduced by the farmer become predominant. Among these, the high number of cuttings can represent a catastrophe for the canopy structure. A great genetic variability for physiological characters, such as time and quantity of regrowth, velocity of growth, earliness in flowering, represents a factor against persistency. Such variability would allow indeed differential responses of the plants to the cutting, because of their different degree of root reserve recovery at the cutting time. This different plant response is the principal cause of mortality (Rotili, 1979).

Therefore a cultivar must show individual plants as homogeneous as possible for the above physiological characters. The best way to obtain such a cultivar is the method which utilizes selfing. It is evident that we hope to obtain cultivars only relatively homogeneous, because a complete homogenization is not realizable in an autotetraploid, and because interplant competition increases these difficulties by emphasizing the differences among the plants.

A second reason for using selfing is the following: to obtain a very high yielding lucerne crop, persistency is not sufficient, but the vigour is necessary as well.

With reference to vigour, our working hypothesis is based on the possibility of cumulating, during the selfing phase, several factors favourable to forage yield. Namely, we ascribe to selfing the role of homogenizing the physiological characters and of concentrating the genetic structures favourable to vigour.

The actual programme represents a second cycle of experiments, aimed to verify the validity of the said working hypothesis.

MATERIAL AND METHODS

Two parental populations (cv. Leonicena and Cantoni) were chosen for this research. Within each cultivar, selection was practised for plants with dry matter weight exceeding the mean by two standard deviations. These plants were self-fertilized. Intense positive selection for vigour (measured by the dry matter yield) was practised between and within families after each generation of selfing.

Parental populations and selfed families were evaluated under competition and frequent cutting conditions. At every level of selfing the chosen plants were polycrossed by hand in the glasshouse. The progenies S_0 x S_0, S_1 x S_1 and S_2 x S_2 were grown in the glasshouse, in concrete boxes 80 cm long, 25 cm wide and 60 cm high; 40 seedlings of each entry were planted in a row-plot in a randomized block design with 7 replications. Data were collected on the 20 central plants of each row. Dry matter weight, earliness and mortality were determined. Cuttings were made every 23-26 days.

The results concerning forage for the parental progenies common to each level of inbreeding are reported.

RESULTS AND DISCUSSION

Table 1 shows the means and the ranges of variation for dry matter yield at the different generations of inbreeding. According to the theoretical results, a peculiarity of the autotetraploid state is that crossing after selfing does not restore vigour. So, the more inbred the parents, the weaker are the crosses. This is valid in absence of selection, and has been verified by several authors (Aycock & Wilsie, 1968; Demarly, 1963; Gallais, 1976).

But in the presence of selection the result is different. In fact, our results show that the mean at the S_2 level is larger than the mean at the S_0 and S_1 level (about 5 and 8%, respectively).

These results confirm those obtained during the first cycle of experiments, already published (Rotili, 1976). They confirm also that selection of vigorous plants within S_2 families is more efficient than within S_1 families.

For a better evaluation of the effectiveness of selfing and subsequent selection, we have compared in Figure 2, the average of results obtained by several authors in the absence of selection with our results obtained in presence of selection. The data are expressed in percent of the S_0.

At the S_1 level, the effect of selection counterbalances the inbreeding effect, while at the S_2 level the effect of selection is about 10% higher than the inbreeding effect. But, for a more complete and correct evaluation of the importance of selfing and subsequent selection in view of the constitution of synthetic varieties, we have to keep in mind the role of the genetic structure in the expression of the hybrid vigour.

We know that at the levels $S_1 \times S_1$ and, chiefly, $S_2 \times S_2$ the first generation show a low level of heterozygosity. To obtain a higher level of heterozygosity we have to go to the second generation. Our previous results showed that at the level $S_2 \times S_2$ the Syn II generation synthetics yield about 20% over their Syn I generation (Rotili, 1976). That is because the Syn II generation is characterized by a higher frequency of trigenic and tetragenic structures.

CONCLUSION

On the basis of the present and previous results, our working hypothesis, based on the combined use of two factors (selfing and competition) seems to produce positive results in the breeding of lucerne. More precisely, the efficiency of selfing and competition in improving the genetic value of the parents appears very important.

Why was selection in an autotetraploid plant such as lucerne so successful for a character as complex as yield? Demarly coined the word 'linkat' to represent the chromosome segment which remain intact for more than one generation. This hypothesis, simplifying the general structure of the genome, allows one to understand the rapidity of concentration of favourable gene and gene combinations present in the mother plants. It is necessary only to assume that favourable linkages are held together within a linkat.

REFERENCES

Aycock, M.K. & Wilsie, C.P. 1968. Inbreeding in Medicago sativa by sib mating. Crop Sci. 8, 481-485.

Busbice, T.H. 1970. Predicting yield of synthetic varieties. Crop Sci. 10, 265-269.

Demarly, Y. 1963. Génétique des tetraploids et amélioration des Plantes. Ann.Amélior.Plantes 13, 307-400.

Gallais, A. 1976. The use of heterosis in autotetraploid cross-fertilized plants with some applications to lucerne and cocksfoot. Ann.Amélior.Plantes 26, 639-646.

Guy, P. 1966. Étude de l'évolution de quelques structures autotétraploides en cours des génération de multiplication. Genetics Agraria 20, 56-65.

Rotili, P. 1976. Performance of diallel crosses and second generation synthetics of alfalfa derived from partly inbred parents. I. Forage yield. Crop Sci. 16, 247-251.

Rotili, P. 1979. Contribution á la mise au point d'une méthode de sélection de la luzerne prenant en compte les effets d'interférence entre les individus. I. Etude expérimentale de la structure de la luzerniére. Ann.Amelior.Plantes 29, 353-381.

Rotili, P. & Zannone, L. 1975. Principaux aspects d'une méthode de sélection de la luzerne basée sur des dispositifs qui utilisent la concurrence entre les plantes. Ann.Amélior.Plantes 25, 29-49.

Rotili, P., Zannone, L. & Jacquard, P. 1976. Effects of association on the evaluation of lucerne populations. Ann.Amélior.Plantes 26, 139-155.

TABLE 1. CULTIVAR CANTONI. DRY MATTER YIELD (G/PLOT). POLYCROSS MEAN VALUES AND RANGES OF VARIATION. NUMBER OF CONSTITUENTS: 26 FOR EACH POLYCROSS. AVERAGES OF 11 CUTTINGS.

	GENERATION OF INBREEDING		
	S_0xS_0	S_1xS_1	S_2xS_2
MAXIMUM	25.43	25.00	26.43
MEAN	20.88	20.11	21.87
MINIMUM	16.36	15.84	17.80

ONLY PARENTAL FAMILIES COMMON TO EACH LEVEL OF INBREEDING ARE CONSIDERED IN THIS TABLE.

FIGURE 1. BREEDING SCHEME OF LUCERNE AT LODI.

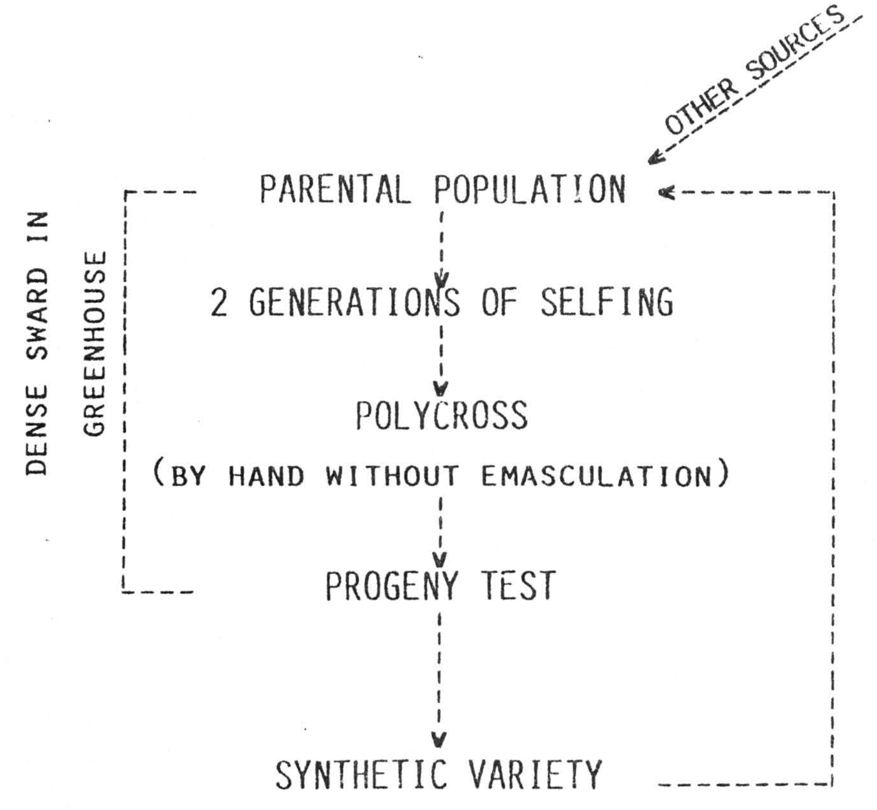
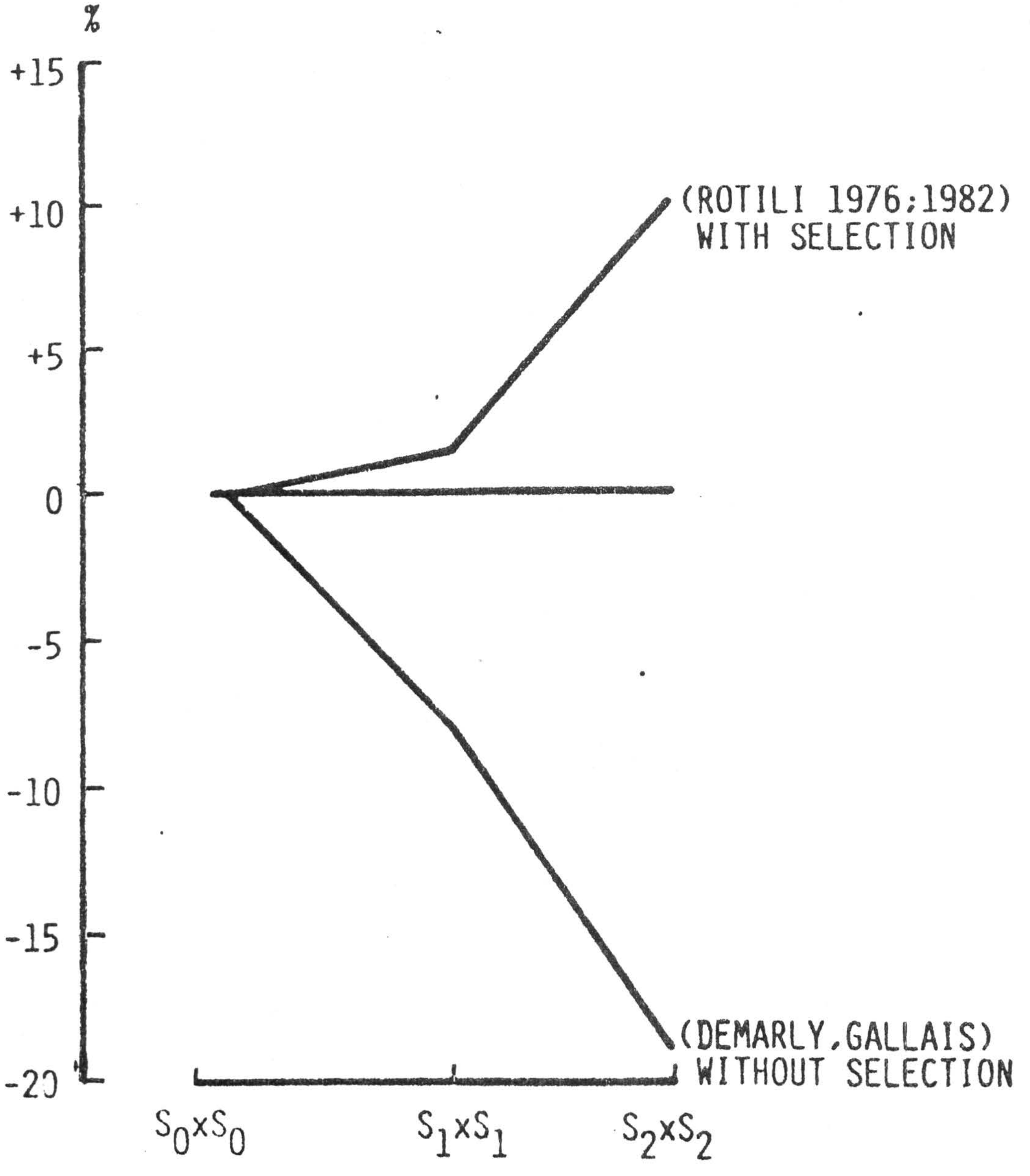


FIGURE 2. DRY MATTER YIELD. AVERAGE VALUES EXPRESSED IN ± % OF $S_0 x S_0$.



TISSUE CULTURE FOR THE CONSERVATION AND CREATION OF GENETIC VARIABILITY IN FORAGE GRASSES AND LEGUMES

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In vitro methods are being developed in many laboratories for a range of plant species. Their applications, or those envisaged, are varied and include vegetative propagation, virus elimination, the mass production of chemicals and genetic manipulation. This report is concerned with two applications of tissue culture in the forage grasses and legumes, first the preservation of genetic variability as vegetative plant material and second the possibility of creating genetic variability through callus and protoplast culture.

Conservation of variability in culture

The conservation of genetic resources for the breeding of forage grasses or legumes is generally best achieved by seed storage. Maintaining seeds at low humidity and temperature (in air-tight containers at 5 ± 1% moisture at -18°C or less) usually ensures minimal loss of viability and genetic integrity (IBPGR, 1976).

There are instances, however, where it is necessary or desirable to maintain plants in the vegetative condition. Plants collected from old pastures which have vegetatively propagated for several decades must be maintained vegetatively if any variability resulting from somatic selection (Breese *et al.*, 1965) is to be preserved. Sterile plants or those with rare aneuploid chromosome numbers may also need to be maintained in this way. Probably the most important application from a breeding viewpoint is the maintenance of the basic plants or mother plants of cultivars. It is important that these are maintained alive and in a healthy condition for future seed multiplication. Death of one or more of the basic plants would result in genetic change in the cultivar and possibly an unacceptable shift in its characteristics.

Conventionally the basic plants are maintained in the glasshouse or field, where they are exposed to pests and viral, bacterial and fungal pathogens and can become difficult to keep alive. This is particularly true for short lived species such as <u>Lolium</u> <u>multiflorum</u>.

An alternative way of maintaining plants vegetatively is in culture and many species have been maintained aseptically on agar solidified culture medium where they are largely disease and pest free. Although forage legumes have been stored in this way, most experience at the WPBS has been with forage grasses (Dale, 1980a; Dale <u>et</u> <u>al</u>., 1980).

Plants to be stored are established in culture by excising shoot tips up to 1 mm long (see Dale <u>et</u> <u>al</u>., 1980) and placing them on an agar based nutrient medium. Small plants of 2-4 cm long grow from the shoot tips in 4-6 weeks, when incubated at 25°C (with 6000 lx continuous fluorescent light). Each culture vessel containing a single plant is then transferred to 2-4°C (with 300 lx fluorescent light, 8 h daily photoperiod) where growth is almost completely arrested. After about one year at this temperature, the plants are subcultured to fresh culture medium by transferring excised tiller buds or 1 cm long tiller bases to another culture vessel. After 4-6 weeks at the high temperature and light conditions a small plant becomes established again and is transferred back to the low temperature storage conditions. By subculturing annually, experimental and basic plants have been maintained successfully for the past six years.

The advantages of maintaining plants _in vitro_ rather than in the field or glasshouse are:

1. Space saving: 500 plants in culture take up approximately 1 square metre
2. Subculturing is non-seasonal and can be carried out when labour is available
3. Plants are generally disease free
4. Mistakes are avoided e.g. cultivation errors, contamination by seedlings etc.

The reason why plants stored in culture are usually free from bacterial and fungal pathogens is that bacteria and most fungi grow rapidly on the culture medium and contaminated cultures can be identified and eliminated. The same is not true for viruses which can be carried systemically within the plant during storage and transfer to soil. Shoot tip culture is widely used to eliminate viruses in vegetatively propagated species and it is now established that virus and mycoplasma pathogens can be eliminated from forage grasses and legumes in the same way (Table 1). In general the smaller the shoot tips cultured and regenerated the higher the proportion of virus free plants.

It is important that the plants stored in culture are genetically stable. It has been known for some time that callus, the unorganized proliferation of cells, is genetically and cytologically unstable. The main substances used in culture media to induce callus are auxins. In this storage system however the culture medium used for plant regeneration and storage of grasses is Murashige & Skoog's medium with 0.2 mg/l kinetin without auxins. Consequently there is no or negligible callus formed and to date we have no evidence of genetic variability arising from in vitro storage.

Creation of variability

Variability among regenerated plants

Because callus is frequently cytologically and genetically unstable, plants regenerated from it often show new genetic variability. It has been suggested that this somatic or somaclonal variation may be of value for plant improvement (Larkin & Scowcroft, 1981), for example, enhanced resistance to certain diseases has been found in sugarcane and potato as well as variation in potato tuber characteristics.

In order to evaluate any variation in the forage species it is necessary to be able to induce callus and regenerate plants. To date, most of our experience has been with Lolium multiflorum from which callus induction and plant regeneration can be achieved routinely. The parts of the plant giving this type of callus most readily are immature embryos, immature inflorescences, immature leaves and vegetative meristems; and plant regeneration is generally from somatic embryos developing on the surface of the callus (Dale, 1980b; Dale et al., 1981).

Variation is observed among regenerated plants and the longer cultures are kept in the callus phase the greater that variation. Some of the variation, most commonly leaf distortion , is of physiological origin and disappears within a few weeks after transfer to soil while other characters are clearly genetic. Chromosome number variation, principally polyploidy, is a common and early change. Plants regenerated after only two months from the initiation of diploid callus can be tetraploid. Chromosome loss is also common after prolonged periods in the callus phase. A sample of 30 plants regenerated after two years consisted of a mixture of tetraploids with 28 chromosomes and aneuploids with 27, 26 and 24 chromosomes.

The regeneration of chlorophyll deficient shoots also increases after prolonged periods in culture but these do not survive outside their culture vessel. There is also evidence for variation in flowering time and tests will soon be carried out for disease resistance. The data on the variation from tissue culture in Lolium is preliminary so it is not yet possible to evaluate it for breeding or research purposes.

Variability from protoplasts

Isolated protoplasts (wall-less cells) may in the future provide means of producing variability by protoplast fusion and the subsequent regeneration of somatic hybrid plants, or by mutation followed by selection for plant characters at the cell level, or perhaps by the incorporation of foreign genetic material into protoplasts and the regeneration of modified plants. The basic limiting factor preventing attempts at these kinds of manipulation in most crop plants is plant regeneration from protoplasts; either regeneration has not been achieved or it is too unreliable for routine application.

In the Gramineae there are only three reports of plant regeneration from protoplasts, that is in Bromus inermis (Kao et al., 1973), Pennisetum americanum (Vasil & Vasil, 1980) and Panicum maximum (Chin-Yi et al., 1981). In each case the protoplasts were isolated from suspension cultures. Protoplasts can be isolated from mature leaves in Lolium multiflorum but so far, division to give callus colonies has not been observed. The lack of response from mature leaf protoplasts is a common feature of the Gramineae, so it is necessary to turn to other sources. Protoplasts derived from cell suspension cultures initiated from embryogenic callus have been induced to divide to give callus colonies and attempts are in progress to regenerate plants from them (Jones & Dale, 1982).

Progress towards plant regeneration from forage legume protoplasts has recently been faster than for the grasses. There are now three reports of plant regeneration from protoplasts in Medicago sativa (e.g. Johnson et al., 1981) and one in Trifolium repens (Gresshoff, 1980). Research at the WPBS is concentrated on repeating these results and making the system more reliable. Recently small plantlets have been regenerated from protoplasts of Trifolium hybridum and regeneration in a number of Trifolium species should be achieved within the next year or two.

SUMMARY

1. Plants have been maintained vegetatively in culture for over six years.
2. Genetic variation is observed among Lolium multiflorum plants regenerated from callus and the extent and nature of this variation is being determined.
3. Isolated protoplasts in Lolium multiflorum have been induced to divide to give callus colonies but plant regeneration has not yet been achieved. Repeatable plant regeneration from protoplasts has been demonstrated in various laboratories for Medicago sativa and regeneration should soon be possible in several Trifolium species.

REFERENCES

Breese, E.L., Hayward, M.D. & Thomas, A.C. (1965). Somatic selection in perennial ryegrass. Heredity 20, 367-379.

Chin-Yi, L., Vasil, V. & Vasil, I.K. (1981). Isolation and culture of protoplasts of Panicum maximum Jacq. (Guinea grass) : somatic embryogenesis and plantlet formation. Z. Pflanzenphysiol. 104, 311-318.

Dale, P.J., Cheyne, V.A. & Dalton, S.J. (1980). Pathogen elimination and in vitro plant storage in forage grasses and legumes. In: Tissue Culture Methods for Plant Pathologists (Eds Ingram, D.A. & Helgeson, J.P.), pp.119-124, Blackwell Scientific Publications, Oxford.

Dale, P.J. (1980a). A method for _in vitro_ storage of _Lolium multiflorum_ Lam. _Ann.Bot._ 45, 497-502.

Dale, P.J. (1980b). Embryoids from cultured immature embryos of _Lolium multiflorum_. _Z.Pflanzenphysiol._ 100, 73-77.

Dale, P.J., Thomas, E., Brettell, R.I.S. & Wernicke, W. (1981). Embryogenesis from cultured immature inflorescences and nodes of _Lolium multiflorum_. _Plant Cell Tissue Organ Culture_ 1, 47-55.

Gresshoff, P.M. (1980). _In vitro_ culture of white clover : callus, suspension, protoplast culture and plant regeneration. _Bot.Gaz._ 141, 157-164.

IBPGR (1976). Report of the International Board for Plant Genetic Resources Working Group on Engineering, Design and Cost Aspects of Long-term Seed Storage Facilities, Rome.

Johnson, L.B., Stuteville, D.L., Higgins, R.K. & Skinner, D.Z. (1981). Regeneration of alfalfa plants from protoplasts of selected Regen S clones. _Plant Sci.Lett._ 20, 297-304.

Jones, M.G.K. & Dale, P.J. (1982). Reproducible regeneration of callus from suspension culture protoplasts of the grass _Lolium multiflorum_. _Z.Pflanzenphysiol._ 105, 267-274.

Kao, K.N., Gamborg, O.L., Michayluk, M.R., Keller, W.A. & Miller, R.A. (1973). The effect of sugars and inorganic salts on cell regeneration and sustained division in plant protoplasts. Colloq.Int.C.N.R.S. 212, 207-213.

Larkin, P.J. & Scowcroft, W.R. (1981). Somaclonal variation - a novel source of variability from cell cultures for plant improvement. Theor.Appl.Genet. 60, 197-214.

Vasil, V. & Vasil, I.K. (1980). Isolation and culture of cereal protoplasts. Part II. Embryogenesis and plantlet formation from protoplasts of *Pennisetum americanum*. Theor.Appl. Genet. 56, 97-99.

Table 1. Viruses and mycoplasmas eliminated by shoot tip culture

Pathogen	Plant species
Ryegrass mosaic virus[1]	*Lolium* and *Festuca* spp.
Barley yellow dwarf virus[1]	"
Cocksfoot mild mosaic virus[1]	*Dactylis glomerata*
Cocksfoot mottle virus[1]	"
Cocksfoot mosaic virus[1]	"
Phyllody mycoplasma[1]	*Trifolium repens*
White clover mosaic virus[2]	*Trifolium pratense*

[1]Dale *et al.* (1980); [2]Cheyne and Dale (unpublished)

THE EVALUATION OF GENETIC RESOURCES AND THE POINT OF VIEW OF THE FORAGE PLANT BREEDER

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I N T R O D U C T I O N

Whatever its intensifying may be, stock farming has to turn a four component association to the best account : the environment, the plant, the animal, the man.

It is a matter of realizing the best equilibrium between the efficiency of this association and the security. But, each of these components has its own dynamics. Thus, during the last decades, several causes have modified this multisecular equilibrium :

- the driving force of the animal is no more used : now the animal is only a protein supplier. Consequently, a great number of animal strains is disappearing, which causes a justified fear concerning the impoverishment of natural wealth.
- the development of the farming methods gives the ability of curing the effects of some limiting factors and increases the efficiency of the couples environment-plant and plant-animal.
- though relatively recently, after having taken interest mainly in animal breeding, the breeders are paying a greater attention to forage plant breeding. For that, they use efficient indeed but sometimes rough means.

They made no delay introducing foreign species and trying either to use them directly on condition of minor interventions, or to cross them with local species to correct their defects. It is a question of evaluating the potentialities of these "genetic resources" on account with present time criteria and their ability to be used in a breeding programme. In the same time, the breeders are trying to satisfy the present needs of the stock farming, and are beginning to imagine methods to answer, as quickly as possible, new requirements.

I. THE DIFFERENT FORMS OF THE GENETIC RESOURCES

The genetic resources can be classified according to the degree of human intervention and the ability of genetic exchanges with the plant stock of breeding programme in progress.

1) The ecotypes

In the species complex, the ecotypes form a sample of a dynamic balanced population, in a definite ecological environment, at a definite moment. The environment induces selective pressure of which we can only imagine the principal components ; consequently, each ecotype differs from the others by its "allelic ratio, linkat stability, permanent expression of genes, composition of cytoplasm in terms of its population of organites" (7). Though the phenotypical aspect of his components is often rather homogeneous, the potential variability of the ecotypes can be very high. The expressed phenotypical variation from an ecotype to another is more or less continuous according to the pollen dispersal ; thus, the variation between the samples of tall fescue, harvested in Brittany wooded districts, are much more discontinuous than those of the South West of France (12). Due to the influence of climatic features on the equilibrium of those ecotypes, the preservation of their characteristics causes serious troubles to the specialists in charge of the collection and preservation of natural genetic ressources.

2) The populations

The human effect is added to that of the environment. In many cases, it is the result of a maternal mass selection, which badly controls the pollen but which favours special characteristics. The man has constantly and intensely protected some morphological structures which make the plant easier to work and to harvest. It is the domestication syndrome. But the even limitated geneflow from spontaneous forms brings up the adaptability to the environment fluctuations (18). Of course, modern criteria, as distinctiveness and homogeneity, aiming only at the breeders protection were of no use to any one, but the limitation of the exchanges has led to the appearance of very distinct forms : thus, in the north of Ivory Coast, each Senoufo village has selected its own maize variety and, during a recent collection of lupine in Turkey, sharp differences between the varieties have been noted from one village to the other (17).

Among the forage crops, lucern offers an example of the influence of man : he has exerted selection pressures which gave birth to forms adapted to peculiar environment as the Luçon marshes or the Chalans marshes or to populations suitable for grazing as the lucerne of Poitou (13).

3) The varieties

In this case, the selection pressure has been much stronger and the commercial requirements (distinctiveness, homogeneity, stability) are compelling to restrict the parent numbers. The rate of the evolution from one generation to the next, in allogamous species, forces to build up a very strict multiplying scheme. Indeed, the homogeneity of these varieties is sometimes dangerous because it enhances the subjection to artificial growing practices and the vulnerability to parasites ; but breeding has allowed to display and to use a large genetic variability (4).

4) The genotypes

Promoting the expression of the variability, the breeders have selected uncommon genes and have constituted various plant stocks which are used to synthesize new varieties by crossing. The expressed characters are often very inheritable and concern as well cytoplasmic properties (male sterility for instance) as nuclear genes.

5) The species complex

Inconsistently, this genetic resource is called to mind only at last. But the gene flow is restricted by internal mechanisms which lead to various accidents, from the absolute sterility to the simple restriction of the exchanges between some parts of the chromosomes. In some instances, these troubles can be removed and the breeder can be led to use interspecific hybridization. But the efficiency of his work can be disturbed by the difficulties which he shall meet in breaking excessively strong links (19).

II. WHICH MATERIAL IS USEFUL ?

The original purpose of forage plant breeding is to try to increase plant-animal transformation ratio. In addition, the organs used are leaves and stems and not storage organs. It is not the question to improve the harvest index, character on which the breeder has a good hold, but to improve yield, environment adaptability and feeding value.

Every day, it is necessary to give to the animals a palatable, and digestible forage : either green, or silage or hay. The satisfying of these needs leads to a list of criteria variable according to the species and the way they are fed. For a silage plant, for instance, as maize, it is necessary to obtain, per surface unit, the maximum quantity of a high feeding value material with dry matter content consistent with silage making. The difficulties of the assessment of each character and their weak heritability leads to search for associated criteria which offer a better hold for the breeder. Thus, it is taking a group of criteria in to account that the plant stock will be collected.

With this object the breeder will profit by the knowledge of the species complex, the geographical distribution of its various units and, possibly, the existing collections. Thus, the work of BORRILL and collaborators (2, 1) has allowed to map the cocksfoot and tall fescue species and ecotypes distribution. In the same time, the work of COOPER and collaborators (9) has allowed to show some correlations between the species behaviour and the climatic conditions.

Using this preliminary great scale work, the breeder is led to carry on more discriminating collections. Thus, using the work done by the plant breeding station of Aberysthwyth, KERGUELEN, REBISHUNG and the cocksfoot breeders, in Lusignan, have been satisfied in a first time, with gathering of ecotypes from Brittany and Cotentin : they knew beforehand that they had serious probabilities to discover rust resistant, late ecotypes, likely able to give rise quickly to varieties fitted for the Western parts of France. Later on, they profited for the knowledge of the Northern Spain and Portugal ecotypes and especially of their spring and autumn growing ability. Consequently, they collected in these areas ecotypes to be crossed with Breton ecotypes.

Taking into account the difficulty of keeping the "personality" of a plant stock, a breeder cannot intend to collect and maintain too large a collection without bearing in mind its future utilization at short or medium term. It is one face of the problem of the genetic resource maintenance.

III. THE EVALUATION OF GENETIC RESOURCES

In connection with beforehand chosen agronomical characters, to what extent this material can be used without amendment or after selection or in a programme intended to improve the performances of a material in a breeding programme in progress ?

Taking into account the already achieved advances, the first possibility very seldom occurs ; however, in the last years, an introduced ecotype of *Bromus sitchensis* could be used in Lusignan without breeding ; but this species is autogamous.

Usually, this material must always go through several cycles of selection and reproduction ; then, it will be necessary to choose the most adapted method to increase the frequency of the requested characters ; but at the same time, we shall have to protect, as much as possible, the genetic arrangements on which an indirect selection will be applied (5). Lastly, it may be necessary to test the combining ability with a material in a breeding programme in progress.

As already said, the first informations about the general behaviour of the plants are gathered in the site of origin. But the breeder must test these plants in the environment where they will be used. The first difficulty, in spite of the careful attention of nowaday collectors is the too small quantity of seeds ; sometimes, that compels to increase it, with all the deviation risks which are linked to this multiplication Often, the strategy of utilization depends on this quantity of seeds. In the second place, the breeder must always remember that the agromical evaluation has only a relative value. It is in connection with the natural or artificial environment where it is carried out and with the methods used to study the characteristics of the material.

As far as possible, the first evaluation is made simultaneously on plots and on isolated plants. Of course, observing in several regions gives the advantage of the heritability estimation of the characters but this is seldom possible.

On isolated plants, it can be observed directly a number of characteristics such as spring growth and flowering earliness, ability to flower several times a year, the susceptibility to diseases or pests in propitious environments, susceptibility to cold or to vernalization, physiological characters linked with the quality (leaf flexibility in tall fescue) and characters linked with the yield. However, in the last case, it is necessary to avoid an excessive generalizing : the observed correlations may fluctuate according to the origin of plant stock.

In plots, it is possible to evaluate the yield or some other characters that can be estimated only from a large enough number of plants (the protein content of lucerne juice for instance). Another character which seems an essential parameter of some forage species must be also observed in plots : it is the competition between plants (8).

As a concrete example, during the 1978 year, cocksfoot ecotypes were collected by C. MOUSSET from Lusignan and a private breeder from Rodez, in the North of Portugal and Galicia. The purpose was to use the early spring and autumn growing ability combined with low disease susceptibility. Before the evaluation, the english collectors had found out that the plant stock was made of diploid and tetraploid types. Two hundred ecotypes were harvested and the quantity of seeds was sufficient to carry out two series of trials, one in Lusignan, in the middle West of France and the other near Rodez in the South.

In the two places, the plants have been studed in nurseries of isolated plants (30 to 50 plants per ecotype 70 x 70 cm apart).

The following characters have been observed : ability to flower several times a year, early spring growth, date of heading, susceptibility to rust, Scoletotrichum, Mastigosporium and criteria associated to yield as height in spring and autumn.

In Lusignan, the microtrial included three replications. Each plot consisted in two rows of one metre in condition of competition. This microtrial was devoted to the estimation of the yield and its partitioning. For practical reasons, in Rodez, it was only possible to use ten square meter plots. Thereby, although not desirable, the ecotypes had to be mixed according to their geographical origins.

In Rodez, only the grazing management was tested with six to seven cuts a year ; in Lusignan, the same rhythm was applied one year and four cuts were made during the second year.

This first series of trials displayed differences in earliness which increase the trouble in choosing a convenient cutting date ; consequently, a second series of trials have been set up in which all the ecotypes with the same earliness have been put together. The first results show that the interecotype variation is higher than the intraecotype variation.

In this case, only field observations were made, but these trials often have to be associated with more specific tests. Artificial inoculation in growth chambers or under glass are used to reveal disease resistant plants as in lucerne or italian ryegrass ; the estimation of cold resistance of forage sorghum is made in artificial conditions (16) and we are trying to perfect an other test for the lupine. But the one must be careful interpreting these tests :
for example, as a result of the pea aphid resistance tests on the european lucerne populations, R. BOURNOVILLE and P. GUY have found differences in the behaviour of european and american pea aphid populations (3).

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Then, we have to know whether it is possible to increase the frequency of some interesting characters avoiding to throw the other parts of the genome out of balance.

Selfing is the first method but, in allogamous forage plants, it is rough and presents well known disadvantages. For instance, leaf flexibility in tall fescue has been selected choosing plants in the second generation of selfing : the selection is severe because it concerns not only the flexibility but also a lot of various criteria . Afterwards the choice of parents is made according to the performances of their descents in four replications polycross between the selected plants. But to tell the truth, although this method has led to very valuable varieties. their seed production potential is still too low.

The disease resistant populations of lucerne have been selected using a quite different method. The Colletotrichum resistance has been selected by a pool of breeders joined together in the "Association for the Creation of Varieties of forage (ACVF). Each of them gave one or several Verticillium and lodging resistant varieties ; each variety has been subjected to two selection cycles interrupted by the recombining of selected plants. The selection was made in growth chamber under artificial inoculation and the scale of rating of each plant was going from zero to five. After two cycles of improvement, the various populations answered in quite a different way : some, from a high enough frequency of resistant plants, have not been improved ; others, of which nearly all the plants died after the first inoculation test, have reached, in two generations, a resistant plant ratio about 30 percent. The others had an intermediate behaviour between there two extremes. After P. GUY (14) this method enabled to establish that the resistance can be due to various genetic factors, one simple, the others more sophisticated ; but, it may be favourable to gather them in only one genetic pool.

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In some cases, the agronomical evaluation is possible only using crooked methods which require a long preliminary period. Thus, the evaluation of the advantages of brown midrib genes in forage maize can be made only after conversions of normal lines into bm lines and comparison of the two series in feeding tests with animals (sheep, bulls and cows) (10). In the same way, it is impossible, under the latitude of Lusignan, to evaluate directly the advantages of the North African lucerne ; but we can evaluate its progenies in crosses with european populations. And the value of photoperiodic maize populations can only be estimated in Europe after crossing them with day length neutral plants.

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Consistently, the agronomical evaluation should have to be complemented by a genetical evaluation ; then, we should be able to discover the unexpressed variability connected with a given character and an eventual polymorphism. This analysis is time consuming but the selection of tall fescue flexibility or breeding for Colletotrichum resistance in lucerne are using those methods to some extent. Moreover, theoretical studies on this subject are going on in lucerne (6) ; they are using enzymatic analysis.

IV. UTILIZATION OF THE GENETIC RESOURCES IN A BREEDING PROGRAMME

1) Intraecotype breeding

Two peculiarities among others, are complicating the breeding work in most of the forage crops : the lowering of growth and yield due to the inbreeding and the complexity of the genetic factors determining some characters we want to improve.

Sometimes, the improvement by using inbreeding is a necessary harm but it leads often to genetic impoverishment and without care, it is difficult to select a large number of lines having a good combining ability. Thus, in some countries, the aim of the studies about male sterility of lucerne is to use the heterosis as in maize ; but, now, only limited results have been reached and one must be aware that it is a long and difficult work.

Consequently, it is a matter to effect a compromise between necessary varietal creation and the best use of the variability which can be made only in a longer term. This idea was the departure point of a recurrent breeding programme on cocksfoot. The aim is to develop gradually the synthesis ability (11) and to raise the mean of all the characters on which the selection pressure is applied. As many others, this method is using simultaneously tests of individuals and progenies from diallel crosses. But, with a view to test numbers of individuals, the diallel crosses consists only in four by four individuals. The choice of the families is made according to the microtrials and individual performances of characters associated with the yield ; those characters are indeed less susceptible to the environment than the yield.

The synthesis ability is estimated at each breeding cycle. The selection intensity is approximately from five to seven per cent and the next generation included the same number of plants as the former one. But it is always possible to constitute, from each generation, synthetic varieties with a more or less large basis. Of course, the occurrence of wind fertilization makes the work easier.

2) How to combine the ecotypes ?

The goal of the recurrent selection is to make the best use of the variability but it can only slow down the speed of the genetic erosion without suppressing it The introduction of new genetic resources plays a great part in rising the level of the variability.

If we consider again the actual example of cocksfoot, seventy portuguese and spanish ecotypes have been retained after agronomical evaluation. Then, the problem is to know how to introduce these new ecotypes into the recurrent breeding programme. Their combining ability is tested using a population whose improvement is in progress at the same time. The choosen families can be used directly regarding them as any member of this population ; but what percentage of parents from each population must be used at best ? We do not know. It seems more advisable to undertake a new programme parallel with the first. Again, several methods are available. We can undertake the improvement of the ecotypes for the adaptation to the environment in a separate recurrent selection. The melting of the population to improve and the population built from the foreighs ecotypes can be made after two or three generations.

During these cycles of selection, it would be possible to improve the combining ability between the two populations.

We can imagine other schemes but, now, it is difficult to know what is the best compromise between the efficiency and the management of time and means. All we can say is that the greatest care has to be taken to make the melting at any step and each step has to be separated from the other.

Although more sophisticated, the problems are still of the same kind when species barriers are being present between the two plant stocks. Sometimes, on the contrary, these problems may be most reduced : thus, after the hybridization between european and mediterranean tall fescue, this hindrance seems to have been removed by doubling the chromosome number. But the drawbacks linked with the inbreeding are still present and the choice of breeding methods remains the same as in a more classical material (15).

3) The preservation of the variability

As already said, the use of recurrent selection arises from the need to protect as much as possible the plant stock variability to turn its potential to the best account. This problem presents two sides, one static and the other dynamic. The first concerns the conservation of genetic resources. One of the ways is the *in situ* conservation : thus, five french populations of lucerne are grown under official control in their regions of origin but this method is far from beeing possible in all circumstances. As to the second, it concerns also improved artificial populations in which one hopes to maintain as long as possible a variability useful to the plant breeder. In lucerne, a pool have been constituted from the plant stocks improved by some firms, for the disease resistance. After two panmictic generations, an attempt of multilocal improvement is beginning to be done by the members of ACVF. The pool has been distributed to six plant breeders ; each is in charge of carrying out two or three phenotypical recurrent selection cycles, with a selection intensity of ten per cent on isolated plants. At each generation, a sampling is made, at all the breeders, on the result of the selection. These samples are used to make a test plot and a new pool is created by panmixy and divided among the breeders.

Owing to the influence of various environments and various men, this process is expected to preserve the variability, while leaving to each breeder the freedom of using the plant stock as he wants. But it is necessary to remark that this method is long and requires a mutual agreement which is not easy to obtain.

With the same aim, some pools of forage maize are being organized. They are devised to use some peculiar characters as earliness, prolificity, protein content and so on.

CONCLUSION

Some of the properties which will be always required from the forage crops are a good regrowing ability, a good photosynthetic efficiency and a yield distribution fitting at best the stock requirements. The point is to find the best compromise between the adaptation to environment and farming realities.

The part of the breeder is to choose his aims so as to satisfy the nearest probable needs but also to be able to face as quickly as possible new demands.

A better knowledge of the species complex, the gathering of ecotypes, the methods used to transform the hidden variability into phenotypical variation seem to place all the winning cards in the breeder's hands. But, it is to be said that we still know only very badly how to act on the genetic factors of the yield of forage plants and on their adaptative power to new environment or farming techniques.

The experience shows that the selection in an ecotype or the sudden introduction of a new character can often bring about the modification of others characters and, correlatively, lead to a falling off of the yield.

As often as possible, it appears advisable to make the best use of the variability of the ecotypes or populations in natural balance with their environment : in the same way, the use of foreign plant stocks requires frequently an adaptative period which seems often too long to the breeder.

The technique of the gene pools, may be one of the admissible compromises for it permits to gather up an available variability in a genetic background where we endeavour to promote the factors of adaptation to the environment.

Just as for genetic resources, the management of the gene pools risks, in turn, to become very troublesome for the breeder. The function of farmer and breeder have been diverging more and more ; shall we expect a new distribution of the roles between the different branches of the breeding work ?

B I B L I O G R A P H I E

1 - BORRILL M., TYLER B.F and LOYD JONES M., 1971. Studies in Festuca. A chromosome atlas of bovinae and scariosae. Cytologia, 36 : 1-14.

2 - BORRILL M., 1977. Evolution and genetic resources in cocksfoot. Welsh Plant Breeding Station. Annual report : 190-209.

3 - BOURNOVILLE R., 1978. Estimate under french conditions of varietal characteristics of some lucerne cultivars selected for resistance to two pest insects. Conference on break-throughs in resistance breeding, Svalöv.

4 - CAUDERON A., 1980. Sur la protection des ressources génétiques en relation avec leur surveillance, leur modelage et leur utilisation. Ac. d'Agr. de Fr. 1051-1068.

5 - COOPER J.P., 1959. Selection and population structure in Lolium. III Selection for date of ear emergence. Heredity 13 : 461-479.

6 - DEDENYS S., 1980. Recherche de marqueurs enzymatiques et comparaison de la variabilité génétique de quelques populations du genre Medicago. DEA, Université Paris XI.

7 - DEMARLY Y., 1981. Theoretical problems of seed regeneration in cross pollinated plants. Seed regeneration in cross pollinated species. CEC Eucarpia Seminar. Nyborg : 7-31.

8 - DE PACE C., SCARASCIA MUGNOZZA G.T., MONTI L.M., PERRINO P., PORCEDDU E. and SPAGNOLETTI ZEULI P.L., 1981. Theoretical aspects and practical implications of cross-pollination on seed regeneration of field crop genetic resources. Seed regeneration in cross pollinated species. CEC Eucarpia Seminar. Nyborg : 211-251.

9 - ELLIS DAVIES W., TYLER B.F., BORRILL M., COOPER J.P., THOMAS H. and BREESE E.L., 1972. Plant introduction at the Welsh Plant Breeding Station Annual Report : 143-162.

10 - GALLAIS A. and al., 1980. Preliminary evaluation of brown midrib maize hybrids for their feeding and agronomic value in France. In Pollmer W.G. and Phipps R.H.(ed) Improvement of quality traits of maize for grain and silage use : 319-339.

11 - GALLAIS A. and WRIGHT A.J., 1980. A general approach of varietal ability for synthetic variation. Theor. appl. Genet., 57 : 81-87.

12 - GILLET M. Personnal communication.

13 - GUY P. Personnal communication.

14 - GUY P., 1976. Amélioration de la luzerne pour la résistance aux ravageurs et aux parasites européens. Réunion Eucarpia groupe Medicago sativa à Piestany : 54-67.

15 - JADAS-HECART J. and GILLET M., 1978. Note sur les caractères agronomiques des hybrides entre fétuques élevées (F. arundinacea Schreb.) européennes et méditerranéennes avant et après doublement. Effet de la sélection dans les amphiploïdes. Annales de l'Amélioration des Plantes 28 : 501-511.

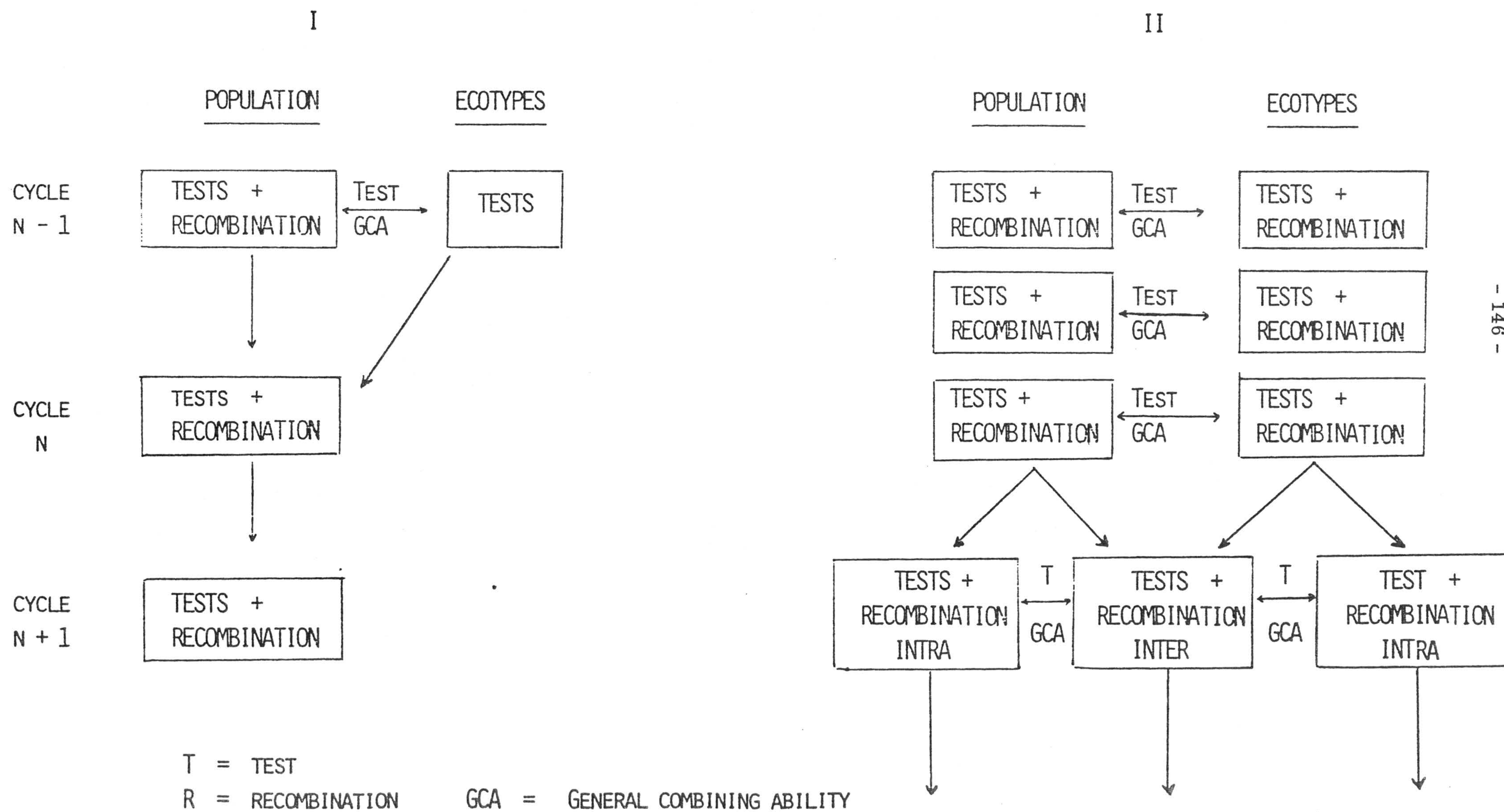
16 - LENOBLE M., LENOBLE S. and PORCHERON P., 1972. Screening for tolerance to low temperature at Lusignan. Sorghum newsletter 14 : 27.

17 - PAPINEAU J., 1982. Report on collection of lupine in Turkey.

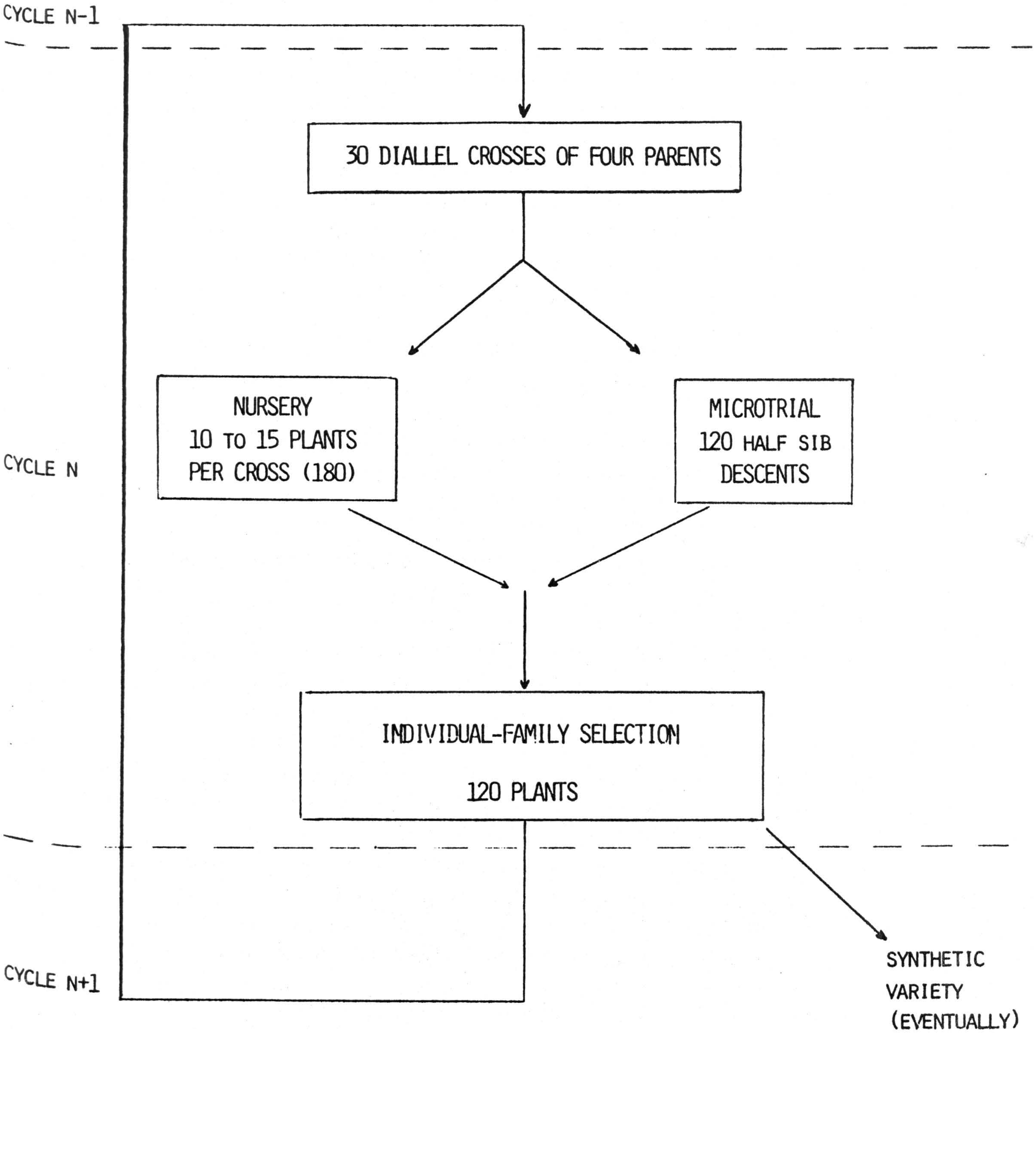
18 - PERNES J., 1980. Les ressources génétiques. Lectures on genetics. Faculty of Sciences, Orsay.

19 - POISSON Ch., 1970. Contribution à l'étude de l'hybridation interspécifique dans le genre Gossypium : transfert de matériel génétique de l'espèce sauvage diploïde G. anomalum à l'espèce cultivée tétraploïde G. barbadense. Thèse présentée à la Faculté d'Orsay.

USE OF ECOTYPES TO IMPROVE A MATERIAL IN A BREEDING PROGRAMME IN PROGRESS



RECURRENT SELECTION IN COCKSFOOT



EVALUATION OF FORAGE GRASS GENETIC RESOURCES IN RELATION TO BREEDING OBJECTIVES AND VARIETAL ASSESSMENT

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The collection, documentation and conservation of genetic resources have received considerable publicity in recent years. Evaluation of these resources, however, has been relatively neglected, although arguably it is the most important phase. It is only at this stage that the value of the collection is revealed and an assessment of its breeding potential realised.

The important choice of 'elite' populations is based on this initial evaluation and it is therefore important that breeders should have confidence in the assessment as breeding success depends largely on the input of good base-material. Preliminary evaluation techniques have thus been designed such that; (1) maximum information is obtained on those characters of value to the breeder and (2) the 'elite' populations will stand comparison in agronomic trials. In order to do this techniques from all disciplines have been utilized, often modified to cater for the large numbers of populations to be evaluated and the small amounts of seed and resources available, and to develop new techniques where necessary.

The following discussion gives examples of preliminary evaluation to illustrate a number of important considerations.

Single plant evaluation and its relationship to sward evaluation

The first example compares the results and conclusions drawn from a preliminary evaluation of *Dactylis* collected in north-western Spain in 1964, using a considerably modified technique, with results from a standard agronomic assessment trial.

At the inception of the Genetic Resources Unit in the early 1960s, with limited seed and resources, the field layout usually consisted of three single plant rows at 20 cm centres with 60 cm between rows. This was a low labour and low seed demanding method which was considered a reasonable compromise between the requirements for obtaining single plant data and providing sufficient interplant competition to give yields comparable with swards (Lazenby & Rogers, 1964). Two of the three rows were frequently cut throughout the year to obtain an estimate of growth rhythm, the third row remaining uncut until data on flowering had been recorded.

The pattern of seasonal growth of an 'elite' population determined by preliminary evaluation of closely spaced single plants compared with the pattern from a four-weekly cut sward trial conducted independently by the Agronomy Department is summarized in Table 1. The pattern of growth shown by both techniques is basically similar i.e. an autumn/winter oriented rhythm with low spring growth. However, a slight summer depression of yield was shown in the single plant evaluation which was not repeated in swards. In addition, data from a three-weekly and five-weekly cutting management and in the second and third harvest years on these plots gave essentially the same pattern. So as a preliminary evaluation of a genetic resource this technique appeared acceptable. However, data obtained in the second and third harvest year of the agronomic plots indicated that the initial single plant evaluation had failed to identify the salient characteristics of the population. This was suspected as the second and third harvest year annual yields showed an increasing superiority over the control S.37; for instance in the three-weekly cutting regime the annual yields increased from a 7% superiority in the first harvest year to 27% in the second and 38% in the third. The main reason for this can be deduced from Table 2 where the persistency of the elite population is compared with S.37. The outstanding feature of this population Bc 5655 was its sward forming capacity and high persistency under both cutting and grazing.

This latter information completely transformed the appraisal of the potential of this population and it was now regarded as a new dimension in the resources available within the genus Dactylis. This population has since been successfully developed as the cultivar Cambria.

Indications of sward characteristics were not apparent during the preliminary evaluation in closely spaced single plants and it is doubtful if it would ever have been revealed over more years of evaluation using this layout. Thus after this experience, although we were confident that closely spaced single plants can give reasonable data on seasonal growth in Dactylis it cannot provide estimates of sward characteristics, so important in any evaluation of forage grasses. The attraction of this spatial layout; with low seed, labour and land requirements was thus discarded for future evaluation in favour of small plots where sward attributes could be monitored. More seed of each accession would obviously be necessary for this method so an initial regeneration of all introduced populations is now routine practice (Tyler, 1982).

Evaluation in relation to collection data, breeding objectives and selection of 'elite' populations

In 1971 an extensive collection of Lolium perenne was made from the Belgium Ardennes through eastern France to Switzerland with altitudinal transects throughout the latitudinal range. The objective was a collection of populations showing variation in spring growth within a winter hardy background (Tyler & Williams, 1972). Observations made during the expedition confirmed our previous experience that the distribution of L.perenne was closely linked with the grazing animal (Tyler et al., 1969). This was particularly evident at the southerly and upper altitudinal limits of the species. In some areas, for example in the relatively summer-dry regions of south central France and the winter cold high Alps of Switzerland, L.perenne was only present in micro-habitats where intensive animal grazing and thus heavy-treading had occurred.

It was, therefore, considered that some assessment of resistance to treading would be pertinent to this collection in addition to a study of spring growth and winter hardiness. Using a technique developed by Dr A.H. Charles for studying the effect of treading on swards (Charles, 1972), a joint evaluation was designed where the material was evaluated both under frequent cutting and frequent defoliation and treading by sheep. Thus in this particular instance the collected material was considered of sufficient potential to deviate from the routine evaluation technique.

The collected vegetative material was regenerated in isolation (Tyler, 1982) and the resulting seed was used to establish five replicates per treatment of metre square plots of the 60 populations and controls. Seasonal cuts and grazings were taken during the first three harvest years and seasonal growth patterns were determined for each ecotype. Figure 1 illustrates the seasonal growth of one ecotype from the Zurich uplands which showed exceptional spring growth combined with high annual yields in comparison with S.24.

Such consistent seasonal superiority and overall performance is exceptional and when it occurs is easily identified, but to obtain a number of 'elite' populations that may not be outstanding at any time of the year, but do combine a number of desirable features is more difficult and requires a different approach. In this evaluation we selected 'elite' populations using both a yield and persistency index. Here we were influenced by the breeders' requirement for populations with high yields under frequent cutting; a requirement for National List testing, combined with high persistency of yield under grazing; a consumer requirement. The yield index included data from all three years under the cutting treatment, seasonal yields being weighted according to the relative importance attached to them by the breeder. In this instance the weighting was in the order, spring, mid-season, autumn. The persistency index was constructed using yield data under the grazing management. This was simply calculated as the percentage change in yield from the first to the third harvest year.

Figure 2 shows the distribution of the populations using this particular character combination. The 'elite' populations were considered to be those occurring in the top right-hand segment of the scatter. These populations are represented by open circles of which four, indicated by numbers alongside, have been developed further into potential varieties.

This example illustrates the need to retain a certain flexibility both in the evaluation, particularly in terms of the estimated potential of the material collected, and also in the method of selecting 'elite' populations.

Development of new techniques

The final example is concerned with the development of a new technique for a character considered to be of great importance but where conventional agronomic techniques were not suitable when applied to genetic resources evaluation.

Over the years it has not been possible to identify with any confidence genetic variation in digestiblity between populations of the same species. A technique was required that was both relatively rapid and had relevance to agronomic evaluation. The method was developed using Lolium multiflorum and either circumvented or allowed for the major factors influencing digestibility, such as maturity, stem:leaf ratio and plant spacing. The salient features of the sampling technique were 1) the plant spacing controversy was circumvented by using swards; 2) the influence of stem:leaf ratio was again avoided by considering only stem digestibility; 3) comparable maturity was obtained by identifying and labelling five reproductive tillers that had emerged on the same day in the plots of all populations. This latter was possible as the interpopulation range of mean emergence date is narrower than for instance in L.perenne; in this collection only 5 days. It was thus possible on one day to identify and label reproductive tillers in the plots of all populations that had emerged on that day as there was a wide range of emergence date between tillers within each population. In L.perenne with considerable difference in emergence dates between very early and very late populations it would be necessary to sample within maturity groups.

The labelled tillers were then harvested 20 days after ear emergence, thus allowing full expression of any variation in the rate of decline of digestibility. The tillers were dried, leaf lamina and sheaths were removed and the stem plus inflorescence ground and analysed for DMD. Composite samples, for comparison, were taken at approximately 50% ear emergence, dried, ground and analysed for digestiblity. Table 3 shows good overall agreement between the two methods, but in the delayed sampling technique it was possible to discriminate between the three Italian populations, i.e. the group that gave the highest digestibility. This appeared to be due to the ability of the delayed sampling technique to identify the slower rate of decline of digestibility shown in population Bb 1683. A full description of the technique and discussion of the results is reported in (Tyler & Hayward, 1982).

Using this technique 51 populations of Lolium perenne from a wide geographical range, and 44 populations of Dactylis glomerata from a narrow geographical range were screened. The data obtained is summarised in Table 4. The variation in DMD, within maturity groups for both species was relatively small, up to a maximum difference of 5.5 DMD units between the lowest and highest, although statistically it was possible to distinguish between ecotypes with a DMD difference of greater than 3 units. Overall L.perenne maturity groups the range was considerably wider.

Coincidentally one of the L.perenne populations showing high digestibility had previously been selected for other characteristics and had been utilised in a breeding programme. The resultant variety, Ba 9436, was evaluated in agronomic trials. It was thus possible to obtain circumstantial evidence of the value of the new method by comparing the initial evaluation results on the original ecotype with the variety derived from it in a more comprehensive standard trial. The results of the comparison are given in Table 5. In the conservation cut of the 5-cut systems a consistent but variable advantage of the derived variety over the control was obtained over the three years. This was obtained even though the control (S.24) emerged 15 to 20 days later than the variety Ba 9436 with both varieties being cut on the same date.

This may partly account for the smaller advantage obtained in the agronomic trial than the initial screening. However, it does suggest that as in the L.multiflorum screening the selected population appears to have a considerably slower rate of decline in digestibility. In the non-reproductive stages of the trial consistent but small differences were observed.

The data suggest that the technique developed for initial screening of genetic resources was of value in identifying populations of higher digestibility which appeared to be of relevance in agronomic testing, although the large differences shown at initial screening were reduced after going through the breeding process and eventually into agronomic trials.

To summarise, the foregoing examples, have illustrated some points, among many, that require consideration in genetic resources evaluation. Firstly, the importance of continual appraisal of initial screening techniques and results in relation to those obtained by the breeder and agronomist.

Secondly the need to retain some flexibility in the type of evaluation so that information obtained during collection can be fully exploited.

Thirdly, the apparent dilution of the expression of a character from initial evaluation, through the breeding process to varietal assessment suggests that only large differences at the genetic resources level will have any impact in an agricultural situation.

Recognition of these points during initial screening will hopefully lead to acceptance of the results derived from genetic resources screening both by breeders and agronomists. This will then narrow the credibility gap that sometimes exists between them as the ultimate objective of collection and evaluation of genetic resources is their maximum utilization in plant breeding.

REFERENCES

Charles, A.H. (1972). Ryegrass populations from intensively managed leys. II. Reaction to management, nitrogen application and Poa trivialis L. in field trials. J.agric.Sci., Camb. 79, 205-215.

Lazenby, A. & Rogers, H.H. (1964). Selection criteria in grass breeding. II. Effect on Lolium perenne of differences in population density, variety and available moisture. J.agric.Sci., Camb. 62, 285-298.

Tyler, B.F. (1982). Practical aspects of a regeneration scheme in forage grasses. In: Seed Regeneration in Cross-Pollinated Species. Proceedings of the CEC/Eucarpia Seminar, Nyborg/Denmark 1981. (Proceddu, E. & Jenkin, G., eds). pp.69-78. A.A. Balkema/Rotterdam.

Tyler, B.F., Davies, I. & Lorenzetti, F. (1969). Forage plant collection:an expedition to Northern Italy. Rivisita di Agronomia, 3, pp.43-50.

Tyler, B.F. & Hayward, M.V. (1982). A sampling technique for assessing digestibility of Italian ryegrass populations. Euphytica 31 (in press).

Tyler, B.F. & Williams, I.G. (1972). A collection of Lolium and Festuca in Western Europe. Rep.Welsh Pl.Breed.Stn for 1971, pp.18-19.

Table 1. Growth rhythm of a population of Dactylis glomerata (Bc 5655) from north-western Spain

	Year	Relative yield (S.37 = 100) Nov-Mar	May	June	July	Aug.	Sept-Oct
Preliminary screening (Closely spaced single plants)	1965	175	85	122	90	84	114
Agronomic trials (Swards)	1973	139	96	147	106	110	135

Table 2. Persistence of a north-western spanish population of Dactylis glomerata (Bc 5655) and S.37 under three cutting and one grazing management

	% Sown grass		
	Bc 5655	S.37	S.143
5-weekly cuts			
1st yr	95	93	
2nd yr	99	92	
3rd yr	99	91	
4-weekly cuts			
1st yr	93	87	
2nd yr	99	89	
3rd yr	99	74	
3-weekly cuts			
1st yr	98	91	
2nd yr	97	78	
3rd yr	98	59	
Grazing			
1st yr	92	-	92
3rd yr	89	-	48

Table 3. Comparison of two sampling techniques for estimation of dry matter digestibility (%) in *Lolium multiflorum*

Origin		Delayed sampling - stem (20 days post ear emergence)	Standard sampling - whole plant (50% ear emergence adjusted for L/S ratio)
Belgium			
Pays de Herve	Bb 1709	66.6	73.3
Pays de Herve	Bb 1710	68.0	74.7
Pays de Herve	Bb 1711	68.2	74.1
Ardennes	Bb 1705	68.8	73.8
Polders	Bb 1715	68.6	73.2
Polders	Bb 1716	67.8	75.7
cv. Tiara	Bb 1402	67.3	76.6
cv. RvP	Bb 1493	66.8	75.3
Italy			
Upland meadow	Bb 1703	71.1	75.9
Upland meadow	Bb 1704	67.6	74.1
Piedmont irrigated meadow	Bb 1654	71.2	76.5
Piedmont irrigated meadow	Bb 1658	69.1	77.6
Lombardy irrigated meadow	Bb 1683	75.2	78.8
Range		8.6 DMD units	5.6 DMD units
SE		1.10	1.31

Table 4. Screening populations of *Lolium perenne* and *Dactylis glomerata* for DMD, using a delayed sampling technique

Maturity group	Sampling date	No. of populations	Range (% DMD)
Lolium perenne (wide geographical range)			
Very early	13/5	3	72.4 - 69.4
Early	4/6	13	67.9 - 63.6
Intermediate	11/6	21	68.2 - 63.3
Late	24/6	14	67.2 - 62.8
Overall	-	51	72.4 - 62.8 (SE 1.30)
Dactylis glomerata (narrow geographical range)			
Early Cambria type (4x)	18/6	30	60.0 - 54.5
Late Conrad type (2x)	10/7	14	59.8 - 56.0
Overall	-	44	60.0 - 54.5 (SE 1.20)

Table 5. Comparison of digestibility of original population and derived variety of *Lolium perenne*

Initial screening (using delayed sampling method)	Population Ba 9105 % DMD - stem	S.24 % DMD - stem	Difference % DMD - stem
	72.4	65.2	7.2 units

Agronomic testing	Derived variety Ba 9436 (% DOMD)	S.24 (% DOMD)	Difference (% DOMD)
5-cut system			
Conservation cut			
1st yr	69.9	67.2	2.7 units
2nd yr	65.5	64.3	1.2 "
3rd yr	63.6	58.9	4.7 "
1st regrowth cut			
1st yr	74.0	69.0	5.0 "
2nd yr	73.1	72.3	0.8 "
3rd yr	72.1	71.5	0.6 "
9-cut system			
Bulk of all cuts			
1st yr	83.2	81.4	1.8 "
2nd yr	83.2	81.1	2.1 "
3rd yr	81.1	79.2	1.9 "

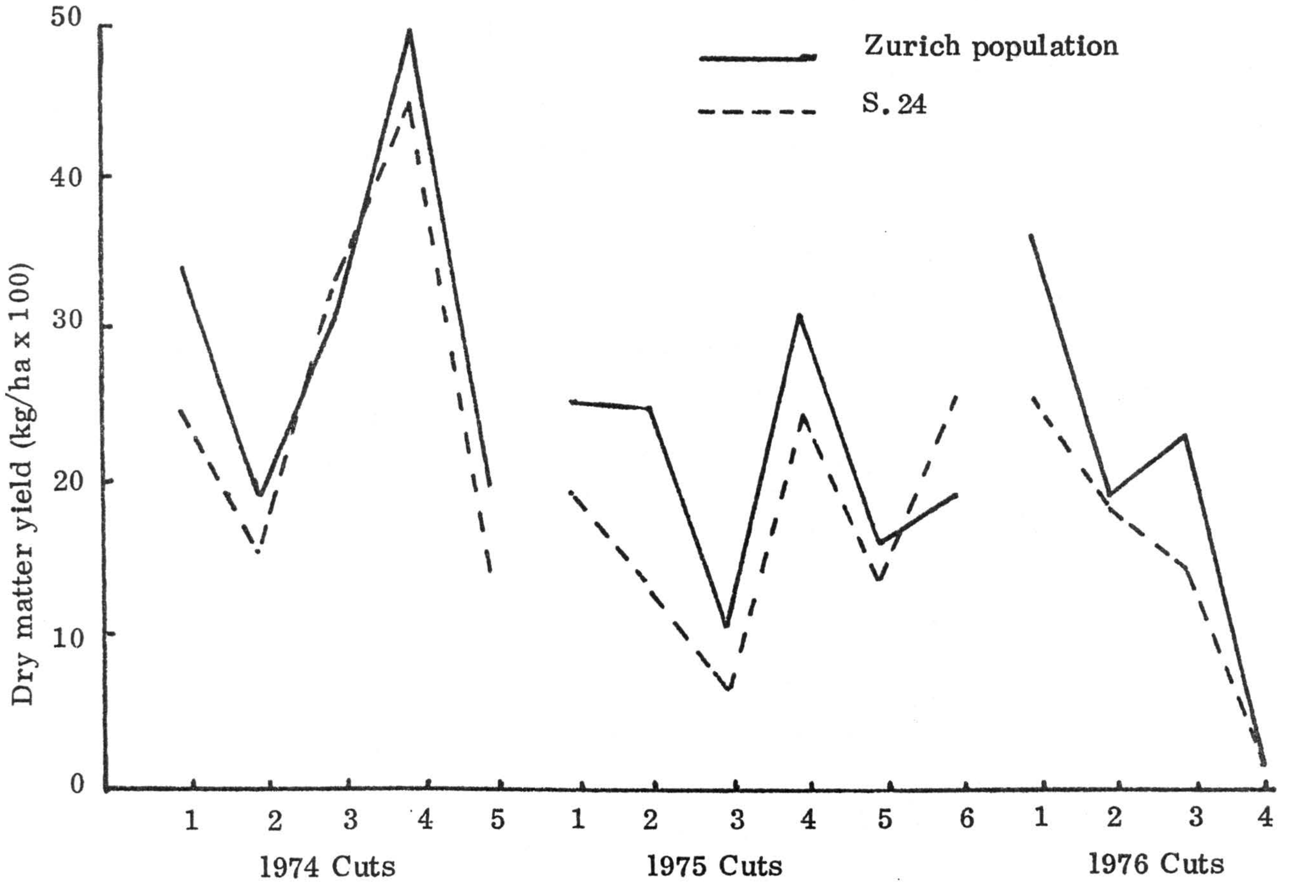

Fig. 1. Seasonal growth of a Lolium perenne population from the Zurich uplands compared with S. 24 under frequent cutting.

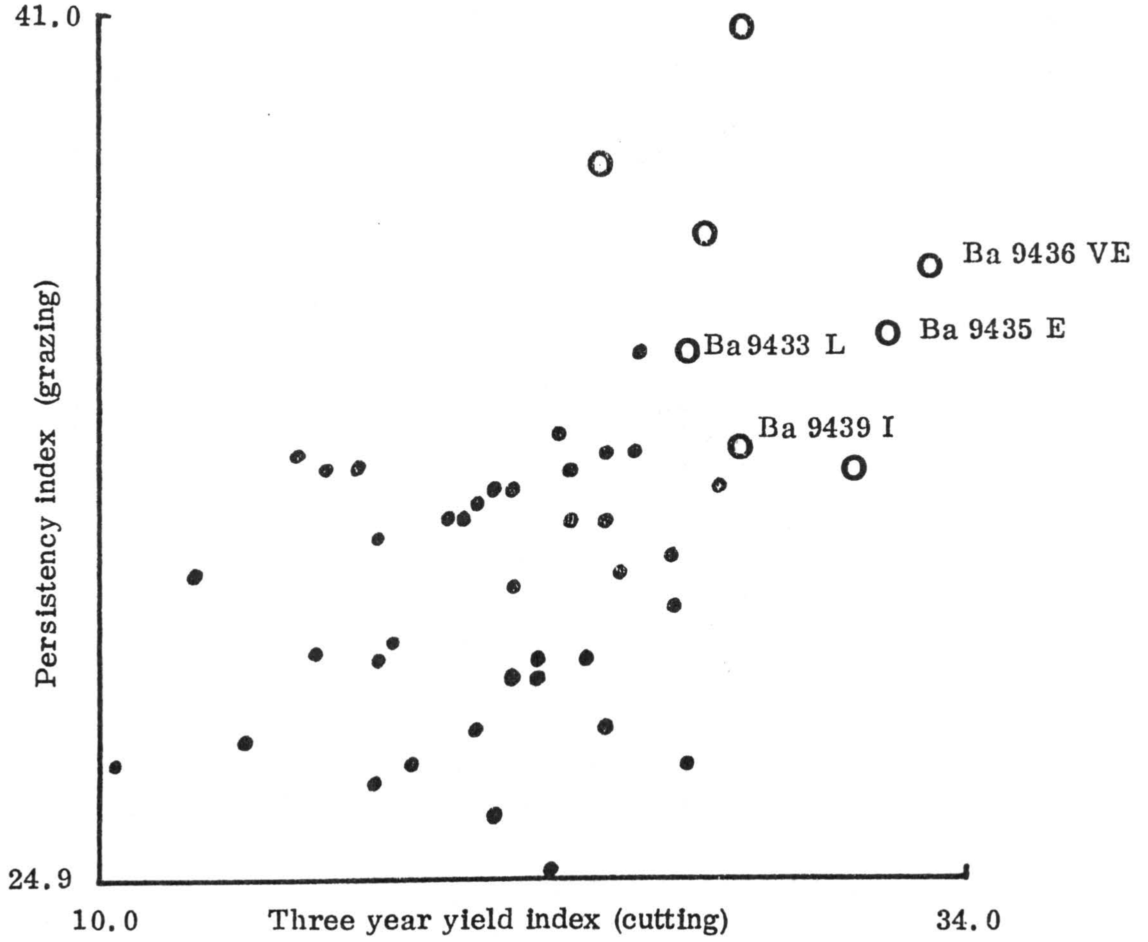

Fig. 2. Selection of 'elite' populations of Lolium perenne using a yield and persistency index. 'Elite' populations indicated by O; those developed into potential varieties followed by varietal number and maturity class i.e. VE = very early, E = early, I = intermediate, L = late.

THE ASSESSMENT OF TIMOTHY INTRODUCTIONS

Chr. Paul *)

Before embarking on the process of variety production a very unambitious yet necessary piece of work has to be carried out: The surveying of those genetic resources available to the breeder which are promising enough to justify further testing, i.e. as cloned material. Obviously this also is the task that a commercial forage plant breeder would wish or expect a gene bank to carry out so that some basic information as to the suitability of a particular accession can be made available to him.

Materials and methods

A timothy collection was set up in 1979 comprising 187 accessions of Phleum pratense consisting mainly of advanced breeding material and varieties and 4 accessions of Phleum bertholonii, two of which were the varieties Evergreen and S.50 and the remaining two of which were ecotypes from Italy. Judged by its origin the material was derived from most of the geographic area over which Phleum is distributed. The material was supplied by breeders holding variety rights and colleagues doing breeding research in this species which is gratefully acknowledged at this occasion.

The plants were set out in the field in 1980 in single plant stand 50 cm by 50 cm apart. The layout was such that the 16 plants to be scored for vegetative characters and the 8 plants to be scored for reproductive characters were grown alongside each other. In the first harvesting year 1981 the first cut was taken according to phenological development, i.e. individually for every accession about ten days after heading. From the characters scored and measured only average dry matter yield per single plant and in vitro digestibility of

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the organic matter (IVDOM) in the first cut as well as average seed yield per plant of the 1981 data are dealt with. Explanatory characters are also included in the analysis. The data were sorted for all accessions according to these main characters in ascending order, classed in ten intervals over the total distribution range and depicted diagrammatically. Additionally, analyses of regression(correlation were carried out over all accessions.

Results and discussion

A continuous decline in digestibility for the four or five lowest yield classes can be observed (Fig. 1). At higher yields, digestibility reaches a constant level except of the two accessions in the highest yielding class which demonstrate a further decline in digestibility. Calculated over all individual accessions there is a negative correlation in the first cut of r = - 0.5 between IVDOM and single plant dry matter yield.

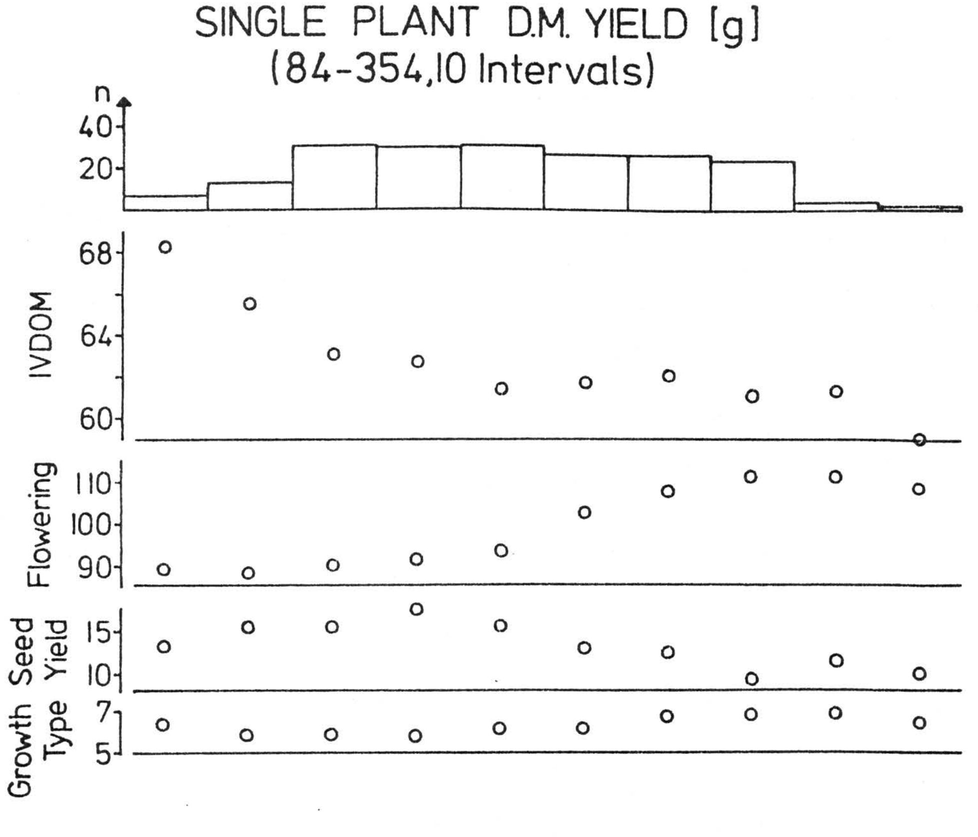

Figure 1 Relation of IVDOM (%), days from beginning of vegetation to flowering, seed yield (g) and growth type to average single plant dry matter yield of first cut (g) in the timothy colletion classed for yield.

As regards the relation between earliness and dry matter yield there appears to be a changeover from the early to the later types around the mean dry matter yield of the population. This relationship is characterised by a correlation coefficient of r = + 0.73.

Taking seed yield into account, it can be seen that the early types which produce small d.m. yields of relatively high digestibility when cut 10 days after heading have to be regarded as relatively good seed producers whereas the opposite is true for the high dry matter producing late types. However, when seed yield is included in this analysis, its extremely high variation within dry matter classes has to be taken into account. Expressed as the coefficient of variation, the variability of seed yield within dry matter classes is five to ten times higher than that of digestibility. The correlation coefficient for this relationship is r = 0.32.

There is a noticable skewed distribution for in vitro digestibility of the organic matter over the total range from 56 % to 70 % IVDOM (Fig. 2).

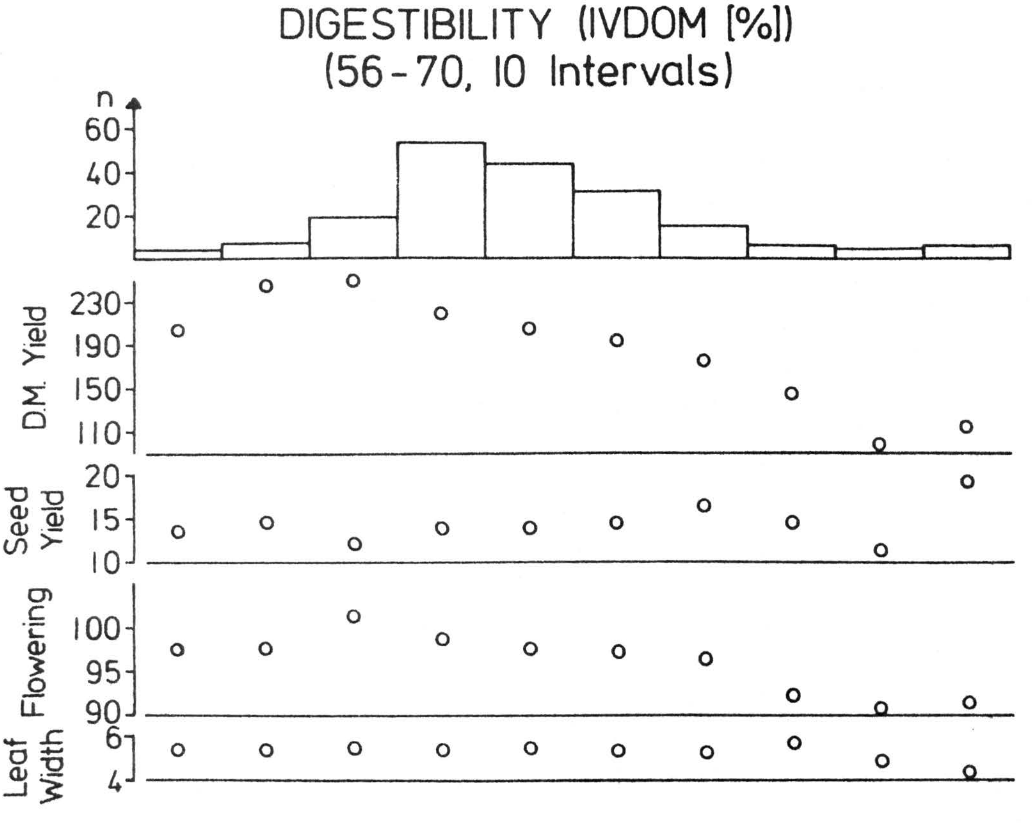

Figure 2 Relation of average single plant dry matter yield (g), seed yield (g), days from beginning of vegetation to flowering and leaf width to in vitro digestibility of organic matter (%) in the timothy collection classed for IVDOM..

As shown before, there is a negative relationship between digestibility and dry matter yield but practically no relationship between digestibility and seed yield (r = + 0.11). The tendency for digestibility to decrease with decreasing earliness at a given phenological stage is weakly expressed in this material (r = - 0.19). The relationship between digestibility and leaf width (r = + 0.11) is statistically not significant indicating that contrary to expectation broad leaved plant types are not predisposed to high digestibility.

The range of distribution of seed yield per single plant for all timothy accessions was between 1 and 27 g (Fib. 3). Its relationship to dry matter yield is negative and is characterised by an overall correlation coefficient of r = - 0.32. Its relation to days to flowering is also negative but stronger (r = - 0.52).

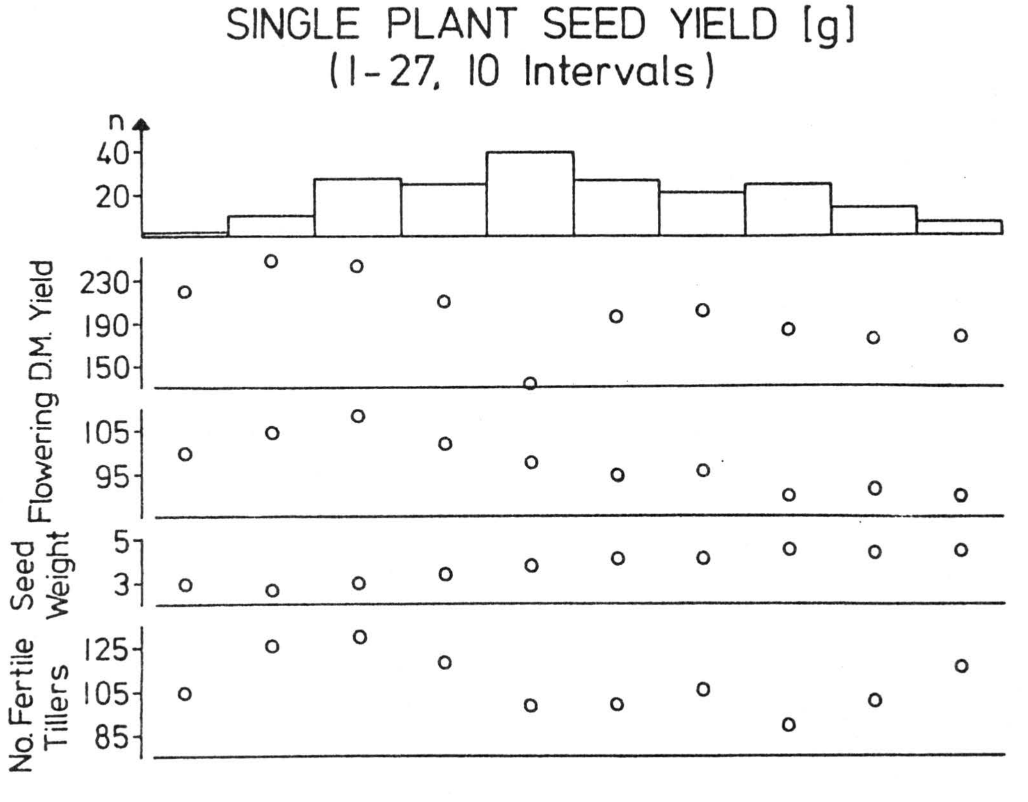

Figure 3 Relation of average single plant dry matter yield of first cut (g), days from beginning of vegetation to flowering, thousand seed weight (g), number of fertile tillers to single plant seed yield (g) in the timothy collection classed for seed yield.

Although this study was not laid out to provide an analysis of seed yield components the influence of seed weight, number of fertile tillers as well as ear length on seed yield was assessed by measurement or visual scoring. Of these seed weight was the variable most highly correlated with seed yield (r = + 0.54). As is seen from Fig. 3, the number of tillers did not exert a big influence on seed yield as was the case for awn length. Since these three components make up total seed yield and should have explained its observed variation, the accuracy of the visual assessments on number of tillers and ear length prior to harvesting must be questioned in this particular experiment.

Conclusions

The evaluation of a timothy collection in its first harvest year under non-competitive conditions for agronomically important criteria has produced evidence of considerable variation in most characters and of certain interrelationships among them. Most significant among the latter is the strong dependence of first cut dry matter yield on earliness when all accessions are harvested at the same phenological stage. Under these circumstances late accessions tend to have lower IVDOM than early ones although this relation is less pronounced than the one between earliness and yield.

Seed yield is also influenced by earliness in that late accessions tend to produce less seed than early ones. Thousand seed weight appears to be the seed yield component most clearly linked with total seed yield.

While these and other relationships can be taken to result from genetic and physiological origin, neither relationships favourable nor unfavourable to breeding aims appear to be sufficiently strong either to warant or preclude success in simultaneous selection work with this material.

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Test of local grass populations in North Norway.

Variety trials in grases were the first research work started at the State Experiment stations in North Norway when these stations were established between 1922 and 1925. The results of these experiments showed that plants from southern parts of Scandinavia and from other countries were unfit in the Northern part of Norway. Therefore, plant breeding based on local plant material and plant material adapted to the conditions in North Norway, was started as early as 1930, and the breeding work resulted in valuable varieties of Phleum pratense and Poa pratensis.

Up to 1970 the breeding work had a rather modest proportion. But from that time plant breeding was appraised as a matter of great importance, and a comprehensive collection of local natural growing plants and adapted plants was carried out. The main species collected were: Phleum pratense, Poa pratensis, Festuca pratensis, Dactylis glomerata, Festuca rubra, Phalaris arundinaceae, Agrostis tenuis and Aleopecurus pratensis. A total number of about 400 populations were collected.

The first step in the treatment of the collected populations was a test where the most promising ones were selected. The model for the experiments was as follow: Two hundred seedlings were selected at random from each population and planted in two replicated plots. The size of the plots was one square meter, and the spacings between seedlings within plots were 10 cm in either direction. The intention of this system of planting was to simulate a sown meadow. The observed characters together with the F-values from the analysis of variance are set out in table 1.

Table 1. F-values from the analysis of variance between populations of the species Phleum pratense and Poa pratensis.

	Phleum pratense	Poa pratensis
Winter hardiness	1,16	1,02
Vegetation start in spring	1,01	1,10
Date of inflorescence emergence	5,82***	0,77
Plant height	4,20***	7,07***
Yield of dry matter	4,96***	2,15***
Attack of Erysiphe graminis		1,69**

** $P < 0{,}01$
*** $P < 0{,}001$

With regard to "plant height" and "yield of dry matter" the results in table 1 indicate significant differences between populations in both species. These two characters were positively correlated with coefficients of correlations of 0,59 and 0,73 for bluegrass and timothy respectively.

In Poa pratensis, there were also significant differences in "Resistance to attack of the fungi Erysiphe graminis", and in timothy the "Date of inflorescence emergence" varied significantly between populations. The latter character did not show any significant variation in Poa pratensis, and the reason may be that bluegrass is an indigenous species in North Norway, and as a consequence well adapted to the climatic conditions there. Timothy on the other hand has been introduced into the part of the country from many different places, and may for that reason be more variable than bluegrass in a character like inflorescence emergence.

In order to show the variation range among populations, the lowest and highest value for some of the observed characters are given in table 2.

Tablo 2. Max- and min-values to indicate the variation range for some of the observed characters.

	Phleum pratense		Poa pratensis	
	Max	Min	Max	Min
Winter hardiness (rel. val.)	100	92	100	85
Plant height (cm)	112	57	75	39
Yield of dry matter (g/m^2)	1634	628	1474	878

After this population test, the 8 - 10 most outstanding populations of each species were selected. In the following testing programme, two ways were followed. In the first case, the selected populations were tested in field trials in comparison with commercial varieties to show whether any of the collected populations had higher agronomically value than the commercial varieties.

In the other case, the selected populations were tested with regard to variation within populations, in order to select the most valuable plants for progeny testing and syntetic varieties.

Results from field trial tests, available for only two years yet, indicate some differences between populations, but no significant differences have so far appeared. The experiments will continue, and the differences between populations are expected to be more marked in the coming years.

The examination of variation within populations was done in single plant trials, where each population was represented by 100 genotypes in two replicated blocks.

The observations made in the single plant trials, together with the weight given to each character, are shown in table 3.

Except for "plant height" all other characters were judged visually.

Table 3. Weight for the characters observed in the single plant tests.

Vegetative extent in spring	0,1
Winter hardiness	0,2
Plant height at 1st cut	0,3
Plant height at 2nd cut	0,2
General impression of 1st harvest	0,3
General impression of 2nd harvest	0,2
Resistance to fungies	0,3

The object of the weights assigned to the characters, was to construct an index for use in ranking plants.

The index was constructed in the following way: Each character was given a weight in relation to its agronomically importance (table 3), which was multiplied by the observed values. For each plant the weight x observed value of the various characters were added up, and the sum figure composed a new character which was called "value".

The plants within each population were ranked according to the "values", and the 20 "best" plant were selected.

Next year, the selected genotypes from each population will be crossed in a polycross system in pollen proof green houses, in order to produce seed for progeny testing.

The single plant tests have shown great variation within the collected populations, and the possibilities for making progress in breeding by utilizing the best part of the variation exists.

EVALUATION OF COLD HARDINESS IN FORAGE GRASS AND LEGUMES

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INTRODUCTION

One of the breeding objectives in forage grasses and legumes for N.Europe is the development of cultivars with potential for growth in the autumn and spring. This out-of-season growth may be achieved by exploiting the winter-growth characteristics of Mediterranean populations. By hybridisation with northern-adapted types and subsequent selection this out-of-season growth has been obtained in hybrids such as cv. Saborto (*Dactylis glomerata* hybrid between S.37 and a Portuguese diploid) and cv. Katrina (*Trifolium repens* hybrid between Kersey, Israeli and Turkish types). However, the strong negative correlation between growth at low teperatures and cold hardiness gives rise to poor winter survival of these Mediterranean types and lower levels of survival in the hybrids than in their northern-adapted parents. Although this negative relationship is a consistent feature in this type of hybrid it may not always be expressed in certain hybrids between parents of contrasting origins. The relative contribution of the two parental types in terms of winter growth and survival may be dependent on the precise origin of the northern parent. As might be expected less winter growth and better survival occurs in hybrids from extreme northern types such as *Dactylis glomerata* cv. Latar (origin, Leningrad). For example, in the hybrid between cv. Latar and the autotetraploid of the Portuguese subspecies *lusitanica* the winter dormancy of Latar seems to be dominant and the hybrid only yields well in summer. Even so, significant improvement in out-of-season growth of this hybrid, while maintaining high levels of cold hardiness, has been achieved by parallel selection for rate of leaf area expansion in a cool glasshouse during winter and for cold hardiness (Eagles & Othman, 1978). However, even in these selections the level of cold hardiness declined appreciably in genotypes where the rate of leaf area expansion exceeded 80 mm^2 d^{-1}.

This general approach to out-of-season growth emphasises the need for a routine test for cold hardiness which can be used for assessing potential breeding material. Whatever test is used the ultimate criterion must be the ability to survive under natural conditions. However, the irregularity and unpredictability of severe winters in many regions such as western Britain means that field testing of hardiness may not be an ideal assessment of potential breeding material. Further, the expression of winter hardiness at different sites may be influenced by a range of climatic factors such as cold, hardening/dehardening cycles, wind exposure, ice encasement and pathogen attack under snow cover together with autumn management thus restricting the general application of results obtained at a single site. In maritime environments prolonged mild, overcast conditions can lead to poor winter survival even without freezing conditions. In view of these interacting factors a routine environmental simulation technique must consider the effects of other factors even when hardening to a single factor such as cold is studied. Development of appropriate environmental simulation techniques is a high priority in our studies of hardiness in forage grasses and legumes and the remainder of this paper is a brief description of one approach to this problem.

Grasses

A seedling test for cold tolerance (Fuller & Eagles, 1978) based on a technique used for winter cereals (Jenkins & Roffey, 1974) has been developed at the Welsh Plant Breeding Station. The environmental requirements for assessing freezing tolerance of populations are not particularly stringent and it has been possible to meet these requirements in the relatively unsophisticated environment of a 'butchers' cold room. However, reliable selection of individual genotypes requires very accurate control of temperature within a freezing cycle and reproducible conditions between freezing cycles to ensure selection of inherently hardy plants. The glycol freezing tank used in our tests achieves these specifications and has been used successfully for individual genotype selections. The accuracy of the tests is improved further by using controlled-environment facilities during the growth and hardening periods prior to freezing and during the recovery period between freezing and assessment of damage. Discrimination between types differing in hardiness may depend on suitable techniques for assessing damage. While the ultimate assessment of damage is normally percentage kill of tillers, stolons or whole plants, attempts have been made to quantify leaf damage or retardation of growth among survivors. Attempts have also been made to measure cellular damage immediately after freezing using techniques such as electrical conductivity of tissues or tissue extracts and vital staining of tissues.

Two types of freezing cycle have been used, each with certain advantages. The simpler one involves a single minimum temperature test where all the material is subjected to one temperature, typically -8°C. This permits either a high degree of replication or multiple comparisons but this technique cannot cope with a wide range of hardiness and is frequently a 'hit' or 'miss' approach resulting in complete survival or complete kill of the material and hence failure to separate even contrasting types. In contrast, the LD_{50} type of test developed by Pomeroy & Fowler (1973) in which six to eight samples are removed from the freezing conditions at a range of temperatures is ideally suited to discriminate between types with a wide range of hardiness. However, this technique has the disadvantage that fewer comparisons or replicates can be used.

Good relationships have been established between winter hardiness of mature plants of a range of forage grasses and cold resistance of seedlings with two leaves (Table 1) or plants with three-four tillers (Table 2) measured as first and second leaf damage, regrowth (appearance of third leaf) and plant kill. However, seedling tests may not always be relevant for perennial species which survive the winter as mature plants. A test which could be adapted for mature material grown either in controlled-environment conditions or under natural conditions would be more appropriate. To meet these requirements we have developed a test which uses isolated tillers from mature plants. Fortunately for this approach variation in cold hardiness of tillers does not seem to be related to tiller age. This was determined using tillers of three varieties of L.perenne which were grown in a glasshouse during summer, and marked at weekly intervals to determine their age structure prior to hardening at 2°C and subsequent freezing at -8°C. Damage was randomly distributed among the tillers of each variety and the effect of tiller age in the analysis of variance was not significant (Fuller, 1979).

Results from an isolated tiller test with three varieties of L.perenne grown in a glasshouse during summer and hardened for 10 days at 2°C, 8 h photoperiod show that these varieties can be separated in this type of test using leaf damage and tiller kill based on damage to the main apex and the lateral apices (Table 3). Although the absolute temperatures for 50% kill differed with stage of maturity the ranking of the varieties was the same in this test as in the seedling test.

The potential of the isolated tiller test was evident in an experiment where seasonal changes in cold hardiness were followed through the winter 1977-78. Individual tillers from mature plants grown under natural conditions at Aberystwyth were sampled at monthly intervals from October to May and prepared for freezing in the glycol tank using an LD_{50} test. Treated tillers were allowed to recover in a heated glasshouse with supplementary lighting and kill was assessed 3 weeks after freezing (Fig. 1). Significant differences between the three varieties were found in most monthly harvests although they were small at the beginning of December when the three varieties showed their maximum hardiness.

These seasonal changes in hardiness were closely related to changes in temperature which the plants experienced prior to the freezing test. Following mild conditions during October the increase in hardiness during November was associated with daily temperatures consistently below 5°C and between 0° and 2°C for two weeks prior to sampling. The decline in hardiness of the varieties during December was associated with a rise in daily temperature to values often above 5°-7°C. The marked dehardening of Grasslands Ruanui compared with the maintenance of high levels of hardiness in Premo and S.23 at these temperatures can be explained by their different threshold temperatures for hardening and dehardening reported in controlled-environment studies (Fuller & Eagles, 1980, 1981).

Careful interpretation of this type of experiment is necessary since seasonal fluctuations in hardiness can give rise to misleading results where samples are taken over a period of time in a large screening experiment.

<u>White clover</u>

These tests which were developed originally for assessing cold hardiness of grasses require little adaptation for use with white clover plants. Studies using either seedlings or rooted stolon tips of ten varieties of white clover differing in leaf size and origin grown and hardened in controlled-environment conditions produced results for cold hardiness which were not entirely consistent with winter hardiness recorded during winter 1978-79 (Table 4). Under field conditions, the lowest stolon kill was recorded in the large leaf type AC 32 and in three of the varieties classified as small (S.184) and medium leaf types

(S.100 and Donna). In contrast, the highest stolon kill occurred in the two large leaf types with Mediterranean origin (AC 4 and Katrina). The ranking of the varieties based on LD_{50} values obtained in the glycol freezing tank deviated from this ranking in respect of S.100 and S.184 which were relatively susceptible and Katrina which was relatively hardy. This poor relationship between cold hardiness and winter hardiness for certain varieties may be the result of variety x hardening environment interactions. This possibility was studied by growing four varieties (S.100, Olwen, Katrina and AC 4) under natural conditions during the winter 1979-80 and sampling individual stolon apices during late December 1979, January and February 1980 for freezing in the glycol tank. Hardiness increased to a peak in mid-January and declined in the later harvests for all four varieties. This technique gave good separation of the varieties in the same order as that recorded during the winter 1978-79 and the results from 16 January 1980 show this clearly (Table 5). AC 4, the large leaf type of Mediterranean origin, was the most susceptible variety while S.100 the medium leaf type was the most hardy variety. Olwen was hardier than Katrina, the hybrid between European and Mediterranean populations, which in turn was hardier than AC 4 one of its Mediterranean parents. This assessment of cold hardiness of naturally hardened material gave a larger range of LD_{50} values than was found for artificially hardened material. As with grasses the seasonal changes of cold hardiness could present a problem in large screening experiments when samples are taken over a period of time.

Although the ultimate criterion must be the ability to survive under winter conditions these artificial tests offer the breeder simple techniques for assessing cold hardiness characteristics which are closely related to winter survival. Single minimum temperature tests are limited in their application and it is desirable that LD_{50} values should be determined at least as the initial step in characterising the hardiness of varieties. While seedling tests on artificially hardened material offer a reproducible technique for assessing cold hardiness the results may not always agree with measurements of winter hardiness. In spite of the greater variability which may arise in experiments using naturally hardened material this technique has definite advantages in terms of creating the most natural hardening responses of the plants and should be adopted where doubts exist about the relationship between cold hardiness induced artificially and winter hardiness.

REFERENCES

Eagles, C.F. & Othman, O.B. (1978). Physiological studies of a hybrid between populations of *Dactylis glomerata* from contrasting climatic regions. II. Intra population variation. *Ann.appl.Biol*. 89, 81-88.

Fuller, M.P. (1979). Physiological aspects of cold hardiness in forage grasses. Ph.D. Thesis, University of Wales.

Fuller, M.P. & Eagles, C.F. (1978). A seedling test for cold hardiness in *Lolium perenne* L. *J.agric.Sci., Camb*. 91, 217-222.

Fuller, M.P. & Eagles, C.F. (1980). The effect of temperature on cold hardening of Lolium perenne seedlings. J.agric.Sci., Camb. 95, 77-81.

Fuller, M.P. & Eagles, C.F. (1981). Effect of temperature on cold dehardening of Lolium perenne L. seedlings. J.agric.Sci., Camb. 96, 55-59.

Jenkins, G. & Roffey, A.P. (1974). A method of estimating the cold hardiness of cereals by measuring electrical conductance after freezing. J.agric.Sci., Camb. 83, 87-92.

Pomeroy, M.K. & Fowler, D.B. (1973). Use of lethal dose temperature estimates as indices of frost tolerance for wheat cold acclimated under natural and controlled environments. Can.J.Pl.Sci. 53, 489-494.

Table 1. LD_{50} values derived from probit analysis of temperature response curves for first leaf damage, second leaf damage, regrowth (appearance of third leaf) and plant kill of seedlings of four contrasting varieties of *Lolium perenne*, *L.multiflorum* and *Festuca arundinacea*

Variety	Origin	Winter hardiness	LD_{50} First leaf damage	Second leaf damage	Regrowth	Plant kill
L.perenne						
Veya	Lithuania	H	-10.2	-12.1	-10.8	-11.9
Premo	Holland	H	-10.1	-11.8	-10.3	-10.6
S.23	Wales	H/S	- 6.7	- 9.4	- 8.7	- 9.9
Grasslands Ruanui	N.Z.	S	- 6.3	- 8.0	- 7.0	- 8.2
L.multiflorum						
Trident	Wales	H/S	-	- 8.6	-13.7	-13.6
Bf 1277	N.Italy	H/S	-	- 8.8	-13.2	-13.1
Tiara	Holland	S/H	-	- 8.9	-12.3	-12.4
Grasslands Ruanui	N.Z.	S	-	- 9.1	-11.3	-11.4
F.arundinacea						
Bn 951	Switzerland	H	- 8.7	-11.5	-13.0	-13.6
S.170	Wales	H/S	- 8.6	-11.8	-12.8	-13.3
Dovey	France	H/S	- 6.9	-10.6	-11.9	-12.6
Bn 379	Tunisia	S	- 7.1	- 8.2	- 7.7	- 9.0

Growth conditions: 20°C, 16 h photoperiod for 14 days (*Lolium*) or 20 days (*Festuca*)

Hardening conditions: 2°C, 8 h photoperiod for 10 days;

Recovery conditions: 20°C, 16 h photoperiod for 14 days (leaf damage and regrowth) and 21 days (plant kill)

Table 2. LD_{50} values derived from probit analysis of temperature response curves for leaf damage, tiller kill and plant kill of 3-4 tillered plants of three contrasting varieties of Lolium perenne

Variety	Origin	Winter hardiness	LD_{50} Leaf damage	Tiller kill	Plant kill
Premo	Holland	H	-11.5	-13.1	-14.3
S.23	Wales	H/S	-10.9	-12.4	-13.4
Grasslands Ruanui	N.Z.	S	-10.0	-11.3	-12.4

Growth conditions: 20°C, 16 h photoperiod for 8 weeks
Hardening conditions: 2°C, 8 h photoperiod for 10 days
Recovery conditions: 20°C, 16 h photoperiod for 14 days

Table 3. LD_{50} values derived from probit analysis of temperature response curves for second leaf damage, third leaf damage, kill of main apex (absence of next leaf), kill of tiller apices (absence of lateral tillers) and kill of individual tillers of three varieties of L.perenne

Variety	LD_{50} Second leaf damage	Third leaf damage	Main apex death	Lateral tiller apex death	Kill
Premo	-10.7	-13.1	-12.8	-13.5	-14.4
S.23	- 9.6	-12.0	-11.9	-11.8	-12.9
Grasslands Ruanui	- 7.2	-10.8	- 9.8	-10.4	-12.2

Table 4. **Relationship between stolon kill during winter 1978-79 and LD_{50} values derived from probit analysis of temperature response curves for seedlings and rooted stolon apices of ten varieties of white clover hardened in controlled-environment conditions**

Variety	Percentage stolon kill during winter	Variety	LD_{50} plant kill for seedlings	Variety	LD_{50} kill of rooted stolon apices
S.184	27.0	AC 32	-9.7	Katrina	-9.9
AC 32	44.9	Olwen	-9.6	Olwen	-9.5
S.100	50.0	Katrina	-9.2	Donna	-9.4
Donna	60.2	Donna	-9.0	AC 32	-9.3
Olwen	60.2	Nesta	-9.0	S.184	-9.3
Kersey	60.7	S.184	-8.7	Kersey	-9.2
Grasslands Huia	73.3	Kersey	-8.5	S.100	-9.2
Nesta	75.3	Grasslands Huia	-8.4	Nesta	-9.2
Katrina	86.4	S.100	-8.3	Grasslands Huia	-9.0
AC 4	100.0	AC 4	-7.8	AC 4	-8.7

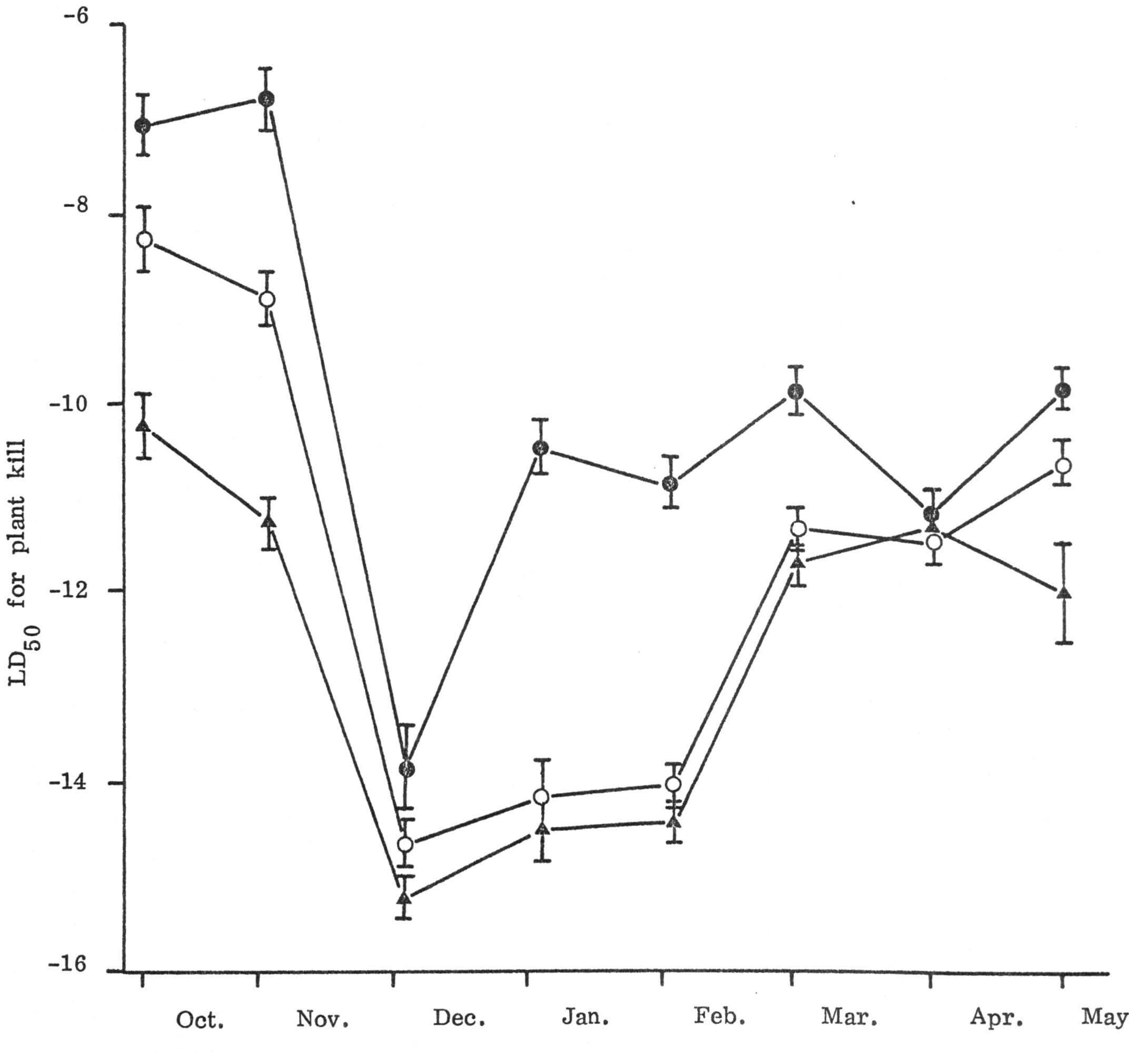

Fig. 1. Seasonal variation in cold hardiness of three varieties of L. perenne during winter 1977-78. Vertical bars represent fiducial limits (P = 0.05).

● Grasslands Ruanui
○ S. 23
▲ Premo

THE ROLE OF AN INTERNATIONAL AGENCY (IBPGR) IN THE CONSERVATION OF GENETIC RESOURCES OF FORAGE PLANTS

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Over the past few decades there has been increasing concern about the erosion of the world's germplasm resources particularly in relation to major economic food plants. This state of affairs has been brought about by the adoption of advanced agricultural technologies, the replacement of local varieties by modern high yielding cultivars, over-grazing and putting land into non-agricultural use.

Although there were attempts to remedy the situation, it was not until 1967 that an FAO Technical Conference suggested a possible long term solution, and the need for genetic conservation became more widely recognised. There was a further delay until 1974 when the IBPGR was set up.

The IBPGR is not an FAO organisation although it works in close association with FAO which provides its Secretariat. IBPGR is one of the centres of the Consultative Group on Agricultural Research (CGIAR) which oversees several International Agricultural Research Centres e.g. CIMMYT, IRRI, ICARDA. The CGIAR is an informal group of donors and for IBPGR this includes most West European countries, USA, Canada, Japan, India, Australia and the World Bank. The Board consists of 15 members including FAO and UNEP representatives and has a current budget (1982) of 3.5 million US$.

As the vast majority of centres of diversity are in the developing countries it follows that a large proportion of the Board's activities are located in those countries.

The IBPGR programme is, however, world wide and makes no discrimination on political or other grounds. Its main task is to organise an international network of plant genetic resource centres to ensure that the genetic diversity for important food crop and other plants is adequately maintained. This entails collection, conservation, evaluation and documentation and making material available to plant breeders and other scientists. Successful completion of this task would prevent or at least diminish the loss of significant genetic diversity, at a time of rapid change and development in agriculture and land use.

Since its inception in 1974, the Board had by 1981 built up a network of activities in 82 countries. This is seen as only a beginning and there is much to be done to enlarge, strengthen and monitor this network. In this context much of the Board's expenditure is designed as pump-priming i.e. to encourage certain activities which are then taken over by those who benefit from them. One of the most significant results of the Board's work has been the catalytic effect it has had on the genetic resources activities of many nations around the world.

In promoting a greater awareness throughout the world of the importance of genetic resources activities the Board's tasks include:[1]

* The collection, conservation and evaluation of plant genetic resources with particular reference to species of major economic importance and their wild and cultivated relatives (hence the IBPGR is responsible for coordinating global efforts and for help in financing essential activities).

* The strengthening of programmes of existing institutions and the encouragement of new programmes; to articulate activities particularly in the areas of major genetic diversity.

* Stimulating the availability of material for plant breeding and other scientific activities.

* The establishment of standards, methods and procedures for exploration, evaluation and for conservation of stocks of both seeds and vegetative material.

* The establishment of a network of replicated storage centres.

* The promotion of training.

* The promotion of the dissemination of plant material and information among centres.

* The promotion of awareness for effective information storage, retrieval system and free exchange of information about the materials.

At present the major direct food crops, i.e. cereals, (30%) and food legumes (25%) between them use up more than half the financial resources while forage plants use up a mere 6 percent.[2] Forage plants generally have had a low priority but in some regions forages are increasing in importance.

PRIORITY CROPS AND PRIORITY REGIONS[3]

Individual crops or groups of species have been assigned priorities according to a set of criteria:

(a) the risk that genetically diverse material or their wild relatives will be lost

(b) the economic value of the crop

(c) the requirements of plant breeders

(d) the size, scope, quality including documentation of present collections

Priority 1 crops include, wheat, Phaseolus beans, cassava, sweet potato, tomato and coffee.

The Board has detailed information on a large number of the more than 120 crops for which it has priorities; some crops still require attention and these include forages and some fruits.

Priorities among regions were assigned according to the following criteria:

(1) that they contain significant genetic variation for one or more crops
(2) rapid change in agricultural practice
(3) widespread crop failures

Priority 1 regions include the Mediterranean, Southwest, Central and South Asia, Ethiopia and Central America.

The subsequent discussion will provide a general background of the kind of activities promoted by the Board, pinpointing the action taken on forages.

COLLECTION

The Board places primary emphasis on collecting in areas where there is evidence of serious genetic erosion. It also regards as its mandate the encouragement of collecting where germplasm is not at present at risk but where it is clearly needed for crop improvement purposes, particularly in developing countries e.g. forages. About one quarter of the Board's resources are disbursed for collecting purposes. In all cases supported by IBPGR the following principles are applied:

a. Duplicates must be left in the host country and if requested local scientists should be included in the collecting team.

b. Appropriate arrangements must be made for conserving the materials collected and for preliminary evaluation.

c. Sponsors must agree to free exchange of materials and information.

During 1981 the Board supported collections of forage species in Pakistan, forage legumes in the Philippines and some forage grasses in Jordan. Recently (1979-81) the Board responded to requests for help and funds from Instituto Nacional de Tecnologia Agropecuaria, Argentina (INTA) to collect native forages in sub-tropical areas and more than 1900 samples were collected. Duplicate samples have been sent to the Centro Internacional de Agricultura Tropical, Colombia (CIAT) for storage. A similar project in Uruguay resulted in 630 accessions from 47 species (primarily wild) of native forages being collected.

These IBPGR efforts supplement those of CIAT which places emphasis on acid infertile soils. CIAT has a very active programme and during 1981 undertook three major missions in Venezuela and Brazil. The total number of accessions held was 8635 with 1500 being added in 1981. Early in 1982 an expedition to Thailand and West Malaysia collected native forage legumes.[4]

CONSERVATION

This entails storing seed under conditions that maximise longevity, or preserving in a vegetative state. A need also arises to multiply/ propagate the material when viability has dropped to a certain point or the supply of seed is too low. IBPGR provides some finance on a conditional basis for these activities but it is limited to equipment and not capital facilities. If financial support is received then there must be a commitment from the host country at least for the forseeable future. Around 10% of the resources are disbursed in this work at present but this is expected to rise.

The Board has adopted FAO definitions of the types of genetic resources centre, as follows:

(1) base collections, for long term conservation

(2) active collections for medium term conservation

(3) working collection, maintained by breeders

The latter type collections are deemed to be outside the general framework but they do generate information which should be incorporated in data bases.

(1) Base collections are kept under the best possible conditions in order to maximise seed longevity. For this the Board recommends a temperature of about -18°C and that the seed is dried (ca 5% MC) and kept in sealed air-tight containers.

It is the Board's policy to designate an international network of centres which will undertake the responsibility for storing major base collections on a global or regional basis. This task should be completed by 1985-1986 for the major seed crops including duplicates held for safety at other centres. Base centres for a large number of crops have already been designated e.g. wheat, rice, maize, barley, oats, Phaseolus etc.

(2) Active collections are for medium term storage (ca 0°C) and are responsible for multiplication and regeneration, characterisation and preliminary evaluation and documentation. The Board must also assure that appropriate links exist between the centres having base collections and those with active collections. It intends to help finance equipment for such seed stores in developing countries providing they undertake to store material for the benefit of a particular region or for the global network.

A major problem facing curators of active collections is the multiplication and regeneration of accessions and this is even more acute in cross pollinated plants. This topic has been the subject of a detailed paper by Singh and Williams.[5] In many cases the costs involved, and the technical difficulties of multiplication in isolation have limited the amount of work undertaken or as in USA cross pollination is discounted and multiplication of grasses is undertaken in adjoining rows (of the same species). For lucerne, on the other hand, a special multiplication project is undertaken at Reno, Nevada where over 200 populations can be multiplied in isolation under cages in the open. Leaf cutter bees are now used for pollination. Isolated compartmented glasshouses through which filtered air is blown are in use at WPBS Aberystwyth and Tropical Crops and Pastures, Queensland and other places, for multiplying grass and legume materials. Such facilities are expensive but essential if the genetic integrity of the population is to be maintained.

CHARACTERIZATION AND EVALUATION

The value of and extent of use of plant collections will depend largely on the amount of information available about them. Reliable, detailed information on individual accessions will enable plant collectors, genebank curators and plant breeders to collaborate more effectively. In this way the full potential of germplasm resources can be better exploited.

To promote the dissemination of information the Board:

(a) Produces directories of crops which will indicate the location and content of important collections, geographical representation, extent of evaluation and documentation, method of storage etc. Directories for wheat, maize, rice, barley, food legumes, and some industrial crops have already been published and one for forage plants is in preparation.

(b) Assists in the development of descriptors. Obtaining agreement on an internationally agreed list of descriptors is an important role for the Board. These lists facilitate the exchange of information by getting the data presented in a standard form. So far lists have been produced for about 25 crops, and work is in progress for grasses and forages in various regions.

(c) Encourages the obtaining of characterization and preliminary evaluation data. This is deemed to be a genetic resources function and should be an IBPGR responsibility. More detailed evaluation is the responsibility of the breeder. Characterization should include a small number of characters which ideally are immediately visible to the observer and with a reasonably high heritability.[6] Preliminary evaluation includes basic characters which are invariably collected on a routine basis and are considered to be important by the crop advisory group e.g. agronomic characters, disease and pest resistance, persistence etc.

(d) Provides assistance to centres. The Board will provide assistance and advice in the handling of germplasm data and where appropriate to put the data in machine readable form.

TRAINING

The Board is placing increasing emphasis on training needs. This includes support for the Birmingham University Training Course in Conservation and Utilization of Genetic Resources, post graduate training and short technical training courses at various centres. Practical manuals and teaching aids are urgently required and a great effort is required on practical aspects of training.

Research

The Board supports research in areas necessary for it to carry out its functions. It has thus supported work on seed physiology in relation to seed storage in "orthodox"seeds and to a lesser degree in "recalcitrant" seeds.[7] Recommendations for optimum seed storage conditions have been published.[8]

FORAGES

As was indicated earlier forages have up till now played a minor role in the overall programme of IBPGR, representing but 6% of the financial disbursements. There is, however, increasing realisation of the basic importance of forages in many regions of the world where they have been given a high priority by regional committees e.g. Andean region, Mediterranean, Southwest Asia, Central Asia etc. During 1980 the Board agreed to assign a high priority to forage plants in arid and semi-arid zones. In particular forage legumes have been more frequently listed in the high priority class than grasses.

There are, however, problems in dealing with the forages in the same way as with other crops for the following reasons:[9]

* The large numbers of species involved -it is not difficult to list over 1000 species.

* As breeding and selection are recent developments differences between bred cultivars and wild ecotypes can be small or non-existent.

* There may be other species whose value has not been recognised.

* Different species are involoved in temperate and tropical regions and in humid and arid areas.

* A successful pasture often depends on the compatibility of a grass/legume combination.

* Biological information on many species is scanty.

Faced with such a complex situation genebanks can only hope to conserve a very small fraction of the available variation Priorities need to be established so that care is taken of the most important species. For many species in situ conservation may be the best and most economical solution.

The working Group on Forages that was convened by IBPGR and the Division of Tropical Crops and Pastures in Townsville in 1979 was however, of the opinion that long term seed storage would be the major method of conserving forage plant genetic resources. IBPGR agrees that collecting must be given priorities in several circumstances:

1. In emergencies, when development poses an immediate threat to vegetation.

2. Where no in-situ conservation can be set up and valuable genetic resources exist.

3. For the few species at fairly advanced stage of breeding when in-situ conservation will not be adequate and collections of ecotypes must be made.

Collection and seed conservation will be undertaken by progressive countries wishing to increase their germplasm resources from other areas of the world.

The Forages Working Group that met in Townsville (1979) produced a report[10] and made numerous recommendations. It considered the question of genetic erosion and also losses occurring in existing collections. Priority species for collection were listed for the major climatic regions and it was recommended that institutions should be invited to assume the responsibility for specific forage plant taxa. It called for greater publicity in relation to training courses and for facilitating the exchange of genetic resources data.

The working group also called for the setting up of an advisory committee on Forage Plant Germplasm to include representatives from countries not present in the group discussions. So far the Board has not taken action on this recommendation although many of the other items form part of the Board's current policy. In addition the Board has appointed a Forage officer to gather basic information. My duties are:

1. To compile a Directory of Forage Germplasm Resources which will list the important collections, the number of genera/species, information on geographic representation, evaluation, documentation, storage conditions and availability for exchange.

2. Assess the current state of germplasm collections with regard to their adequacy, evaluation, documentation.

3. Establish priorities for collection and conservation.

4. To encourage germplasm resource activity and visit important centres.

5. To devise a rolling global five-year plan of action for IBPGR to implement, taking into account ongoing work and the balance between tropical, sub-tropical and arid/semi-arid zones.

SUMMARY

1. The basic function of the IBPGR is to promote an international network of genetic resources activities to further collection, conservation, documentation, evaluation and utilization of germplasm of important food crops and other plants.

2. The Board has assigned priorities to crops based on criteria e.g. the risk of genetic erosion, the economic value of the crops, the requirements of breeders and the status of existing collections.

3. Priorities have likewise been assigned to regions, based on whether the region contains at least one centre of diversity, the speed of change in agricultural practice and the occurrence of widespread crop failures.

4. Help and conditional financial inducement are provided for activities under (1).

5. Only six percent of current resources are spent on forages, but in several regions forages are now in the high priority class .

6. Forages present difficult problems on account of the large numbers of species involved, the mainly cross pollinating nature of the species and they cover most climatic regions of the world.

7. IBPGR has appointed a forages officer to gather basic information on forages and to devise a plan for future action.

References:

1. Crop Genetic Resources. International Board for Plant Genetic Resources, Rome Sept. 1981, AGP:IBPGR/81/67

2. The IBPGR in the Eighties-A strategy and planning report. Rome Nov. 1980, AGP:IBPGR/80/32

3. Revised Priorities among Crops and Regions. International Board for Plant Genetic Resources, Rome June 1981, AGP:IBPGR/81/34

4. International Board for Plant Genetic Resources, Annual Report 1981 Rome, p.34, AGPG:IBPGR/82/19 March 1982

5. Singh, R.M. and Williams, J.T. 1982. Maintenance, Multiplication and Rejuvenation of Plant Genetic Resources. International Board for Plant Genetic Resources, Rome, AGP:IBPGR/82/21/, 1-20

6. Erskine, W. and Williams, J.T. 1980. The Principles, Problems and Responsibilities of the Preliminary evaluation of Genetic Resources of Seed-Propagated Crops. InternationalBoard for Plant Genetic Resources, Rome,AGP:IBPGR/80/9 Jan. 1980

7. King, M.W. and Roberts, E.H. 1979. The Storage of Recalcitrant Seeds- Achievements and Possible Approaches, International Board for Plant Genetic Resources, Rome, AGP:IBPGR/79/44

8. Report of IBPGR Working Group on engineering, design and cost aspects of long term seed storage facilities. International Board for Plant Genetic Resources, Rome, AGPE:IBPGR/76/25 Dec. 1976

9. International Board for Plant Genetic Resources, Annual Report 1980 Rome, p.31, AGP:IBPGR/81/24 April 1981

10. Interim Report on Working Group Convened by the Board to advise on action needed on the genetic resources of forage plants. International Board for Plant Genetic Resources, Rome 1979, AGP:IBPGR/79/49

The Evaluation and Utilization of Annual Medics at ICARDA

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Pastures and grazing lands with an increased carrying capacity are an essential component of any improved livestock production system in the Near East and North Africa (the region to which ICARDA'S research is directed). To increase capacity it is essential to select and introduce high yielding pasture species which are not only adapted to the Mediterranean and Near Eastern environments but are also suitable for introduction into a productive crop rotation. For example, there is considerable potential for expanding forage production by replacing the extensive fallow areas in this region by an annual self-regenerating Medicago species. The development of a successful rotation of pasture legumes and cereals to replace the traditional cereal-fallow rotation is therefore a major objective of the Pasture and Forage Improvement Programme at ICARDA. Considerable progress has been made to date in identifying high yielding ecotypes of annual medic species that can possibly be integrated into the local cropping systems.

A wide genetic diversity in the annual medics was essential in this research programme, for without such diversity the possible gains that could be made by selection would be severely limited. A large germplasm collection was therefore assembled and around 2,800 accessions of 32 species have been evaluated during the past four cropping seasons at ICARDA'S main research station at Tel Hadya, northern Syria. The material has been screened in preliminary observation rows, in microplots and advanced yield trials. Adapted and productive lines have been identified and selected. The results of studies on the changes in the composition of the original germplasm collection as a response to selection are presented in this paper.

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Materials and Methods

A collection of 2,800 annual medics of 32 different species was assembled. Approximately 1,200 accessions, from the Near East and N. Africa, were donated by the South Australian Department of Agriculture and 1,500 accessions have been collected by personnel from ICARDA in collaboration with others. Material was collected with the South Australian Dept. of Agric., from Jordan, Syria and Iraq in 1977 and from Iran and Turkey in 1978. A continuing collecting programme by ICARDA has obtained material from Jordan (1981) and from Syria (1979 through to 1982). The remainder of the accessions have come from various sources.

Three successive screening trials were used: nursery (preliminary observation rows), microplots and advanced yield trials. Material that did well in an early trial was promoted to the next stage in the evaluation.

(a) Nursery

In 77/78, 78/79 and 79/80 the accessions were planted in 5m rows with 1.25m between the rows. Regular control rows were planted but the accessions were unreplicated. (In subsequent seasons a cubic lattice design with three replications and 2.5m rows with 1.25m between rows has been used). Selections were based on visual observations.

(b) Microplots

In 79/80 and 80/81 a randomised complete block design was used with 2 replicates in 79/80 and 3 in 80/81. Plot size was $1.62m^2$ in 79/80 and $3.5m^2$ in 80/81. In 79/80 a quadrat of 35 x 35cm was sampled for yield and in 80/81 half the plot was sampled. In 81/82 a triple lattice design of 3 replicates for D.M. yield and 3 replicates for seed yield was used. The plot was $3m^2$ and all of it was harvested for yield assessment.

(c) Advanced Yield Trial (AYT)

In 80/81 the trial was planted in a randomised block design with three replicates of $21m^2$ plots. An area of $5m^2$ was harvested from each plot to assess yield. In 81/82 a triple lattice design with $24m^2$ plots with three replicates for D.M. yield and 3 replicates for seed yield was employed; $12m^2$ were harvested from each plot to assess yield.

In both the microplots and AYTs a 200-300g weighed sub-sample of the fresh material was dried in a forced draught oven at 100°C for 18-22h before reweighing in order to assess D.M. yields. Harvesting was at the end of June in every season.

Results and Discussion

The results of visual selection for vigour and dry matter yield (as judged by establishment, winter and spring growth, canopy width, leafiness and height at flowering stage) in the 1977/78 nursery plots resulted in a significant change to the original composition of the germplasm collection (Table 1). Less than half the species (11 from 32) and less than half the countries (12 from 28) represented in the nursery of 1977/78 were selected for trials in the microplots, which are the next stage in the evaluation.

A comparison of the accessions in the microplots in 1979/80 with those of the nursery, shows that there has been selection for material from Turkey and for *M. rigidula* and *M. aculeata* (Tables 2 and 3). These two species were selected from the nurseries because they often exhibit more cold tolerance and more tolerance to heat stress later in the season.

In both the 1979/80 and 1980/81 microplots, the highest yielding 10% of the material differed (in most cases significantly) in composition of species and country from the original population comprising the trial (Tables 2 and 3). *M. rigidula*, *M. aculeata* and material from Turkey were more frequent in this superior material. Accessions of *M. aculeata* differed greatly in their behaviour between the 1979/80 and 1980/81 microplot trials; accessions of *M. aculeata* were in the top 10% of the trial only in 1979/80. It is suspected that this differing behaviour is due to the more specific rhizobial requirement of *M. aculeata* and a change in the rhizobia between these two seasons. However, climatic differences between the two seasons is also a possible explanation.

There was a marked tendency for *M. rigidula* and accessions originating from Turkey to be selected as elite germplasm in successive trials (Table 4). A remarkable increase in *M. rigidula* from Turkey can be seen from the 3.8% in the 1977/78 nursery (which is more or less typical of all the nurseries) to 89% in the best performing lines of the advanced yield trials of 1981/82.

The conclusion is inescapable that M. rigidula is well adapted to the climatic zone in which the trials were conducted. An examination of the original sites from which these accessions were collected show that many of them came from S.E. Turkey. M. rigidula is the best species in Tel Hadya and almost certainly for much of the higher elevation and drier zones of the region. This would include many parts of Turkey, N. Syria, higher elevations in Jordan, N. Iraq, Iran, Afghanistan and Pakistan and in total covers an area with an enormous potential for forage production. M. rigidula is a species that hitherto has not been used as an annual medic forage crop. For example, it has not been selected in Australia even though it is present in their germplasm collections. The Australian cultivars that have been produced such as Jemalong (M. truncatulata) Harbinger (M. littoralis), Snail (M. scutellata), and Tornafield (M. tornata), are considered more suitable for the Mediterranean littoral and lower elevations. Since M. rigidula is a widespread species and is found in W. and S. Europe, the Middle East, N. Africa (Morocco and Algeria), and S.W. Asia up to Afghanistan (Townsend, 1974) there is no reason to suppose its adaptation should be so limited.

Despite the apparent superiority of M. rigidula four other species (all of them new medic forage crop species) M. aculeata, M. blancheana, M. constricta and M. noeana, on the basis of their performance in microplots, qualified for the advance yield trials. The yields of these species, with the exception of M. noeana, proved to be disappointing under the conditions of the advanced yield trials (Figures 1 and 2). M. noeana is a promising species and a limitation of material in the nursery (1% of the accessions) probably means that the true extent of its' genetic potential has not yet been revealed. Further collections of M. noeana need to be made from its area of natural distribution: S.E. Turkey, Syrian desert, N. Iraq and Iran (Davis, 1970).

Although the trend for M. rigidula from Turkey to be superior was pronounced, some other regions were represented in the best lines.

These were N. Syria, N. Iraq and N. Iran which probably differ little climatically from S.E. Turkey. Material from Syria has an obvious potential but since many of the Syrian accessions were collected recently most are still at the nursery stage or in recent microplots and have yet to reach the advanced yield trials. Further collections from Iraq and Iran would be worthwile.

These results confirm those of many previous workers (e.g. Williams et al. 1980) that variation in forage species is geographically distributed. Nurseries of differing composition need to be examined over a wide environmental range in order to exploit fully the germplasm material of ICARDA and select suitable ecotypes for all agro-climatological zones of the region. The species and countries of origin of material that will perform well in the higher elevation arid zones have already been identified. The species so identified have not previously been used as annual medic forage crops.

Acknowledgements

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References

Davis, P.H. (Ed.) (1970) Flora of Turkey and the East Aegean Islands. Vol 3. Edinburgh University Press.

Townsend, C.C. (1974) Flora of Iraq. Vol 3. Leguminales. Ministry of Agriculture and Agarian Reform, Republic of Iraq.

Williams, W.T., R.L. Burt, B.C. Pengelly and P.J. Robinson (1980) Network Analysis of Genetic Resources Data: I. Geographical Relationships. Agro-Ecosystems, 6, 99 - 109.

Table 1

Composition of Accessions in Nursery 1977/78.

Species	%	Country[1]	%	Country	%
M. aculeata	5.7*	Algeria*	10.6	Turkey*	17.5
M. blancheana	1.5*	Australia*	3.8	USA	0.3
M. constricta	2.8*	Canada	0.1	USSR*	0.3
M. coronata	0.3	Chile	0.2	Uraguay	0.1
M. disciformis	0.6	Cyprus	1.3	Yugoslavia	0.3
M. intertexta	2.1	DDR	2.5	Unknown	25.5
M. laciniata	0.6	Egypt	0.8		
M. lanigera	0.1	France	0.3		
M. littoralis	4.6*	Greece	0.8		
M. minima	1.7	Hungary	0.2		
M. murex	0.5*	Iraq	4.4		
M. muricoleiptis	0.1	Iran*	2.0		
M. noeana	0.4*	Israel*	2.3		
M. orbicularis	11.6	Italy*	1.9		
M. polymorpha	1.9*	Jordan*	6.2		
M. rigidula	8.9*	Libya*	0.8		
M. rotata	1.7*	Morocco*	7.4		
M. rugosa	1.2	Malta	0.1		
M. sauvagei	0.1	Portugal*	0.6		
M. scutellata	1.4*	Spain	0.3		
M. soleirollis	0.1	Sweden	0.1		
M. tornata	4.9	Syria*	9.7		
M. truncatulata	23.9*	Tunisia*	1.0		

* Some accessions in these categories have been selected for microplot trials.

[1] This is normally the country of origin but is, in some cases, the country where bred (e.g. Australia).

Table 2

Composition of Accessions in Microplots According to Species.

Species	% in trial 1979/80	% in 10% selected	% in trial 1980/81	% in 10% selected
M. aculeata	35.4	28.6	20.8	-
M. blancheana	3.6	3.6	4.0	-
M. constricta	-	-	4.0	7.7
M. littoralis	4.3	-	2.4	-
M. murex	-	-	0.8	-
M. noeana	-	-	8.8	-
M. polymorpha	-	-	3.2	-
M. rigidula	42.0	64.3[1]	52.0	92.3[2]
M. rotata	.4	-	0.8	-
M. scutellata	2.5	3.6	1.6	-
M. truncatulata	12.1	-	1.6	-

1979/80[1]

Increase in proportion of M. rigidula X_1^2 - 6.03^{*}

1980/81[2]

Increase in proportion of M. rigidula X_1^2 - 8.81^{***}

Table 3

Composition of Accessions in Microplots According to Country of Origin.

Country of Origin	% in trial 1979/80	% in 10% selected	% in trial 1980/81	% in 10% selected
Algeria	7.1	-	-	-
Australia	7.5	3.6	2.4	-
Iran	6.4	7.1	8.0	15.4
Iraq	5.7	-	4.8	-
Jordan	2.9	3.6	2.4	-
Morocco	5.0	3.6	-	-
Syria	7.5	7.1	9.6	15.4
Tunisia	-	-	2.4	-
Turkey	25.7	50.0[1]	49.3	69.2[2]
USSR	0.7	3.6	1.6	-
Others	4.4	-	4.8	-
Unknown	27.2	17.9	15.2	-

1979/1980[1]

Increase in proportion of Turkish accessions X_1^2 - 8.6^{***}

1980/1981[2]

Increase in proportion of Turkish accessions X_1^2 - 2.3 ns

Table 4

Percentage of *M. rigidula* and Turkish Accessions in Various Trials.

Trial		% Turkish All	% Turkish Selected[1]	% *M. rigidula* All	% *M. rigidula* Selected	% Turkish *M. rigidula* All	% Turkish *M. rigidula* Selected	No. Accessions in Trial
Nursery	77/78	17.5	-	8.9	-	3.8	-	1454
Microplots	79/80	25.7	50.0	41.4	64.3	22.1	46.4	280
Microplots	80/81	49.3	70.2	52.0	92.3	39.2	70.2	125
Microplots	81/82	36.0	92.3	64.8	100	34.4	92.3	125
AYT	80/81	57.1	75.0	83.7	100	53.1	75.0	49
AYT	81/82	72.2	88.9	91.7	100	69.4	88.9	36

[1] 10% from microplots and 25% from AYTs

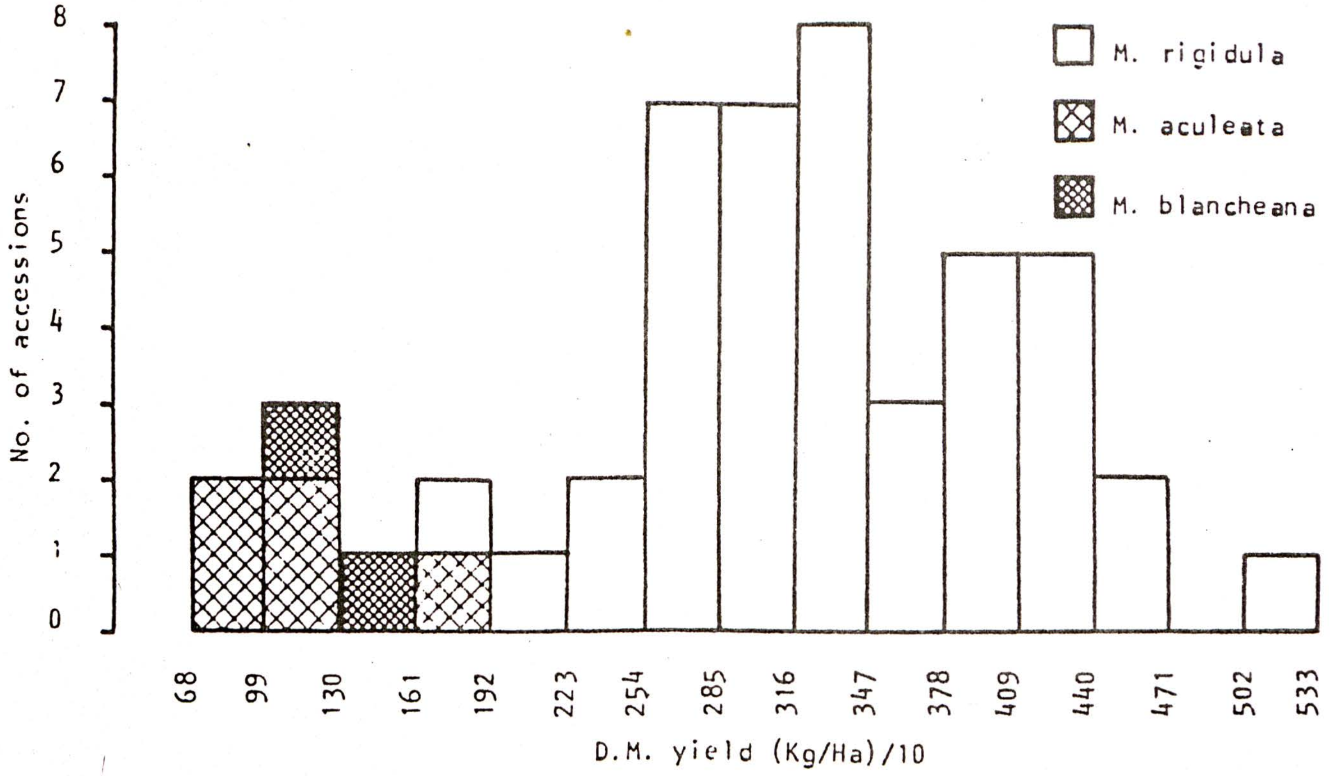

Figure 1. Distribution of Dry Matter Yield of the Accessions in the 1980/81 Advanced Yield Trial.

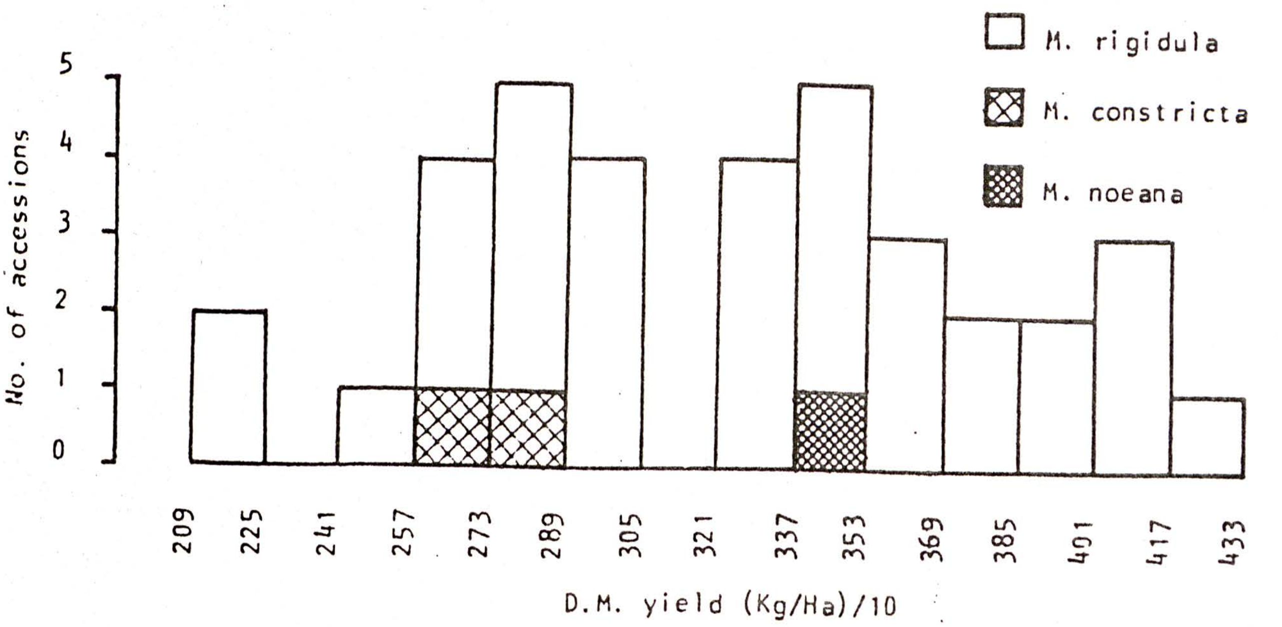

Figure 2. Distribution of Dry Matter Yield of the Accessions in the 1981/82 Advanced Yield Trial.

Evaluation of native and introduced forage grasses under rainfed conditions in Northern Syria

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INTRODUCTION

Annual and perennial grasses, many of which are native in North Africa and Middle-East, are believed to have been important components, in the past, of the vegetation of grazing lands. Decades of mismanagement and overgrazing have caused a rapid deterioration of all the natural grazing lands (Butzer, 1961; Cento, 1964; Erkun, 1964; Bobek, 1968; Pearse, 1971; Box, 1977).

However these areas are still a very substantial source of forage production, and a great part of the sheep flocks in the Region depend on rough grazing for 60-70% of their diet (Hardinson and Fox, 1973; Baillie, 1979).

In Syria it is estimated that there are 3.2 million hectares of marginal lands in the higher (> 350 mm) rainfall zone.
These marginal lands, which are rapidly deteriorating, cannot be profitably used for cropping either because of topography (hilly slopes) or soil characteristics (stony or rocky, and shallow), or a combination of both.

Perennial grasses collected in the Region, as well as commercial varieties and germplasm received from Germplasm Centers have been evaluated at Tel Hadya (30 Km South of Aleppo, Syria) in adaptation trials established in 1979 and in 1980. The objective was to evaluate attributes, such as summer dormancy, which are known to be important components of persistance under a Mediterranean type climate of a hot dry summer and cold and moist winter (Silsbury, 1961; Whalley and Davidson, 1968; Hoen, 1968; McWilliam and Kramer, 1968; Biddiscombe et al., 1977). Seasonal distribution of growth was also studied, to assess the potential of perennial grasses to fill gaps in the "feast and famine" livestock nutritional cycle.

MATERIALS AND METHODS

a) 1979 Adaptation Trial

The species included in the 1979 adaptation trial were as follows: *Agropyron cristatum*, *Agropyron desertorum*, *Agropyron elongatum*, *Agropyron intermedium*, *Agropyron libanoticum*, *Bromus inermis*, *Dactylis glomerata*, *Festuca arundinacea*, *Festuca ovina*, *Lolium perenne*, *Phalaris aquatica*, *Poa pratensis*. For each species a variable number of cultivars and/or ecotypes was grown, ranging from a minimum of 2 (*Agropyron intermedium*) to a maximum of 27 (*Dactylis glomerata*) with a total of 81 accessions. Details on the origin of all materials are given in Table 1.

Seed was sown in the field on December 3, 1979 in 1.5 m^2 plots with three rows at 25 cm distance.

Due to the large number of cultivars and/or populations and to low quantity of seed available, an augmented design (Federer, 1956) with systematic control (*Agropyron desertorum*) was adopted.

The material was not defoliated until May 1980 except that mature inflorescences were removed to prevent the establishment of new seedlings. On

September 14 and 16, 1980 scoring for summer dormancy was given by two different observers: 0 was given to the plots with no green vegetation, and 5 to plots with maximum amount of green tissues. Lower value of the score indicate therefore increasing levels of summer dormancy. Since this procedure does not strictly differentiate between dormant and dead plants, scoring for regrowth was carried out after autumn rainfalls.
Regrowth was scored on January 12, 1981 and on January 28, 1981; on both dates 0 was given to plots with no regrowth and 5 to plots with maximum regrowth.
The material included in the nursery was utilized in 1981 for seed multiplication. After seed harvesting, the plots were clipped at 5 cm height, and commencing on December 6, 1981, cuts were taken whenever herbage height reached 10-15 cm.

Yield was expressed as oven-dried weight per square meter.
The data were analyzed according to Federer (1956); the analysis for summer dormancy included an additional sum of squares which estimates the variability between the scores given by the two independent observers: this sum of squares was used as "error" term for comparisons between and within species. Broad leaf weeds were periodically removed by hand-weeding in 1981 and with an application of "Brominal Plus" in 1982. Weed grasses were only clipped but not removed.

b) 1980 Adaptation Trial

The species evaluated in the 1980 adaptation trial were as follows: Dactylis glomerata, Festuca arundinacea, Festuca ovina, Phalaris aquatica, Phalaris arundinacea, Lolium rigidum, Bromus mollis, Bromus inermis, Ehrharta calycina and 27 species and/or accessions of Agropyron sp., as shown in Table 2.

Seeds were germinated in "Jiffy" pots in a plastic-house on October 28, 1980, and the seedlings were transplanted into the field between November 19 and November 26, 1980 without irrigation. The experimental design was the balanced lattice with eight replications. In each replicate 50 plants were grown in a 1 m^2 plot, in five rows of ten plants with 20 cm between rows and 10 cm between plants.

The plants were clipped at 3 cm height whenever plant height was about 10-15 cm, six times in the first season (March 11, April 12, May 6, May 29, June 18, and July 20, 1981), and eight times in the second season (December 5, 1981, January 10, February 28, March 22, April 20, May 11, May 30, and June 28, 1982). At each cut dry matter yield per plot, and number of plants per plot were recorded. In summer 1981 summer dormancy was evaluated on six dates (July 4, July 21, August 1, August 18, September 1, and September 22) as the percentage of plants without green tissues in each plot.

On March 23, 1982 the percentage of growing plants per plot was taken as a measure of percentage survival that was then used to adjust the percentage dormancy scored in the previous summer by removing the percentage of dead plants.

Weeds were controlled as described for the 1979 adaptation trial, and no fertilizer was applied.

Both adaptation trial were grown under rainfed conditions. Rainfall and maximum and minimum temperatures between October 1980 and June 1982 are given in Table 3.

RESULTS AND DISCUSSION

a) 1979 Adaptation Trial

The mean score for summer dormancy (September 1980), winter regrowth in

January 1981, and dry matter yield in the winter of 1981/82, are given in Table 4 for the twelve species of perennial grasses. The species showed marked differences for summer dormancy, although a high variability was also observed within species, as for example in F. arundinacea, F. ovina and A. elongatum. The two more extreme species were P. aquatica, with all cultivars and ecotypes highly summer dormant, and B. inermis with all cultivars and ecotypes maintaining green leaves throughout most of the summer. B. inermis showed little regrowth after the first summer, and no regrowth after the second, while P. aquatica was amongst the more actively growing species in the first winter (1980/81) and definitely the most productive in the second (1981/82). Only two species (D. glomerata and F. ovina) were able to show early winter regrowth (Dec. 6, 1981). Although quantitatively not impressive, this early winter production is very important, as it coincides with a period of severe shortage of animal feed.

Generally the regrowth in both the first and the second winter seems to be related with the level of summer dormancy. The correlation coefficients between the species means for the two attributes (Table 5) show that the species with a higher level of summer dormancy (low score) tend to have a more active winter regrowth (high score).

However, a higher level of summer dormancy is not necessarily associated with early winter regrowth, as shown by the correlation coefficient (- .07 n.s.) between summer dormancy and dry matter yield on Dec. 6, 1981.

The variability within species was analyzed in some detail in D. glomerata, for which a higher number of populations (27) was available. Both summer dormancy and winter regrowth appear to be related to the geographical origin of the cultivars and/or ecotypes (Table 6). The ecotypes collected in Syria and Jordan were more summer dormant and regrew more actively in winter than the foreign cultivars and the ecotypes from Turkey..

The differences in summer dormancy between foreign varieties and local ecotypes of D. glomerata was also studied by measuring leaf elongation rate (Fig. 1). At the end of the spring, a summer active population has a much higher leaf elongation rate than a summer dormant population. It would appear that this is the period of the year when a summer dormant type begins to "switch off". Other data (see table 8) show that at the end of the spring there is a decline in the productivity of a summer dormant type, as compared with a summer active type.

A high variability was observed among the twelve ecotypes collected in Syria. The collection sites of these ecotypes range from 280 mm to 1000 mm of total annual rainfall. The distribution of the collection sites is however discontinuous as no ecotypes were collected in the interval 450 mm - 700 mm rainfall.

The ecotypes collected at sites with 450 mm rainfall or less, were therefore compared with those collected at sites with 700 mm rainfall or more (Table 7).

The ecotypes of D. glomerata collected from lower rainfall sites were more summer dormant than those collected from higher rainfall areas. The more summer dormant ecotypes were also more actively growing both in the first and in the second winter after sowing.

The results obtained in 1980/81 by scoring for both summer dormancy and winter regrowth appear to agree closely with the dry matter yields in 1981/1982. On June 2, 1982 all ecotypes were still growing, but those collected in higher rainfall areas were significantly more productive than those collected in lower rainfall areas. These data suggest that towards the end of the spring the ecotypes collected from lower rainfall areas are already entering into a stage of very limited growth which likely preceeds the stage of complete dormancy.

This is confirmed by the data on leaf elongation rates of two ecotypes which were collected from two sites in different rainfall zones (Fig. 2). The rate of leaf elongation in the ecotype collected in a site with 1400 mm rainfall was nearly 5 times higher than in the population collected in a site with 280 mm rainfall.

b) 1980 Adaptation Trial

The seasonal distribution of growth of the most productive cultivars or accessions of the perennial grasses evaluated in the 1980 adaptation trial, is given in Table 8. The pattern of growth, with the maximum yield in spring and a second peak in winter is also a common feature of the less productive species.

More active growth coincides with that period of the year when neither moisture nor temperature can be considered limiting factors. At other times the main climatic constraints appear to be low temperature in winter, and both high temperature and drought in summer and autumn. Early in summer some additional growth is possible on residual moisture, and this varies both between and within species, depending on the summer dormancy of the accession and the rainfall distribution. Table 8 also shows that, in agreement with the results of the 1979 adaptation trial, P. aquatica is the most productive perennial grass tested to date, and "Sirosa" appears to be the most productive cultivar.

In addition to high spring productivity, P. aquatica also has a comparatively high winter production, which is a highly desirable attribute in view of the scarce availability of animal feed in this period of the year.

A few species, such as F. arundinacea, A. varnense, A. intermedium, and A. cristatum are capable of growing early in the summer; however only

A. cristatum is able to combine summer growth with autumn regrowth, but its total productivity is low compared with the best cultivars of P. aquatica. Agropyron dasystachyum (not included in the Table) also showed the ability to grow in summer and autumn, but its productivity was even lower (375.3 g/m^2 as total of two years) than A. cristatum.

Two other species characterized by early regrowth after summer are D. glomerata (the ecotype collected in Syria) and A. desertorum. Both these species however, as well as other Agropyron species, may prove difficult to establish, as indicated by the slow growth at the beginning of the experiment.

F. arundinacea showed a very satisfactory growth in the establishment year, and one accession (U.S.S.R. n°16) had a long growing season. The productivity of this species decreased sharply in the second year, and due to the relatively high mortality (see Table 9), it is expected to decline further in the third year.

The decline in productivity in the second year was a general feature of all species, and it varied greatly both between and within species. In P. aquatica it ranged from 3.8% (cv. Seedmaster) to 29% (cv. Sirocco); in F. arundinacea from 40.8% (U.S.S.R. n. 15) to 48.8% (cv. Demeter), and in D. glomerata from 16.0% (ecotype from Syria) to 92.3% (cv. Potomac).

Part of the decline in productivity has to be attributed to the low temperature in March 1982 (see Table 3) which limited plant growth when productivity is usually near its maximum.

The data on summer dormancy and on mortality after the first summer are given in Table 9. A high variability was observed, both between and within species, for the final levels of summer dormancy, as well as for the time at which a cultivar becomes dormant. In P. aquatica, for example, the cultivar Sirocco becomes dormant much earlier than the other cultivars, and has a higher percent of summer dormant plants by the end of September.

These differences, however, are not reflected in the levels of mortality.

In D. glomerata, the ecotype collected in Syria, has an earlier and higher level of summer dormancy than the three introduced cultivars, as already found in the 1979 adaptation trial. In this species there is a direct relationship between the final level of summer dormancy and the percent mortality in March 1982.

Table 9 also shows that similar levels of dormancy led to different percent mortality in different species. For example, F. arundinacea (U.S.S.R. n. 16) and A. desertorum, with a percent dormancy on September 22 of 14.8% and 14.5%, have a percent mortality of 45.9% and 10.5%, respectively. This suggests that, although important for survival, summer dormancy is only one of the adaptive strategies which enable a plant to persist under dry conditions. Also it must be mentioned that for some species of perennial grasses a rapid decline in survival is expected only after the second summer.

In general a negative and significant correlation was found between summer dormancy and mortality (Tab. 10). The correlation coefficients also indicate that the higher the summer dormancy late in the summer, the lower is the mortality.

CONCLUSIONS

The results of two adaptation trials with introduced and native perennial grasses have shown that attributes which are of adaptive importance, such as summer dormancy, are related to the geographic origin of the materials, as found in other studies (Clausen and Hiesey, 1958; Silsbury, 1961, 1964; Cooper, 1963; Cooper and Mc William, 1966; Knight, 1966; Sankary et al. 1969; Lorenzetti and Falcinelli, 1976; Panella et al., 1976; Falcinelli and Ceccarelli, 1977).

In an environment where low rainfall is limited to the winter season, a high degree of dormancy is, for many species, an efficient adaptive mechanism which enables the plants to survive through the summer. As rainfall increases, a lesser degree of dormancy is required for survival because moisture is available for a longer period of time. The ecotypes collected from higher rainfall areas are expected to be more productive in their area of adaptation. When they are grown in drier areas they are expected to maintain their superiority in the establishment year due to their longer growing period. Subsequently, as an effect of the environmental stresses, they show a much higher mortality, and a decline in productivity mainly due to their late regrowth in winter.

The differences in the timing of regrowth in winter are likely to be associated with the utilization of the carbohydrate reserves as found by Arcioni et al., (1980). The more summer active ecotypes continue to utilize carbohydrate reserves late in the spring and early in the summer, when photosynthesis is presumably limited by stomatal closure and low leaf water potential. At the beginning of the rainy season, with low levels of carbohydrate supply in the roots or in reserve organs, the regrowth of these ecotypes is much slower compared with summer dormant ecotypes.

These information on the growth pattern of various locally collected ecotypes provide guidelines for making germplasm collections when particular attributes are required. For D. glomerata it would appear that a desirable attribute such as early regrowth can more frequently be found in populations collected from low rainfall areas.

In general the results have shown the unique ability of some perennial grasses to produce some forage yield for grazing early in winter, which represents one of the major nutritional gap in animal feed availability. In some species (e.g. D. glomerata) this ability is related to the degree of summer dormancy which permits a deferred utilization of carbohydrate reserves until the end of the dry period. In other species, such as P. aquatica, high levels of summer dormancy are not necessarily associated with an early winter regrowth; in general, however, higher levels of summer dormancy are related to higher dry matter yield in winter.

The assessment of the agronomic value of the materials as pasture species constitutes another part of this study. Both adaptation trials and grazing trials established in 1980 are confirming that P. aquatica and D. glomerata are in fact among the most productive perennial grasses evaluated to date in the study area.

The results of this study also underlined the importance of the variability within species when assessing the potential value of a perennial grass. For a particular climatic zone conclusion on the adaptation of a species can be misleading if it is based only on the observation of few, not adapted, populations.

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REFERENCES

Arcioni, S., Mariotti, D., Falcinelli, M., and Ceccarelli, S., 1980: Relationship between ecological adaptation and carbohydrate reserves evolution for two different varieties of Lolium perenne L. Ann. Amel. des plantes, 30 (3), 309-319.

Baillie, D.M., 1979: Final Report to the Ministry of Agriculture and Agrarian Reform, Vol. I, 1-130.

Biddiscombe, E.F., Rogers, A.L., and Maller, R.A., 1977: Summer dormancy, regeneration and persistence of perennial grasses in South-Western Australia. Aust. J. Exp. Agric. and Anim. Husb., 17, 795-801.

Bobek, H., 1968: Cambridge history of Iran. Vol. I University Press. Cambridge p. 280.

Box, T.W., 1977: Potential of Arid and Semi-arid Rangelands for Ruminant Animal Production. In "Potential of world Forages for Ruminant Animal Production", Winrock International Research and Training Center, Morillton, Arkansas, pp. 81-92.

Butzer, K.W., 1961: A history of lande use in arid climates; climatic change in arid regions since the pliocene. UNESCO. Paris p. 31.

Cento, 1964: Travelling seminar on range management. Cento Ankara.

Clausen, J., and Hiesey, W.M., 1958: Experimental studies on the nature of species. IV. Genetic structure of ecological races. Carnegie Inst. Wash. Publ. 615; 1.

Cooper, J.P., 1963: Spe ies and population differences in climatic response. pp. 381-404. In Evans (ed), Environmental control of plant growth. Academic Press, New York.

Cooper, J.P., and Mc William, J.R., 1966: Climatic varation in forage grasses. II. Germination, flowering and leaf development in mediterranean populations of Phalaris tuberosa. J. Appl. Ecol., 3: 191-212.

Erkun, 1964: Investigation on Bala Country grazing lands. Typescript, unpublished. Ankara.

Falcinelli, M., and Ceccarelli, S., 1976: Seasonal productivity and persistence of grass varieties in Central Italy. Proc. 13th Int. Grassland Congr., 251-258.

Federer, W.T., 1956: Augmented designs. Hawaii Planters, Record 55, 191-208.

Hardinson, W.A., and Fox, C.W., 1973: Present livestock situation in the Near East and the possibility of developing integrated crop livestock farming system: ALAD, Ford Foundation, Beirut, Lebanon, 1-14.

Hoen, K., 1968: Summer dormancy in Phalaris tuberosa L. Aust. J. Agric. Res., 19, 227-239.

Knight, R., 1966: The growth of cooksfoot (Dactylis glomerata L.) in a winter-rainfall environment. Proc. 10th Int. Grassland Congr., 308-311.

Lorenzetti, F., and Falcinelli, M., 1976: Valutazione di specie e varietà e direttive per il miglioramento genetico di graminacee foraggere per i pascoli asciutti dell'Italia centrale. Riv. di Agron. 10, 94-101.

Mc William, J.R., and Kramer, P.J., 1968: The nature of the perennial response in mediterranean grasses. I. Water relations and summer survival in Phalaris. Aust. J. Agric. Res. 19: 281-285.

Panella, A., Lorenzetti, F., and Ceccarelli, S., 1976: Growth rhythm and productivity of differently adapted types of forage species. Report of Eucarpia Fodder Crops Section Meeting, Roskilde 7-9 Sept., 1970, 11-18.

Pearse, C.R., 1971: Grazing in the Middle East: Past, Present and Future. Journ. Range Manag.24, 13-16.

Sankary, M.N., Laude, H.M., Love, R.M., and Fox, R.E., 1960: Variation in summer dormancy among collections of Phalaris tuberosa at Davis, California. J. British GRass. Soc. 24, 134-137.

Silsbury, J.M., 1961: A study of dormancy, survival and other characteristics in Lolium perenne L. at Adelaide. S.A. Aust. J. Agric. Res. 12, 1-19.

Silsbury, J.H., 1964: Tiller dynamics, growth and persistancy of Lolium perenne L. and of Lolium rigidum Gaud. Aust. J. Agric. Res. 15, 9-20.

Whalley, R.D.B., and Davidson, A.A., 1968: Physiological aspects of drought dormancy in grasses. Proc. Ecol. Soc. Aust. 3, 17-19.

Table 1. Species and ecotypes of perennial grasses evaluated at Tel Hadya (Syria) in 1979-82

Species	Cultivar or origin	Country
Agropyron cristatum	Fairway	Canada
" "	Parkway	"
" "	comm.seed	"
" "	loc.coll.	Turkey
Agropyron desertorum	Summit	Canada
" "	Nordan	U.S.A.
" "	comm.seed	unknown
Agropyron elongatum	unknown	W.Germany
" "	loc.coll.	Turkey
" "	Orbit	Canada
Agropyron intermedium	Chief	Canada
" "	loc.coll.	Turkey
Agropyron libanoticum	" "	Syria
" "	" "	"
" "	" "	"
" "	" "	"
Bromus inermis	" "	Turkey
" "	Beacon	Canada
" "	Carlton	"
" "	Redpatch	"
" "	Tempo	"
" "	Manchar	U.S.A.
" "	unknown	W.Germany
Dactylis glomerata	Napier	Canada
" "	Chinook	"
" "	Majestic	"
" "	Rideau	"
" "	Kay	"
" "	Currie	Australia
" "	"	"
" "	Hera	W.Germany
" "	Phyllox	"
" "	loc.coll.	Syria
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	"

Table 1. (contd.)

Species	Cultivar or origin	Country
Dactylis glomerata	loc.coll.	Syria
" "	" "	"
" "	" "	"
" "	" "	Jordan
" "	" "	"
" "	" "	"
" "	" "	"
" "	" "	Turkey
" "	" "	"
Festuca arundinacea	Demeter	Australia
" "	Fawn	U.S.A.
" "	Nutex	"
" "	K 31	"
Festuca ovina	loc.coll.	Syria
" "	" "	"
" "	" "	"
Lolium perenne	" "	"
" "	Kangaroo	Australia
" "	Victoria	"
" "	Semperweide	W.Germany
" "	Verna	Denmark
Phalaris aquatica	El Golea	Australia
" "	Sirocco	"
" "	"	"
" "	Sirosa	"
" "	Sirolan	"
" "	unknown	"
" "	loc.coll.	Syria
" "	" "	"
" "	" "	"
Poa pratensis	" "	Turkey
" "	Enprima	Netherlands
" "	Baron	"
" "	Entopper	"
" "	Campus	"
" "	Berbi	-
" "	SK 46	Poland
" "	Delft	Netherlands
" "	Nuturf	-

Tab. 2 - Species and ecotypes of annual and perennial grasses evaluated at Tel Hadya (Syria) in 1980-82

Species	Cultivar or origin	Country	Species	Cultivar or origin	Country
Dactylis glomerata	loc. coll.	Syria	Agropyron desertorum	collection	U.S.A. (N.Dakota)
" "	Phyllox	W.Germany	" imbricatum	"	Iran
" "	Porto	Australia	" curvifolium	"	Spain
" "	Potomac	"	" inerme	"	U.S.A. (Utah)
Festuca arundinacea	Demeter	"	" acutum	"	U.S.S.R.
" "	collection	U.S.S.R.	" campestre	"	France
" "	"	"	" caespitosum	"	U.S.S.R.
" "	"	"	" spicatum	"	U.S.A. (Washington)
" "	"	"	" "	"	" "
" "	"	"	" smithii	"	" (Wyoming)
Festuca ovina	"	U.S.A.(Oregon)	" taurii	"	Iran
Phalaris aquatica	Sirocco	Australia	" stipifolium	"	U.S.S.R.
" "	Australian	"	" intermedium	"	Australia
" "	Seedmaster	"	" nodosum	"	U.S.S.R.
" "	Sirosa	"	" tricophorum	"	Iran
Phalaris arundinacea	collection	U.S.S.R.	" varnense	"	unknown
" "	"	"	" pectiniforme	"	U.S.S.R.
" "	"	"	" sibiricum	"	"
Lolium rigidum	Wimmera	Australia	" podperae	"	Iran
Bromus mollis	Blando	-	" scythicum	"	U.S.S.R.
Bromus inermis	collection	unknown	" libanoticum	"	Iran
Ehrharta calycina	Mission	Australia	" cristatum	"	Australia
Agropyron elongatum	collection	U.S.S.R.	" "	"	U.S.S.R.
" dasystachyum	"	U.S.A. (Idaho)	" "	induced tetraploid	
" ferganense	"	U.S.S.R.			

Table 3 - Climatic data at Tel Hadya (30 Km south of Aleppo, northern Syria).

Month	1979-80 Air temperature Max (C°)	1979-80 Air temperature Min (C°)	1979-80 Rainfall mm	1980-81 Air temperature Max (C°)	1980-81 Air temperature Min (C°)	1980-81 Rainfall mm	1981-82 Air temperature Max (C°)	1981-82 Air temperature Min (C°)	1981-82 Rainfall mm
October	27.0	14.0	63.9	28.0	12.7	10.6	29.4	12.2	4.6
November	20.6	9.7	55.8	20.6	6.9	17.4	16.9	5.5	69.4
December	12.0	4.0	71.3	14.0	3.6	93.0	14.5	5.2	55.6
January	8.5	1.8	53.3	11.6	3.8	69.8	11.5	2.4	56.5
February	12.4	3.3	41.5	14.1	3.0	55.3	11.3	-0.6	45.5
March	16.0	6.4	68.1	18.6	6.4	51.8	16.5	2.3	28.4
April	21.1	8.8	59.3	16.7	4.8	26.3	23.8	9.7	51.9
May	28.8	12.0	10.4	26.7	9.6	31.9	28.3	12.2	23.6
June	35.3	18.0	0.4	33.8	17.1	14.8	33.8	15.8	2.0
July	37.5	22.7	0.0	37.4	20.0	0.4			
August	35.9	22.3	0.0	36.6	20.8	0.0			
September	32.4	17.9	0.0	35.5	16.4	0.0			
Total			424.0			371.3			(337.5)
N° of frost days				23			39		
Absolute minimum (C°)				-4.0 (Nov. 24)			-7.8 (Feb. 17)		

Table 4- Summer dormancy, winter regrowth in 1980-81, dry matter yield on December 6, 1981 and total dry matter yield in the period December 1981 - March 1982 of 12 species of perennial grasses.

Species	Number of cultivars and/or ecotypes	Summer dormancy (0=dormant 5=green) Sept.15,1980	Winter Regrowth (0=min; 5=max)		Dry matter yield (g/m^2)		N° of cultivars and/or ecotypes actively growing by March 1982
			Jan.12,1981	Jan.28,1981	Dec.6,1981	Winter'81-'82	
Phalaris aquatica	9	0.8±0.1	2.6±0.3	3.9±0.3	0.0	205.6±27.3	9
Lolium perenne	5	0.3±0.1	0.6±0.2	0.8±0.4	0.0	6.3	1
Poa pratensis	9	1.3±0.3	1.1±0.1	1.1±0.1	0.0	0.0	0
Bromus inermis	7	4.4±0.2	0.7±0.3	1.1±0.1	0.0	0.0	0
Festuca arundinacea	4	3.1±0.8	1.5±0.5	2.3±0.5	0.0	14.0±11.1	2
Festuca ovina	4	2.8±1.2	3.0±0.8	3.5±0.9	6.9	95.5±20.1	4
Dactylis glomerata	27	1.6±0.2	2.4±0.3	3.1±0.3	9.1±2.6	91.7±17.7	18
Agropyron cristatum	4	2.3±0.5	2.8±0.6	3.5±0.9	0.0	10.3± 6.3	2
Agropyron libanoticum	4	2.1±0.5	2.3±0.3	2.8±0.3	0.0	46.1±19.7	4
Agropyron elongatum	3	2.5±0.8	2.7±0.3	4.0±0.6	0.0	56.5	1
Agropyron desertorum	3	1.2±0.4	3.3±0.3	4.1±0.1	0.0	31.5± 6.7	3
Agropyron intermedium	2	1.8±0.3	2.0±1.0	3.0±1.0	0.0	70.2±38.0	2

Table 5 - Simple correlation coefficients between summer dormancy and winter regrowth in ten perennial grasses.

	Summer dormancy
Winter regrowth (Jan.12, 1981)	-.71*
Winter regrowth (Jan.28, 1981)	-.78**
Dry matter yield (Dec.6, 1981)	-.07
Tot. dry matter yield (Dec.'81 - March '82)	-.64*

* $P < 0.05$; ** $P < 0.01$

Table 6 – Summer dormancy, winter regrowth in 1980–81, dry matter yield on December 6, 1981, and total dry matter yield in the period December 1981 – March 1982 of 27 populations of *Dactylis glomerata* of different origin.

Origin	Number of popul.	Summer dormancy (0=dormant; 5=green) Sept.15,'80	Winter regrowth (0=min; 5=max)		Dry matter yield (g/m^2)	
			Jan.12,'81	Jan.28,'81	Dec.6, '81	Dec.'81 – March '82
Foreign cultivars	9	2.6b	1.2b	1.4b	0.0b	2.1b
Syria	12	1.1a	3.0a	4.1a	14.1a	141.7a
Jordan	4	0.5a	3.8a	4.3a	19.2a	186.5a
Turkey	2	2.5b	1.0b	3.0b	0.0b	5.7b

Means followed by the same letter are not significantly different ($P<0.05$) based on t-test

Table 7 - Summer dormancy, winter regrowth in 1980-81, dry matter yield on December 6, 1981, total dry matter yield in the period December 1981 - March 1982, and dry matter yield on June 2, 1982 of 12 ecotypes of *Dactylis glomerata* grouped according to rainfall of the collection site.

Rainfall	Number of popul.	Summer dormancy (0=dormant; 5=green) Sept.15,'81	Winter regrowth (0=min; 5=max)		Dry matter yield (g/m^2)		
			Jan.12,'81	Jan.28,'81	Dec.6,'81	Dec.'81-March'81	June 2,'81
450 mm or less	7	0.6	3.9	4.6	22.6	178.9	4.5
700 mm or less	5	1.9	1.8	3.4	2.1	89.6	14.4
d		-1.3*	2.1*	1.2*	20.5**	89.3**	-9.9**

*P < 0.05; **P < 0.01

Table 8 - Seasonal distribution of growth of 14 perennial grasses in two growing seasons under rainfed conditions (g/m^2)

Species	Cultivar or Origin	Winter '80-'81	Spring '81	Summer '81	Autumn '81	Winter '81-82	Spring '82	Summer '82	Total
Phalaris aquatica	Sirosa	46.0b	605.2a	0.0d	0.0d	158.1a	310.2a	3.3d	1122.8a
" "	Australian	45.6b	539.8b	0.0d	0.0d	98.8c	337.3a	5.1c	1026.7b
" "	Sirocco	76.8a	484.9b	0.0d	0.0d	175.6a	221.2c	2.0d	960.6b
" "	Seedmaster	32.5b	443.5c	0.0d	0.0d	136.9b	316.5a	4.3c	933.7b
Festuca arundinacea	Demeter	38.1b	470.5b	0.0d	0.0d	65.8d	177.1c	17.3a	768.8c
Agropyron varnense	unknown	0.0d	426.4c	24.3b	0.0d	90.9c	190.4c	9.0c	740.9c
" acutum	U.S.S.R.	0.0d	389.2c	0.0d	0.0d	91.9c	248.7b	8.3c	738.2c
Festuca arundinacea	" (n° 16)	35.4b	356.1d	29.9a	0.0d	37.2e	175.8c	21.3a	655.7d
Agropyron intermedium	Australia	0.0d	363.0d	22.0b	0.0d	61.7d	164.7d	10.4b	621.8d
" desertorum	U.S.A.	0.0d	318.9d	0.0d	14.8a	98.5c	161.4d	11.9b	605.5d
Festuca arundinacea	U.S.S.R.(n° 15)	27.4c	349.7d	0.0d	0.0d	54.0d	152.5d	16.9a	600.5d
Dactylis glomerata	Syria	0.0d	322.8d	0.0d	9.2b	79.6c	179.7c	2.8d	594.0d
" "	Porto	46.9b	323.2d	0.0d	0.0d	32.5e	102.2e	14.7b	519.5e
Agropyron cristatum	ind. tetraploid	0.0d	279.9e	15.0c	5.5c	56.7d	108.0e	5.5c	470.7f

Means followed by the same letter are not significantly different based on Scott-Knott test

Table 9 - Percent summer dormancy at six different dates in 1981, and percent mortality on March 23, 1982 in 16 perennial grasses

Species	Cultivar or Origin	% dormancy July 4	July 21	Aug. 9	Aug. 18	Sept. 9	Sept. 22	% mortality March 23,1982
Phalaris aquatica	Sirosa	8.0b	11.8c	19.3c	28.1c	32.7d	63.0b	6.9d
" "	Australian	5.3c	9.4c	13.0c	19.7c	28.1d	63.6b	7.5d
" "	Seedmaster	5.5c	7.2c	9.4d	21.9c	28.8d	70.8b	4.1d
" "	Sirocco	58.8a	62.5a	74.0a	79.3a	83.8a	91.6a	0.0d
Dactylis glomerata	Syria	12.7b	27.6b	31.9b	63.1b	66.4b	85.2a	1.2d
" "	Phyllox	0.2d	0.3d	0.8e	1.7e	4.8f	10.8d	82.5a
" "	Porto	0.2d	1.0d	5.6d	11.8d	17.6e	40.4c	38.9b
" "	Potomac	0.0d	0.0d	0.3e	1.6e	1.9f	11.7d	86.0a
Festuca arundinacea	Demeter	0.0d	0.0d	0.0e	0.1e	1.0f	6.5d	41.4b
" "	U.S.S.R.(n° 15)	0.1d	0.3d	0.4e	2.3e	3.6f	9.2d	46.5b
" "	" (n° 16)	0.1d	0.2d	0.3e	1.6e	2.5f	14.8d	45.9b
Agropyron varnense	unknown	0.3d	2.3d	5.7d	15.7c	27.5d	61.1b	11.0c
" acutum	U.S.S.R.	0.4d	1.0d	2.8e	12.5d	18.4e	40.0c	18.9c
" intermedium	Australia	0.7d	4.8c	16.0c	34.1c	41.2c	61.9b	20.2c
" desertorum	U.S.A.	0.5d	0.7d	0.7e	2.1e	5.2f	14.5d	5.8d
" cristatum	ind. tetraploid	1.8d	2.3d	3.8e	11.7d	19.8e	43.1c	10.5c

Means followed by the same letter are not significantly different based on Scott-Knott test

Table 10 - Correlation coefficients between summer dormancy (scored six times from July 4, 1981 to September 22, 1981) and % mortality on March 23, 1982 in 47 perennial grasses.

			% mortality March 23, 1982
Summer	dormancy	July 4,1981	-.30*
"	"	" 21,1981	-.36*
"	"	Aug. 9,1981	-.39**
"	"	" 18,1981	-.51**
"	"	Sept. 1,1981	-.57**
"	"	" 22,1981	-.68**

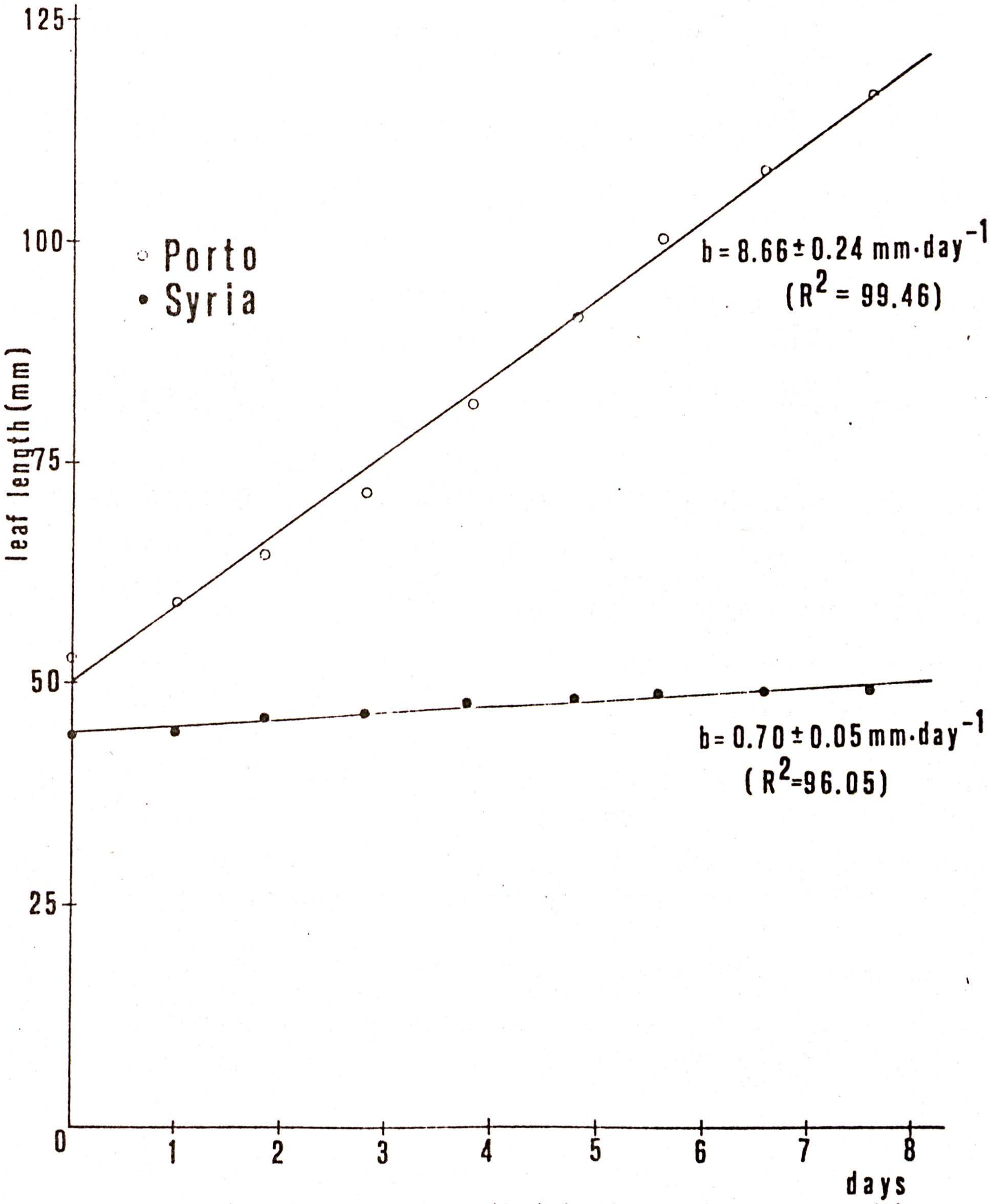

Fig. 1 - Leaf elongation rate (mm/day) in the cultivar Porto and in a ecotype from Syria of Dactylis glomerata between May 28 and June 5, 1982

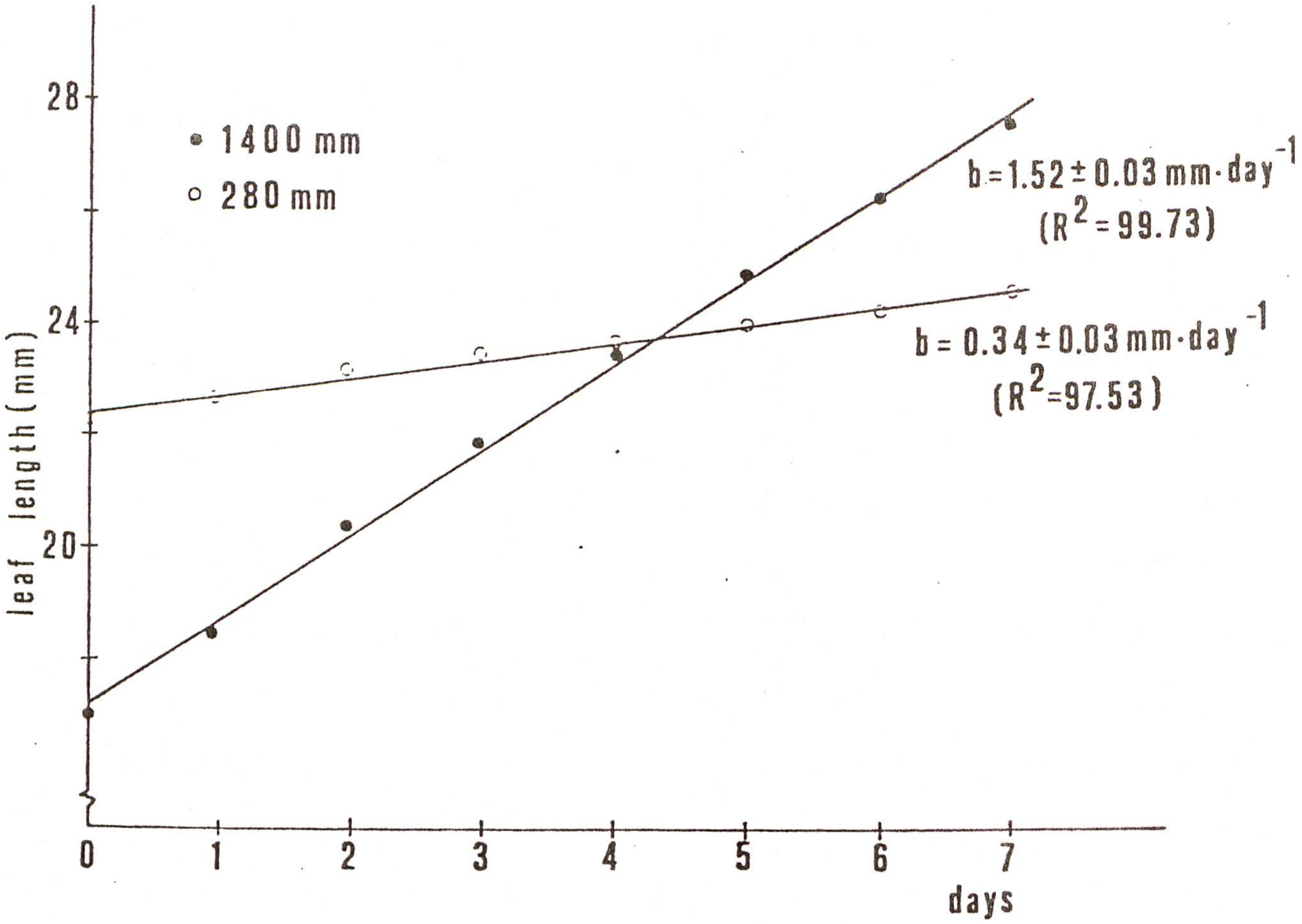

Fig. 2 - Leaf elongation rate (mm/day) in two ecotypes of *Dactylis glomerata* collected in Syria in two different rainfall zones (June 12 - June 19, 1982)

VARIATION IN RESPONSE TO DROUGHT OF POPULATIONS OF FOUR TEMPERATE GRASS SPECIES

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INTRODUCTION

Variation in rainfall during the growing season is the main cause of year-to-year differences in dry matter yields of grass swards in Britain (Morrison, Jackson & Williams, 1974; Aldrich, 1977). Consequently, tolerance of drought and subsequent recovery growth are important aims in pasture breeding (Wilson, 1976).

This paper summarises the results of a number of field and glasshouse studies of the responses to drought of *Lolium perenne*, *L.multiflorum*, *Dactylis glomerata* and *Festuca arundinacea*. Differences between and within the species in dry matter yield, in growth components (leaf and tiller production) and in physiology are described.

DRY MATTER PRODUCTION

During severe drought, when herbage yields are reduced to less than half of 'normal yields' in irrigated plots or during wet years, absolute differences between grass species are small. For example, Hughes *et al*. (1977) measured a range of only 0.4-0.8 t DM ha^{-1} ('normal', 4 t DM ha^{-1}) and Garwood *et al*. (1979) a range of 0-0.2 t DM ha^{-1} ('normal' 1 t DM ha^{-1}). When drought ends, however, and growth resumes the range is far greater: 0.3-2 t DM ha^{-1} (Hughes *et al*., 1977), 0-1.5 t ha^{-1} (Garwood *et al*., 1979).

Differences between species

The ranking of these species for recovery growth in field trials is generally found to be *D.glomerata* > *F.arundinacea* > *L.perenne* > *L.multiflorum* (Fig. 1). There is usually a resonable correlation between herbage mass during drought and subsequent recovery (Fig. 1). These species differences are also observed when plants are grown under simulated drought in the glasshouse (Thomas & Norris, 1982a,b).

Variation within species

It is difficult to generalise from field trials the differences in drought response within species, because there are strong interactions with cutting height and frequency. In *L.multiflorum*, for example, Hughes *et al*. (1977) found that Bb 1277, an ecotype from N.Italy, produced only half as much herbage as the cultivar Titania under infrequent cutting, but three times more under frequent cutting. Initial screening is therefore best carried out under the more controlled conditions of the glasshouse.

In a glasshouse experiment on the four species mentioned in the introduction, Norris & Thomas (1982b) imposed water shortage on named cultivars bred in moist climates and on natural populations from dry habitats in southern Europe. Xerophytic types were little affected by drought, but growth of the more mesophytic cultivars was significantly reduced. Unfortunately the xerophytic types were of little agronomic use because they grew very slowly, presumably a means of drought avoidance.

An encouraging finding was that some populations of *L.multiflorum* collected from Northern Italy by WPBS Plant

Introduction Unit grew more rapidly than existing cultivars under both moist and dry conditions (Table 1). Survivors from a third cycle of severe simulated water stress are at present being crossed and will be evaluated in 1983.

Considerable variation also exists between perennial ryegrass populations: in July 1975, which was very dry, B.F. Tyler (personal communication) measured herbage yields ranging from 56 kg ha^{-1} in a population from N.W. Europe to 1247 kg ha^{-1} in a Polish population.

GROWTH COMPONENTS

The first obvious indication of drought in grasses is a reduction in leaf extension rate, followed by deceleration of tillering and leaf appearance (Norris, 1982); leaves become shorter and specific leaf weight (wt lamina / area lamina) increases. Water soluble carbohydrate reserves in shoot bases first increase, then decline (Malaoui, 1981). Recovery growth, if the drought has not been too severe, is associated with accelerated leaf extension, leaf appearance and tillering.

Species differences

In a field experiment Norris (1982) found only small differences between species in the effects of drought on rate of leaf expansion. In cocksfoot, however, leaf appearance rate and tillering were far less sensitive to drought than in the other species - indeed, in one cocksfoot variety, tiller numbers were almost doubled by stress. When *L.multiflorum* and *L.perenne* were compared in a more detailed glasshouse experiment, *L.perenne* regrew the more rapidly after drought, and this was associated with better survival of tillers during drought, and with faster tillering and leaf production after re-watering (Norris & Thomas, 1982a).

Variation within species

Norris (1982) found large differences in the response of L.multiflorum x perenne hybrids to irrigation. In Bx 157, for example, irrigation increased leaf extension rate from 8 to 17 mm d^{-1}, but in the closely related cultivar Snowdon irrigation increased extension only slightly, from 8 to 9 mm d^{-1}. Glasshouse studies of a range of L.multiflorum hybrids (Norris & Thomas, 1982b) have shown that recovery growth is related to the rate of leaf extension.

PHYSIOLOGICAL VARIATION

Although, as we have seen above, very large differences already exist between and within grass species in their sensitivity to water stress, the mechanisms are as yet only partly understood. Whilst simple screening techniques can detect genotypes which appear to have drought resistance under a restricted range of conditions, a more satisfactory approach is to carry out selection on the basis of more basic physiological measurements. There are two complementary ways of doing this. In the analytical approach physiological mechanisms in genotypes already selected can be compared. In the ideotype approach, selection is carried out for characters presumed to confer drought resistance, and the effectiveness of this is assessed under stress. It is also possible to use a drought resistant species (e.g. D.glomerata) as a 'model' of ways in which a susceptible species may be improved.

Exploration for water

Where there are untapped water reserves in the lower soil horizons, breeding for deep roots may help to delay the onset of water shortage. The relatively deep root systems of *F.arundinacea* (Garwood *et al.*, 1979) and of *Festuca pratense* x *L.perenne* (O'Brien *et al.*, 1967) have been found to confer drought resistance. Both root length and nodal root production are under genetic control (Troughton, 1978; Troughton & Whittington, 1968).

A massive root system is not always advantageous, however. For example, in a comparison of young cocksfoot and ryegrass plants grown without water on soil columns 75 cm deep (Thomas, unpublished), cocksfoot grew for a much longer period than ryegrass, and had greater water use efficiency, because its root system explored the soil volume more gradually and extracted water more slowly (Table 2).

Control of evaporation

Restriction of water absorption by roots is likely to lead to water stress in shoots when evaporation exceeds uptake. A more effective method of water conservation is to control water loss through reduced leaf conductivity during drought.

Selection within species has produced populations of *Lolium* and *Festuca* with significant differences in water use. For example, Wilson (1975a) found that during dry weather the crop growth rate of a population selected from *L.perenne* Grasslands Ruanui for low leaf conductivity was 11.8 g m^{-2} d^{-1}, and of a population with high leaf conductivity was only 8.2 g m^{-2} d^{-1}.

In many grasses, most stomata lie along the sides of ridges on the adaxial surface of the lamina. Wilson (1975b) and Silcock & Wilson (1981) have shown that populations of _L.perenne_ and _F.arundinacea_ with relatively shallow leaf ridges had relatively high water use efficiency (compared with deeply ridged leaves), probably because their stomata were more exposed to the bulk atmosphere and closed sooner.

Water economy may also be increased by leaf rolling, especially in _F.arundinacea_ (Silcock & Wilson, 1981).

Tolerance of stress

The physiological restriction of transpiration can only delay the onset of drought, and eventually canopy photosynthesis is reduced. This is due more to reduction in green leaf area than to depression of the photosynthetic rate of individual leaves (Leafe _et al_. 1980). Maintenance of green leaf area during dry weather has contributed to drought tolerance in _F.pratense_ and _D.glomerata_ (Jantti & Heinonen, 1957).

Maintenance of cell turgor is necessary for metabolic processes, including cell division and extension, to continue. Morgan (1977) showed that drought resistant wheat species were able to adjust their osmotic potentials (π) to compensate for decreasing bulk leaf water potentials (Ψ), thus maintaining turgor. Differences between grass species appear to be smaller (Thomas, unpublished), and are only significant when drought is imposed suddenly: for example _L.perenne_ was found to adjust π by -4.3 bars, _D.glomerata_ by only -1.9 bars.

Variation also exists in the rate of recovery of Ψ during the evening. Norris (1978), working with _L.perenne_ x

L.multiflorum hybrids, found that at 2000 h a drought susceptible variety (Snowdon) had Ψ = -10 bars whilst Bx 157, a drought resistant variety, had Ψ = -4 bars.

Hydration control has been associated with drought resistance in Siratro (Wilson *et al.*, 1980). This may also apply to grasses, since *D.glomerata* has a turgid water content (TWC, g water DM at full turgidity) of 4.4 g g^{-1}, whilst *L.multiflorum* has a much higher TWC of 5.9 g g^{-1} (Thomas, unpublished).

CONCLUSION

There is ample variation amongst the most important herbage grasses to enable drought resistance to be increased through empirical and, especially, physiologically based selection.

REFERENCES

Aldrich, D.T.A. (1977). Factors affecting the performance of grass and legume cultivars in the UK. In: *Proceedings International Meeting on Animal Production from Temperate Grassland, Dublin* (Ed. B. Gilsenan), pp.20-22.

Garwood, E.A., Tyson, K.C. & Sinclair, J. (1979). Use of water by six grass species. I. Dry matter yields and response to irrigation. *J.agric.Sci., Camb.* 93, 13-24.

Hughes, R., Jones, E.L., Rushton, W.H. & Evans, W.B. (1977). Herbage yields in 1976. *Rep.Welsh.Pl.Breed.Stn* for 1976, pp.39-44.

Hurd, E.A. (1974). Phenotype and drought tolerance in wheat. Agric.Meteorology 14, 39-55.

Jantti, A. & Heinonen, R. (1957). Effect of defoliation and soil moisture on grassland regrowth. J.Br.Grassld Soc. 12, 56-61.

Lancashire, J.A., Wilson, D., Bailey, R.W., Ulyatt, M.J. & Singh, P. (1977). Improved summer performance of a 'low cellulose' selection from Grasslands Ariki. N.Z.J. agric.Res., 20, 63-67.

Leafe, E.L., Jones, M.B. & Stiles, W. (1980). The physiological effects of water stress on perennial ryegrass in the field. Proc.XIII Intern.Grassld Congr., Leipzig. 1977, pp.253-260. Akademia-Verlag, Berlin.

Malaoui, S. (1981). Effect of drought on growth in perennial ryegrass populations. M.Sc. Thesis, Univ.Coll.Wales, Aberystwyth.

Morgan, J.M. (1977). Differences in osmoregulation between wheat genotypes. Nature 270, 234-235.

Norris, I.B. (1979). Soil water and weather effects on growth components and yield in grass varieties. M.Sc.Thesis, Univ.Coll.Wales, Aberystwyth.

Norris, I.B. (1982). Effect of soil moisture on yield and growth components of contrasting varieties of Lolium, Dactylis and Festuca species. J.Grass Forage Sci. (in press).

Norris, I.B. & Thomas, H. (1982a). Recovery of ryegrass species from drought. J.agric.Sci., Camb. 98, 623-628.

Norris, I.B. & Thomas, H. (1982b). The effect of droughting on varieties and ecotypes of Lolium, Dactylis and Festuca. J.appl.Ecol. 19 (in press).

O'Brien, T.A., Moorby, J. & Whittington, W.J. (1967). The effect of management and competition on the uptake of ^{32}phosphate by ryegrass, meadow fescue and their natural hybrid. J.appl.Ecol. 4, 513-520.

Silcock, R.G. & Wilson, D. (1981). Effect of watering regime on yield, water use and leaf conductance of seven Festuca species with contrasting leaf ridging. New Phytol. 89, 569-580.

Troughton, A. (1978). Shoot:root relationships. Rep.Welsh Pl. Breed.Stn for 1977, pp.147-149.

Troughton, A. & Whittington, W.J. (1968). The significance of genetic variation in root systems. In: Root Growth (W.J.Whittington, Ed.). Butterworths.

Wilson, D. (1975a). Leaf growth, stomatal diffusion resistance and photosynthesis during droughting of _Lolium perenne_ plants and selected for contrasting stomatal length and frequency. _Ann.appl.Biol._ 79, 67-82.

Wilson, D. (1975b). Stomatal diffusion resistances and leaf growth during droughting of _Lolium perenne_ plants selected for contrasting epidermal ridging. _Ann.appl.Biol._ 79, 83-94.

Wilson, D. (1976). Climatic stress and productivity - efficiency of water use. _Rep.Welsh Pl.Breed.Stn_ for 1975, p.56.

Wilson, J.R., Ludlow, M.M., Fisher, M.J., Schulze, E.-D. (1980). Adaptation to water stress of the leaf water relations of four tropical forage species. _Aust.J. Pl.Physiol._ 7, 207-220.

Table 1. **Relative herbage yields of Italian ryegrass varieties and populations in a greenhouse drought experiment (RvP = 100). Pre-treatments: W = well watered, D = droughted. Titania is derived from both RvP and a Po Valley ecotype, Bb 1691 and Bb 1693 are populations from irrigated and Bb 1662 from unirrigated pasture in Northern Italy**

Variety or population	Yield during pretreatment		Regrowth after re-watering	
	W	D	W	D
RvP	100	55	100	60
Titania	105	56	95	57
Bb 1691	110	64	120	91
Bb 1693	117	66	134	88
Bb 1662	114	59	97	66
SED	4.3		7.2	

(Thomas & Norris, 1982)

Table 2. **Leaf growth, herbage yield, root density, soil water deficit and water use efficiency of *D.glomerata*, *Lolium perenne* and *L.multiflorum* grown without irrigation on deep soil cases**

	D.glomerata	*L.perenne*	*L.multiflorum*	SED
Wt herbage (g dm^{-2})	12.0	12.2	11.6	0.6
Leaf extension at end of experiment (mm d^{-1})	7.3	2.3	0.01	1.6
Root density (dm^2) at				
10 cm	69	101	122	9
73 cm	4	10	21	3
Available soil water below 50 cm (g kg^{-1})	67	45	16	5
Total soil water deficit (mm)	99	114	129	12
Water use efficiency (g DM herbage kg^{-1} water)	5.4	4.8	4.0	

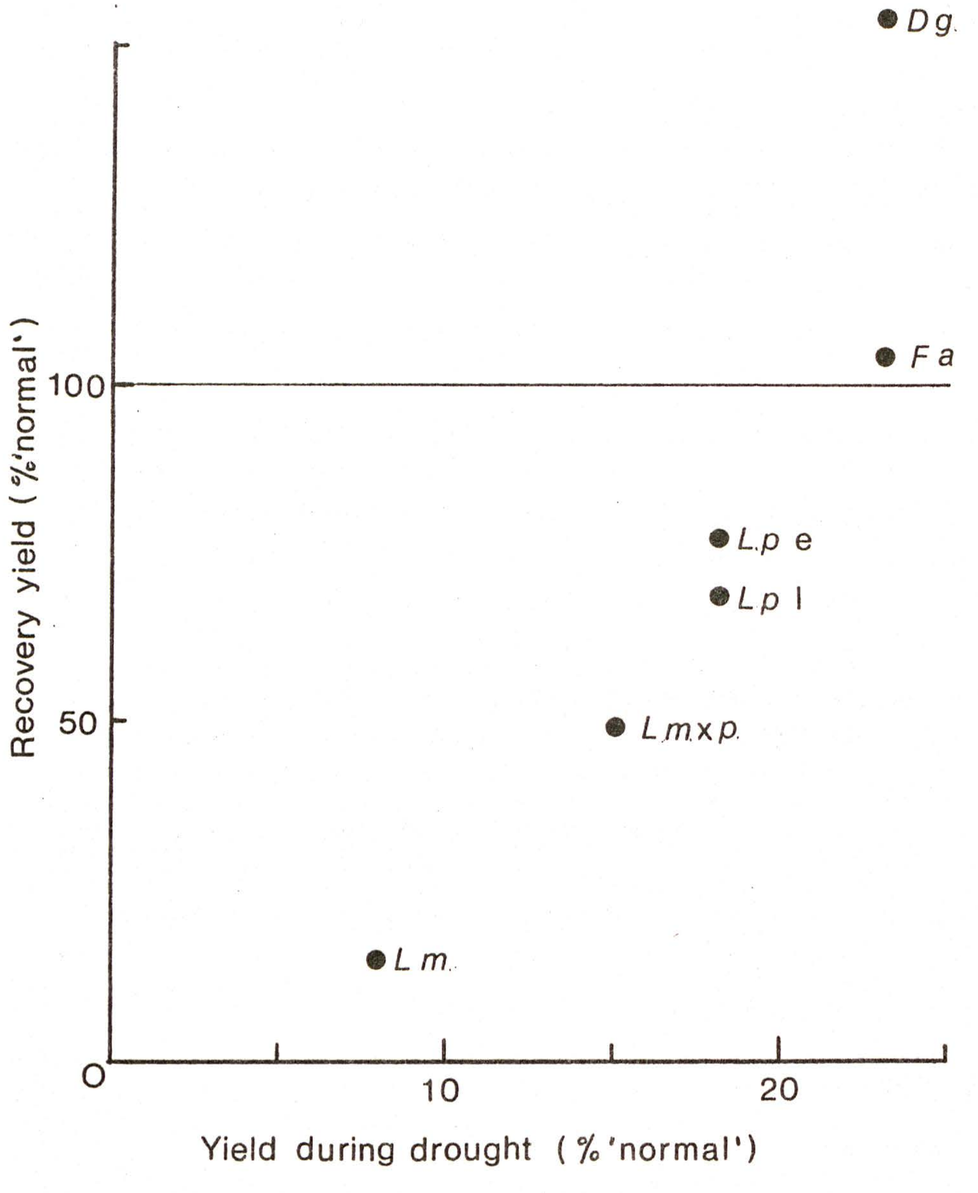

Fig. 1. Herbage yields of grass plots during and after drought, expressed as a percentage of yields during 'normal' (wet) seasons. Data from Hughes et al. (1977). Points are means of several varieties: L. m., Lolium multiflorum; L. p., Lolium perenne (early, e and late, l); F. a., Festuca arundinacea; D. g., Dactylis glomerata.

UTILIZATION OF GENETIC RESOURCES IN BREEDING PROGRAMMES

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GENETIC RESOURCES

Genetic resources in the broad sense may be defined as any kind of basic breeding material. It includes either individual plants or populations of the following:

1) Ecotypes, which are derived from either domestic or foreign habitats. European breeders of temperate perennial forage grasses are settled right in the middle of the gene centre of the species they are working with. It is quite logical, therefore, that the early European grass breeders took advantage of this situation and selected their basic breeding stock from the indigenous grassland surrounding them. A large number of well known and still widely grown cultivars in Germany (Arbeitsgemeinschaft für Landwirtschaftliches Saatgutwesen 1968), Britain (Cooper 1978), Scandinavia (Frandsen 1970), and elsewhere in Europe is based on such initial material. An important feature of ecotypes from old productive pastures and meadows is their adaptation to the past farming management which included cutting, grazing, fertilization and treading due to natural selection. Because it is already preselected for farm use, this material is of extremely high value for the grass breeder (Cooper 1978, Lackamp 1968). Care should be taken to preserve this great and unique genetic potential. As long as the concept of the economical superiority of the permanent grassland over temporary grassland prevailed among the farmers, the maintenance of the gene pool was not severely affected. Nowadays, however, an increasing proportion of permanent grassland is subject to the so-called renovation. In the Netherlands, for instance, an estimated 8-10 % of the total grassland area is resown each year (Hoogerkamp 1975, Luten 1977). This is certainly a pleasant situation for the seed trade, but at least the breeders should be aware that with every destroyed hectare of an old adapted grassland sward an irreplacable part of the gene pool is eroded away. Foreign ecotypes particularly of European origin are important genetic resources for the breeders of temperate grasses outside the gene centre viz. U.S.A., Australia, New Zealand, Japan etc. On the other hand, ecotypes from the Mediterranean region and from the Iberian peninsula serve as genetic stock in central and west Europe for the improvement of Dactylis, Festuca, and Lolium (Tyler 1979).

2) Locally adapted populations - land races. Such material formed the genetic basis of improved varieties of forage legumes some of which may itself be considered ecotypes. The acceptance of breeders rights systems in European countries led to the near elimination of such genetic resources in the Trifolium and Medicago species.

3) Cultivars. Why should one look among the "wild children of nature" (Lackamp 1968) for initial breeding material if there is already available a wealth of improved, highly performing cultivars adapted to various types of modern forage crop management? The OECD-List of Cultivars Eligible for Certification (1981), for example, contains the names of over 200 cultivars of perennial ryegrass only! If one accepts the hypothesis of the agronomic superiority of advanced cultivars to the wild children of nature, cultivars should form a very valuable genetic basis for further breeding activities. In addition, this material is normally much easier to obtain than ecotypes from nature, but legal provisions must be obeyed when varieties should be used. In West Germany protected cultivars may be used for breeding purposes without restrictions except when seed is brought out of the country.

4) Experimental material may be a useful genetic source for the achievement of specific breeding aims. Such material includes male sterile plants like the widely used 20 DRC type (Childers and Mc Lennan 1960) in lucerne, artificial mutants and their progeny as in the creation of panicle-retaining meadow foxtail (Simon, unpublished), induced polyploids as in Lolium (Wit 1958) or clover (Julén 1959), and inbred lines.

5) Other species and genera must be used if intraspecific or intrageneric variation does not include the desired combination of characters. Well known examples are the artificial hybridization between Lolium species or between Lolium and Festuca species.

In any case, the genetic stock the breeder draws on must contain the desirable characters which he tries to incorporate into a new variety. Cooper (1978) emphasizes, for this reason, that with such plant collections whether used directly as the basis for a variety or as genetic material in hybridization programmes, it is important to establish a sufficiently large gene pool.

UTILIZATION IN BREEDING PROGRAMMES

Breeding Programme

According to the definition given above the utilization of genetic resources does not principally differ from the utilization of any other kind of basic plant material in a breeding programme. Any breeding programme which is intended for the creation of a new improved variety consists essentially of four steps:

1. Acquisition or creation of basic breeding materials with sufficient intraspecific variation
2. Selection
3. Evaluation
4. Variety formation.

Within this scheme hybridization or inbreeding may be missed. In my opinion, both operations belong to step no. 1. Any step may be repeated in the given or another order.

Choice of Category of Genetic Resource

The decision which category of genetic resources to choose depends on several factors. First of all, the geographic and climatic region of utilization of the potential variety has to be considered. European breeders are able to select their germplasm from locally adapted populations, whereas Australia is singularly deficient in indigenous legumes and grasses (Hutton 1970) and therefore relies exclusively on foreign resources. C-4-grasses are required for the tropics and subtropics, C-3-grasses are appropriate in the temperate zone, and even here the breeder faces marked climatic differences. Winterhardiness, for instance, may be of minor importance in some west European countries but is a prerequisite of any breeding material to be used in Scandinavia.

Secondly, the choice of the proper genetic resource depends on breeding aims and breeding procedures. The breeding aims in turn are determined by agronomic requirements such as yield and type of usage (grazing, zerograzing, hay, silage), and the animals needs. The performance of the genetic resource and its offspring must be evaluated in the geographic area of the prospective cultivars utilization. This includes the seed-setting capacity of clover and lucerne in the area of seed multiplication which in many cases is outside the area of forage production.

Pretreatment of genetic resources prior to their utilization may or may not be necessary depending on their origin, adaptation and reproductive mechanism. Ecotypes from adapted populations may be taken as breeding material per se. But if the photoperiodic response in cross-breeding parents is very different, the careful timing of their flowering dates is necessary. If apomictic Poa genotypes are to be crossed, they must first be converted into sexually reproducing types. In more advanced breeding programmes only the progenies of the initial germplasm may be useful. Such progenies include inbred lines, induced mutants and polyploids, and the offspring from interspecific and intergeneric crosses.

Last but not least, the choice of the type of basic material depends on the present cultivars average level of agronomic performance. When a species like Lolium perenne has been subject of intensive effort by numerous breeders for generations, one should anticipate that a high level of improvement has already been achieved. In this particular case it would probably be more logical to select the basic breeding stock from among the best available cultivars rather than from ecotypes. The ecotype approach, on the other hand, can lead to rapid progress either with species that have so far attracted little attention by the breeders or in regions with hitherto little or no plant breeding activity.

Breeding Aims and Breeding Procedures

Yield

In any breeding programme aiming at the creation of new cultivars the breeding aim yield is of paramount importance. Yield itself can be specified as yield of green or dry matter, digestible organic matter, yield of total digestible nutrients and so on. Furthermore, a good variety must have sufficient seed productivity, too. The magnitude of both dry matter and seed yield is often influenced by the conditions under which the material is grown. These conditions may be either due to the natural environment or they may be set by the farmers type of management, e.g. pasture or conservation, short or long term, low or high input of fertilizes. Consequently, when working toward a new variety, the breeder must specify the conditions under which the prospective variety is to be grown, and select and treat the breeding material accordingly. This specification is complicated by the fact that the creation of a perennial forage variety is a long-term procedure. If we add to the pure breeding time the periods of official testing and basic seed production, about 20 years are needed until the initial breeding stock is passed on to the farmer. Who knows under which conditions he will grow the cultivar in the year 2000 and beyond? Will there be more or less fertilizer nitrogen be applied than at the time being? Will it be feasible to breed a lucerne variety especially suitable for dehydration? What are the prospects of incorporating legumes into crop rotations? We can only guess. But the breeder cannot circumvent or postpone the decision. He has to make it at the risk that he is wrong. So, setting the conditions under which the breeding material is to be evaluated and selected is like gambling. Perhaps the best thing the breeder can do is to subject his material to several of the most probable conditions and compose the variety accordingly. Yield can generally be improved in two ways, either directly by increasing the plant mass per unit of area and time, or indirectly by decreasing the adverse effects of yield constraints.

Increasing plant mass

Let us first consider the direct methods of utilization of genetic resources for the improvement of forage and seed yield. As far as forage yield is concerned, choose initial stock that appears promising per se. Further progress can be made if from the combination of this material a certain degree of heterosis can be expected. I do not believe in the necessity of creating and crossing inbred lines in order to induce hybrid vigour, because the possible heterosis effect in the F_1 generation of forage grasses and legumes does not compensate for the loss of vigour due to inbreeding. Consequently, there is little chance that the inbred approach renders significantly higher yields than the original parental population. Much more important for the induction of heterosis seems that the parental stock be as unrelated as possible. This requirement is particularly stressed by Russian workers (Novoselova 1980). The effects of genetic relationship among clones on dry matter yields of syn-1 generations in lucerne may serve as an example (table 1, Simon 1971):

Table 1. Effect of genetic relationship of clones on dry matter yield of Syn-1 generation in Medicago sativa L. (Simon 1971)

Synthetic No.	Clone[1)] No.	Dry matter tons/ha
Du Puits		14.3 = 100
11	A_1 A_2 A_3	97
9	B_1 B_2 B_3	96
8	C_1 C_2 C_3	108
6	A_1 B_3 C_2	108
3	A_1 A_3 C_3 D	113[2)]
2	C_3 D E	113[2)]
1	A_1 D	120[2)]

1) Clones identified by the same capitals are closely related

2) Exceeding (p 0.05) Du Puits

Another example is our registered lucerne cultivar Luna, which ranks as top or among the top yielding varieties even in climatically diverse regions like West Germany, Austria (Wolffhart 1977), Yugoslavia (Bosnjak and Stjepanović 1980), or South Korea (K.G.G.R.P. 1976). The rather different origins of the 12 basic clones (Franconia, France, Turkey, falcata x media) contributes very likely to the superior yield potential of this synthetic variety. For the same reason an appreciable degree of hybrid vigour could be expected from interspecific crosses of which the recently developed Dutch hybrid ryegrass cultivar Inca is an example.

The third approach to increasing plant mass is the induction of polyploidy in diploid species. But one should keep in mind that polyploidization should be applied only to preselected material because the expected genetic gain from selection pressure in tetraploids is much less than in diploids. An example for the successful combination of both heterosis through crossing unrelated germplasm and polyploidization is the tetraploid hybrid ryegrass cultivar Augusta bred at the Welsh Plant Breeding Station.

Plant mass can be increased by the utilization of certain genotype : environment interactions. Bugge (1974) found marked differences among Italian ryegrass genotypes in their response to fertilizer nitrogen. Also, genotypic differences exist in forage legumes in their ability to profit from rhizobium symbiosis.

The importance of seed yield as an indispensable character in forage varieties has already been emphasized. Seed yield can also be improved by increasing the components of seed mass - number of inflorescences/m^2, number of seeds/inflorescence, weight of seed -. One of the most difficult problems in forage crop breeding is the successful combination of good forage and seed yield. This is particularly true in the socalled pasture types in grasses as well as in tetraploid clover. Comprehensive information on this matter can be found in the Report of the Eucarpia Fodder Crops Section Meeting in Merelbeke (van Bogaert 1981).

Breeding for resistance

The elimination of the adverse effects of yield constraints means, generally speaking, breeding for resistance to unfavourable environmental conditions. It is often more important than the increase of plant mass itself. Breeding for resistance implies, of course, that unfavourable conditions with respect to the breeding material actually occur. You cannot select for winterhardiness where there is no harmful winter at all or if the probability of its occurence is low. In other words, where there is regularly sufficient natural selection pressure, the evaluation and utilization of the breeding stock can be successfully based on it. Otherwise, artificial selection pressure by the application of a refined screening technique must be imposed, or the material must be evaluated in an area where natural selection pressure regularly takes place.

Constraints to forage yield can be of abiotic or biotic nature. Abiotic constraints may originate from extreme conditions of either the climate (temperature, rainfall, length of growing season) or the soil (moisture, nutrients, acidity). Among the many biotic factors are harmful organisms like viruses, bacteria, fungi that attack plant shoots and/or roots, nematodes, slugs and insects. Numerous cases of successful utilization of resistant genetic resources in forage breeding programmes are known.

Seed yield may principally be affected by the same constraints as already mentioned, but some must be added. An important role plays sensitivity to photoperiod whenever seed is multiplied outside the geographic origin of a cultivar. A very important biotic constraint is the loss of seed through shattering at an advanced stage of maturity in many grasses. Nonshattering ecotypes like those found in Dactylis glomerata by Falcinelli et al. (1981) could form a useful resource in improving this character. Certain insects may influence either favourably (pollinating bees) or adversely (aphids, chalcids) the seed yield primarily in forage legumes. Considerable work has been devoted to select basic genetic stock for more attractiveness to and effectiveness of pollinating insects.

Quality

Forage crops are bred and grown in order to feed farm animals, particularly ruminants. The improvement of forage quality, therefore, is a target that has been aimed at ever since forage breeding began. Leafiness combined with lateness of plants has been the criterion for forage quality in the past. It is based on the assumption that the leaves are of higher quality than the stems. Recent findings have shown that this is not generally true. In Dactylis glomerata, for instance, lines selected for high in vitro dry matter digestibility were earlier heading and had thicker stems than those selected for low digestibility (Breese and Davies 1970), and crude protein content in the leafy and late maturing cultivar Holstenkamp was found to be significantly lower than in the stemmy and early cultivar v. Kamekes (Simon 1974). In fact, little progress has been made so far with respect to the selection for forage quality by visual plant observation.

Components of quality

Breeding for quality is more difficult than breeding for yield, because quality in itself is a complex character composed of numerous contributing factors. The three principal ones are palatability or the relative amount of forage eaten, digestibility, and the content of quality related constituents. Each factor can be subdivided into several components which may be interrelated or influenced by others. The content of quality constitutents, for instance, includes water, protein, crude fibre, soluble carbohydrates, and necessary minerals. But there may also be antiquality substances like alkaloids in tall fescue, estrogens in clovers, saponins in lucerne, cyanogenic glycosides in white clover, and coumarin in sweet clover. It is impossible to select simultaneously for the whole range of quality constituents. So, in order to improve quality, a clearly specified character must be determined in advance. Fortunately for the breeder, a strongly positive relationship exists between some of the more important properties like digestibility, protein content and intake. These characters are negatively correlated with crude fibre content. Therefore, by improving one of these factors one could expect that the other factors mentioned would also be favourably affected.

Quality may not only be important in forage but also in seed. Seed weight, for instance, is positively correlated with seedling vigour. Increased 1000 kernel-weight, which is usually a consequence of induced polyploidy, could therefore improve the early establishment of a cultivar under adverse conditions. In awned species like Italian ryegrass or tall oatgrass the sowing property of the seed could be improved by the utilization of awnless genetic stock.

Evaluation of quality

The next difficulty is that the evaluation of characters of quality requires specialized laboratory equipment and procedures which results in considerable additional amounts of costs, time, and labour. These additional expenses must be weighed against the possible genetic gain and, even more important for the practical breeder, against the possible additional economic returns. Perhaps the greatest problem in the utilization of genetic resources for the improvement of quality is the adoption of the proper basis for valid comparisons among the breeding material. Unlike in most arable crops, the quality of herbage is not determined at its rapid stage of growth, but during this rapid morphological and physiological development. Morphological differentiation of the plants is accompanied by changes of quality characters as well. So, if the plants which are to be compared at a distinct calendar date differ in earliness, the observed differences in quality could be attributed to the difference in their stages of growth. It has been suggested that the confounding of quality and stage of growth could be avoided when the material is compared at an identical stage of development, say the beginning of heading. Depending on the basis chosen the comparisons may lead to different and sometimes contradicting conclusions. For example, when an early and a late type of perennial ryegrass were compared for content of crude protein on May 31st, the late type was four units higher than the early one. On the other hand, when both types were compared at the stage of 20-30 % ears emerging, the late type was found to contain over four percentage units of protein less than the early type (table 2, Simon 1974).

Table 2. Crude protein content of early and late perennial ryegrass determined on the same calendar date and at the same stage of growth (Simon 1974)

Cultivar/Maturity		Percentage of crude protein on May 31st 1972	at 20-30 % ears emerging
Angeliter Presto	(early)	14,2	16,9
N.F.G.	(late)	18,2	12,1

In a voluntary intake experiment with sheep grazing tetraploid perennial ryegrass, the early cultivar is preferred in weeks 1 to 5, but later on the preference of the animals is reversed (table 3).

Table 3. Voluntary dry matter intake of grazing sheep from early and late tetraploid perennial ryegrass (kg/ha)

Cultivar/ Maturity	Week after May 1, 1973: 1	2	3	4	5	6	7	8
Reveille (E)	650	960	1310	3230	1720	1260	2420	2110
Havier (L)	390	610	1060	1060	1410	2080	3490	4120

The question whether quality characters should be compared at the same date or at the same stage of growth is still being disputed. The answer depends probably on the intended use of the cultivar. Under grazing conditions, it seems logical to compare at the same date. For conservation, the comparison at the same stage of growth may be more appropriate.

Various breeding procedures are being applied in the utilization of genetic resources forthe improvement of quality characters. Selection based on visual observation of quality related plant characters like leafiness and earliness has already been mentioned. Interspecific or intergeneric hybridization has successfully been used in the breeding of more palatable tall fescue (c.v. Kenhy; Asay et al. 1979) and low-coumarin sweet clover (c.v. Denta; Smith 1964). Polyploidization of ryegrass and red clover increases palatability, digestibility and protein content (Simon 1970).

Selection for quality is expensive. Consequently, the evaluation is usually carried out at an advanced stage of the breeding programme. Furthermore, selection for quality may reduce yield. A negative correlation between protein content and yield has been observed in lucerne (Simon 1969), perennial ryegrass (Lackamp 1965), and other grass species (Green et al. 1971). Lackamp expressed the opinion that high protein content is not only correlated to low productivity but is also its cause.

Type of usage of prospective cultivars

Forage plants may be managed and used by the farmer in various ways. A variety can be sown in pure stand, or accompanied with other varieties of the same or of different species. Vigorous establishment and maintenance in a mixed sward requires additional competing ability of the variety. So, if a variety is to be grown in mixed stand, the breeding material must be assessed for competing ability, because its performance in combination with other components may differ from that in pure stand. Aspects of competition and assessment of competing ability in forage plants have been treated in detail at the Eucarpia Fodder Crops Section Meeting in Roskilde, 1976 (Dennis 1976).

The need for persistence depends on the anticipated period of utilization. Persistence may be neglected when the forage is intendend for short rotation leys. In most cases, however, it would be desirable to grow forage for a longer period of time. A high degree of persistence may be an inherent character in certain species like Phleum pratense or Poa pratensis. But in many cases the actually observed persistence is the result of the probability and severity of abiotic and biotic constraints several of which have already been mentioned.

Intensive forage management practices like increasing the number of defoliations, higher stocking rates, and frequent use of heavy farm machinery exert additional pressure to the sward. Improved persistency is particularly important in species with considerable interspecific variation of this character like red and white clover, or perennial ryegrass and meadow fescue. The utilization of genetic resources for the improvement of the duration of the stand requires first the careful analysis of the active constraints in the area of production, second the proper choice of the basic breeding stock, and third the evaluation and selection of the breeding material under the prevailing conditions. Needless to say that any programme aiming at persistence extends the breeding procedure. The red clover breeding programme at Weihenstephan may serve as an example. Step one: Insufficient persistency has been found to be due to lack of winterhardiness the reason of which was mainly susceptibility to Sclerotinia trifoliorum. Step two: Basic breeding stock was chosen from early flowering Swiss ("Mattenklee") and late flowering Danish ("Lyngby") landraces with known good persistence, and intercrossed and selected for earliness and persistence in the field. Step three: Several cycles of artificial infection and selection were imposed. The additional selection pressure resulted in a marked increase of resistance to Sclerotinia as shown in table 4, but it took ten more years to achieve the best results.

Table 4. Surviving plants of red clover after several cycles of artificial infection with Sclerotinia trifoliorum and selection

Breeding stock	Number of cycles	Surviving plants %
Lembkes	0	17
Weihenstephan	5	24
Weihenstephan	7	39
Weihenstephan	9	41

The two registered cultivars Lutea and Lucrum emerged from this programme.

Perennial ryegrass is the most commonly grown grass species in Central and Western Europe. Yet its persistence has markedly declined with increasing grazing intensity. Large areas have been resown in recent years for this reason. Surviving plants from such resown pastures are expected to be well adapted to intensive management and therefore could form a valuable source for further improvement.

As the farm management of herbage varieties is becoming more specialized, the initial breeding material must be selected and evaluated according to the intended use. A pasture type must certainly endure more frequent defoliation and treading than a haytype, and high total yield combined with high protein and low water content are required in lucerne grown for dehydration.

Conclusion

Genetic resources (g.r.) comprise any type of basic breeding material including ecotypes, landraces, experimental material and other species and genera. The choice of g.r. in a breeding programme depends on breeding aims and breeding procedures. They are determined by agronomic requirements such as yield, quality and type of usage regarding both forage and seed. Yield may increased by selecting for heritable traits of plant mass or by making use of genotype : environment interaction or by the elimination of abiotic or biotic yield constraints. Genetic improvement of quality requires g.r. either superior in quality constituents or low in antiquality characters. The incorporation of g.r. must also be in accordance with the intended farm use of the prospective cultivar.

References

Arbeitsgemeinschaft für landwirtschaftliches Saatgutwesen, 1968: Sortenratgeber Gräser und Kleearten. 2. Auflage. DLG-Verlags-GmbH. Frankfurt a.M..

Asay, K.H., Rod V. Frakes, and R.C. Buckner, 1979: Breeding and cultivars. In Buckner, R.C., and L.P. Bush: Tall fescue. Agronomy, a series of monographs, No.20, 111-139.

Bošnjak, D., and M. Stjepanović, 1980: Some domestic alfalfa creations in comparison with the quantitative and qualitative characteristics of the foreign varieties in Osijek-Yugoslavia. Proc. 8th E.G.F. Meeting, Zagreb 1980, I, 4.59-4.67.

Breese, E.L. and W.E. Davies, 1970: Herbage plant breeding. Jubilee Rep. Welsh Plt. Breed. Stn. 1919-1969, 11-47.

Bugge, G., 1974: Untersuchungen über die Stickstoffverwertung bei verschiedenen Sorten von Lolium multiflorum L.. Z.Acker- und Pflanzenbau 139, 259-272.

Childers, W.R., and H.A. McLennan, 1960: Inheritance studies of a completely male sterile character in Medicago sativa. Canad. J. Genet. Cytol. 2, 57-65.

Cooper, J.P., 1978: Genetical constraints to the growth and production of grassland. Proc. 7th E.G.F. Meeting, Gent 1978, I, 1.3-1.17.

Dennis, B. (Editor), 1976: Breeding methods and variety testing in forage plants. Rep. Eucarpia Fodder Crops Section Meeting. Roskilde.

Falcinelli, M., F. Veronesi, and F. Lorenzetti, 1981: Adaptive strategies of Italian ecotypes of Dactylis glomerata L. and their relationship with seed production. Rep. Eucarpia Fodder Crops Section Meeting. Merelbeke - Gent, 153-162.

Frandsen, K.J., 1970: The breeding of pasture plants in Scandinavia. Proc. XI Intern. Grassland Congr., Surfers Paradise 1970, A63-A70.

Green, J.O., A.J. Corrall, and R.A. Terry, 1971: Grass species and varieties. Tech. Rep. No. 8, Grassld. Res. Inst., Hurley.

Hoogerkamp, M., 1975: In - en herinzaai von grasland. Meded. van de N.A.K. 33, 7-8.

Hutton, E.M., 1970: Australian research in pasture plant introduction and breeding. Proc. XI Intern. Grassland Congr., Surfers Paradise 1970, A1-A12.

Julén, G., 1959: Rotklee (Trifolium pratense L.). In Th.Roemer und W. Rudorf: Handb. d. Pflanzenzüchtung. 2. Aufl., Bd. IV, 242-305. Paul Parey, Berlin und Hamburg.

Korean-German Grassland Research Project,1976: Annual Report.

Lackamp, J.W., 1965: Een onderzoek naar variabiliteit en vererving van het ruweiwitgehalte in Engels raaigras. Versl. Landbouwkund. Onderzoek 656, Pudoc Wageningen.

Lackamp, J.W., 1968: Some remarks about methods in pasture grass breeding. Rep. Eucarpia Fodder Crops Section Meeting. Köln, 83-86.

Luten, W., 1977: Herinzaaien en doorzaaien van grasland. Landbouwmechanisatie 28, 757-758.

OECD, 1981: List of cultivars eligible for certification. Organisation for Economic Co-Operation and Development, Paris.

Novoselova, A.S., 1980: The gene pool and its use in breeding grassland plants. Proc. XIII Intern. Grassland Congr., Leipzig 1977, I, 51-59.

Simon, U., 1969: Relationship between morphological characters and protein content in lucerne. Rep. Eucarpia Fodder Crops Section Meeting. Aberystwyth, 45-49.

Simon, U., 1970: Polyploidie und Futterpflanzenzüchtung. Bayer. landwirtsch. Jb. 47, 131-159.

Simon, U., 1971: Einfluß der Zusammensetzung auf den Ertrag synthetischer Luzernesorten. Z. Acker- u. Pflanzenbau 134, 165-174,

Simon, U., 1974: The importance of high protein content as an objective in breeding forage plants. Växtodling 28, 26-32.

Smith, W.K., 1964: Denta sweet clover (Reg.No.5). Crop Sci. 4, 666-667.

Van Bogaert, G. (Editor), 1981: Breeding high yielding forage varieties combined with high sed yield. Rep. Eucarpia Fodder Crops Section Meeting. Merelbeke-Gent.

Wit, F., 1958: Tetraploid italian ryegrass (Lolium multiflorum Lam.). Euphytica 7, 47-58.

Wolffhardt, D., 1977: Futterpflanzen-Sortenversuche 1975-76. Bundesanstalt für Pflanzenbau und Samenprüfung in Wien, Heft 239.

Tyler, B.F., 1979: Collections of forage grass in Europe. Proc. Conf. Broadening the Genetic Base of Crops. Wageningen 1978, 83-89, Pudoc Wageningen.

SIBERIAN GENOFOND USED IN FODDER GRASS BREEDING

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Severity of climate in Siberia, Far East and Asian Extreme North often accompanied by soil moisture deficit and poor chemical composition sets a limit to the growing of cultivated species both in field and fodder crop rotations as well as to explain the relatively poor botanical composition in natural rangelands.

Seed and variety improvement is a basis of steady increases in yield and production quality. Research and experience have proved that yields can be considerably increased through farming of adapted varieties approximately by 25%, while through using high-quality seed - by 20%. Varieties should be suitable for growing under the local enviornmental conditions, which are rather changeable and extreme (unsteady hydrothermal regime) in the region.

Being rather adaptive the local material often serves as a basis for developing the so-called local varieties. In our severe region a local variety should receive emphasis when solving the problem of fodder grass distribution. Therefore, it is no mere chance that over 80% of fodder grass varieties regionized in different regions (territories and autonomous republics) have been developed by the Siberian and Far Eastern research institutions and are the Siberian local populations as well. The alfalfa 'Marusinskaya 425' (Morshansk Plant Breeding Station), sainfoin 'Pestchany 1271' (Veselo-Podolyansk Experimental Plant Breeding Station) and spring vetch 'Lgovskaya 31/292' (Lgovsk Experimental Plant Breeding Station) regionized here are the only varieties introduced from another region.

To a considerable degree the progress in breeding is ensured by selection of an appropriate initial material, reliable methods used for producing the initial (breeding) material as well as by proper selection, grading and many-sided evaluation of the material. Since our region is noted for severe climatic conditions, the forms introduced from another regions, where climate is somewhat milder, often happen to be under the threat of mortality or spareness due to low temperatures, drought, nutritional deficiency as well as salt and acidity excess. That is why it is important to introduce the material from the regions of more severe climatic zone. As a rule, the material, taken from the regions notable for a milder climate, is not promising for the growing under severe climatic conditions.

As it has been shown by breeding the plant breeders, who make use of local varieties, populations and wild flora material, get good results. It can be evidenced by the varieties bred at the Tulun State Plant Breeding Station (Irkutsk region, Eastern Siberia), Siberian Research Institute of Plant Growing and Selection (Siberian Branch of the Lenin All-Union Academy of Agricultural Sciences, Novosibirsk region, Western Siberia).

The climate of Irkutsk region, where the Tulun State Plant Breeding Station is situated, is very continental, with a 74-day frost-free period, 1110-1400° sum of positive temperatures during the growing season and 354 mm annual rainfall. The temperature at the depth of tillering node often falls down to minus 20-24°.

The varieties to be grown here should be notable for proper winter-hardiness, drought-resistance during the first half of vegetative stage, resistance for excess moisture and warmth deficiency during the second half of vegetative stage as well as for early ripening.

Investigation of the world collection of the All-Union Research Institute of Plant Growing has shown that, by a number of fodder grass species, the varieties, introduced from the regions of mild climate, undergo considerable spareness and even mortality after the first hibernation.

To solve the problem of developing resistant forms we often use local wild or selected forms of the Siberian research institutions (which have undergone natural selection in the severe climatic zone and have been adapted to extreme hydro-thermal regimes) as one of the components when crossing.

Awnless brome grass (Bromus inermis Leuss).

The new variety was bred from the local specimen of Tulun district, Irkutsk region, as a female parental form and the selection 'Omsky 15' (the Siberian Scientific Research Institute of Agriculture, Omsk region) as a male parental form and named 'Tulunsky'. It has proved to be highly winter hardly (the plants remain vital for 5-7 and more years, provided that proper technology is strictly kept to) and high-yielding as far as biomass and seed are concerned. The average yield of the awnless brome grass variety 'Tulunsky' for three growing cycles was equal to: hay - 38.2; seed - 3.1 h kg/ha. The check variety produced 30.2 and 2.2 h kg/ha, respectively. The variety has been regionized in Irkutsk, Chita, Amur and Perm regions and in the Buryat Autonomous Soviet Socialist Republic.

Meadow fescue grass (Festuca pratensis Huds.)

The variety bred was named 'Priangarskaya'. It orignated from the wild form, collected on the Angara River valley (Bratsk district, Irkutsk region), as a female form and the selection bred at the Tulun Plant Breeding Station as a male parental form. The variety is notable for high winter hardiness, good after growth since spring and after hay cuttings as well as for rather heavy productivity during 4-5 years. It may be also found valuable for using as a pasture crop. The yield for three cycles averaged: hay - 43.1: seed - 4.7 h kg/ha. The check variety showed 38.9 and 2.4 h kg/ha, respectively. The variety has been regionized in Irkutsk and Kemerovo regions.

Alfala (Medicago L., subgenus Falcago Crossh.)

This is a more difficult species for farming, seed growing and breeding in the Eastern Siberia. Though a number of winter hardy varieties have been developed, the yield of seed in some years is problematic (particularly in undertaiga and north taiga zones) due to lack of warmth and pollinators when blooming. Yet, alfalfa growing wild and as a field crop for the recent 20-30 years has been widely distributed. We have managed to evaluate various alfalfa material in collections received practically from all over the world. Particular attention was given to the wild yellow-flowered and hybrid forms. The former was notable for its very high resistance, while the latter - for rich genoplasm.

The research work has shown that more resistant varieties can be developed on the basis of yellow-flowered local wild forms of alfalfa. But they fail to be productive. Application of alfalfa M.sativa, notable for its high productivity, is complicated in the Siberian conditions due to low winter hardiness. This problem has been solved by using the selected alfalfa 'Kamalinskaya 930' (the motley-flowered hybrid alfalfa from forest-steppe zone, Krasnoyarsk territory) and 'Alarskaya' (the blue-flowered hybrid alfalfa growing near the Baikal zone, Irkutsk region). Both parental forms have been developed from local wild alfalfa. The alfalfa variety 'Tayozhnaya' was bred as the result of evaluation and selection of the hybrid material against the productive, infectious and selective backgrounds. With rather high winter hardness it is notable for long life (5-7 year and even longer), remains productive and surpasses the standard variety in hay approximately by 10%, in seed - by 25-30% (with the hay yield averaging 40 and seed yield - 1.5 h kg/ha). The variety has been regionized in Irkutsk region.

The personnel of the Siberian Scientific Research Institute of Plant Growing and Selection has obtained rather valuable material of Russian wild rye, orchard grass and wheat grass.

Variety and seed improvement is a basis of steady increases in yield and production quality under severe environmental conditions of the Far East and Siberia. Thanks to adaptability the local wild-growing forms and varieties-populations often solve the problem of fodder grass distribution.

Awnless brome grass 'Tulunsky', meadow fescue grass 'Priangar skaya' and alfalfa 'Taiozhnaya' have been developed in Eastern Siberia. Rather valuable material of the same species as well as of Russian wild rye, orchard grass and wheat grass (Agropyron cristatum) has been also obtained in Western Siberia. The rich material of wild grasses, collected in the Altai Territory, receives emphasise in the present breeding programme of the Siberian Scientific Research Institute of Plant Growing and Selection (the Lenin All-Union Academy of Agricultural Sciences, Siberian Branch).

Genetic resources for fodder plant breeding in the northern parts of Sweden

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In north Sweden as well as in the most northern parts of Finland and Norway agriculture is found much more to the north than somewhere else in the world. Thanks to the Gulf Stream running near the Norwegian coast, the whole northern Scandinavia has such a climate, that permits agriculture all over this area.

In Sweden this region stretches from latitude 62°N to 68°N. The length of the growing season is very short, from 170-180 days to only 140 days farthest in the north.

All overwintering species must therefore be well adapted to days with long daylength during a very short summer but also to a very long winter with a covering of deep snow.

The area of arable land in northern Sweden amounts to about 250 000 hectares. Leys are a dominant feature and cover about 60 per cent of arable land.

Plant breeding for the northern parts of Sweden was started 1906 by the Swedish Seed Association (from 1980 named Svalöf AB) at Luleå, situated about 100 kilometres south the polar circle. This breeding work started with grasses, mostly timothy and meadow fescue, collected both from natural meadows and from sown old leys. Nowadays timothy is dominant in the northswedish ley. The species timothy has migrated from south Sweden to the north during the last three centuries and timothy is today quite well adapted to the severe climate there.

After selection during a long time in collected endemic plants of timothy the first breeded variety "Bottnia" was aproved 1933 (1). Also the next new cultivar of timothy "Bottnia II" - approved 1954 - was selected from a collection made in the coastal region of the Gulf of Bothnia (2).

The conditions for seed production of ley plants are not so good on account of the short growing season in northern Sweden. Most of the seed therefore is brought in from southern Sweden. Seed-growing in a climate with shorter daylength seems to give changes in some characters. In meadow fescue as well as in timothy first harvest is reduced at the same time as second harvest has increased.

Bottnia II (Meadow fescue)

Pre-basic seed grown in north Sweden (relative value = 100) compared with Certified seed grown 4-5 generations in middle of Sweden.

	Number of trials	Certified seed, relative value first harvest	second harvest	Total yield
Ley year 1	27	99	108xxx	102
Ley year 2	26	96xxx	107xxx	97
Ley year 3	19	98	108xxx	101

In Norwegian trials was found that winter survival in the northern "Engmo"timothy is reduced with increasing years of seed production in southern Norway (5). This implies that if the characters selected for are not required in the environment, a genetic relapse due to natural selection may occur.

Red clover has been extensivly grown in north Sweden for somewhat more than a hundred years. An important adaption to local conditions has made many of the so-called land-races very valuable. As matter of fact one of such local strains still dominate in the herbage production in northern Sweden. This variety is named "Bjursele" and is the most winterhardy red clover in whole northern Scandinavia.

Most of these local strains are lost by crossfertilization with imported red clover from southern Sweden. Intense plant selections in "Offer"- one of the few preserved land-races - have resulted in Svalöf Björn. This is the first bred red clover variety for northern Sweden and Björn was approved as late as 1977 (4).

Particularly in northern Sweden the ley grasses are often attacked by the low temperature fungi Typhula ishikariensis and Sclerotinia borealis. These fungi cause annually a loss on 25-30 million Swedish crowns. Nevertheless the variety "Bottnia II" has a relatively good resistance, mostly owing to an intense natural selection.

Infection experiments with Typhula ishikariensis and Fusarium nivale have shown how superior a northern timothy variety is compared with a southern variety (3).

Variety		Attack index 1)	
		Typhula	Fusarium
Vanadis	(southern Sweden)	91	16
Bottnia II	(northern Sweden)	48	9
Engmo	(northern Norway)	38	2

1) Attack index = per cent dead plants + per cent surviving plants x per cent damage on surviving plants x 1/100.

Timothy is not so susceptible to Fusarium. Fusarium is also uncommon in north Sweden.

The two timothy varieties "Bottnia" and "Bottnia II" are mostly bred by renewed mass selections in material with a rather narrow genetic basis. Today the grass breeding in north Sweden is based upon intercrosses between timothy plants with much more varying origin.

<u>Breeding plan for the new variety Saga timothy</u>.

Svalöf Gloria (56°N) X Villmanstrand (Finnish local variety, 63°N)

↙

Svalöf Å 0850 (63°N) X 136 collects from the east Finland (63°N)

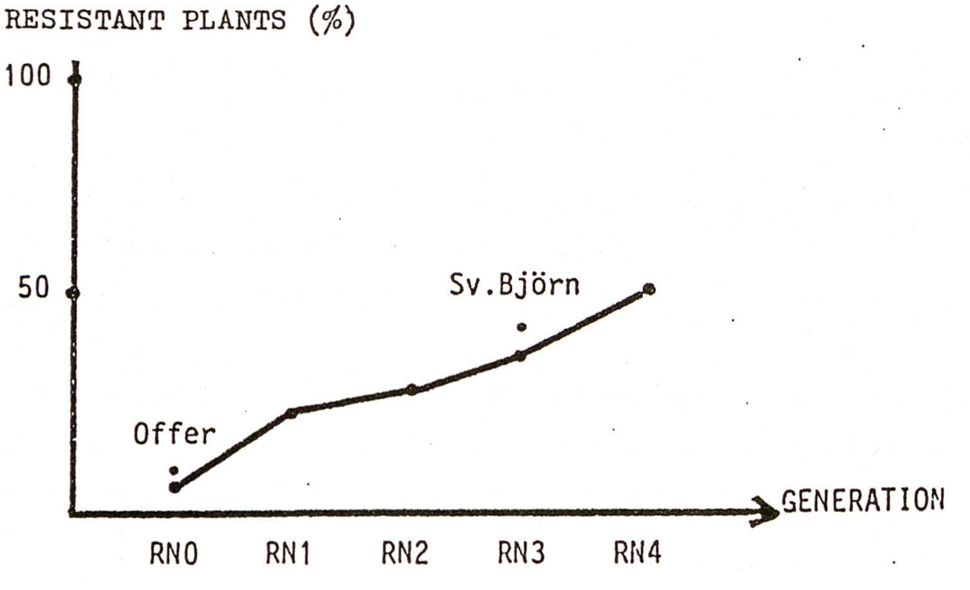
↓

Svalöf Saga (63°N) Approved 1981.

After intensive progeny test this new variety was based on 27 selected plants (4). The highyielding Saga seems to have the same winter hardiness as its precursor "Bottnia II" in spite of a further south origin.

The resistance against stem nematode is very low in all northern local strains of late red clover. By selection in inoculated seedlings the number of resistant plants has increased from 7 % in Offer to 45 % in the new variety Björn. Specially for seed production in southern Sweden all new northern red clover varieties must have a good nematode resistance.

Increasing resistance against stem nematode (Ditylenchus dipsaci) by repeated selections in the red clover variety Å 0146 (from Offer).



New promising varieties both of grass and clover indicate that the original northswedish collections still are a very good source for continued plant breeding. Today also new materials from the Nordic Gene Bank and from neighbouring countries within the Scandinavian Shield are tested.

Literature cited

1. N.Sylvén, Allm.Sv.Uts.AB,katalog 1933
2. G.Julén, Sver.Utsädesf.Tidskr. 1954
3. G.Vestman, Sver.Lantbr.Univ., not published
4. Kj.Wiklund, Svalöf AB, not published
5. I.L.Andersen, Forsk.Fors.Landbr. 1971

UTILIZATION OF TRIFOLIUM PRATENSE L. ECOTYPES IN THE BREEDING PROGRAMME OF TETRAPLOID CULTIVAR - RADYKA

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Wild ecotypes and indigenously cultivated populations of red clover are utilized as a basic plant material in breeding new cultivars. Almost all researchers working on that subject (Choroszajlow, 1964; Janossy, 1965; Julen, 1960; Laczynska-Hulewicz, 1966; Polak, 1974 and others) emphasize, that indigenous forms of red clover are best adjusted to local ecological conditions. That adjustment is due to long time natural selection. A breeder's task is to accumulate in a new cultivar as many traits, that condition good yields, as possible.

MATERIAL AND METHODS

In the breeding programme were utilized wild ecotypes *Trifolium pratense* var. spontaneum Willk., earlier sampled in the north-eastern regions of Poland (Góral, 1974) and a tetraploid cultivar Wielkolistna, which has been bred by Laczynska-Hulewicz (1966). The polyploidization of wild ecotypes was done by colchicinization. Fixed tetraploids of that forms of red clover were manually or with the employment of honey bees hybridized with the cultivar Wielkolistna. This was done under conditions of isolation chamber. Similar hybridization was conducted with diploid ecotypes of red clover and Hruszowska cultivar.

The assessment of seed setting and seed yield was performed on the basis of seed number per 100 florets and number of florets per one inflorescence, as well by the number of inflorescences and seed weight per unit area of canopy.

Single plants were picked out from a selection nursery, where they were grown in spacing 50 x 50 cm. As a basic criterion for selection of single plants, including plant vigour and plant healthiness, was seed weight per plant and seed quality. The main aim to breed polyploid hybrids was to achieve seed yield as high as seed yield of diploid cultivars. The yield of dry matter was estimated in field trials according to routine methods.

Breeding of a new cultivar was performed by the pedigree selection. A simplified scheme of that method is as follows:

I year	- hybridization of initial plant material
II year	- estimation of F_1 progeny and selection of single plants in the sowing year
III year	- sowing F_2 single plants and assessment of plant vigour in the sowing year
IV year	- selection and seed sampling from the F_2 plants
V & VI years	- reproduction of selected forms and assessment of seed yield
VII year	- foundation of parental material nursery and sowing for selective seed (elite); set up of preliminary trials
VIII year	- selective seed harvest; elaboration of results from the trials conducted in the VIIth year; set up of new trials; sowing of earlier reproduced parental seeds (seed from the VIth year
IX year	acceptance of R-72 cultivar into the registration list

RESULTS AND DISCUSSION

The preliminary selection conducted among the wild ecotypes allowed to specify forms of red clover showing plant vigour approximated to the vigour of cultivated clover. Seed setting by that plants was better than in the cv. Hruszowska. The newly selected forms set approximately 68.2 seeds per 100 florets, while Hruszowska only 54.2 seeds per 100 florets (Table 1).

The hybrids of red clover ecotypes with cv. Hruszowska had also higher percent of seed setting than Hruszowska, however they, in this regard, were not as good as the original ecotypes. In particular, the F_2 progeny had significantly lower seed setting (59.4%). Nevertheless, from the practical point of view should be said that the percent of seed setting by the hybrids was similar to that of cv. Hruszowska (Table 1).

The polyploidization decreased the seed setting. This could be distinctly seen in the frequency distribution from Figure 1. However, in this case also an average fertility of colchiploids C_2 was higher (44.6%) than the fertility of cv. Wielkolistna (28.1%). In comparison to the parental forms hybrids of the above mentioned two tetraploid forms represented an intermediate fertility. But the variability of F_2 progeny in regard to fertility was considerably higher than in cv. Wielkolistna and colchiploids obtained from wild ecotypes. Such a feature allowed to introduce, in the studied plant material, an effective selection for higher seed yield and establish of the tetraploid strain R-72.

Selection performed among wild ecotypes of red clover and their hybrids with cv. Hruszowska did not give desirable results. The strain L-427 showed, however, extremely high number of stems and very good seed setting (Table 1). Nevertheless its yield of green matter was lower 14-22% than of cv. Hruszowska (Góral, 1976b). Because of this feature the strain L-427 was left out in the further breeding.

The hybrids of wild ecotypes of red clover with cv. Hruszowska showed to be very weak in vigour and regrowth ability after cutting already in the F_1 generation. From the breeder's point of view there were not interesting forms in the progeny of hybrids with cv. Hruszowska. The hybrids were of the early type, shorter and less vigorous plants than of cv. Hruszowska (Góral, 1976b). Because of these traits, they were also left out in the further breeding.

Polyploids obtained from the same initial material gave lower seed yield than Hruszowska, but higher than tetraploid cultivars - Polish Wielkolistna and Czechoslovakish Tatra (Table 1 and Góral, 1976b). This material was multiplied and tested in the field trials in two locations. The yield of green and dry matter of first cut was as good as that one of tetraploid cultivars. However, plant regrowth after first and second cuts was significantly lower in comparison to the above mentioned cultivars. As a consequence, the total yield of dry matter of tested tetraploids was lower than in the standard cultivars.

The hybrids of tetraploid cv. Wielkolistna and tetraploids obtained from ecotypes were the most interesting as the breeding material. High morphological variability and plant vigour were the traits which characterized them most (Góral, 1976a).

Therefore already in the F_1 generation the basic criterion of selection was good seed setting per head, provided that the plant vigour characteristic for tetraploids was preserved. Thus in the first generation had been picked out plants with highest number of seeds per head (Table 1). In further generations there were selected single plants on the basis of high seed weight. It had been proved, that the weight of seeds per plant is conditioned not only by plant fertility, but also by plant vigour. The plant of weak vigour, even very fertile, rarely gives lower yield of seeds than an average for a population. If a single plant, even of weak vigour, gives high yield of seeds it is worthy for observation and further reproduction. Such a point of view is due to low seed yields in tetraploids which is the most important problem in breeding tetraploid clovers.

In relatively short time with the application of pedigree selection method was possible to specify forms of higher green matter yield, than that one of the cv. Wielkolistna. In addition to that above, their seed setting, in comparison to diploid forms, was relatively good (Góral, 1976b). That results were confirmed in preliminary trials conducted in Plant Breeding Stations Nieznanice and Skrzeszowice. The new strain R-72, yielded in fresh matter 11 to 32% better and in dry matter about 7% better than the standard cv. Hruszowska (Table 2).

On the basis of positive results with yield assessment in northern and southern regions of Poland the newly formed tetraploid cultivar of red clover R-72 has been accepted to the registration list and introduced to trials of the Centre for

Cultivar Research in Poland in 1974. The R-72 strain was tested in 10 locations in different regions of Poland. It was shown, that in comparison to cv. Hruszowska, R-72 strain on an average yields 600 kg more of digestible dry matter per one hectare. Its seed yield is not lower than the diploid cultivars and better than other tetraploid varieties (Table 3). Finally the strain R-72 has been admitted to the list of original cultivars and registered under the name Radyka. At present this variety is grown on 15% of the total acreage of red clover in Poland.

CONCLUSIONS

1. Wild ecotypes of Trifolium pratense L. originated from north-eastern regions of Poland showed considerable morphological and physiological variability and their fresh and dry matter yield was lower than that of cultivated forms.

2. The ecotypes of red clover showed the feature of poor regrowth ability and therefore the dry matter yield appeared to be not sufficient criterion of selection.

3. Polyploidization of selected ecotypes significantly increased fresh and dry matter yield per plant as well per unit of area, but the feature of weaker regrowth was not improved. Therefore, the fresh and dry matter yield of tetraploid clovers obtained from wild ecotypes was lower than the yield of cultivated forms.

4. In general, the hybrids obtained from the cross of wild ecotypes with cultivated clover yielded worse than the cultivated parental forms. However, the reduction of yield of the tetraploid hybrids was not significant.

5. The wild ecotypes of red clover and their tetraploids had better seed setting than the cultivated forms. The hybrids obtained after crossing tetraploids of the selected ecotypes with tetraploid clover cultivars give seed yield equal to diploid varieties. These hybrids made the initial material for breeding recently registered original tetraploid red clover variety - Radyka.

REFERENCES

Choroszajlow, N.G. 1964. Trudy po prikladnoj botanike, genetike i selekcii. 36, w.2,L.

Góral, S. 1974. Hod.Roslin Aklim. i Nasien. 18, 61-80.

Góral, S. 1976a. Hod.Roslin Aklim. i Nasien. 20, 131-143.

Góral, S. 1976b. Hod.Roslin Aklim. i Nasien. 20, 145-155.

Janossy, A. 1965. Acta Agr.Hung. 14, 49-58.

Julén, G. 1960. Handb.Pflanzenzuchtung IV, 239-320.

Laczynska-Hulewicz, T. 1966. Postepy Nauk Rolniczych 97, 77-84.

Polak, J. 1974. Acta F.R.N. Univ.Comen., Genetica 5, 149-162.

Table 1. Seed setting in di- and tetraploid red clover

Forms of clover	Number of seeds per 100 florets
'Wild' strain 427 2x	68.2
Hruszowska - cv. 2x	54.2
F_1 (exh) 2x	66.3
F_2 (exh) 2x	59.4
Total 2x	61.8
'Wild' strain 402 4x	44.6
Wielkolistna - cv. 4x	28.1
F_1 (C_2 x W) 4x	34.3
F_2 (C_2 x W) 4x	39.2
Total 4x	37.5

Table 2. Dry matter yields (t/ha)+ in I and II year of vegetation

Varieties		I Veg. year	II Veg. Year
Tatra 4x	CS	3.6 a	13.6 a
Radyka 4x	PL	3.5 a	13.3 a
'Wild' 4x L-402		3.1 ab	11.2 b
Hruszowska 2x PL		3.3 a	12.4 ab
Hybrid 2x ec x Hrusz.		2.8 b	9.8 c
'Wild' 2x L-427		2.3 c	8.6 d

+Average of three trials

Table 3. Comparison of seed yield of ten tetraploid varieties at Radzikow 1979

Varieties		Yield of seed (kg/ha)
Perenta	DDR	395 a
Radyka	PL	389 a
Hungaropoly	H	345 a
Pelly	S	266 b
Rea	S	264 b
Jubilatka	PL	230 bc
Tripo	N	212 bc
Tetri	NL	193 c
Rotra	B	137 cd
Hera	DK	97 d

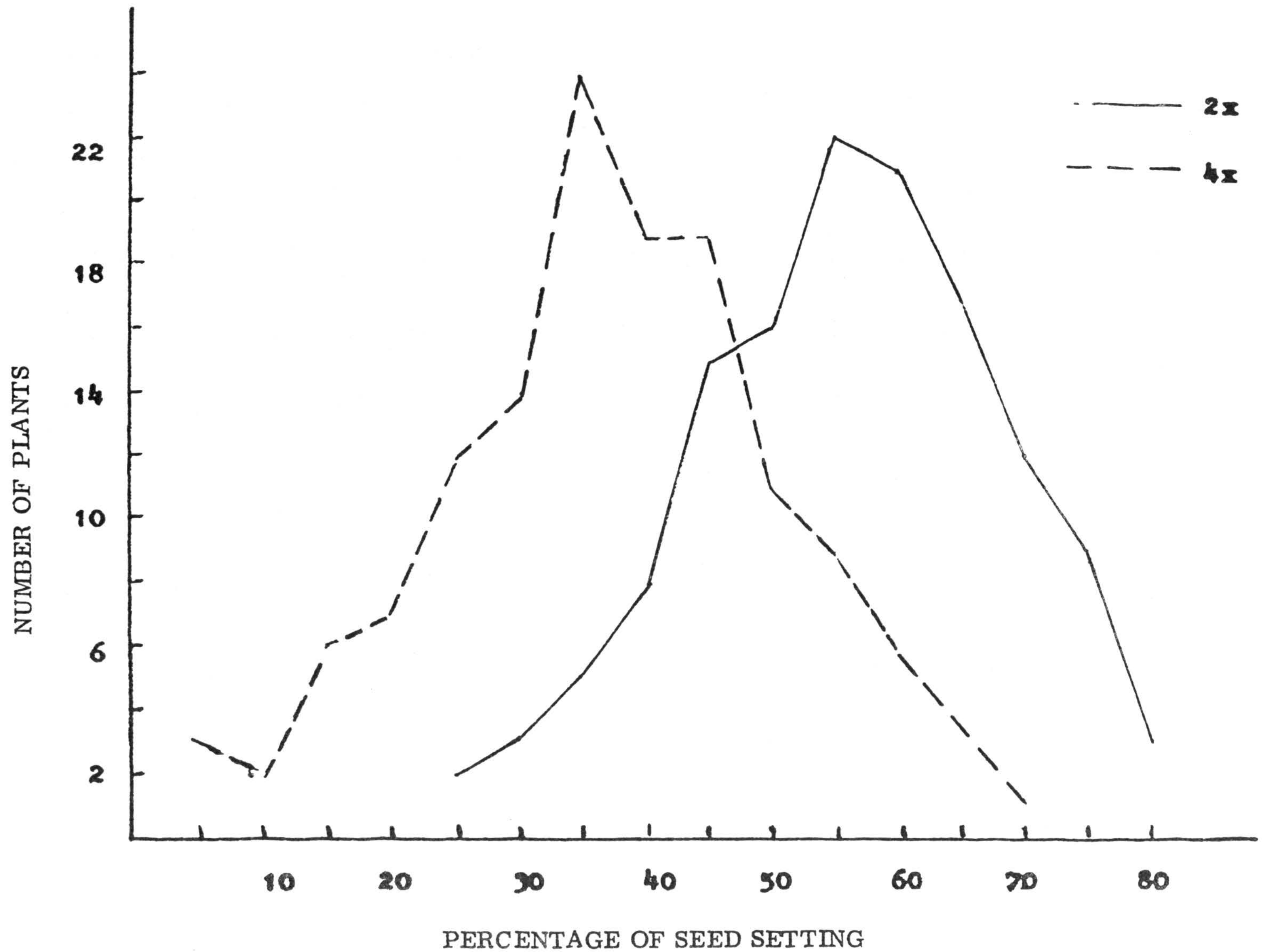

FIGURE 1. DISTRIBUTION OF SEED SETTING IN DI- AND TETRAPLOID RED CLOVER

USE OF GENETIC RESOURCES IN BREEDING DIPLOID RYEGRASSES FOR CONSERVATION

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The aim of our work is to produce ryegrass (Lolium spp.) cultivars which can provide grazing for as much of the year as possible as well as reliably high yields of digestible dry matter for conservation in late May, June or July. Short-term cultivars, typified by Italian ryegrass, can be very useful for rotational farming systems. But there is a potentially even greater role for highly persistent types for use on all-grass farms. For this latter purpose, substantial improvements over existing pastures (many of which now contain a high proportion of ryegrass) must be achieved in order to justify the cost of ploughing and re-seeding. This paper describes our use of three very different types of ryegrass in the breeding programme.

Perennial Ryegrass

One major deficiency of the present perennial ryegrass cultivars is their poor early spring growth compared with that of some other species such as Italian ryegrass. There is considerable variation in spring growth within the species but there is a close association between early growth and early flowering. Populations with the best spring growth (collected by B.F.Tyler from the Piedmont plains of Northern Italy) have a mean ear emergence date at Aberystwyth of 5-20 April, depending on the season. At the start of the project it was not clear whether this association between early growth and early flowering was due to a plieotropic effect or to the simultaneous evolution of increased ability to grow at low temperatures and early flowering being necessary for successful reproduction in certain habitats.

Early in the spring of 1978, 30 plants with the best growth were taken from plots sown with five populations from the Piedmont plains (Welsh Plant Breeding Station accession numbers Ba 8590, Ba 8596, Ba 8598, Ba 8622 and Ba 8624). These plants were multiplied vegetatively and grown as clonal plots, along with a range of other material. There were two 1.2 x 1 m plots per clone and plants were 10 cm apart. In March of 1979, which was unusually cold, the mean dry matter yield of these early clones when cut at 4 cm was 310 kg/ha, while that of 10 clones from cv. Frances was only 20 kg/ha. Large differences between the early clones in winter hardiness and persistency were evident and some seemed highly productive. However, it was clear that this material could not provide high conservation yields because the time between the onset of growth in spring and anthesis would be too short to allow the accumulation of enough dry matter. Grazing in March or April would add to the problem by removing most of the inflorescences which are important in providing a tall canopy and a sink for photosynthates.

One selected clone from each of three early populations was cross-pollinated with five extremely late-flowering clones (2 from cv. Melle Pasture and 3 persistent clones with good resistance to ryegrass mosaic virus). Flowering time was co-ordinated by growing the late-flowering clones in a heated glasshouse while plants of the early clones were kept in a controlled environment room at 5°C for 3 weeks before use. Following polycrossing and two generations of intensive selection for early growth and late flowering, 23 F_4 plants were recovered which had as good spring growth as the early parental clones but whose inflorescences emerged some 30 days later (at about the same time as cv. Frances). These have formed a synthetic which is being evaluated at present. If the results of these trials are as good as we expect, we will use this as a basis for the production of a series of cultivars with different inflorescence emergence dates but with uniquely early growth. These will allow grazing early in spring, when grass is in short supply, to be followd by heavy conservation crops. So far this has been possible only with the short-lived Italian ryegrasses and Italian/perennial hybrids.

Italian Ryegrass

Some Italian ryegrasses collected from the Po Valley region of Italy are outstanding in two respects. Firstly, the digestibility of their flowering stems is some four units higher than other Italian ryegrasses at the same stages of inflorescence emergence (Hides, Lovatt & Hayward, 1983). This is attributable mainly to a lower cellulose content and is equivalent to a yield increase of approximately 9% at the first conservation cut. Secondly, they regrow extremely rapidly after cutting and so can intercept more light during the season. The amount of light intercepted by photosynthetically active tissue is the main factor limiting crop yields where there is adequate water and nutrients (Monteith, 1981). Table 1 shows that this increased yield potential can be realised in field plots, particularly when they are harvested frequently. The rapidly regrowing synthetic Bb 2042 was bred from a range of Po Valley populations and is presently being multiplied for further trials.

The deficiencies of Po Valley populations include poor winter hardiness, low tiller density, susceptibility to leaf rust (Puccinia recondita) and mildew (Erysiphe graminis), and a tendency to shed seed. Significant improvements in all these characters have been achieved by selecting plants of Po valley origin. In one instance, this was done by breeding from within Bb 1276, a single Po valley population (Hides, Lovatt and Wilkins, 1980). The resulting synthetic (Bb 1906) did well in our trials and is now undergoing national trials. This population still contains genetic variation which has not yet been utilised, in magnesium content for example (Table 2). However, levels of winter hardiness remain inadequate to avoid the risk of yield loss in the second harvest year. To improve this further it may be necessary to use a non- Po valley type such as Tarquin. When grown as closely spaced plants, F_2 families from hybrids between one Po valley population and north European types such as cv. RvP Lemtal showed dominance for the favourable expression of several characters affecting yield (Hides, 1978). But later generations of this material did not yield as much as pure Po valley types when grown as plots.

Since it is difficult to accurately measure the yield of large numbers of genotypes under high density conditions, these results emphasise the need to identify specific, single-component characters when attempting to introduce genes from very different plant types.

Exchange of Genes Between Italian and Perennial Ryegrass

Until now, breeders have concentrated mainly on tetraploid or F_1 hybrids as means of combining the better characteristics of Italian and perennial ryegrass. Since gene action in ryegrass is often additive (Breese & Hayward, 1972), such hybrids are intermediate for many characters. The slower but perhaps ultimately more fruitful approach of transferring specific characters from one species to another has been given less attention. In perennial ryegrass, there are much higher levels of cold tolerance, resistance to shoot-flies, and resistance to ryegrass mosaic virus (RMV) than can be found in Italian ryegrass. Conversely, the stem digestibility and rapid regrowth of some Po valley Italian ryegrasses are superior to anything yet found in perennial ryegrass.

Salehuzzaman (1982) studied resistance to ryegrass mosaic virus (RMV) in two clones of perennial ryegrass from this point of view. He found two types of resistance under independent genetic control, resistance to infection and resistance to virus multiplication and spread within the plant. Resistance to infection was thought to be the most useful since it was highly effective aganst a wider range of virus isolates than was resistance to multiplication and spread. Judging from the number of fully resistant plants recovered from F_2 of hybrids between these resistant clones and Italian ryegrass (about 1 in 500), resistance to infection was controlled by 4 or 5 genes. It was linked weakly with narrow leaves and absence of awns but not with leaf length or with three independently segregating isozyme loci. This resistance to infection is currently being transferred to Italian ryegrass Bb 1906 by repeated cycles of backcrossing followed by polycrossing of the hybrids and recovery of fully resistant plants. By using artificial lighting and vernalisation it has been possible to complete one such cycle within a year. If genetic linkages are generally as weak as those found in this study, five such cycles may well be adequate to obtain a resistant cultivar very similar to Bb 1906. Resistance appears to be due to a heat-labile high molecular weight virus inhibitor and not to differences in leaf anatomy (Salehuzzaman & Wilkins, 1983), so undesirable plieotropic effects are not expected in this case.

Unfortunately, not all characters can be measured as quickly and easily as RMV resistance. If each cycle of backcrossing took two or even three years to complete, transfer of characters could easily take 15 or 20 years instead of the five years envisaged for resistance to RMV infection. It would be essential to do a thorough feasibility study before embarking on such a long-term project but the work described above suggests that similar studies may well be worthwhile for several other characters.

CONCLUSIONS

So far then, we have had little difficulty in manipulating characters by breeding provided that:

1) they are specific single-component characters (not total annual yield)

2) there is plenty of genetic variation in each character

3) the genotype of thousands of segregating plants can be identified quickly and accurately.

If there are very few valuable characters that meet all three of these conditions then work should concentrate on increasing their number before embarking on long-term breeding projects. This approach will lead to the fullest possible use of the available genetic resources and, because they know that their work will be put to good use if at all possible, it will encourage scientists not directly involved in breeding programmes to help in extending those resources.

REFERENCES

Breese, E.L. & Hayward, M.D. (1972). The genetic basis of present breeding methods in forage crops. Euphytica 21, 324-336.

Hides, D.H. (1978). Breeding for improved seasonal yield distribution and regrowth potential in Italian ryegrass. Rep.Welsh Pl.Breed.Stn for 1977, pp.28-29.

Hides, D.H., Lovatt, A.J. & Hayward, M.V. (1983). Influence of stage of maturity on the nutritional value of Italian ryegrass cv. RvP and an introduced ecotype from the Po valley region of Italy. Grass and Forage Science (in press).

Hides, D.H., Lovatt, A.J. & Wilkins, P.W. (1980). Breeding for improved seasonal yield distribution and regrowth potential in Italian ryegrass. Rep.Welsh Pl.Breed.Stn for 1979, pp.41-44.

Monteith, J.L. (1981). Does light limit crop production? In: Physiologucal Processes Limiting Plant productivity (C.B. Johnson ed.). pp.23-38. Butterworths.

Salehuzzaman, M. (1982). Resistance to ryegrass mosaic virus. Ph.D. Thesis, University College of Wales, Aberystwyth. pp.171.

Salehuzzaman, M. & Wilkins, P.W. (1983). Inhibitory activity in *Lolium perenne* associated with resistance to infection by ryegrass mosaic virus. Physiol.Pl.Path.(in press).

Table 1. Mean yield (t/ha) over two harvest years (1980 and 1981) under two different cutting systems of Italian ryegrass synthetics differing in speed of regrowth

	RvP	Bb 2042	Gain	P
5-cut yield	35.3	36.2	+ 3%	NS
9-cut yield	17.7	19.3	+ 9%	0.05
Mean regrowth score (1-5)	2.6	4.4	+69%	0.01

Table 2. Response of the Po valley Italian ryegrass population Bb 1276 to two generations of phenotypic selection for high magnesium content (Mean Mg % in dry matter)

	Selection cycle 1 (September 1975)	Selection cycle 2 (April 1978)
Bb 1276	0.212	0.121
High Mg Bb 1276	0.265	0.180
Gain	+25%	+49%
LSD (5%)	0.016	0.030

Development of clubroot resistance breeding programmes for the forage brassicas

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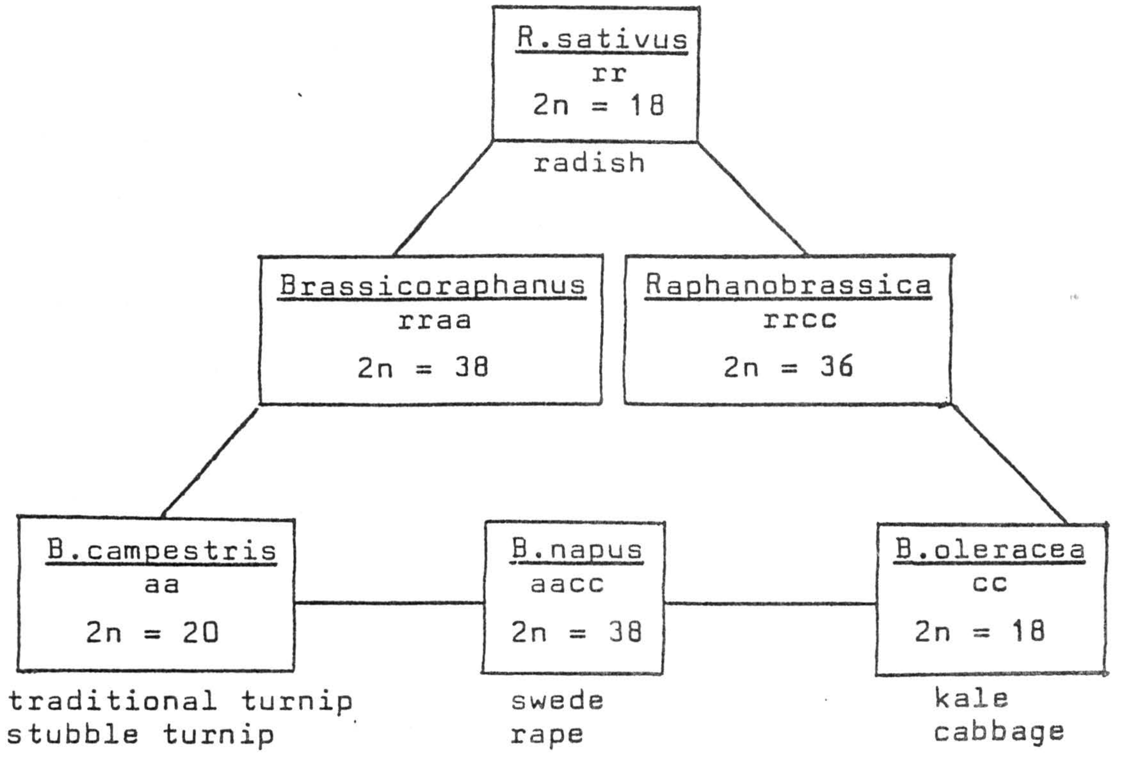
Introduction

The three main breeding programmes in the Brassica Breeding Department at the Scottish Crop Research Institute are on swede, forage rape and kale. There are also small breeding programmes on traditional turnips and fodder cabbage. Advanced lines of fodder radish and Raphanobrassica are also available in the Department providing altogether a very wide range of fodder brassica material.

The species relationships among the forage brassicas can be illustrated diagramatically:-



Disease Assessment

Clubroot is probably the most important disease of the fodder brassicas and the breeders consider resistance to clubroot to be one of the highest priority breeding objectives.

The disease is caused by a soil borne organism, Plasmodiophora brassicae Wor. with a cosmopolitan distribution. It may persist in the soil as resting spores for several years. A severe infection can lead to complete crop loss due to gall formation on the roots and the consequent interference with functioning and development of the root system.

Less severe disease symptoms may result in reduced dry matter yields, but mild infections also occur without causing any loss in yield (Table 1).

Table 1. Rape clubroot trial 1981 (plot means)

		Lair	Nevin	AR5/7
% infection	Control	24.00	0.23	7.43
	Inoculated	100.00	7.91	29.55
FW yield (kg)	Control	4.63	3.13	6.52
	Inoculated	0	3.24	6.61

Collections of P.brassicae from field soils and even from galls on a single host plant are composed of mixtures of pathotypes. These mixtures, when derived from a specified host, are called populations. Interaction with host and environment may affect the virulence pattern of a population; some populations are more stable than others.

Each population gives a characteristic reaction when inoculated onto a series of differential hosts under standard conditions. The European Clubroot Differential (ECD) set comprises fifteen host genotypes; five *B.campestris*, five *B.napus* and five *B.oleracea* (Buczacki *et al* 1975).

At SCRI, in order to minimise environmental variation, glasshouse tests are used to screen all material; advanced breeding lines are also field tested. Seedlings are inoculated two to five days after germination with a suspension of resting spores. Disease incidence and severity are scored five weeks after inoculation. Comparable results have been obtained from glasshouse and field tests where the same host and pathogen combinations have been used.

A survey of soil populations of *P.brassicae* in SE Scotland by Lewis (1981) showed that 36 out of 80 collections were pathogenic on all *B.oleracea* and *B.napus* ECD hosts. None of the collections were pathogenic on two *B.campestris* differentials which are derived from Dutch stubble turnips.

Brokenshire (1982), using some of Lewis' collections showed that some swede cultivars are resistant to populations which infect all the ECD *B.napus* lines. Preliminary work at Pentlandfield confirmed that at least one of the 'local' populations of *P.brassicae* was pathogenic on all the most widely grown swede cultivars. This population, coded Pb 7806, was subsequently used as a standard in the survey for resistance.

<u>Survey of forage brassica cultivars for resistance to P.brassicae</u>

Pb 7806 was used as the standard inoculum source but less pathogenic populations were also used in some tests. Disease severity was scored on individual seedlings and was used to calculate a disease index (Williamson and McRitchie, 1981) from samples of between 16 and 30 seedlings from each cultivar.

A summary of disease indices of cultivars inoculated with Pb 7806 is given in Table 2.

Table 2. Number of cultivars (cv) in each range of disease index

		Disease Index									
		0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100
Rape	23 cv	0	0	0	0	0	1	0	2	2	18
Swede	72 cv	0	0	0	1	0	2	0	6	30	34
Turnip	24 cv	0	0	0	2	0	0	9	8	5	0
Kale	48 cv	0	0	0	1	3	8	20	12	3	1
Cabbage	39 cv	0	0	0	0	0	0	3	14	19	3
Radish	67 cv	13	10	14	4	2	7	6	7	2	2
		Resistant			Susceptible				Very susceptible		

The results are not strictly comparable between crop types since these were tested on different occasions - apart from the cabbage and kale cultivars which were assessed at the same time. But a similar distribution of disease indices has been obtained in other, less comprehensive tests.

Forage rape cultivars were all very susceptible to the standard population and to several less pathogenic populations. The only cultivar resistant to some of the latter was Nevin (Johnston, 1970).

Samples from the SCRI Swede Gene Bank have been included in clubroot tests as they became available. All the swede cultivars tested were susceptible to the standard population but, unlike rapes, there was some variation between cultivars in resistance to less pathogenic populations of P.brassicae.

The turnip cultivars tested were all traditional turnips and were susceptible to the standard population.

Kale cultivars showed a greater range of disease indices than cabbage cultivars, and generally developed less severe disease symptoms.

The Raphanus accessions tested included cultivars from the UK, Germany, China and Japan; more than half the accessions were resistant to the standard population, the remainder showed symptons varying from mild to severe. Eleven cultivars were also resistant to a population which was pathogenic on all B.campestris ECD lines, obtained from Dr. P. Mattusch in Fed. Rep. Germany.

As a result of this survey, it was clear that in the more important forage brassica crops, the cultivars currently in use in the UK were all susceptible to the standard population of P.brassicae. The immediate objective, therefore, is to produce cultivars with resistance to the Pb 7806 range of virulences.

Resistance is predominantly oligogenic in B.campestris and B.napus, and polygenic in B.oleracea (Crute et al, 1980)

In the latter species, there appears to be scope for selection for clubroot resistance within the kales. There is no evidence that the required resistance occurs in *B.napus* or in the traditional turnips although it is present in some stubble turnips. The other potential source of differential resistance identified was in *Raphanus*, but this is less accessible for inclusion in breeding programmes as the introgression from *Raphanus* into *Brassica* species will be difficult.

Utilisation of sources of resistance in breeding programmes

1. Traditional turnip breeding programme

In 1978 six of the highest yielding traditional turnip cultivars were crossed with the most resistant stubble turnip from the ECD series, ECD 04. The progenies have been selected for clubroot resistance and backcrossed to the traditional turnip parents. In the third backcross generation, progenies were still segregating for resistance.

2. Kale breeding programme

The current kale breeding programme at SCRI is based on population improvement and the production of open pollinated varieties. The kales have previously been reported to be generally 'tolerant' to clubroot in the field and consequently little selection for resistance has been practised. However, seedling tests using several of the local populations of *P.brassicae* indicated that many cultivars were susceptible. Results from a field trial confirmed that clubroot can cause serious yield losses (Table 3).

Table 3. Plot means from kale field trial; plants inoculated with Pb 7806

	Inoculated		Control		SED
	Kestrel	Rawara	Kestrel	Rawara	
Percentage infection	100.00	82.9	1.3	1.3	
No.plants at harvest	4.75	18.75	19.50	19.50	0.94
Dry matter yield (kg)	0.396	0.679	0.869	0.851	0.072
Percentage yield loss	54.4	20.2			

Two kale populations have been established from different sources and family selection is being used in both populations for clubroot resistance.

3. Swede and forage rape breeding programmes

There are two methods which can be used for the introgression of characters from *B.campestris* into *B.napus* (McNaughton and Ross, 1978). Both have been used at Pentlandfield for the introgression of clubroot resistance and for other characters.

a) Production of the sesquidiploid F_1 hybrid (2n = 29) between *B.campestris* and *B.napus*, then backcrossing to *B.napus* and selecting 2n = 38 plants with the required resistance genes. This is similar to the method used by Lammerink (1970).

Two series of material have been produced in this way. The first, started in 1971, was backcrossed to swedes. The second was backcrossed to oil seed rape (Gowers, 1979) but some lines have subsequently been used in the swede programme. There are currently several advanced SCRI swede lines with resistance to Pb 7806 from these series.

b) Production of artificial B.napus by crossing B.oleracea and B.campestris; this is a difficult cross requiring embryo culture to attain an 'acceptable' success rate of c.8 hybrids per 100 pollinations (Snell, 1978). Recently, ovary culture has also been successfully used to facilitate production of the interspecific hybrids (McNaughton, personal communication).

There are several artificial B.napus lines with resistance from the stubble turnip ECD 04. Most of these have a complex background since the newly synthesized amphidiploids have usually been crossed to swede or rape cultivars to improve seed fertility before they are used in breeding programmes.

There are three series of material with clubroot resistance from ECD 04. In one series, artificial B.napus lines were crossed with swede cultivars and advanced breeding lines in 1980. A second series was crossed to forage rape cultivars in 1981. A third produced in 1981 and 1982 will be treated in the same way.

Current strategies and long term objectives

Currently at SCRI the known and accessible sources of resistance in the forage brassicas are being used in the breeding programmes. There is evidence that pathotypes of P.brassicae with virulence factors matching the stubble turnip resistance genes appear where stubble turnips are intensively grown. This suggests that it would be counterproductive to use this form of resistance exclusively.

In the longer term, several strategies are being examined which should lead to further improvements in clubroot resistance.

1. Investigation of the genetic control of resistance in the Brassica crops.

This work will now be facilitated by the use of pathotypes which have been isolated by Jones (1981) and Fox-Roberts (verbal communication).

2. The synthesis of B.napus with resistance from both parent species.

Clubroot resistance has been introduced from the stubble turnips (B.campestris) but kale populations selected for clubroot resistance have not previously been available.

3. Introgression of resistance genes from Raphanus into B.napus.

There are at least three theoretically possible pathways which are being investigated for introgression:

a) B.napus x R.sativus with the F_1 hybrid treated with colchicine to give the allohexaploid aaccrr; the hybrid would then be backcrossed to B.napus, screened cytologically for additional Raphanus chromosomes and selected for clubroot resistance.

b) B.oleracea (diploid or tetrapolid) x R.sativus with the F_1 hybrid backcrossed to B.oleracea; plants with an additional 'r' chromosome and clubroot resistance would then be crossed with *B.campestris* to obtain an artificial *B.napus*.

c) As an alternative to the initial hybridisation in method b), existing lines of *Raphanobrassica* produced at SCRI are being used.

A number of putatively hybrid seeds have been obtained from crosses in 1981 and 1982. It is expected that mutagenic treatment will be required to induce translocations betweens the *Raphanus* and *Brassica* genomes.

4. A wider survey for useful resistance in the Brassica species.

Both *B.campestris* and *B.oleracea* include a range of morphological variation and several crop types in addition to those so far examined. Also, resistance to UK populations of *P.brassicae* has not yet been assessed in the related species *B.nigra*, *B.carinata* and *B.juncea*.

5. The possibility of using partial resistance to P.brassicae.

This depends first on the identification of major genes as they may mask, or influence, any assessment of partial resistance. Its effective use will need to be examined in relation to yield and pathogen populations in the soil.

6. The use of mutagenic treatments to improve disease resistance.

Both pollen irradiation and chemical treatments (using ethyl methane sulphonate) are being examined.

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References

Brokenshire, T. (1982). The reaction of forage brassicas to nine populations of *Plasmodiophora brassicae* Woron. from S.E.Scotland. Annals of Applied Biology 100 Supplement: Tests on Agrochemicals and Cultivars, 3, 92-93.

Buczacki, S.T., Toxopeus, H., Mattusch, P., Johnston, T.D., Dixon, G.R. and Hobolth, L.A. (1975). Study of physiologic specialization in *Plasmodiophora brassicae*: proposals for attempted rationalization through an international approach. Transactions of the British Mycological Society 65 (2), 295-303.

Crute, I.R., Gray, A.R., Crisp, P. and Buczacki, S.T. (1980). Variation in *Plasmodiophora brassicae* and resistance to clubroot disease in brassicas and allied crops - a critical review. Plant Breeding Abstracts 50 (2), 91-104.

Gowers, S. (1979). Clubroot resistant oil-seed rape. Eucarpia, Cruciferae Newsletter No. 4, 26-27.

Johnston, T.D. (1970). A new factor for resistance to clubroot in *Brassica napus* L. Plant Pathology 19, 156-158.

Jones, D.R. (1980). A study of factors affecting the differential pathogenicity of Plasmodiophora brassicae Wor. PhD thesis, Cambridge University.

Lammerink, J. (1970). Inter-specific transfer of clubroot resistance from Brassica campestris L. to B.napus L. New Zealand Journal of Agricultural Research 13 (1), 105-110.

Lewis, Susan J. (1981). Studies on variation in Plasmodiophora brassicae populations. PhD. thesis, University of Edinburgh.

McNaughton, I.H. and Ross, Carol L. (1978). Inter-specific and inter-generic hybridization in the Brassicae with special emphasis on the improvement of forage crops. Annual Report of the Scottish Plant Breeding Station, 1977-1978, 75-110.

Snell, Carol L. (1978). Brassica oleracea x B.campestris hybrids in forage rape and swede (B.napus) breeding. In: Interspecific hybridization in plant breeding. Proc. 8th Eucarpia Congress, Madrid, 1977, 339-343.

Williamson, Cynthia J. and McRitchie, Allison M. (1981). Resistance of kale and some cabbage cultivars to two populations of Plasmodiophora brassicae Woron. Annals of Applied Biology 97 Supplement: Tests on Agrochemicals and Cultivars, 2, 70-71.

GENETIC RESOURCES AND THE BREEDING OF SEED PRODUCING AND LEAFY FORMS OF BRASSICA SPECIES

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The programme of hybridization between *B.oleracea*, *B.campestris* and *B.napus* species selected from our own genetic resources - collection of winter and summer forms of *Brassica* genus - was started in 1976 (Balicka *et al.*, 1978; Mlyniec *et al.*, 1979; Mlyniec, 1981). The analysis of the genetic and phenotypic features of hybrids, as well as their agricultural value in comparison with the forms in the collection was started recently. This paper presents some results of this evaluation with emphasis on their value as the initial material for the leafy fodder catch crop breeding.

MATERIAL AND METHODS

Collection consisted of:

1. *B.napus* ssp. *oleifera* f.*biennis* and *annua*:

Polish and foreign winter rape seed varieties	- 81 accessions
Foreign winter leafy fodder forms of rape	- 14 accessions
Polish and foreign rape seed summer varieties	- 12 accessions

2. Species of 10-chromosomes complex of *B.campestris*:

ssp. *oleifera* f.*biennis* and *annua*	
Polish and foreign winter turnip rape varieties	- 32 accessions
Polish and foreign summer turnip rape varieties	- 12 accessions
ssp. *pekinensis* - Chinese cabbage	- 2 accessions
ssp. *trilocularis* - yellow sarson	- 1 accession

3. *B.oleracea*:

var. *acephala* - fodder kale, Polish and foreign varieties	- 8 accessions
var. *gemmifera*	- 1 accession

4. *B.subspontanea*:

ssp. *planifolia*	- 1 accession
ssp. *crispifolia*	- 1 accession

Our investigations took into account F_3, F_4 and F_5 generations of different, more or less phenotypically stabilized lines (number given in brackets) derived from following hybrids.

1. B.c. ssp. pekinensis Granaat x B.c. ssp. trilocularis Yellow Sarson (21)
2. B.c. ssp. pekinensis Granaat x B.n. ssp. oleifera cv. Bronowski (8)
3. B.n. ssp. oleifera cv. Bronowski x B.c. ssp. pekinensis Granaat (45)
4. B.c. ssp. pekinensis (4x) x B.c. ssp. oleifera cv. Pluto (1)
5. B.c. spp. pekinensis x B.n. cv. Asparagus Kale (2)
6. B.c. spp. oleifera cv. Pluto x B.c. ssp. pekinensis Granaat (4x)
7. B.n. (leafy fodder form) cv. Akela x B.c. ssp. pekinensis Granaat (10)
8. B.n. (leafy fodder form) cv. Siberian x B.c. ssp. oleifera cv. Arctus (2)
9. B.n. (leafy fodder form) cv. Siberian x B.n. (leafy fodder form) cv. Asparagus Kale (intraspecific) (12)

Cytological analyses covering the number of somatic chromosomes visible during metaphases were made by method of Jochemsen & Mlyneic,(1974).

The description of each form was based on spaced plants grown in one replication experiment on fields of the National Genetic Resources Department, Plant Breeding and Acclimatization Institute in Radzików, near Warsaw and some selected forms - on the fields of the Plant Genetics Institute Polish Academy of Sciences in Poznan.

The collection at the beginning considered as the source of the parental forms for hybridization and later on as a background for evaluation of the hybrids obtained was described according to the following agricultural features:

1. Intensity and vigour of vegetative growth in autumn (scale 1-6)
2. Winter hardiness - percent of plants surviving the winter (in 10 classes)
3. Intensity and vigour of spring vegetative growth (scale 1-6)
4. Measurements of the following morphological features:
   height of plants (cm)
   number of leaves and their size
   index of leaf surface per plant = $\frac{\text{length x breadth}}{100}$ x number of leaves
   index of leaf surface per plot
   index of leaf surface x number of plants surviving the winter
5. Earliness of generative development (results of observations are divided into 5 groups), seed weight per plant (in g)
6. Seed production per plant (in g) and some fertility parameters
7. Quality features such as fatty acid composition of seeds; and glucosinolates, protein and fibre content of both seeds and green matter
8. Disease occurrence and pest attacks (scale 0-5)
9. Anthocyanin colouration and presence of wax on the stem and leaves regarded as the morphological marker - were also observed.

Differences in the relief of seed coat as a quick test of the uniformity of seed samples in the collection and the way of identification of hybrids - is still under investigations (Mlyniec et al., 1979; Röhm-Rodowald, in preparation).

Self compatibility or incompatibility was expressed by silique formation and seed setting under isolation and after free pollination. Fertile silique per plant were recorded and measured and developed seeds - counted. Results of biometrical measurements were complemented by information of pollen grain vitality. Inflorescences of low fertile plant were fixed for meiotic and mitotic investigations.

SOME RESULTS AND DISCUSSION

There is a great need in our country for catch crop cultivation as the basis for animal feeding and forms the main point of evaluation of our Brassica collection as well as hybrids obtained.

The results of intensity and vigour of vegetative growth in autumn and in spring observations and winter hardiness screening are shown in Tables 1, 2 and 3.

Chinese cabbage cvs representing high quality of green matter with very low glucosinolate contents grew intensively in autumn and were vigorous. But as seen in Table 2 they were not completely winter-hardy. Night temperatures just below 0°C killed the plants outright.

Fodder kale varieties also grew intensively, producing high green matter yield in autumn. They were more frost resistant than the chinese cabbage, but frosts of temperatures about -4°C killed the plants. There were no differences in this respect between fodder kale cultivars in our collection.

Of particular interest from the winter catch crop point of view seemed to be the leafy forms of fodder rape. They grew intensively in autumn. Among varieties in our collection there were differences in this respect, the intensively growing varieties (Bishop, Akela, Asparagus kale) were insufficiently winter-hardy (Coboru, 1976). On the other hand, slower growing plants and of rather low vigour for green matter productivity (e.g. cv. Siberian) were very winter-hardy and because of that was considered as the source of winterhardiness in our hybridization programme. Turnip rape cultivars differed in intensity of vegetative growth and vigour in autumn, but in general they were rated higher than rape seed varieties. Their winter hardiness was high and varieties did not differ much from this point of view. Differences between cultivars in green matter productivity was the main criterion for selection of parental forms for crossings. Pluto and Arctus cvs seemed to be the most suitable for this purpose.

We had at our disposal a great range of new and old traditional varieties of rape seed cultivars. Among them were some well adaped to Polish climatic and soil conditions e.g. Gòrczanski, Dolnoslaski, Skrzeszowicki as well as new, improved, Polish (Janpol, Start) and foreign varieties. They differed in winter hardiness, the intensity of vegetative growth, and green matter production, and are a rich source of potential parents for hybridization.

Hybrids numbers (see Material and Methods in this paper) 2, 3, 5, 7 and 8 were mainly sesqui-diploids with 2n=29 chromosomes. They are being multiplied and selected to stabilize the chromosome number and genomic constitution at that of B.napus (McNaughton & Ross, 1978). Hybrid numbers 1, 4 and 6 had 2n=20, and the intraspecific hybrid No. 9 2n=38 chromosomes.

Fertility disturbances were not found in hybrids numbers 1, 4 and 6 which were derived from crosses between different subspecies of B.campestris (Olsson, 1954; Andersson & Olsson, 1961) regarded by certain taxonomists as distinct species (for example Helm, 1963; Claus, 1975, 1978). Hybrids showed great phenotypic variability even within lines. This variability was strongly marked in the progeny of hybrids numbers 2 and 3. Variation ranged from the typical seed forms with distinctive main stem and high seed yield to the very leafy forms. Time of flowering, length of the vegetative period as well as such markers as anthocyanin colouration and presence of wax on the stem and leaves also varied.

As was expected ssp. pekinensis introduced into hybrids such features as intensity and vigour of vegetative growth and earliness of generative development. When it was used as the female parent (hybrids numbers 4 and 5) winter hardiness was low (12-35%). Winter hardiness of reciprocal hybrids (numbers 6 and 7) varied greatly 60-100%. The most winter hardy lines are promising as potential substitute to Perko, which as a winter aftercrop is not reliable in Poland every year (Coboru, personal communication). In contrast, hybrids derived from crosses with B.napus cv. Siberian (numbers 8 and 9) gave almost 100% of winter hardiness (Table 2) and very high green matter production in spring (Table 3 and 4) although in general they were slower in vegetative growth both in autumn and in spring and in generative development.

Hybrid lines and forms within lines were evaluated as initial material for late summer, late autumn and winter aftercrops according to their winterhardiness as well as to their intensity and vigour of vegetative growth in autumn and in spring.

Some information on fertility features are given in Table 5. As a result of self pollination shortening of the silique and lowering of seed setting in relation to free pollination was observed, particularly in the case of hybrid plants. Forms in the collection did not differ much in this respect. Pollen grain fertility of hybrid plants was in all cases lower than those observed in cultivars in the collection and could account for the lower seed setting by self pollination. An exception was the hybrid number 8 (*B.napus* cv. Siberian x *B.campestris* Arctus) which showed very low pollen grain fertility (33.8%), very short silique and low number of seeds per silique in the case of both self and open pollination.

Preliminary data on quality features of green matter and seed are shown in Tables 6 and 7. The contents of protein in seeds and green matter in hybrids seemed to be higher than in the forms in the collection. As far as fibre and fat are concerned the differences were not high. Quality features should be completed by analyses of glucosinolates content both - in seeds and in green matter.

Amongst the variability observed in hybrid progenies there also occurred forms which can be considered as oleiferous seed types. Those with the yellow seed coat colour of *B.campestris* ssp. *trilocularis* Yellow Sarson were of special interest. Lines with lighter than average or yellow seed coat colour presented a greater range of variation in oil, protein and fibre content in seeds than their parental forms.

CONCLUSIONS

Our collection has proved useful in the production and evaluation of hybrids. But we do and need to keep in mind the warning statement on the narrowing of diversity in brassicas (Sneep, 1978).

The enormously valuable Report of Genetic Resources of Cruciferous Crops (IBGR Scretariat, Rome 1981; Toxopeus &

van Sloten, 1981) opens perspectives for the broadening of our gene bank, gives practical indications of where we should turn to for new accessions and inspires their utilization for our purposes.

REFERENCES

Andersson, G. & Olsson, G. 1961. Cruciferen-Ölpflanzen. Handbuch der Pflanzenzüchtung. V.B. 1-66.

Balicka, M., Barcikowska, B., Mlyniec, W. & Zwierzykowska, E. 1980. Synthesis of new genotypes within the genus _Brassica_. _Cruciferae Newsletter_ 5, p.28.

Balicka, M., Barcikowska, B., Chwalek, B., Mlyniec, W. & Szyld, L. 1978. Synthesis of new rape (_Brassica napus_ L.) genotypes to obtain oil and fodder forms. _Cruciferae Newsletter_ 3, p.10.

Claus, E. 1975. Methoden der Artbastardierung innerhalb der Gattung Brassica zur Schaffung neuen Ausgangsmaterials für die Züchtung. Tag-Ber.Akad.Landwirtsch.-Wiss.DDR. Berlin 145, 83-98.

Claus, E. 1978. Allohexaploide Gattungsbastarde vom Typ _Brassica_ - _Raphanobrassica_. _Arch.Züchtungsforsch.Berlin_, pp. 297-302.

Coboru, 1976. Rzepak i rzepik ozimy na zielona mase. Synteza wynikõw doswiadczen odmianowych przeprowadzonych w roku 1976. z.295, pp.1-22.

Helm, J. 1963. Die Chinakohle im Sortiment Gatersleben II. Brassica chinensis Julsen. Die Kulturpflanze. B.XI. 333-357.

IBPGR Secretariat. 1981. Genetic resources of Cruciferous Crops. Rome. pp.1-48.

Jochemsen, G. & Mlyniec, W. 1974. An effective squash technique for root tips of cultivated crucifers. Genetica Polonica. 15, 443-447.

Mlyniec, W., Balicka, M., Barcikowska, B., Chwalek, B. & Wiatroszak, L. 1979. Identification of new allohaploids within the Brassica genus. Genetica Polonica 20, 499-506.

Mlyniec, W., Barcikowska, B., Balicka, M. & Zwierzykowska, E. 1981. New Brassica oil and fodder hybrids obtained by interspecific crossings. In: Eucarpia 'Cruciferae 1981' Conference Aas, Norway, 15-18 September 1981.

Mlyniec, W. 1981. Some features of the hybrids obtained in the results of interspecific crossing within the genus Brassica. Crucifera Newsletter 6, p.38.

McNaughton, I.H. & Ross, C.L. 1978. Interspecific and intergeneric hybridization in the *Brassicae* with special emphasis on the improvement of forage crops. *Rep.Scottish Pl.Breed.Stn* for 1977, 75-110.

Olsson, G. 1954. Crosses within the *campestris* group of the genus *Brassica*. *Hereditas* 40, 398-418.

Sneep, J. 1979. The breeders point of view on broadening the genetic base of crop. In: *Proceedings of the Conference Broadening of Genetic Base of Crops*. pp.13-18. 3-7 July 1978.Wageningen, Netherlands.

Toxopeus, H. & van Sloten, D.H. 1981. The genetic resources of cruciferous crops. *Plant Genetic Resources Newsletter* 47, 3-8.

Table 1. Intensity and vigour of vegetative growth in autumn of forms in the collection, parents for crossings and hybrids - after 60 days of autumn growth (arranged from the highest to the lowest evaluation)

Forms	Scale
In the collection:	
B.c.pekinensis cvs	6
B.o.acephala cvs	5-6
B.n. leafy fodder cvs	5-6
B.c.oleifera f.biennis cvs	1-4
B.n.oleifera f.biennis cvs	1-3
Parents for crossing:	
B.c.pekinensis cv.Granaat (2x and 4x)	6
B.n.leafy fodder cv.Asparagus kale, Akela	6
B.c.oleifera cvs Pluto, Arctus	5
B.n. leafy fodder cv. Siberian	3
Hybrids:	
No. 4. B.c.pekinensis (Granaat (4x) x B.c.oleif.Pluto	6
5. " " " " x B.n.l.f.f., Asparagus kale	5-6
6. B.c.oliefera Pluto x B.c.pekinensis Granaat (4x)	4
7. B.n., l.f.f. Akela x " " " "	4
8. B.n., l.f.f. Siberian x B.c.olifera Arctus	3
9. B.n., l.f.f. Siberian x B.n., l.f.f. Asparagus kale	3

Poznan, Radzikow 1978/9, 1979/80, 1980/81

Table 2. Winter hardiness of forms in the collection, parents for crossing and hybrids - in % of plants surviving the winter (arranged according to the best winter hardiness)

Forms		%
In the collection:		
B.c.oleifera f.biennis cvs		98
B.o.oleifera f.biennis cvs		95
B.n. leafy fodder cvs		30
B.o.acephala cvs		5
B.n.pekinensis cvs		0
Parents for crossing:		
B.n.leafy fodder cv. Siberian		100
B.n.oleifera cv. Pluto		99
" " cv. Arctus		91
B.n. leafy fodder cv. Asparagus kale		60
" " " " Akela		60
B.c.pekinensis cv. Granaat (2x and 4x)		0
Hybrids:		
No. 8 B.n., l.f.f. cv. Siberian	x B.c.oleifera cv. Arctus	92
9 " " " "	x B.n.cv. Asparagus kale	92
6 B.c.olifera Pluto "	x B.c.pekinensis Granaat (4x)	77
7 B.n.l.f.f., Akela	x B.c.pekinensis Granaat (4x)	40
4. B.c.pekinensis Granaat (4x)	x B.c.oleifera Pluto	35
5. " " " " "	x B.n.Asparagus kale	12

Radzikow, 1978/9, 1979/80, 1980/81, 1981/82

Table 3. Intensity and vigour of vegetative growth in spring of forms in the collection, parents for crossings and hybrids - after 30 days of spring growth (arranged from the highest to the lowest evaluation)

Forms	Scale
In the collection	
B.c.pekinensis cvs[a]	6[a]
B.c.oleifera f.biennis cvs	5-6
B.n.oleifera f.biennis cvs	4-5
B.n.leafy fodder cvs	3-5
B.o.acephala cvs	1
Parents for crossings	
B.c.pekinensis cv. Granaat[a] (2x x 4x)	6[a]
B.c.oleifera cv. Pluto, Arctus	5
B.n.leafy fodder cvs Akela, Asparagus kale, Siberian	3
Hybrids	
No.6. B.c.oleifera Pluto x B.c.pekinensis Granaat (4x)	6
9. B.n.l.f.f. Siberian x B.n. l.f.f. Asparagus kale	6
8. " " " x B.c.oleifera Arctus	5
7. B.n.l.f.f. Akela x B.c.pekinensis Granaat	3
4. B.c.pekinensis Granaat (4x) x B.c.oleifera Pluto	2
5. " " " x B.n. l.f.f. Asparagus kale	2

Poznan, Radzików 1978/9, 1979/80, 1980/81

[a]Data from experiment with spring forms

Table 4. Some morphological features of forms in the collection, parents for crossing and hybrids in experiments with winter forms (arranged according to the plant height)

Forms	Height of plants (cm)	No. of branches	Index of leaf surface	
			per plant	per plot
In the collection				
B.c.oleifera cvs	132	15	31.6	309.1
B.n.oleifera cvs	120	13	30.5	289.8
B.n.leafy fodder cvs	85	16	40.8	122.4
B.o.acephala cvs	60	13	18.0	90
B.c.pekinensis cvs	60[a]	9[a]	80.5[a]	800.1[a]
Parents for crossing				
B.c.oleifera Pluto	140	13	36.0	360
" " Arctus	132	16	40.0	396
B.n.leafy fodder f.Asparagus				
" " " Kale	125	21	66.0	600
" " " Akela	116	19	37.0	222
" " " Siberian	100	8	30.0	300
B.c.pekinensis Granaat[a]	98[a]	10[a]	77.0[a]	770[a]
Hybrids[b]				
No. 6	133	14	51.0	393
8	129	12	38.2	351
9	127	13	50.0	460
7	90	11	37.0	148
4	90	11	43.0	150
5	85	12	40.0	48

Poznan, Radzikow 1978/9, 1979/80, 1980/81

[a]data from experiment with spring forms
[b]explanation in Tables 1, 2 and 3

Table 5. Some fertility features of forms in the collection, parents for crossing and hybrids in the experiment with winter forms

Forms	Length of silique (cm) Free pollinated	Length of silique (cm) Selfed	No. of seeds per silique Free pollinated	No. of seeds per silique Selfed	Pollen grain fertility (%)
In the collection					
B.n oleifera cvs	7.5	6.7	29.0	25.0	100.0
B.n.leafy fodder cvs	6.3	5.5	20.0	18.0	100.0
B.c.oleifera cvs	4.7	4.2	22.4	18.0	97.2
B.o.acephala cvs	5.7	5.0	22.0	18.0	98.0
Parents for crossing					
B.c.oleifera Pluto	4.3	4.1	26.0	22.0	99.0
" " Arctus	5.6	4.9	24.0	21.0	98.0
B.n.leafy fodder f.Asparagus					
" " " Kale	5.8	5.1	20.0	17.0	100.0
" " " Akela	8.0	7.5	20.0	16.0	100.0
" " " Siberian	5.2	5.0	21.0	18.0	100.0
Hybrids[a]					
No. 4	5.7	4.6	10.0	8.0	89.2
5	5.6	5.0	8.0	6.0	90.1
6	6.2	5.0	14.8	6.7	91.0
7	7.4	5.9	23.0	14.0	94.0
8	2.7	1.9	3.0	1.0	33.1
9	7.2	6.7	24.4	17.1	92.0

Poznan, Radzikow 1978/9, 1979/80, 1980/81

[a]explanation in Tables 1, 2 and 3

Table 6. Some green matter quality features of forms in the collection, parents for crossing and hybrids in the experiment with winter froms)

Forms	Dry matter (%)	Protein (%)	Fibre (%)
In the collection:			
B.c.oleifera f.biennis cvs	12.1	27.8	12.2
B.n. leafy fodder cvs	11.8	20.8	10.7
B.c.oleifera cvs	12.9	19.1	11.0
Parents for crossing:			
B.c.oleifera cv. Pluto	11.1	23.0	12.0
" " cv. Arctus	11.0	22.7	12.0
B.n. leafy fodder cv. Asparagus kale			
" " " " Kale	12.0	23.0	11.0
" " " " Akela	11.8	21.3	11.0
" " " " Siberian	12.0	22.8	11.0
Hybrids[a]			
No. 4			
5			
6	12.7	24.2	8.2
7	12.5	23.2	10.8
8			
9	12.0	26.6	12.2

Poznan, Radzikow 1980/81

[a]Explanations in Tables 1, 2 and 3

THE UTILISATION OF GENETIC RESOURCES IN FODDER CROP BREEDING IN TURKEY

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In Turkey there is a big capacity for the utilisation of genetic resources in fodder crop breeding. Very many fodder crops which we are using in the world agriculture have their origin from Turkey. According to Vavlilov's (1951) statement each civilisation in Anatolia has used their own fodder crops in agriculture. Again, he writes that a plant breeder would not exclude the material of this region, while he is working in breeding of these crops. However, in most of the forage crop literature, we can see that the writers give the origin of different plant material of this type as Anatolia. For example, different species of Trifolium, Vicia, Medicago which are very important forage plants in agriculture.

In our collection and breeding work with fodder crops for Turkish agriculture we have obtained very big variation among plant materials and we have used this genetic resource in our fodder crop breeding programme.

We have found big differences among vetch (Vicia) plants collected in different regions of Turkey. These differences were in winter hardiness foliage production, seed shattering, seed size and seed colour. In other forage plants we have seen quite a large variation in different plant characteristics; in red clover (Trifolium pratense L.), white clover (Trifolium repens L.), Persian clover (Trifolium resupinatum L.), strawberry clover (*Trifolium fragiferum* L.), birdsfoot trefoil (*Lotus corniculatus* var. *tenuifolius* L.), Alfalfa (*Medicago sativa* L.),Sainfoin (*Onobrychis arenaria* Kit. ex. Willd (D.C.)).

In some grasses we have obtained very important variations in different characteristics of the plants. We can give some examples in sheep fescue (*Festuca ovina* L.), crested wheatgrass (*Agropyron cristatum* (L.) Geartn.), *Puccinellia distans* L., *Andropogon ischaemum* L.

All these observations and findings during our researches explain that Turkey has important genetic resources in fodder crop breeding.

Turkey actually is one of the gene center regions of crop plants. But, from the view point of fodder crop breeding I think Turkey has a special potential.

Turkey and FAO have established a plant introduction centre in Izmir. This centre is still working in order to collect the seed and plant material throughout the country.

After our researches on fodder plants in Turkey we have obtained the following results:

Puccinellia distans L.

This plant is indigenous material in Anatolia. Especially, under saline soils conditions in dry lands, *Puccinellia* can stand well and set seed. I have found diploid (2n=14) and tetraploid (2n=28) plants in the same place in Bala State Farm situated in an arid region 90 km from Ankara. The diploid plant was only 8 m distance from the tetraploid one. This chromosomal difference and other vegetative variations have been studied.

Under dry land conditions there are saline soils on which we cannot grow hardly any crop except a few forage plants. On an initial test plot in Bala we could not establish the following forage plants except Puccinellia distans L. on this problem area:

Tall fescue (Festuca arundinacea)
Sheep fescue (Festuca ovina L.)
Crested wheatgrass (Agropyron cristatum (L.) Geartn.)
Tall wheatgrass (Agropyron elongatum)
Perennial ryegrass (Lolium perenne L., prostrate type)
Birdsfoot trefoil (Lotus corniculatus var. tenuifolius L.)
Sainfoin (Onobrychis arenaria Kit. ex. Willd (D.C.), prostrate type)

The soil analysis of this land is given in Table 1.

Native forage plants on the Mediterranean coast

From Yumurtalik to Karatas, on the coastal area of Adana we have found several autochtone forage plant species like a perennial grass Agropyron junceum mediterranean (L.) S. 2n=42, an annual medick (Medicago littoralis Rohde) and one perennial medick (Medicago marina L.).

The analysis of the sea water which these plant take up is given below:

Mediterranean sea water at Yumurtalik coast (July, 1975).

pH: 8.02		
EC: x 10^6 25°C:71550		
Cation	me/lt:	
Na	"	640.0
K	"	12.25
Ca	"	25.90
Mg	"	112.80
Total	"	790.95
Carbonate	"	-
Bicarbonate		3.01
Cl	"	652.0
SAR	"	76.6
Salinity T	:	T_4
Alkalinity A	:	A_4

The following figures are obtained from the soil analysis of the land on which the plants mentioned above were grown.

Soil analysis of Mediterranean sea coast of Yumurtalik:

Depth	: 0-20 cm	$CaCO_3$	:	64.8
	: 30	P_2O_5 kg/da	:	0.15
E.C. x 10^3 25°C	: 7.933	K_2O kg/da	:	32.9
	: 8.40	Total N %	:	0.083
pH in extract	: 8.40	Organic matter	:	0.16

Particle size distribution, %:

1 mm	24.45
1-1/2 mm	13.94
1/2-0,250 mm	53.35
0,250-0,176 mm	4.60
0,176-0,105 mm	3.18
0,105-0,04 mm	0.40
0,047 mm	0.08

Agropyron junceum mediterranean (L.) S. is a very promising plant for the coastal area of Adana region. This plant can be used for erosion control and grown on the moving sand dunes. There are very large variations among plants. We have found a quite vigorous and early growing leafy type at Yumurtalik in 1975 and at Karatas in 1976. The chromosome number of this plant is 2n=42. Chromosome counts were made in somatic cells of the root tips. After the pretreatment with α-monobromonaphthalin at 4°C for 16 h the material was treated for 30 min in glacial acetic acid and hydrolized for 12 min at 60°C in N HCl, staining made in Feulgen for at least one hour.

The seeds collected from native plants have germinated well and new plants obtained successfully under glasshouse conditions during 1975-76 winter. This plant can be grown from clones. We could grow clonally propagated tillers in pots under the same conditions mentioned above. The seeds are big enough to seed under unfavourable conditions and fall sowing may give good results in the mediterranean region. The spikes do not break down easily, so, obtaining the seed is not creating a big problem. To protect the sea shores from erosion, this plant can be grown successfully.

Annual medick (Medicago littoralis Rhode) 2n=16.

We have found this plant on the Mediterranean sea side in 1974 in the vicinity of Yumurtalik and in 1976 on the moving dunes of Karatas. We have collected the seed and plant material of this plant. This Medicago has been described by Lesins & Gillies (1972). They have stated that pod characteristics are as follows:- pods completely hairless, dorsal suture not higher than the sides of the edge, spines inserted at 180° or obliquely to the coil face. Lesins & Erac (1968) have pointed out that "Medicago littoralis strains had an anticlockwise pod coiling direction..... The plants are self-fertile and no manipulation of flowers is needed for seed setting".

This plant is covering the surface of the soil in April and flowers in the middle of this month. It has yellow small flowers. It is a very good seed yielding material. This species has prolific seed setting characteristics in the Adana region under Mediterranean environmental conditions. This plant reseeds very easily. If the land is protected from heavy grazing very dense population of the seedlings will cover the surface of the ground like a green carpet during early spring in the coastal area of Adana.

Perennial medick (Medicago marina L.) 2n=16.

We have found a perennial Medicago species on the same mentioned above. This plant also is a promising material for erosion control of the coastal area in Adana. This species is shooting underneath the soil from the ground. It flowers in April, and has yellow flowers. It is also a prolific seed setting plant. Medicago marina grows successfully with the annual Medicago littoralis mentioned above and gives a favourable composition from the view point of erosion control.

Lesins & Gillies (1972), have described the characteristics of the plant "......... Pods and the whole plant covered with felty hairs, seashore plant ....".

It seems a very important plant material in order to use as a mixture with other grasses and legumes for soil conservation. Its spreading habit is valuable for this purpose. On land protected from heavy grazing this plant can cover the land very easily.

Our efforts up to the present have enabled selection of some forage plants suitable to saline and alkaline soils in Turkey's different regions.

Agropyron cristatum (L.) Gaertn.

Under dry land conditions, we have selected an indigenous tetraploid crested wheatgrass (Agropyron cristatum (L.) Gaertn.) 2n=28. Different characteristics in terms of colour of the plants, habitat, size and shape of the spike, rhizome and meiotic configurations have been studied by Elci (1966c). This plant is growing well under moderate saline conditions of Malya

State farm 30 km from Kirsehir. Especially, it supplies a very good quality hay crop when it is seeded with a leguminous forage plants sainfoin (Onobrychis arenaria Kit. ex. Willd (D.C.).

Crested wheatgrass has been grown successfully for seed production under the dryland and salinity conditions of Malya. This plant improves soil organic matter when seeded in a mixture with sainfoin. In three years, we have observed very healthy plant populations of crested wheatgrass and sainfoin on this saline plot of Malya.

Our selected material of tetraploid crested wheatgrass is an autotetraploid plant. According to our meiotic analysis of the pollen mother cells, it has quadrivalents of +, ◇ , 8 shape at diakinesis so it has AAAA genomes.

Birdsfoot trefoil (Lotus corniculatus)

Through reselections of the native Turkish birdsfoot trefoil we have obtained erect type birdsfoot trefoil (Lotus corniculatus var. corniculatus) and prostrate type (Lotus corniculatus var. tenuifolius L.). These types adapted to dryland and saline conditions Elci (1966b). In order to investigate the effects of salt on these selected materials researches have been conducted in water culture, having different salt concentrations by Onal (1974), Elci & Hindistan (1975).

Onal (1974) has concluded that optimal growth of birdsfoot trefoil erect type occurs in 0.1% Na Cl, and for prostrate type this concentration is 0.3% Na Cl. Elci & Hindistan (1975) have found that "........... at 50% yield levels for erect type of birdsfoot trefoil exposed to 9.5 millimhos, exhibited lower salt tolerance than the prostrate type. The prostrate type of birdsfoot trefoil showed a high degree of tolerance at 15 millimhos".

These two varieties of birdsfoot trefoil have an important place in saline soils of Turkey.

Trifolium fragiferum L.

We have selected a better type of strawberry clover (Trifolium fragiferum L.) among collected autochtonal genetic resources of strawberry clover in different regions of Turkey. Elci (1975) has pointed out that "...... our selected strawberry clover has a very prostrate habit with the rooting at the nodes. This characteristic is very important from the view points of surface coverage against the wind and water erosions, heavy grazing and for soil building. The plant has reasonable salt tolerance. At 50% yield levels for strawberry clover exposed to 6.6 millimhos, it showed a modest level of tolerance". Strawberry clover can be used under soil conditions of the central plateau. According to our observations on these soils, this plant covers the land and even under severe conditions of heavy grazing by sheep it can stand on dryland conditions at Aksaray - Konya on the native range land this clover is a dominant plant in the vegetation of saline soil of this vicinity. These are many examples of this type in different regions of Turkey.

In Burdur and Eshisehir regions on the saline pasture land we have observed that this plant can withstand and give some grazing material. In Ören on a saline sandy range of small village at the Aegean sea coast we also have collected some clones and some seed samples of strawberry clover.

Lolium perenne L.

In general we assume that ryegrass is not a salt tolerant plant. But when we have studied the saline pasture land we have observed that Lolium perenne L. was growing under these conditions. We have collected ryegrass from this pasture and clonally propagated under glasshouse conditions. In one region near the province of Burdur, the material was collected from a native pasture with a crust of white salt on the surface of the soil. Another autochtone perennial ryegrass has been obtained from the province of URFA; the maximum temperature in this area is 46.5°C with a minimum of -12.4°C. The average annual rainfall in this area is 473 mm, mostly in the fall and winter. All these informations give us an idea about the wide range of adaptability of perennial ryegrass to different climatic and soil conditions in Turkey.

Trifolium pratense L. (native tetraploid (2n=28)

Red clover is a native forage plant in Turkey. In general there are different plants with wide variation from the view point of habitats and flowering time, leafiness and so on. Beside these we have collected a plant with 2n=28 chromosomes from the east Anatolia near Erzurum. This tetraploid red clover is a better forage yielding material with large leaves and vegetative organs.

Vicia sativa L.

This is one of the most important forage legume in Turkey.

Vetch (*Vicia sativa* L.) has its gene center in Turkey. Among the material which we have collected in Anatolia we have selected two different materials. One of them has a plain black seed coat colour the other one has plain yellow seed coat. The black seeded variety is good yielding under the Mediterranean area and in central plateau. The yellow seeded vetch is adaptable under winter conditions of the coastal area and the transition zones.

Secale montanum Guss.

In the dry land region of Turkey I have collected normal and mutant types of perennial rye (*Secale montanum* Guss.). In normal perennial rye we have observed very regular meiotic configuration. For example at diakinesis and metaphase I we observed seven bivalents (Elci, 1966a).

In the native mutant type of perennial rye there were polyvalent configurations, like one hexavalent and four bivalents; in another group of cells, one pentavalent, four bivalents, one univalent; and in another group of cells, one quadrivalent, five bivalents at metaphase I.

In the other native mutant type of rye, I have observed one quadrivalent and five bivalents at diakinesis.

After treatment with 0.1% colchicine of normal perennial rye seedlings for 3 hr at 27°C, we have obtained a new mutant type of rye.

In this material we have observed mainly one hexavalent and four bivalents at the diakinesis and metaphase I. Penta, quadri, and trivalent configurations have been observed also.

In the second and third generations of this material trisomic plants (2n=14+1) with 15 chromosomes have occurred. These plants have very wide variations in the meiotic configurations. In some trisomic plants we have observed three, four, five .... up to seven valents.

In the third generation we have obtained a single plant with very many leaves. In this plant the chromosome number is (2n=14). But, the meiotic configurations are not regular. It means we need more selection in the next generations.

In general, the Turkish perennial rye both in native normal and mutant types and colchicine treated mutant material offers us quite wide variations in genetic resources. In order to obtain a better perennial rye for fodder production this material is valuable.

REFERENCES

Elci, S. (1966a). Chromosome morphology, meiotic analysis and some morphological characteristics of perennial rye (Secale montanum Guss.) and obtaining tetraploid perennial rye. University of Ankara, Faculty of Agriculture, No.281, researches No: 176.

Elci, S. (1966b). Researches on the yellow flowered birdsfoot trefoil (Lotus corniculatus L.) as pasture and fodder plant. University of Ankara, Faculty of Agriculture, Department of Forage Crops, Meadow and Pasture (with English summary).

Elci, S. (1966c). Some morphological and cultural characteristics, and mitotic and meiotic behaviour of native tetraploid crested wheatgrass _Agropyron cristatum_. University of Ankara, Faculty of Agriculture, No:280, researches No:175.

Elci, S. (1975). Breeding of forage crop varieties for salt tolerance and drought resistance in Turkey. In: _CENTO Panel on the Optimum Use of Water in Agriculture_, 3-5 March 1975, Lyallpur, Pakistan.

Elci, S. & Hindistan, M. (1975). The salt tolerance of the fodder plants prostrate type birdsfoot trefoil (_Lotus corniculatus_ var. _tenuifolius_ L.), erect type (_Lotus corniculatus_ var. _corniculatus_) and strawberry clover (_Trifolium fragiferum_ L.). Turkish Research Council (T.B.T.A.K.). TOAG, Dryland Unit Research No. 1, Ankara.

Lesins, K. & Gillies, C.B. (1972). Taxonomy and cytogenetics of _Medicago_ (from Alfalfa Science and Technology 1972. Amer.Soc. of Agron., Inc. Pub. Madison, Wisconsin, USA. pp.53-86.

Lesins, K. & Erac, A. (1968). Relationship of taxa in the genus _Medicago_ as revealed by hybridization. I. _M.striata_ x _M.littoralis_. _Can. J. Genet. Cytol._ 10, 263-275.

Onal, M. (1974). The effect of sodium chloride on the fodder plants _Trifolium fragiferum_, _Lotus corniculatus_ var. _corniculatus_ and _Lotus corniculatus_ var. _tenuifolius_. Turkish Research Council (T.B.T.A.K.). Project No.: TOAG:207, Ankara.

Vavilov, N.I. (1951). The origin, variation, immunity and breeding of cultivated plants. Translated from the Russian by K.S. Chester, Chronica Botanica Vr. 1/6.

Table 1. Soil characteristics of the experimental site in Akkosan-Bala

Soil depth (cm)	Particle size distribution (%)			T.S.S. (%)	pH in sat. paste	Lime (%)	O.M. (%)	Total N (%)	Plant available kg/da	
	Sand	Silt	Clay						P_2O_5	K_2O
0-30	5.7	27.7	66.6	0.810	7.40	12.9	2.17	0.11	16.83	205.2
0-30	5.8	27.7	66.5	0.685	7.50	12.3	1.88	0.11	17.52	195.5
0-30	5.5	27.0	67.5	0.970	7.45	11.9	1.56	0.08	25.99	140.4

(The soil and water analysis in this paper have been made by Soil & Fertilizer Research Institute of Ankara)

POLYMORPHISM AS A GENETIC RESOURCE IN COCKSFOOT

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Three aspects of the available genetic resources in cocksfoot (*Dactylis glomerata* complex) must be investigated :

1. genetic diversity ;
2. functional diversity ;
3. demographic diversity.

GENETIC DIVERSITY

Genetic polymorphism can be studied at different taxonomic levels, and has been investigated for more than 50 populations of the autotetraploïd group (LUMARET et al., 1981). Frequencies have been estimated for several loci. Data are presented only for a locus coding for a glutamate-oxalo-acetate transaminase (GOT 1). The allelic distributions have been compared at two scales.

1) The first comparison is at a large scale, for populations ranging from those of North Western Europe (Scotland) to North Africa 200 alleles per population were analysed on average (Table 1).

Latitude	No. of Populations	Allelic frequencies (%) $GOT_1^{1.00}$	$GOT_1^{0.72}$	$GOT_1^{0.38}$	$GOT_1^{0.10}$	$GOT_1^{1.26}$
57°-50°	4	82.5	17.5	0.0	0.0	0.0
49°-45°	10	72.4	26.0	0.0	0.5	1.1
44°-43°	10	21.5	36.5	31.7	10.3	0.0
42°-40°	10	7.4	70.3	19.0	3.3	0.0
39°-33°	10	2.8	80.2	16.3	0.7	0.0

Table 1. Allelic distribution at the GOT 1 locus in 44 tetraploid populations of *Dactylis glomerata* ranging from the North of Europe (Scotland) to North Africa (200 alleles per population were analysed on average). (LUMARET et al., 1981).

2) The other comparisons are at a small scale, along 2 transects exhibiting a clinal variation for water availability, one located in Southern France (LUMARET, 1981), the other in Britain (ASHENDEN, 1978, and LUMARET, 1981) (Figure 1).

It was concluded that, at the GOT 1 locus, the frequencies of several alleles seem to be related to ecological factors.

FUNCTIONAL DIVERSITY

This is the second aspect.

1) A first example is for responses of gas exchange to drought. A study of these mechanisms has been made in parallel with the analysis of genotypic variation. Several characteristics are specific to extreme populations, like : stomatal density, osmotic potential, ... (Table 2). In the same work, the ranking of the values

	Dry sub-population	Wet sub-population
Stomatal density	Higher	Lower
Stomata on upper surface	More	Less
Change in relative water content when Leaf Water Potential decreases (LWP)	Smaller	Higher
Osmotic potential at saturation	$-28.5.10^5$ Pa	$-25.5.10^5$ Pa

Table 2. Studies of the genotypic adaptation carried out in parallel with the analysis of physiological mechanisms for individuals of the 2 extreme sub-populations of the transect located in Southern France (ROY, 1980).

of (LWP) at which turgor potential became zero was -26.10^5 for individuals collected in Central France (Mountain), and -33.10^5 Pa for a sample from Morocco.

2) Nutrient competitive abilities are an another example of functional diversity. Here, in Table 3, abilities are measured in terms of producer and associate effects and related to characteristics of roots. The more dominating the cocksfoot is, the more the electronegative charges of its root system are increased, the more its content in K is high.

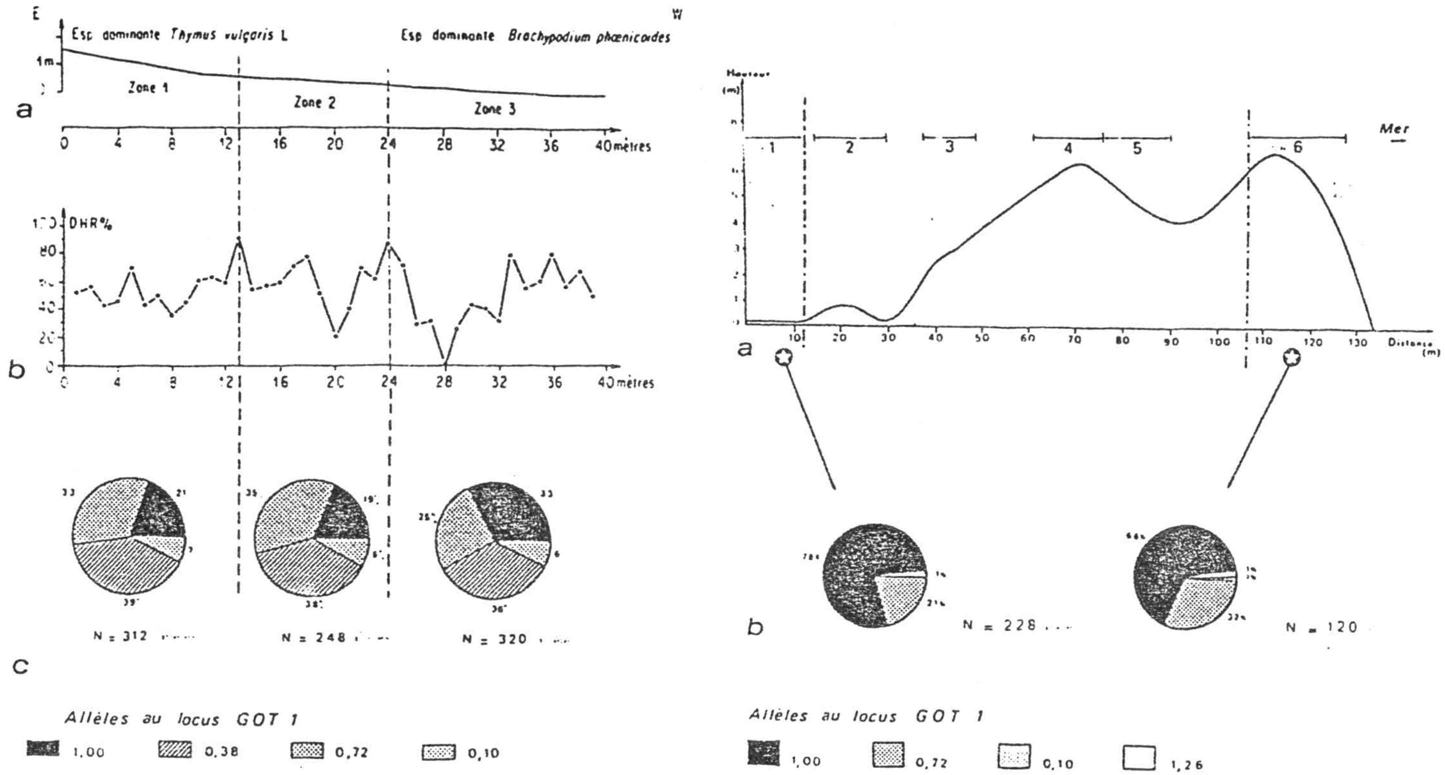

Fig. 1. Study of 2 transects : left : La Jasse (France), a) topography of the site, b) change in botanical composition, measured in terms of HAMING's distances, c) allelic frequencies ; right : Druridge (Britain), a) topography of the site, b) allelic frequencies.

Genotypes of cockofoot	D_2	D_3	D_5
Producer effect α_D	- 3.05	-0.21	+ 3.28
Associate effect β_D	+ 0.31	+0.02	- 0.31
Domination ability $C_D = \alpha_D - \beta_D$	- 3.36	-0.23	+ 3.59
Electronegative charges μ Eq	25.8	32.7	35.0
K content mEq	1.07	2.07	3.04
CECR mEq/100g	17.6	17.9	11.0

Table 3. Relationship between competitive abilities, measured in terms of producer and associate effects, and characteristics of the roots (WACQUANT et al., 1979).

DEMOGRAPHIC DIVERSITY

The last aspect of genetic polymorphism is connected with survival in terms of demographic parameters.

1. A first type is concerned with contrasting levels of disturbance. Three populations of *D. glomerata* originatin from 2 contrasting environment :

a. managed by man (irrigation combined with hay-making),
b. "garrigue" vegetation where the only disturbance is an infrequent grazing (2 populations) ,

have been compared in optimal conditions (LUMARET et al., 1981, and HEIM, unpublished). Results show differences between the populations with regard to cumulative tiller production and DM accumulation. The number of tillers produced was much lower in the "managed" population, in spite of the fact that DM production was of the same order of magnitude for the 3 populations ; tillers of the "managed" population were therefore bigger in size, and more "vigorous". There was an important within population variation, especially with respect to DM production. This variation was twice as great in the wild populations, as compared to the semi-domesticated population.

2. The second example is for competition, in relation with the changing environment along a succession, mainly in terms of panicles per individual (JACQUARD et al. 1983). This demographic polymorphism is associated with a change in enzymatic polymorphism (Table 4).

		Description of the sites			
Number of years of abandonment (old vineyard)		15-20	60	60-100	100
% of *Dactylis glomerata*		10-15	10-20	10-15	10
Vegetation		Open	Open with trees	Open wood	Closed wood
		Demographic parameters (number of panicles/ind.)			
Pure stand		15	30	24	14
Domination ability		+ 3.2	+ 1.5	+ 3.0	+ 1.7
General Mixture Ability		+ 0.7			+ 3.2
		Allelic distribution (%)			
Acid-Phosphatase	Allele 1	88.4	81.3	84.3	83.0
	2	9.9	13.8	15.7	13.1
	6	0	4.4	0	1.4
GOT	Allele 1	14.8	13.9	17.4	23.0
	2	34.1	40.0	33.7	23.7

Table 4. Variation of demographic parameters and polymorphism along a succession. (% are given only for alleles showing a between sites variation).

As in previous studies, from a dry and sunshiny environment to a wet and shaded environment, the frequencies of some alleles increase (AcPH 2 and GOT 1) and the frequencies of others decrease (AcPH 1 and GOT 2). AcPH 6 is an "oceanic" allele very unfrequent under Mediterranean climate.

CONCLUSION

Two examples of combining genetics (in terms of allelic polymorphism) and demographic parameters, revealed by diversity studies of available genetic resources in cocksfoot, will be given with a view to approach the genotype - phenotype interface. These cases concern an investigation of the relationships between diversity, for a set of enzymatic systems, and vigour.

In the first study, controled populations have been used :

a) for a comparison of *glomerata* and *hispanica* responses (Table 5) ;

b) for a comparison of families of *glomerata* (Table 6).

Systems	Number of alleles	Sign of the relationships	Type of the relationships
GOT 1	4	+ *glomerata* (g) 0 *hispanica* (h)	S < D,T
PX 1	3	+ g 0 h	S < D,T
ADH	2	(+) g (+) h	S < D M < S,D

Table 5. Relationships between vigour and allelic diversity in experimental populations. M = monogenic ; S = simplex ; D = duplex ; T = trigenic

In table 5, the relation between diversity and vigour is quite clear for glomerata but not as for hispanica. Differences of responses of 3 other enzymatic markers (AcPH 1, TO, and Phosphoglucose isomerase) show that we cannot use the number of bands (isozymes) cumulated on all systems to evaluate diversity.

Table 6 gives a summary of the relationships between genetic parameters and vigour in families of cocksfoot. There is often a

Days from sowing		22	29	37
Tetragenic		NC	NC	NC
Trigenic		< 0.2	< 0.2	< 0.2
Digenic	(Duplex	$\geq$ + 0.2	$\geq$ + 0.2	$\geq$ + 0.2
	(Simplex	$\geq$ - 0.2	$\geq$ - 0.2 ⁕	> - 0.2 ⁕
Monogenic		$\geq$ - 0.2	$\geq$ - 0.2	$\geq$ - 0.2 ⁕

Table 6. Relationships between the genetic parameters and the vigour, estimated by 2 peoples, independently (0.2 = correlation coefficient).

NC = Not computable ⁕ Significant at the 5% level

positive relation between the degree of heterozygosity and vigour. The relationship is improved along the time (increasing growth of plants) and may reach a statistical significance for the Acid Phosphatase system. 64 days after sowing, for the AcPH system, there is a clear negative relation between the DW/box and the expected relative frequencies of monogenics, for 43 tested crosses.

In a second study, heterozygosity has been related to the vigour of individual plants (Table 7). The proportion of heterozygosity withing the gametes has been computed following the formula :

$$QL = \frac{1}{2} DS + \frac{2}{3} DD + \frac{5}{6} TRI + TET,$$

DS, DD, TRI and TET being respectively the proportions of digenics simplex, digenics duplex, trigenics and tetragenics observed at the L locus (DEMARLY, 1973). The gametes of the progenies from the vigourous plants present a tendency to be more heterogeneous, mainly at the locus GOT_1, so there is a trend to a more heterozygote progeny.

Loci	GOT_1	$AcPH_1$	PX_1
Vigorous plants	0.62	0.32	0.60
Progenies from vigorous plants	0.64	0.25	0.63
Progenies from weak plants	0.55	0.23	0.58
Progenies from dead plants	0.54	0.25	0.57

Table 7. Proportion of heterogenic gametes at each locus for 4 categories of plants from a population of cocksfoot (natural population) (TOMEKPE et al., 1982).

Both in natural populations and in controlled material under experimental conditions, a positive relationship is more evident for one specified locus than for a global approach of the whole genotype.

So, a good evaluation of genetic resources allows to combine.

1. a genetic approache of the diversity ;
2. a functional or demographic appraisal of heterosis.

Genetic resources must be considered not only, in terms of agronomic traits, for their direct use in breeding. But, in a strictly speaking way of defining it, at the level of alleles, they are also a means of clarifying some "accepted" relationships that allow one to confront the theory of controlled selection with the reality of nature.

REFERENCES

ASHENDEN, T.W., 1978 - Drounght avoidance in sand dune populations of *Dactylis glomerata* . J. Ecol., 66 (3), 943-951.

DEMARLY, Y. (1963) - Génétique des tétraploïdes et amélioration des plantes. Thèse Fac. Sciences, Ann.Amélior. Plant., 13, 13, 307-400.

LUMARET, R., 1981 - Structure génétique d'un complexe polyploïde : *Dactylis glomerata* L. (Fam. Graminacées). Relations entre le polymorphisme enzymatique et certains aspects de la biologie, de l'écologie et de l'évolution de l'espèce. Thèse de Doctorat d'Etat, Université des Sciences et Techniques du Languedoc, Montpellier, France.

LUMARET, R., ROY, J., HEIM, G., JACQUARD, P., 1981 - Genetic and functional diversity between and within cocksfoot populations, in Plant Physiology and Herbage Production, C.E. Wright, Ed. British Grassland Society, Occ. Symp. n° 13, 201-203.

ROY, J., 1980 - Comportement photosynthétique et hydrique de la feuille chez *Dactylis glomerata* L. : adaptation phénotypique et génotypique à la sécheresse. Thèse de spécialité, Université des Sciences et Techniques du Languedoc, Montpellier, France.

TOMEKPE, K., LUMARET, R., VALDEYRON, G., 1982 - Diversité enzymatique et vigueur dans une population naturelle de dactyles tétraploïdes (*Dactylis glomerata* L. Agronomie, 2 (2), 107-112.

WACQUANT, J.P., DE FAY E., JACQUARD P., 1979 - Etude préliminaire de la concurrence entre dactyle et trèfle blanc en milieu pauvre en potassium. Bull. Soc. Ecophysiol., 4, 1, 49-52.

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ROY, J., 1980 - Comportement photosynthétique et hydrique de la feuille chez *Dactylis glomerata* L. : adaptation phénotypique et génotypique à la sécheresse. Thèse de spécialité, Université des Sciences et Techniques du Languedoc, Montpellier, France.

TOMEKPE, K., LUMARET, R., VALDEYRON, G., 1982 - Diversité enzymatique et vigueur dans une population naturelle de dactyles tétraploïdes (*Dactylis glomerata* L. Agronomic, 2 (2), 107-112.

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