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Proceedings of the

TWENTY-THIRD GRASS BREEDERS WORK PLANNING CONFERENCE

SEPTEMBER 9-11, 1975

ST. PAUL, MINNESOTA

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TWENTY-THIRD

GRASS BREEDERS WORK PLANNING CONFERENCE

University of Minnesota
St. Paul, Minnesota

September 9-11, 1975

FOREWORD

Report of the Resolution Committee:

All participants of the 23rd Grass Breeders Work Planning Conference held September 9-11 at the St. Paul Campus wish to extend their sincere thanks and appreciation to: Dr. Arne Hovin and his colleagues at the University of Minnesota for the fine local arrangements and kind hospitality enjoyed by those in attendance and to the conference officers, Paul Voigt, Tom Lawrence, and Arne Hovin for carrying out the affairs of the conference during the past two years, and for preparing an interesting and informative program intertwined with tours. Thanks is also extended to the invitational speakers for their contribution and to Dr. Burton for his eyewitness report on China.

Thanks is also extended to the commercial companies for their monetary contributions to defray expenses and to Northrup King and Co. for providing tours at their Stanton and Eden Prairie research centers.

Resolutions Committee:

I. T. Carlson
R. P. Knowles
D. E. Brown, Chairman

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(Formerly Western Grass Breeders Work Planning Conference)
UNIVERSITY OF MINNESOTA, ST. PAUL, MINNESOTA

September 9-11, 1975

MONDAY, September 8

7:00 p.m.	Registration, Ramada Inn, Arden Hills, wine and cheese party.	

TUESDAY, September 9

8:00 a.m.	Announcements	
8:25 a.m.	Welcome........................	W. F. Hueg, Jr., Deputy Vice President & Dean, Institute of Agriculture, Forestry and Home Economics, University of Minnesota, St. Paul
8:45 a.m.	Food for All - Challenge and Responsibility	W. F. Hueg, Jr., University of Minnesota
9:15 a.m.	Variation, Selection and the Construction of New Varieties of Forage Grasses..............	M. D. Hayward, Welsh Plant Breeding Station, Aberystwyth, Wales
10:15 a.m.	Break	
10:30 a.m.	Anatomical Features of Grasses Influencing *in vitro* Digestibility.........................	J. B. Powell, ARS-USDA, Plant Genetics and Germplasm Institute, Beltsville, Maryland
11:00 a.m.	Breeding for Improved Forage Quality in Reed Canarygrass....	A. W. Hovin, University of Minnesota, St. Paul
11:30 a.m.	Breeding Reed Canarygrass for Improved Forage and Seed Characteristics................	I. T. Carlson, Iowa State University, Ames, Iowa
12:15 p.m.	Lunch (Student Union Building)	
1:30 p.m.	Tour of Facilities and Forage Crop Research, St. Paul Campus	
6:30 p.m.	Dinner at Ramada Inn followed by Special Address by Dr. Glenn W. Burton, ARS-USDA, Tifton, Georgia: "The People's Republic of China in 1974".	

WEDNESDAY, September 10

8:20 a.m.	Objective Descriptions of Grass Varieties......................	Kenneth Evans, Examiner, Plant Variety Protection Office, ARS-USDA, Hyattsville, Maryland
8:40 a.m.	Recurrent Restricted Phenotypic Selection to Increase Forage Yields.........................	G. W. Burton, ARS-USDA, Tifton, Georgia
9:00 a.m.	Synthesis Behavior of Single Clone-derived Lines of Timothy.	C. C. Lowe, Cornell University, Ithaca, New York
9:20 a.m.	Cultivar Synthesis in Orchardgrass..................	J. S. Shenk and J. L. Starling, Pennsylvania State University, University Park, Pennsylvania
9:40 a.m.	Selection for Winter Survival Ability........................	P. W. Voight, ARS-USDA, Temple, Texas
10:00 a.m.	Break	
10:20 a.m.	Selection for Seed Retention in Creeping Foxtail (*Alopecurus arundinaceus* Pois).............	J. G. Ross, South Dakota State University, Brookings, South Dakota
10:40 a.m.	Hairy Seedling Marker as a Breeding Tool in Smooth Bromegrass.....................	R. P. Knowles, Research Station, Saskatoon, Saskatchewan
11:00 a.m.	Nematode Susceptibility of Cool Season Grasses in the Southeast.....................	R. L. Haaland, C. S. Hoveland, and R. Rodriquez, Kabana, Auburn University, Auburn, Alabama
11:20 a.m.	Variation of Photosynthesis and Water Relations in Three Wheatgrass Species.............	R. E. Barker and A. B. Frank, ARS-USDA, Mandan, North Dakota
11:40 a.m.	Fertility Trends in Colchicine-induced Triticeae Amphiploids...................	K. H. Asay and D. R. Dewey, ARS-USDA, Utah State University, Logan, Utah

12:15 p.m.	Lunch (Student Union Building)
1:30 p.m.	Research Reports and Business Meeting
4:00 p.m.	Tour of St. Paul Research on Forage and of Seed Certification of OECD Varieties

THURSDAY, September 11

8:30 a.m.	Depart St. Paul for Rosemount Agricultural Experiment Station (approximately 35 miles south of Ramada Inn).
9:30 a.m.	Tour of forage research at station.
12:10 p.m.	Box lunch, Rosemount
12:45 p.m.	Depart for Stanton (20 miles south of Rosemount near Minn. Highway 3).
1:30 p.m.	Tour of research at Northrup, King & Company Research Centers. Eden Prairie (Turf)-H. E. Kaerwer Stanton (Forages) -G. A. Page

FOOD FOR ALL - CHALLENGE AND RESPONSIBILITY

W. F. Hueg, Jr.
Deputy Vice President and Dean
University of Minnesota
St. Paul, Minnesota 55108

My topic this morning has significance as the United States celebrates the Bicentennial of its independence; the fact of the Centennial of the State Agricultural Experiment Stations; and the critical food needs throughout the world. All are significant to Americans. The Bicentennial celebrates a revolution for independence; the Centennial of the State Agricultural Experiment Stations celebrates a peaceful revolution as it relates to food in our country. However, around the world in the developing nations the lack of food may be the source of revolution. Headlines during the past year have told of governments that have crumbled, primarily because they have not been able to meet the most basic need of people -- food.

At no time in recent American history has agriculture played a more vital role; captured more headlines; been placed under greater constraints; been asked to go for maximum production; moved so quickly from surplus to scarcity; or seen so many anxious about their food supply. The unwritten policy of our national government--cheap and abundant food--is now being challenged, for if we are to have abundant food, it will not necessarily be cheap. The attitude of consumers, government and labor must become more positive toward agriculture if we are to develop the full potential of America respecting worldwide agriculture.

Meanwhile, 6% of the world's population living in the United States uses about 40% of the world's resources, including food. Will this situation change, and if so, how?

At least part of this answer may be found in the success or failure of U.S. agriculture in meeting an unparalleled challenge to produce for a world that has gone through several so-called "explosions." They include: growth of population and disposable income, technological advance, increased education, and general desire to live better than past generations.

Simultaneously, American agriculture is forced to function under many restraints, such as shortages of machinery, fuel, fertilizers and pesticides. It also must live with regulations established during the hysteria days of ecology and environment in the late 1960's and early 1970's which limit production potential.

It is impossible, of course, to predict the outcome of the agricultural crisis which depends so much on action of the government and the people. But we can examine the evidence and make recommendations.

A brief look at American history can aid understanding of our national policy toward food. No one at this period in time can know whether the strategy was so planned, but the end result of various historical events has been development of a nation with one of the highest standards of living. It also became one of the best fed, best clothed, and best housed countries in the world.

In 1862, three major acts were signed into law by President Abraham Lincoln. The first was the Homestead Act which provided 160 acres of land to those who could "prove" (build a home and plant and harvest) 5 acres in three years. The second was the Morrill Land Grant Act which made it possible for states to receive the income from federal lands to establish colleges of agriculture and mechanic arts. The third was the establishment of the United States Department of Agriculture to provide whatever professional help was needed in producing food and developing marketing systems. These actions came when the United States was a vast and sparsely developed empire looking for a way to use its tremendous energies, accumulating wealth and increasing population. Reading histories of the 1840's and 1850's, much of the concern we read and hear about in the world today was expressed at that time. Legislators and others commented on the dilemma of the day which was too little food and too many people. It took nearly 20 years to accomplish what was done by the three significant acts of 1862.

In 1887, the Hatch Act made it possible for states to establish Agricultural Experiment Stations and to receive federal funds on a formula basis. The State of Connecticut established the first experiment station in the United States at Middletown in 1875. This was moved to New Haven two years later in 1877. The Centennial for the State Agricultural Experiment Stations commemorates that development in Connecticut in 1875.

In 1914, the Smith-Lever Act made it possible for states to establish Agricultural Extension Services and to receive federal formula funds. Also in 1914, the Smith-Hughes Act established funds for programs in vocational agriculture in the secondary schools.

All of these events have had great significance for the development of American agriculture and efforts are being made to create such a system in other parts of the world. Various foundations and consortia of universities are and have been at work in developing nations for this purpose. Significantly, they must be created to meet the needs of individual countries. The Famine Prevention Act of 1975 is a major step forward in the type of legislation similar to that which established the Experiment Stations and the Extension Service as we know it in the United States.

American agriculture is the vast agri-business complex which is capitalized at over $460 billion annually. It is the single largest industry in the United States and contrasts to the $80 billion automobile industry.

Agriculture is often considered the five to six percent of the population which lives on the land and produces the raw agricultural products. But we would not have the agricultural productivity we know if we lacked the important input and output industries which provide the supplies for production, storage, and the processing and transportation of raw products to the consumer. There are about 2-1/2 million farms in the United States. About 800,000 of these produce 85% of our food. Farms are getting larger, but less than 2% of the total land in agriculture in the United States is controlled by corporations.

There are estimates that world food production must double in the next 18 to 20 years. A logical question is whether this is possible. Improvement must make greater use of the land resources, of inputs such as water, fertilizer, machinery and labor and do a better job in storing and processing. There is a practical potential to increase production two or three times, but probably the major food increases can come in the developing nations of the world.

For example, the average corn production in the United States in 1973 was 94 bushels an acre, but top production averaged 230 bushels and a record 360 bushels under research conditions was reported. The very next year, because of tremendous variations in weather throughout the growing season and an extremely early frost, that average yield dropped 15 to 20 bushels. Farmers who produce at the average level of production probably will not be operating five years from now because of the cost-price relationship. Many of them will not survive that long as, unfortunately, we are seeing evidence in the livestock sector of agriculture. This is one of the great challenges to the research and extension system and the clientele who use that system.

What is America's Role in a Hungry World?

It is difficult for any of us to comprehend what, in fact, is happening related to food around the world. It is difficult to comprehend because we see all of these situations based on our experience and those in developing nations where hunger exists at the highest levels see the world from their experience. Few of us have experienced hunger, and yet tonite approximately half of the world's population will experience hunger as they attempt to sleep.

We know almost too much about world affairs, and it is constantly blurted out at us several times each day, drumming into us the peril of facing each day. It is difficult then from our experience to comprehend a situation as existed in the Sahel area of Africa where it was nearly four years from the time the drouth began for the government to realize the perilous effects of this climatic situation. It was only when the tattered and hungry farmers came into the cities, hoping for food, that the government realized what was taking place. The irony, of course, was that the cities and towns were depending on the farmers to provide their food supply.

Asking the simple question in many of our urban centers in this country and throughout the world "Where does your food come from?" not only gets a startled look but an incoherent response all too often. In the United States, we have developed a great system which includes science and education, financial institutions, manufacturing, storage, processing and transportation.

Population

Currently, there are over 3.8 billion people on the earth. With zero growth we'll have 5.9 billion and with present growth rates, it is predicted there will be 7 billion people by the year 2000. We're adding more than 200,000 mouths per day as a demand on present food supplies. This is like adding one-half of St. Paul, Minnesota, every day to the world's population. On the other side of the balance, over 10,000 people die from starvation daily. This is losing a town the size of Faribault, Minnesota, each day. But with this balance, where do we stand on population?

The demographers tell us that a half million of this population are starving in a very slow and painful way, and it is difficult to imagine that such a condition can exist. Another half million are undernourished.

Imagine a town of 1,000 residents with a proportionate mixture of the world's population. A population breakdown would include:

570	Asians
190	Europeans
100	Africans
90	North Americans
50	South Americans
1,000	

Of the 90 North Americans, 60 would be from the United States and would control 30 percent of the income of the total group. 500 of the 1,000 would be hungry, 250 would be seriously malnourished, and 250 would enjoy a fair to good diet. This represents the world population in 1975.

A Desire to Improve Diets

Developing nations desire to improve their diets. They look around and see what is happening in the more affluent parts of the world and ask why can't we have the same? These are legitimate goals but how rapidly can they be achieved, what pressure do they place on an existing food production system? We must develop programs to upgrade the agricultural production, improve storage and marketing systems, and develop those industries so essential for a productive agriculture. These are the first steps, the essential steps to control world population and the future destiny of the world. They must begin now and accelerate rapidly.

The People's Republic of China has made a conscious effort to improve protein intake of their citizens by one percent each year, and the USSR five percent each year. That decision has opened up a market to the Green Belt Nations of the world of nearly one-third of the world's population. Part of the currency in the trade relations with these countries will be food. This will be a continuing market, a difficult market with which to deal, but will have strong impact on the United States' ability to produce domestically as well as for export.

We cannot overlook the cultural and ethical issues which deal with improved diets and population control. In the Sahel area the economy is built around livestock. The protein supply is milk and blood. There is also an additional factor that the livestock are used as part of a dowry in the marriage system.

In India, the sacred animals consume about 30 percent of the food production of that country. Also, how does one go about convincing an Indian farmer that he should control the number of children when his religion speaks to this point and, in fact, his children are his labor force and his insurance for old age which may arrive at 45 to 50 years of age.

Weather Dependence

Climatologists and micrometeorologists are telling us that we did not listen to them when they predicted drouth cycles and the possibility of colder cycles into the future. Certainly we all became believers in the crop season 1974 and many farmers who for years had been pushing the limit of corn production to longer and longer days to maturity now will return to shorter growing time varieties. When one considers that much of our crop improvement has been done on the basis of selecting for maximum rather than optimum production, what implications does this have in relation to drouth resistance and cold tolerance?

Scarcity and Cost of Inputs

One example may serve to illustrate the delicate balance of world food production and its interrelation with many of the facets of world economy. One event in crop season 1974 reduced the estimated production of wheat in India by one million metric tons. The reason was a five-day delay in obtaining gasoline to run the pumps to provide water to newly seeded wheat fields. This occurred at the same time we were concerned about our own gasoline supplies; the fact that we had to wait in line and the increasing price at the same time. This brings up the question of priority in commitment with respect to the use of fuel supplies to feed hungry people where starvation is a stark reality, or to provide fuel so that Americans and others can have the convenience of automobiles for pleasure and business.

In our own country we are experiencing some difficulty in getting all the fertilizer supplies we would like, certainly at a price farmers would like. The price of nitrogen has gone up over 200 percent in the last two and a half years and, of course, there are difficulties with pesticides being available or cleared for use because of legal restrictions.

It would seem that as we negotiate with the OPEC countries, part of these discussions must be how the oil income can be used to share the burden of world food production. In the United States we have seen the role of agricultural exports in the balance of payments which exceeded $21 billion in 1974 as against $25 billion of oil imports. This speaks to the interrelationship of food and fuel and also the burden which the oil rich countries must begin to assume in helping to develop a food production system in developing nations.

The Food Delivery System

Earlier I made reference to the agricultural system in the United States which includes the primary production as well as the input and output industries. Although our system is not perfect, it is the envy of much of the world and wherever possible, attempts are made to emulate the success we have in the United States.

Several magazine articles and the daily newspapers have made reference to our consideration of reducing the per capita consumption of livestock products, in particular beef. As a matter of fact, this may occur quicker than we would wish unless we can resolve some of the critical problems faced by cattle feeders in the spring of 1975, a situation which has existed for the last 12 months and probably will continue by estimates of some until late 1976 or early 1977. Those who would suggest that we reduce our consumption of animal products are under the delusion that such a practice would provide more grain for the hungry nations of the world. Nothing is farther from the truth.

Over the last 20 years, the United States has provided in excess of $25 billion of feed grains and agricultural products to hungry nations. This has done nothing to help them develop their agricultural system. And so if we would make available these extra supplies of grains, there is no guarantee that they will get to the people who need them the most. In many of the developing nations, there is no system for distribution or storage until distribution can be accomplished. The net result is that much of the grain so critically needed by people is lost to rodents and the fouling of birds.

If the developing nations are truly concerned about feeding the hungry of their countries, they can look at the agricultural system in the United States and develop at least those portions that fit the local situation. In no way should we attempt to force our system on others, but there are some strengths. One of these strengths has been the research and extension programs which have led to the peaceful revolution and food for all. At this point in mankind's development, the question is whether this nation or any other nation can supply the food for these developing nations for all time. For the short term which I consider 15 to 25 years, we will still be called upon to give of our tremendous production potential, but for the long term it is essential that the developing nations come up with a system which fits their needs and assures more adequate food production and a food system which better assures adequate food supply distribution.

A simple homily speaks to the critical need of food production in the world today: Give a man a fish, and you will have to feed him every day. Teach a man to fish, and he will feed himself and have the opportunity to grow. Truly this has been the essence of the peaceful revolution as we have known it in our agricultural experiment stations, our extension service, and the food system we have in the United States. This, to me, is the great challenge of this century and beyond, and one in which all of us who are willing can become intimately involved. We have the challenge of our own domestic production and at the same time in order to keep our total economy strong, to make it possible to have export markets that can command the production of our system at a price. At the same time, in developing these nations to have their own food systems, we will accomplish a great deal toward their growth as well as the growth of the world as a better place to live and not only survive.

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VARIATION, SELECTION AND THE CONSTRUCTION OF NEW VARIETIES OF FORAGE GRASSES

M. D. Hayward
Welsh Plant Breeding Station
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The breeding methods adopted for any crop species is dependent upon the variability present within it and the manner in which this variability is controlled by the breeding system. This will be further influenced by its stage of evolution as a crop species which will depend upon whether it be new to cultivation or one which has been subjected to many generations of directed selection. The breeding system is itself subject to genetic control and will have evolved in response to the diversity of selection pressures which may have operated in the past (Darlington and Mather, 1949).

The important forage species, which in Europe comprise mainly grasses and legumes, are relatively undeveloped as crop species with only a limited history of practical selection. The majority are outbreeders with a genetically controlled incompatibility system. Populations thus exhibit a wealth of free and potential variability, this variability being associated with adaptation to a vast array of climatic, edaphic and biotic factors.

The early forage breeders were in a fortunate position as they were able to exploit directly this ecological variation. Rapid progress was achieved by these methods and many varieties in use today have been founded on the critical eye of the breeder. However, due to the demands for varieties specifically tailored to meet the demands of increasingly specialized farming systems we now have to consider the application of detailed genetical studies to breeding methodology.

Before examining the techniques available to the breeder one must consider the variability of the material which he works with. Most of the characters, which may be morphological, physiological or biochemical nutrient characteristics, are quantitative in nature. Advances in biometrical genetics over the past forty years have established for the majority of them that this variation is controlled by genes, each of small effect, which behave in a Mendelian manner, together with an environmental component.

What the breeder is particularly concerned with is the relative importance of these primary components and how they will influence his choice of breeding method. Before examining some of the techniques which are currently available and their suitability for use in forage breeding I would like to consider briefly further aspects of these components of variation and what they mean in breeding practice. The aim of any breeding programme is to increase the frequency of desirable genotypes in the population so as to raise the mean in the desired direction. To do this the breeder must be assured that they will breed true to type. Within a breeding programme therefore it is desirable to obtain information on the ability to select elite individuals and whether those plants actually selected, when combined together to form a variety, will give rise to a superior progeny. Much of this information is specified by the heritability, which is generally presented in two forms. The 'broad sense heritability' is the ratio of the total genetic variance to the phenotypic variance, whilst the 'narrow sense' is the additive or fixable portion of the total phenotypic variance. The full implications of heritability in plant breeding and in grass breeding in particular have been well reviewed by Hanson (1963) and Latter (1964). What I would like to deal with, is how may this sort of information be obtained? Before doing so I would like to put this situation into historical perspective by reading a quotation from Stapledon written in 1931 about his work on orchardgrass.

"In order to bring about a degree of improvement...one does not necessarily need to hybridize, nor indeed need one necessarily concern oneself with the mode of inheritance of the various characters of ones' species. By adopting an appropriate technique it is often possible to find out comparatively quickly whether one can achieve what one wants or at least go a long way towards achieving what one wants without anything like a full knowledge of the facts. If this proves impossible then the investigator has no alternative but to conduct innumerable and detailed genetical researches at the outset".

Biometrical genetics has made considerable advances since the time that Stapledon was first faced with this problem and the development of various mating designs and analyses has rapidly outpaced their application to practical plant breeding. I would like to consider some of these biometrical techniques to see where they can be usefully employed in a forage breeding programme, bearing in mind these two objectives, firstly, the need for general information on which to base the strategic planning of breeding operations and, secondly, the selective screening of potential parents of high breeding value.

The strategic survey of breeding material

For the initial survey stage of a programme, such as that frequently employed in the preliminary evaluation of plant collections, the need is for techniques which provide general information on heritability and the genetic architecture of those characters of interest. This requires the handling of large numbers of plants with the minimum of time and labour.

Three methods may be considered of general applicability to forage crops bearing in mind the wide range of genetic systems which occur within these species. These are clonal evaluation, biparental matings and the triple test cross.

Clonal evaluation is the simplest procedure which may be applied to the forage grasses wherever vegetative propagation is possible. It has received widespread application since the days of the earliest grass breeders, but it is only more recently that the genetic principles involved have been put forward by Burton and DeVane (1953). It involves the growing of a number of clonal ramets in a suitably replicated and randomized design. A straightforward analysis of variance will reveal differences between individuals and allow estimates of broad sense heritability to be made. As a practical technique, it has several desirable features in that it will allow testing over a range of environments and for characters which may involve destructive sampling. In terms of the numbers of individuals and ramets to be tested no precise limits can be given. For the former this will depend upon the heterogeneity of the population.

With a relatively uniform population, a greater number, together with a higher ramet replication may be more necessary than with a more heterogeneous one. The numbers of ramets should be assessed in relation to the field layout. For instance, individuals may be replicated in row plots, within or over blocks, or single ramet randomization may be applied with or without field blocking. The practical considerations are in terms of time, labour and field space. Numerous examples can be found of the application of this method to population surveys and the consequent utilization of the information in a breeding programme. However, one must be aware of the fact that clonal differences do not necessarily mean genetic differences which will be inherited in a Mendelian fashion. We have recently encountered this problem in a collection of *Lolium perenne*. A clonal analysis revealed apparent differences among individuals for both productivity and timing of inflorescence emergence (see Fig. 1). However, a more detailed genetic analysis involving a progeny test showed a complete absence of genetic variation for the productivity but a high heritability for ear emergence (Hayward, 1970).

Turning to the second scheme for the preliminary survey of a population - Biparental Matings of BIPS of Mather and Jinks (1971). This involves taking a sample of the population and making a series of pair crosses. Assessment of the resulting progeny families on a single plant basis allows simple estimates of heritability to be derived from the components of the analysis of variance. If the parental plants are included in the field layout, parent-offspring covariances may be calculated, which, in the presence of equal gene frequencies, are direct estimates of the additive component, thus allowing precise estimates of narrow sense heritability to be derived.

One of the more recently developed techniques for the genetic survey of populations is the triple test cross of Kearsey and Jinks (1968). This is an extension of the North Carolina Design III of Comstock and Robinson (1952) which in its original form consisted of the crossing of the members of an F_2 to two inbred tester lines. Here, however, a sample of the population is crossed to the two tester parents and the F_1 between them. The experimental material will thus consist of 3n families (where n is the number of individuals sampled) which are raised in a suitably replicated layout. The analysis consists of two parts - a test for epistasis and a test for the presence of additive and dominance variation. Epistatic effects are estimated from a comparison of the crosses to the F_1 with those of the parental lines, whilst the presence of additivity and dominance is determined by the method of Comstock and Robinson (l.c.) namely from the variance of sums and differences of the test crosses to the two lines.

This design has many advantages for assessing the mode of gene action operative in plant collections in that it can be applied to populations of unknown mating system, gene frequencies and linkage relationships without invalidating the principles of the tests applied. One of the main problems of this test is of course the establishment of suitable tester lines. Ideally, they should be the high and low extremes for the characters under consideration. These may be obtained by selection from, or be the phenotypic limits observed, within the population. Implicit within this limitation is, of course, the fact that one is only assessing gene action for the loci by which these tester lines differ and, hence, absolute estimates of the components may not reveal the true extent of the several components of variation, but only whether they are present or absent. In this respect this design does not necessarily allow precise estimates of heritability and potential response to selection but does provide the sort of information which can guide the breeder in determining his system of variety construction. If, for instance, epistasis and dominance were present one should consider possible means of exploitation, such as the development of 'F_1 hybrid' varieties or the use of selection procedures which give emphasis to these forms of gene action. These designs are but two of a multiplicity and indicate the sort of information which can be easily obtained by these survey techniques and can be usefully employed in the preliminary phases of a breeding programme.

Identification of Elite Plants

I would now like to consider some of the techniques which I think are appropriate for the final stages of a breeding programme, i.e. progeny testing procedures to identify potential parents of superior combining ability.

The majority of the forage grasses that we deal with are generally outbreeders, of various ploidy levels, with differing degrees of self fertility. This restricts suitable testing procedures to those which maintain the heterozygous balance under which these species have evolved. Through the maintenance of this outbreeding situation one must be aware that undue emphasis may be given to genotypes showing dominance and epistasis at the expense of desirable recessives. This, of course, is particularly important where the individuals being tested are to form the parents for a further cycle of selection. There are three basic procedures which are applicable to this situation in the forage grasses: the polycross, the test cross and the diallel cross. Each technique is now well established in its practicalities, but difficulties do arise for the breeder in deciding which is the appropriate method for this final selection phase. On the practical side the polycross has considerable advantages in its ease of construction and in providing large quantities of seed which may be tested under a variety of conditions such as small plots, differing cutting managements, or even in animal trials. The test cross and diallel cross do have the major disadvantage in that controlled pollinations have to be carried out, thus numbers and mode of assessment are restricted by operational difficulties.

I would like to compare the relative efficiencies of the polycross and test cross as aids in discriminating between potential parents before considering the special role of the diallel cross.

A theoretical examination of the polycross and test cross and their application to cross fertilized species has been carried out by Opsahl (1966) who clearly showed for diploids that the polycross could provide satisfactory discrimination between genotypes when both additive and dominance effects were present under a situation of equal gene frequencies. In breeding, a situation of unequal gene frequencies is very likely to arise as a consequence of selection, and here discrimination would be more difficult. Similarly, the various forms of interaction will influence the differences between progeny families - increasing them in the presence of complementary interaction and decreasing where duplicate types occur (see Fig. 2).

With regard to the test cross, successful discrimination will depend on the gene action among the selected plants and the genetic constitution of the tester. If only additive effects are present the tester plant may be of any genotypic constitution. With dominance and/or interaction among the selected plants the choice of tester is more critical. Satisfactory discrimination can only be achieved by the use of a recessive tester (see Hull 1947), a situation clearly exemplified by Carlson's (1966) use of a low performance tester for disease resistance in Phalaris (see Fig. 3). As breeding progresses there is obviously a need for a more critical assessment of the type of tester plant to be used. From the practical side this again raises the problem of actually obtaining and maintaining a tester plant combining all the desired characters.

At the tetraploid level both the polycross and test cross can provide effective discrimination when gene action is additive. In the presence of dominance and unequal gene frequencies, however, greater difficulties may be encountered. Here there is obvious need for further investigation of the suitability of the various mating designs.

The complete diallel cross, in contrast to the techniques previously considered, is the most sophisticated of the various mating designs, allowing a complete specification of the breeding value of the individual genotypes which are included. It involves the crossing together in all possible combinations the selected potential parents and may or may not include reciprocals. The analyses of Jinks and Hayman (see Mather and Jinks 1971) allow the detection of epistasis, heterozygosity, non-random gene distribution, unequal gene frequencies and fairly precise estimates, depending on the magnitude of the former effects, of the additive and dominance components. Thus the behaviour of specific combinations of potential parents can be examined before making the final decision as to which and how many of the selected individuals should form the basic plants of the variety.

The diallel has a major disadvantage as far as its application to practical breeding is concerned in that it requires considerable technical effort to make the requisite number of crosses, and thus the number of potential parents which can be sampled is extremely limited in comparison with the other designs. Its applicability is therefore restricted to those situations where detailed information is required on the specific behaviour of certain combinations of plants such as may be necessary in the production of F_1 hybrid varieties.

To summarize the situation, as the material which the breeding is involved with becomes more highly selected, and, as a consequence, dominance and interaction are of greater importance, the efficiency of the polycross and test cross decreases. It is only under these situations that the employment of a diallel assessment may be fully justified.

To return to Stapledon's dilemma, we thus have available today a range of techniques which meet his requirement. There are those which can indicate whether one can achieve what one wants without a full knowledge of the facts, but, where essential, full and detailed genetical researches may be carried out by application of the more sophisticated methods.

Selection and Adaptability

The forage breeder in carrying out a selection programme is placed in a very difficult position compared with his counterpart in cereal production. New varieties of forage grasses are required to perform under a wide range of conditions of managements, soil types, and often over a long period of time. At the same time he is often seeking to improve characters of agronomic importance which can only be measured in the spaced-plant nursery whereas the final product is to be utilized under the highly competitive conditions of a dense sward.

Before considering some aspects of these problems and how they may be alleviated it is worth emphasizing the rather paradoxical situation which we are faced with in the herbage grasses. Selection is predominantly for vegetative characters and is carried out over periods of sexual generations. In the majority of our temperate grasses sward establishment is by seed with survival in the mature pasture being dependent on continual asexual reproduction by vegetative tillers. Seed rates in general are much higher than is theoretically necessary and are adopted in order to provide for rapid ground cover with control of weeds. Of those seed which germinate the survival rate in a newly sown sward may be as low as 10% by the end of the first year. Competition between seedlings is thus intense with a consequent high genetic wastage, but the species we use have evolved under situations whereby they tolerate this loss by their ability to reproduce by asexual tillering. We thus have these dual modes of reproduction, each with its differing systems of genetic control, together with the forces of establishment and survival, to consider in formulating our selection and variety construction procedures (Breese and Hayward 1972).

I do not intend to discuss in detail the various selection procedures which are available to the herbage breeder for they have been well reviewed (Latter, l.c.; Breese and Hayward, l.c.; Burton, 1973), and numerous examples can be found of the varying degrees of success achieved. What are the possible implications of these selection procedures, many of which have been developed for inbreeding annual crops, to the grass breeder and how can he alleviate some of these problems bearing in mind the outbreeding and hence variable populations he is dealing with?

As previously indicated, the herbage grasses are unique in that they are expected to perform well over a wide range of situations after having been selected in the somewhat restricted environment in which the breeder is forced to operate. One of the extreme examples of this is encountered in selecting under non-competitive spaced-plant conditions for productivity under the highly competitive situation of a mature pasture often in association with other varieties or even species of grasses and legumes. The complexity of the interactions which breeders have encountered have for long proved a major hindrance in the establishment of suitable selection methods. On a wider scale, as breeding has progressed, they have also brought out the need for varieties of both wide ranging adaptabilities and for special restricted purposes.

Adaptation in the herbage grasses may be examined from several aspects. Firstly, there is a general and specific adaptive capacity which is dependent upon the inherent plasticity properties of the individuals within the populations and can be associated with the "developmental homoeostatic" properties of heterozygotes. Secondly, there is the "population buffering" as a consequence of the genetic variability among individuals which occurs within these outbreeding species. The former is of importance throughout the life of the population and is revealed by the capacity of the variety to withstand fluctuating environmental stresses. The buffering capacity plays its most important role during the establishment phases of a pasture in determining which phenotypes actually survive and thereafter depends upon further reproduction which may be by seed, asexually by vegetative tillering, or even apomictically in some species. For these latter two processes any somatic variability could well be of adaptive significance. How may we as breeders specify these parameters of adaptation and incorporate them into our selection programmes?

The development of the regression technique for the analysis of genotype environment interaction in general and its application to outbreeding forage crops in particular has provided new guidelines on which to measure the adaptability of potential selections (Hill, 1975). The regression analysis of Yates and Cochran (1938) was applied by Finlay and Wilkinson (1963) in Australia and by the Birmingham School of Genetics in Britain to the examination of genotype environment interaction. The Australian studies were particularly concerned with the measurement of the adaptability of a set of cereal varieties to a wide range of environments involving sites and seasons, whilst the genetical approach was directed to an understanding of the interaction components and their inheritance.

The technique basically consists of growing a set of varieties in a range of environments, the analysis of variance revealing the presence of any genotype x environment interaction. If the environments are specified according to the mean expression of all the varieties in that environment, the performance of individual varieties may be assessed by its regression onto these means. It has now been shown that many cases of genotype environment interaction can be explained by differential linear responses to the changing environment. The environments may range from location, soil, seasonal or management effects, or even from the spaced-plant situation to sward behavior, this latter attribute being of predictive importance in a selection program. The actual response as measured by the 'b' value, i.e. the slope of the regression is thus a measure of the stability of a variety over a range of environments. As it allows the breeder to predict the change in mean expression it can be incorporated into a selection program. In selecting, therefore, two factors can be taken into account - the mean expression and the response - the particular desirable combination being determined according to the selection criteria. Eberhart and Russell (1966) have proposed that in general a high mean and a stable response are desirable. In grasses, however, due to the diversity of environments in which they are utilized, no strict criteria can be laid down.

The question of the environment in which one should select has recently received consideration (Daday *et al.* 1973) in view of the manner in which it may influence both the mean expression and the response.

On the basis of their selection studies on the fungus *Schizophyllum*, Jinks and Conolly (1973) put forward a number of proposals which they considered to have general validity in selection procedures.

(i) "To achieve a desirable average performance over a wide range of environments selection within any one of a number of environments that are well within the range appears to be equally satisfactory, to achieve an equally desirable performance in one specific environment selection must be practiced in that or a closely related environment".

(ii) "To achieve a desirable average over the range, including an acceptable performance in the worst of these, selection must be based on average performance in two or more contrasting environments within this range".

(iii) "Selection for mean performance will lead to greater or lesser sensitivity to environmental change within a range of environments according to whether the environment in which selection is carried out deviates from the mean of the range in the same or in the opposite direction to the direction of selection".

We may examine these proposals from their applicability to grass breeding in the light of what evidence is available.

I think we would all agree with the general approach of their first proposal in that it is the basic selection system which we have adopted for so long. With regard to the suggestion that performance over a range of environments, including a satisfactory performance in the worst situations, can be obtained by selecting in two or more contrasting environments, from the limited experimental results available this would appear to be valid where the major portion of the genotype environment interaction can be accounted for by the linear regression. In one of our recent selection experiments for winter survival in Lolium multiflorum, differential levels of winter kill were obtained by cutting at varying periods throughout the autumn at the lowland site of the WPBS. From these results we were able to successfully predict what the relative kill of the selections would be when tested at the more severe location of one of our upland sub-centres (Hides, unpublished).

Over this range of environments the linear response holds good, but in some circumstances it has been found to break down, particularly under extreme stress conditions.

Turning to consider the final proposal of Jinks and Connolly that selection for mean performance will lead to a corresponding change in the sensitivity, as measured by the response factor, according to the environment in which the selection is made, this will, of course, depend on the relationship between the mean and response and whether the latter is inherited in a regular manner. Several studies in grasses have shown that the response is under genetic control, the mode of gene action depending on whether the genotypes have been subjected to directional selection in the past. In some instances a high correlation exists between mean and response, but it does not necessarily imply that it is the same set of genes which are controlling both processes. In another selection experiment which we have carried out in Lolium perenne, no consistent pattern of response has come about with directional selection for mean productivity under supra-optimal conditions (see Fig. 4). These results would appear to contradict their third proposal; however, if one considers sensitivity not as the response but as the "stability of the response" as measured by the deviations around the regression (Eberhart and Russel 1966, Breese 1969), the sensitivity has increased with selection. This is undoubtedly a reflection on the genetic organization of the populations and obviously requires further investigation. It further emphasizes the need for a more extensive appraisal of the effects of selection both in extreme or varying environments.

We know little as yet of the manner in which we may construct varieties in order to maintain high adaptability and can only draw inferences from studies on other species and some of our past results. The superior stability of the heterozygous state, arising as a consequence of the genic balance produced by past natural selection, is now well established in many organisms irrespective of whether the basic breeding system is self or cross fertilizing (Jinks and Mather 1955, Griffing and Langridge 1963). Our past selection programmes, particularly in Lolium perenne, have helped to maintain heterozygosity. This has been done both deliberately and unconsciously according to the origin of the basic plants which have gone into the synthesis of our varieties. The success of our widely adapted perennial ryegrass S.23 may well be accounted for by its heterogeneous parentage. The majority of the parent plants derived from old permanent pastures of inherently high fertility, together with a lower frequency of individuals of more diverse origin. Heterozygosity was thus well maintained, providing the homeostatic capacity for adaptation. More recently we have deliberately utilized this phenomenon in the production of 'Sabrina' (a Lolium perenne x L. multiflorum hybrid). This has been established at the tetraploid level in order to maintain heterozygosity, together with any F_1 'heterotic vigor', for as long as possible over the generations of multiplication (Breese et al, 1975).

Population Buffering

The second aspect of adaptability is that conferred by the heterogeneity of the individuals within the population. In practice this variability, giving rise to a high degree of flexibility, is often achieved by the use of mixtures of varieties within one or more species. Studies on mixtures and the various aspects of competition and cooperation in the herbage grasses has recently been well reviewed (Trenbath 1974), and it is not my intention to consider this subject further. I would like to consider the way that selection may change a population and its implications on the buffering capacity of the variety. Before doing so, however, we may briefly examine the evidence for buffering in the herbage grasses. Unfortunately, very little direct information is available although here again one can infer from allied studies on simple mixtures.

Brougham and Harris (1969) and Charles (1966) have clearly shown how different managements can influence the proportion of various genotypes surviving in pastures after sowing down to mixed populations.

Recently we have determined the frequency of various survivor types from within a single cultivar after having subjected it to a controlled cutting management for two years. Seedling counts during the establishment phase revealed a marked decline in the numbers of seedlings present (see Fig. 5). A clonal comparison with a sample of the original cultivar, of the same physiological age, showed that elimination had been predominantly of the modal types, with both extremes of the population surviving (see Fig. 6). This population would thus have the capacity for further change if the management should alter. The ability to reproduce asexually could lead to complete domination of the sward by the individuals contained in one tail of the distribution. Any further change thereafter would be dependent on chance sexual reproduction and establishment from seed. Any somatic variability could of course be of potential adaptive capacity, but even this may be limited with increasing age of the population (Breese, Hayward, and Thomas 1965).

How are we likely to affect this population buffering capacity by the normal processes of selection and variety construction that we adopt? Here again we have little conclusive evidence on the variability of a population, especially after it may have gone through a series of generations of multiplication.

In a selection experiment for seedling vigor in tall fescue conducted by my colleague Mr. B. F. Tyler, in all lines there was an increase in variance over the unselected population. Similarly, in selecting for productivity in Lolium perenne we again obtained an increased variance (see Fig. 7). In 'Pensacola' bahiagrass, Burton (1974) has recently reported that no change in variance was obtained with four cycles of selection in a narrow gene pool based line, whereas a decline occurred in a wide gene pool line to the level of the narrow gene pool line. It would be of interest to ascertain whether this resultant variance was lower than that exhibited by any of the individual 39 seed lots that went to make up the wide gene pool.

It is worth emphasizing that in no instance has a marked decrease in variance been obtained in spite of the intense selection pressures which have been applied and the possible effects of inbreeding through using a restricted number of individuals. Selection itself is probably causing a release of variability by producing a correlated change in the number or position of chiasmata within the chromosome complement. In our own selection experiment previously referred to, the total number of chiasmata has declined, but the proportion of interstitial as compared to terminal has increased.

Some of these questions which I have raised may be answered by the judicious application of the various biometrical techniques considered in the first part of this review. Others will, however, require the development of more detailed studies involving the plant breeder with the biochemist, physiologist and agronomist before we can confidently put forward schemes for selection and variety construction to meet the demands which are going to be put on the grass breeder in the future. I hope they may receive some consideration in your future "Work Planning Conferences".

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	df	Establishment Cut (M. S.)	Hay Cut (M. S.)	Ear Emergence (M. S.)
Between Clones	16	174,260***	719,958***	1,066***
Within Clones	333	8,268	25,898	11

Analysis of progeny families.

Between parental Arrays	df			
Group A	8	13,771	3,394	81.2**
Group B	8	13,328	12,523	662.5***
A x B	64	11,861	3,747	16.7***
Reps	1	159	827	14.5
Error	68	10,315	12,731	5.5

Figure 1. Analysis of variance of clonally propagated material (after Hayward, 1970).

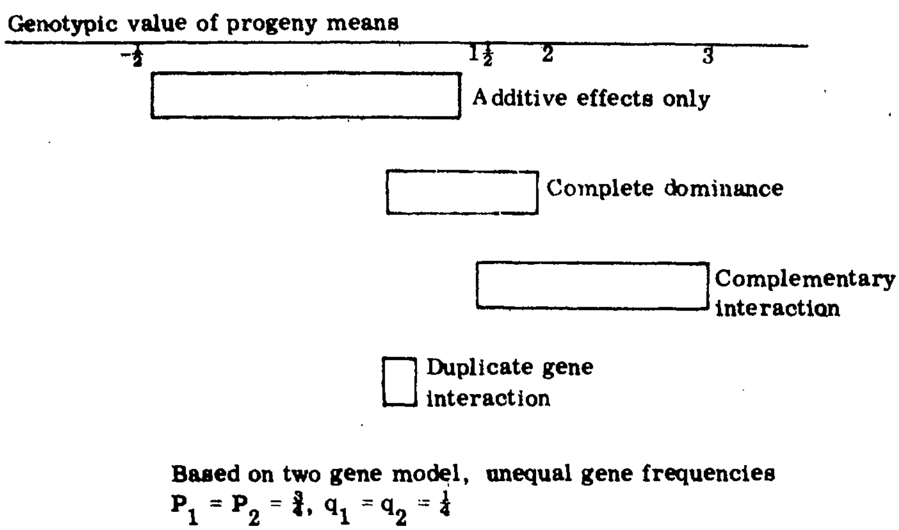

Figure 2. Relative range of discrimination in a polycross.

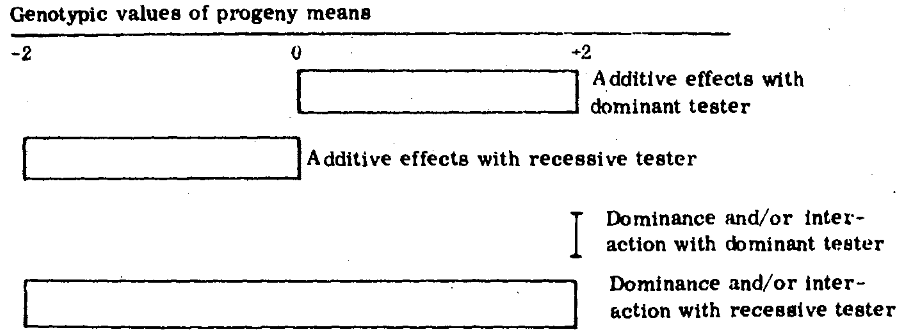

Figure 3. Relative range of discrimination in a test cross.

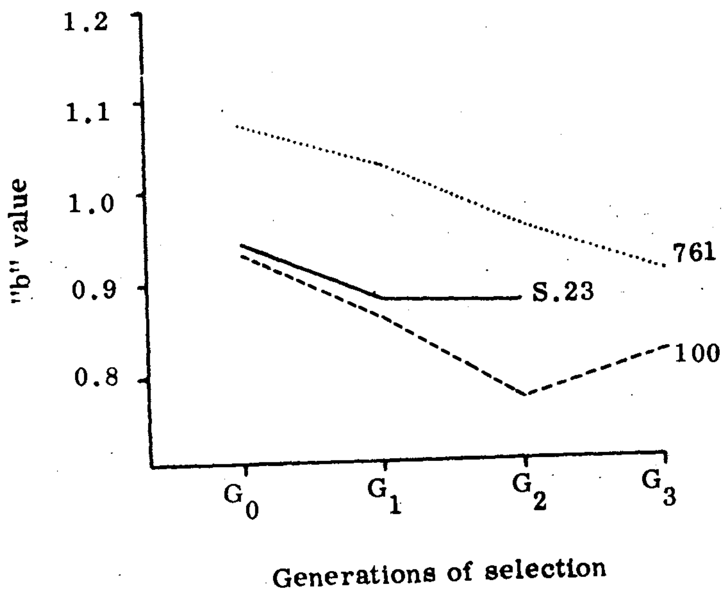

Figure 4. Change in stability with selection for productivity in *Lolium perenne* as measured by the regression value.

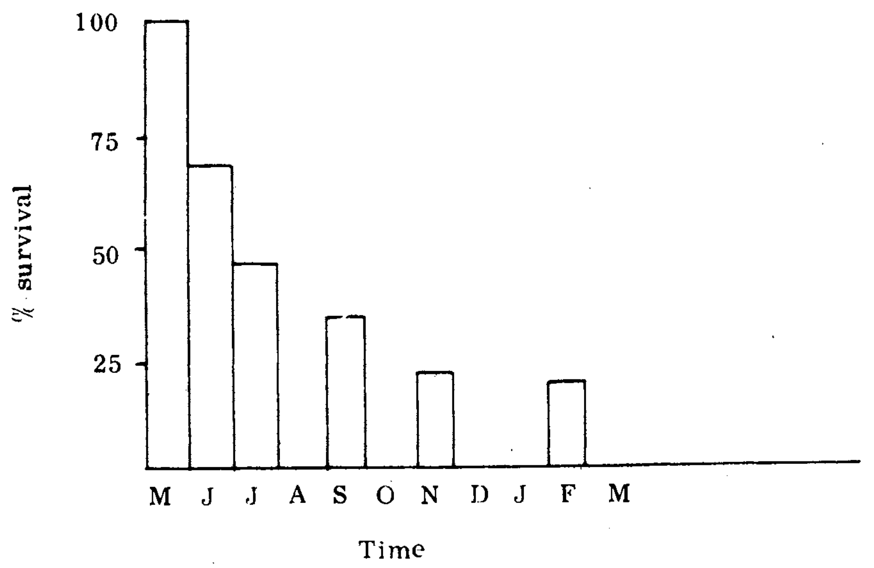

Figure 5. Seedling survival in a sword of Lolium perenne cv. S.24.

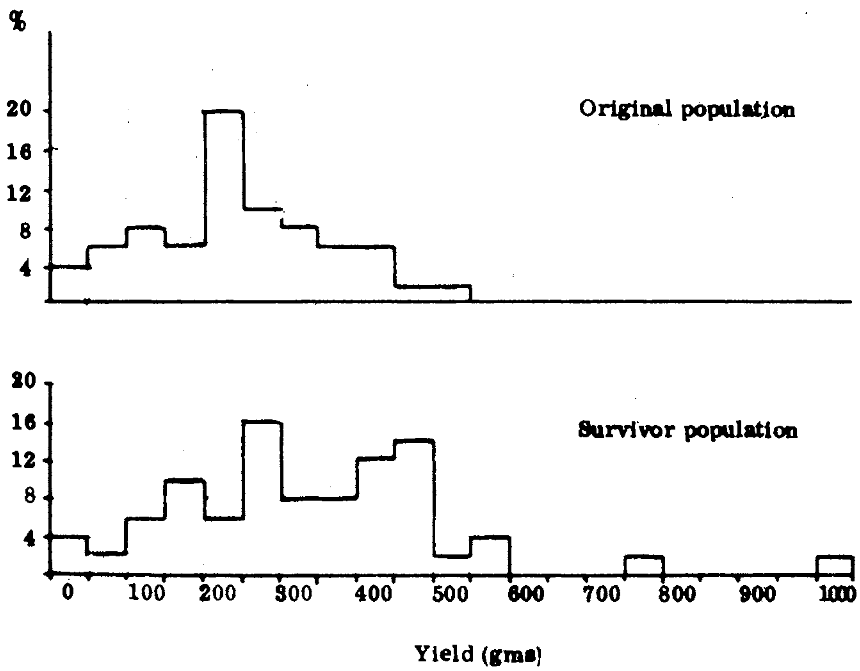

Figure 6. Selective survival in a population of Lolium perenne cv. S.24.

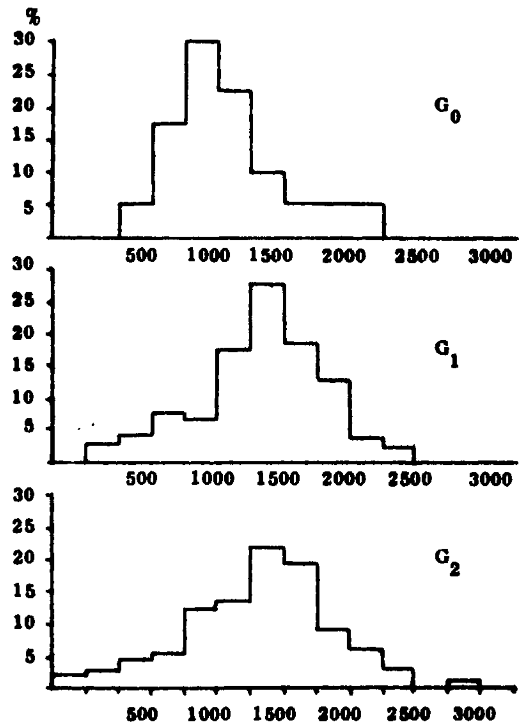

Figure 7. Frequency distribution of yield classes in selected generations of Lolium perenne cv. S.23.

ANATOMICAL FEATURES OF GRASSES INFLUENCING *in vitro* DIGESTIBILITY

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The chemical characterization alone of plants cannot provide absolute predictive information on their digestibility by ruminants. Van Soest (12) cites the case of cottonseed hulls and rice hulls which have lignin-cellulose ratios of .55 and .45 respectively; however, the cottonseed hulls were 50% digestible while rice hulls had 0% digestibility. Clearly other factors must contribute a large measure of influence on digestibility. I wish to consider one facet of these "other factors" which have an important role. This facet is the anatomical features of grasses which influence *in vitro* digestibility.

While at Tifton, Georgia some 5 years ago Dr. Warren G. Monson and I began looking through *in vitro* samples of forage after digestion to identify undigested plant parts. We were struck by the number of undigested trichomes in the sample. Do trichomes possess a chemical or structural characteristic which make them undigestible? We tested many different grasses and found absolutely none which had digestible trichomes. Thus, trichomes or protuberances from epidermal cells have no value for the ruminant animal and take up valuable fill space in the rumen. Therefore, they could be eliminated from their diet. The question of whether they can be eliminated from the plant however, is quite a different matter. In pearl millet, the summer annual forage, a single gene pair controls trichome development and is easily manipulated (10). What is the consequence of removing the trichome from the plant? This question has not been satisfactorily answered.

While investigating the nondigestibility of trichomes, we also noted that the cuticle was virtually indigestible and served as a powerful barrier to microbes. They could not enter except at cut or broken places in the leaf or stem (8). These observations also suggested to us a method of separating the cuticle from the other tissues of the leaf (9). The impermeability of the cuticle and epidermis was vividly illustrated by Monson and Burton (7). They reported chewed forage by the ruminant animal contrasted with unchewed forage which increased digestibility 40-50% while forage samples cut into .3 cm lengths contrasted with samples cut into 2.5 cm lengths had triple the dry matter digestibility. Perforating or abrading the cuticle caused a 4 to 5 fold increase in digestion of bermudagrass.

Several features other than cuticle characteristics influence digestion. Stomata in the epidermal surface of leaf blades were examined as possible modes of entry for microbes into the mesophyll and inner tissue of leaf and stems. We investigated stomata openings and found this mode of entry a very unlikely avenue of entry, because the guard cells were almost as resistant to digestion as the cuticle (2). We saw no evidence of pockets of digestion beneath stomata as would be expected if stomata were providing entry points. Inside the leaves and stems different tissue have different degradation periods. Hanna, et al (6) examined transections of leaves after digestion. These revealed the order of degradation as mesophyll, phloem, epidermal cells, and bundle sheath cells. Lignified tissue and cuticle were not attacked during the digestion period of their test. Akin, et al (1) showed similar results with the aid of a scanning electron microscope.

A very significant observation by Hanna, et al (6) revealed that mesophyll arrangement differed in grass leaves and was apparently under genetic control. One pearl millet inbred tended to have homogenous, loosely arranged, large cells while another had compact more organized, and smaller cells. The mesophyll cells of the latter inbred were not as quickly degraded by microbes as the inbred with the large mesophyll cells. Another example of differential degradation of the same cell type occurs in bermudagrass. The bundle sheath cells of leaf blades in 'Coastcross 1' and 'Coastal' bermudagrass digest at different rates with Coastcross 1 being the more digestible.

Other anatomical differences can be cited which bear on possible genetic manipulation for increase digestibility. A case can be given from studies of the species Lolium perenne L. and Festuca pratensis Huds and their hybrids by Essad (5). Transections of the leaf of L. perenne revealed bundles of flattened sclerenchyma attached to the cuticle which seldom contacted the vascular bundles of the leaf. F. pratensis, in contrast, had rounded bundles of sclerenchyma and came in contact regularly with both cuticle and vascular bundles. The hybrid between these two species was more like the F. pratensis than the L. perenne. The L. perenne was predictably the more digestible because of less sclerenchyma, therefore, this characteristic would be the most desirable and should be screened for in a forage improvement program.

In a detailed study of the anatomy of several warm season and cool season grasses (Stiff and Powell (11)) it became very apparent that digestibility can be limited by barriers of cell organization as well as tissue constituents. On the inside of the stem the fiberond which is a continuous ring of sclerenchyma running the length of the internode is separated from the heavily cutanized epidermis by the outer cortex in all the grasses examined. Both the epidermis and the fiberond are formidable barriers to penetration of microbes to the inner pith of the stem.

Our more recent work at Beltsville has been to study the basis of the cuticle barrier to rumen microbes. The work is cooperative with the animal scientists at this location. We chose barley for these studies because there are at least 41 different genes that are known to control the surface wax deposits of leaf, sheath and spike (13). While studying some 30 different barley lines, we also have been attempting to develop methodology to screen for the "surface penetration by microbes" characteristic. Variation in penetration of the cuticle have been reported in bloom and bloomless sorghum (Cummins and Dobson (4)). Bloomless sorghum gave a 22.5% increase in digestibility over the bloom type. What is the nature of this variation for penetration: Does it occur in other plants? Is the effect due to structural alteration of the cuticle or to chemical alterations of the lipids (3)?

To screen for surface penetration the cut surfaces of the leaf or stem must be protected from penetration by the microbes. We tried several kinds of waxes and glues and found that rubber cement worked as well as any compounds tried and was easily handled. The microbes were observed to attack the paraffins and waxes as well as the rubber cement, although slowly. Care was exercised to not leave air bubbles in the cement when sealing the cut ends of the leaf, because the microbes would degrade the thin wall of the bubble and gain access to the cut surface of the leaf.

The screening tests revealed very marked differences in the ability of microbes to penetrate the barley leaves of different stocks. For example, in 'Gateway' barley and the *gl4* mutant we scored digestion as 0.70 and 1.63 respectively in one test. In another test Gateway was scored 0.96 and the *gl4* mutant 1.78. The difference in digestion is a difference in the ability of the microbes to penetrate the surface of the leaf blades of these two barley stocks. The condition is controlled by a single gene pair and could be incorporated into other stocks.

While screening for surface penetration by rumen microbes we also noted that differences existed for rate of water penetration through the surface of the leaf when the cut edges were sealed. Water penetration and rate of digestion were significantly correlated in tests of the barley stocks.

It is my opinion, that anatomical features of forage grasses have important variation that can be genetically manipulated and significant improvement in digestibility can be accomplished. Improvement in more rapid penetration by microbes could also result in significantly increasing intake, because the physical properties of the forage is maintained in contrast to fine grinding or pelleting.

The author wishes to acknowledge the assistance of Dr. David A. Dinius for the *in vitro* screening of barley leaves with rumen fluid.

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BREEDING FOR IMPROVED FORAGE QUALITY IN REED CANARYGRASS

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Introduction

Recent interest among grass breeders in improving reed canarygrass, *Phalaris arudinacea* L., has resulted from recognition of the forage yield potential of this widely adapted species. In Minnesota, reed canarygrass is high-yielding and performs somewhat better than smooth bromegrass during mid-summer (Marten and Donker, 1968). Chemical feed analyses from comparative trials conducted at several state experiment stations have shown reed canarygrass to be equal or better than many other cool-season species in *in vitro* digestible dry matter (IVDDM), crude protein and major minerals, but somewhat higher in crude fiber and silica. It has the reputation of being unpalatable to livestock. Simons and Marten (1971) found palatability to grazing sheep offered a choice of reed canarygrass clones to be negatively associated with concentration of total alkaloids. This observation led to the plant breeding research program with this species in our Department. Progress over the last five years in breeding for lower alkaloid concentration and breeding for other forage quality characteristics will be reported and discussed in this paper.

Alkaloids

At least eight alkaloids are present in reed canarygrass (for review see Marten, 1973). The primary alkaloids are indole alkaloids and include gramine, tryptamines and β-carbolines. In addition, one phenol (hordenine) may also be present. Recent cooperative studies at Minnesota have demonstrated the biological significance of reed canarygrass alkaloids to lamb performance (Marten et al., 1975). We measured performance of lambs confined without choice to single-clone pastures having specific alkaloid types and concentrations. During the 1973 grazing season of 52 days, lambs grazing three high-alkaloid (0.35% dry wt) clones lost an average of 4 g/day, while those grazing three low-alkaloid (0.10%) clones gained 82 g. During the 1974 season of 97 days, lambs grazing four high-alkaloid (0.24%) clones gained 71 g/day, while those grazing four low-alkaloid (0.08%) clones gained 118 g. Alkaloid concentration of the clones was correlated ($r = -0.91$ and $r = -0.90$) with lamb gains during the two years. Incidence of diarrhea in lambs ranged from a low of 3% for low-gramine clones to a high of 51% for high-tryptamine clones. Our observation on diarrhea confirmed a previous report to this conference by Woods (1973).

We may need to breed for alkaloid concentration levels below 0.10% in order to exploit the improvement in palatability and animal products. Our current breeding program utilizes parent clones with alkaloid concentration below 0.10% when determined on regrowth forage. Progenies from these clones show no apparent reduction in forage yield potential.

We have obtained heritability estimates for alkaloid concentrations based on a 36-plant sample obtained from a population of 120 plants (Barker and Hovin, 1974). The seasonal mean whole plant alkaloid concentration for the 120 plants ranged from 0.01% to 2.75%. The 36 parents, grouped in 3 groups (low:<0.30%, intermediate:0.30-0.59%, and high:>0.59%), were used in two-clone crosses within groups. Realized narrow and broad sense heritability estimates ranged from 55% to 74% and from 45% to 87%, respectively. The lower estimates were in the low-intermediate alkaloid range and resulted in part from a larger genotype-environment variance component.

A second emphasis in our alkaloid breeding program is to use only gramine-containing genotypes as these appear to cause less diarrhea in sheep. We are presently conducting a qualitative genetic study of indole alkaloids, including gramine, tryptamines, and β-carbolines.

Alkaloid Characteristics of Varieties

Oram (1970) surveyed 33 strains of 14 *Phalaris* species and found none to be entirely free of tryptamines. Woods and Clark (1971) found tryptamine-free plants in reed canarygrass to contain gramine, the simplest indole alkaloid. We have compared spaced plants of several reed canarygrass varieties and some experimental strains for frequency distribution of specific alkaloids (Hovin and Marten, 1975). We found 'Vantage' to be the only variety that contained exclusively gramine. 'Frontier,' 'Grove,' and 'Rise' contained both gramine and tryptamines. We have yet to determine whether reed canarygrass pastures seeded to Vantage or similar gramine-containing varieties will result in improved health of grazing livestock.

We have shown (Hagman et al., 1975) that maximum concentration of alkaloids in reed canarygrass occurs in the early regrowth stage and diminishes with advanced maturity. The highest alkaloid concentration occurs in leaf blades and low concentrations occur in leaf sheaths and stems.

In a variety trial, Grove and MN-72 (a 12-clone experimental strain developed in our breeding program) had significantly lower total alkaloid concentration than Rise and Vantage (Table 1). Frontier was intermediate. Alkaloid concentration appeared to distinguish some reed canarygrass varieties only at times of high leaf production at regrowth stages. MN-72 yielded equal to Rise and Vantage (Table 1) and it is grazed by livestock at specific time intervals in preference to Rise. Our research has not uncovered any adverse relationship between alkaloids and other quality factors of reed canarygrass forage.

Cell Wall Constituents

Fiber (cellulose and hemicellulose) or structural cell-wall constituents (CWC) and soluble carbohydrates supply the greatest portion of energy for ruminant animals. Van Soest (1965) suggested that voluntary intake would be affected adversely when CWC represented at least 55% of forage dry matter. A better understanding of the variability and interrelationship of cell wall components and cell solubles among plant genotypes may result in valid indirect estimates of digestible energy and voluntary intake potential. Because voluntary intake potential is affected by several factors (Waldo, 1969), it cannot be estimated accurately by any single laboratory method. We have used the neutral detergent fiber method described by Goering and Van Soest (1970) to estimate CWC.

We estimated heritabilities and genetic variance components for CWC of first regrowth reed canarygrass forage (Hovin et al., 1975). The analyses were based on a 12-clone incomplete diallel also used to estimate IVDDM and crude protein. Broad and narrow sense heritabilities for CWC were 0.83 and 0.33. Correlation between parent clone performance and general combining ability (GCA) was $r = 0.87$ and $r = 0.83$ for CWC and forage dry matter yield, respectively.

Because CWC contributes directly to forage yield, a positive correlation is expected between these traits. The non-significant correlation were $r = 0.53$ and 0.24 for the 12 parent clones and their 30 crosses, respectively. The low correlation for crosses was possibly the result of genotype x location and genotype x year interactions for forage yield. Correlations between CWC and IVDDM over 2 locations and 2 years were -0.77 and -0.68 for clones and crosses and are of similar magnitude as those obtained by other workers.

By reducing CWC of regrowth forage to below 50% of dry matter we do not know whether this may affect also the culm strength of first growth. This aspect needs to be examined further because lodging resistance may become important in seed production.

Digestible Dry Matter

Reed canarygrass forage has high digestibility when compared to other cool-season grasses (for review see Marten and Heath, 1973). Research conducted in our laboratory (Marten, 1973; Hovin et al., 1974) has shown no association between *in vitro* digestible dry matter (IVDDM) and alkaloid concentration in reed canarygrass. Therefore, these two quality traits can be dealt with as independent parameters in selection programs.

Very little information has been published on the heritability of IVDDM in reed canarygrass. Carlson et al. (1969) reported broad sense heritabilities of 0.51 to 0.80 for IVDDM of deferred harvest. We studied IVDDM of first regrowth forage harvested in July or August to determine genetic variance components and environment interaction (Hovin et al., 1974). The 12 parent clones and 30 progenies were grown at two locations and were harvested for two years (Table 2). In a separate study we examined IVDDM of 13 two-clone crosses between 26 parent clones with a wide range of alkaloid concentration.

Broad sense heritability estimates (based on the 12 parent clones) was H_b = 0.58. A similar narrow sense (H_n) estimates was obtained when we excluded negative genetic variance estimates. Negative estimates may result when the experimental procedure is not sufficiently accurate to determine the size of the variance components in relation to error variance. Heritability estimates based on two-clone crosses (and using parent-offspring regression) was H_n = 0.71. In this case parents and offspring were grown in the same environment and, therefore, did not offer an opportunity to determine the size of the genotype x environment effect.

The correlation between IVDDM for parent clones and the general combining ability of the parent clone was r = 0.88. The results suggest that initial selection for IVDDM could be based on clone performance. Estimates of forage yield is also necessary and we have considered yield potential in our selection for quality. We concluded that progress could be made in improving digestible dry matter further if necessary.

<u>Crude Protein</u>

Several workers have reported crude protein concentration in reed canarygrass to be equal to or higher than that of other cool season grasses when cut at the same time. Lawrence et al. (1971) showed that crude protein concentration decreased whereas crude protein yield increased significantly with advanced plant maturity. Asay et al. (1968) found a negative relationship between crude protein concentration and yield of deferred forage. Their estimates for heritability of crude protein were H_b = 0.44 - 0.70 and H_n = 0.19 - 0.41.

We estimated heritability of crude protein of regrowth forage. Broad sense heritabilities were 0.29 when determined independently for 12 unrelated parent clones and their 30 crosses resulting from an incomplete diallel. Our estimates of H_n were near 0, which resulted in part from genotype x location interaction and intergenotypic competition within plots. Our results suggested that protein yield could be improved more rapidly by breeding for improved forage yield than by breeding for higher crude protein concentrations. Correlations between rankings of parent clone-mean performance vs. general combining ability were 0.77, 0.64 and 0.38 for crude protein concentration, forage yield, and protein yield, respectively (Tew, 1974).

Relationships Between Forage Yield and Some Forage Quality Characteristics

I have summarized the results from our data on forage yield of regrowth and the corresponding forage quality traits CWC, IVDDM, and crude protein (Table 2). You will note the close relationship in the ranking of parent clone performance and their gca effects for each trait. Because the parent clones had not been selected previously for any of the traits we studied, it appears that the method we used to determine the performance of the 12 parent clones per se could have been used to estimate their gca.

The positive relationship between forage yield and CWC and the negative relationship between these traits and IVDDM and crude protein indicate that selecting genotypes with low fiber content, high IVDDM, and high crude protein will result in a reduction of forage yield potential. We have advanced 4 of the 30 crosses used to illustrate this point. These four were crossed to unrelated breeding material characterized by having low concentration of gramine alkaloids, no or insignificant concentrations of tryptamine or β-carboline, as well as having relatively intermediate quality characteristics.

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Table 1. Alkaloid concentration and forage yield of reed canarygrass varieties, Rosemount, Minnesota.

	Total Alkaloids						
	1973		1974				
	Aug. 4	Aug. 20	July 15	Aug. 28	Mean	Forage yield	
Variety	(4 wk)	(6 wk)	(3 wk)	(4 wk)	x	1973	1974
	% dry wt					t/ha	
Frontier	.19	.09	.10	.13	.1275	10.1	11.8
Grove	.18	.10	.09	.10	.1175	9.7	10.9
MN-72	.19	.10	.10	.10	.1225	9.7	12.7
Rise	.27	.14	.11	.13	.1625	9.9	12.7
Vantage	.25	.10	.12	.12	.1475	10.9	11.4
RC-2	.24	.15	.12	.17	.1700	10.8	12.6
LSD 5%	.04	.03	.03	.04	.0178	.9	.9
CV %						5.7	4.9

Table 2. Performance and rank of 12 reed canarygrass clones and general combining ability effects.

Clone	Forage yield				CWC				IVDDM				Crude protein			
No.	Clone	GCA	Clone	GCA	Clone	GCA	Clone	GCA	Clone	GCA	Clone	GCA	Clone	GCA	Clone	GCA
	---t/ha----		---rank---		-% dry wt--		---rank---		-% dry wt--		---rank---		-% dry wt--		---rank---	
R36	3.01	-0.08	11	11	53.9	-0.53	7	10	66.4	1.23	4	4	15.0	0.51	5.5	3
R37	3.60	0.02	6	6	55.8	0.46	3	3	61.1	-1.46	10	10	14.1	-0.49	9	10
R38	2.60	-0.19	12	12	49.5	-0.91	12	11	67.5	2.19	3	2	16.3	0.81	1	1
R42	4.54	0.26	1	1	54.1	0.36	6	6	60.6	-2.76	11	12	13.6	-0.58	12	12
R45	3.41	-0.05	8	8	55.3	0.13	4	7	62.2	0.12	8.5	6	14.2	-0.56	10.5	11
R49	3.06	-0.06	10	9	52.5	-0.47	10	9	62.6	-0.99	7	9	15.1	0.58	4	2
R50	3.68	0.02	5	4	56.9	1.38	2	2	60.1	-1.71	12	11	15.7	0.03	2	6
R52	4.01	0.14	3	2	52.7	-0.33	9	8	67.9	1.64	2	3	15.0	-0.30	5.5	9
R91	4.37	0.02	2	5	54.8	0.36	5	5	63.8	-0.96	6	8	14.8	-0.29	7	8
R92	3.17	-0.07	9	10	50.7	-2.24	11	12	69.9	2.45	1	1	15.4	0.25	3	4
R93	3.86	-0.01	4	7	57.5	1.38	1	1	62.2	-0.42	8.5	7	14.2	0.17	10.5	5
R94	3.56	0.11	7	3	53.5	0.41	8	4	65.4	0.68	5	5	14.5	-0.13	8	7

BREEDING REED CANARYGRASS FOR IMPROVED FORAGE AND SEED CHARACTERISTICS

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Reed canarygrass shows considerable potential for use in pasture improvement because of its adaptation to a wide range of environmental conditions, high forage yield, good seasonal distribution of yield, disease resistance, drought tolerance, and persistence under a wide range of management and fertilization treatments. There are, however, several problems connected with its use. Seed shattering is a problem in seed production. It is sometimes difficult to establish good stands of reed canarygrass. Other disadvantages include low palatability, low average daily gains on beef cattle particularly in the fall, and low frost tolerance. In addition, reed canarygrass may be difficult to eradicate when a farmer wants to grow another crop.

Dr. R. R. Kalton initiated a breeding program on reed canarygrass at Iowa State University in 1954 by collecting germplasm mainly from the North Central Region of the United States. Material from the collection was evaluated initially in a space-planted source nursery. Subsequently, selected plants were clonally tested in a topcross nursery and progeny tested. Some of the results of that work have been published (2, 3, 4). In those stages of the breeding program, selection for seed yield and seed retention was emphasized, however, winterhardiness, maturity, forage yield, disease reaction, leafiness, and palatability were considered also. The variety 'Vantage', released in 1972, is a product of that work. Vantage is characterized by early maturity, high seed yield, improved seed retention, high weight per 100 seeds, high forage yield, and the forage contains only the indole alkaloid gramine. In Iowa, Vantage is similar to Ioreed in date of seed maturity and a day or two earlier than Rise. Vantage is much superior to Ioreed in seed retention and it was somewhat superior to Rise in that trait in Iowa and Minnesota tests.

In work on other seed traits, Topark-Ngarm (7) studied effects of seed maturity and seed weight on stand establishment traits. He found that mature seed was superior to immature seed in 100-seed weight, germination, field emergence, and seedling vigor. Therefore, seed harvest should be timed to minimize immature seed content. His results indicated also that selection against low weight per 100 mature seeds should help to maintain a high level of performance for stand establishment traits.

In recent years, we have placed more emphasis on improving forage characteristics. We have conducted research on percentage *in vitro* dry matter digestibility (IVDMD), percentage crude protein, palatability, and forage yield.

Most of our studies on IVDMD were conducted on nonflowering regrowth in solid stands. In our first study (5), we found significant differences among 20 clones and their topcross progenies in digestibility of third-cutting forage. Significant parent-progeny correlations indicated the presence of heritable variation in IVDMD. The correlation between parent and progeny means over two years and two clipping managements was 0.69. In another experiment, D. J. Baker (unpublished data) found significant differences in IVDMD of third- and fourth-cutting forage of 14 clones, their S_1 progenies, and 42 two-clone crosses, but the range among all entries in average digestibility was only four units for each cutting. A narrow range in IVDMD was found in other tests also. A significant clone x year interaction and low correlations between years indicated that selection should be based on more than one year's results.

Asay et al. (1) reported indications of heritable differences in protein percentage and palatability among 20 clones and their topcross progenies. Similar to the situation for IVDMD, there were sizeable genotype x year interactions for both traits. Protein percentage was negatively correlated with yield. Dried and ground forage was used in palatability tests conducted before a relationship between palatability and alkaloid content was found at the University of Minneosta. Since then, some of the clones were analyzed for alkaloid content and the results did not agree closely with previous palatability scores.

Reed canarygrass is a good species for investigating forage yield because yield differences usually are not confounded with differences in disease susceptibility or winterhardiness. Also, reed canarygrass offers unique opportunities for investigating components of forage yield.

We began investigating possibilities for improving forage yield by determining the general combining ability of clones selected mainly for seed retention. We found significant differences in general combining ability and there was a positive correlation between a vigor index on space-planted parent clones and forage yield of topcross progenies (4). About the same time, Asay (1) investigated genetic variability in forage yield among 20 clonal lines. He evaluated the yield of the clones and their topcross progenies under two clipping managements. There were significant differences among clones but not among progenies in analyses of data combined over years and managements. Interactions of clones and progenies with years and cuttings were significant.

Genetic parameters and expected genetic advance for forage yield over years and clipping managements were as follows:

Broad-sense heritability	0.83
Narrow-sense heritability	0.33
Parent-progeny correlation	0.57**
Additive genetic variance/total genetic variance	0.40
Expected genetic advance (%)	7.33

**significant at the 1% probability level.

The expected genetic advance of 7% from selection of the top 5% of the population from which the clonal lines were derived indicated that selection based on the performance of clonal lines in solid stands would be worthwhile. Since the additive genetic variance constituted less than half of the total genetic variance, the breeder should attempt to take fullest advantage of both additive and nonadditive effects.

With that in mind, D. J. Baker (now with North American Plant Breeders, Ames, Iowa) investigated hybrid vigor for forage yield in two-clone crosses. He measured dry-matter yield of 14 clones, their S_1 progenies, 42 two-clone crosses, and 5 check varieties in solid stands. The 42 two-clone crosses involved three complete diallels each with six parents. Since two diallels had three parents in common, the total number of crosses was 42 instead of 45. One diallel involved the parent clones of Vantage, another involved the parent clones of the experimental synthetic RC-2, and the third involved six clones selected for high general combining ability (GCA) for forage yield. The test was harvested 4 times in 1971 and 5 times in 1972.

Over years, 14 of the 42 two-clone crosses yielded more forage than the highest yielding check variety with the best one yielding 12% more. The 15 crosses in diallel 1 (Vantage clones) ranged in yield from 84 to 101% of the yield of Common, those in diallel 2 (RC-2 clones) ranged from 85 to 107% of Common, and those in diallel 3 (high GCA clones) ranged from 89 to 112% of Common. Only four crosses yielded significantly more than Common. Eight of the ten highest yielding crosses were in diallel 3. This indicates that one should select first for high GCA in development of high yielding two-clone crosses. A selection from a Turkish introduction gave the highest yielding crosses on the average in diallel 3 indicating the importance of genetic diversity. All other parent clones originated from Iowa or Minnesota. Percentages of heterosis relative to the midparent ranged from -3 to 7% in diallel 1, from -3 to 16% in diallel 2, and from 0 to 17% in diallel 3. On the average, crosses in diallels 2 and 3 exhibited greater heterosis (6.9 and 7.5%, respectively) than those in diallel 1 (1.7%). The five crosses that showed the greatest heterosis in diallel 3 had the selection from the Turkish introduction as one parent.

Baker also observed wide variation in tiller density and spreading ability in his material. Those traits were correlated with yield during the second harvest year. Clones and progenies with low tiller density were invaded by weeds and yields were reduced. Differences in tillering ability appeared to be rather highly heritable indicating possibilities for improvement by selection. Tiller density would be most important under frequent cutting or grazing.

Topark-Ngarm (8) just completed a study of direct and correlated responses to selection for specific leaf weight (SLW) in reed canarygrass. Specific leaf weight was defined as dry weight per unit leaf area. It has been studied in several species and found to be positively correlated with photosynthetic capability.

Topark-Ngarm used the broad-based germplasm source NCRC-1 as a base population. He evaluated 1016 plants of NCRC-1 and selected 48 plants for high and 48 for low SLW. Selected plants were intercrossed within each group and the derived populations were evaluated in comparison with the base population in a space-planted experiment. Results from the evaluation are summarized in Table 1. There were substantial responses to selection for both high and low SLW. The average change over all measurements was 11% for high and 10% for low SLW. There were significant correlated responses in all other traits of initial growth. Initial growth of the high SLW population had thicker leaves, a higher net CO_2 exchange (NCE) rate, fewer tillers per plant, heavier tillers, and a lower dry matter yield per plant than the low SLW population. The strong correlated responses in tillering and weight per tiller were unexpected and suggest a difference in utilization of photosynthates between the two populations. Greater tiller production was the main factor in the higher dry matter yield per plant of the low SLW population.

Table 1. Means expressed in percentage of base population for traits measured on initial growth and regrowth of high and low SLW populations.

	% of base population			
	Initial growth		Regrowth	
Trait	High SLW population	Low SLW population	High SLW population	Low SLW population
SLW	113	90	112	89
Leaf thickness	112	92	111	93
NCE rate	113	96	107	92
Tillers/plant	76	116		
Dry weight/tiller	121	92		
Dry matter yield/ plant, 1974	96	107	101	96
Dry matter yield/ plant, 1975			103	96

Results from regrowth forage were similar to those from initial growth except for dry matter yield per plant. Plants of the high SLW population tended to yield more than those of the low SLW population. The difference was not significant in 1974 but it was significant at the 10% level in 1975. The three populations were included in a forage yield test planted in August, 1974 and at the first two harvests this year the high SLW population yielded significantly more than the low population. In that test, entries were seeded in rows 9 inches apart with 6 rows 12 feet long per plot.

Results from Topark-Ngarm's study showed that selection for SLW among spaced plants was effective. Average realized heritability values were 0.59 for high and 0.55 for low SLW. His results also showed that photosynthetic capability per unit leaf area can be increased by selection for high SLW. However, the lower tiller number and dry matter yield of initial growth of the high SLW population leaves unsettled the question as to which direction one should select for SLW. As mentioned previously, good tillering ability is important for persistence and high yield under frequent cutting.

The high SLW population has darker green and more upright leaves than the low SLW population. Rhodes (6) found that ryegrass populations with upright leaves outyielded those with more horizontal leaves under infrequent clipping, but the opposite was true under frequent clipping. Therefore, the desired direction of selection for SLW may vary depending on the management system to be imposed.

In Baker's study, the clone that averaged highest in yield of two-clone crosses under rather frequent cutting was characterized by light green plant color, horizontal leaves, and low SLW. One of the highest yielding two-clone crosses involving that clone also had low SLW and more horizontal leaves. In contrast, high yield was associated with upright leaves (r = 0.44) in a test of 60 clones cut only three times last year. Obviously, additional research is needed before definite conclusions can be made regarding the value of SLW as a selection criterion in improvement of forage yield under sward conditions.

In conclusion, reed canarygrass shows great potential for improvement by breeding. There is a wide range of variation in most forage and seed characteristics. The task of the breeder is to combine all the desired characteristics into one variety.

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OBJECTIVE DESCRIPTIONS OF GRASS VARIETIES

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The objective description form serves as a part of a descriptive system used by the Plant Variety Protection Office, The purpose of the descriptive system is to help the applicant describe his cultivar for variety protection and make it easier for us to verify the novelty of a cultivar described with the system.

The descriptive system used by the Plant Variety Protection Office has four different exhibits to describe cultivars. Each exhibit contributes to the total description.

Exhibit A gives the parentage, method of development, stability, and variants.

Exhibit B asks for a description of the cultivar from germination through maturity.

Exhibit C is our objective description form. This form is intended to describe all cultivars in a similar manner (see pp. 43a and 43b).

Exhibit D is the novelty claim. At present we are asking applicants to compare their cultivar to the most similar cultivar and then describe the difference between them. Other possible methods of showing the novelty are to give the type and then give the difference between your cultivar and all other cultivars of the type, or give the character or characters which make your cultivar different from all other cultivars of the species. We welcome suggestions or discussion of improved methods of stating novelty.

The system is intended to describe cultivars in a manner that will allow the cultivars to be distinguished on the basis of their descriptions. This requires stable characters or characters that can be standardized by the use of check cultivars or formula. Characters that have complicated genotype environment interactions are of little value in this descriptive system.

The objective description is only one part of the description. It is intended mainly for computer searching to reduce the total cultivars to a reasonable number of similar cultivars to be compared more closely.

An objective description implies two characteristics or assumptions. First, to be objective it should not be influenced by external factors. It should be verifiable by others, or others should be expected to give the same description of a cultivar using the system. Second, to be a description, it should be a detailed picture of the cultivar. This picture should be sufficiently detailed to identify the cultivar.

In most cases it is not possible to satisfy both assumptions with an objective description form. Where the assumption of objectivity and completeness cannot be satisfied, a compromise must be made.

Where objectivity is compromised, care must be exercised in interpreting the description.

Where completeness is limited, other descriptive information is required to identify the cultivar. In practice the objective descriptions are not completely objective nor are they a complete identification.

The purpose of the objective description form is to describe some of the more stable characters in a uniform manner so that the cultivars can be compared directly. It is intended for use in computer comparisons to select the cultivars that are most similar to the cultivar being searched. These similar cultivars can then be more thoroughly studied to differentiate these similar cultivars from the cultivar being searched. Some of the items on the objective description form are not used in the computer search but serve as a reminder to the applicant to describe his variety for the

9/3/75

U.S. DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Grain Division
Objective Description of Cultivars
RYEGRASS
(Lolium spp.)

1. SPECIES:

☐ 1=L. multiflorum (annual or Italian: includes Westerwoldicum)
2=L. perenne (perennial) 3=L. rigidum (includes Wimmera)
4=Hybrid (of species) ____________ 5=Other (specify) ____________

2. PLOIDY:

☐ 1=Diploid 2=Tetraploid 3= Other (specify) ____________

3. DURATION:

☐ 1=Annual or biennial 2=Short lived perennial (3-4 years)
3=Perennial (more than 4 years)

STANDARD CULTIVARS

1=Gulf	2=Wimmera 62	3=Linn	4=Pelo
5=Norlea	6=Aberystwyth S-23	7=Manhattan	8=Pennfine

4. MATURITY (50% Headed): (Use standard cultivars from above.)

☐ 1=Very early 3=Early 5=Medium 7=Late 9=Very late
☐☐ Days earlier than ☐ standard cultivar
☐☐ Days later than ☐ standard cultivar

5. MATURE PLANT HEIGHT: (Use standard cultivars from above.)

☐☐☐ cm. High ☐☐☐ cm. Shorter than ☐ standard cultivar
☐☐☐ cm. Taller than ☐ standard cultivar

6. PERCENT WINTER DAMAGE (estimated as percent of the area appearing dead): (Use standard cultivars from above.)

☐☐☐ Percent damage of application cultivar
☐☐☐ Percent damage of ☐ standard cultivar

7. TURF DENSITY: (Use standard cultivars from above.)

☐☐☐☐ Tillers per 100 sq. cm.
☐☐☐☐ Less tillers per 100 sq. cm. than ☐ standard cultivar
☐☐☐☐ More tillers per 100 sq. cm. than ☐ standard cultivar

8. FLAG LEAF (at full growth): (Use standard cultivars from above.)

☐☐☐ cm. Length (from ligule to tip)
☐☐☐ cm. Shorter than ☐ standard cultivar
☐☐☐ cm. Longer than ☐ standard cultivar
☐☐☐ mm. Width (at widest point)
☐☐☐ mm. Narrower than ☐ standard cultivar
☐☐☐ mm. Wider than ☐ standard cultivar
☐ Flag leaf at boot stage: 1=Deflexed 3=Recurved 5=Horizontal
7=Semi-erect 9=Erect

9. LEAVES:

☐ Vernation: 1=Leaves rolled in young shoots
2=Leaves semi-rolled (folded with rolled edges)
3=Leaves folded in young shoots
☐☐☐ % Plants with anthocyanin in lower leaf sheath
☐ Foliage color: 1=yellow green 2=medium green 3=blue green

10. SPIKE:

☐☐☐ mm. Spike length (tip to internode below lowest floret)
☐☐ mm. Shorter than ☐ (Use standard cultivars from above.)
☐☐ mm. Longer than ☐

10. SPIKE (continued):

☐☐☐☐ mg. per ten spikes (trimmed to internode below lowest floret)
☐☐☐☐ mg. lighter per ten spikes than ☐ } Use standard cultivars from above.
☐☐☐☐ mg. heavier per ten spikes than ☐ }
☐ Florets per spikelet

Percentage of plants with:

Rachis: ☐☐☐ % smooth ☐☐☐ % rough
Spike color: ☐☐☐ % green ☐☐☐ % purple
Lemma: ☐☐☐ % awned ☐☐☐ mm. awn length

☐☐ mm. glume length
☐ 1=Spikelet length nearly equal to outer glumes
2=Spikelet length much longer than outer glumes

11. COLEOPTILE:

☐☐☐ %Plants with anthocyanin in coleoptile

12. ANTHER COLOR:

☐☐☐ % Plants with white anthers ☐☐☐ % Plants with yellow anthers
☐☐☐ % Plants with purple anthers

13. ROOT AND PLANT CHARACTERS:

☐☐☐ % Plants with prostrate growth habit
☐☐☐ % Plants with upright growth habit
☐☐☐ % Plants with fluorescent roots

14. SEED:

☐☐☐ mg. per 1,000 seed ☐☐☐ mm. total length of 10 seeds ☐☐☐ mm. total width of 10 seeds

15. DISEASE (0=Not tested, 2=Highly susceptible, 4=Moderately susceptible, 6=Moderately resistant, 8=Highly resistant):

☐ Crown rust (Puccinia coronata) ☐ Mildew
☐ Leaf spot (Helminthosporium) ☐ Red thread (Corticium)
☐ Snow mold (Typhula) ☐ Brown patch (Rhizoctonia)
☐ Dollar spot (Sclerotinia) ☐ Other (specify) ______

16. INSECT (0=Not tested, 2=Highly susceptible, 4=Moderately susceptible, 6=Moderately resistant, 8=Highly resistant):

☐ Specify ______

17. GIVE RESEMBLANCE VALUE IN LEFT COLUMN AND VARIETY IN RIGHT COLUMN FOR VARIETY WITH WHICH COMPARISON IS MADE: (1=Less than, 2=Same as, 3=More erect, more resistant, denser, more persistent, darker or greater height.)

Resemblance	Character	Similar variety
☐	Plant habit (erectness)	______
☐	Tillering	______
☐	Winter hardiness	______
☐	High temp.stress resistance	______
☐	Turf persistence	______
☐	Plant color	______
☐	Vertical seedling growth rate	______
☐	Crown density	______
☐	Mower shredding resistance	______

18. GIVE AREA OF ADAPTATION AND INTENDED USE: ______

19. GIVE AREA TEST RESULTS PRESENTED FROM: ______

COMMENTS:

character. Some other characters are good descriptive characters but have not been much used in cultivar descriptions. An example would be phenol in wheat. Some characters of questionable merit have been included because they may be useful in describing a cultivar. Plant height, maturity and other characters are not stable characters nor are they characters that can be easily standardized by some formula. These characters are still of use in describing cultivars and can be used to distinguish between extremes of these characters.

The characters used in the descriptive forms are obtained from the literature, suggestions, and personal knowledge. Characters used to describe released cultivars, in research papers, suggested by reviewers, and observed by the Examiner are used. Many of you have more experience with the crop or character. We try to profit from your experience by having you review the forms. We depend on reviewers to point out characters that should be included and how they should be measured. We also appreciate comments or explanations on characters that should be deleted from the forms. Please include a reference or explain your suggestion if possible.

We depend on researchers for evaluation of characters and methods of measuring characters. We have no funds or time to study descriptive characters at the present time. This is not intended to relieve us of the responsibility for the forms and what is in them but to ask for your assistance where you have expertise.

In the crops we have been working with the descriptive forms have worked fairly well. These crops have been mostly self-pollinated with rather uniform cultivars. In contrast, many of the grasses are cross-pollinated and made up of several clones or lines. The characters that were distinctive in self-pollinated crops appear in a frequency in a cross-pollinated crop. The frequency may even change with generations.

Disease reaction is an economic character and it is also a good descriptive character. The problem arises when one tries to standardize disease ratings. Differences in reaction may be due to race of the pathogen, reaction type of the host plant and frequency of different phenotypes in the cultivar.

With our present knowledge we do not differentiate between the different types of resistance in our classification. If you know of ways to make the classification more definitive we would appreciate your advice.

RECURRENT RESTRICTED PHENOTYPIC SELECTION TO INCREASE FORAGE YIELDS

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Recurrent restricted phenotypic selection (RRPS) is an improved modification of mass selection as generally practiced (Burton, 1974). With four two-year cycles of RRPS, we were able to advance the forage yield (in replicated seeded plots) of Pensacola bahiagrass 17.7% - 2% per cycle for the previously selected narrow-gene population and 6% per cycle from the unselected wide-gene population. The variances remaining in the populations indicate that forage yields can be further increased with additional cycles of RRPS.

The six restrictions in RRPS that improve the efficiency of mass-selection for yield improvement are as follows:

1. We choose germplasm with a high degree of self-incompatability but good cross-compatability to reduce the likelihood of selfing. This restriction (normal in Pensacola bahiagrass) is probably not too important.

2. We divide the 1000-plant spaced population into 25-plant square plots and select the best five plants in each plot to reduce soil heterogeneity effects and facilitate visual selection in lieu of taking forage yields.

3. Instead of using open-pollinated seed from the 200 selected phenotypes to plant the next cycle, we intermate them in isolation to produce seed for the next generation. This procedure doubles the rate of advance by imposing paternal as well as maternal selection.

4. We greatly facilitate intermating and gene recombination by bringing together in isolation two culms (ready to flower the next day) from each phenotype. These culms, placed together in water in the laboratory, are in such intimate association that agitation each day ens res maximum cross-pollination.

5. By using two heads from each selected phenotype we avoid unequal representation of parents in the next cycle.

6. We keep the intermated seeds from each of the 200 selections separate and plant enough for 100 plants of each in a single row in flats of sterile soil in the greenhouse in December. When old enough to transplant, we pull the whole row and

select the five largest plants to set in sterile soil in 5-cm clay pots. (It is well to have an extra plant potted to insure against loss). This procedure helps keep the gene base wide and gives a combined seedling spaced-plant population of 20,000 plants.

A more detailed description of a single cycle of RRPS currently practiced in Pensacola bahiagrass improvement follows.

One thousand 4-month old seedlings grown in 5 cm pots under uniform greenhouse conditions are transplanted .9 x .9 m apart in a uniform well-prepared seed bed with a new transplanting tool that insures uniform well-prepared seed bed with a new transplanting tool that insures uniform depth and establishment. Green forage yields at a uniform height are taken either with a sickle bar mower or a riding rotary mower. Four men with the rotary mower, a cylindrical grass catcher made from hardware cloth on a long handle, a dial milk scale and a hardware cloth weighing pan can cut and weigh 1,000 plants in less than 8 hours.

After two seasons of assessment, the five top yielding plants in each 5 x 5 plant block are selected and tagged with red merchandising tags carrying their location number. Beginning at 8 a.m., two culms with heads that will start flowering the next day are pulled to include some stolon from each tagged plant; these are tagged together and put in water. Culms from all 200 selections are placed in containers of water (plastic gallon milk jugs with the top cut out but handle attached) and are grouped together on a laboratory table with a north window exposure. A large bag made from kraft wrapping paper to enclose the culms in the 12 milk jugs is suspended from the ceiling and left open at the bottom. Each morning as anthesis is in full sway, the bag covering the heads is squeezed and opened rapidly to insure complete intermixing of the pollen shed from the 200 selections. After anthesis is completed on all heads the bag is removed and the culms mature their crossed seed without further treatment.

Mature heads from each selection are threshed separately. In December when the next cycle is started, seeds of each selection are planted in a single 45 cm row with 5 cm between rows in 45 x 60 cm flats of uniformly fertilized steam-sterilized soil at rates to give about 100 seedlings per selection. When about a month old, the seedlings in each row are pulled, the five most vigorous seedlings are transplanted to 5 cm clay pots and the remainder are discarded. By combining seedling selection with field selection, it is possible to screen the 19,900 recombinant plant population necessary to allow the equivalent of one single chance recombination between each of the 200 selected clones. There is increasing evidence that the five top yielding plants in each 5 x 5 block could be selected by visual rating about as well as by actual weight.

We have used a 2-year cycle and have saved 20% of the best plants. Our Pensacola bahiagrass study suggests that we might double the rate of yield increase by using a 1-year cycle and saving three or four rather than five of the best plants in each 25-plant block. To do this would not allow us to screen as well for winter injury or reactions that cannot be assessed in one growing season. The following procedure, however, will allow us to make progress breeding for winter hardiness with a 1-year cycle.

The field number is kept with each 5-plant progeny until we are ready to set the population in the field - usually late April. By this time we will have additional information including a winter hardiness rating on the parent plants. If the parent of a 5-plant progeny fails to survive the winter, we can eliminate its 5 plants from the population to be set in the field. The paternal influence of these plants will remain in the population but by eliminating their maternal influence we will improve the hardiness of the population 50% more than if they had been left in it. With this procedure, we can also eliminate the progeny of plants that performed poorly after the selections were put together in the polycross. The five seedlings of each remianing selection are thoroughly randomized before they are set in the field for final evaluation.

Reference

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SYNTHESIS BEHAVIOR OF SINGLE-CLONE DERIVED LINES OF TIMOTHY

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Elite timothy clones from three cycles of selection were studied in diallel crosses. Clones were mid-late in maturity, ranging 1-2 weeks later in anthesis than Common early timothy. Performance of crosses appeared to be associated with close matching of parent clones for maturity.

Parent clones of best crosses were used to derive single clone lines by the following procedure: $S_0 \rightarrow S_1 \rightarrow S_1F_1 \rightarrow S_1F_2$ etc. About half of all selected clones set sufficient selfed seed to start derived lines. Succeeding generations after the S_1 were produced by intercrossing plants of previous generation in seeded rows within 8' x 16' x 5' muslin-covered isolation cages. Known superior cross combinations were synthesized both by clones and derived lines. Synthesis methods were compared by performance evaluation of the products in forage and seed yield trials. The purpose of the study was to indicate if there was realizable advantage in using derived single-clone lines in variety synthesis.

The first study compared all 2-clone combinations among 4 elite clones. Each combination was produced as: $(S_{0_{(A)}} \times S_{0_{(B)}})$, $(S_{1F1_{(A)}} \times S_{1F1_{(B)}})$ and $(S_{1F2_{(A)}} \times S_{1F2_{(B)}})$. Six years of data from two locations showed no effect of synthesis method on forage yield. However for seed yield, derived line crosses averaged only 83% and 64%, respectively, of their counterpart 2-clone hybrids.

Derived line crosses contain true crossed or hybrid seed plus sib-produced advanced generation progeny of the two parent lines. Clone x clone crosses contain only crossed or hybrid seed. Advanced generation seed lots of parent lines were included in evaluation trials for comparison with the derived line crosses. They averaged slightly less in forage yield (3%) and about the same for seed yield as the derived line crosses of which they were a fraction.

Overall conclusions were that true crossed progeny in the combinations had a forage yield advantage but the crossed-sibbed mixtures in derived line crosses were equivalent to full hybrid populations under forage yield culture. The seed yield results suggest the partial inbreeding in derived lines may have affected fertility.

A second series compared $(S_{0_{(A)}} \times S_{0_{(B)}})$, $(S_{0_{(A)}} \times S_{0_{(B)}})_2$ and $(S_{1F2_{(A)}} \times S_{1F2_{(B)}})$ synthesis methods. Data taken show the 2-clone hybrids significantly lower in forage yield. Accurate measurements of maturity based on forage dry matter content show the cause to be genetic shifts toward earliness during synthesis. Seedling vigor, maturity and season yield of forage are closely associated in timothy. Five generations of increase with seedling competition during development and crossing of derived lines shifted cross populations 4-5 days ealier from original parent clones. The results do not rule out possible use of derived lines in variety synthesis but they do emphasize that best methods for this species should minimize the number of increase generations where genetic shifts can occur.

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CULTIVAR SYNTHESIS IN ORCHARDGRASS

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The typical method of synthesizing cultivars in orchardgrass has been to intercross a number of clones with high general combining ability (GCA) for performance and advance the bulk progenies over a restricted number of generations. An alternative method would be to produce cultivars via single- or double-cross synthetics. The objective of this study was to compare the total forage yield and quality responses of different methods of synthesizing cultivars from the four parental clones of Pennlate and Pennmead. The synthesis products tested were conventional synthetics (CS), restricted polycrosses (RP), single-cross synthetics from selfed progeny of each parental clone (S_1 x S_1), single-cross synthetics from S_1 progeny intercrossed in isolation (S_{1F1} x S_{1F1}), and double-cross synthetics from syn 1, S_1 x S_1, and S1F1 x S_{1F1} single crosses. Data was obtained for three years from replicated field plot trials.

Yields decreased as the level of inbreeding increased from RP, to S_1 x S_1, and S_{1F1} x S_{1F1}. The average yield level of the double-cross synthetics was restored when S_{1F1} x S_{1F1} single cross synthetics were used as parent lines. Inbreeding did not effect the expression of GCA among clones in either of the two types of single-cross synthetics. The yield of specific single crosses was rather consistent regardless of the level of inbreeding and one Pennlate single cross (S_{1F1} x S_{1F1}) yielded slightly more than the CS. The yield rank order for double-cross synthetics derived from syn 1 single crosses was completely reversed when compared to the yield rank order of double-cross synthetics from S_1 x S_1 or S_{1F1} x S_{1F1} single crosses. One of the double-cross synthetics out yielded the CS but not significantly.

Forage quality was assessed for the Pennlate synthesis products. Protein concentration and in vitro dry matter disappearance IVDMD were the parameters measured. Inbreeding decreased protein slightly and significant differences existed among combination. Clones exhibited significant GCA for protein. No effect of inbreeding was evident for (IVDMD) and synthesis products did not differ significantly for IVDMD. In general, synthesis methods had a smaller influence on forage quality than yield.

The yield, protein and IVDMD data from the Pennlate experiment was used in a computer model to simulate the feeding value of the synthesis products to a dairy cow. The cow's ration was supplemented with grain and soybean oil meal to maximize milk production. Output from the computer program was in terms of net profit ($/ha) to the dairy farmer. Both types of single-cross synthetics were lower in $/ha than the double-cross synthetics derived from them. Two of the double-cross synthetics derived from S_{1F1} x S_{1F1} single crosses had higher $/ha values than the CS but these higher profit values were not significantly greater than the CS.

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SELECTION FOR WINTER SURVIVAL ABILITY

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Buffelgrass, Cenchrus ciliare (L.) Link; kleingrass, Panicum coloratum L.; and hardinggrass, Phalaris tuberosa var. stenoptera (Hack.) Hitchc., are important forages of the southern prairies whose areas of adaptation are limited by relatively poor winter survival ability. Bermudagrass, Cynodon dactylon (L.) Pers. and weeping lovegrass, Eragrostis curvula (Schrad.) Nees, are more winter hardy, but their primary areas of adaptation do not extend much beyond northern Oklahoma.

Selection for winter survival ability is difficult because of the breeders inability to detect differences among relatively hardy strains, after mild winters. Previous work demonstrated that, in many years, the increased winter injury caused by fall mowing can result in increased discrimination for survival among weeping lovegrass strains.

I routinely use the fall mowing technique on old lovegrass nurseries prior to their abandonment. The results obtained can be compared to those from previous years, and selections can be made.

Several strains selected were more tolerant to the fall-mowing stress than present cultivars. The best of these are now being evaluated further to determine their usefulness to the lovegrass breeding program. The present studies will also provide additional information on the value of the fall-mowing technique.

Results obtained with lovegrasses suggest that the fall-mowing technique should be tried on other grasses where increased winter survival ability is one of the research objectives.

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SELECTION FOR SEED RETENTION IN CREEPING FOXTAIL

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Creeping foxtail (Alopecurus arundinaceus Pois.) is an early-growing species adapted to low lands subject to flooding. It produces seed in a compact spike-like panicle from which seed normally shatters at the top while the bottom is still immature. In addition, an indeterminate production of panicles occurs so panicles reaching maturity may be present on the same plant with those at anthesis.

Selection for seed retention began in a nursery established in 1965 from the cultivar 'Garrison' and was continued in a nursery established in 1967 from open-pollinated seed from outstanding plants selected from the 1965 nursery. Outstanding plants from these nurseries have been tested through their open-pollinated and diallel crossing progenies. Significant differences for leafiness, height, panicle weight, seed weight, and seed percent from five panicles were found in a four-replicate test of 30 diallel progenies from six parents. Using Griffings analysis (Method 3, Model 1) significant differences for general combining ability (GCA) specific combining ability (SCA) and also reciprocal effects were found for these characters in 1972. Of these, GCA effects were greatest in all instances. Reciprocal effects may have been due to partial self fertility. For each parent GCA effects were computed and found to be positive in all cases for parent 6. Seed percent effects were greatest for parent 2. In 1973 a more precise measure for seed retention was sought by harvesting on two dates, 16 days apart. Since on the second date of harvest bias was found in selection for later heads, it was found necessary to repeat the experiment in 1974 marking two groups of five panicles on each plant on the first date of harvest. The difference between the threshed seed on the two dates would therefore represent the degree of seed retention. GCA effects using this measure were greatest for parent 6 and parent 2. From the parents showing highest GCA effects, progeny with outstanding seed production and retention as well as improved forage yield have been selected for inclusion in a synthetic for possible release as a new cultivar.

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HAIRY SEEDLING MARKER AS A BREEDING TOOL IN SMOOTH BROMEGRASS

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Pubescence of seedlings was examined to find if present cultivars could be distinguished on this basis. Pure breeding smooth and pubescent stocks also were developed for use in studies of distance of isolation requirements.

Seedlings were examined for pubescence at the 3-leaf stage. Greatest pubescence was shown by southern varieties, especially Lincoln, Baylor, and Fischer. Least pubescence was shown in northern cultivars Carlton, Manchar, and Polar. However, southern bred strains Saratoga, Redpatch, Magna, and Tempo were in the reduced pubescence group. This character could be used as an aid in the identification of varieties.

Essentially pure breeding pubescent and smooth stocks were developed following 4-5 cycles of recurrent mass selection. Of 23 S_1 lines examined 8 were true breeding pubescent and 3 almost smooth. Such pure breeding lines would be useful in any hybrid program to check on the completeness of crossing.

A preliminary test was made of the hybridization of S-7133 pubescent and S-7288 smooth stocks. Plots of 10 rows 3' apart were planted adjacent of these two strains without an isolation interval. Seed collected 1974 indicated contamination of the pubescent stock ranging from 38% next to the smooth stock to 12% at 10 yards. Reverse contamination on the smooth stock ranged from 26% to 7%.

A surprising aspect of the above test was the occurrence of seedlings fully typical of the opposing contaminant type. This suggests that considerable androenous seed development may be occurring in smooth bromegrass.

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NEMATODE SUSCEPTIBILITY OF COOL-SEASON GRASSES IN THE SOUTHEAST

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Cool-season perennial forage grasses, particularly tall fescue (Festuca arundinacea), contribute greatly to the winter forage supply in the southeast. New experimental lines of tall fescue and phalaris (Phalaris aquatica) produce much more winter forage than "Kentucky-31' tall fescue, the prevalent cool season cultivar. However, on sandy soils in the southeast lack of persistance is a problem. In an experiment conducted at Auburn University root damage on tall fescue and phalaris was found to be associated with high populations of stubby root (Trichodorus sp.) and stunt (Tylenchorynchus sp.) nematodes. These root pruning nematodes reduced dry matter yields of phalaris by 78% and tall fescue by 52%. Plant parasitic nematodes were decreased by methyl bromide and carbofuran nematicide treatments. Poor performance of cool-season grasses on sandy soils of the southeastern USA may be due to a nematode complex which destroys roots leaving the plants more susceptible to drought and heat stress.

Seedling screening trials have been initiated in the greenhouse. Seeds of tall fescue and phalaris were sown in boxes of soil containing nematodes. Seedlings were dug when they were 6 weeks old and scored for root damage, plant height and leaf number. Nematodes severely damaged seedling roots and plant height and leaf number were reduced on nematode damaged seedlings. Seedlings grown in methyl bromide treated soil were not damaged. The frequency for nematode resistance was very low in the material examined.

Further field and greenhouse studies are being conducted to determine the extent of nematode damage, number of nematode species involved, and sources of resistance.

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VARIATION IN PHOTOSYNTHESIS AND WATER USE IN THREE WHEATGRASS SPECIES

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Photosynthesis (net carbon exchange) and transpiration were measured on individual leaves of plants grown in controlled environment chambers in 1974 and in the greenhouse in 1975. Three clones, differing in leaf area and orientation, were selected in each of crested wheatgrass [Agropyron desertorum (Fisch. ex Link) Schult.], intermediate wheatgrass [A. intermedium (Host) Beauv.], and western wheatgrass (A. smithii Rydb.). In 1974, four ramets and in 1975, eight ramets of each clone were grown in individual pots containing 10 kg of four parts fine sandy loam soil to one part peat mix. When the clones were in the desired growth stage for measurements, four pots of each were moved to a high light intensity (1100 μ E m^{-2} s^{-1}) growth chamber. CO_2 exchange was measured on five leaves of each ramet using a leaf chamber and a differential infrared gas analyzer. Transpiration was determined by continuous weighing of each pot.

We found significant differences in photosynthetic rates between species and between clones within species (Table 1). Generally, photosynthetic rates tended to be lower when measured at the heading growth stage than at the tillering stage. There were also species and clonal differences for transpiration (Table 2). However, transpiration differences were variable between years and between growth stages due, apparently in part, by the environment in which the plant was grown before measurement. After the study was completed, clone 3 of crested wheatgrass was determined to have a chromosome number of 2n = 14, while clones 1 and 2 were 2N = 28.

Photosynthesis and transpiration are dynamic processes. As has been reported in the literature for many species, their measurement for a short period of time at a single growth stage does not always correlate well with final production. We found photosynthesis to have simple correlation coefficients of -.37*, -.39*, and -.81**, and transpiration to have coefficients of -.58**, -.61**, and -.62** when correlated with whole plant dry matter production in crested, intermediate, and western wheatgrasses, respectively. We believe the potential of a plant to photosynthesize is important in determining production. Likewise, the potential of a plant to maintain an optimum plant water status and a high water-use-efficiency (WUE) especially under water stress is an important factor in realizing maximum productivity. In our future research, we will place emphasis on determining the potential of plants to photosynthesize and evaluating plant water relationships with emphasis on determining water conserving characteristics of leaves which contribute to maximumization of production. Correlation of these physiological parameters with production and the development of screening techniques are necessary if selection for physiological processes is to be practiced in a breeding program.

Table 1. Mean photosynthesis for three clones within each wheatgrass species.

Species	Clone	1975 Tillering	1975 Heading	1974 Heading
		--------mg CO_2 dm^{-2} hr^{-1}--------		
Crested wheatgrass	1	18.8a[1/]	15.3b	15.9b
	2	19.6a	19.9a	19.8a
	3	14.2b	11.0c	11.0c
	Mean	17.5c[2/]	15.4c	15.6b
Intermediate wheatgrass	1	23.7a	22.8ab	20.0a
	2	19.4b	13.7b	13.8b
	3	22.1ab	23.1a	21.7a
	Mean	21.7b	19.9b	18.5b
Western wheatgrass	1	33.3a	24.5ab	27.7a
	2	32.2a	25.2ab	30.2a
	3	30.8a	20.1b	23.7b
	Mean	32.1a	23.3b	27.2a

1/ Clone means within a species and year followed by different letters are significantly different at 95% probability.

2/ Species means with year followed by different letters are significantly different at 95% probability.

Table 2. Mean transpiration for three clones within each wheatgrass species.

Species	Clone	1975 Tillering	1975 Heading	1974 Heading
		--------g H_2O dm^{-2} hr^{-1}---------		
Crested wheatgrass	1	2.8a[1/]	2.3a	4.3a
	2	2.9a	1.9b	4.4a
	3	1.8b	1.3b	2.7b
	Mean	2.5b[2/]	1.8b	3.8a
Intermediate wheatgrass	1	2.9a	1.1c	3.1a
	2	2.5b	1.0c	3.0a
	3	2.5b	2.4b	3.3a
	Mean	2.6b	1.5b	3.2a
Western wheatgrass	1	4.4a	3.2ab	3.5a
	2	4.4a	2.6b	3.5a
	3	3.3ab	2.5b	2.8a
	Mean	4.0a	2.8b	3.2a

1/ Clone means within a species and year followed by different letters are significantly different at 95% probability.

2/ Species means within years followed by different letters are significantly different at 95% probability.

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FERTILITY TRENDS IN COLCHICINE-INDUCED TRITICEAE AMPHIPLOIDS

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Fertility (seed-set and pollen stainability) was determined for 17 colchicine-induced amphiploids derived from triploid and tetraploid F_1 hybrids of *Agropyron*, *Elymus*, *Hordeum*, and *Sitanion* species. The objective was to assess the potential of synthesizing new Triticease species by induced amphiploidy. All F_1 hybrids were nearly or completely sterile. Treatment with colchicine to double the chromosome number restored fertility. However, fertility declined sharply from the initial amphiploid (C_0) generation to the C_1. Fertility stablized in most hexaploids (2n=42) after the C_0 generation; whereas, fertility of most octoploids (2n=56) continued to decline. Seed-set (seeds/spike) of nine hexapolids averaged 17.5, 18.9, and 17.4 in the C_1, C_2, and C_3 generations, respectively. The eight octoploids (2n=56) averaged 8.1, 9.1, and 4.2 seeds/spike over the same three generations. Three hexaploid derivatives, *A. libanoticum* x *A. caninum*, *A. spicatum* x *A. dasystachyum* and *E. canadensis* x *A. libanoticum* were particularly promising with an average seed-set of over 33 seeds/spike from the C_1 to C_3 generations. None of the octoploids approached this fertility level.

Synthesis of new Triticeae hexaploid species with adequate fertility appears to be feasible; however, synthesis of fertile octoploids will be much more difficult.

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RESEARCH REPORT

Ron Haaland
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Breeding work is being conducted on Phalaris (*Phalaris aquatica*), Tall Fescue (*Festuca arundinacea*) and Orchardgrass (*Dactylis glomerata*) at Auburn University. Main emphasis is being placed on the development of cold tolerance, winter growth, and nematode resistance. To date material with excellent cold tolerance and winter production has been developed but nematode resistance seems to be at an extremely low level within existing populations.

Eight synthetics of phalaris and three synthetics of tall fescue are being evaluated for winter forage yield, cold tolerance, and persistence. A broad spectrum of orchardgrass germplasm is being screened for winter productivity and disease resistance. Rust resistance on tall fescue continues to be an objective of the Auburn program.

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RESEARCH REPORT

J. Moutray, J. Mansfield, J. Koonce,
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North American Plant Breeders
RFD #2, Brookston, IN 47923
and
RFD #3, Ames, IA 50010

Grass research and variety development is conducted primarily at four locations: Brookston, Indiana; Ames, Iowa; Columbia, Missouri; Halsey, Oregon; and Warden, Washington.

Forage varieties and/or hybrids are under development in orchard-grass, tall fescue, ryegrass, reed canary, timothy, and brome. Turfgrass research involves bluegrass, ryegrass and fescue under the direction of Johnny Thomas. Breeding of sudangrass, sorghum x sudan hybrids and forage sorghums is centered at Hutchinson, Kansas, under the direction of Jimmy Barber.

Objectives in the forage species include winter hardiness, higher forage and seed yield and resistance to the important diseases with seed and seedling characteristics given increased emphasis in brome and reed canary.

Forage quality work began in 1975 with the opening of the quality lab at Brookston. Digestibility, protein and antiquality components in several grass species are under study.

Breeding nurseries are established using a tobacco transplanter or thin seeded with a 10 row cone seeder. Forage yield nurseries are established with the same seeder. A Carter harvester is used for forage yield determination.

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RESEARCH REPORT

Irving T. Carlson
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Iowa State University
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We are conducting breeding and evaluation work on reed canarygrass, orchardgrass, smooth bromegrass, and tall fescue. Varieties and experimental strains of all four grasses are being tested.

In reed canarygrass, we are participating in a cooperative regional study of genotype x environment interactions for forage yield and related traits. Investigations of (1) development of hybrid varieties with improved forage yield and (2) improvement of morphological and physiological traits related to forage production are being continued.

In orchardgrass, selection for increased winterhardiness and disease (mainly rust) resistance is being continued. Five synthetics selected for these traits are being evaluated. Materials are being formed to determine whether preferential pairing was a factor in variation in segregation ratios for the chlorophyll deficiency alboviridis.

In smooth bromegrass, we are testing 15 two-clone crosses involving clones selected for high general combining ability for forage production. We are forming six synthetics of fourth-cycle selections for high seed weight. Parent clones were selected for high and low forage yield, good aftermath production, brown leaf spot resistance, high 100-seed weight, and good seed set on the basis of clonal performance and a topcross progeny test.

In tall fescue, we are evaluating rhyizomatous spreading ability of progenies derived from crosses between vigorous, winterhardy selections and relatively nonhardy selections from a Portugese introduction with long rhizomes.

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RESEARCH REPORT

R. R. Kalton, D. E. Brown, and K. Gelder
Land O 'Lakes, Inc. - Research Farm
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Land O' Lakes, Inc. currently has breeding projects on orchardgrass, reed canarygrass, and sudangrass. Emphasis with orchardgrass is on forage and seed productivity, winterhardiness, and disease resistance. Winter killing has been severe in recent years on orchardgrass in North Central Iowa. The last two years we have been looking at a large source nursery which contains a number of recent Russian introductions and some of our own selection materials. Interestingly the Russian material appears to offer a wide range of new germplasm. Generally, the plant introductions were much later, more susceptible to rust, and flowered both spring and fall in the year of establishment. Individual plants were observed to be highly rust resistant, longer leafed, taller, well headed, hardy, and 2-3 weeks later than adapted elite selections.

Selection for improved male sterile clones and the search for non-restoring B lines of orchardgrass is continuing.

In reed canarygrass, we screened a large source nursery twice for animal palatability, recovery ability, survival, and heading capacity in 1974 and 1975. Germplasm represented included Vantage, Rise, Flare, Castor, NCRC1, RC2 and several European introductions. Plants rating high in palatability on the second and third growth and showing good recovery have been included in a new polycross nursery for seed production, shattering resistance, and further palatability studies.

Pasture system studies comparing (1) reed canarygrass, (2) bromegrass-sudan, (3) bromegrass-tall fescue-sudan, and (4) an alfalfa-orchardgrass mixture in summer maintenance of cow-calf herds are demonstrating the superior survival of reed canarygrass under heavy management and the high performance of a legume-grass mixture. High fertilizer costs for pure grass stands reduce their use potential substantially compared to the alfalfa-orchardgrass mixture on high value land.

Sudan breeding involves male sterile and male line development work with the ultimate objective of male sterile single cross or 3-way hybrids with suitable forage traits.

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RESEARCH REPORT

D. Woods, B. Coulman, and K. Clark
University of Manitoba
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Reed canarygrass and meadow fescue are being worked with, with emphasis on reed canarygrass. We are currently at the stage of having potential parental clones out of a cross involving selected clones and seed retaining material of Bob Knowles' S6982. Both parents were screened and were free of tryptamines and β-carbolines. The potential parents will be progeny-tested and gramine levels will be determined.

We have screened a world-wide collection of introductions for percentage of tryptamine-containing reed canarygrass plants and for gramine and hordenine levels, with the intention of being able to recommend the better sources for low alkaloids.

We are studying the effect of ensiling on alkaloid levels in relationship to soil fertility levels. This work is being done in cooperation with Frank Calder at Nappan, Nova Scotia.

Some time ago we screened some parental material and S_1 seedlings for Steve Bonin of Beaverlodge, Alberta for tryptamines, and I believe he is now on the way to a tryptamine free variety.

We are also conducting what might be called academic studies on hordenine - its seasonal pattern, distribution within the plant and heritability.

Preliminary studies on variation in alkaloid levels have been started with meadow fescue.

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RESEARCH REPORT

Arne W. Hovin
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We are conducting breeding work on reed canarygrass and evaluation work on bromegrass, big bluestem, orchardgrass, reed canarygrass, switchgrass, tall fescue, and timothy. Varieties and experimental strains of all these grasses are being tested.

In reed canarygrass, we are putting emphasis on improving forage quality. Traits under study include alkaloid concentration and alkaloid type, cell wall constituents, IVDDM, and mineral uptake. Two-clone crosses are being evaluated for quality and yielding ability. Parents were previously selected for high general combining ability with respect to quality traits. We have identified one relatively high-yielding, low alkaloid (gramine) single cross and one double-cross. Seed increase of this material is expected to provide seed for variety testing by 1976.

In tall fescue we are evaluating winter hardiness and rhizomatous growth habit. Progenies of two-clone crosses are being compared for winter hardiness, spreading ability and recovery after injury and clipping.

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RESEARCH REPORT

D. A. Sleper
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Emphasis has been placed on breeding tall fescue for improved quality and quantity. Research is presently underway in cooperation with C. J. Nelson to identify yield components and incorporate these into the breeding program. Work is also underway to identify tall fescue genotypes with a high rate of net carbon exchange. Breeding materials are presently being screened for *in vitro* digestibility in cooperation with A. G. Matches, USDA, ARS. Preliminary results suggest that *in vitro* digestibility may not be highly associated with animal performance in tall fescue, so alternative measures of quality are being sought. Cooperative grazing trials are being conducted in southwestern Missouri to study factors associated with animal performance in tall fescue and to evaluate experimental strains. Tall fescue is also being bred for use as turf in Missouri.

Research in orchardgrass is being done to improve disease resistance and persistance under Missouri conditions.

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RESEARCH REPORT

Jurgen R. Schaeffer
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Research on male sterility in intermediate wheatgrass is being continued. This sterility has been produced by intergeneric crossing and backcrossing. Difficulties in scoring male sterility have been encountered because of:

1. Heterogeneity within plants
2. Misidentification of vacuolar stage
3. Staining procedures.

In order to correct for these difficulties a new SB_4 backcross will be produced from SB_3-1-9-79 which has been thoroughly tested for male sterility and seed set. Average male sterility over 3 years was 98.8% and seed set 38.1 seeds/spike in 1971.

A total of 900 vegetatively propagated plants of this genotype will be interplanted with 'Oahe' as pollinator. This genotype has a calculated average number of 5.4 additional *T. durum* chromosomes.

Dr. A. B. Frank, a plant physiologist, has become involved in the breeding program. To date, we have been characterizing the species in the breeding program for some of the physiological parameters that have not been available in the literature. Our future research will be to determine the variability within breeding populations for some physiological process potentials and to develop possible screening techniques that may be used in selection.

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RESEARCH REPORT

Clyde C. Berg, K. E. Zeiders, and R. T. Sherwood
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Twenty-eight cultivars of orchardgrass were screened for resistance to a single isolate of Stagonospora arenaria Sacc. which causes the disease purple leafspot. Although none of the cultivars was resistant to the disease, varying numbers of resistant seedlings were found within cultivars. Resistant plants were intercrossed. About 100 progeny of each of 126 plants were screened twice for disease resistance by artificial inoculation in the greenhouse. Three hundred fifty of the most vigorous plants with the least disease development were transplanted to the field in a replicated nursery. About 150 of the most desirable clones will be interpollinated in 1976 to produce seed for another cycle of selection for resistance to purple leafspot.

A similar breeding program was initiated to develop resistance to Pyrenophora bromi (Died.) Drechs (Helminthosporium brown spot) in smooth bromegrass. We screened 93 foreign introductions of smooth bromegrass. All strains were moderately susceptible, but 175 resistant plants were selected from 70 entries and interpollinated. We plan to screen the progeny in the greenhouse in 1975-76.

Over 55 cultivars of perennial ryegrass are currently being studied for forage quality, forage yield and other agronomic traits. Twenty-five cultivars under test for 4 years have survived. First-year harvest yields were good, but in subsequent years total forage yields were considerably lower from ryegrass than from orchardgrass. A nursery with 40 cultivars was established in 1973. Good forage yields were obtained in 1974.

Testing of ryegrass-fescue hybrid derivatives for forage yield and quality is continuing. Results from a test of nine 4-clone synthetics indicated that two synthetics compared favorably with tall fescue cultivars. A nursery of polycross progeny of 95 clones was established in the summer of 1975 to test the forage yield and quality of these materials.

A search for a suitable male sterility maintainer line is being continued. Genes for maintaining male sterility in the species could not be found in the 4 breeder's genotypes of 'Oahe'.

SB_3-1-9-79 has now been interplanted with 'Greenleaf' in order to screen for male fertility non-restorer genes.

Male sterility in crested wheatgrass is being explored in A. repens x A. desertorum backcrosses. Work on this project is being continued.

A rhizomatous plant of A. repens x A. cristatum which was produced by Dewey was increased vegetatively. An area of 190 x 40 ft. was planted with 480 vegetative propagules in 1972 and is now completely sodded with this material. The material is now being transferred to several experimental sites in the State.

Comparative light and electron microscopical investigation of male fertile and male sterile intermediate wheatgrass is being continued in order to study the cause of male sterility at the ultramicroscopic level.

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RESEARCH REPORT

K. P. Vogel, F. A. Haskins, H. J. Gorz, and W. M. Ross
University of Nebraska
Lincoln, NB

Grasses (K. P. Vogel)

Two new wheatgrass varieties have recently been released. 'Ruff' crested wheatgrass (Agropyron cristatum (l.) Gaertn.) was developed by Dr. L. C. Newell and Dr. E. C. Conard. Ruff is recommended as a short-season forage crop in areas of low rainfall of the central plains latitudes. 'Flintlock' western wheatgrass (Agropyron smithii Rydb.) was developed by Dr. L. C. Newell. Flintlock is a genetically broad-based western wheatgrass which combines in one variety several of the better plant and seed characteristics of natural strains from Nebraska and Kansas. The variety is for use primarily in mixtures of cool-season grasses for conservation plantings and for forage production in the Central Plains. Research plans for the current year included establishment of potential breeder seed fields of sand love grass and prairie sandreed. Nurseries of bromegrass, intermediate wheatgrass, switchgrass, and the tall bluestems are being established for heritability studies to identify strains to be used as base populations for recurrent selection programs. Preliminary cyto-genetic studies of warm- and cool-season grasses will be conducted. Germplasm of important strains and varieties of perennial grasses are maintained in small field plantings and by seed storage.

Grasses (F. A. Haskins and H. J. Gorz)

Individual plants of indiangrass, switchgrass and sand bluestem were sampled at the heading stage and analyzed for IVDMD and protein content. An attempt will be made to determine the heritability of these characteristics in indiangrass.

Forage Sorghum and Sudangrass (H. J. Gorz, F. A. Haskins, and W. M. Ross)

Experimental forage sorghum hybrids have been produced by appropriate crosses among lines with complementary height genes, and evaluated for yield and other characters. Near-isogenic lines are being developed to study the relative value for animals of specific plant characters. A range of germplasm is being screened for greenbug resistance and for IVDMD and protein content. An attempt is being made to develop simple, improved assay procedures for dhurrin content and B-glucosidase activity in sorghums. A range of grain sorghum germplasm is being sampled after grain harvest in an attempt to determine the extent of variation for IVDMD and protein content.

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RESEARCH REPORT

Ferdinand A. Quinones
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Department of Agronomy
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The objectives of the range grass project of the Agronomy Department are: (a) to evaluate varieties and strains of western wheatgrass, indian ricegrass, tall wheatgrass and black gramagrass for seedling vigor, establishment, growth, seed production, disease and insect tolerance, persistency, and forage production; and (b) to develop new varieties of the above grasses with desirable traits.

Western Wheatgrass

The variety Arriba was released in 1973. It is outstanding in seed production, the major defect of this species, and satisfactory in the other agronomic traits. A 3-clone experimental Syn 2 is being tested against Arriba. It showed better seedling vigor and 23% more dry matter yield. Forty other clones are being evaluated for possible use in synthetics with a larger number of clones.

Indian Ricegrass

Accession PMC-42, selected at the Plant Materials Center, and intensively evaluated in this project was released last year as the variety Paloma. Tests indicate that it establishes well, is good in seed and forage production, is tolerant to root rots, and has much better longevity than most of the other 45 accessions evaluated. Trials being conducted with 71 new selections indicate that 10 of them are significantly better than Paloma in seed and forage production, and are similar in other traits.

Black Gramagrass

A test with 30 accessions and varieties showed significant differences among entries in bulk seed yield during the last two years, but pure live seed yield was low. No significant differences were found in the other five traits studied. A test to compare three new composites with the varieties Nogal and Sonora is being conducted.

Tall Wheatgrass

The varieties Jose and Largo were evaluated for forage yield and quality. About 150 plant selections from four genetic sources were made to start a breeding program with this grass.

Spike Muhly

El Vado, tested in cooperation with the Plant Materials Center, was released as a variety. Its important traits are good seed production and freedom from seed-head gall infection caused by *Aceria tulipae*.

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RESEARCH REPORT

Reed E. Barker
Northern Great Plains Research Center, ARS-USDA
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The breeding program at Mandan has continued to expand since our 1973 report. We have assembled at least two germplasm populations in each of crested wheatgrass (*Agropyron cristatum* and *A. desertorum*), intermediate wheatgrass (*A. intermedium* and var. *trichophorum*), western wheatgrass (*A. smithii*), Russian wild rye (*Elymus junceus*), reed canarygrass (*Phalaris arundinacea*), and orchardgrass (*Dactylis glomerata*) species. First cycle populations without selection have been synthesized in all species but Russian wildrye and reed canarygrass. The first cycle populations will be characterized for their variability for several characters and will form the base population on which selection will be initiated. These base populations will probably be released in the near future.

Many grass species have not been comparatively evaluated for adaptability to North Dakota environments. Therefore, in cooperation with North Dakota State University at Fargo, we have initiated species evaluation trials at several North Dakota locations. We are also initiating a cooperative forage grass variety testing program in the state. Other activities include the evaluation of forage grasses for suitability for revegetation of coal strip-mine spoil banks and participation in the regional reed canarygrass genotype x environment interaction study.

Reed canarygrass clones are being evaluated in a municipal sewage effluent disposal field. The clones are irrigated with 2 acre-inches of digested effluent each week from late May through early September. Alkaloid content, disease reaction and insect infestation and digestibility are being evaluated.

The mechanism for general resistance of reed canarygrass to leaf disease fungi is being studied. Anatomical and biochemical studies have implicated papilla formation, and lignification of the papilla as a resistance mechanism.

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RESEARCH REPORT

R. P. Knowles
Agriculture Canada Research Station
Saskatoon, Saskatchewan, CANADA

The grass breeding program involves improvement of bromegrass and crested wheatgrass in particular with minor work on intermediate wheatgrass and reed canarygrass. Hardier strains of orchardgrass seem to be available now and we have established nurseries of several world introductions.

In bromegrass we are making crosses with Bromus erectus and related species with the objective of getting better recovery and better spring and fall growth than in B. inermis. We are trying to assess the desirability or undesirability of self fertility in farming synthetics. As an alternative to polycross progeny testing we are using open pollination progenies, limited replication in progeny tests, and using less rigid selection in the selection of parents for the next generation. Midge insects are causing considerable loss and we are looking for plant resistance.

In crested wheatgrass we are trying to introgress qualities of diploid Agropyran cristatum into tetraploid A. desertorum. We are also trying to improve digestibility of crested wheatgrass using the acid-pepsin test.

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RESEARCH REPORT

T. Lawrence
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S9H 3X2 CANADA

Emphasis continues to be placed on providing pasture grasses with good curing qualities so that the grazing season can be lengthened into the winter period.

An extensive breeding and seed production research program is underway with Altai wild ryegrass (Elymus angustus Trin.), the objective being to develop varieties with improved seed yield, forage yield, and resistance to disease. An experimental line is under increase and will be submitted for licensing by March, 1976. It is anticipated that this species will be widely used for late fall and winter grazing in the arid rangelands of western Canada as well as in areas with perched water tables and as an interceptor crop for saline seep areas.

Breeding on Russian wild ryegrass (Elymus junceus) has concentrated on the improvement of seedling vigor and more recently the development of tetraploid lines. Observations at the present time would suggest that although tetraploids indeed have a larger seed and coarser leaves they do not have any greater seedling vigor or greater dry matter yield.

Final selections in a breeding program on intermediate wheatgrass (Agropyron intermedium) are awaiting the results from progeny tests prior to formation of synthetics for evaluation.

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RESEARCH REPORT

James G. Ross
Plant Science Department
South Dakota State University
Brookings, SD 57006

Major attention is being given to filling the need for pasture during the hot, normally dry summers in South Dakota. Two avenues are being explored to fill this need. Selection for regrowth within the species smooth bromegrass has been made using the variability within the variety Saratoga. From approximately 40,000 plants selection for regrowth through field and greenhouse tests has resulted in the production of a four-genotype and a two-genotype synthetic. These are under test. Also, a program of selection of genotypes for regrowth in an irrigated alfalfa stand, harvested three or four times each season, has been made since 1971. Heavy nitrogen application in the early spring will be made. The remaining bromegrass genotypes will be evaluated agronomically and selected for formation of synthetics. The general combining ability of selected clones for regrowth is being studied in a diallel progeny under irrigation.

The second avenue is selection of agronomically suitable varieties from the warm season native grasses, switchgrass, big bluestem, and Indiangrass. Collections of these native grasses have been made from sites in eastern and southeastern South Dakota. Breeding objectives for these species are high forage and seed yield as well as ease of establishment. A big bluestem variety selected for seed production on normally sterile spikelets is being increased for testing.

In addition to the above, selection for seed retention in the wet land grasses, reed canarygrass and creeping foxtail, is being made. A creeping foxtail synthetic is being tested for possible release.

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RESEARCH REPORT

P. W. Voigt
Grassland-Forage Research Center, ARS-USDA
Temple, TX

The grass breeding program at the U.S. Southern Great Plains Field Station, Woodward, Oklahoma was transferred to the Grassland-Forage Research Center, Temple, Texas in July of 1974. Research is continuing at both locations with major emphasis on *Eragrostis curvula* and closely related species. The new location will allow us to better utilize less winter-hardy strains in our studies of apomixis and in our search for better forage quality. Because of this increased use of less hardy strains, winter survival ability will become an even more important selection criterion in our effort to produce new lovegrass varieties.

Progeny tests of lovegrass hybrids suggest that the inheritance of apomixis is relatively simple and that apomixis may be dominant to sexuality. Many new lovegrass hybrids have been produced, including some with cold-hardy Lehmann lovegrass used as the male parent.

Evaluation of indiangrass, sand bluestem, and blue grama synthetics continues. 'Texoka' buffalograss was cooperatively released in 1974 by ARS, SCS, Kansas Agricultural Experiment Station, Oklahoma Agricultural Experiment Station, and Texas Agricultural Experiment Station. Texoka will be of value for forage, conservation, and turf uses. Work with Block E sideoats grama was termінted. We concluded that its small advantages in forage production and drought tolerance were not sufficient to warrant its release, in view of the limited demand for sideoats grama seed within its primary area of adaptation.

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RESEARCH REPORT

Douglas R. Dewey and Kay H. Asay
Crops Research Laboratory, ARS-USDA
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Logan, UT 84322

A grass breeding project has been established at Logan to complement the existing cytogenetic program. Kay Asay has initiated breeding work in four groups of species:

1) Crested wheatgrass - The genetic resources of all ploidy levels of crested wheatgrass--diploid, tetraploid, and hexaploid--are being exploited; but most of the breeding will be at the tetraploid level. Breeding emphasis will be placed on forage quality, ease of establishment on harsh sites, and persistence under intense use. Close attention will be given to rhizomatous strains.

2) *Agropyron spicatum* and *A. dasystachyum* - A large collection of *A. spicatum* (including *A. inerme*), *A. dasystachyum* (including *A. riparium*) and their interspecific hybrids (amphiploids) have been accumulated and will be established in a source nursery in 1976. The population will be bred for productivity and persistence under drought conditions. Ultimate use may be on reclamation sites where EPA regulations allow only for native species.

3) *Elymus triticoides*, *E. salina*, and Relatives - For use primarily on sites disturbed by surface mining operations. Breeding will be for establishment, persistence, and spread on subsurface soils usually high in salt and heavy metals. An effort will be made to improve the seed quality of *E. triticoides*, especially germinability.

4) Interspecific and Intergeneric Hybrids - More than 100 hybrids have been generated by the cytogenetics program, and about 1/4 of these have been doubled with colchicine. Most induced amphiploids are inferior to naturally occurring species, but a few show some potential as forage grasses. These include amphiploids of *A. repens* x *A. desertorum*, *A. repens* x *A. cristatum*, and *A. libanoticum* x *E. canadensis*. The most promising hybrid is an undoubled population of *A. repens* x *A. spicatum*. All hybrids and amphiploids will be selected for fertility and productivity. Conditions of ultimate use have yet to be determined.

***

RESEARCH REPORT

P. N. Drolsom and J. R. Davis
University of Wisconsin-Madison
Madison, WI

The principal perennial species involved is smooth bromegrass. A population of plants has been developed from several cycles of selection for 1) seedling disease resistance, 2) vigor, 3) foliage disease resistance, and 4) improved seed production characteristics. Currently, major emphasis is on selection of lines with improved digestibility by use of the acid-pepsin digestion procedure, and with better recovery capacity and persistence when grown in a mixture with alfalfa. The latter objective appears critical at this time, since alfalfa is the major forage species in Wisconsin. Farmers desiring grass in their forage mixture need a species that is well accepted by cattle, that is very winter hardy, and that will persist well under the recommended 3-cut schedule for alfalfa.

At present, orchardgrass is receiving less emphasis, in part, because of severe winter damage among spaced plants during the past two years.

***

RESEARCH REPORT

J. L. Moyer
Plant Science Division
University of Wyoming
Laramie, WY 82071

1) R. L. Lang is establishing a nursery of his ecotype collection of Oryzopsis hymenoides for seed maintenance and increase.

2) One cycle of selection of five Elymus triticoides accessions for improved seed germination has been made.

3) Selections of tetraploid Russian wildrye are being maintained for further work.

4) Fifteen species of grass and five legumes are being studied for survival, production, and nutrient removal in a wastewater irrigation project under a short growing season in Star Valley.

5) Forage variety trials are being ably conducted by R. L. Richardson.

MINUTES

The business meeting of the Grass Breeders Work Planning Conference (GBWPC) was held on September 10, 1975 at 1:30 p.m. at the Classroom Office Building, St. Paul Campus. The meeting was attended by 43 members (see attendance list) and the offices of the GBWPC (1973-75):

President:	Paul Voigt, ARS-USDA, Temple, TX
Vice President:	Tom Lawrence, Agriculture Canada, Swift Current, Saskatchewan, CANADA
Secretary:	Arne Hovin, University of Minnesota, St. Paul, MN

The meeting was called to order by President Voigt.

It was moved and seconded that the minutes of the previous meeting, as presented in the Proceedings of the 22nd Western Grass Breeders Work Planning Conference, be approved.

CARRIED

It was moved and seconded that the bylaws be adopted with the addition in 3b after planning: "and executing". (See page 72 for the bylaws).

CARRIED

It was moved and seconded that a permanent record file be established at Mandan, ND, to include all Proceedings (if available) and relevant correspondence by officers.

CARRIED

Following a discussion regarding response to a questionnaire on uniform grass variety trials prepared by Voigt, a committee was formed to review possible locations, procedures for uniform tests, and need for regional committees to carry out such function. Committee members were Lawrence, Berg, Barker, Kalton, and Ross (Chairman).

The recommendation and nomination committee (Asay, Chairman) recommended that the 1977 meeting be held at Tifton, GA. It was moved and seconded that GBWPC accept this recommendation.

CARRIED

The same committee recommended the following slate of officers for the 1975-1977 period:

President:	Tom Lawrence, Agriculture Canada Research Station, Swift Current, Saskatchewan, CANADA
Vice President:	Arne W. Hovin, Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, MN
Secretary:	Jerrel Powell, Plant Genetics and Germplasm Institute, Agricultureal Research Center, Beltsville, MD

It was moved and seconded that these nominations be accepted as officers of the GBWPC for 1975-77.

CARRIED

It was moved and seconded that the report by the resolution committee be accepted (See Foreword I).

CARRIED

President Voigt then adjourned the meeting.

Bylaws of the Grass Breeders Work Planning Conference

The objectives of the GBWPC are:

1. To provide a means for regular contact and communication among breeders of forage, turf, and conservation grasses;

2. To promote the exchange of information on procedures and progress related to grass breeding;

3. To provide a forum for exchange of information on new plant collections, plant materials available for testing, new variety releases, and germplasm requiring preservation;

4. To broaden the experience, thereby increasing the insight, of the members; and

5. To coordinate grass breeding activities on an informal basis.

To achieve these ends:

1. The biennial conferences of the GBWPC will be held during the growing season at or near a location where grass breeding is in progress.

2. Membership in the GBWPC is open to all grass breeders, whether public or private, and to all others interested in grass improvement. Membership is maintained by attending and participating in the conferences or by some other indication of interest in the GBWPC.

3. The officers of GBWPC shall be grass breeders or geneticists selected from the membership at large and shall consist of:

    a. The President who is responsible for conducting all business meetings and for appointing all necessary committees;

    b. The Vice-President who is responsible for planning and executing the program of the conferences, and

    c. The Secretary who is responsible for taking the minutes of the business meeting, for duplicating and distributing the conference proceedings, and for maintaining the membership list.

    To provide continuity, when possible and desirable, officers will be elected for consecutive two-year terms as Secretary, Vice President, and then President.

4. Conference hosts may charge a registration fee to cover costs incidental to the conferences. There will be no regular dues.

Attendance List Grass Breeders Work Planning Conference

September 9-11, 1975

Name	Representing	Location
Asay, K. H.	Utah State University	Logan, UT
Barnes, D. K.	University of Minnesota	St. Paul, MN
Barnes, R. F.	ARS-USDA	Beltsville, MD
Barker, Reed	No. Great Plns. Res. Center	Mandan, ND
Berg, C. C.	U.S. Regional Pasture Lab	University Park, PA
Brown, Donald E.	Felco-Land O' Lakes	Caldwell, ID
Burton, Glenn W.	University of Georgia	Tifton, GA
Coulman, Bo	University of Manitoba	Winnipeg, Manitoba, CANADA
Cuany, R. L.	Colorado State University	Fort Collins, CO
Carlson, Irving T.	Iowa State University	Ames, IA
Dewey, Douglas R.	Utah State University	Logan, UT
Drolsom, P. N.	University of Wisconsin	Madison, WI
Echols, J. W.	Colorado State University	Fort Collins, CO
Elling, L. J.	University of Minnesota	St. Paul, MN
Evans, Kenneth	USDA-AMS	Hyattsville, MD
Gorz, H. J.	University of Nebraska	Lincoln, NB
Haaland, Ronald L.	Auburn University	Auburn, AL
Haskins, F. A.	University of Nebraska	Lincoln, NB
Hayward, M. D.	Welsh Plant Breeding Station	Nr. Aberystwyth, Wales, U.K.
Hovin, Arne W.	University of Minnesota	St. Paul, MN
Hurst, Steve	No. American Plant Breeders	Ames, IA
Jacobson, Erling	SCS Plant Materials Center	Bismarck, ND
Kaerwer, Howard E.	Northrup King & Company	Minneapolis, MN
Kalton, Robert R.	Land O' Lakes-Felco, Inc.	Webster City, IA
Knowles, R. P.	University of Saskatchewan	Saskatoon, Sask., CANADA
Koonce, J.	No. American Plant Breeders	Brookings, IN
Lawrence, Tom	Canada Agric. Research Sta.	Swift Current, Sask., CANADA
Littlefield, R.	Northrup King & Company	Minneapolis, MN
Lowe, Carl C.	Cornell University	Ithaca, NY
Marten, G. C.	University of Minnesota	St. Paul, MN
Martin, N. P.	University of Minnesota	St. Paul, MN
Marum, P.	University of Minnesota	St. Paul, MN
Mings, Jack L.	Northrup King & Company	Washington, IA
Moutray, J. B.	No. American Plant Breeders	Ames, IA
Moyer, J. L.	University of Wyoming	Laramie, WY
Newell, L. C.	University of Nebraska	Lincoln, NB
Page, Glenn A.	Northrup King & Company	Northfield, MN
Pickett, Robert C.	Purdue University	Lafayette, IN
Powell, Jerrel B.	USDA-ARS	Beltsville, MD
Quinones, F. A.	New Mexico State University	Las Cruces, NM
Ross, James G.	South Dakota State University	Brookings, SD
Savage, M.	Grassland Resources, Inc.	Santa Fe, NM
Schaffer, J. R.	Montana State University	Bozeman, MT
Schmid, A. R.	University of Minnesota	St. Paul, MN
Shenk, John	Pennsylvania State Univ.	University Park, PA
Sleper, David	University of Missouri	Columbia, MO
Stanely, F.		Northfield, MN

Attendance List Grass Breeders Work Planning Conference continued.

Name	Representing	Location
Vogel, Ken	University of Nebraska	Lincoln, NB
Voigt, Paul W.	Grassland-Forage Res. Center	Temple, TX
Walters, Chuck	No. American Plant Breeders	Ames, IA
Woods, Don	University of Manitoba	Winnipeg, Manitoba, CANADA

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