THE BREEDING AND TURFGRASS QUALITY ASSESSMENT OF CREEPING BENTGRASS (*Agrostis stolonifera* L.)

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by

Douglas John Cattani

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DOUGLAS JOHN CATTANI

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ABSTRACT

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In 1982, selections were made from space planted nurseries. The selections were tested for turf adaptability and some were placed in polycrosses (PC) in the field on the basis of seed yield and turf colour. One synthetic (Syn) was looked at in the field. Another Syn was planted in the controlled environment facilities to ascertain the feasibility of utilizing these facilities in a breeding program.

Based on visual colour and density ratings from the turf trial, 15 of the 31 selections are being recommended for further testing.

The effectiveness of visual selection for turf colour and density from space plants were as follows: visual colour was well correlated with space plant visual colour with r = .553 ***[1] for 1984. The correlation between visual turf density and visual space plant density was r = .240 and was non-significant for 1984. The use of stolon measurement on space plants may be a better indicator of visual turf density.

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[1] *,**,*** P(r=0) of .05, .01 and .001 respectively.

Wear simulation, using a spiked roller, on the turf plots was carried out to see the effects of wear on visual density ratings and some biological components of the turf. Wear treatment tended to decrease dry weight, tiller number, leaf number, dry weight per tiller and visual density. The use of wear in the selection process would appear not to be warranted as applied in this trial.

Visual density was correlated with dry weight, with r ranging from .363* to .631***, with tiller number with r = .630*** to .715*** and with leaf number with r = .669*** and .714***. These correlations validate the use of the visual density ratings.

The space planted field trials from which seed was harvested showed significant differences between the clones for all the characteristics measured. Significant correlations were found between seed yield and its components. These trials also indicated that seed yield component compensation is present in creeping bentgrass.

Important correlations included a positive correlation between seed yield and plant area with r values ranging from .337** for PC 83-02 to .819*** for PC 83-04, a negative correlation between seedheads per plant and seed yield per cm^2 with r ranging from -.381** for PC 83-04 to -.781*** for Syn 84-01 and a negative correlation between seedheads per cm^2 and seed yield per seedhead with r ranging from -.523*** for PC 83-02 to -.755*** for Syn 84-01.

The use of the controlled environment facilities demonstrated that the growthroom has potential for use in a breeding program.

Albinism has been found in some of the progeny of the selections, with the underlying genetic control being monogenic for crosses between clones 82-06 and 82-20.

The ideal clone of creeping bentgrass for turf use has short stolons, with upright, dark green leaves. The ideal clone for seed production in a space planted environment has long stolons, extensively creeping with upright seedheads.

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INTRODUCTION

There have been no cultivars of creeping bentgrass bred and licensed for use especially for the Prairies and Canada. Dr. A. C. Ferguson at the University of Manitoba made many selections of creeping bentgrass between 1963 and 1973 from around the Winnipeg area. "Manitoba" creeping bentgrass is a 3 clone synthetic formulated from the 1963 selections; however although seed is available, it was never licensed. The lines used to put together "Manitoba" were 63-3-1, 63-3 and 63-11. "Manitoba" was originally thought to be a colonial bent but it is a creeping bent.

The aim of the research program was to identify and select clones with good turf and seed yielding characteristics to be used in formulating synthetics for use in Canada. As no work has been reported in the literature on any aspect of breeding creeping bentgrass, there are no precedents to follow. Therefore studies into the ability to select from space plants for turf characteristics and seed yield and its components were undertaken.

Visual turf density and the biological characteristics of turf density were studied in order to see if the use of visual density ratings are justified. The characteristics that contribute to the visual density rating may then be used to attempt to select for turf density.

The effects of wear on turf density were examined to ascertain the value of using simulated turf wear in the selection process.

LITERATURE REVIEW

Creeping bentgrass, Agrostis stolonifera L., is a perennial, cool-season grass creeping by stolons and preferring wet areas (Hubbard 1968, Hitchcock 1935). It is a long day plant needing greater than 16 hours for flowering to be initiated (Salisbury and Ross 1969).

Creeping bentgrass is used mainly for golf and bowling green turf in the temperate zone (Voykin 1976). The natural habitats include the coastal areas of Great Britain, (Hubbard 1968) and the United States (Hitchcock 1935) and unimproved pastures in Great Britain including the highlands (Hubbard 1968) and the flood plains of rivers (Bradshaw 1958).

Different biotypes have been selected for or isolated within the species. Wu and Antonovics (1978) worked with a copper tolerant creeping bentgrass, Ahmad and Wainwright (1977) worked with salt tolerant clones, Younger et al. (1967) selected for salt tolerant plants and Lee and Wright (1980) selected for a triazine tolerant line of creeping bentgrass.

Creeping bentgrass was first used as a golf green turf in the late 1800's when it was included in a mixture called South German Bent (Duich 1985). This mixture included three other Agrostis species and their natural hybrids, however creeping bent proved to be the best adapted to a golf green environment (Duich 1985). Hitchcock (1935) mentions that creeping bentgrass was frequently used for lawns and extensively used for golf greens. Voykin (1976) does not recommend the use of creeping bentgrass for home lawns because of the cost of maintenance and the intensive management required.

This intensive management includes nitrogen fertilization, up to 976 kg N/ha/year (Goss *et al*. 1975), topdressing (Zontek 1980), frequent, if not daily irrigation, close and frequent mowing, again usually daily, and preventative disease control.

Taxonomy

Creeping bentgrass is a member of the family *Graminae*, the sub-family *Agrostidae*, the genus *Agrostis*, and is the species *A. stolonifera* L.(Hubbard 1968) or *A. palustris* Huds.(Hitchcock 1935). There is confusion as to whether these are the same species, different species or that there are two subspecies of *A. stolonifera* L., namely ssp. *palustris* and ssp. *stolonifera* (Hubbard 1968).

The confusion in the taxonomy of *A. stolonifera* L. or *A. palustris* Huds. also involves confusion between these and *A. tenuis* Sibth.(Bradshaw 1958, Budd and Best 1964) and *A. alba* L.(Budd and Best 1964).

The use of common names may also have caused part of the above problem. *A. stolonifera* L. has been called by at least four different common names and *A. palustris* Huds. has had at least three common names, (See Table 1). The most used common name is creeping bentgrass with other names including fiorin and red top for the former and marsh bent for the later. Red top, the common name given to *A. stolonifera* L. by

Budd and Best (1964) is the common name given to A. alba L. in Hitchcock (1935) and A. gigantea Roth. by Hubbard (1968). Fiorin has also been used for A. gigantea Roth. by Hubbard (1968). Jones (1956) used A. gigantea Roth. in his hybridization work yet Funk and Ahmed (1973) report it as A. alba L..

The characters used by Hitchcock (1935) to distinguish between A. stolonifera L. and A. palustris Huds. are one, with A. stolonifera L., the panicle remains open after flowering while A. palustris Huds. is contracted and two, that A. palustris Huds. has longer stolons. Bradshaw (1958) and Hubbard (1968) both note that A. stolonifera L. has a contracted panicle after flowering and Bradshaw (1958) notes that A. tenuis Sibth. remains open. Hubbard (1968) suggests that the difference between ssp. palustris and stolonifera is that the ssp. palustris has longer stolons.

Cytogenetic Studies

The basic chromosome number of the Agrostis genus is x=7 (Jones 1953,Muniyamma 1976). Some Agrostis species and their chromosome numbers can be found in Table 2. The Agrostis genus can also have accessory or B-chromosomes (Jones 1956, Stebbins 1971).

Bjorkman (1954) found three different ploidy levels in A. stolonifera L. collected from different locations throughout Europe. Some were tetraploids, 2n = 28, pentaploids, 2n = 35, and hexaploids, 2n = 42. The tetraploids formed only bivalents, the hexaploids acted as an autotriploid, and the pentaploid had progeny of varying chromosome

TABLE 1

Some Agrostis species and their common names.

Species	Common Name(s)	Reference
A. alba L.	Red top	Hitchcock 1935
	Creeping Bent	Budd and Best 1964
A. canina L. *canina*	Velvet Bent	Hubbard 1968
A. gigantea Roth.	Red top	"
	Blackbent	"
	Fiorin	"
A. palustris Huds.	Creeping Bent	Hitchcock 1935
	Marsh Bent	Hubbard 1968
	Coos Bent	Duich 1985
A. stolonifera L.	Creeping Bent	Hubbard 1968
	Fiorin	"
	White Bent	"
	Red top	"
A. tenuis Sibth.	Common Bent	"
	Browntop	"
	Fine Bentgrass	"
	Colonial Bent	"

numbers. There were no morphological characteristics which could be used to distinguish between the plants with the different chromosomes numbers. Duich (personal communication 1986) found the same range of chromosome numbers as Bjorkman when working with selfed progeny of *A. palustris* Huds..

Jones (1953), through interspecific crosses, determined the genomes of the species involved. These can be found in Table 3. This work suggests that *A. stolonifera* L. is an allotetraploid, therefore behaving like a diploid during meiosis.

Bradshaw (1958) located natural hybrids of *A. stolonifera* L. and *A. tenuis* Sibth. and found that the hybrids were not greater than 20% fertile. He also noted that the hybrid was able to compete vegetatively with the parental species in their natural habitat.

TABLE 2

Some Agrostis species and their reported chromosome numbers.

Species	Chromosome Number	Reference(s)
A. canina L. *canina*	2n = 14	Jones 1956
A. canina montana Hart.	2n = 28	"
A. tenuis Sibth	2n = 28	"
A. stolonifera L.	2n = 28	"
		Bjorkman 1954
	2n = 35	"
	2n = 42	"
A. palustris Huds.	2n = 28	Funk and Ahmed 1973
A.alba L.	2n = 28	Hubbard 1968
	2n = 42	Funk and Ahmed 1973
A. gigantea Roth.	2n = 42	Jones 1956
A. pilosula Trin.	2n = 44	Muniyamma 1976

TABLE 3

Some Agrostis species and their genomes (Jones 1956).

Species	Genome
A. canina L. *canina*	A_1 A_1
A. canina canina Hart.	A_1 A_1 A_1 A_1
A. tenuis Sibth.	A_1 A_1 A_2 A_2
A. stolonifera L.	A_2 A_2 A_3 A_3
A. gigantea Roth.	A_1 A_1 A_2 A_2 A_3 A_3
A. alba L.	A_1 A_1 A_2 A_2 A_3 A_3

(Funk and Ahmed 1973)

Polycross Testing

The polycross test was devised by Frandsen, Tysdal and Wellensiek (Schaepman 1952) to be used to select parents for a synthetic variety (Tysdal and Crandall 1948). Tysdal and Crandall (1948) reported that the polycross test was effective in selecting alfalfa clones with high combining ability. This refers to general combining ability (GCA) as opposed to specific combining ability (SCA) (Wellensiek 1952, Schaepman 1952). Johnson (1952) defined GCA as "... the relative performance when outcrossed to a broad base of heterozygous germplasm,..., due primarily to the additive effects of polygenes.". Allard (1960) defined GCA as the general productivity of plants in crosses.

Wellensiek (1952) stated that by selecting for good GCA, selection for near homozygosity may also be taking place for the desired character. Wit (1952) states that a certain degree of homozygosity is needed in order to maintain the desired characteristic through the several generations of seed increase.

Simmonds (1979) states that the polycross is a good test with the average number of parents being 5 to 10. However, Busey (1983) states that there are usually too few parents and they are tested in too few environments. However he makes no recommendations as to what should be done. Johnson (1952) feels that by using greater than 8 to 10 inbred lines, there is little to be gained in testing for GCA. Frandsen (1952) states that the polycross is a simple test for the combining ability of a large number of parents.

Sneep *et al*. (1979) suggest that when only 4 or 5 entries are selected for use in a synthetic, diallel crosses should be made to determine the SCA for the selected parents.

Frandsen (1952) feels that the polycross should be used at the beginning of a breeding program and then other tests such as the topcross should be used in further cycles of selection.

There are several reasons for using the polycross test in particular and progeny testing in general. There is a need to find out the correlation between the performance of the parent and the progeny with respect to the desired traits (Burton 1952, Frandsen 1952). Graumann (1952) also states that if there is a high proportion of undesireable polycross progeny, the worth of the maternal parent in further testing is reduced. If the genotypes of the parents are divergent enough, the polycross progeny offer a good source of recombination, and are therefore a good source for reselection (Graumann 1952).

Field Design

A randomized, replicated design is needed to ensure the opportunity for pollination by the greatest number of other clones (Allard 1960). Olesen and Olesen (1973) recommend that a latin-square design be used if the number of parents is small. Schaepman (1952) recommends that the random complete block design be used with the clone on either side being different. Sneep *et al*. (1979) and Schaepman (1952) state that with fifty clones, at least 8 replicates are needed.

Wit (1952) found that with perennial ryegrass, Lolium perenne, an outcrossing grass, that 74% of the pollination of an individual clone could be attributed to the 3 neighbouring clones on either side, despite up to a one week difference in flowering time.

Plant Adaptability to the Polycross Test

There are two characteristics that a species requires to be easily used in a polycross test. The first characteristic is that it must be an outcrossing species (Tysdal and Crandall 1948, Schaepman 1952). As the aim of the polycross test is to select for clones with good GCA, any degree of self-fertility would decrease cross pollination and thus decrease the accuracy of the GCA estimate (Tysdal and Crandall 1948).

The second characteristic is that the plant must lend itself to vegetative propagation and the breeder must be able to maintain the plant over a period of years (Wellensiek 1952, Schaepman 1952).

Schaepman (1952) states that with most perennial grasses, the mechanism of inheritance for polygenic traits is unknown. The ability to recognize and select for desirable digenic trait using the polycross has been theoretically demonstrated by Wellensiek (1952).

Creeping Bentgrass and the Polycross Test

Creeping bentgrass is an outcrossing species (Jones 1953) and it is easily vegetatively propagated by stolons (Younger et al., 1967), and therefore it meets the criteria for use in a polycross test.

Creeping Bentgrass Synthetics

The only information available on creeping bentgrass varieties and their breeding is found in the Agriculture Canada Description of Variety that are released upon licensing.

"Penncross" is sold as Synthetic 1 seed from the crossing of three parental clones (Anon. 1958). "Penneagle", the most recently licensed synthetic variety, has four parental clones selected from a topcross nursery (Anon. 1985). "Prominent" is a synthetic from Europe with eight parental clones (Anon. 1974). "Emerald" is a selection out of "Congressional", one of the old vegetative lines, with selection made for seed production and turf performance (Anon. 1973).

Seed Yield and Seed Yield Components

The seed yield of a plant is affected by many factors including seed weight, plant size, numbers of seedheads per plant and fertility or the number or seeds per seedhead (Dewey and Lu 1959).

Dewey and Lu (1959) found a positive correlation between seed yield and plant size, (the dry weight of the plant), with r, the correlation coefficient, = .44, with p = .01, in crested wheatgrass.

McGraw *et al*. (1986) found a negative correlation between plant density and seed yield per plant and a positive correlation between seed yield per area and plant density for birdsfoot trefoil.

The relationship between seed yield and seed size has varied depending on the crop. Knott and Talukdar (1971) found positive correlations, significant at p=.01, of r = .572 and r = .566 in two of their experiments and no significance in a third in wheat. Hsu and Walton (1971) also found nonsignificant correlations in wheat between seed yield and seed size. Dewey and Lu (1959) working with crested wheatgrass found negative correlations between seed yield and seed size with r = -.465 and r = -.606, with p = .01 for both. Schaff and Rogler (1963) also found a negative correlation between seed yield and seed size in bromegrass with r = -.60 with p = .05.

The relationship between seed yield and fertility has generally been positive. Knowles *et al*. (1970) and Jessen and Carlson (1985), working with bromegrass, found positive correlations of r = .43 and r = .85 respectively, the former significant at p = .05 and the latter at p = .01. Dewey and Lu (1959) found a correlation of r = .256, p = .05, for seed yield and fertility in crested wheatgrass. Hsu and Walton (1971), with wheat, found a correlation of r = .79, with p = .001, while Knott and Talukdar (1971) reported a nonsignificant correlation for seed yield and fertility in wheat.

The relationship of seed yield per seedhead and seed yield per plant has also been positive with Dewey and Lu (1959) using crested wheatgrass and Hsu and Walton (1971) with wheat reporting correlations of r = .579, with p = .01, and r = .71, with p = .001, respectively.

Hsu and Walton (1971) reported a negative correlation value of r = -.39, significant at p = .001, in wheat between seed weight and the number of spikes per plant.

Knott and Talukdar (1971) reported a negative correlation of $r = -.868$, significant at $p = .01$, in wheat between the number of seeds per seedhead and the number of spikes per plot. The negative correlations between the components of seed yield are referred to as yield component compensation (Adams 1967). Grafius (1956) stated that selection for yield without consideration of the components of yield could be fruitless. However, Adams (1967) proposed that competition between the components of seed yield is probably developmental and not genetic, therefore making it difficult to establish breeding values for the components. Therefore, Adams (1967) proposed that breeding experiments should take place under conditions to allow for full expression of the underlying genetic control of a trait and thus reduce the effect of competition.

Hayward and Vivero (1984) found that selection for seed yield on a spaced clonal trial basis did not give similar results in more competitive environmemts.

Parent-Progeny Inheritance

Whether or not a trait is passed from one generation to its progeny is most important in a breeding program (Allard 1960). If a parent does not pass on its desirable traits, it is of little value in a breeding program (Burton 1952, Frandsen 1952).

Seed yield and seed weight in crested wheatgrass have positive parent-progeny correlations of $r = .546$ and $r = .647$, significant at $p = .05$ and $p = .01$ respectively (Schaaf and Rogler 1963) and Jessen and

Carlson (1985) reported correlation values of r = .67 and r = .73, significant at p = .10, in bromegrass. Knowles *et al*. (1970) reported a correlation of r = .46, significant at p = .05, between parent and progeny seed yields in bromegrass.

Christie and Kalton (1960) reported a polycross parent-progeny correlation of r = .56, with p = .01, for seed weight in bromegrass.

Jessen and Carlson (1985) found a parent-progeny correlation for seeds per seedhead of r = .76, with p = .10, in bromegrass.

Knowles *et al*. (1970) reported a correlation of r = -.42, with p = .05, between seed yield of the progeny and the creeping rootedness of the parent in bromegrass.

Plant Albinism

Plant albinism has been observed in some of the progeny of lines selected at the University of Manitoba. Therefore, the selections used for this study may carry alleles for plant albinism.

Plant albinism, in general, is controlled by a recessive allele and is lethal (Sinnott and Dunn 1939, Burton and Powell 1965, Strickberger 1976, Lebowitz 1985). However, Burton and Powell (1965) have found some digenic control in pearl millet.

Turfgrass Ratings

Visual ratings in turfgrass for colour, density and quality have been used since 1934 (Horst et al. 1984). The problem with using these ratings, especially quality and density may not be the ability of the evaluator to visually discern between grass species and/or cultivars of a species, but the lack of, one, a universal measuring scale, and two, a clear definition of how these characteristics should be considered and what attributes should be used to judge these characteristics (Horst et al. 1984).

Christians et al. (1979) state that "The primary goal of turf production is to achieve high quality from a visual standpoint.". This high quality includes a uniform colour and a good density as the golfer or bowler must be able to judge which direction the ball will roll when it is stroked or rolled if he is to score well. A mottled, uneven surface makes play very difficult.

Colour

Visual colour ratings have been used by many researchers (Roberts 1986, Kohlmeier and Eggens 1983, Christians et al. 1979, Waddington et al. 1978, Goss et al. 1979) and is employed for its simplicity and its saving of time and labour. Quantitative methods have been used to look at the colour of grasses and these include chlorophyll measurement (Rahman 1983, Madison 1960, Madison and Andersen 1963, Mantell and Stanhill 1966) and the tristimulus colourimeter (Hamill and Camlin 1984).

Correlation values between visual colour ratings and chlorophyll content per area of turf have been high as shown by the following r values, r = .85, with p = .01, (Rahman 1983), r = .895 and r = .692, both with p = .01 (Madison and Andersen 1963). For chlorophyll content per unit weight, Mantell and Stanhill (1966) found a correlation of r = .81, with p = .01.

The scales used for visual assessment vary. Rahman (1983) used a scale of 1 to 5, with 1 being for dark green and 5 for yellow. Kohlmeier and Eggens (1983) used a scale of 0 to 3, with 3 being for the darkest green colour. A third scale, and the most common, referred to by Horst _et_ _al_. (1984), and used by Roberts (1986) and Christian _et_ _al_. (1979) is a scale of 1 to 9, with 9 being the most desirable, which is the darker green and 1 being brown or chlorotic. A fourth scale, used by Waddington _et_ _al_. (1964) consisted of a statement of either good, fair or poor. These researchers also used chlorophyll content per gram of fresh weight and stated that the methods were well correlated. Madison (1960) stated that the best colour is represented by a high amount of chlorophyll per unit dry weight.

The environment in which a turfgrass is growing can have an effect on turf colour. An increase in nitrogen (Kohlmeier and Eggens 1983, Mantell and Stanhill 1966), an increase in the frequency of irrigation (Mantell and Stanhill 1966), an increase in potassium (Waddington _et_ _al_. 1972) and a decrease in phosphate (Waddington _et_ _al_. 1978) all either resulted in a darker green colour or more acceptable colour.

Density

The density rating is used in general, to estimate the amount of topgrowth or the ground cover of a turf. There appears to be either a difference in the ability of the evaluators to visually judge the density of a turf or a difference in the concept of the evaluators as to what density is (Horst et al. 1984).

Madhi and Stoutemyer (1953) developed a quantitative method to measure the shoot density of a plot. This method involves the removal of a plug of turf 2.5 cm in diameter and the counting of the number of stems present.

Madison (1960), Waddington et al. (1978) and Duff and Beard (1974) all used vegetative yield, either fresh or dry weight, as a measure of density. However, Christians et al. (1979) suggest that with a dense, uniform turf, a high yield of vegetation may not necessarily be desirable. Horst et al. (1984) and Christians et al. (1979) used visual density ratings with a scale of 1 to 9, with 9 being the most desirable.

Duff and Beard (1974) observed that a visual difference in density may be due to a less upright growth habit rather than a lower shoot density, although no apparent quantitative measurement was made.

Quality

The quality rating can be defined as the evaluators impression of the plot compared to his or her conception of the ideal turfgrass (Christians et al. 1979). Horst et al. (1984) demonstrated that what is visually appealing quality-wise is different to different turfgrass evaluators. Therefore, quality may be influenced by a bias of the evaluator towards a character which may have no effect on the use of the grass.

Effects of Wear on Plot Density

Creeping bentgrass golf and bowling green turfs are subject to wear from the trampling by users and the machinery used to maintain the turf.

Shearman and Beard (1975a) define wear injury to be, "... injury resulting from the weight and motion of traffic, crushing and tearing of leaves, stems and crowns of the turfgrass plant.", and is not the same as the effects of soil compaction on the turfgrass.

Waddington and Baker (1964) found that with "Penncross" creeping bentgrass a reduction in oxygen diffusion rates, a primary effect of soil compaction, did not affect the depth of rooting or the accumulation of nutrients by the plants. Therefore, soil compaction does not seem to affect creeping bentgrass root growth and thus the main problem may be with wear damage.

Simulated Wear Testing

There have been two types of wear machines developed to simulate wear on turfgrass areas. They are either a scuffing type machine, which spins on the plant, and/or the spiked roller type machine, which tears and shreds the plant parts and also compacts the soil (Younger 1961). Canaway (1976) has developed the differential slip wear machine 1, which is a scuffing type, and a second machine which has a weighted spiked roller as well (Canaway 1982).

Younger (1961) found that creeping bentgrass, mown at a normal height for a golf green, 3-6 mm, turned to a pulpy mass after a short time of the wear treatment. However, these tests were to see how much wear a turf could withstand at one time, therefore, the testing was done at a height of 12 mm. This study also showed that the spiked roller machines caused more damage to the turfgrasse than the scuffing type machine.

Kohlmeier and Eggens (1983), also working with "Penncross", mown at 5 mm, subjected the turf to 3 and 6 passes of a wear treatment, similar to the spiked roller machines. They found that as the level of wear increased there was a decrease in the amount of clippings, the healing potential of the turf and the amount of thatch. Younger (1961) stated that thatch gives an increase in the wear tolerance to the turf. Beard (1982), defined thatch as the layer of living and dead stems, leaves and roots intermixed on the soil surface.

Shearman and Beard (1975a,b,c) looked at the mechanisms of turfgrass wear. They found that the total cell wall content was highly correlated (r=.99) to wear tolerance between species (Shearman and Beard 1975b). The percent scleremchyma cells and lignified cells were both closely associated with the difference in wear tolerance between rough bluegrass, Poa trivialis L., and tall fescue, Festuca arundinacea Schreb. (Shearman and Beard 1975c). It was also found that visual rating, percent total cell wall, percent verdure, and chlorophyll analysis were all acceptable in measuring wear tolerance, however as visual rating is subject to personal bias, it was recommended that percent verdure be used, with verdure being the layer of green living material left after mowing (Shearman and Beard, 1975a).

Shildrick and Peel (1983) and Younger (1961) found differences in wear tolerance between cultivars within a species, the former with tall fescue and the latter with bermudagrass.

METHODS AND MATERIALS

University of Manitoba Selections

The first University of Manitoba (U of M) selections were made by Dr. A. C. Ferguson. The selections were plants that survived in a turf area the severe winter of 1962-63, thus demonstrating winterhardiness. These selections were from both creeping and colonial bentgrass plots. Table 4 gives the selections and their parentage.

The selection 63-19 was a selection made by Emile Tonn. This selection is thought to be native, however it probably escaped from an introduced sward. From selections 63-3, 63-3-1 and 63-11, the cultivar "Manitoba" was produced. Seed is available of this cultivar, however it has never been licensed.

The next U of M selections were made in 1967 by Dr. Ferguson using similar criteria as those used in 1963. The parentage of the selections is unknown and these were selections from both plots at the University and from local golf courses. The 1967 selections and a description of the line can be found in Table 5.

Table 6 gives the visual seed yield ratings from 1968 and 1971 for many of the 1963 and 1967 selections. These ratings are very similar and were based on plant size and an estimation of the number of seedheads.

TABLE 4

The 1963 U of M selections and their parentage.

Selection	Parentage
63-1	Congressional
63-2	Penncross
63-3	Colonial
63-4	Astoria
63-5	Pennlu
63-6	Toronto
63-7	Washington
63-8	Seaside
63-9	Northland
63-10	Old Orchard
63-11	Highland
63-12	Arlington
63-13	St. Charles selection
63-14	Old Orchard (Glendale)
63-15	Baldwin
63-16	Washington (St. Charles)
63-17	Colonial (light green)
63-18	Colonial (dark green)
63-19	Native Clone
63-20	Congressional (blue-green)

TABLE 5

The 1967 U of M selections and a description of the line.

Line	Description
67-1	Dark green, medium-coarse leaves
67-2	Dark green, medium-coarse leaves
67-3	Dark green, medium-coarse leaves, upright
67-4	Pale green, medium-coarse leaves, upright
67-5	Medium green, fine leaves
67-6	Medium green, medium-fine leaves
67-7	Blue-green, medium-coarse leaves
67-8	Blue-green
67-9	Dark green
67-10	Blue-green, medium-coarse leaves
67-11	Dark green, medium-fine leaves
67-12	
67-13	
67-14	

TABLE 6

U of M selections: The 1968 and 1971 visual seed yield rating and other comments.

Selection	Seed Yield Rating 1968	1971	Comments
63-3	5*	5*	
63-5	-	4	
63-10	2	1-2	
63-11	4	4	
63-17	-	3	
63-19	2	2-3	
67-1	-	3	Discarded, poor turf
67-2	3	3	
67-3	4	4	
67-4	4	4	
67-5	-	1	Discarded, poor turf
67-6	-	3	Discarded, poor turf
67-7	4	4	
67-8	4	4	
67-9	1	1	
67-10	3	3	
67-11	-	3	Discarded, poor turf
67-12	5	5	

*5 = very high, 4 = high, 3 = medium, 2 = poor, 1 = very poor

Table 7 gives some disease resistance (snow mold), spring regrowth and general appearance visual turf ratings for some of the 1963 and 1967 U of M selections. These are the only disease comparisons made amongst these lines.

The next U of M selections were made in 1973. Very little is known about these selections other than there were 17 lines isolated. Of these lines, 73-3 and 73-8 were creeping bentgrasses and lines 73-9, 73-11, 73-12 and 73-13 were Kentucky bluegrasses.

In 1975, the lines found in Table 8 were increased. A description of these lines is also found in Table 8.

The 1982 U of M selections were made by Dr. K. W. Clark, Mr. K. Bamford and Mr. D. Cattani from space plant nurseries planted in 1980 and 1981. The plants in the nurseries are open-pollinated progeny from all lines except those noted in Table 9. These selections were made for leaf colour, seed yield, plant aggressiveness and plant density. The selections, their parentage, their source and the reason for selection are found in Table 9.

TABLE 7

Disease resistance (snow mold), regrowth and general appearance visual turf ratings made on May 3, 1971.

Selection	Disease Resistance	Regrowth	General Appearance
63-10(a)	5.0*	3.5*	3.5*
63-10(b)	3.5	3.5	3.5
63-11	3.5	5.0	5.0
63-19	3.0	4.0	3.0
67-2	4.0	3.5	4.0
67-3	4.0	3.5	4.5
67-4	2.0	3.5	4.0
67-7	5.0	4.5	5.0
67-8	2.5	3.5	3.0
67-9	3.5	5.0	5.0
67-10	3.5	4.0	3.5
67-11	3.0	4.5	4.0

* 5 = best, 1 = poorest

TABLE 8

Comments from 1975 on the U of M selections for increase.

Selection	Comments
63-3-1	Dense, semi-upright, light colour, shoots 6"
63-3	Low growth, shoots 5"
63-10	Low growth, dwarf type, dense, shoots 2"
63-11	Upright, heavy growth, shoots 6"
67-2	Long shoots
67-3	Semi-upright, shoots 4"
67-4	Heavy growth, semi-upright, shoots 6"
67-10	Dwarf type, dense,shoots 1.5"

TABLE 9

The 1982 U of M selections, their parentage, their source and the reason for selection.

Selection	Parentage	Source	Reason for Selection
82-01	67-3		Colour
82-02	67-3		Density
82-03	63-3-1		Colour, upright seedheads
82-04	63-19	OP	Colour
82-05	63-19	OP	Colour
82-06	67-2		Yield, colour, aggressiveness
82-07	67-2		Yield
82-08	67-3		Yield, density
82-09	67-3		Colour
82-10	67-3		Colour, yield
82-11	67-3		Colour
82-12	67-3		Colour
82-13	Northland	OP	Yield, upright seedheads
82-14	Norhtland	OP	Yield
82-15	Toronto	OP	Yield
82-16	Penncross	OP	Yield, colour, aggressiveness
82-17	67-4		Yield, colour, density
82-18	67-4		Colour, density
82-19	67-4		Colour, density
82-20	67-2		Yield, colour, aggressiveness
82-21	67-2		Yield
82-22	67-12	OP	Colour, density
82-23	63-19	OP	Yield, colour
82-24	67-14	OP	Yield, colour
82-25	67-14	OP	Yield, colour
82-26	67-10		Colour
82-27	67-10		Colour
82-28	67-3		Colour
82-29	73-3	OP	Yield, colour, density
82-30	73-3	OP	Colour
82-31	73-8	OP	Colour

OP = Open-pollinated

U of M 1982 Selections

Turfgrass Trial

In October 1982, stolons from the 31 U of M 1982 creeping bentgrass selections were laid out in single plots, each plot being 2 m x 1.5 m, to produce a turf. By the end of June 1983, these plots were dense enough for visual colour ratings to be initiated. These plots and all other golf green plots in this study were maintained under golf green conditions. These conditions include mowing at 3/16" five days a week, irrigation as needed, fertilization as needed with either 20 - 0 - 15 or 22 - 0 - 16 fertilizer at a rate of 500 gms N / 100 square meters approximately every 6 weeks and aeration and topdressing once a year.

On May 7,1984, six 30.5 cm x 30.5 cm squares were cut using a sod cutter from each of the stolon propagated plots except 82-03 of which there was not enough turf. One year old "Penncross" and "Emerald" were also cut to get the six pieces of each to be used as check varieties. The experimental design was a randomized complete block (RCBD), with six replications. Appendix 1 shows the plot plan for the 1982 U of M selection turf trial. This trial was rated throughout 1984 and 1985 for visual colour and density.

These plots were located at the University of Manitoba Agricultural Research Plots (the Point) located at the east end of the Winnipeg Campus. The soil type has been modified to a sandy clay loam with 68% sand, 12% silt and 20% clay with a pH of 7.4.

On August 5, 1984, wear treatment was applied to one half of the plots using a spiked roller. The cylindrical roller was 60cm in length and 45cm in diameter with 10cm tubes with 7.5cm pads on the end, each pad contained three golf shoe spikes 4.5cm apart. The tubes were 15cm apart within rows and rows were 15cm apart, with the rows being staggered. The roller was filled with water to increase its weight. The roller is shown in Figure 1.

Three replicates were worn, with each worn replicate receiving 2 passes of the roller three times a week. Because of the lack of visual damage in 1984, the wear treatment was increased to 6 passes, five days a week in 1985.

The winter of 1984-85 caused the loss of some plots due to ice-sheeting in low lying areas. The low lying areas were generally in the worn areas and these appeared to be less thatchy. Clone 82-11 was completely brown in 5 of 6 plots in the turf area, and was removed from further testing and was therefore not rated in 1985.

All analysis of data was carried out on the main-frame computer using the SAS package, except where otherwise noted. The data for all trials based on the above set-up was analyzed on a split block basis once wear was initiated. All correlations involving rated data was done using Spearman's correlation coefficient.

Space Plants

On May 15, 1984, six 10cm in diameter pieces of the 30 selections in the turf trial were taken from the stolon produced area and planted on 61cm spacings in a RCBD with 6 replications. "Penncross" and "Emerald" from a seeded area were used as checks. This plot was located next to

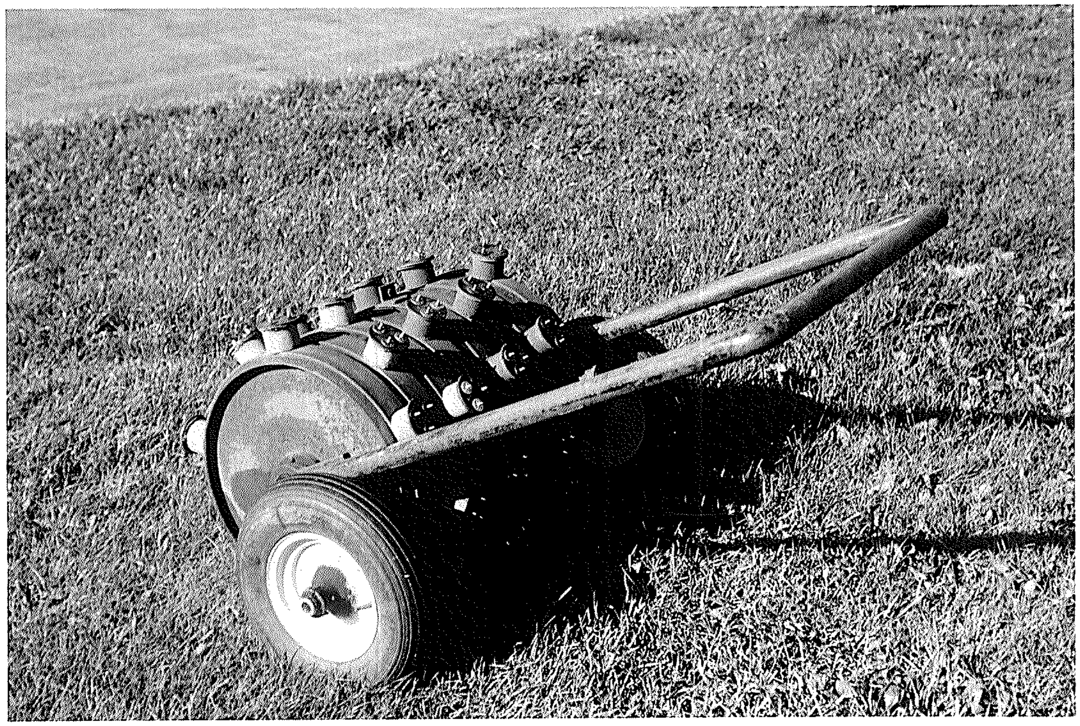

Figure 1: The spiked roller used for wear simulation.

the turf trial at the Point and has the same soil type. The plot plan is found in Appendix 2.

Visual ratings were initiated for colour and density on May 25, flowering dates were observed and stolon length was measured. The stolon length was measured using 5 stolons per plant and the measurement was made from the collar of the youngest leaf to the youngest node to be rooted down.

By October 1984, the plants had grown together and the plot was abandoned in 1985.

Polycross 83-02

The plants for this polycross were selected to try to increase the seed yield of the U of M 67-10 selections, as these had good turf qualities but poor to medium seed yields. All selections, their parentage, their seed yield and the reason for their selection are found in Table 10.

The clones were vegetatively propagated in the greenhouse by sprigging-in stolons collected from the mother clone.

The polycross was planted on July 4, 1983 in the northwest corner of the old U of M Arboretum, located at the west end of the Winnipeg Campus. The soil type is an Osbourne clay (Ehrlich et al., 1953). The field design was a RCBD with 8 replicates. Each replicate consisted of one plant of each clone, (10 plants), spaced 122cm apart both within and between rows. Appendix 3 shows the field plan for Polycross (PC) 83-02.

TABLE 10

Selections for Polycross 83-02: Their parentage, their seed yield and the reason for selection.

Clone	Source	Yield g/plant	Reason for Selection
82-06	67-2	55.7	seed yield, colour, aggressiveness
82-08	67-3	61.0	seed yield, density
82-09	67-3	24.0	colour, good line
82-11	67-3	28.6	colour, good line
82-15	Toronto	57.8	seed yield
82-17	67-4	32.9	seed yield, colour, density
82-20	67-2	46.5	seed yield, density, aggressiveness
82-26	67-10	-	colour, good line
82-27	67-10	13.4	colour, good line
82-29	73-3	45.1	seed yield, colour, density

A border of 82-22 was planted around this plot, as this clone had not produced seedheads in the nursery, to reduce border effects. However, in the late spring of 1984, it was obvious that this clone was producing seedheads and the border was removed.

Clone 82-11 was removed from this polycross in the spring of 1984 because of its poor performance in the turf trial and its poor overwintering in this polycross.

This planting received 100 kg N/ha in October of 1983.

Flowering dates were noted and on July 16,1984, the seedheads were harvested. Harvesting was done on a plant basis with the seedheads of each plant being placed into an appropriately labelled bag and placed into the drying room for 1 week. Seedheads/plant were calculated by weighing all of the seedheads of a plant and then counting out 100 seedheads and weighing these and then calculating the number per plant from these weights.

The seedheads were threshed using a Vogel stationary head thresher with the wind control being very low to prevent the blowing away of the seed. The seed was then hand cleaned and weighed to the nearest mg. The area of the plant was measured one week after harvest.

This polycross was damaged by flooding twice in January 1985 due to City of Winnipeg water main breaks. The damage was severe enough to exclude further seedhead harvest.

Polycross 83-02 Progeny Test

Transplanted Trial

The nine progeny lines of PC 83-02 and "Penncross" were seeded to flats 45cm x 30cm x 5cm. The medium used was a 1:1:1, soil:sand:peat mixture with the flats being filled to three-eights of inch below the top. The seeding rate was 500gms/100 square meters, the rate used to establish golf greens (Turgeon 1985), on February 28,1985. Four replicates were used with the design being the RCBD. See Appendix 4 for the original layout.

The flats were placed in the greenhouse where the day/night light cycle was 16hr/8hr. The flats were rotated every second day to attempt to remove position effects of the greenhouse bench. The flats were irrigated daily and fertilized every three weeks.

During emergence, albino seedlings were noticed in some of the lines. The number of albinos per flat were counted and the number of seedlings per flat were calculated by making two counts with a 5cm square. Percentage albinos were then calculated for each flat.

The flats were mown every 5-6 days with a bench top mower. The clippings were collected on March 19 and 24. The flats were mown to approximately 1/8" above the top of the flat.

Clipping collection was halted due to Pythium seedling disease. The infestation was random and it was controlled using the recommended rate of chloroneb.

The flats were topdressed with the planting medium with the new soil level being 1/4" below the top of the flat to facilitate a mowing height closer to the actual field conditions.

Fresh weights were measured on the clippings which were then placed into a drying oven for 24hrs at 75 degrees C. Dry weights were measured and the percentage dry weight was calculated.

On May 1, the flats were placed into cold frames for hardening-off and on May 6 they were transplanted to the turf area at the Point. The soil type has been modified to a sandy loam with 77% sand, 8% silt and 15% clay and has a pH of 7.2. The plots were irrigated as necessary during establishment, fertilized on May 7 with a 20 - 26 - 6 starter fertilizer at a rate of 500 gms N/100 square meters and this plot was topdressed with a fine mortar sand on May 10. Mowing was started at this time and the plot was thereafter treated as a golf green.

The plot plan can be found in Appendix 5.

Visual ratings for colour and density were started on July 5.

Seeded Trial

A second turf trial for PC 83-02 progeny with the same control cultivar, "Penncross", was directly seeded into the field on June 12,1985, adjacent to the transplanted progeny turf test. The plots were 50cm x 50cm with a seeding rate of 1.25 gms/plot (500gm/100 sq. meters). The plots were then covered with "Famcomat", a fibreglass material, to assist in moisture retention for germination and emergence. The covering was removed on June 22, and these plots were mown on July 12. Visual ratings commenced on August 2.

This area was maintained as a golf green as previously mentioned. There are 4 replicates and the plot plan can be found in Appendix 5.

Albino Counts

Reciprocal crosses had been made between U of M selections 82-06 and 82-20 in 1983. On March 8,1985, the seeds produced from these crosses were set to germinate in 100mm x 60mm plastic petri dishes on a bench in the lab. Two Whatman # 1 qualitative filter papers were placed into each dish, the seed spread on top and 4ml of .075% potassium nitrate solution added to each dish. On March 21 the seedlings were counted and the number of albino seedlings noted.

The surviving green seedlings were then planted in 5cm square peat pots and placed in the greenhouse. The plants were transplanted into 10cm plastic pots on April 15. The soil mixture used for all potting was a 1:1:1 soil:sand:peat mix. Plants were fertilized every three weeks.

The plants were placed into the vernalization chamber on May 17 and removed on August 21. The vernalization chamber was on a 8hr/16hr day/night light regime and a 5 degrees C/2 degrees C day/night temperature regime.

After removal from vernalization, the plants were placed into a growth room with a 17hr/7hr day/night light regime and a 24 degrees C day and 15 degrees C night temperature regime. The plants were fertilized every three weeks.

Heading started on September 14 and all flowering was completed by October 4.

The seedheads were harvested on October 23, hand threshed and put to germinate, as described above, on October 30.

Plant counts were made on November 21.

Polycross 83-03

Polycross (PC) 83-03 was established using the 10 highest seed yielding clones from the U of M 1982 selections to look at seed production. The selections, their parentage and their seed yield are found in Table 11.

This polycross was planted on August 8,1983, in the northeast corner of block 25 at the Point. The soil is a Riverdale clay loam (Ehrlich *et al*., 1953) however it tends to be lighter than the surrounding soils. The plants were space planted with 91cm between plants within and between rows. There were 8 replicates and the design was a RCBD. Appendix 6 shows the plot plan.

Fertilizer was applied in October 1983 and April 1985 at a rate of 100kg N/ha with a 27 - 14 - 0 fertilizer.

The seedheads were harvested on July 17,1984 and July 22,1985. These were treated the same as PC 83-02.

TABLE 11

Polycross 83-03: the selections included, their parentage and their seed yield.

Clone	Parentage	Seed Yield (gms/plant)
82-06	67-2	55.7
82-07	67-2	40.9
82-08	67-3	61.0
82-10	67-3	35.0
82-15	Toronto	57.8
82-20	67-2	46.5
82-21	67-2	34.8
82-24	67-14	34.3
82-25	67-14	39.3
82-29	73-3	45.1

In 1983, because of the small size of the plants, seedhead number and seedhead characteristics were not measured.

In 1985, all seedhead characteristics were measured and seed weight was measured using two hundred seeds.

Polycross 83-04

Polycross (PC) 83-04 was set up with the 8 selections that had the best overall turf colour in 1983 in the 1982 selections vegetatively produced turf area. The selections, their source and their mean turf colour ratings for 1983 are found in Table 12.

Six pieces of each clone were taken from the field and potted in the greenhouse on November 13,1983. The plants were fertilized every three weeks.

They were placed into the vernalization chamber for six weeks on December 12. The vernalization chamber conditions were the same as noted above.

After the 6 weeks the plants were placed into the greenhouse with a 16hr/8hr day/night light regime. Four weeks later the lighting regime was changed to a 16.5hr/7.5hr day/night.

There was no initiation of flowering by April 18 and the plants were placed into the cold frames for hardening off.

On May 7,1984, this polycross was transplanted to the field at the north end of the turf area at the Point. The soil type is a Riverdale

TABLE 12

Polycross 83-04: The selections, their source and their 1983 overall turf colour rating.

Clone	Source	Colour Rating
82-03	63-3-1	7.72*
82-07	67-2	7.39
82-10	67-3	7.50
82-17	67-4	7.61
82-24	67-14	8.33
82-25	67-14	8.56
82-27	67-10	8.33
82-30	73-3	8.61

* 9 - dark green, 1 - light green

clay (Ehrlich et al.,1953) and has 5% sand, 37% silt and 58% clay and a pH of 7.3. The design was a RCBD with 6 replicates. The plants were spaced 91cm between plants within and between rows. See Appendix 7 for the plot plan.

There were no seedheads to be harvested in 1984. In 1985, seedheads were harvested on July 19. The harvest was processed similar to PC 83-03 in 1985.

There was a germination test performed to calculate correlations between seed yield components and germination. The test consisted of 50 seeds per petri dish and treated the same as the germination for the albinos. The dishes were kept in their replicates and placed into plastic bags to cut down evaporation. There was one replicate per bag with the plates being randomized within the replicates. There were three complete replicates (i.e. 3 x 48 = 144 dishes). These were placed into a growth chamber with a day/night light regime of 16hr/8hr. The temperature regime was 18 degrees C/12 degrees C day/night. After 10 days, germination counts were made.

Synthetic 84-01

This synthetic was planted in September 1982 in the Old Orchard at the Point. The soil type was a Riverdale clay (Ehrlich et al., 1952). There were five selections out of U of M 67-10 selected for their morphological uniformity. There were six replicates in a RCBD, however two replicates were sprayed with glyphosate because of weed infestation.

This planting received 150 kg N/ha with a 27 - 14 - 0 fertilizer in October 1983 and April 1985.

This synthetic had to be abandoned in May 1985 because of severe destruction of the plot due to glassy cutworms.

The seedheads were harvested on July 15,1984, and were treated the same as PC 83-02. One hundred seeds per plant were counted out and weighed to obtain seed weight.

Synthetic 85-03

Synthetic (SYN) 85-03 was initiated from 5 clones selected out of a U of M 67-10 seed increase field planted from the progeny of the 1976 harvest. The plants were selected for large plant size and therefore presumably high seed yield, similar flowering date and aggressive, upright growth. These clones have been designated SYN 85-03-1 through SYN 85-03-5 and will be referred to as clones 1 - 5 within this section.

In the field, ten pieces of the periphery of each selected plant were removed, with a hole cutter 10cm in diameter, on May 9,1985. The loose soil was removed from the roots of each piece and each piece was then potted in a 15cm plastic pot in a 2:1:1 soil:sand:peat growing medium. Each plant was then fertilized every three weeks.

The synthetic was then set out into two balanced Latin Squares. One was placed into the greenhouse with a 17hr/7hr day/night light regime and the other was placed into a growth room with a similar lighting regime and a temperature regime of 20 degrees C/15 degrees C day/night cycle. Each pot was watered daily to prevent wilting.

Clones 1 and 5 had to be removed from this test due to a lack in synchronization in flowering. As these plants were synchronized in the field, it is possible that either stress due to transplanting or the forcing of flowering in the greenhouse resulted in this difference.

The pots were individually harvested on July 2. Seedheads were counted, threshed, manually cleaned and then the seed was weighed. Ten mg of seed from each plant was weighed out and the number of seeds counted. All other characters were calculated from these measurements.

Clone 2 in replicate 2 in the greenhouse did not produce any seedheads, and therefore, missing values were calculated for this plant before analysis.

Wear Treatment and Its Effects on Turf Density

Visual density ratings were made on June 28, July 12 and August 2, 1985 on ten of the 1982 U of M selections. These selections were 82-02, 82-05, 82-08, 82-09, 82-12, 82-13, 82-15, 82-21, 82-23 and 82-29. These were chosen because of the uniformity of the replicates of these clones when wear treatment started on May 4, 1985.

On the above mentioned dates, core samples were removed from each plot from the 1982 Selections Turf Trial by the method described by Madhi and Stoutemyer (1953). These samples were sealed in plastic bags and placed into a cooler at 2 degrees C. Samples were then removed 6 at a time and live tiller number and green leaf number (July 12 and August 2 only) were counted. All tillers and leaves were then packaged and placed back into the cooler until all counts were completed.

The packages were then placed into a drying oven for 24 hours at 75 degrees C. The dried material was then weighed to the nearest milligram.

The dry weight and the counts were then used to calculate dry weight per tiller and leaves per tiller.

These characteristics were analysed using SAS. Analysis of Variance and correlation coefficients were computed. Correlation coefficients pertaining to the visual density ratings are Spearman's coefficient.

RESULTS AND DISCUSSION

Polycross 83-02 1984 Harvest

There were significant differences between clones for all characteristics studied pertaining to first year seed yield(Table 13). This shows that there is variation present to allow for selection of the characteristics studied. Figure 2 shows this polycross prior to harvest.

Table 13 shows the seed yield for the 9 clones in the polycross. Clones 82-08, 82-06 and 82-20 were the highest yielding clones respectively and clones 82-27, 82-26, 82-09 and 82-15 were the lowest yielding clones respectively.

Clone 82-15 was the latest to initiate flowering while 82-27 and 82-09 began to flower the earliest. However as flowering on a plant takes place over a period of approximately two weeks and flowering of a single seedhead can take place over a period of 3-4 days, the early and late flowering clones were flowering for at least one week simultaneously. Being early or late, therefore, does not preclude cross-pollination, however, it does appear to reduce the total seed yield of those specific clones.

Flowering of the seedhead starts with the lowermost branches of the panicle opening up and proceeds up the panicle with the uppermost

Figure 2: Polycross 83-02 prior to harvest July 1984.

TABLE 13

Seed yield parameters for Polycross 83-02 1984 harvest: Seed yield, seed yield/cm^2, seed yield/seedhead, seedhead/plant, seedheads/cm^2 and plant area.

Clone	Seed Yield (gm)	Yield/Area (mg/cm^2)	Yield/Seedhead (mg)
82-08	40.20a*	22.10ab*	21.88bc*
82-06	38.53ab	18.91abc	30.00a
82-20	36.15ab	23.58a	23.45ab
82-29	28.60bc	17.70bc	19.92bc
82-17	24.28cd	14.46cd	15.19cd
82-15	21.22cde	11.76d	25.83ab
82-09	20.35cde	11.11d	11.04d
82-26	17.78de	11.76d	10.63d
82-27	14.20e	15.90cd	12.05d

Clone	Seedheads	Seedheads/Area (# / cm^2)	Plant Area (cm^2)
82-08	2014ab*	1.13ab*	1919ab*
82-06	1208cd	0.60cd	2115a
82-20	1709abc	1.08ab	1566b
82-29	1439bcd	0.89bc	1663b
82-17	1588abc	0.96abc	1656b
82-15	862d	0.48d	1831ab
82-09	2106a	1.11ab	1959ab
82-26	1773abc	1.22ab	1659b
82-27	1261cd	1.36a	969c

* Means followed by the same letter are not significantly using Duncan's Multiple Range Test (P = .05).

branches being the last to flower. After flowering the panicle closes and it re-opens about three weeks later when the seed is ready to harvest. This would appear to be the most opportune time for the farmer to swath.

Seed yield per cm^2 of plant area is also shown in Table 13. Clones 82-17, 82-15, 82-26 and 82-09 were the lowest and 82-20, 82-08 and 82-06 were the highest. The ranking of the clones for seed yield per cm^2 was similar to the ranking for seed yield per plant.

The yield per seedhead is shown in Table 13, and again clones 82-27, 82-09 and 82-26 are the lowest for this character. However, clone 82-15, in the lowest group for seed yield per cm^2 is higher for yield per seedhead, yielding twice as much as the lower group. Therefore, there appears to be another restriction on the seed yield of 82-15 other than seed yield per seedhead. Clone 82-06 was significantly higher than the rest while 82-15, 82-20, 82-08 and 82-09 were in the next highest grouping. Table 13 also shows the number of seedheads per plant. Clones 82-15, 82-06 and 82-27 are in the lowest group and 82-09, 82-08 and 82-26 are in the highest group. This low number of seedheads for 82-15 is the probable explanation for its low seed yield.

Also, clones 82-09 and 82-26 have a high number of seedheads but a low seed yield and clone 82-08 has a high number of seedheads and a high seed yield. This would appear to make the number of seedheads per plant, at least for the above selections, not a good indicator of potential seed yield.

Seedheads per cm^2 are also found in Table 13. Clones 82-27, 82-26, 82-09 and 82-08 are in the highest group and clones 82-06 and 82-15 are in the lowest group. Clone 82-08 again is high for both seedhead density and seed yield while 82-27, 82-26 and 82-09 are high for seedhead density but low for seed yield. Clones 82-06 and 82-15 are low for seedhead density but high for seed yield per seedhead. This may indicate that a low seedhead density means less competition between seedheads for seed production requirements, thus giving rise to a higher seed yield per cm^2 . Also, the lower seedhead density may allow for more cross pollination and less selfing thus increasing seed production.

Plant area (Table 13) was significantly different between clones, with those clones which spread the fastest tending to have higher seed yields. Clones 82-29, 82-17 and 82-26 all had a similar mean plant area (Table 13) however, 82-29 and 82-17 yielded approximately 161% and 137% more than 82-26 respectively.

The results of this polycross show that there is significant variation between clones for first year seed yield and its components.

The relative ranking of the seed yield of the clones appears to coincide with those rankings of the clones on a single plant basis (Table 10). This appears to show that selection for seed yield may be done on a single plant basis. However, this is only the first year seed yield and it may not be indicative of performance over the long term. Also, these are yields from a space planting and according to Adams (1967) you would expect to see a wider separation of values under these conditions as opposed to a more competitive environment. The effect of competition needs to be examined to see which characteristic(s) are important and therefore, should be used for selection for seed production.

Also, as seed production fields can either be broadcast or seeded into rows 75-90 cm apart (Bolton 1975), the method of seeding could also affect which characteristic(s) should be selected for.

Polycross 83-03: 1984 and 1985 Harvests

There were significant differences between clones for all characters for both 1984 and 1985 harvests, except for seed yield per cm^2 in 1985 (Table 14). This is the only trial with two years data for some characteristics.

There were significant differences in seed yield between clones for both years (Table 14). However, there appears to be an interaction between clones and years. Changes in seed yield ranged from 222% for 82-06 to -53% for 82-20.

Clones 82-29, 82-07 and 82-06 had the highest overall combined seed yield respectively, while clones 82-10, 82-20 and 82-21 had the lowest combined seed yield.

In 1984, clones 82-21, 82-24 and 82-07 started to flower 3 days before all of the rest except 82-15 which was 7 days later. Flowering date appeared to have no effect on seed yield in 1984. In 1985, flowering was relatively even amongst the clones with no clone being consistently earlier or later than the others.

TABLE 14

Polycross 83-03: Seed yields for 1984, 1985 and combined, plant area and seed yield/cm^2 for 1984 and 1985.

	Seed Yield (gms/plant)		
Clone	1984	1985	Total
82-07	16.450a*	23.618bc*	40.068
82-29	15.193ab	32.124a	47.317
82-25	14.104abc	16.218cd	30.322
82-08	14.003abc	15.424d	29.427
82-15	11.438bc	20.512bcd	31.950
82-21	10.308cd	7.365e	17.673
82-20	9.156de	4.813e	13.969
82-06	8.666de	27.970ab	36.636
82-24	7.176de	17.720cd	24.896
82-10	5.262e	5.229e	10.491
Mean	11.176	17.099	28.275

Clone	Seed Yield/cm^2 (mg/cm^2)		Plant Area (cm^2)	
Clone	1984	1985	1984	1985
82-07	19.101bcd*	4.489a*	913a*	5579a*
82-29	21.361bc	5.768a	747ab	5949a
82-25	17.925bcd	3.978a	835ab	4028bc
82-08	22.327b	4.978a	641bc	3383bc
82-15	12.271de	5.962a	931a	4274b
82-21	34.462a	5.358a	297d	1776d
82-20	31.310a	3.904a	338d	1603d
82-06	13.466de	4.931a	638bc	5809a
82-24	8.477e	6.065a	856ab	2987c
82-10	13.747cde	3.279a	400cd	1395d
Mean	19.65	4.780	660	3678

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test (P = .05)

The mean plant area for 1985 increased on average slightly more than 6 times the plant area of 1984 (Table 14). This large increase in plant area did not result in a similar increase in seed yield. One possible explanation was the timing of the fertilizer applications with fertilizer being applied in the fall of 1983 and not again until the spring of 1985. This may indicate that fall fertilization to be preferable, however, the length of time between fertilizer applications could also be an important factor, with there being a possible depletion of nutrients prior to the 1985 application.

Clones 82-29, 82-07 and 82-06 were the largest clones in 1985 and these clones had the highest combined seed yield for both years. Clones 82-10, 82-20 and 82-21 were the opposite, being the smallest clones in 1985 and having the lowest combined seed yields. The mean seed yield per cm^2 in 1985 decreased by 75% from 1984 (Table 14). This could partly be due to the centers of the plants not producing seedheads even where they did survive the winter. Also, the timing of the fertilizer application could have contributed to the lower than expected seed yield possibly because of nutrient depletion during the time of floral primordia initiation. There were significant differences in 1984 only and this may have been due to the fertilizer timing.

The clones with the highest seed yields per cm^2 in 1984 were amongst the lowest in 1985. The clones with the highest two year seed yield, 82-29 and 82-07, had intermediate values for seed yield per square cm in both years. Clone 82-06 had a low seed yield per cm^2 in 1984 but it also had an intermediate value in 1985.

These lower second year values may also have been the result of greater intraplant competition and/or greater interplant competition.

Selection for consistent seed yield may be best served by opting for intermediate seed yield per cm^2 which appears to give consistent seed yields. As these plants with the intermediate seed yield per cm^2 were also the largest plants, selection may be made on this criterion.

A comparison between the seed yields of the clones given in Table 11 (sinlge plant values) and Table 14 (means), show that selection for seed yield without replication may be ineffective, thus being opposed to the results of PC 83-02.

Table 15 contains the number of seedheads per plant, the number of seedheads per cm^2 , seeds per seedhead, seed yield per seedhead (mgs) and two hundred seed weights for the 1985 harvest.

Clones 82-29 and 82-07 were the highest in the number of seedheads per plant while 82-25, 82-20, 82-10 and 82-21 were the lowest. The number of seedheads per plant seems to parallel seed yield and plant area. The number of seedheads is therefore probably the result of the larger plants having more stems, and therefore more possible sites for seedhead primordia to arise from leading to more seedheads and finally more seeds per plant.

The seedheads per cm^2 was, in general, similar to the seedheads per plant with clone 82-10 being an exception because it had a high seedhead density but a low number of seedheads per plant (Table 15). However, the small plant area probably caused the relatively high seedhead density.

TABLE 15

Seed production parameters for Polycross 83-03: Seedheads per plant (SH), seedheads per cm^2 (SH/A), seeds per seedhead (S/SH), seed yield per seedhead (YSH) and two hundred seed weight (TSW) for 1985.

Clone	SH	SH/A	S/SH	Y/SH (mg)	TSW (mg)
82-07	4163a*	.766a*	95d*	6.417e*	13.50ef*
82-29	3740a	.628ab	143bcd	9.404bcde	13.13fg
82-06	2608b	.440bc	154bc	11.485b	15.00cd
82-24	2271b	.773a	92d	8.010cde	15.88bc
82-15	2115b	.533ab	161bc	10.480bc	12.13g
82-08	2035bc	.625ab	111cd	7.731cde	14.00def
82-25	1057cd	.262c	226a	16.231a	14.50de
82-10	1047cd	.731a	111cd	6.702de	12.25g
82-21	534d	.366bc	180ab	15.784a	17.38a
82-20	470d	.361bc	125cd	10.251bc	16.38b

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Yield per seedhead and seeds per seedhead show a similar pattern in ranking of the cloneswith 82-25 and 82-21 being the highest and clones 82-10, 82-07 and 82-24 being the lowest (Table 15). Therefore, it is probably only necessary to measure one of these characteristics.

Two hundred seed weight was highest for 82-21 and 82-20 and the lowest for 82-10 and 82-15. The range of seed number per kg is approximately 11 - 17.2 million seeds. Bolton (1975) reports a seed number per kg of 16.5 million while Turgeon (1985) reports a seed number per kg of 14 million. The difference in the range or average in these seed lots may be attributed to the fact that our seed was manually cleaned with more glumes, lemmas and paleas present while Turgeon and Bolton used commercially cleaned seed or our seed may actually be heavier.

Polycross 83-04: 1985 Harvest

The mean seed yield and a comparison of means can be found in Table 16. Clones 82-24 and 82-25 yielded the most while clones 82-17, 82-10, 82-27 and 82-30 yielded about one-half or less than the highest yielding clones.

There were significant differences between clones for all characteristics except seeds per seedhead (Table 16).

The flowering dates for this polycross were relatively uniform with no clone being consistently earlier or later. The plants started flowering on June 17 and were finished flowering by July 2.

TABLE 16

Seed production parameters for Polycross 83-04 1985 harvest: Seed yield, plant area, seed yield/cm^2, seedheads/plant, seedheads/cm^2, seed yield/seedhead, 200 seed weight, seeds/seedhead and percent germination.

Clone	Seed Yield (gms)	Plant Area (cm^2)	Seed Yield/ cm^2 (mgs)
82-24	38.588a*	3138a*	12.9ab*
82-25	29.111b	2697ab	10.5abc
82-07	23.805bc	2182b	10.8abc
82-03	23.252bc	1927bcd	12.6ab
82-27	16.196cd	1179d	13.2a
82-10	14.767cd	1247d	12.7ab
82-17	12.931d	2045bc	6.6c
82-30	12.616d	1310cd	8.5bc

Clone	Seedheads/ Plant	Seedheads/ cm^2	Seed Yield/ Seedhead (mgs)
82-24	3996a*	1.306b*	10.5abcd*
82-25	2049b	0.758bc	15.3a
82-07	2451b	1.133bc	9.7bcd
82-03	2115b	1.136bc	12.6abc
82-27	1070c	0.897bc	14.7ab
82-10	2126b	1.858a	7.2d
82-17	1572bc	0.777bc	9.0cd
82-30	885c	0.665c	12.7abc

Clone	200 Seed Weight (mgs)	Seeds/ Seedhead	Germination %
82-24	16.7bc*	132.2a*	80.3bc*
82-25	17.7ab	174.0a	71.5d
82-07	15.8c	122.0a	88.3ab
82-03	16.3bc	153.3a	93.1a
82-27	18.3a	160.5a	77.6cd
82-10	12.8e	114.2a	74.0cd
82-17	14.2d	130.2a	88.0ab
82-30	17.0bc	146.8a	86.8ab

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Plant area (Table 16) is a major factor in the difference in seed yield between the clones. However, by increasing plant density we could influence seed yield by increasing interplant competition.

The mean seed yield per cm^2 and a comparison of clonal means for seed yield per cm^2 can be found in Table 16. Clone 82-27 had the highest seed yield per cm^2 while 82-17 had the lowest, approximately one-half that of 82-27. The clones 82-30, 82-25 and 82-03 were the first to finish flowering, although all clones initiated flowering at the same time. These clones were amongst the lowest for seed yield per cm^2 . Therefore, the length of time of flowering could have resulted in poorer pollination than the rest and therefore, less seed set per cm^2 of plant area.

The mean number of seedheads per plant, seedheads per cm^2 and seed yield per seedhead are found in Table 16. Clone 82-24 was the most prolific seedhead producer and clones 82-27 and 82-30 were the lowest. Seedheads per cm^2 for the clones was somewhat similar in ranking to seedheads per plant. However, there were very few significant differences between the clones. Clone 82-10 was significantly higher with 1.86 seedheads per cm^2 , and clone 82-30 was the lowest with 0.67 seedheads per cm^2 . All of the other clones had seedhead per cm^2 numbers that were not significantly different from one another.

Clones 82-25 and 82-27 were the highest yielding per seedhead and 82-10 had the lowest yield per seedhead, approximately one-half that of the highest (Table 16). The yield per seedhead appears to be inversely related to seedheads per cm^2 . This will be discussed under Seed Yield and Seed Yield Components.

The seedweight range was much similar to that of PC 83-03. Clones 82-27 and 82-25 had the highest seed weight while 82-10 was the lowest (Table 16). There were no significant differences between clones for seeds per seedhead (Table 16).

Percent germination did not appear to be related to characteristics such as seed weight, seed yield per cm^2 and seeds per seedhead. Clone 82-03 had the highest germination percentage and 82-25 had the lowest, about 20% less (Table 16).

The low germination percentage of this trial may be due to the cleaning methods used, i.e., small, inviable seed not cleaned out, possible dormancy, although no dormancy has been noted in the literature, or immature seed and therefore the possibility of a period of afterripening being needed for some clones.

Synthetic 84-01: 1984 Harvest

This synthetic was studied for two reasons, it was the first year of harvest and there was very little bare ground between plants, and therefore at near full competition. Figure 3 shows Synthetic 84-01 prior to harvest.

Flowering dates were similar between the clones with flowering starting on June 16 and being finished on July 3.

Table 17 shows the seed yield and component of yield comparisons. There was no significant difference between clones as to the seed yield per plant and plant area. All other characteristics showed significant differences between the clones.

Figure 3: Synthetic 84-01 prior to harvest in July 1984.

TABLE 17

Synthetic 84-01: Seed yield and components of seed yield for the 1984 harvest.

	Clone				
	84-01-1	84-01-2	84-01-3	84-01-4	84-01-5
Seed Yield (gms)	37.542	40.575	28.867	37.092	27.218
Plant Area (cm^2)	3588	4556	4137	5000	5831
Seedheads/ Plant	3098b*	3846b	3994b	3718b	7238a
Seedheads/ cm^2	0.857b*	0.844b	0.984ab	0.798b	1.262a
Seed Yield/ cm^2 (mgs)	10.4a*	9.1ab	7.1bc	7.5abc	5.1c
Seed Yield/ Seedhead (mgs)	12.7a*	10.9ab	7.1bc	10.4ab	4.0c
Seeds/ Seedhead	91.4ab*	101.3a	66.8bc	91.1ab	44.1c
100 Seed Weight (mgs)	14.0a*	11.0b	10.8b	11.3b	9.3b

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Clone 84-01-5 is the clone that is different. It either has the highest or the lowest mean, and when it is left out of the analysis, there are no significant differences between the other clones for any of the characteristics. Clone 84-01-5 was the highest for seedheads/plant and seedheads per cm^2 and was the lowest for seeds per seedhead, seed yield per cm^2 and one hundred seed weight.

It should be noted that these are all selections out of U of M 67-10 and were selected for their similar phenotypes. Therefore, this may not be an accurate estimation of the genetic response to competition because of the possible close genetic relationship. However, it may also be, as noted by Adams (1967), that genetic variation is best seen where competition is low and nutrition and other important factors are not limiting.

Seed Yield and Components of Seed Yield

Table 18 contains the correlation coefficients from PC 83-02, PC 83-03 1984 harvest, PC 83-03 1985 harvest, PC 83-04 and Syn 84-01.

All of the outdoor seed production trials, except Synthetic (Syn) 84-01, had statistically significant positive correlation coefficients for seed yield and plant area. These correlation coefficients (r) ranged from $r = .337$ with $p = .01$ for PC 83-02 to $r = .819$ with $p = .001$ for PC 83-04, Table 18. This agrees with Dewey and Lu (1959) who obtained a positive correlation between seed yield and plant size. Figure 4 shows the relationship between seed yield and plant area for the first year of seed harvest. PC 83-02 is ignored because of the different spacing of the plants.

TABLE 18

Correlations from all outdoor seed production trials: Yield (Y), plant area (PA), yield/cm^2 (YA), seedheads/plant (SH), yield/seedhead (YSH), seeds/seedhead (SSH), seedheads per cm^2 (SHA) and seed weight (SW).

		PA	YA	SH	YSH	SHA	SSH	SW
Y	1$	.585c*	.293b	-	-	-	-	-
	2	.337b	.757c	.322b	.593c	.022	-	-
	3	.706c	.515c	.763c	-.014	.315b	.086	-.255a
	4	.819c	.479b	.750c	.228	.155	.159	.307a
	5	.203	.638b	-.018	.471a	.032	.478a	.224
PA	1		-.470c	-	-	-	-	-
	2		-.319b	.133	.216	-.522c	-	-
	3		-.109	.705c	-.164	-.021	-.037	-.334b
	4		-.045	.653c	.106	-.136	.077	.179
	5		-.588b	.726c	-.366	-.016	-.360	-.242
YA	2			.242a	.427c	.394c	-	-
	3			.259a	.204	.527c	.168	-.236a
	4			.319a	.288a	.573c	.247	.167
	5			-.457a	.596b	.032	.604b	.322
SH	2				-.453c	.133	-	-
	3				-.453c	.597c	-.371c	-.332b
	4				-.381b	.561c	-.424b	.014
	5				-.781c	.653b	-.706c	-.547b
YSH	2					-.523c	-	-
	3					-.551c	.938c	.363c
	4					-.555c	.943c	.511c
	5					-.755c	.857c	.694c
SHA	3						-.538c	-.236a
	4						-.526c	-.346a
	5						-.596b	-.596b
SSH	3							.060
	4							.209
	5							.240

*a,b,c = P(r=0) of .05, .01 and .001 respectively.
$1 = PC 83-03 1984 harvest, 2 = PC 83-02, 3 = PC 83-03 1985 harvest, 4 = PC 83-04, 5 = Syn 84-01.

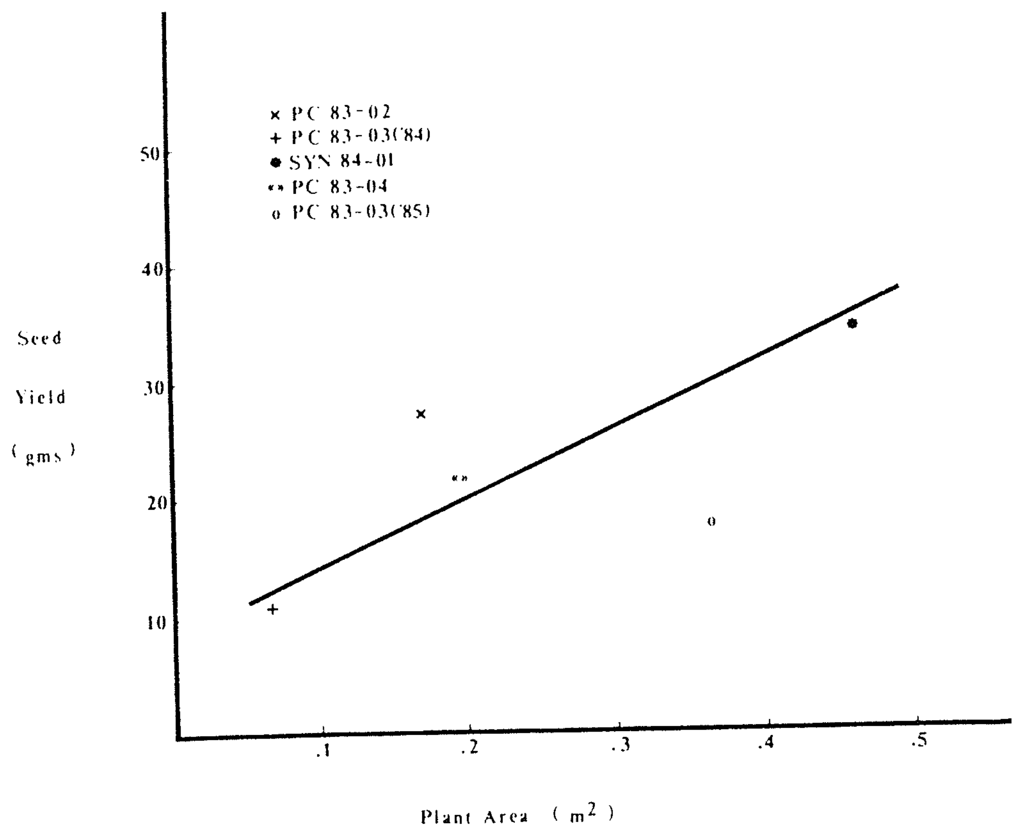

FIGURE 4. Seed yield per plant versus plant area in square m.

In general, the correlation coefficients between seed yield and plant area in 1984 were lower than in 1985, due in some part to the drier conditions in 1984.

Syn 84-01 had little open ground between plants, therefore, competition between and within plants for moisture and nutrients may have influenced the seed yield and plant area correlation and thus limiting the total seed production for the ground area covered. The results from Syn 84-01 may also indicate that the size of the clone may not be an important factor in a seed production field where there is little or no open ground.

Seed yield and the number of seedheads per plant were significantly correlated in all trials except Syn 84-01. However when clone 84-01-5 was removed from Syn 84-01 the analysis of the remaining clones gave a significant correlation with $r = .579$, with $p = .001$.

The range of significant r values for seed yield and the number seedheads were $r = .322$, with $p = .01$ for PC 83-02 to $r = .763$, with $p = .001$ for PC 83-03 1985 harvest, Table 18. Again the dry conditions of 1984 could have resulted in the lower r values because of increased competition for moisture.

The correlation coefficients for plant area and seed yield per cm^2 were negative when it was significant. The 1984 trials were the only ones to show significant r values. This result could again be due to the drier conditions of 1984.

The yield per cm^2 was higher for 1984 than for 1985, except for Syn 84-01. However this appears to be due to the plant area of the trials. Figure 5 shows the average seed yield per cm^2 of the trial versus the average plant area of the trials. There appears to be a negative effect of plant area on the seed yield per cm^2 of plant area. This seems to imply that if selection for seed yield per cm^2 was attempted, smaller clones would be favoured in a space-planted environment. Figure 4 shows the average seed yield per plant in the trial versus the average plant area of plants in the trial. This shows that seed yield is related to plant area, and therefore if selection from a spaced planted trial was made for seed yield per plant, the large plants would be favoured. The important factors missing here are the correlation of these factors to seed production in a seed production field. Further research is necessary in this area before effective selection is possible.

Plant area and seedheads per plant were positively correlated in all trials and significant in all trials except PC 83-02. The significant r values ranged from $r = .653$ to $r = .726$, with $p = .001$ for all r values. This appears to explain the relationship between seed yield and plant area in that the larger plants produce more reproductive tillers and thus seedheads.

Seed yield per cm^2 appears to be positively correlated with seedheads per cm^2 (Figure 6). However, an increase in the number of seedheads per cm^2 did not lead to an increase in seed yield as evidenced by the r values in Table 18 of which only PC 83-03 1985 harvest had a significant r value of .315 with $p = .01$. Therefore, the highest correlation value obtained only accounts for approximately 10% of the variation in seed

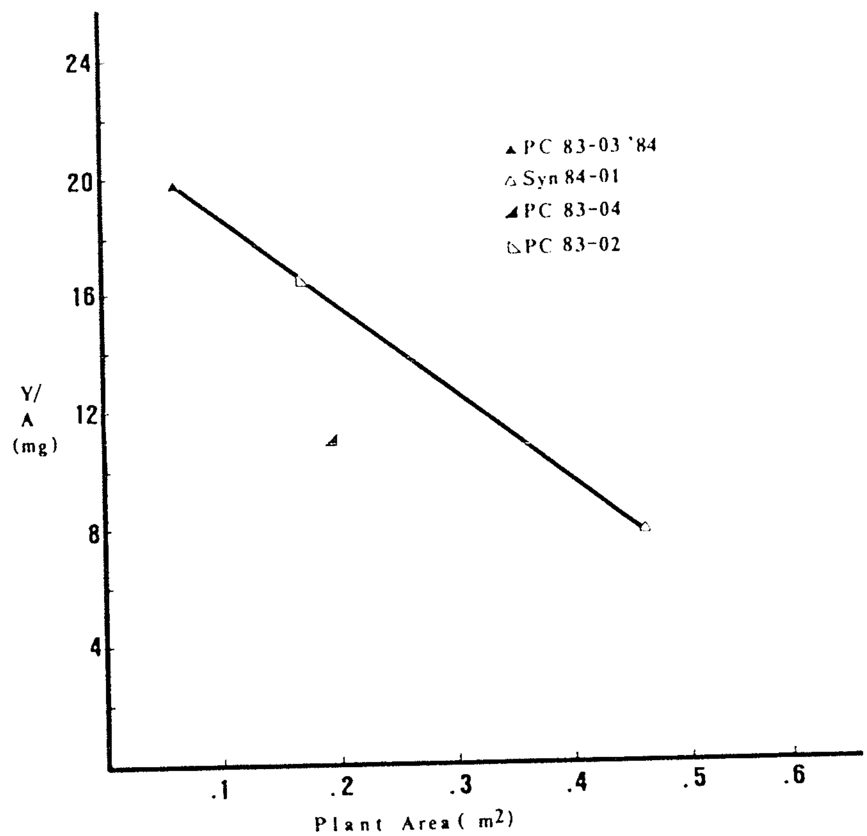

FIGURE 5. Seed yield per square cm versus plant area in square meters.

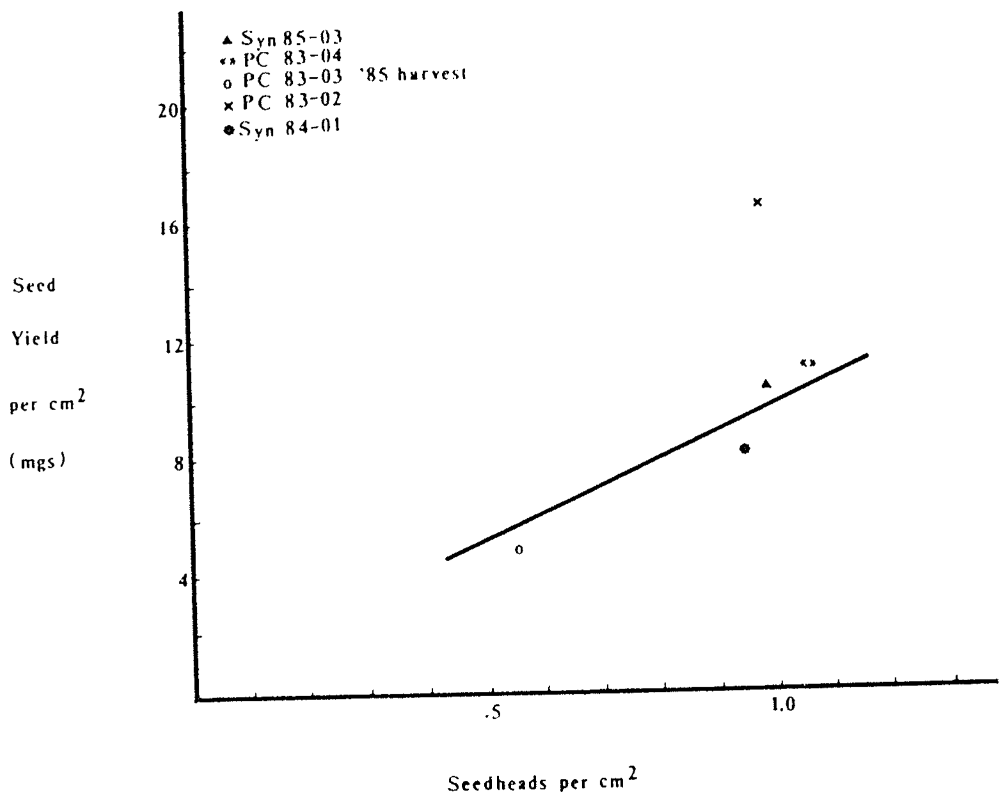

FIGURE 6. Seed yield per square cm versus seedheads per square cm.

yield per plant. The correlation coefficients for seed yield per cm^2 and seed yield per plant obtained are all positive and statistically significant, ranging form r = .293 with p = .05 for PC 83-03 1984 harvest to r = .757 with p = .001 for PC 83-02 (Table 18). In general, seed yield per cm^2 accounts for 25 - 50% of the variation in seed yield per plant and with Syn 84-01, the trial nearest full competition, r = .638 with p = .001 (Table 18), thus accounting for 40% of the variation.

Seed yield per seedhead was negatively correlated with seedheads per cm^2 for all trials with r values ranging from -.523 with p = .001 for PC 83-02 to -.755 with p = .001 for Syn 84-01 (Table 18). Again as competition increased, the correlation increased, with 57% of the variation in seed yield per seedhead being accounted for by the number of seedheads per cm^2 .

Yield per seedhead and seedheads per plant were also negatively correlated with r values ranging from -.381 with p = .01 for PC 83-04 to -.781 with p = .001 for Syn 84-01 (Table 18). This appears to imply that an increase in one component of yield, in this case in the number of seedheads per plant, results in a decrease in another component, yield per seedhead. The above are examples of seed yield component compensation as defined by Adams (1967). The compensation appears to take place due to developmentally induced relationships, such as the competition for a limited supply of nutrients by seedheads on a plant, as the number of seedheads per plant increases, the amount of nutrients available to each seedhead decreases, thus causing the compensation to take place (Adams 1967).

Another example of seed yield component compensation is the relationship between the number of seedheads per cm^2 and seeds per seedhead. The r values were consistent, ranging from r = -.526 with p = .001 for PC 83-04 to r = -.596 with p = .001 for Syn 84-01 (Table 18). These results appear to agree with those reported by Knott and Tulukdar (1971) who obtained a negative correlation between the number of seeds per seedhead and the number of spikes per plot.

Seed weight and seedheads per cm^2 were negatively correlated with a range of r = -.236 with p = .05 for PC 83-03 1985 harvest and r = -.547 with p = .001 for Syn 84-01 (Table 18).

Seed weight and seed yield per seedhead were positively correlated with r values ranging from r = .363 with p = .001 for PC 83-03 1985 harvest to r = .694 with p = .001 for Syn 84-01 (Table 18).

Yield per seedhead was highly correlated with seeds per seedhead with r values ranging from r = .857 with p = .001 for Syn 84-01 to r = .943 with p = .001 (Table 18). It appears that, while the seed weight does have some effect on the yield per seedhead, the number of seeds per seedhead has a greater effect on the yield per seedhead and that possibly only one of these characteristics needs to be measured.

A germination trial was done for PC 83-04 and this character was not found to be correlated to any of the other characters. Therefore, selection for seed size may not be important as it does not appear to confer a higher germination rate on the progeny.

Selection for seed yield in a space planted nursery should be based on plant area and the number of seedheads per plant. The C.V. of the trials are high and shows the need for more replicates the trials. With creeping bentgrass it is recommended that the number of replications be equal to or greater than the number of clonal entries in the trial (Olesen and Olesen 1973). Selection for the components of yield may not be too effective for two reasons: one, yield component compensation appears to be taking place and two, the importance of the characteristics in a seed production field have not been studied and therefore, a character that is important in a space-planted field may not be an important character in a broadcast seeded production field.

In a space-planted field plant area, seed yield per area and seedheads per plant have high correlation coefficients and appear to account for a high degree of the variation in seed yield (Table 18). These characteristics may not be important in seed production fields for, in the case of Syn 84-01 which is a seed production field near full competition, seed yield per cm^2 may be the charactistic to use as it had the largest correlation coefficient, accounting for approximately 40% of the variation in seed yield per plant.

Synthetic 85-03

Synthetic (Syn) 85-03 was initiated in part to look at the feasibility of using the greenhouse and/or growthroom to produce small quantities of seed. At least 10 grams of seed per clone would be needed to allow for turf and seed production progeny testing.

The growthroom test produced enough seed of clone 85-03-3 from 5 plants to allow the testing mentioned above. The other two clones, 85-03-2 and 85-03-4 would have needed 10 plants of each clone to produce enough seed for progeny testing. With the progeny from such a program ready for transplanting to the field by mid-August, this could benefit our breeding program by giving us progeny testing data one year earlier than if field work only is utilized.

The lack of success of utilizing the vernalization chamber makes the use of natural vernalization in the field a necessity. This only allows the use of the controlled environment chambers as an aid to breeding in the field and not an alternative. Therefore, an effective vernalization program needs to be worked out to allow for a significant speeding up of the breeding program by allowing for breeding to be done on a year round basis and allowing for possibly two generations in one year.

Yield and Yield Components for PC 85-03

The plant area was the same for all plants used in this study, therefore, we have removed one factor that had greatly influenced the seed yield in the field studies.

The correlations between seed yield and seed yield components can be found in Table 19.

Comparing the correlation coefficients between the greenhouse and growthroom locations, the direction of the correlations are the same but the magnitudes are different.

TABLE 19

Synthetic 85-03: Correlation coefficients (r) between seed yield (Y), seedheads/plant (SH), number of seeds in ten mg (STM), yield/seedhead (YSH) and seeds/seedhead (SSH).

		SH	STM	SSH	YSH
Y	GH$	.72**	-.69**	.10	.09
	GR	.92***	-.10	.02	.01
SH	GH		-.61*	-.53*	-.46
	GR		-.28	-.31	-.32
STM	GH			.34	.11
	GR			.70**	.51*
SSH	GH				.96***
	GR				.95***

$ - GH = Greenhouse, GR = Growthroom
*,**,*** P(r) = 0 of .05, .01, .001 respectively.

In the growthroom, the yield per seedhead and seeds per seedhead were significantly correlated to the number of seeds in ten mg of seed with r = .51 with p = .05 and .70 with p = .01 respectively. This shows as the number of seeds per seedhead and yield per seedhead increases, the smaller the seeds are by weight as there are more in 10 mg.

In the greenhouse, seed yield and seedheads per plant were negatively correlated with the number of seeds in 10 mg with r = -.69 with p = .01 and r = -.61 with p = .01 respectively. Therefore, as the seed weight decreased, the yield decreased. Also, as the seedheads per plant increased, there was an increase in seed weight. The number of seedheads was not statistically different between the two locations (Table 20), however, the seed yield of the growthroom plants was eight times as much as those in the greenhouse. The growthroom plants had approximately five times the number of seeds per seedhead (Table 20). Therefore, there should have been less competition between seeds in a seedhead for nutrients needed for seed fill and seed set in the greenhouse,and therefore, a higher seedweight expected. It is also possible that as the number of seeds per seedhead in the greenhouse was so low that an increase in the number of developing seeds in a seedhead increased the seedheads capacity as a sink, allowing the seedhead to draw in the needed nutrients.

The poor seed set and seed yield in the greenhouse was probably due to two factors, the fluctuation of temperatures in the greenhouse, and less air movement, therefore less pollination, fertilization and ultimately seed production. Therefore, because of the controlled temperatures, less heat stress and the increased air movement in the growthroom, it appears to be a good tool for the production of limited amounts of seed of creeping bentgrass.

Table 20 shows a comparison of the two environments as to seed yield and its components. Only seedheads per plant and therefore seedheads per cm^2 are statistically the same for both locations.

There were significant interactions between the environments and the clones and this was due to the relative performance of clones 85-03-2 and 85-03-4 in the different environments. Clone 85-03-2 did better than 85-03-4 in the growthroom and the opposite was true in the greenhouse. Clone 85-03-3 was the best seed yielder in both environments.

The results of this trial (Table 20) would point to the use of the growthroom, with its higher degree of environmental control, to be a possible site for seed production. The greenhouse, because of its wider range of temperatures, was less effective than the growthroom.

TABLE 20

Synthetic 85-03: Seed yield and seed yield components for the growthroom and greenhouse.

Character	Greenhouse	Growthroom
Seedheads/ Plant	64.4a*	86.0a
Seed Yield (mgs)	105.9b*	910.9a
Seeds in Ten mg	119.1a*	101.7b
Seeds per Seedhead	24.3b*	114.3a
Yield (mg)/ Seedhead	2.0b*	11.4a
Yield (mg)/ cm^2	1.2b*	10.5a
Seedheads/ cm^2	.743a*	.993a

* Means followed by different letters are significantly different at alpha = .05 using LSD.

PC 83-02 Progeny Tests

The analysis of the data from the collected clippings showed no significant differences between "Penncross" and the progeny lines for fresh weight, dry weight or percent dry weight (Table 21). The mean fresh and dry weights for March 25 were 150% those of March 19, however the percentage dry weights are equal. Therefore, there appears to be little difference between lines for percent dry weight.

Table 22 shows the correlation coefficients for the three characters measured. For both dates, fresh weight and dry weight were highly correlated with $r = .914$ and $.955$ with $p = .001$ for March 19 and March 25 respectively. Fresh weight and percent dry weight were negatively correlated with $r = -.520$ and $-.649$ with $p = .001$ for March 19 and 25 respectively. On March 25, the correlation coefficient between dry weight and percent dry weight was $-.407$ with $p = .01$. The r value for March 19 was $-.145$ and was not statistically significant. Therefore it appears that as fresh weight increases, the percent dry weight decreases and the fresh weight increase is due to increased water uptake.

PC 83-02 Progeny Turf Trials

All of the progeny lines rated equal to or better than "Penncross" for colour and density in the establishment year (Appendices 8,9). However, as this is promising, more data is needed before selections can be properly made.

The colour ratings showed significant differences, with "Penncross" being in the lowest group. The colour ratings for the last two rating

TABLE 21

PC 83-02 Progeny Test: Fresh weight (FRW), Dry weight (DRW) and percentage dry weight (PDW) of clippings collected on March 19 and 25.

Lines	March 19 FRW (gms)	March 19 DRW (gms)	March 19 PDW	March 25 FRW (gms)	March 25 DRW (gms)	March 25 PDW
Penncross	22.8	2.94	13.0	31.6	4.08	13.3
82-15	23.3	2.87	12.3	35.8	4.45	12.4
82-08	21.1	2.74	13.2	35.2	4.52	12.8
82-20	20.9	2.63	12.6	29.1	3.70	12.9
82-29	24.9	3.21	12.9	31.0	4.00	13.0
82-27	19.1	2.70	14.2	30.2	4.07	13.5
82-09	18.3	2.45	13.4	32.7	4.36	13.4
82-17	21.1	2.76	13.1	31.4	3.96	12.6
82-26	20.6	2.67	13.0	36.0	4.64	12.9
82-06	17.7	2.35	13.6	27.3	3.60	13.2
Mean	21.1	2.74	13.1	32.0	4.14	13.0

TABLE 22

Correlation coefficients for fresh weight, dry weight and percent dry weight for March 19 and 25 for PC 83-02 progeny.

		Fresh Weight	Dry Weight
Percent	1.$	-.649**	-.407*
Dry Weight	2.	-.520**	-.145
Fresh	1.		.955**
Weight	2.		.914**

$ = 1. March 25, 2. March 19.
*,** = P(r) = 0 being < .01 and .001 respectively.

dates showed that the transplanted trial had lower colour ratings. These plots appeared to contract more leaf diseases in the fall and this could have influenced the ratings.

Two composite lines from PC 83-02 were formulated in part to see if clones that rated similarily in the 1982 Creeping Bentgrass Turf Test would be compatible in a synthetic. Syn 85-01 consisting of the progeny of 82-17, 82-27 and 82-29 and Syn 85-02 consisting of the progeny of 82-08, 82-09 and 82-26 were put into the 1985 U of M Creeping Bentgrass Cultivar Trial. The results (Table 23) are from the U of M Turfgrass Research Report (Clark and Bamford 1986). This trial is also encouraging with the good performance of the U of M lines being better than or equal to the licensed varieties. However this is again only establishment year data and at least two more years of trials is needed.

TABLE 23

The 1985 Creeping Bentgrass Cultivar Trial (Clark and Bamford 1986).

1985 Data

Quality 1 - 9 (9 best)

Cultivar	Sept.24	Oct.22	Mean
Syn85-01	8.50	7.13	7.81a*
UM67-10	8.75	6.87	7.81a
Syn84-01	8.63	6.63	7.63ab
Syn85-02	7.63	6.88	7.25bc
Penncross	7.25	6.63	6.94c
Emerald	5.88	5.50	5.69d

Colour 1 - 9 (9 best)

	Aug.19	Sept.24	Oct.22	Mean
UM67-10	8.88	9.00	7.00	8.29a*
Syn84-01	8.50	8.63	6.63	7.92b
Syn85-01	7.75	8.13	7.13	7.67b
Syn85-02	7.38	7.63	7.00	7.33c
Penncross	6.88	7.00	6.88	6.92d
Emerald	5.88	6.13	5.25	5.75e

Density 1 - 9 (9 best)

	Aug.19	Sept.24	Oct.22	Mean
Syn85-01	7.63	8.88	8.75	8.42a*
UM67-10	7.50	8.75	8.75	8.33a
Syn84-01	7.50	8.75	8.63	8.29a
Syn85-02	7.25	8.38	8.38	8.00b
Penncross	6.63	7.88	7.75	7.42c
Emerald	5.63	6.50	6.50	6.21d

* Means with the same letter are not statistically different using Duncan's Multiple Range Test with alpha = .05.

Albino Counts

Table 24 shows the mean percentage albinos per line and a comparison of the means for PC 83-02 Progeny Test. The lines 82-06, 82-20, 82-26 and 82-29 all have relatively high percentages. All other lines showed .05% or less albinos and probably have no heterozygous loci the same as any of the other clones in PC 83-02.

Table 25 shows the results of the reciprocal crosses between 82-06 and 82-20 and their respective Chi-Square results. The data appears to fit a 3 : 1 ratio of green : albino plants. This would suggest a 1 gene difference governing albinism in this set of crosses.

Table 25 also contains the results of the progeny of the F_1 . Less than half of the progeny headed out and only 9 had greater than 10 seeds germinate. From this data, the selection of three progeny lines was made for further study, these being 20 x 06-31 and 20 x 06-33, both being heterozygous and 20 x 06-2, being homozygous.

The F_2 population is not large enough to make a definite statement as to whether the data fits the 2 : 1 hypothesis.

The backcrossing of the selected progeny to the parents would give definite proof of the genetic relationship between the parents. These plants are being asexually propagated for a backcrossing program.

TABLE 24

Percentage of albinos in Polycross 83-02 progeny.

Line	Percentage Albinos
82-06	4.06a*
82-20	2.76b
82-26	1.90c
82-29	1.19d
Penncross	0.05e
82-27	0.02e
82-09	0.01e
82-15	0.00e
82-17	0.00e
82-08	0.00e

* Means followed by the same letter are not statistically different using Duncan's Multiple Range Test with alpha = .05.

TABLE 25

U of M 82-06 x 82-20 and the reciprocal cross, F_1 and F_2 progeny, and Chi-Square results.

F_1

Cross	Seeds Germinated	# of Albinos	Chi-Square P (3 : 1)
82-06 x 82-20	70	12	.1-.25
82-20 x 82-06	26	6	.75-.9
Combined	96	18	.1-.25

F_2

Progeny	Seeds Germinated/# of Albinos	Classification
20 x 06-32	18 / 1	heterozygous
20 x 06-29	15 / 2	"
20 x 06-33	75 / 7	"
20 x 06-31	73 / 6	"
20 x 06-21	13 / 1	"
20 x 06-15	10 / 1	"
20 x 06-2	24 / 0	homozygous
20 x 06-17	12 / 0	"
20 x 06-8	11 / 0	"

Expected 2 heterozygous : 1 homozygous

P(Chi-Square Result) = 1.00

Wear Effects on a Creeping Bentgrass Turf

Dry Weight

Dry weight measurements showed significant differences between clones on all dates, however on August 2 there were very few significant differences between the clones. The clones 82-21, 82-12 and 82-08 were in the statistically highest group on all dates while 82-15 was in the lowest group on all dates (Table 26). The mean dry weight per clone showed little fluctuation between the measurement dates. Clone 82-23 was the only clone to show a large difference in values between dates with a difference of 16.7 mg between the July 12 and June 28 means.

A significant difference between the wear and no wear treatment was obtained for the June 28 and July 12 measurements (Table 26). In general, the wear treatment decreased the dry weight production of the clones. The August 2 measurements also showed that the worn plots had less dry weight than the non-worn plots, however the difference was not statistically significant. These results agree with the results of Kohlmeier and Eggens (1983).

Tiller Number

The only significant differences in tiller number were between clones on all dates (Table 27). There were no significant differences between wear treatments, however, the non-worn treatment had a higher mean on all dates.

The mean tiller counts for June 28, July 12 and August 2 were 53.9, 60.1 and 60.1 respectively. Clones 82-08, 82-09, 82-12, 82-23 and 82-29

TABLE 26

Effects of wear on dry weight in mg, and the effect of the wear treatments for measurements taken on June 28, July 19 and August 2.

	Dry Weight (mg)		
	Date		
Clone	June 28	July 12	August 2
82-21	71.5a*	63.0a*	67.0a*
82-12	63.5ab	60.2abc	58.5ab
82-08	61.3abc	64.5a	60.2ab
82-09	56.7bcd	56.0abcd	60.5ab
82-29	56.2bcd	63.5a	59.2ab
82-13	53.8bcd	51.0cd	50.3bc
82-05	53.3bcd	51.8bcd	53.3bc
82-02	50.3cde	55.0abcd	54.3bc
82-23	45.5de	61.2ab	53.3bc
82-15	40.3e	49.7d	46.0c
Mean	55.3	57.6	56.3

Treatment	June 28	July 12	August 2
Not Worn	60.17a*	63.40a*	60.87a*
Worn	50.33b	51.77b	51.67a

* Means followed by the same letter are not statistically different using Duncan's Multiple Range Test with alpha = .05.

TABLE 27

Tiller counts of the clones for June 28, July 12 and August 2.

Clone	June 28	July 12	August 2
		Date	
82-08	69.2a*	71.0b*	72.0a*
82-29	68.3a	85.0a	71.8a
82-09	66.7a	62.0bcd	73.8a
82-12	62.0ab	64.3bc	60.8bc
82-23	61.2ab	67.2b	64.7ab
82-21	56.0b	54.2cd	61.3bc
82-13	43.3c	51.8de	53.5cd
82-02	41.3cd	53.5cd	55.0bcd
82-15	37.7cd	51.0de	45.2e
82-05	33.5d	40.7e	48.2de
Mean	53.9	60.1	60.1

Treatment	June 28	July 12	August 2
Not-Worn	55.10a*	61.13a*	62.57a*
Worn	52.73a	59.00a	57.47a

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

each were in the significantly higher groups for all dates while 82-05, 82-15, 82-13 and 82-02 were in the significantly lower groups (Table 27).

The worn treatment had lower mean tiller counts on all dates than the non-worn treatment but the differences were small and were non-significant (Table 27).

Dry Weight per Tiller

There were significant differences in the dry weight per tiller between clones on July 12 and August 2, between wear treatments on July 12 and there was a significant interaction between clones and wear treatment on June 28 for dry weight per tiller (Table 28).

On July 12, clone 82-05 was significantly higher for dry weight per tiller than all the other clones except 82-21. Clone 82-29 was significantly lower for dry weight per tiller than the other clones except 82-08, 82-09 and 82-23 (Table 28).

Figure 7 shows the worn and the non-worn measurements for each clone for June 28. The interaction between the clones and wear treatment is best illustrated by comparing clones 82-13 and 82-21, which showed increases of 15.5% and 8.9% in dry weight per tiller respectively from the non-worn to the worn treatments, to 82-05 and 82-12 which showed decreases of 34.5% and 24.1% respectively. One observation that was made on June 28 was the presence or absence of seed culms in the turf plots. The non-worn plots had more seed culms than the worn plots. This could be the result of a build up of thatch in the non-worn plots,

TABLE 28

Dry weight per tiller for clones and wear treatment for July 12 and August 2.

Clone	Dry Weight per Tiller (mgs) July 12	Dry Weight per Tiller (mgs) August 2
82-05	1.28a*	1.19a*
82-21	1.17ab	1.11ab
82-02	1.04bc	0.99abc
82-13	1.00c	0.94bc
82-15	0.98c	1.10ab
82-12	0.95c	0.98abc
82-08	0.92cd	0.84c
82-09	0.91cd	0.82c
82-23	0.91cd	0.96abc
82-29	0.76d	0.83c
Mean	0.99	0.98

Treatment	July 12	August 2
Worn	0.904a*	0.953a*
Non-Worn	1.080b	0.998a

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

allowing the seed culms to be pressed into the turf and thatch and escape clipping.

Number of Leaves

On July 12 the only significant difference found in leaf number was between clones (Table 29), however there was a trend towards less leaves with the worn treatment. On August 2 there was a significant interaction between clones and wear treatments at the .05 level.

On July 12, clone 82-29 was significantly higher for leaf number, with 242.3 leaves per 2.5 cm in diameter plug, than all the other clones while clone 82-05 was significantly lower than the other clones, with 108.7 leaves per plug, except for 82-15 (Table 29).

Figure 8 shows the interaction between the clones and wear treatments for August 2. Clones 82-13 and 82-08 had an increase of 2.5% and 0.2% in leaf number respectively while 82-12, 82-29, 82-15, 82-21 and 82-23 had decreases in leaf number of 27.1%, 26.9%, 24.5%, 23.9% and 21.1% respectively, from the non-worn to the worn treatment. All clones decreased in the visual density rating on August 2 from the non-worn to the worn plots, however, 82-08, 82-13 and 82-02 had the smallest decreases. Clone 82-12 had the largest decrease in the visual density rating between the non-worn and the worn plots.

Number of Leaves per Tiller

There were no significant differences in the number of leaves per tiller for either clones or wear treatments (Table 30). The worn

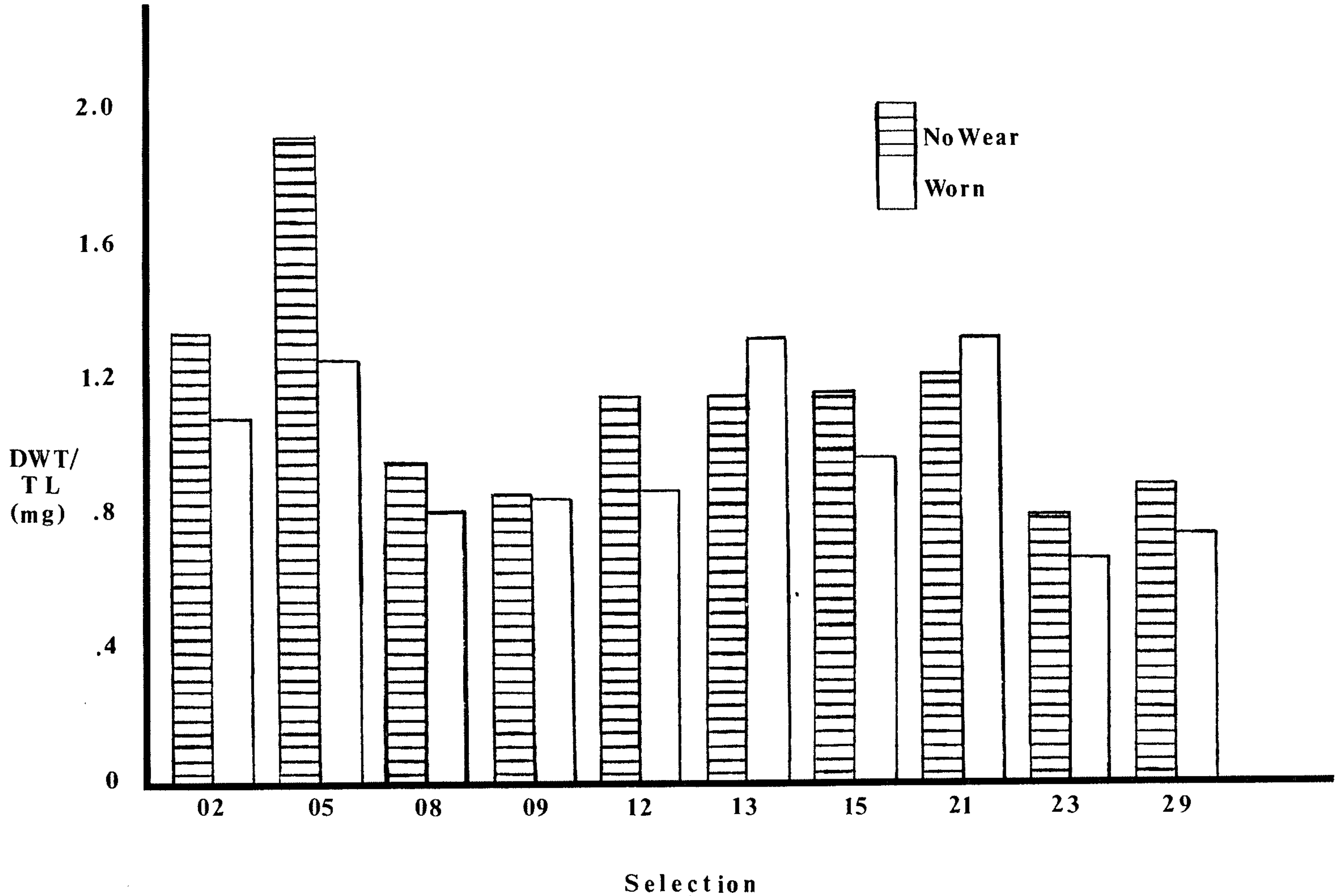

Figure 7. A comparison between worn and non-worn plots for dry weight/tiller for June 28.

TABLE 29

Leaf number for clones and wear treatment measured on July 12.

Clone	Leaf Number
82-29	243.2a*
82-08	198.8b
82-23	191.2bc
82-09	184.3bcd
82-12	168.0bcde
82-21	165.7bcde
82-02	157.5cde
82-13	148.3de
82-15	135.5ef
82-05	108.7f
Mean	170.1

Treatment	July 12
Not-Worn	179.9a*
Worn	160.6a

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

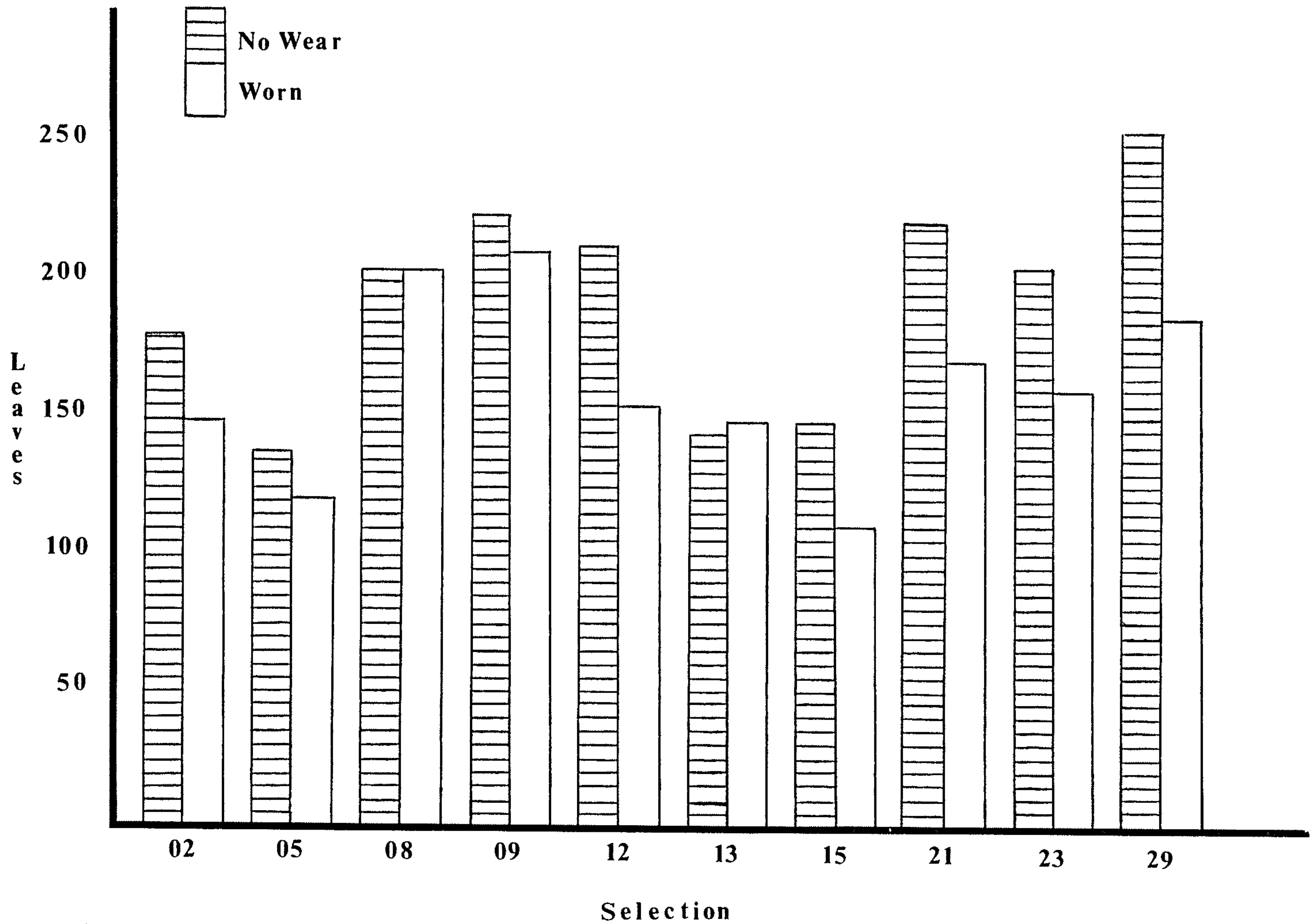

Figure 8. A comparison between worn and non-worn plots for leaf number for August 2.

treatment had a lower number of leaves per tiller on both dates, but they were not statistically different.

The number of leaves per tiller was the only character that did not show a significant difference between clones (Table 30). However, the F value for Wear had P = < .10 for both dates that this was measured. Because of this relative stability, the number of leaves per tiller may be species dependent.

This trend, resulting in a lower number of leaves per tiller under the wear treatment, could be due to the shredding and puncturing of the leaf blade by the spikes, thus causing the damaged leaves to brown-off and therefore not be counted.

Visual Density Rating

The density ratings were the easiest to obtain as they were visual. There were significant differences between clones for all dates and between wear treatments for the last two dates (Table 30).

The worn treatment rated lower on all dates, indicating that there were at least visual differences in density between the worn and non-worn. The non-worn rated close to or just above one rating point higher than the worn plots.

Clones 82-29, 82-09 and 82-08 were in the highest rated group for all dates while clones 82-05 and 82-15 were in the lowest rated group for all dates. Because of the lack of an statistically significant interaction between the clones and the wear, it would appear that all of

TABLE 30

Number of leaves per tiller as measured on July 12 and August 2, 1985.

	Number of Leaves per Tiller	
Clone	July 12	August 2
82-21	3.07a*	3.20a*
82-09	2.99a	2.95a
82-02	2.93a	3.02a
82-13	2.90a	2.76a
82-23	2.87a	2.82a
82-29	2.87a	3.06a
82-08	2.81a	2.85a
82-05	2.67a	2.88a
82-15	2.67a	3.09a
82-12	2.63a	3.04a
Treatment	July 12	August 2
Not Worn	2.96a*	3.11a*
Worn	2.72a	2.82a
Mean	2.84	2.96

* Means followed by the same letter are not significantly different using Duncans Multiple Range Test with alpha = .05.

TABLE 31

Visual density rating: Comparision of clones and worn and not-worn treatments for June 28, July 12 and August 2.

	Visual Density Rating		
	Date		
Clone	June 28	July 12	August 2
82-29	8.67a*	8.50a*	8.33ab*
82-09	8.00a	8.17ab	8.33ab
82-23	8.00a	7.50bc	7.17de
82-12	8.00a	8.00ab	8.00bc
82-08	7.83ab	8.00ab	8.67a
82-21	7.00bc	7.83ab	7.83bc
82-13	6.67cd	6.33de	7.00ef
82-02	6.67cd	6.83cd	7.67cd
82-05	6.17cd	5.67e	6.00g
82-15	5.83d	5.67e	6.50fg
Mean	7.28	7.35	7.55

Treatment	June 28	July 12	August 2
Not Worn	7.77a*	7.83a*	8.13a*
Worn	6.80a	6.87b	6.97b

* Means followed by the same letter are not statistically different using Duncan's Multiple Range Test with alpha = .05.

the clones showed a decrease in visual density from the non-worn to the worn. This seems to indicate that either wear treatment is unnecessary as all the clones responded in a similar fashion, that not enough clones were included in the experiment to see different responses to wear, or that the duration of the trial was not sufficient to see the differential responses to wear. The visual perception of density appears to show that it is not necessarily a decline in the density of the worn plots, but an increase in the density of the non-worn plots over the summer which results in the statistical differences. The increase in the non-worn plots was also seen in 1984 with the means for the 1982 Selections Turf Trial being 6.875 on June 29, 7.073 on July 20 and peaking at 7.438 on August 13 (Appendix 10).

Correlation Coefficients from the Wear Test

Dry weight was positively correlated with the visual density on all dates with r = .363*, .631*** and .605*** for June 28, July 12 and August 2 respectively (Table 32). The estimation of dry matter appears to be a part of the visual density rating. The average dry weight of the clones appears to be relatively constant across all dates demonstrating an even growth throughout the experiment (Table 26).

The correlation coefficients for tiller number and visual density rating were r = .715***, .665*** and .630*** for June 28, July 12 and August 2 respectively (Table 32). This indicates that tiller number is an important component of the visual density rating and therefore those plots with a greater number of tillers, in general, rated higher for visual density.

TABLE 32

Correlation coefficients for dry weight (DRW), tiller number (TILL), DRW/tiller (DRWTL), leaf number (LVS), leaves/tiller (LVTL) and visual density rating (DEN) for June 28, July 12 and August 2.

		TILL	DRWTL	LVS	LVTL	DEN$
DRW	JN28	.416***	.385**	-	-	.363*
	JL12	.558***	.213	.642***	.272*	.631***
	AU02	.579***	.116	.619***	.719***	.605***
TILL	JN28		-.641***	-	-	.715***
	JL12		-.661***	.902***	-.096	.665***
	AU02		-.619***	.903***	-.108	.630***
DRWTL	JN28			-	-	-.391**
	JL12			-.472***	.357**	-.190*
	AU02			-.423***	.369**	-.259*
LVS	JL12				.328*	.669***
	AU02				.319*	.794***
LVTL	JL12					.157*
	AU02					.475***

*,**,*** = P(r) = 0, alpha = .05, .01, .001 respectively.
$ = Spearman's correlation coefficient used.

Dry weight per tiller showed a small, but consistent negative correlation with the visual density rating on all dates. The r values were -.391**, -.190* and -.259* for June 28, July 12 and August 2 respectively (Table 32). This may be due to the negative correlation between tiller number and dry weight per tiller (Table 32). This appears to indicate that there is competition within the turf between the production of tillers and increasing the weight of the existing tillers.

The negative correlation between dry weight per tiller and visual density rating, although small, could be the visual discernment of larger tillers and assigning these a lower visual density score. This also could be the result of accepting a lot of small spaces in the turf versus a few large spaces.

The correlation coefficients for the number of leaves and the visual density rating were r = .669*** and .794*** for July 12 and August 2 respectively (Table 32). Therefore the number of leaves in a plot positively influenced the perception of density.

The correlation coefficients for leaves per tiller and density were r = .157* and .475*** for July 12 and August 2 respectively (Table 32).

There was a high correlation between the tiller number and the number of leaves with r = .904*** and .903*** for July 12 and August 2 respectively (Table 32). The relative consistency of the number of leaves per tiller is expected considering the relationship between leaf number and tiller number. The positive correlation between tillers and dry weight and the small and nonsignificant correlation between dry weight and dry weight per tiller (Table 32) appears to show that the dry weight per tiller is dependent upon on the number of tillers present.

One observation that should be noted is that at the end of the 1985 growing season, the non-worn plots were approximately 3/8" higher above the soil surface than the worn plots. There are at least two factors involved here, one, the compaction of the turf and thatch by the roller and two, the greater production of dry matter by the non-worn plots. Kohlmeier and Eggens (1983) had higher clipping weights with the non-worn plots which appears to agree with our results.

The relatively high r values for visual density ratings and dry weight, visual density ratings and tiller number, and leaf number and visual density ratings, indicate that the visual density ratings can be effective in selecting clones for further testing. It must be noted that where visual density ratings are used, the characteristics being included by the evaluator in the rating should be defined in the reporting of the visual ratings. Horst et al (1984) did not give the criteria used by the individual evaluators in rating the turfgrasses and therefore, the differences in rating may have been the result of differing opinions of what density is or what type of density they were evaluating. For example, was density of the plant or the density of plants in the turf or the amount of bare ground or a combination of the above being rated.

One recommendation that is implicated in the work done by Horst et al (1984) is the need for one trained evaluator to do all the visual ratings for a trial. This would, hopefully, ensure at least a uniform treatment (i.e. visual rating) of all plots for the trial, thus avoiding error based on differing conceptions of the components of the visual rating.

Turf Visual Ratings and the Effects of Wear

Colour Ratings

There were no significant differences between the worn and the non-worn treatments for any rating date except July 19. There were significant wear by clone interactions on August 30 and September 28 however the October 21 ratings had only clonal differences. All rating dates had clonal differences.

In general, the non-worn plots rated higher for colour and the comparison of means for July 19 demonstrates this. The reason for this could be the shredding and puncturing of the leaves thus resulting in senesence and a partial browning in the plot or there is less green material as shown by the dry weights in the Wear Section, (Table 26), and therefore a lower rating.

There were significant interactions between wear and colour on August 30 and September 28. These interactions are the ability of some of the clones to maintain their colour under the wear treatment while others did not. As this interaction was not seen at the last rating date, this could be due to environmental effects at the late summer-early fall ratings. Further study will be needed to see what the controlling factor(s) are and should include quantitative measurements of the colour.

The colour ratings will be used in the selection and formation of synthetics. Table 33 shows the colour ratings for 1984 for clones 82-01, 82-17, 82-27 and 82-29. The Duncan Multiple Range Test shows that none of these clones are significantly different in visual colour, except for the first date and therefore, depending upon other factors as well, could be used in the formation of a synthetic.

Appendices 10 and 12 contain the colour ratings for all clones for 1984 and 1985 respectively.

Based on the colour ratings only three clones will not be recommended for further testing and these are clones 82-13, 82-14 and 82-15 as one of our selection criteria is for a darker green colour than the available cultivars.

Density Ratings

The density ratings for 1984 and 1985 can be found in Appendices 11 and 13.

There were significant differences between clones on all dates and there were significant differences between wear treatments on June 20, July 19, September 28 and October 21 (Table 34). There was no clone by wear interaction on any of the ratings dates. The worn treatment was always lower than the non-worn treatment for density ratings.

The use of wear as a selection tool is not yet recommended because of the above mentioned lack of an interaction and continued testing is needed. It would appear that those clones that perform well under the wear pressure are the ones that perform well in a no wear situation.

TABLE 33

The Visual Colour Ratings for 1984 for Clones 82-01, 82-17, 82-27 and 82-29.

Clone	May 25	June 29	July 20	Aug. 13	Sept. 14
82-01	6.50hijk*	8.00bcd*	8.33ab*	8.17ab*	8.67ab*
82-17	8.17abc	7.83cde	8.00bcd	7.83bcd	8.33abc
82-27	8.67ab	8.67ab	8.33ab	7.83bcd	8.33abc
82-29	7.33defg	8.00bcd	7.83bcde	7.83bcd	8.67ab

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

TABLE 34

Comparison of wear and no wear for the 1982 creeping bentgrass selections turf trial for the visual density ratings for 1985.

Treatment	Non-Worn	Worn
Date		
June 20	7.88a*	6.96b
July 19	8.21a*	7.49b
August 16	7.32a*	6.52a
September 28	8.11a*	6.56b
October 21	8.19a*	6.91b

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Based on the density ratings, only those which performed as well as or better than "Penncross" are being recommended for further testing. These clones are 82-01, 82-07, 82-08, 82-09, 82-12, 82-17, 82-18, 82-19, 82-23 to 82-29 for a total of 15 clones. As well, clone 82-03 is not being discarded but it will be progeny tested with the rest of PC 83-04 in 1986. The results of this test will determine its future use in the breeding program.

1982 Selections Spaced Planted Trial

Stolon Length

Table 35 shows the mean stolon lengths and a comparison of means. In general, those clones rejected from further study had longer stolons than those which have been recommended for further study. Exceptions to the above are clones 82-10, 82-20 and 82-21 which are at the shorter end of the scale. This appears to show that those clones that creep with long stolons tend to make a less dense turf. The correlation coefficient for mean turf density and stolon length is $r = -.417$ with $P(r = 0) = .02$.

Flowering Dates

Table 36 shows the relative flowering dates for the 1982 selections in 1984. This is the first trial to have all of the selections at the same location in the same year and the plants being of the approximate same age. This information will be important in the formulation of synthetics to be made up from these selections. Because of the

TABLE 35

The 1982 selections space plant trial stolon length measured on August 17, 1984.

Clones	Stolon Length (cm)
82-16	34.333a*
82-12	33.771a
82-22	30.771b
Penncross	30.208b
82-15	30.125b
82-06	29.250bc
82-05	28.958bc
Emerald	28.500bcd
82-13	26.958cde
82-19	26.271de
82-02	25.479ef
82-11	24.917ef
82-04	23.229fg
82-28	22.375gh
82-21	22.292gh
82-20	21.958gh
82-23	21.375ghi
82-31	21.354ghi
82-24	21.146ghi
82-29	20.771ghi
82-17	20.250hij
82-27	20.167hij
82-01	19.813hij
82-25	19.667hij
82-14	19.042ijk
82-30	18.104jkl
82-18	17.989jkl
82-08	17.021klm
82-07	16.917klm
82-26	16.313lm
82-09	15.271m
82-10	11.375n

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

overlapping of the flowering periods, early and medium and medium and late combinations could probably be used without being too detrimental to seed production. However, with the experience gained from the polycrosses in this study, it would have to be recommended that early and late clones should not be used in the same synthetic.

The polycrosses did give some conflicting flowering dates when compared to the above trial. In PC 83-02, clones 82-27 and 82-29 were about a week earlier than 82-15 however in this trial they were approximately the same with all three being late.

This proves to be difficult to reconcile unless different environments caused the differences with the plants for the 1982 selections spaced plant trial being maintained as a golf green in 1983. This could, therefore, have an effect on the flowering dates shown in Table 36.

The selections that have been kept will be put out in a replicated trial to look at relative flowering dates and to be used as a polycross.

TABLE 36

The 1982 creeping bentgrass selections relative flowering times in 1984.

Clone	Flowering Time
82-01	Early
82-02	Early
82-04	Medium
82-05	Late
82-06	Early
82-07	Late
82-08	Late
82-09	Medium
82-10	Late
82-11	Late
82-12	Late
82-13	Early
82-14	Early
82-15	Late
82-16	Late
82-17	Medium
82-18	Medium
82-19	Medium
82-20	Early
82-21	Early
82-22	Late
82-23	Early
82-24	Late
82-25	Medium
82-26	Late
82-27	Late
82-28	Late
82-29	Late
82-30	Medium
82-31	Early

Spaced Plants and Turf Correlations

The spaced plants were rated for colour and density to ascertain the effectiveness of visual selection for these characters from a space-planted nursery.

Table 37 shows the correlation coefficients for May 25, June 29, August 13, October 5, 1984 and all dates combined for colour. The r values for the year combined is r = .553 with p = .001. However, when looking at the individual dates, there is a steady decline in the correlation coefficients as the year progresses. The May correlation coefficient is r = .871 with p = .001 while on October 5 it was r = .253 and was not significant. These results appear to suggest that selection for colour on space plants would be best achieved in the late spring. The effects of seedhead production, irrigation, mowing and fertilization are most likely the factors which cause the difference between the turf and the space plants.

Table 37 shows the density correlations for August 17 and October 5 1984 and the two dates combined.

The combination of the two dates and the August 17 rating did not give significant r values. The October 5 rating had an r value of r = .563 with p = .001. Here, the optimum time for density selection may be in the fall. However, as stolon length appears to also be a character that can be used for density estimation and can be quantitatively measured, it may be more valuable.

TABLE 37

Correlation coefficients for the 1982 creeping bentgrass selections turf and space planted trials for visual colour and density ratings for 1984.

	May 25	June 29	Aug. 17	Oct. 05	Combined
Colour	.871**	.600**	.419*	.253	.553**
Density	-	-	.086	.563**	.240

*,** = P(r=0) of .05 and .001 respectively.

SUMMARY AND CONCLUSIONS

The selection of creeping bentgrass from a space planted nursery was successful in identifying clones with visual colour and density equal to or better than two commercially available cultivars. It appears that spring and early fall are the best times to make the selections.

A plant that creeps with relatively short stolons and has upright leaves appears to be the best turf type. A plant that creeps extensively by long stolons and increases the ground area that it covers relatively quickly appears to be the best for seed production.

In general, as the area of the plant increases, the seed yield per unit of plant area decreases, as the seedheads per unit of plant area increases, the seed yield per unit of plant area increases, and as the plant area increases, the seed yield of the plant increases. Therefore, it appears that as a plant gets bigger it becomes less efficient in seed production although it does yield more.

This could be partly due to the increased number of tillers in the smaller plants, leading to a higher number of seedheads per unit area and thus a higher seed yield per unit area.

Knowledge of the effect(s) of interplant competition is going to be needed before seed yield and its components can be selected for due to the seed yield component compensation.

The polycross tests have proven successful in identifying differences between the clones.

The progeny of the 1982 U of M selections have proven to establish as well as "Penncross" and are equal to or better than "Penncross" in establishment colour and density.

It is recommended that approximately one-half of the 1982 Creeping Bentgrass selections are being recommended to be removed from further testing. These include 82-10 which has very prostrate seedheads, 82-06 and 82-20 which had a high proportion of albino seedlings, 82-16 which is of "Penncross" parentage and was studied to see the characteristics of a single "Penncoss" plant, 82-02, 82-04, 82-05, 82-11, 82-13, 82-14, 82-15, 82-21, 82-22, 82-30 and 82-31 because of turf quality.

The effect of wear on the performance of the clones in a golf green environment was for the most part consistent with regards to visual density and colour. In general, the wear treatment reduced both ratings. The lack of consistent clone X wear interactions means that the clones are the same in response to wear or that we have not allowed for enough time for the effects to be seen.

Wear tended to reduce tiller and leaf number, and dry weight of the worn plots. Those clones that rated high for visual density were higher in dry weight tiller number, leaf number and the number of leaves per tiller than those that rated poorly.

It may therefore be possible to select for turf density using tiller and leaf numbers per unit area as a selection criteria.

There is at least one allele for plant albinism in the 1982 selections and between clones 82-06 and 82-20 there is a one gene difference.

FURTHER RESEARCH

Progeny testing for both turf and seed production are necessary and should be initiated or continued on with. These trials will allow for heritability estimates to be calculated and allow for effective selection.

Trials to determine the effect of plant density on seed production should be initiated immediately. It is evident from the field trials that seed yield will be affected by two factors. These are the size of the plants and the competition between other individual plants and within a plant, and two the age of the stand and its affect on seed production (Dr. A. K. Storgaard, personal communication). Seed production field management could be looked at to see if a method such as a close mowing could be used to rejuvenate the center portion of the plants.

The spacing between the plants in the density trial could be .25, .50 and 1.00 meters. Also, plants could be selected for different components of seed yield such as plant area and seed yield per square cm of plant area and look to see if this has an effect on the seed yield per plant in relation to the plant density.

A technique such as the utilization of anther culture may be of importance especially as the selfing of plants seems to lead to abnormal chromosome numbers. This would hopefully allow for the development of homozygous lines which could be used for breeding purposes.

Some preliminary work with respect to tissue culture using the mature caryopsis as the explant source has been carried out with results indicating that the line with a smaller genetic base had a smaller range of medium conditions in which success was achieved. "Seaside" creeping bentgrass, a mass selection cultivar, was the broad based line and it had a much wider range of media on which callus initiation was successful.

The actual utility of tissue culture as part of the breeding program is not great given the ease of vegetative reproduction. It may however find use in the selection of lines for tolerance to environmental factors and agricultural inputs such as herbicides and fungicides.

Work should be undertaken to define a vernalization technique which would allow for seed production in the controlled environment chambers and thus allow for the possibility of two generations within a year instead of within three years under good conditions as is now possible.

The five clones which appear to have the best turf qualities are 82-01, 82-08, 82-17, 82-27 and 82-29. It may be possible to look at setting up 3, 4 or 5 clone synthetics from these clones to attempt to produce a synthetic with good turf characteristics. These lines may be used to proceed towards finding a good cultivar for licensing or they could be used for reselection.

A possible breeding program is shown in Figure 9.

The following lines and synthetics should be proceeded with in the interim. Lines 67-10, 67-3 and 67-4, and synthetics Syn 84-01, 85-01,

<u>Year 1</u> Space plant nursery for selection (1 meter)

<u>Year 2</u> Visual colour ratings on space plants
Relative flowering dates and seed harvest
Plant size measurement
Stolon measurement for turf density
Selection of clones for further testing

<u>Year 3</u> Turf trial using stolonized plots of selections
Polycrosses (PC) based on relative flowering dates

<u>Year 4</u> Turf trial ratings
Polycross seed harvest

<u>Year 5</u> PC progeny tests: i) Seed production
ii) Turf performance
Turf trial ratings

<u>Year 6</u> Selection of clones from turf performance trial
Progeny testing continued with seed harvest and turf ratings

<u>Year 7</u> Synthetic formation (3 - 6 clones)

<u>Year 8</u> Seed harvest of synthetics

<u>Year 9</u> Syn 2 seed production fields planted
Turf tests of Syn 1 lines

<u>Year 10</u> Syn 2 seed harvest
Syn 1 turf test continued

<u>Year 11</u> Syn 2 lines from promising Syn 1 lines sent away for external testing
Syn 2 turf trials planted

<u>Year 12</u> Syn 2 turf trials continued

<u>Year 13</u> Syn 2 lines doing well in tests: original synthetic reconstituted for breeders seed production

<u>Year 14</u> Harvest of breeders seed

<u>Year 15</u> Release of breeders seed for commercial production

Figure 9: Breeding program outline for creeping bentgrass.

85-02 and 85-03. At the present only Syn 84-01 is undergoing a seed increase and this should be carried out on all of the other lines and synthetics mentioned above so that they may be tested at other locations.

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APPENDICES

Appendix 1: The 1982 creeping bentgrass selection turf trial plot plan transplanted on May 7, 1984.

Replicate 6

82-02	82-19	82-07	82-23	Pncrs	82-30	82-13	82-04
82-08	82-06	82-28	82-26	82-14	82-22	82-09	82-05
82-24	82-16	82-20	82-12	82-10	82-27	Emrld	82-29
82-17	82-11	82-25	82-01	82-31	82-15	82-18	82-21

Replicate 5

82-25	82-29	82-07	82-18	82-06	82-10	82-11	82-01
82-22	Emrld	82-17	82-24	82-20	82-27	82-23	82-28
82-12	82-15	82-31	Pncrs	82-05	82-30	82-16	82-13
82-02	82-09	82-14	82-21	82-26	82-18	82-04	82-08

Replicate 4

82-04	82-01	82-18	82-09	82-31	82-22	82-20	82-12
82-30	82-15	82-21	Emrld	82-10	82-13	82-07	82-11
82-26	82-28	82-27	82-17	82-25	82-02	82-14	82-29
82-24	Pncrs	82-23	82-06	82-08	82-19	82-05	82-16

Replicate 3

82-31	82-18	82-28	82-22	82-07	82-21	82-24	82-17
82-26	82-04	82-30	82-16	82-06	82-01	82-05	Pncrs
82-11	82-23	82-29	82-19	82-20	82-12	82-10	82-09
82-25	82-14	Emrld	82-15	82-08	82-13	82-27	82-02

Replicate 2

82-18	82-24	82-11	82-25	82-05	82-23	82-07	82-06
82-29	82-20	82-02	82-13	82-30	82-19	82-01	82-26
82-22	82-14	82-09	Pncrs	82-15	82-17	82-31	Emrld
82-27	82-16	82-08	82-10	82-21	82-12	82-04	82-28

Replicate 1

82-27	82-19	82-18	82-12	82-23	82-11	82-02	82-21
82-30	82-28	82-01	82-04	82-13	82-07	82-08	82-16
82-06	82-10	82-22	82-05	82-15	82-29	82-25	82-20
Pncrs	82-31	82-26	82-17	82-09	Emrld	82-24	82-14

N->

<u>Appendix</u> <u>2</u>: The 1982 creeping bentgrass selection space plant trial plot plan transplanted on May 15, 1984.

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Replicate 6

82-13	82-10	82-06	82-27	82-25	82-16	82-26	82-21
82-04	Emrld	82-17	82-14	82-31	82-29	82-02	82-28
82-12	82-30	82-11	82-24	82-09	82-07	82-01	82-19
82-05	Pncrs	82-08	82-22	82-23	82-18	82-15	82-20

Replicate 5

82-12	82-13	82-16	82-18	82-04	82-01	82-31	82-30
82-19	82-17	82-15	82-22	82-07	82-20	82-29	82-24
Pncrs	82-26	82-25	82-08	82-10	82-14	82-05	82-28
82-06	82-23	82-21	82-02	82-11	82-27	82-09	Emrld

Replicate 4

82-12	82-10	Pncrs	82-24	82-28	82-06	82-30	82-31
82-20	82-15	82-27	82-29	82-14	82-18	82-17	82-07
82-11	82-21	82-13	82-23	82-26	82-04	82-02	82-22
Emrld	82-08	82-25	82-09	82-19	82-16	82-05	82-01

Replicate 3

82-06	82-09	82-27	82-07	82-10	82-08	82-25	82-29
82-04	82-11	82-12	Emrld	82-20	82-22	82-13	82-28
82-18	82-30	82-23	82-24	82-31	Pncrs	82-14	82-19
82-01	82-26	82-17	82-05	82-16	82-21	82-02	82-15

Replicate 2

82-28	82-24	82-27	82-01	82-17	82-02	82-18	82-25
82-09	82-15	82-16	82-29	82-23	82-26	82-08	82-30
82-13	82-10	82-12	Emrld	82-07	82-20	82-21	Pncrs
82-31	82-11	82-05	82-14	82-19	82-06	82-04	82-22

Replicate 1

82-07	82-27	82-12	82-21	82-30	82-06	82-23	Emrld
82-11	82-25	82-04	82-08	82-31	82-28	82-16	82-19
82-13	82-15	82-24	82-10	82-20	Pncrs	82-02	82-09
82-29	82-05	82-22	82-26	82-01	82-18	82-17	82-14

N->

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<u>Appendix 3</u>: PC 83-02 plot plan transplanted on July 4, 1984 into the northwest corner of the arboretum.

82-29	82-11	82-06	82-20	82-08	82-27	82-26	82-17
82-27	82-17	82-26	82-15	82-29	82-11	82-06	82-08
82-26	82-09	82-08	82-11	82-20	82-17	82-29	82-26
82-20	82-06	82-17	82-27	82-15	82-09	82-08	82-11
82-17	82-26	82-20	82-29	82-11	82-06	82-09	82-15
82-15	82-08	82-09	82-06	82-17	82-08	82-20	82-29
82-11	82-27	82-29	82-08	82-26	82-15	82-27	82-06
82-09	82-20	82-15	82-09	82-06	82-29	82-17	82-09
82-08	82-29	82-11	82-26	82-27	82-20	82-15	82-27
82-06	82-15	82-27	82-17	82-09	82-26	82-11	82-20
1	2	3	4	5	6	7	8

<u>Replicate</u>

N
↓

<u>Appendix</u> <u>4</u>; PC 83-02 progeny turf trial; Greenhouse plot plan.

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Replicate 1

82-29	82-15	82-06
82-08	82-20	82-27
82-26	82-17	Pncrs
82-09		

Replicate 2

82-17	82-29	82-26
82-06	82-27	82-09
Pncrs	82-08	82-15
82-20		

Replicate 3

82-29	82-06	82-20
82-09	82-15	82-17
82-26	Pncrs	82-08
82-27		

Replicate 4

Pncrs	82-26	82-06
82-15	82-29	82-17
82-20	82-27	82-09
82-08		

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Appendix 5: PC 83-02 progeny turf trials; Transplanted and seeded.

Seeded

82-20	82-29	82-15	82-09	82-26	82-28	82-27	Pncrs
82-27	82-17	82-26	Pncrs	82-15	82-29	82-08	82-06
82-06	82-08	82-20	82-17	82-27	Pncrs	82-09	82-20
Pncrs	82-09	82-06	82-29	82-20	82-17	82-15	82-26
82-15	82-26	82-08	82-27	82-06	82-09	92-17	82-29
1		2		3		4	

Replicate N->

Transplanted

Replicate 4

82-29 82-27 82-20 82-08 82-26 82-15 82-06 82-09 82-17 Pncrs

Replicate 3

82-06 Pncrs 82-09 82-17 82-15 82-08 82-20 82-29 82-27 82-26

Replicate 2

82-17 82-15 82-29 82-20 82-27 Pncrs 82-26 82-08 82-06 82-09

Replicate 1

82-08 82-26 Pncrs 82-06 82-09 82-29 82-27 82-17 82-20 82-15

Appendix 6: PC 83-03 plot plan transplanted on August 8, 1983 located in the northeast corner of Block 25 at the Point.

82-29	82-07	82-06	82-08	82-24	82-15	82-10	82-07
82-25	82-10	82-15	82-24	82-29	82-21	82-20	82-15
82-24	82-06	82-25	82-20	82-10	82-06	82-25	82-08
82-21	82-08	82-21	82-29	82-07	82-20	82-24	82-10
82-20	82-25	82-07	82-10	82-21	82-29	82-07	82-06
82-10	82-20	82-29	82-15	82-06	82-25	82-08	82-29
82-15	82-21	82-24	82-07	82-20	82-24	82-15	82-21
82-09	82-29	82-10	82-25	82-15	82-08	82-06	82-20
82-08	82-15	82-20	82-06	82-08	82-07	82-21	82-24
82-06	82-24	82-08	82-21	82-25	82-10	82-29	82-25
1	2	3	4	5	6	7	8

Replicate

N ↓

Appendix 7: PC 83-04 plot plan transplanted on May 7, 1984 to the north end of the turfgrass area at the Point.

82-30	82-27	82-17	82-24	82-25	82-03
82-25	82-10	82-24	82-07	82-17	82-27
82-24	82-17	82-30	82-27	82-07	82-10
82-27	82-07	82-10	82-03	82-24	82-30
82-03	82-30	82-25	82-10	82-27	82-07
82-17	82-03	82-07	82-25	82-30	82-24
82-10	82-24	82-27	82-17	82-03	82-25
82-07	82-25	82-03	82-30	82-10	82-17
1	2	3	4	5	6

Replicate

N ↓

Appendix 8: PC 83-02 progeny turf test (transplanted) 1985 colour and density ratings.

	July 05		Aug. 02		Aug. 30	
Line	Colour	Density	Colour	Density	Colour	Density
82-29	8.75a*	8.00a*	9.00a*	9.00a*	8.25ab*	9.00a*
82-08	8.50a	8.25a	9.00a	9.00a	8.50a	9.00a
82-06	8.50a	7.00a	8.75a	8.25b	8.00ab	8.25a
82-26	8.25a	7.25a	8.50a	8.25b	8.50a	8.25a
82-17	8.25a	7.50a	8.75a	9.00a	8.50a	8.75a
82-27	8.25a	8.00a	9.00a	9.00a	8.50a	8.75a
82-20	8.00a	7.50a	8.75a	8.75ab	8.25ab	8.25a
82-09	7.25b	8.25a	8.50a	8.75ab	7.75ab	8.75a
82-15	7.00bc	8.25a	7.75b	8.50ab	7.25b	8.25a
Penn-cross	6.50c	8.25a	6.75c	8.75ab	6.25c	8.00a

	Sept. 27		Oct. 21	
Line	Colour	Density	Colour	Density
82-29	8.00ab*	8.25a*	6.50a*	8.25a*
82-08	8.25a	8.75a	7.25a	8.25a
82-06	8.00ab	8.50a	7.50a	7.75a
82-26	8.25a	8.25a	5.75a	7.75a
82-17	7.75ab	8.00a	7.25a	8.00a
82-27	8.00ab	8.50a	7.25a	8.25a
82-20	7.50ab	8.00a	6.75a	8.00a
82-09	7.25b	8.25a	6.75a	7.75a
82-15	7.25b	8.00a	7.00a	7.75a
Penn-cross	6.00c	8.00a	6.25a	8.00a

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 9: PC 83-02 progeny turf test colour and density ratings for 1985 for the seeded trial.

Line	Aug. 02 Colour	Aug. 02 Density	Aug. 30 Colour	Aug. 30 Density	Sept. 27 Colour	Sept. 27 Density
82-20	8.25a*	8.00a*	8.50a*	7.50ab*	9.00a*	9.00a*
82-06	8.25a	7.75a	8.25a	7.50ab	8.75a	8.50ab
82-08	8.25a	9.00a	8.25a	8.25a	8.75a	8.75ab
82-27	8.25a	8.50a	9.00a	8.00ab	9.00a	9.00a
82-26	8.00a	8.50a	8.50a	8.00ab	9.00a	9.00a
82-29	8.00a	8.25a	8.25a	8.25a	9.00a	8.25ab
82-17	8.00a	8.25a	8.75a	7.75ab	9.00a	8.75ab
82-15	7.75ab	7.75a	7.00b	8.25a	7.75b	8.25bc
82-09	7.50ab	8.75a	8.50a	8.25a	8.75a	9.00a
Penn-cross	7.25b	8.00a	7.00b	7.25b	7.50b	7.75c

Line	Oct. 21 Colour	Oct. 21 Density
82-20	8.50ab*	8.50ab*
82-06	7.75bc	7.75b
82-08	8.25ab	8.75a
82-27	8.50ab	8.50ab
82-26	8.50ab	8.50ab
82-29	8.25ab	8.25ab
82-17	8.75a	8.00ab
82-15	7.75bc	7.75b
82-09	8.00abc	8.75a
Penn-cross	7.25c	7.75b

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 10: The 1982 creeping bentgrass selection turf trial colour ratings for 1984.

Clone	May 25	June 29	July 20	Aug. 13	Sept. 14
82-01	6.50hijk*	8.00bcd*	8.33ab*	8.17ab*	8.67ab*
82-02	6.00jkl	6.67ghi	7.17efgh	6.83efghi	7.17fghi
82-04	6.17ijkl	8.17abc	7.67bcdef	6.83efghi	6.83ghij
82-05	7.50cdef	7.17efgh	7.17efgh	6.67fghij	7.17fghi
82-06	6.67ghij	7.83cde	7.50cdefg	7.33cdef	7.17fghi
82-07	7.00fgh	6.50hij	7.00fghi	7.17defg	7.33efg
82-08	7.50cdef	7.00fgh	7.50cdefg	7.33cdef	7.83cdef
82-09	6.50hijk	6.83gh	7.00fghi	6.50ghi	6.83ghij
82-10	8.00bcd	7.67cdef	7.33defgh	7.33cdef	8.17bcd
82-11	5.00n	7.67cdef	7.33defgh	7.17defg	6.67hijk
82-12	7.17efgh	7.33defg	6.67hijk	6.33hijk	7.83cdef
82-13	5.67lmn	5.83jk	6.00kl	5.50l	6.00k
82-14	6.50hijk	6.83gh	6.67hijk	6.00jkl	6.00k
82-15	5.67lmn	6.00ijk	5.83l	5.67kl	6.60ijk
82-16	5.50lmn	7.00fgh	6.83ghij	7.50bcde	8.33abc
82-17	8.17abc	7.83cde	8.00bcd	7.83bcd	8.33abc
82-18	6.17ijkl	7.00fgh	7.00fghi	7.17defg	8.00bcde
82-19	6.17ijkl	7.33defg	7.33defgh	6.83efghi	8.17bcd
82-20	6.83fghi	6.83gh	6.33ijkl	6.17ijkl	6.67hijk
82-21	7.00fgh	7.83cde	6.83ghij	6.33hijk	6.33jk
82-22	8.67ab	8.33abc	7.50cdefg	8.00bc	8.67ab
82-23	7.00fgh	7.17efgh	7.33defgh	6.83efghi	7.17fghi
82-24	8.67ab	8.67ab	8.00bd	7.00efgh	8.50abc
82-25	8.83a	8.83a	8.83a	8.83a	9.00a
82-26	6.50hijk	8.33abc	7.67bcdef	7.00efgh	7.17fghi
82-27	8.67ab	8.67ab	8.33ab	7.83bcd	8.33abc
82-28	7.33defg	6.67ghi	6.83ghij	7.33cdef	8.33abc
82-29	7.33defg	8.00bcd	7.83bcde	7.83bcd	8.67ab
82-30	7.83cde	8.83a	8.17abc	7.83bcd	7.50defg
82-31	5.83klm	8.00bcd	7.67bcdef	6.83efghi	6.67hijk
Penn-cross	5.50lmn	7.00fgh	6.33ijkl	6.83efghi	7.33efg
Emer-ald	5.17mn	5.67k	6.17jk	5.67kl	6.17jk
Mean	6.84	7.42	7.26	7.02	7.48

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 10: con't.

Clone	October 12
82-01	8.50ab*
82-02	7.50def
82-04	7.50def
82-05	8.00bcd
82-06	7.67cde
82-07	7.33defg
82-08	7.67cde
82-09	6.67ghi
82-10	7.83bcd
82-11	6.83fghi
82-12	7.33defg
82-13	6.17i
82-14	6.17i
82-15	7.00efgh
82-16	8.33abc
82-17	8.00bcd
82-18	7.83bcd
82-19	7.67cde
82-20	6.83fghi
82-21	6.17i
82-22	8.00bcd
82-23	7.67cde
82-24	8.00bcd
82-25	8.50ab
82-26	7.33defg
82-27	7.67cde
82-28	8.50ab
82-29	8.83a
82-30	7.67cde
82-31	7.50def
Penncross	7.83bcd
Emerald	6.50hi
Mean	7.53

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 11: The 1982 creeping bentgrass selection turf trial density ratings for 1984.

Clone	June 29	July 20	Aug. 13	Sept. 14
82-01	7.50abcd*	8.33ab*	8.83ab*	8.67ab*
82-02	5.67ijk	5.50hij	6.83hij	7.00efgh
82-04	7.17bcdef	7.83abcd	7.67defgh	6.83efgh
82-05	5.50jk	5.00j	5.67kl	5.50i
82-06	6.67defgh	7.50bcde	7.83cdefg	7.67abcdef
82-07	7.00cdefg	6.33efghi	6.33jk	7.33cdef
82-08	6.83defg	6.33efghi	7.17fghi	7.50bcdef
82-09	7.50abcd	7.33bcdef	7.83cdefg	7.50bcdef
82-10	7.00cdefg	7.33bcdef	7.67defgh	8.33abcd
82-11	6.50efghi	6.67defgh	6.67ij	5.83hi
82-12	6.83defg	7.33bcdef	6.50ijk	5.83hi
82-13	5.33k	5.67ghij	5.33l	6.00ghi
82-14	7.00cdefg	6.83defg	8.00bcdef	7.33cdef
82-15	5.83hijk	5.33ij	6.50ijk	7.00efgh
82-16	6.50efghi	7.50bcde	7.67defgh	6.83efgh
82-17	7.33abcde	6.83defg	7.33efghi	8.50abc
82-18	7.83abc	7.83abcd	8.33abcd	8.83a
82-19	6.50efghi	6.17fghij	6.83hij	7.17defg
82-20	6.83defg	5.33ij	6.67ij	6.83efgh
82-21	6.17ghijk	6.17fghij	7.33efghi	7.33cdef
82-22	8.00ab	7.83abcd	8.67abc	7.83abcde
82-23	7.33abcde	7.83abcd	7.17fghij	7.83abcde
82-24	7.33abcde	8.17abc	8.17abcde	7.67abcdef
82-25	7.83abc	8.50ab	9.00a	8.50abc
82-26	7.33abcde	7.83abcd	8.33abcd	6.67efghi
82-27	8.17a	8.83a	8.50abcd	8.83a
82-28	6.50efghi	6.67defgh	8.00bcdef	7.67abcdef
82-29	7.17bcdef	8.33ab	8.83ab	8.67ab
82-30	6.33fghij	7.50bcde	6.67ij	6.00ghi
82-31	6.83defg	7.50bcde	7.00ghij	6.50fghi
Penn-cross	7.33abcde	7.67abcd	7.83cdefg	7.50bcdef
Emer-ald	6.33fghij	7.00cdef	7.17fghij	7.00efgh
Mean	6.88	7.09	7.45	7.33

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 11: con't.

Clone	October 12
82-01	8.17abc*
82-02	7.00defg
82-04	6.83defg
82-05	6.50fg
82-06	7.00defg
82-07	7.67bcde
82-08	8.17abc
82-09	8.50ab
82-10	7.00defg
82-11	5.50h
82-12	6.67efg
82-13	6.33fgh
82-14	7.00defg
82-15	7.00defg
82-16	7.00defg
82-17	8.83a
82-18	8.50ab
82-19	6.33fgh
82-20	6.67efg
82-21	6.17gh
82-22	7.67bcde
82-23	7.83bcd
82-24	7.83bcd
82-25	7.17defg
82-26	7.17defg
82-27	8.17abc
82-28	7.33cdef
82-29	8.50ab
82-30	6.50fg
82-31	6.50fg
Penncross	7.17defg
Emerald	6.67efg
Mean	7.23

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 12: The 1982 creeping bentgrass selection turf trial colour ratings for 1985.

Clone	Apr. 29	May 17	June 20	July 19
82-01	7.67bcd*	8.33abc*	7.50cdef*	7.83bcde*
82-02	6.50ghi	7.17defg	6.83fghij	7.33defgh
82-04	5.33kl	7.00efg	7.67bcde	7.83bcde
82-05	7.33cdef	8.17abc	7.50cdef	7.17efg
82-06	6.33hij	7.50cdef	7.33cdefg	7.50cdefg
82-07	5.67jkl	7.83bcde	6.83fghij	7.17efgh
82-08	7.50cde	8.83a	6.67ghij	7.67cdef
82-09	6.50ghi	8.17abc	6.83fghij	7.50cdefg
82-10	7.50cdef	8.50abc	7.50cdef	8.00bcd
82-12	7.17defg	8.33abc	6.83fghij	6.67h
82-13	7.33cdef	6.67fg	5.17l	4.50j
82-14	7.00defgh	6.67fg	6.33ijk	6.83gh
82-15	6.67fghi	6.33g	5.33l	4.67j
82-16	6.80efghi	7.80bcde	6.80fghij	6.83gh
82-17	8.17bc	8.17abc	7.67bcde	7.67cdef
82-18	6.50ghi	7.83bcde	7.00efghi	7.17efgh
82-19	7.83bcd	7.67bcde	7.33cdefg	7.50cdefg
82-20	6.40ghij	6.67fg	6.67ghij	6.67h
82-21	8.67a	8.17abc	8.33ab	7.67cdef
82-22	6.20hij	7.80bcde	8.00bc	8.17bc
82-23	7.83bcd	7.17defg	7.33cdefg	7.33defgh
82-24	7.50cdef	8.50abc	8.83a	8.50ab
82-25	7.60bcde	7.80bcde	9.00a	9.00a
82-26	7.50cdef	7.83bcde	7.00efghi	7.83bcde
82-27	7.60bcde	8.20abc	7.83bcd	8.00bcd
82-28	8.33ab	7.83bcde	6.50hijk	7.00fgh
82-29	8.17bc	8.67ab	7.33cdefg	7.83bcde
82-30	7.20defg	8.00abcd	8.33ab	9.00a
82-31	7.00defgh	7.00efg	7.17defgh	7.33defgh
Penn-cross	6.00ijk	6.33g	6.17jk	6.67h
Emer-ald	5.00l	6.33g	5.83kl	5.67i
Mean	7.07	7.66	7.13	7.31

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 12: con't.

Clone	Aug. 30	Sept. 28	Oct. 21
82-01	7.67bcde*	8.00bcd*	7.33abc*
82-02	7.33cdefg	7.50defg	6.83bcde
82-04	7.33cdefg	7.33defgh	5.50ghijkl
82-05	7.00efghi	7.33defgh	6.00efghi
82-06	7.33cdefg	7.33defgh	6.83bcde
82-07	7.17defgh	6.33jkl	6.00efghi
82-08	7.83bcd	8.00bcd	7.83a
82-09	6.17jk	6.17klm	6.00efghi
82-10	7.67bcde	7.67cdef	5.17hijklm
82-12	6.50hijk	6.83ghijk	4.83jklm
82-13	5.33m	5.17n	4.50lm
82-14	6.00kl	6.33jkl	4.83jklm
82-15	5.50lm	5.83lmn	5.00ijklm
82-16	7.33cdefg	7.33defgh	6.00efghi
82-17	7.83bcd	7.83bcde	7.83a
82-18	7.00efghi	6.67hijk	6.67cdef
82-19	8.00bc	8.00bcd	6.00efghi
82-20	6.67ghijk	6.33jkl	5.67fghijk
82-21	6.83fghij	7.00fghij	4.33m
82-22	7.83bcd	7.67cdef	7.17abcd
82-23	7.50cdef	7.50defg	6.17defgh
82-24	8.33ab	8.50ab	4.67klm
82-25	8.83a	8.83a	7.67ab
82-26	7.50cdef	7.50defg	5.83efghij
82-27	7.50cdef	8.00bcd	6.00efghi
82-28	7.17defgh	7.83bcde	5.67fghijk
82-29	7.67bcde	7.50defg	6.83bcde
82-30	8.00bc	8.33abc	6.50cdefg
82-31	7.33cdefg	7.17efghi	5.50ghijkl
Penn-cross	6.33ijk	6.50ijkl	6.50cdefg
Emer-	6.17jk	5.50mn	6.67cdef
Mean	7.18	7.22	6.08

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 13: The 1982 creeping bentgrass selection turf trial density ratings for 1985.

Clone	May 07	June 20	July 19	Aug. 16
82-01	7.50abcde*	8.50ab*	8.50abc*	8.17ab*
82-02	6.67bcdefg	6.67efghij	7.33fghi	6.33efgh
82-04	6.50cdefg	7.33cdefg	7.50efg	6.83cdefg
82-05	6.50cdefg	6.17ij	6.33j	4.50i
82-06	6.50cdefg	7.67bcde	7.83cdefg	6.83cdefg
82-07	6.67bcdefg	7.67bcde	8.17abcde	8.00abc
82-08	8.00ab	7.83abcd	8.83a	8.00abc
82-09	7.83abc	8.00abcd	8.17abcde	7.33abcdef
82-10	6.33defg	7.00defghi	8.33abcd	6.83cdefg
82-12	6.83bcdef	8.00abcd	8.33abcd	5.33hi
82-13	7.33abcde	6.67efghij	7.50efg	4.33i
82-14	6.50cdefg	7.83abcd	7.67defg	7.33abcdef
82-15	6.67bcdefg	5.83i	6.67hij	4.83i
82-16	6.40defg	7.40cdef	7.40efgh	6.20fgh
82-17	7.67abcd	8.83a	8.83a	8.17ab
82-18	7.00abcdef	8.83a	8.83a	7.83abc
82-19	7.50abcde	7.17cdefghi	8.00bcdef	7.00bcdefg
82-20	6.33defg	6.33ghij	7.17ghi	7.17bcdefg
82-21	6.67bcdefg	7.00defghi	8.00bcdef	7.00bcdefg
82-22	6.20efg	6.40fghij	7.80cdefg	7.60abcd
82-23	7.33abcde	8.00abcd	7.83cdefg	7.83abc
82-24	6.67bcdefg	8.17abc	8.17abcde	7.50abcde
82-25	5.40g	7.20cdefgh	7.40efgh	8.00abc
82-26	6.33defg	7.83abcd	8.50abc	8.00abc
82-27	7.20abcdef	8.60ab	8.60abc	8.40a
82-28	7.17abcdef	7.17cdefghi	7.67defg	6.00gh
82-29	8.33a	8.67ab	8.67ab	8.17ab
82-30	5.80fg	6.20hij	6.60ij	6.00gh
82-31	5.83fg	7.40cdef	8.20abcde	6.20fgh
Penn-cross	6.67bcdefg	7.00defghi	7.33fghi	6.50defg
Emer-ald	6.17efg	6.50fghij	7.17ghi	6.50ij
Mean	6.81	7.42	7.86	6.92

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.

Appendix 13: con't.

Clone	Sept. 28	Oct. 21
82-01	8.33ab*	8.50ab*
82-02	7.33cdefgh	7.50cdefgh
82-04	6.67ghij	7.00fghij
82-05	6.33jk	6.83ghij
82-06	7.17defghij	7.67bcdefg
82-07	8.17abc	8.50ab
82-08	8.50a	8.67a
82-09	7.50cdefg	7.83abcdef
82-10	7.33cdefgh	7.33efgh
82-12	7.17defghi	7.50cdefgh
82-13	6.67ghij	7.33efgh
82-14	7.67bcdef	7.50cdefgh
82-15	5.67kl	6.33j
82-16	7.00efghij	7.20efghi
82-17	8.50a	8.67a
82-18	8.17abc	8.50ab
82-19	7.50cdefg	7.67bcdefg
82-20	7.00efghij	6.83ghij
82-21	6.83fghij	7.00fghij
82-22	7.80abcde	8.00abcde
82-23	7.50cdefg	6.83ghij
82-24	7.33cdefgh	6.67hij
82-25	7.40cdefgh	7.40defgh
82-26	8.17abc	8.33abc
82-27	7.80abcde	8.20abcd
82-28	7.50cdefg	7.50cdefgh
82-29	8.00abcd	8.33abc
82-30	5.60l	6.40ij
82-31	6.60hj	6.80ghij
Penn-cross	7.67bcdef	7.50cdefgh
Emer-ald	6.50ij	7.67bcde
Mean	7.34	7.56

* Means followed by the same letter are not significantly different using Duncan's Multiple Range Test with alpha = .05.