Yield and seed quality of Phalaris arundinacea L under certain fertilizer and management practices

John Reuben Thompson

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YIELD AND SEED QUALITY OF
PHALARIS ARUNDINACEA L. UNDER CERTAIN
FERTILIZER AND MANAGEMENT PRACTICES

by
John Reuben Thompson

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Crop Production

Approved:

Signature was redacted for privacy.
In Charge of Major Work

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Ames, Iowa

1964
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INTRODUCTION

When a crop is grown for seed purposes the primary factors with which the seed producers are concerned are the yield and quality of the seed. In this study the factors which affect these seed characteristics in reed canarygrass, *Phalaris arundinacea* L., are of primary concern. The study includes the effects of a wide range of fertility and cultural practices and factors of seed handling and processing which may affect the germination of the seed.

Reed canarygrass is a high yielding perennial forage grass which is used primarily for pasture on low wet soils. It is a widely adapted forage which could be used more extensively for grazing and other forage purposes. It thrives on both upland and lowland soils and it has exhibited an extreme drought tolerance as well as the ability to withstand a considerable amount of flooding. Certain undesirable features have prevented widespread acceptance of this species. Among the disadvantages are poor palatability, under some management systems, and the lack of a uniform supply of high quality seed. The annual production of seed varies greatly and the standards for germination are lower than is acceptable for most grass species. The price of the seed fluctuates greatly from year to year as it is largely based upon the available supply of high quality seed.

The major objectives of this study were as follows: to
determine the effects of certain fertility and cultural practices on the yield of seed, to investigate seed handling practices and to determine the effect that the commonly used harvesting and processing methods have upon seed germination. To obtain information concerning these factors a wide range of fertility levels was studied on commercial reed canarygrass seed fields, located on both peat and muck soils. A series of plots was established on mineral soils using both cultivated rows and solid stands, with fertility treatments similar to those used on the low land plots. The commercial seed harvesting practices were studied and various methods of curing and drying the seed heads, and the threshed seed, were investigated. It was hoped that better fertilizer and management practices would lead to larger seed yields and a more stable annual production. The seed handling practices were studied in an attempt to determine some of the factors which contribute to the rapid deterioration of seed viability. If a good supply of high quality seed, at a stable price, was consistently available, the use of this species might be increased.
Adaptation and Distribution

Reed canarygrass *Phalaris arundinacea* L., is a widely adapted perennial forage grass which has been reported indigenous to the temperate climates throughout the world (Hughes and Heath, 1962). In North America it is commonly found throughout the northern half of the United States and southern Canada. Its native habitat is in low lying areas of abundant moisture. Arny *et al.* (1929) reported that it could withstand flooding for several weeks and that established plants would emerge through several inches of mud or silt. Bolton (1946) cited an instance where 49 days of flooding had not caused permanent injury.

One of the reasons for the good acceptance of reed canarygrass for use in the low lying areas is its ability to form a dense sod. Arny *et al.* (1929) cited examples of meadows established on some of these low wet areas with a sod strength sufficient to support haymaking machinery and to carry loaded hay wagons. Before the reed canarygrass sods were established, these same areas had been so soft that animals tended to mire down in them. Hay yields of from 4 to 6 tons per acre were reported from these wetland meadows.

In spite of its excellent adaptation to wet areas reed canarygrass thrives also on upland soils. Wilkins and Hughes (1932) compared the yields of several grasses and legumes
growing on upland mineral soils during the drought of 1930. They found that reed canarygrass was more drought tolerant than any of the other 12 species of grasses with which it was compared. Its drought tolerance also exceeded the 5 legumes tested, with the exception of alfalfa. In a yield trial conducted from 1925 to 1928 they found that reed canarygrass averaged 2.06 tons of hay per acre while the yields of brome-grass, timothy, and orchardgrass were 1.45, 1.44 and 0.83 tons per acre respectively.

Due to its ability to grow on wet or dry soils, and its dense system of tough rhizomes, reed canarygrass is ideally adapted for conservation purposes. Heath and Hughes (1962) reported that its use for gully control, grass waterways and protection for stream channels was increasing. However, it is sometimes objectionable in small ditches as the rank vegetative growth tends to impede a small flow of water. D. E. Hutchinson, State Soil Conservationist of Lincoln, Nebraska, reported, in a personal communication, that its use for conservation purposes was increasing across the states of Nebraska, Kansas, Missouri and into Oklahoma and Texas, so the range and use of this species appears to be increasing. Hutchinson stated that vegetative cuttings were being used to gain rapid establishment in wet gullies. Heath and Hughes (1962) also reported this method of establishment. The fresh cut culms are pushed into wet muddy areas and roots develop at the nodes.

In view of its excellent adaptation to a wide range of
conditions, and its high yielding potential, reed canarygrass should be used more extensively. Farmer acceptance has been rather slow due to conflicting reports on quality and a lack of research information on proper management.

Palatability and Quality of Forage

Numerous reports attest to the high quality and palatability of reed canarygrass and likewise numerous others cite instances showing its lack of palatability. Among the former Wilkins and Hughes (1932) found that it compared favorably with other pasture grasses which are commonly used for dairy cows. They also stated that horses preferred the coarse reed canarygrass hay, made after the seed harvest, to good quality timothy hay.

Alway (1931) gave excellent background information on the species. He dated its early history and possibly the first recorded use as a forage to Sweden in 1749. He referred to Hesselgren of Sweden, who under the guidance of the famous Swedish botanist Linnaeus, tested the palatability of over 600 species of plants growing in Sweden. Reed canarygrass was reported to be one of the most palatable grasses to all classes of livestock used in the test, i.e. cattle, horses, sheep, and goats; however, he reported it as being unpalatable to swine. Conflicting with this is a report by Arny et al. (1930) in which they stated that hogs relished it when it was grazed closely.
Arny *et al.* (1929) reported that reed canarygrass hay was superior to timothy, or wild hay, but inferior to alfalfa. They also reported that the protein content was 13.99 per cent when cut when the panicles were emerging and dropped to 10.84 per cent when left standing for six weeks longer. This last stage was obviously far beyond the optimum, as they stated that the seed crop had matured and all seeds had shattered.

In comparing the most common grasses of the northeastern United States, namely, alta fescue, bromegrass, Kentucky blue-grass, orchardgrass, reed canarygrass, redbtop, timothy and tall oatgrass, Phillips *et al.* (1954) reported that reed canarygrass was a superior grass. It was reported as being high in protein and minerals but low in lignin and fiber content, had a sparser bloom and fewer seed stalks, more foliage leaves, and underwent less change in composition than the other grasses in passing from one stage of maturity to another.

In a comprehensive study of the vegetative development of reed canarygrass, Evans and Ely (1941) reported that the protein content of hay ranged from a high of 16.2 per cent, when harvested on May 20th, to a low of 6.6 per cent on July 13th. The later date was obviously beyond the optimum stage for use as hay.

Vary *et al.* (1950) found that at least 90 per cent of the farmers using reed canarygrass for grazing with beef and dairy cattle in Michigan reported satisfaction with its use. Holden (1936) stated that less than 3 per cent of over 100 farmers
contacted in Wisconsin had difficulties in getting cattle to consume reed canarygrass forage as hay or pasture. Burson\(^1\) stated that in grazing trials on pastures fertilized with various rates of phosphate fertilizer, the cattle refused to graze the unfertilized strips but readily consumed the forage where the phosphate fertilizer had been applied.

In contrast to the many favorable reports, several researchers report difficulties in getting livestock to consume adequate quantities of the forage. In Michigan, Van Arsdell (1954) reported that beef steers on reed canarygrass pasture developed a rough coat and had a rate of gain of only about one pound per day. Blakeslee (1956), also working in Michigan, reported on a grazing trial of ewes and lambs on reed canarygrass and bromegrass pasture. The per acre gain of lambs was 249 pounds on reed canarygrass but the ewes gained only 17 pounds per acre. On the bromegrass pasture the lamb gains were only 229 pounds but the ewes gained 75 pounds. This would suggest that after grazing animals have established a preference for other forage, it is sometimes difficult to get them to consume sufficient quantities of reed canarygrass. Arny et al. (1929) indicated that this was true for dairy cattle.

There have been several other reports of poor palatability.

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Beaumont et al. (1933) found reed canarygrass to be the least palatable of several species tested. However, when nitrogen fertilizers were applied, these differences in palatability practically disappeared. These workers found that leaves of reed canarygrass were less tough than those of several other species. Rogler (1944) confirmed the finding that reed canarygrass was the least tough of all the commonly grown cool season grasses, but in a palatability trial he found it to be the least preferred.

Many ideas have been advanced to explain the great variability in results of various palatability trials. One of these relates to strain differences. Roe and Mottershead (1962) found widely differing acceptability among various strains of reed canarygrass from a world wide collection. This relative difference in palatability was unaffected by the stage of growth. The strains not accepted at the immature stages were the same strains that were unacceptable at later stages. In a cafeteria type grazing trial with sheep, acceptable strains were grazed to the ground, but the sheep would go hungry for considerable periods of time before they would graze unacceptable strains. This work suggested that trials in different areas, on different genetic strains could result in widely differing palatability reports.

In an attempt to determine what caused the difference in palatability between strains, Roe and Mottershead (1962) extracted a leachate from several strains by using solvent
extraction process. When the leachate from the unpalatable strain was sprayed on the palatable strain the animals refused to eat the forage. Identical samples, sprayed with leachate from the palatable strain, found ready acceptance. This would indicate that the objectionable material came from the forage and not from the extracting materials. The exact nature of the material in the leachate had not been determined at the time of the publication but further tests were being conducted to determine its chemical properties. The authors indicated that the effect was possibly caused by an odor factor in the unpalatable strains. If a quick chemical test for palatability could be devised, it would be a relatively simple matter to screen all breeding material for palatability, and researchers could easily check the palatability resulting from various fertility and management practices. If available, such a research tool would soon lead to much greater use of reed canarygrass.

Seed Production

The total annual production of seed varies greatly. Accurate figures are unavailable as there is no listing of this crop in the United States Agricultural statistics. Information supplied by a representative of the seed industry¹

suggests that portions of three counties in south central Minnesota comprise one of the largest and most concentrated areas of seed production in the United States. The annual production in this area has exceeded one million pounds. The production, however, fluctuates greatly, being dependent upon weather conditions and seed prices. In years of high rainfall, many of the low areas are too wet for normal harvesting operations, however, when seed prices rise a considerable quantity of seed is harvested from these problem areas also. Although seed production appears to be centered in this Minnesota area, considerable quantities are also produced in Wisconsin, Michigan, Western Oregon and in Canada. European seed formerly was imported (Arny et al. (1929)) but in recent years domestic production has exceeded the demand and some seed is exported.

Seed Formation and Plant Development

In perennial plants many factors are involved in the processes of floral induction, initiation and finally seed formation itself. The exact dependence of one factor upon another, or the dependence upon some external condition, is difficult to measure but as all these factors play important roles in a seed production study, they all must be given some consideration. Evans and Ely (1941) have presented an excellent review of the vegetative development of reed canarygrass. Holt (1954) presented a detailed study of the initiation and development of the inflorescence and Cooper (1960) included
reed canarygrass in the group of perennial plants which need floral induction by low temperatures and/or short days. Other factors such as root reserves, availability of moisture and fertilizer nutrients, also are important in seed formation and development processes.

The number of tillers produced by reed canarygrass plants is largely dependent upon the rhizomes which were developed the previous season. Evans and Ely (1941) found that rhizomes developed primarily in the fall and spring. Tillers which developed in the spring and formed above ground vegetative portions are limited in growth to that season. During the summer and fall an increasing number of rhizomes were noted to curve upward at their apices; these developed into vegetative tillers. Monthly counts made in July, August, September, October, and November showed an increasing proportion of tillers with apices turned upward. The increase ranged from 22, 26, 27, 41 and 56 per cent respectively by the months indicated. The internodes of these shoots elongated very little during the fall season and if their growing points did not emerge above ground level during the fall growth period they then developed into tillers the following spring. Other tillers were shown to arise from above-ground nodes but the ones developing into an inflorescence were shown to have been underground tillers the previous fall. From these observations it appears that a seed crop is highly dependent upon the rhizome formation of the previous season.
The removal of topgrowth can have a distinct effect upon the amount of subsequent root growth and the amount of carbohydrates which remain in the underground portions of a plant. The carbohydrate reserves, in turn, have a marked effect on the subsequent forage growth. Graber (1931) found that bluegrass which had been clipped six times the previous season produced only 1/2 as much forage and 1/2 as much flower stalks, by weight, as were produced on plots which had been clipped once. Harrison (1931) found that the more frequently turf grasses were cut the greater the reduction in root growth and if the cuttings were frequent enough the turf would eventually be killed due to lack of root reserves. In comparing the re-growth of several forage grasses, Harrison and Hodgson (1939) found that the greatest yields of both topgrowth and underground parts were from plots which were not clipped.

Smith and Graber (1948) found that the weight of rhizomes of sweet clover and the amount of available carbohydrates in the roots was considerably less under any type of cutting system than when the topgrowth had not been removed. Sturkie (1930) reported that when Johnson grass was cut before the seed stage there was a reduction in forage yield the following year. He also reported that plants with well developed root-stalks yielded 50 per cent more topgrowth than plants which did not have a well developed system of rootstalks.

In a greenhouse study with reed canarygrass, Davis (1960) found that the yield of dry matter was twice as great from
plots where the stubble was clipped at 4 or 5 inch heights as from plots clipped at 1 or 2 inch heights. The number of tillers produced also was significantly greater in the plots where higher clipping was practiced. There are no reports in the literature, of the effects of clipping on seed yields of reed canarygrass, but Mr. Joseph Strohl of Janesville, Minnesota, in a personal interview with the author, reported severe reductions in seed yield from areas where the forage had been removed the previous season when compared to adjacent areas where only the mature seed heads were removed. A similar reduction in forage growth and panicle production was noted by the author where forage had been removed from the reed canarygrass plots at Waseca in 1962.

Evans and Ely (1941) noted that the inflorescences of reed canarygrass began to develop about the middle of April at their northern Ohio location. Holt (1954) stated that initiation of the inflorescence occurred during the period from April 6 to May 2, at Ames, Iowa. The initiation and induction of floral primodia of reed canarygrass appear to parallel closely similar processes in bromegrass and orchardgrass. Gardner and Loomis (1953) found that floral induction in orchardgrass was a chemical or hormonal differentiation which occurred as a response to both low temperature and short days. Induction occurred naturally in the fall but it did not occur under cool temperatures when combined with long days. Under these same conditions bromegrass flowered sparsely, but timothy flowered
heavily. Initiation of floral primodia did not occur except under long days and moderate temperatures. Evans and Wilsie (1946) found that flowering of bromegrass could be induced by long days in the greenhouse in the winter. They also found that a greater production of flowers was achieved under warm temperature conditions (80°F.) and a high level of soil fertility. Gardner and Loomis (1953) found that floral development was greater and the production of seed was favored by long days and high nitrogen fertility.

From these studies it would appear that floral induction, initiation, and development in bromegrass, orchardgrass, and reed canarygrass occur under similar conditions of light, temperature and soil fertility. It is reasonable to suggest that results of fertility trials and similar work on one species might have application to another species. Such an inference would be especially advantageous for a researcher with reed canarygrass as there has been far less research with this species than with either bromegrass or orchardgrass.

Fertilization and Cultural Practices

Most recent research on cultural practices for grass seed production cite advantages for row type plantings. Patterson et al. (1956), Carter (1961), Hollowell and Beard (1962), Cooper et al. (1957) and Garrison (1960) all are in agreement that row plantings have a definite advantage over solid stands for grass seed production. From among the many advantages cited
for row plantings over broadcast stands the following are enumerated by Patterson et al. (1956):

1. Less seed is required for planting.
2. Stands can be cultivated longer.
3. They remain productive longer.
4. Proper roguing is easier to do.

In general, most workers agree that yields also are higher from cultivated rows.

Very little research has been reported on either the cultural practices or the fertilization of reed canarygrass. Hawk and Sherman (1958) obtained increasing seed yields for up to 100 pounds of N on upland soils at Elsberry, Missouri. They used ammonium nitrate as the nitrogen source and obtained an increase of 2 pounds of seed for each pound of ammonium nitrate applied up to 100 pounds. For the second and third 100 pounds of ammonium nitrate they obtained increases of one pound of seed for each pound of fertilizer. Beyond this rate they received no increases. Most of the reed canarygrass seed is produced on peat and muck soils and the literature does not reveal any instances of the use of fertilizer for seed production under these conditions.

For most other grass species there have been many reports on the use of nitrogen for grass seed production. Harlan (1956), Cooper et al. (1957), Sumner et al. (1958), Anderson et al. (1946), are among the many citing the advantage of using nitrogen. The use of phosphate and potash usually have not shown the same response as nitrogen; however, yields were
increased when phosphate and potash were added in conjunction with nitrogen applications. With bromegrass, Harrison and Crawford (1941) found that high phosphate and potash applications served to depress yields when applied at low nitrogen levels. Burton (1943) studied several southern grasses and found that phosphate and potash increased the number of seed heads produced in only one species, Coastal bermudagrass. When nitrogen was added, a significant increase in production was noted. Grunes (1959) found that nitrogen fertilization had a marked effect on the uptake of phosphorous.

In general, it appears that nitrogen is the most important element in increasing grass seed production. Garrison (1960) stated that additional nitrogen is required for grass seed production in all areas. There are possibilities of increasing nitrogen beyond the optimum, however, as was shown by Harrison and Crawford (1941) who obtained severe lodging in bromegrass fertilized with more than 100 pounds of nitrogen per acre.

Certain other cultural practices have been noted by several authors as having an effect on grass seed yields. Burton (1944) found that burning of seed fields significantly increased seed yields of common bahiagrass and common bermudagrass but had no effect on ribbed paspalum. Scott (1956) found similar benefits for burning of some south African grasses. When leaf diseases were a problem Musser (1947) obtained increased seed yields by following the practice of burning red fescue seed fields after harvest. He found no
advantage from burning the fields in early spring, which would indicate that in this case the benefit was achieved from a lower incidence of disease in the later part of the season preceding the seed crop. More recently Canode (1963) found that burning significantly increased seed yield of Agropyron intermedium. He noted that in this same instance there was no response to nitrogen fertilizer.

Most of the seed production fields of reed canarygrass are burned either in late fall or in early spring. The purpose of this burning, from the seed growers standpoint, is to remove old dead plants. There is general concurrence that the burned fields start earlier the next spring, due to the removal of the insulating material and the effect of the black color in serving to absorb heat more readily.

Many reed canarygrass seed growers claim that more uniform maturity is achieved, and larger seed yields are obtained, by following the practice of burning; however, no data are available concerning the relationship between burning and seed yields of reed canarygrass.

Seed Shattering

One of the biggest problems in seed production of reed canarygrass is its natural tendency to shatter seed shortly after maturity. Baltensperger (1958) has given an excellent review of these problems and they will not all be repeated in this discussion.
It is a natural characteristic of the species for maturity to begin at the tip of the panicle and gradually mature downward. The time required to complete the maturity of one panicle may range from a few days to more than a week, depending on weather conditions. Arny et al. (1929) gave a description of the manner in which seeds disarticulated from the rachilla at maturity and then fell freely from the glumes when the seed heads were tipped. The factors which affect shattering have recently been considered by Bonin and Goplen (1963a and 1963b) who found that seeds were first loosened as a result of disarticulation and then any external stress would cause the seeds to be released from the glumes. The disarticulation occurs approximately 12 days after anthesis and the release of the seeds may happen at any time thereafter, depending on the strength of the glumes which encase the seeds.

Baltensperger and Kalton (1958) found that different clones showed a wide range in seed shattering resistance. Bonin and Goplen (1963) inferred that differences in shattering were due to glume strength and that selection for plants with strong glumes is the answer to the seed shattering problem. They referred to the work of Vogel (1941) on glume strength in wheat, who showed how the glumes serve to hold the caryopsis in the wheat spike. The development of strains of reed canarygrass, which are more resistant to shattering, would be of extreme importance in seed production of this species.
Harvesting and Seed Drying

One of the problems which has plagued the producers of reed canarygrass has been that of getting the harvesting done before the seeds have shattered. A second problem has been that of drying the seeds properly so that germination would not be injured. Arny et al. (1929) cited early attempts at seed harvest as consisting of hand gathering of the panicles or of beating the seeds from the heads into a pan or a sack. These methods were very inefficient and helped to promote extremely high seed prices. Several mechanical methods of harvesting were soon developed, but seed shattering, and high moisture content of the seed still remain serious problems.

Wilkins and Hughes (1932) used an ordinary grain binder for cutting. The sheaves were then shocked and the shocks covered with burlap to prevent further shattering. Good seed quality could be obtained in this manner but a considerable amount of seed was lost in the handling processes and the amount of labor used was excessively high. The Wisconsin Agricultural Experiment Station annual reports (1934, 1936, 1937) cited many methods of mechanical handling. An improvised header was made to cut the grass above the leafy portions of the stems. A thresher was operated at a central location and seed harvested in the various field areas was hauled to the thresher. A considerable amount of handling was necessary and shattering was again excessively high. Where fields were dry
enough to permit the use of a combine, seed was harvested directly from the standing crop. It was noted that the moisture content of the seed was high and seed bagged directly from the thresher germinated only 60-70 per cent. However, when samples of these seed lots were spread in thin layers and stirred frequently, a germination of nearly 90 per cent was obtained.

Griffith and Harrison (1954) made a survey of harvesting and curing methods in Michigan. They found that most of the directly combined seed contained approximately 50 per cent moisture. When seed was harvested at this moisture content the germination was low regardless of the method of drying used. Seed which had been harvested with a beater also was sampled. By this method only the mature seed is harvested and consequently it is lower in moisture at harvest. This seed germinated well even if stored in bags at the time of harvest.

The lower germination of the combined seed may be due in part to the amount of immature seed which is collected when the standing crop is combined. Arny et al. (1929) reported that immature seeds weighed only 0.358 grams per 1000 seeds and the germination averaged only 36.5 per cent. Mature seeds from the same seed lots weighed 0.865 grams per 1000 seeds and germinated 91 per cent. It seems evident that to obtain the maximum yielding potential, and the desired quality, it is necessary to have a high percentage of the seeds in the fully mature condition. Recent work in Oregon by Rampton and Warren
(1963) has indicated that windrowing of orchardgrass results in more mature seeds than direct combining and can be done effectively with crops grown in rows, if the rows are narrowly spaced. De Witt et al. (1962) compared windrowing with direct combining of bromegrass and bluegrass seed. They concluded that the seed which had been allowed to dry on the culm before combining was consistently higher in germination than seed which had been combined from the standing crop. It is impracticable to windrow reed canarygrass, due to the excessive amount of green forage at the base of the plant. The practical means of getting a high proportion of mature seed and at the same time reducing seed moisture, appears to be by the use of headers. Table 2 showing the 1960 survey of reed canarygrass seed production indicates that this is currently the method most commonly used for harvesting.

Seed Quality

When a crop is grown for seed purposes the most vital factor of seed quality is the germination percentage. Reed canarygrass seed has traditionally been low in germination. The seed industry accepts seed of 70 per cent germination, or better, as the standard for commercial use and the Iowa Crop Improvement Association (1961) lists the minimum acceptable standards for certification at 65 per cent germination.

Standard procedures for germination tests of reed canarygrass have been established by the Association of Official
Seed Analysts (1949). These standards include the use of light and alternating 20°-30° C temperatures. If the seeds are dormant, the use of a 0.2 per cent solution of potassium nitrate as the moistening agent is recommended. It has been suggested by a private laboratory\(^1\) that the \(\text{KNO}_3\) solution favors the growth of mold during the germination process. Colbry (1953) tested 9 freshly harvested seed lots of reed canarygrass under a wide range of conditions and concluded that the present regulations in the rules for testing reed canarygrass seed are adequate but suggested that the 0.2-per cent solution of potassium nitrate be used for all seed lots regardless of age or dormancy. It was noted in these tests that molds increased more rapidly under conditions where higher than normal temperatures were used. There was no greater amount of mold where \(\text{KNO}_3\) was used as the moistening agent than where water was used and the germination percentage was lower where water was used as the moistening agent.

Morris (1938) found that "hulless" reed canarygrass seeds would mold and rot before a germination test could be completed and suggested that the "hulless" seeds of reed canarygrass were practically worthless for seed purposes. Crosier and Cullinan (1941) tested dehulled seeds of reed canarygrass and found that the \(\text{KNO}_3\) solution was detrimental to the germination of the

\(^1\text{Ramy Seed Co., Mankato, Minnesota. Reed canarygrass seed germination. Personal communication. 1961.}\)
dehulled seeds, however, they concluded that the molds and rot were the factors which caused the lower germination. When organic mercury seed treatments were used, to reduce the growth of molds, it was reported that the "dehulled seeds produced at least as many sprouts as did the normal seeds." Fungicides were used by Griffith and Harrison (1954) to inhibit mold in reed canarygrass seed lots during the curing process, but the fungicides which prevented mold formation i.e. Ceresan M, Dowicide B and Actidione, seriously reduced the germination percentage of the seed. Arasan tended to reduce mold without injuring germination, however, the germination was not greatly improved over the check samples.

When reed canarygrass seed is properly handled a high germination is possible. Arny et al. (1929) found that mature seed germinated significantly higher than immature seed. These seed lots were hand harvested and dried in small quantities so heating of the moist seed should not have been a factor affecting germination.

In experiments with bluegrass seed, Bass (1953, 1954) found that the major factor affecting the germination was maturity at harvest. De Witt et al. (1961) found that bromegrass and bluegrass seed which was cured in the windrow was consistently higher in germination than seed which was combined from the standing crop. The higher germination was attributed to post-harvest maturation of the seed which remained attached to the plant after windrowing. With reed
canarygrass, Griffith and Harrison (1954) found that commercial seed lots which had been combined from the standing crop and then dried, germinated from 52 to 79 per cent. Comparable seed lots which had been harvested with a header and dried in piles, germinated from 93 to 98 per cent, however, in small seed lots, which were hand harvested, there was no difference in germination between seed dried in the heads or seed which had been threshed and then dried. The effect of maturity on germination appears to vary between species, as Grabe (1956) found that bromegrass seed had reached its maximum size and ability to germinate before it was dry enough to combine.

If high temperatures are used for drying seeds, the germination may be reduced. There appears to be a difference between species in the thermal death point at different moisture levels, as Grabe (1957) found that bromegrass seed dried at varying moisture levels, of up to 56 per cent, could withstand temperatures of 40°C. for a period of 52 hours without injury to germination. At a lower moisture content the temperatures could be increased considerably without injury to the seed. Griffith and Harrison (1954) found that reed canarygrass seed with 30 per cent moisture could not be dried at temperatures above 100°F. without seriously reducing the germination percentage.

The importance of vigor in a seed lot cannot be overlooked, but it is seldom specified on the seed analysis tag. Isely (1957) has defined vigor as, "the sum total of all seed
attributes which favor stand establishment under unfavorable field conditions."

Testing for vigor is a more complex process than testing for germination. Plant breeders often use the weight of the plant material produced in a given length of time, under uniform conditions in a greenhouse, as a measure of vigor. These tests are very time consuming when a large number of seed lots are involved and they are not generally in use by seed laboratories.

At the present time the only type vigor test which is commonly used is the cold test for corn. Some garden seeds for commercial market gardeners are given vigor ratings but the use of vigor tests is not a common practice.

The speed of germination and the rate of growth have probably been the most commonly employed methods of vigor testing. Lawrence (1963) used the daily germination count divided by the number of days from the start of the test in measuring vigor in ryegrass and found a correlation of +.66 between speed of germination and emergence from the 1 1/2 inch planting depth.

Asgrow Seed Company (1954) cited the use of the first count method as a test for vigor in garden seeds. The vigor rating given seeds at the time of the first germination count is currently being used by Asgrow Seed Company (1954) and was explained in a personal communication with Dr. J. S. Tidd,
Research Department, Asgrow Seed Company, New Haven, Connecticut, 1963. Each crop must be given a certain standard by the investigator and lots which meet these standards are labeled with a letter or number describing their vigor characteristics. It was noted by Asgrow Seed Company (1954) that a decline in vigor is usually noticeable six months or more before there is a decline in viability. Reed canarygrass seed often is carried over by growers or processors from a year of heavy production and this seed often is blended into new seed lots the following year. A vigor test which would help to detect a decline in viability would be a valuable tool for the industry.
MATERIALS AND METHODS

The objective of this study was to evaluate factors that cause low germination percentages and variable yields in the seed production of reed canarygrass. It was deemed necessary to obtain accurate information concerning the exact extent of these problems among seed producers and to determine the overall amount and quality of seed produced. The area under consideration was located in south central Minnesota, centered primarily in the counties of Blue Earth, LeSueur and Waseca.

Seed Production Survey

A survey was made of the amount and quality of seed offered for sale. Accurate information was available only from the principal seed buyer of the area\(^1\), but it was felt that this would constitute a good sample as this buyer has consistently contracted for the major portion of the annual seed production of the area. The results of this survey are listed in Table 1.

In obtaining the data for the seed survey the names and locations of the seed producers were recorded. A farm survey was then conducted to determine the field conditions under which the seed was being produced. Soil samples were collected

\(^1\)Ramy Seed Co., Mankato, Minnesota.
from about 50 seed production fields. Wherever it was possible to identify a seed lot with the field where the seed had been produced, both soil and seed samples were collected. The seed samples were tested for germination at the State Seed Laboratory in St. Paul, Minnesota. The soil samples were analyzed for pH, organic matter content, extractable phosphorous, exchangeable potassium, and were classified according to soil type by the University of Minnesota Soil Testing Laboratory. The results of the soil tests and the seed germinations are listed in Table 2.

On March 3, 1961, after the results of the seed germination trials and the soil tests had been compiled, a meeting was held with about 50 seed growers and processors of the area. Representatives of the seed industry, the Department of Soil Science, and the Department of Agronomy and Plant Genetics of the University of Minnesota also were in attendance. Following a thorough discussion of the problems concerned, plans were made to investigate some of the factors affecting seed production and quality.

The seed grower survey had revealed that much of the reed canarygrass seed was being produced on peat and muck soils (Table 2). There is very little information available concerning the use of mineral fertilization for grass seed production on these soil types so it was decided to use a wide range of fertility levels and combinations.
Statistical Design

Factorial designs are commonly used in the experimental determination of optimum levels of fertilizer inputs for maximum return. However, when the required levels of the various nutrients are unknown, and when three factors are involved, a factorial experiment can become extremely large. The amount of plot space, time, labor and materials necessary for running a complete factorial at several levels soon may exceed the resources available for the experiment.

Hader et al. (1957) have stated that where interactions exist the characterization of the response surface is necessary to evaluate the responses. It is possible to estimate a response surface by using a complete factorial, but the large number of treatment combinations which are necessary when three factors are used at several levels often has prevented the use of this design.

A new type of design has recently been developed by Box (1954) and is described by Cochran and Cox (1957) as a "composite" design. For this experiment a central composite rotatable design with 3 X variables was chosen. The variables in this instance were nitrogen, phosphorous and potash. In using this design with 3 variables it is possible to use 5 levels for each variable and add a center point with 6 identical treatments. This permits the analysis of a single replication as the 6 treatments give 5 degrees of freedom for
a within-error term. However, in using a single replication, the number of degrees of freedom for both lack of fit and error are small and a combination of more than one replication at each location gives more precision.

Two replications were combined for each location. The yields of all plots were computed and the analyses of variance, including regression coefficients, were computed with a desk calculator. It soon became evident, however, that these calculations and the estimation of the 125 possible predicted equations by the method of least squares as a multiple regression analysis was extremely time consuming. The model for the equations was:

\[ Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_{11} X_1^2 + b_{22} X_2^2 + b_{33} X_3^2 \]

\[ + b_{12} X_1 X_2 + b_{13} X_1 X_3 + b_{23} X_2 X_3. \]

The data were then turned over to the Computer Center at the University of Minnesota and a detailed analysis for the combined replications at each location was performed. Detailed analyses and graphs of the various response surfaces will be represented in the experimental results.

Plot Layout

An experiment was initiated in the spring of 1961 on established reed canarygrass sods. Two sites were selected, one on peat soil on the farm of a cooperating farmer in the
Soil samples were taken from the surface 6 inches of soil before the fertilizers were applied. The University of Minnesota soil testing laboratory analyzed these samples for pH, organic matter content, extractable phosphorous, exchangeable potassium and classified them according to soil type. The soil test results are included with those from the other seed production fields (Table 2).

Rainfall and temperature both before and during the seed production stage and during the various phases of harvesting can have a great influence on seed yields and quality. Weather records were kept for the growing season during each year of the experiment. An official United States Weather Bureau station is located within one-quarter mile of the plots on the Waseca Experiment station. The records from this station were believed to be useful also in relation to the plots located on the lowland soils as both outlying locations were within 6 miles of this weather station. A record of weather data is included in Table 3.

Much of the grass and legume seed now being commercially produced in the United States is grown in cultivated rows. Carter (1961), Hollowell and Beard (1962) and Garrison (1960) are among the many who cite advantages for using row plantings for seed production. These advantages include increased seed yields and ease of roguing and harvesting. The commercial seed production of reed canarygrass is largely from solid stands growing on low lying soils. It was believed, however,
that an investigation of the cultural methods as well as fertilization practices on mineral soils would be of interest and could possibly eliminate the necessity of harvesting seed from excessively wet soils of the low lying areas. To investigate this possibility new plots were established on the Waseca Experiment station in the spring of 1961.

A plot which had been summer fallowed the previous season was selected as it was believed that some weed competition might be eliminated and thereby permit better stand establishment. The area was marked into 36 inch rows with a field marker. Planting was done with a "Planet Jr." hand planter adjusted to plant two pounds of seed per acre. Another set of plots was established, to simulate solid stands, with rows spaced only one foot apart.

These systems of planting permitted cultivation with hand wheel hoes during the early part of the season. In this manner weed competition was satisfactorily controlled while the reed canarygrass seedlings were small. Later in the season the plots were clipped with a self propelled swather set to cut between four and five inches above the ground. The weed growth and reed canarygrass leaf material that was clipped with the swather was removed from the plots to prevent smothering of the seedlings. Cultivation with a tractor mounted cultivator also was possible in the 36-inch rows. One spraying with 4 ounces of actual 2-4,D amine per acre eliminated most of the broadleaf weeds. A slightly greater grass
weed competition was in evidence in the one foot rows as hand cultivation was possible only early in the season. Clipping, however, proved to be satisfactory in controlling weed competition and good stands were established on all plots.

Harvesting and Seed Processing

In 1961 the only seed harvest possible was on the low lying plots. Hand harvesting was practiced on all plots. To assure a uniform area of harvest, even where some lodging was in evidence, a square yard quadrat was used. This quadrat consisted of a steel rod which was bent in the form of a U. It measured 36 inches on each side. The open end was inserted near the base of the forage and another rod or bar was placed across the open end. The entire apparatus was then raised and all the culms of one square yard were enclosed. The bar was pushed towards the center to compress the culms into a smaller area. While being cut the panicles were held in an upright position to help eliminate the shattering of seed. Two square yards were harvested per plot.

The harvested panicles were immediately placed into cloth bags and hung in a building to dry. When dry, the panicles were threshed in a small plot thresher and cleaned by sieving and screening with a small seed cleaner. The seed from each plot was weighed to the nearest 1/2 gram and the seed weights were converted into yield in pounds per acre. Seed lots were cleaned by using a "South Dakota seed blower" with a setting
of 14 for 2 minutes. This cleaning eliminated all glumes which did not contain a caryopsis. The cleaned seeds were stored at room temperature conditions until tested for germination.

Germination Trials

Germination tests were conducted during the fall and winter following seed harvest. As a daylight type germinator was not available, a substitute germinator was constructed from a household refrigerator. Three florescent tubes were mounted on the back wall and were set to be operated by a manual switch. A separate thermostat was installed, and two small unit heaters were added, to permit a more rapid change from the dark, cool night temperatures to warm, light daytime conditions. The regular refrigerator compressor and condenser served as the cooling unit. Two laboratory thermometers and a recording thermometer were placed in the chamber to check its accuracy. Periodic checks did not reveal any deviations greater than 2° C from the desired temperatures.

The standard procedures for germination as set by the Association of Official Seed Analysts (1949) were followed. These standards consist of the following:

"Reed canarygrass seeds shall be placed to germinate for a period of 21 days at the alternating temperatures of 20°-30° C with light at the higher temperature. The substratum shall be moistened with water unless the seed is dormant, in
which case a 0.2 per cent solution of potassium nitrate shall be used as the moistening agent."

As it is normal to have a considerable amount of dormancy in reed canarygrass, and as it was impossible to determine the dormancy before running germinations, the 0.2 per cent solution of potassium nitrate was used as the moistening agent for all lots.

The seeds harvested in 1963 were tested in the walk-in 20°-30° C germinators at the Iowa State University seed testing laboratory. Covered petri dishes containing blotters, which had been moistened with a potassium nitrate solution, were used for all tests.

Morris (1938) and Crosier and Cullinan (1941) have reported that reed canarygrass seeds are often seriously injured by molds developing during the germination tests. Crosier and Cullinan (1941) suggested the use of seed treatments to prevent mold damage during germination. After discussing the feasibility of using fungicides to inhibit mold development during germination with personnel of the Iowa State University seed testing laboratory,¹ and reviewing some preliminary work done at the laboratory, it was decided to determine which of several commonly used fungicides might serve

¹Grabe, Don F. Iowa State University of Science and Technology. The use of fungicides to inhibit mold formation in the germination of reed canarygrass. Personal communication. January, 1964.
to inhibit mold development.

A laboratory trial was set up using five seed lots which had previously been determined to have a wide range of germination potential. The following fungicides were used:

Panoram 75

Active ingredient: Thiram (tetramethylthiuram disulfide) 75%

Ceresan M

Active ingredient: (Ethyl Mercury P-tolulene Sulfonilide) 7.7%

Captan 75 or Orthocide 75

Active ingredients: N-trichloromethylthiotetrahydrophthalimide 75%

Evaluation of the germination trials for vigor, mold rating and percentage germination were made and will be reported in the germination test results.

It was observed in the original seed grower survey that many of the seed lots had a musty odor. A similar condition probably contributed to the molding during germination as noted by Morris (1938).

In an attempt to determine which factors contribute to the low germination and mustyness of many seed lots, it was decided to investigate the seed handling methods and to observe conditions from seed harvest to market. In 1961 commercial harvesting operations were observed throughout the seed producing area of south central Minnesota. The observations
correlated very well with the findings of the seed grower survey, namely:

1. Most of the reed canarygrass seed harvested in south central Minnesota is harvested with a header.

2. The harvested heads are placed into small piles for curing or until sufficiently dry to be threshed. Threshing operations usually are performed by a small grain combine.

3. The drying of most of the threshed seed is accomplished by spreading the seed in thin layers on either wood or concrete floors. During the drying process the seed is stirred from one to several times each day. A few seed lots are dried with unheated forced air and a few seed producers use heated air for drying.

Seed Drying Trials

In 1962 samples were collected from several commercial production fields at the time of harvest. The samples were placed in small piles, or in bags hung in open sheds, to permit drying by natural air but to eliminate any possibility of rain from interfering with the drying process. The piles in the fields from which the samples were removed were marked and samples were again collected when threshing operations began. Over 4 inches of rain fell between the harvesting and threshing operations in 1962 (Table 3). It was observed that a considerable amount of mold and mustyness was present in the piles at the time of the second sampling.
The same system of sampling was repeated in 1963, although different production fields had to be used due to the fact that a severe hailstorm ruined some of the fields which had been sampled in 1962. Very little rainfall occurred between harvesting and threshing operations in 1963 (Table 3) and the piles of seed heads did not exhibit the mold and mustyness that was present at the second sampling in 1962.

Griffith and Harrison (1954) noted that reed canarygrass seed collected from the combine heated in a period of a few hours if left in bags or was stored in bins where the layer of seed was deeper than 3 inches. In checking their results, it was noted that they used seed which had been combined from the standing crop and had a moisture content of approximately 50 per cent. As the seed harvested in south central Minnesota is often dried in bins, where the depth exceeds 3 inches, it was decided to investigate this phase of seed handling more thoroughly. A notable difference between this trial and that of Griffith and Harrison was that in this instance all seed was field cured in piles of seed heads before threshing and the moisture at the time of threshing was in the range of 25 per cent. It was believed that at this lower moisture level it might be possible to cure the seed at slightly deeper depths without danger from heating.

Approximately 1000 pounds of commercially harvested seed was collected at the time of harvest and placed into bins 2 feet by 4 feet in size, at depths of 3 inches and 6 inches.
RESULTS AND DISCUSSION

The primary objectives of this study were to determine some of the factors which affect the yield and quality of reed canarygrass seed. The results will be presented in the following parts: survey of production and seed quality, methods of production and seed handling, seed yield trials, seed curing processes and seed germination. The major portion of this investigation was concerned with seed production on various soil types under various cultural practices, and a range of fertility levels. These portions of the results will be given more detailed attention than the other sections.

Seed Production Survey

A survey of the seed processors was conducted in the fall of 1960, to obtain an estimate of the amount and quality of reed canarygrass seed produced in the area. Because many seed lots traditionally have a low germination, the major processors will only purchase seed which they have tested for germination. The seed buyers inspect and sample the seed lots at the growers storage site. In this manner a fairly accurate estimate of the amount and quality of seed which is available is known to the processors before the purchasing contracts are signed.

The seed producers are contacted by more than one processor and therefore the combined information from all the processors would result in a considerable amount of duplication. It was
One set of bins was located on a concrete floor and one on a wood floor. In addition, bags of seed were placed adjacent to the bins in each instance to check the effect of seed stored directly in bags. The bins were arranged so that stirring of seed could be accomplished in some bins and others could be left undisturbed.

Seed temperatures and moisture percentages were recorded and at periodic intervals samples were removed for germination tests.

Effect of Forage Removal on the Following Seed Crop

In harvesting the 1962 seed crop it was noted that wherever the forage had been removed the previous year there was a considerable reduction in both vegetative growth and number of panicles. As there was no prearranged plan for checking this factor in 1962 it was decided to investigate the effect of forage removal upon the seed yields the following year. A border row on each plot had been cut for forage in June and this was again removed as forage in mid-August in 1962. In 1963 it was noted that both vegetative growth and the number of inflorescences produced were less on these rows than on the adjacent areas from which forage had not been removed. Seed harvests were made to determine any differences in seed yield as influenced by the previous seasons management.
northwestern portion of Waseca County.\textsuperscript{1} The other site was on a muck soil on the farm of a cooperating farmer in the northeastern portion of Waseca County.\textsuperscript{2} Both of these sites were selected because they appeared to be typical of the soil types on which reed canarygrass seed was being produced. Both fields were located in low lying areas but they were readily accessible for the necessary plot work. Seed of reed canarygrass had been harvested from each of the fields for the past several years and the stands appeared to be uniform across the areas chosen for the fertilizer trials.

Ammonium nitrate was used for the N source,\textsuperscript{3} concentrated superphosphate for the P source and muriate of potash for the K source. The fertilizer materials were weighed, mixed and bagged in the laboratory. They were spread by hand across the plots which were 10 feet by 27 feet in size. The large plot width was chosen because previous observations had shown reed canarygrass to exhibit a considerable amount of border effect if a plot were adjacent to a cultivated area or a heavily fertilized area. It was hoped also to investigate the carry-over effects of fertilizer and with a plot 27 feet in length this could be accomplished by fertilizing only 13.5 feet of each plot the next year.

\textsuperscript{1}Mr. Joseph Strohl, Janesville, Minnesota.

\textsuperscript{2}Mr. Eugene Miller, Waseca, Minnesota.

\textsuperscript{3}Fertilizers will be referred to by their chemical symbols.
decided to use the survey information from the largest processor and thus avoid duplication. From the information available it was felt that the survey would account for at least 75 per cent of the total production of the area. The results of the survey are listed in Table 1.

Table 1. Amount and quality of reed canarygrass seed offered for sale to one seed processor in 1960 in south central Minnesota

<table>
<thead>
<tr>
<th>Amount of seed</th>
<th>Germination</th>
<th>Per cent of crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>76,000 pounds</td>
<td>above 90%</td>
<td>12.0%</td>
</tr>
<tr>
<td>306,000 pounds</td>
<td>80-90%</td>
<td>48.5%</td>
</tr>
<tr>
<td>157,000 pounds</td>
<td>70-80%</td>
<td>25.0%</td>
</tr>
<tr>
<td>65,000 pounds</td>
<td>60-70%</td>
<td>10.0%</td>
</tr>
<tr>
<td>18,000 pounds</td>
<td>50-60%</td>
<td>3.0%</td>
</tr>
<tr>
<td>8,000 pounds</td>
<td>below 50%</td>
<td>1.5%</td>
</tr>
<tr>
<td>630,000 total pounds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of the seed survey indicated that 40 per cent of the seed had a germination percentage of less than 80 and nearly 15 per cent of the crop produced in 1960 was below 70 per cent germination and was technically unsalable.

A follow-up survey of the above was conducted among the seed producers who had sold seed during the fall of 1960. Soil samples were collected from 44 production fields and if
Table 2. 1960 Survey of production and harvesting methods used by 25 reed canai

growers.

<table>
<thead>
<tr>
<th>Grower number</th>
<th>Average acres harvested</th>
<th>Soil types</th>
<th>Average seed yield #/A</th>
<th>Average germination low</th>
<th>High</th>
<th>Harvesting methods</th>
<th>Seed drying methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>P</td>
<td>300</td>
<td>59</td>
<td>80</td>
<td>Header</td>
<td>floor-stirr-fan-no heat</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>P</td>
<td>100</td>
<td>70</td>
<td>90</td>
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<td>&quot;</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>P</td>
<td>200</td>
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<td>91</td>
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<td>&quot;</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>M</td>
<td>175</td>
<td>72</td>
<td>82</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>5</td>
<td>190</td>
<td>P &amp; M</td>
<td>175</td>
<td>80</td>
<td>93</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>6</td>
<td>220</td>
<td>P &amp; M</td>
<td>125</td>
<td>80</td>
<td>86</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>P</td>
<td>130</td>
<td>77</td>
<td>90</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>8</td>
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<td>P</td>
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<td>97</td>
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<td>&quot;</td>
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<tr>
<td>9</td>
<td>50</td>
<td>U</td>
<td>140</td>
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<td>89</td>
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<td>&quot;</td>
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<tr>
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<td>30</td>
<td>P</td>
<td>100</td>
<td>63</td>
<td>85</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>11</td>
<td>25</td>
<td>P &amp; M</td>
<td>90</td>
<td>78</td>
<td>90</td>
<td>Binder</td>
<td>fan-no heat</td>
</tr>
<tr>
<td>12</td>
<td>150</td>
<td>P &amp; M</td>
<td>175</td>
<td>63</td>
<td>85</td>
<td>Header</td>
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</tr>
<tr>
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<tr>
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</tr>
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<td>P</td>
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<tr>
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<tr>
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<td>94</td>
<td>&quot;</td>
<td>&quot;</td>
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<tr>
<td>20</td>
<td>275</td>
<td>P &amp; M</td>
<td>130</td>
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<td>86</td>
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<td>&quot;</td>
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<td>22</td>
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<td>P &amp; U</td>
<td>175</td>
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<td>90</td>
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<td>23</td>
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<td>300</td>
<td>67</td>
<td>92</td>
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<td>&quot;</td>
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<tr>
<td>24</td>
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<td>P &amp; M</td>
<td>175</td>
<td>55</td>
<td>85</td>
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<td>&quot;</td>
</tr>
<tr>
<td>25</td>
<td>50</td>
<td>P</td>
<td>200</td>
<td>67</td>
<td>92</td>
<td>&quot;</td>
<td>fan-w/heat</td>
</tr>
</tbody>
</table>

Total         2317                   4150
Average        92.68                   166

Strohl Plot
Miller Plot
Waseca Stat

\[a^p = \text{Peat} \quad M = \text{muck} \quad U = \text{upland soil.}\]

\[b\text{Soil tests V.H. = very high} \quad H = \text{high} \quad M = \text{medium} \quad L = \text{low.}\]
Average Seed Germination Harvesting drying Soil test of 1960

<table>
<thead>
<tr>
<th>Average germination harvest methods</th>
<th>Harvesting methods</th>
<th>Seed drying methods</th>
<th>pH</th>
<th>O.M</th>
<th>P</th>
<th>K^2</th>
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<td>78</td>
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<td>70 90 &quot;</td>
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<td>6.3 V.H. L. L.</td>
<td>76</td>
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<tr>
<td>59 91 &quot;</td>
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<td>74</td>
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<td>72 82 &quot;</td>
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</tr>
<tr>
<td>30 93 &quot;</td>
<td>&quot;</td>
<td>7.2 V.H. L. L.</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 86 &quot;</td>
<td>&quot;</td>
<td>6.5 V.H. M. V.H.</td>
<td>74</td>
<td></td>
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<td>77 90 &quot;</td>
<td>&quot;</td>
<td>7.0 V.H. V.H. V.H.</td>
<td>83</td>
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<td>53 91 &quot;</td>
<td>&quot;</td>
<td>6.7 V.H. M. M.</td>
<td>79</td>
<td></td>
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</tr>
<tr>
<td>53 89 &quot;</td>
<td>&quot;</td>
<td>6.9 H. V.H. V.H.</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>78 90 Binder</td>
<td>fan-no heat</td>
<td>5.8 H. V.H. V.H.</td>
<td>84</td>
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<td></td>
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<tr>
<td>65 85 Header</td>
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<td>7.0 V.H. H. V.H.</td>
<td>80</td>
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</tr>
<tr>
<td>65 93 &quot;</td>
<td>floor-not V</td>
<td>7.0 H. V.H. V.H.</td>
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<tr>
<td>50 94 &quot;</td>
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<td>89</td>
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<tr>
<td>55 90 &quot;</td>
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<td>71</td>
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</tr>
<tr>
<td>58 94 &quot;</td>
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<td>93</td>
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<tr>
<td>68 86 &quot;</td>
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</tr>
<tr>
<td>65 90 &quot;</td>
<td>&quot;</td>
<td>6.7 V.H. H. M.</td>
<td>89</td>
<td></td>
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</tr>
<tr>
<td>70 90 &quot;</td>
<td>&quot;</td>
<td>6.6 V.H. H. M.</td>
<td>71</td>
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</tr>
<tr>
<td>55 85 &quot;</td>
<td>&quot;</td>
<td>7.2 V.H. L. M.</td>
<td>82</td>
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<tr>
<td>67 92 &quot;</td>
<td>fan-w/heat</td>
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<td>91</td>
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<tr>
<td>67 92 &quot;</td>
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<td>68 89 Strohl Plots</td>
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<td>77.44</td>
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<td>77.44</td>
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<td>Waseca Station</td>
<td>6.3 V.H. H. M.</td>
<td>77.44</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

= medium  L = low.
seed, which had been produced on the same field, was available. A seed sample was also collected. The soil samples were analyzed and the seed samples were tested for germination. Results of the growers survey are listed in Table 2. The soil tests for the plots used in the seed yield study also are included in this table.

The weather plays an important role in any crop production study. It is even more critical with a seed crop like reed canarygrass as the harvested heads are exposed to the weather elements for a period of from one to several weeks after harvest. Weather data were collected at the Waseca station and a summary for the three years of this study is listed in Table 3.

Seed Yield Trials

One of the main objectives of this study was to determine the effects of various fertilizer combinations on the yield of reed canarygrass seed. A composite design was used. There were 20 rates and combinations of N, P and K in each of the two replications at each location. In 1962 one set of plots were split to enable a heavier rate of fertilization to be applied to one-half of the plot area and to check the residual effect of the 1961 fertilizer applications on the other one-half of the plot. An adjacent set of plots was fertilized at the initial rate. This permitted the comparison of residual effects, and two rates of fertilizer applications.
Table 3. Weather data 1961-1963, Waseca, Minnesota

<table>
<thead>
<tr>
<th></th>
<th>Average maximum</th>
<th>Average minimum</th>
<th>Departure from long term means</th>
<th>Total rainfall</th>
<th>Departure from long term means</th>
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<td><strong>1961</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>49.8</td>
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<td>43.1</td>
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<td>5.87</td>
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<td>July</td>
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<td>6.73</td>
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<td>+2.25</td>
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<td>September</td>
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<td><strong>1962</strong></td>
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<tr>
<td>April</td>
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<td>+2.2</td>
<td>5.41</td>
<td>+.83</td>
</tr>
<tr>
<td>July</td>
<td>82.2</td>
<td>61.3</td>
<td>-1.1</td>
<td>5.18</td>
<td>+1.92</td>
</tr>
<tr>
<td>August</td>
<td>79.1</td>
<td>57.0</td>
<td>-2.8</td>
<td>2.27</td>
<td>-1.20</td>
</tr>
<tr>
<td>September</td>
<td>75.0</td>
<td>51.3</td>
<td>+1.2</td>
<td>4.03</td>
<td>+1.11</td>
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</tbody>
</table>

Daily rainfall of .10 inches or greater 6/25 through 7/31

<table>
<thead>
<tr>
<th></th>
<th>1961</th>
<th>1962</th>
<th>1963</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>1.30</td>
<td>1.23</td>
<td>1.12</td>
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<td>May</td>
<td>2</td>
<td>.96</td>
<td>1.41</td>
</tr>
<tr>
<td>June</td>
<td>1.49</td>
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<td>July</td>
<td>.25</td>
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<td>.39</td>
</tr>
<tr>
<td>August</td>
<td>1.35</td>
<td>Total 6.48</td>
<td>Total 7.33</td>
</tr>
<tr>
<td>September</td>
<td>16</td>
<td>.30</td>
<td>19.09</td>
</tr>
</tbody>
</table>
The seed yields were calculated and statistically analyzed. The analysis of variance for each set of plots are presented in tabular form for each set of replications. The results can be most easily interpreted through the viewing of a response surface graph. Graphs depicting the predicted yields are presented with the analysis of each set of replications.

An examination of the predicted yield equations of the 1961 production revealed that the maximum yield, within the range of the rates which were studied, occurred at the maximum inputs of N and K and at the third level of P. Thus in this experiment the maximum predicted yield was achieved with 80 pounds of N, 28 pounds of P and 66 pounds of K. At these inputs the predicted seed yield was calculated to be 649 pounds per acre. The midpoint of the response surface yielded only 540 pounds of seed per acre. In using a response surface a more meaningful evaluation can be made if the maximum yield is achieved near the midpoint of the surface. In this manner a study of the response surface will reveal diminishing returns when inputs exceed the optimum rate. In this instance the maximum productivity occurred near the maximum input and hence the point of diminishing return was not as obvious as it would have been if the maximum yield had been reached with a lower input.

The plots on the muck soils had to be abandoned due to excessive flooding. An unusually heavy rainfall occurred shortly after the fertilizer had been applied to these plots.
and the water level in the area remained high for several weeks. Some plots were covered with as much as 6 inches of water for several days. Although the water receded and harvesting was possible a great amount of variation was evident between various portions of the plot area. It was felt that no accurate data could be derived under these conditions and yield data will not be presented from these plots.

**Effect of N, P and K upon seed yields of reed canarygrass on peat soils in 1961**

The yield responses corresponding to the various treatment rates and combinations are presented in Table 4. The predicted yield equations for all possible levels and combinations of each nutrient were calculated. Some of the predicted yield equations are presented in the form of a surface response graph in Figure 1, and the analysis of variance derived from the predicted yield data is presented in Table 5.

The linear effect was highly significant and an examination of the data and the response surface indicates that the major portion of the linear effect was due to applied N. There was also a positive response to applied K. This was especially true at the higher rates of N. The quadratic effect was largely due to the applied P.
Table 4. Reed canarygrass seed yields obtained in 1961 with the specified fertilizer rates and combinations on peat soils

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
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</tr>
<tr>
<td>3</td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
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<td>28</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
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<td>6</td>
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<td>7</td>
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<td>8</td>
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<td>9</td>
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<td>13</td>
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<td>18</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>18</td>
</tr>
<tr>
<td>6 identical center points</td>
<td>40</td>
<td>18</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 1. Predicted production surface for yield of reed canarygrass seed on peat soils in 1961 as a function of applied N and K when applied P is 36 pounds per acre.
Table 5. Analysis of variance 1961 reed canarygrass seed yields

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Degrees of freedom</th>
<th>Sum of squares</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
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<tr>
<td>Replications</td>
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<td>275.6250</td>
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<td></td>
</tr>
<tr>
<td>Linear regression</td>
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<td>100577.3464</td>
<td>33525.7821</td>
<td>40.69**</td>
</tr>
<tr>
<td>Quadratic regression</td>
<td>6</td>
<td>22309.2131</td>
<td>3718.2021</td>
<td>4.51*</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>14083.5905</td>
<td>741.2416</td>
<td>0.90</td>
</tr>
<tr>
<td>Experimental error</td>
<td>10</td>
<td>8240.0000</td>
<td>824.0000</td>
<td></td>
</tr>
</tbody>
</table>

*In this and future tables the single asterisk indicates a probability level of less than or equal to 0.05.

**In this and future tables the double asterisk indicates a probability level of less than or equal to 0.01.

Effect of N, P and K applied in 1962 plus the residual effects of the fertilizer applied in 1961 upon the 1962 seed yields

The 1961 fertilizer plots were divided in an attempt to study a wider range of treatments. To facilitate the study of residual fertilizer effects one-half of each plot was left unfertilized. As the maximum seed yields had occurred with the maximum input of fertilizer in the 1961 trial a double rate of fertilizer was applied to the other one-half of each plot. It was hoped that this would result in maximum yields which more nearly fit the center points of the design and thereby would be more easily interpreted when viewing the response surface. Another set of plots was established adjacent to the
original set and fertilized at the initial rate.

The various treatment rates and combinations with the respective yield responses are listed in Tables 6, 7 and 8. The respective surface response graphs are shown in Figures 2, 3 and 4, and the corresponding analyses of variances are listed in Tables 9a, 9b and 9c.

The commercial seed production fields were considerably lower in yield in 1962 than in 1961 and the plot yields in 1962 were likewise lower than in 1961.

Applied nitrogen was the major factor which affected seed yields and the highly significant linear effect on all the yield trials in 1962 was largely due to applied N.

The highest yields on the peat soils were achieved at the high nitrogen rates. This was true on the residual plots and at both the high and low application rates.

On the residual plots, which had not received fertilizer since the spring of 1961, the yields were higher than on the adjacent plots which received the same fertilizer rates and combinations for the first time in the spring of 1962. The highest yield on the residual plots was 450 pounds per acre while the adjacent plots fertilized in 1962 had a top yield of 370 pounds per acre. The plots which had the 1961 residual plus the heavy fertilization rate in 1962 produced a maximum yield of 649 pounds per acre. This would indicate that a yield effect is achieved from both the residual fertilization of the preceding year as well as from the fertilizers applied during
Table 6. Reed canarygrass seed yields obtained on peat soils in 1962 as the residual effect of the specified fertilizer rates and combinations which were applied in 1961

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
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<tr>
<td>1</td>
<td>16</td>
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<tr>
<td>2</td>
<td>64</td>
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<tr>
<td>3</td>
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</tr>
<tr>
<td>center points</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 2. Predicted production surface for the yield of reed canarygrass seed on peat soils in 1962 as a function of the residual effects of the 1961 applications of N and K when P was at 18 pounds per acre.
Table 7. Reed canarygrass seed yields obtained on peat soils in 1962 as the residual effect of the specified fertilizer rates and combinations listed in Table 4 plus the specified fertilizer combinations which were applied in 1962

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
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<td>6 identical center points</td>
<td>80</td>
<td>35</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 3. Predicted production surface for the yield of reed canarygrass seed on peat soils as a residual of the 1961 applications of N and K plus the 1962 applications of N and K when P was at 0 pounds per acre.
Table 8. Reed canarygrass seed yields on peat soils in 1962 with the specified fertilizer rates and combinations which were applied in 1962

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>7</td>
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</tr>
<tr>
<td>6 identical center points</td>
<td>40</td>
<td>18</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 4. Predicted response surface for the yields of reed canarygrass seed on peat soils in 1962 as a function of applied N and K when applied P was 18 pounds per acre.
Table 9. Analysis of variance of 1962 reed canarygrass seed yields on peat soils

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Residual or plots which were fertilized in 1961 and on which no additional fertilizer was applied in 1962</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reps</td>
<td>1</td>
<td>748.22496</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>36455.01069</td>
<td>12151.67023</td>
<td>33.33**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>30465.61840</td>
<td>5076.10306</td>
<td>13.92**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>17749.10839</td>
<td>934.16359</td>
<td>2.56</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>3646.00000</td>
<td>364.60000</td>
<td></td>
</tr>
<tr>
<td>b. Plots fertilized at double rate of the 1961 fertilization or 0 to 160 pounds per acre</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reps</td>
<td>1</td>
<td>18.2248</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>80298.6288</td>
<td>26766.2096</td>
<td>27.55**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>54201.8928</td>
<td>9033.6488</td>
<td>9.30**</td>
</tr>
<tr>
<td>Lack of fit</td>
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<td>98202.2285</td>
<td>5168.5383</td>
<td>5.32*</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>9714.00000</td>
<td>971.4000</td>
<td></td>
</tr>
<tr>
<td>c. Plots, fertilized at the initial rate of from 0 to 80 pounds per acre</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Reps</td>
<td>1</td>
<td>0.0999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
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<td>23529.6602</td>
<td>195.10**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>21261.1460</td>
<td>3543.5243</td>
<td>29.38**</td>
</tr>
<tr>
<td>Lack of fit</td>
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<td>8712.8732</td>
<td>458.5722</td>
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<tr>
<td>Error</td>
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<td>1206.00000</td>
<td>120.6000</td>
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</tbody>
</table>
the seed production year. On the plots which received the low application rate the residual effect had a greater influence on seed yield than the effect of the fertilizer which was applied in the spring of the production year.

In viewing the response surface the linear effect of applied N is obvious. This is especially true at the low rates of applied K. Increasing inputs of N resulted in proportionate yield increases, however, with high inputs of both N and K there was a noticeable reduction in yield.

The plots which were fertilized for the first time in 1962 exhibited a highly significant linear effect. Most of the linear effect was due to applied N.

On all of the plots on peat soil in 1962 the maximum production was achieved at the highest rates of applied N. The predicted yield equations were not extrapolated beyond the response surface as there is danger of incorrect interpretation when one extends a predicted yield beyond the original surface.

**Effect of N, P and K on yields of reed canarygrass seed when produced on mineral soils in both cultivated rows and solid stands in 1962** The plots established on Nicollet silty clay loam soils at the Waseca station in 1961 were fertilized in the early part of April, 1962. The same rates and combinations of N, P and K which had been used on the peat soils were applied to these plots. The 1961 trials on the peat
soils had indicated that seed yields increased with increasing inputs of N, and K up to the maximum rates of the design, and increases were measured for applied P up to the fourth input level. An additional heavier application rate was applied to the peat soils in 1962, and it was decided to also include the heavier rate of application on the mineral soils. The initial rate was 0 to 80 pounds per acre and for the heavier rate this was doubled or 0 to 160 pounds per acre. As there were plots in both 36 inch cultivated rows and in solid stands the data cover four sets of plots each consisting of two replications.

The plot yields corresponding to the various combinations and rates of N, P and K are listed in Tables 10, 11, 12 and 13. The surface response graphs depicting the predicted yield equations are shown in Figures 5, 6, 7 and 8.

On the mineral soils there was a highly significant linear effect at both the 0 to 80 pound and at the 0 to 160 pound rates of application. Applied N accounted for the major portion of the linear effect. There was a positive yield increase attributable to applied P and K at the lower rates of application, however, at the higher rates there was a yield depression, which would account for the major portion of the quadratic effect.

On the solid stands the maximum predicted yields were achieved at the maximum inputs of N, P and K. The 36 inch row plots reached the maximum predicted yields at less than the maximum inputs and diminishing yields were evident at the
Table 10. Reed canarygrass seed yields obtained in 1962 in 36 inch row plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
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<tr>
<td>1</td>
<td>16</td>
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<td>2</td>
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<td>18</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>18</td>
</tr>
</tbody>
</table>

6 identical center points 40 18 33 300.0

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 5. Predicted response surface for the production of reed canarygrass seed in 1962 in 36 inch rows on Nicollet silty clay loam soils as a function of applied N and K when applied P was 35 pounds per acre.
Table 11. Reed canarygrass seed yields obtained in 1962 in 36 inch row plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>32</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>128</td>
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</tr>
<tr>
<td>3</td>
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<td>4</td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
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</tr>
<tr>
<td>7</td>
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<td>8</td>
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<td>56</td>
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<tr>
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<td>80</td>
<td>35</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 6. Predicted response surface for the yield of reed canarygrass seed yields in 1962 in 36 inch rows on Nicollet silty clay loam soils as a function of applied N and K when P was at 35 pounds per acre.
Table 12. Reed canarygrass seed yields obtained in 1962 in solid stand plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates(^a)</th>
<th>Mean seed(^b) yields</th>
</tr>
</thead>
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<td>N  P  K</td>
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<td>2</td>
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<td>16  28 13</td>
<td>269.0</td>
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<td>4</td>
<td>64  28 13</td>
<td>314.0</td>
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<td>16  7  53</td>
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<td>64  28 53</td>
<td>326.5</td>
</tr>
<tr>
<td>9</td>
<td>0  18  33</td>
<td>200.0</td>
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<td>80  18  33</td>
<td>327.0</td>
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<td>11</td>
<td>40  0  33</td>
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<td>12</td>
<td>40  35  33</td>
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<td>40  18  66</td>
<td>261.0</td>
</tr>
<tr>
<td>6 identical center points</td>
<td>40  18  33</td>
<td>293.0</td>
</tr>
</tbody>
</table>

\(^a\)Rates of N, P and K in pounds per acre (rounded to the nearest pound).

\(^b\)Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 7. Predicted response surface for the yields of reed canarygrass seed in solid stands on Nicollet silty loam soils as a function of applied N and P when applied K was 66 pounds per acre
Table 13. Reed canarygrass seed yields obtained in 1962 in solid stand plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>N</td>
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<tr>
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<td>32</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>128</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>56</td>
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<td>4</td>
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</tr>
<tr>
<td>14</td>
<td>80</td>
<td>35</td>
</tr>
<tr>
<td>6 identical center points</td>
<td>80</td>
<td>35</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 8. Predicted production surface for the yield of reed canarygrass seed in solid stands on Nicollet silty clay loam soils in 1962 as a function of applied N and P when applied K was 133 pounds per acre.
maximum rates.

The analyses of variance for the 4 sets of plots are listed in Tables 14a, 14b, 14c, and 14d. From these data it is evident that the linear effect explains the major portion of the variation and, as is indicated by both the yield data and the surface response graphs, the major portion of the linear effect was due to applied N.

The yields on the mineral soils were slightly lower than the comparable plots on the peat soils. This cannot be interpreted as being due to soil type alone because the plots on the peat soils were well established stands while on the mineral soils the plots had been established in the previous season and did not have as dense a system of rhizomes as the established stands on the peat soils.

Effect of the 1963 applications of N, P and K plus the residual effect of the 1962 applications on the yield of reed canary-grass seed in 1963 The plots on the peat soils were ruined by a severe wind and hail storm which occurred on June 26. After the storm there was virtually no seed left in the panicles and consequently no yield data can be presented from these plots for 1963.

A considerable number of the commercial fields were not harvested due to storm damage. The seed yields in the portions of the commercial production area which was not affected by the storm, were lower than normal due to seasonal fluctuation.
Table 14a. Analysis of variance of 1962 reed canarygrass seed yields from 36 inch row plots on mineral soils at the 0 to 80 pound fertilization rate

<table>
<thead>
<tr>
<th></th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
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<td>714.0250</td>
<td>714.0250</td>
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</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>48631.8585</td>
<td>16210.6195</td>
<td>40.76**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>16841.7910</td>
<td>2806.9651</td>
<td>7.08*</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>16463.1004</td>
<td>866.4789</td>
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</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>3977.0000</td>
<td>397.70</td>
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</tr>
</tbody>
</table>

Table 14b. Analysis of variance of 1962 reed canarygrass seed yields from 36 inch row plots on mineral soils at the 0 to 160 pound fertilization rate

<table>
<thead>
<tr>
<th></th>
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<th>M.S.</th>
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</tr>
</thead>
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<tr>
<td>Reps.</td>
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<td>15.73**</td>
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<tr>
<td>Linear</td>
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<td>28188.8914</td>
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</tr>
<tr>
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<td>6</td>
<td>18733.5150</td>
<td>3128.9191</td>
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<tr>
<td>Lack of fit</td>
<td>19</td>
<td>22901.1436</td>
<td>1205.3233</td>
<td></td>
</tr>
<tr>
<td>Error</td>
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<td>5974.0000</td>
<td>597.4000</td>
<td></td>
</tr>
</tbody>
</table>
Table 14c. Analysis of variance of 1962 reed canarygrass seed yields from solid stands on mineral soils at the 0 to 80 pound fertilization rate

<table>
<thead>
<tr>
<th></th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
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<tr>
<td>Reps.</td>
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<tr>
<td>Linear</td>
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<td>17235.3038</td>
<td>5745.1012</td>
<td>10.07**</td>
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<tr>
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<td>1735.7278</td>
<td>3.04*</td>
</tr>
<tr>
<td>Lack of fit</td>
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<td>31481.4293</td>
<td>1656.9173</td>
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<tr>
<td>Error</td>
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<td>5706.0000</td>
<td>570.6000</td>
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</tbody>
</table>

Table 14d. Analysis of variance of 1962 reed canarygrass seed yields from solid stands on mineral soils at the 0 to 160 pound fertilization rate

<table>
<thead>
<tr>
<th></th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
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<td>600.6250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
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<td>23737.4252</td>
<td>30.20**</td>
</tr>
<tr>
<td>Quadratic</td>
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<td>2539.1983</td>
<td>423.1997</td>
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<tr>
<td>Lack of fit</td>
<td>19</td>
<td>16132.2756</td>
<td>849.0671</td>
<td>1.08</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>7859.0000</td>
<td>785.9000</td>
<td></td>
</tr>
</tbody>
</table>
Most of the commercial growers, who were contacted, reported that production was less than one-half of a normal yield. Local seed processors have reported that less than 200,000 pounds of seed were offered for sale in 1963. This represents only one-fifth to one-third of a normal crop.

The seed yields from the experimental plots on mineral soil had been harvested before the storm occurred, but they reflect the seasonal trend of lower than normal yields. Tables 15, 16, 17 and 18 list the seed yields which were obtained with the specified fertilizer rates and combinations.

The analyses of variance for the four sets of plots are listed in Tables 19a, 19b, 19c, and 19d. A highly significant linear effect is evident for each set of data. The major portion of both the linear and the quadratic effects are due to applied N.

The predicted yield equations were calculated and are illustrated in Figures 9, 10, 11, and 12. An examination of the response surfaces indicates that the maximum returns were obtained with lower inputs of N on the cultivated rows than on the solid stands. The cultivated rows were rototilled which mixed the organic residues with soil and probably contributed to a more rapid decay than occurred on the solid stands.

The plants in the solid stands did not reach the same intensity of color as was noted in the cultivated rows with the same rates of applied N.
Table 15. Reed canarygrass seed yields obtained in 1963 in 36 inch row plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates*a</th>
<th>Mean seed yields</th>
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</thead>
<tbody>
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<td></td>
<td>N</td>
<td>P</td>
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<tr>
<td>1</td>
<td>16</td>
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<tr>
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<td>18</td>
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<tr>
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<td>18</td>
</tr>
<tr>
<td>6 identical center points</td>
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<td>18</td>
</tr>
</tbody>
</table>

*aRates of N, P and K in pounds per acre (rounded to the nearest pound).

bSeed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 9. Predicted production surface for the yield of reed canarygrass seed in 1963 in 36 inch rows on Nicollet silty clay loam soils as a function of applied N and K when applied P was at 18 pounds per acre
Table 16. Reed canarygrass seed yields obtained in 1963 in 36 inch row plots on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
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<tr>
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<tr>
<td>3</td>
<td>32</td>
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<td>8</td>
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<tr>
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<td>center points</td>
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</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 10. Predicted production surface for the yield of reed canarygrass seed in 1963 in 36 inch rows on Nicollet silty clay loam soils as a function of applied N and K when applied P was 70 pounds per acre.
Table 17. Reed canarygrass seed yields obtained in 1963 in solid stands on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt; N P K</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
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<td>64 7 13</td>
<td>116.0</td>
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<td>16 28 13</td>
<td>36.0</td>
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<td>4</td>
<td>64 28 13</td>
<td>120.0</td>
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<td>5</td>
<td>16 7 53</td>
<td>30.5</td>
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<tr>
<td>6</td>
<td>64 7 53</td>
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<td>6 identical</td>
<td>40 18 33</td>
<td>104.0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 11. Predicted production surface for the yield of reed canarygrass seed in 1963 in solid stands of Nicollet silty clay loam soils as a function of applied N and P when applied K was 66 pounds per acre.
Table 18. Reed canarygrass seed yields obtained in 1963 in solid stands on Nicollet silty clay loam soils with the specified fertilizer rates and combinations

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rate&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>32</td>
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<tr>
<td>4</td>
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</tr>
<tr>
<td>6 identical</td>
<td>80</td>
<td>35</td>
</tr>
<tr>
<td>center points</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 12. Predicted response surface for the yield of reed canarygrass seed in 1963 in solid stands on Nicollet silty clay loam soils as a function of applied N and P when applied K was 106 pounds per acre.
Table 19a. Analysis of variance of reed canarygrass seed yields obtained in 1963 from plots in 36 inch rows when fertilized at the rate of 0 to 80 pounds per acre

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>28.8999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>48887.6646</td>
<td>16295.8882</td>
<td>62.27**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>8096.6732</td>
<td>1349.4455</td>
<td>5.15*</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>5636.8621</td>
<td>296.6769</td>
<td>1.13</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>2617.0000</td>
<td>261.0000</td>
<td></td>
</tr>
</tbody>
</table>

Table 19b. Analysis of variance of reed canarygrass seed yields obtained in 1963 from plots in 36 inch rows when fertilized at the rate of 0 to 160 pounds per acre

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>518.40000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>167526.3889</td>
<td>55842.4629</td>
<td>183.03**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>37489.6622</td>
<td>6248.2770</td>
<td>20.48**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>12313.1487</td>
<td>648.0604</td>
<td>2.12</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>3051.0000</td>
<td>305.1000</td>
<td></td>
</tr>
</tbody>
</table>
Table 19c. Analysis of variance of reed canarygrass seed yields obtained in 1963 from solid stands when fertilized at the rate of 0 to 80 pounds per acre

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>19.5999</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>58336.8747</td>
<td>19445.6249</td>
<td>129.28**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>9706.9834</td>
<td>1617.8305</td>
<td>10.76**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>8184.8418</td>
<td>430.7811</td>
<td>2.86*</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1504.1000</td>
<td>150.4100</td>
<td></td>
</tr>
</tbody>
</table>

Table 19d. Analysis of variance of reed canarygrass seed yields obtained in 1963 from solid stands when fertilized at the rate of 0 to 160 pounds per acre

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>616.2250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>70786.1513</td>
<td>23595.3837</td>
<td>149.52**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>24647.4920</td>
<td>4107.9153</td>
<td>26.03**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>3344.1065</td>
<td>176.0056</td>
<td>1.11</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>1578.0000</td>
<td>157.8000</td>
<td></td>
</tr>
</tbody>
</table>
A comparison of the seed yields as listed in the Tables 15 and 17 indicates that 20 to 40 additional pounds of applied N are required on the plots in the solid stands to obtain seed yields which are equivalent to the yields obtained in the cultivated rows.

Effect of applications of N, P and K on the 1963 seed yields of reed canarygrass on plots from which the forage had been removed in 1962

From plot observation, in 1962, it was visibly apparent that a smaller number of seed heads and less vegetative growth occurred on the plots where the forage had been removed in 1961. When the plots from which the forage had been removed were compared with the adjacent rows where a seed crop had been harvested, but the aftermath of vegetative growth had not been removed, an obvious difference existed.

The forage growth was removed from one row of each plot, in the fertility study, on June 10 and again on August 15, 1962. Seed yields were harvested from these plots in June of 1963. Tables 20 and 21 list the seed yields which were obtained with the specified fertilizer rates and combinations. Extremely low yields were obtained especially at the low inputs of N.

An examination of the yield data from the plots on which the forage had been removed and the identical plots where the aftermath remained, is very illuminating. Table 15 and Table 20 are comparable sets of data as are Tables 17 and 21. A
Table 20. Reed canarygrass seed yields obtained in 1963 in 36 inch row plots on Nicollet silty clay loam soil with the specified fertilizer rates and combinations made in 1963 on plots from which the forage had been removed in 1962

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Mean seed&lt;sup&gt;b&lt;/sup&gt; yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>28</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>28</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>18</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>35</td>
</tr>
<tr>
<td>13</td>
<td>40</td>
<td>18</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>18</td>
</tr>
<tr>
<td>6 identical center points</td>
<td>40</td>
<td>18</td>
</tr>
</tbody>
</table>

<sup>a</sup>Rates of N, P and K in pounds per acre (rounded to the nearest pound).

<sup>b</sup>Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 13. Predicted response surface for the yield of reed canarygrass seed in 1963 in 36 inch rows on Nicollet silty clay loam soils, on plots from which the forage had been removed in 1962, as a function of applied N and P when applied K was 66 pounds per acre
Table 21. Reed canarygrass seed yields obtained in 1963 in solid stands on Nicollet silty clay loam soils with the specified fertilizer rates and combinations made in 1963 on plots from which the forage had been removed in 1962

<table>
<thead>
<tr>
<th>Treatment number</th>
<th>Fertilizer rates$^a$</th>
<th></th>
<th>Mean seed$^b$ yields</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
<td>K</td>
</tr>
<tr>
<td>1</td>
<td>16</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>64</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>6</td>
<td>64</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td>7</td>
<td>16</td>
<td>28</td>
<td>53</td>
</tr>
<tr>
<td>8</td>
<td>64</td>
<td>28</td>
<td>53</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>10</td>
<td>80</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>13</td>
<td>40</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>40</td>
<td>18</td>
<td>66</td>
</tr>
<tr>
<td>6 identical</td>
<td>40</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>center points</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$Rates of N, P and K in pounds per acre (rounded to the nearest pound).

$^b$Seed yields are expressed in pounds per acre of air dried seed (approximately 12% moisture).
Figure 14. Predicted response surface for the yield of reed canarygrass seed in 1963 in solid stands on Nicollet silty clay loam soils, on plots from which the forage had been removed in 1962, as a function of applied N and P when applied K was 66 pounds per acre.
REED CANARYGRASS SEED YIELD (LBS./ACRE)
statistical analysis between two separate surfaces is not a legitimate process, but a visual comparison reveals that the seed yields were from three to five times as large on the plots where the aftermath remained when compared with seed yields from plots where the forage had been removed.

The surface response graphs illustrated in Figures 13 and 14 reveal the effect of applied N and P. Increasing increments of N were extremely effective in producing increased seed yields on these plots. The analyses of variances listed in Tables 22a and 22b indicate a highly significant linear response which is largely due to applied N. P was selected as the other ordinate on the surface response graph as it contributed more to the yield than was contributed by applications of K. There was a slight yield depression due to high applications of P at the low rates of N but with increasing inputs of N the P applications served to increase seed yields and a slight NP interaction was evident. The maximum yields on both row plots and solid seedings occurred at maximum inputs of N, P and K but the response surface indicates that applied N was largely responsible for the yield increases.

The results have indicated that forage removal lowered the capacity of the plant to produce seed the following year. The study on the peat soils indicated that the residual effect of fertilizer nutrients, which had been applied the previous year, had a greater effect of increasing seed yields than the nutrients which were applied in the spring of the year in
Table 22a. Analysis of variance of reed canarygrass seed yields obtained in 1963 from 36 inch row plots from which the forage had been removed in 1962

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>27.2250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>17178.1125</td>
<td>5726.0375</td>
<td>1402.41**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>893.7144</td>
<td>148.9524</td>
<td>36.48**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>649.8930</td>
<td>34.2048</td>
<td>8.38**</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>40.8300</td>
<td>4.083</td>
<td></td>
</tr>
</tbody>
</table>

Table 22b. Analysis of variance of reed canarygrass seed yields obtained in 1963 from solid stands from which the forage had been removed in 1962

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>d.f.</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reps.</td>
<td>1</td>
<td>18.2250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>3</td>
<td>13751.6320</td>
<td>4583.8773</td>
<td>540.36**</td>
</tr>
<tr>
<td>Quadratic</td>
<td>6</td>
<td>811.5028</td>
<td>135.2504</td>
<td>15.94**</td>
</tr>
<tr>
<td>Lack of fit</td>
<td>19</td>
<td>497.7850</td>
<td>26.1992</td>
<td>3.08*</td>
</tr>
<tr>
<td>Error</td>
<td>10</td>
<td>84.8300</td>
<td>8.4830</td>
<td></td>
</tr>
</tbody>
</table>
Figure 15a. Reed canarygrass seed yield plots on mineral soils showing a plot in the foreground which received 0 pounds of nitrogen per acre. The plot in the background received 80 pounds of nitrogen per acre.

Figure 15b. A closeup of the reed canarygrass plot which received 80 pounds of nitrogen per acre.
which the seed crop was harvested.

Evans and Ely (1941) found that most of the rhizomes of reed canarygrass are developed during May, June, July and August and that the shoots which produce the next year's inflorescence develop from rhizomes which had been formed the preceding year.

This study had indicated that the residual effect of fertilizer nutrients had a greater effect on seed yields than fertilizer which was applied three months preceding the seed harvest and that forage removal, the year preceding the seed harvest, had a depressing effect on seed yields.

As the residual effect of fertilizer probably had an effect on the previous year's plant growth and rhizome development and the removal of the photosynthetic material would probably have a depressing effect on root and rhizome development, a further study should be made into the effects of these practices on the development of rhizomes and the carbohydrate reserves under various systems of fertilization and cutting practices.

Seed Harvesting and Drying

During the 1962 and 1963 seed harvests, samples were collected from piles of seed heads in commercial fields. The samples were dried at room temperature in the laboratory. Seed heads were collected from the same field piles at the time of threshing. During 1962 over 4 inches of rain fell
when the piles were in the field and the seed heads were wet and musty. In 1963 only 0.34 inches of rain fell during the field drying period and no mold or mustyness was in evidence.

The samples were tested for germination and the results are listed in Table 23a and Table 23b. It is evident that the 1962 samples, which were exposed to excessive rainfall during the field drying period, had deteriorated during the drying process and a buildup of fungi is evident from the mold ratings. It is interesting to note the difference in rate of germination. The seed lots which were dried under ideal conditions germinated considerably faster than the lots which were field cured.

The rate of germination is sometimes used as an indication of vigor. In testing vegetable seeds, Asgrow Seed Company (1954) found that the speed of germination declines more rapidly than the actual loss in viability and that a loss in vigor is followed by a drop in viability a few months later. These data would indicate that in reed canarygrass the speed of germination declines more rapidly than the actual viability itself.

The seed growers survey had indicated that a large portion of the harvested seed was dried by spreading the seed on floors. In 1962 commercial seed was collected at harvest and placed in small bins at various depths. Table 24 indicates the moisture loss from the various curing methods. The treatments listed as stirred were thoroughly mixed twice
Table 23a. Reed canarygrass seed germination in 1962 as influenced by methods of curing of seed heads

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Germination counts (mean of quadruplicate test)</th>
<th>Total germination percentage</th>
<th>Mold(^a) rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Germination counts (mean of quadruplicate test)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 days</td>
<td>14 days</td>
<td>21 days</td>
</tr>
<tr>
<td>After 5 months laboratory storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heads dried in piles in field</td>
<td>52</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Heads dried in laboratory</td>
<td>82</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>After 1 year and 5 months laboratory storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heads dried in piles in field</td>
<td>20</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Heads dried in laboratory</td>
<td>54</td>
<td>28</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^a\)Mold ratings: 1 indicates no evidence of mold, 5 = large colonies of mold covering several seeds
Table 23b. Reed canarygrass seed germination in 1963 as influenced by methods of curing of seed heads

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Germination counts (mean of quadruplicate tests)</th>
<th>Total</th>
<th>Mold</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
<td>14 days</td>
<td>21 days</td>
<td>percentage</td>
</tr>
<tr>
<td>Heads dried in piles in field</td>
<td>72</td>
<td>18</td>
<td>4</td>
<td>94</td>
</tr>
<tr>
<td>Heads dried in laboratory</td>
<td>74</td>
<td>17</td>
<td>5</td>
<td>96</td>
</tr>
</tbody>
</table>
Table 24. Moisture percentage in reed canarygrass after various drying methods\textsuperscript{a}

<table>
<thead>
<tr>
<th>Treatment Storage depth</th>
<th>Floor type</th>
<th>Mean moisture percentage\textsuperscript{b}</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 inch--not stirred</td>
<td>Concrete</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>6 inch--not stirred</td>
<td>Wood</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Burlap bag</td>
<td>Concrete</td>
<td>19.9</td>
<td></td>
</tr>
<tr>
<td>6 inch--stirred</td>
<td>Concrete</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>Burlap bag</td>
<td>Wood</td>
<td>18.9</td>
<td></td>
</tr>
<tr>
<td>3 inch--not stirred</td>
<td>Concrete</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td>3 inch--stirred</td>
<td>Concrete</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>6 inch--stirred</td>
<td>Wood</td>
<td>16.2</td>
<td></td>
</tr>
<tr>
<td>3 inch--not stirred</td>
<td>Wood</td>
<td>14.3</td>
<td></td>
</tr>
<tr>
<td>3 inch--stirred</td>
<td>Wood</td>
<td>12.7</td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{a}All seeds placed into bins at approximately 25.0\% moisture.

\textsuperscript{b}Mean moisture percentages ranked in order.

\textsuperscript{c}Means not joined by same bar differ significantly at .05 level as computed by Duncan's multiple range.
daily for the three week period of the drying trial. The samples listed as not stirred were left undisturbed except for probing with a thermometer to check seed temperature.

In the stirred samples the temperature never exceeded the daytime air temperature and in the unstirred samples no readings of greater than 90° F. were recorded. Griffith and Harrison (1954) indicated that reed canarygrass seed at 30 per cent moisture could be heated to 100° F. without injury to seed germination. As none of these samples ever exceeded 90° F. it was believed that the small rise in temperature during the drying process was not a factor which affected germination.

An analysis of variance of the moisture loss of the samples was computed and Duncan's multiple range analysis was utilized to determine the means which were significantly different at the .05 level. These data are included in Table 24.

An obvious difference existed between the means of the moisture percentages and an examination of the data indicated that in the drying of reed canarygrass seed on floors the moisture loss was more rapid from seeds on wood floors than on concrete, the 3 inch storage depth was superior to the 6 inch depth and stirring of seed promoted more rapid drying than seed which was left undisturbed.

Germination tests were made on the samples and an analysis of variance was computed for the germination counts. The
data are listed in Table 25. Duncan's multiple range analysis was used to test for significant differences and is included in Table 25. The seed from the deeper unstirred lots and from the burlap bags was musty and showed evidence of mycelial threads which matted the seed into small clumps.

Germination counts were significantly higher for the shallow layers and the stirred samples had a higher germination than the unstirred lots. The seed in the burlap bags was very musty and caked. Germination counts of the seed from the deeper unstirred lots and from the bagged seed indicated that a rapid decline in viability occurred with this type of seed drying.

Germination of Seeds Produced on Plots of Different Fertility Levels

Seed samples were collected from the yield trials and germination tests were conducted. The seed samples had been harvested at optimum maturity and were air dried in small bags in a building. All of the samples had germination counts in excess of 90 per cent.

An examination of the data revealed that no significant differences in germination existed. From this information it was concluded that seed samples which are carefully harvested and thoroughly dried retain a high percentage of viability. It seemed apparent that the soil fertility levels of this study did not affect seed germination and the variation in
Table 25. Germination percentages in reed canarygrass after various drying methods

<table>
<thead>
<tr>
<th>Treatment Storage depth</th>
<th>Floor type</th>
<th>Mean germination percentage</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 inch--stirred</td>
<td>Wood</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>3 inch--stirred</td>
<td>Concrete</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>6 inch--stirred</td>
<td>Wood</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>3 inch--not stirred</td>
<td>Wood</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>6 inch--stirred</td>
<td>Concrete</td>
<td>89</td>
<td></td>
</tr>
<tr>
<td>3 inch--not stirred</td>
<td>Concrete</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>6 inch--not stirred</td>
<td>Wood</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Burlap bag</td>
<td>Wood</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>Burlap bag</td>
<td>Concrete</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>6 inch--not stirred</td>
<td>Concrete</td>
<td>68</td>
<td></td>
</tr>
</tbody>
</table>

aAll seeds were placed into bins at approximately 25% moisture.

bMean germination percentages ranked in order.

cMeans not joined by same bar differ significantly at .05 level-Duncan's multiple range.

Germination of these samples was too small to merit further investigation in this study.
Reed canarygrass seed is subject to serious injury from molds which develop during the germination tests. During the germination of the seed lots involved in this study a wide range of mold development was apparent. Colonies of mold which developed from an infested seed appeared to encroach upon other seeds in the immediate area and thereby prevent their normal germination.

Seeds of three commercial seed lots and two older experimental lots were treated with four different fungicide treatments. An untreated sample of each seed lot was used as a check. The seeds were then subjected to the standard germination processes.

The fungicide Ceresan-M prevented mold development in all the seed lots but it appeared to be entirely too toxic for use in germination tests of this type. A few abnormal sprouts developed in some seed lots but sprouts which could be listed as normal occurred in only one seed lot. In this seed lot, when treated with Ceresan-M, the germination was only one-third as high as it was when other treatments were used. The other fungicides inhibited mold development to a lesser degree than Ceresan-M but they appeared to have no inhibiting effect on germination.
Table 26 lists the treatments and the germination results. The results indicated that the seed lots, which had been treated with a mild fungicide, had a significantly higher germination percentage than the check plots. All treatments, including the check, had a significantly higher germination than the lots which were treated with Ceresan-M.

The effect of the mild fungicide treatments were more pronounced for the seed lots which had been subject to heavy infestations of fungi during the seed drying process.

A tetrazolium test of seed viability had been performed on all seed lots before they were treated with the fungicides. The results of the tetrazolium test are listed at the base of Table 26 as a comparison with the actual germinations. The seed lots, which had been treated with a mild fungicide, had germination percentages which approximated the tetrazolium test but none of the lots reached the potential as predicted by the tetrazolium test.

The analysis of variance of the germination tests is listed in Table 27. The highly significant F values for the treatments can be explained in the following manner:

1. A check of Table 26 reveals that a wide difference existed between the potential germination of the various seed lots. This potential difference proved to be even greater under actual germination conditions and is manifested in the analysis of variance.
Table 26. Effect of fungicide treatments on the mean germination percentages of 5 reed canarygrass seed lots

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Seed lots&lt;sup&gt;a&lt;/sup&gt; and their mean germination</th>
<th>Statistical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Captan-75</td>
<td>81.25</td>
<td>65.00</td>
</tr>
<tr>
<td>Orthocide-75</td>
<td>81.00</td>
<td>64.50</td>
</tr>
<tr>
<td>Panoram-75</td>
<td>80.50</td>
<td>63.50</td>
</tr>
<tr>
<td>Check</td>
<td>74.25</td>
<td>58.75</td>
</tr>
<tr>
<td>Ceresan-M</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tetrazolium test&lt;sup&gt;c&lt;/sup&gt;</td>
<td>82</td>
<td>66</td>
</tr>
</tbody>
</table>

<sup>a</sup>A - 1963 seed air dried.
B - 1963 seed floor dried.
C - 1963 seed drying methods unknown.
D - 1962 seed floor dried in 3-inch layers--stirred.
E - 1962 seed floor dried in 6-inch layers--not stirred.

<sup>b</sup>Means not connected by some bar are statistically significant at 5 percent level by Duncan's multiple range method.

<sup>c</sup>Viability of seed lots by tetrazolium test.
Table 27. Analysis of variance of the effects of various fungicides on the germination of reed canarygrass seed

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>S.S.</th>
<th>M.S.</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replications</td>
<td>3</td>
<td>4.16</td>
<td>1.38</td>
<td>.70</td>
</tr>
<tr>
<td>Seed lots 4</td>
<td></td>
<td>26796.80</td>
<td>6699.20</td>
<td>3412.73**</td>
</tr>
<tr>
<td>Treatments</td>
<td>24</td>
<td>42178.80</td>
<td>10544.70</td>
<td>5371.72**</td>
</tr>
<tr>
<td>Fungicides 4</td>
<td></td>
<td>7022.90</td>
<td>438.93</td>
<td>223.60**</td>
</tr>
<tr>
<td>Seed lots x</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fungicides 16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>72</td>
<td>141.34</td>
<td>1.963</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>99</td>
<td>76144.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Significant at the 1 percent level.

2. As the fungicide, Ceresan-M proved to be toxic to most of the seed lots a wide variation in the effect of the fungicides was inevitable.

3. The seed lot x fungicide interaction can be explained by the reaction of seed lot C to the fungicide Ceresan-M. This lot proved to be more tolerant to a strong fungicide and had a mean germination of 25.75 per cent, when all other seed lots were killed.
Figure 16a. Illustrations of reed canarygrass seed germination after treatment with various fungicides

The seed lots are referred to in Table 26 from top to bottom. The seed lots are D, E, A.

The fungicide treatments from left to right are: Check, Ceresan-M, Panoram-75, Captan-75 and Orthocide-75.

Figure 16b. Illustrations of reed canarygrass seed germination after treatment with various fungicides

The seed lots are referred to in Table 26 from top to bottom. The seed lots are D, B, C.

The fungicide treatments are the same as in Figure 16a.
An investigation of the seed production of reed canarygrass *Phalaris arundinacea* L. was initiated in 1960. A survey of seed producers and processors, conducted in the major seed production area of south central Minnesota, included determination of the amount of production and seed quality based on germination. The amount of seed produced varies greatly from year depending on weather conditions and seed prices. In years of high prices attempts are made to harvest additional acreages. The total production of a three county area in south central Minnesota usually exceeds 500,000 pounds. Quality, as based on germination, varies from year to year due to the influence of weather conditions during harvest and seed drying.

A soil fertility experiment was initiated in 1961 on native reed canarygrass stands on peat and muck soils. A central composite rotatable design was used and fertility treatments to conform to a design of 20 rates and combinations of N, P and K per replication. Seed yields were harvested and yields were computed. Predicted yield equations were calculated for the 125 possible combinations for each set of replications.

Two additional fertility experiments were initiated in 1962 on stands which had been established on a Nicollet silty clay loam soil on the Waseca Experiment Station. Both cultivated row plots and solid stands were established.
Samples of harvested heads were collected from commercial harvesting operations at harvest. Comparisons of seed quality were made between seeds which were dried in piles in the field and portions of the same samples which had been dried in the laboratory.

Seed was collected from commercial harvesting operations at the time of the threshing and placed into small bins for a comparison of seed drying methods.

Fungicides were used during germination tests to check the effect of inhibiting molds during the germination tests.

1. Nitrogen had the greatest effect of any of the applied nutrients in increasing seed yields. A positive response to applied N was found in each experiment on both the peat soils and the mineral soils. The response to applied P and K was more erratic. At the low rates of applied N and at the high rates of P and K, a negative response to applied P and K was noted in some instances.

2. The residual effect of nutrients which had been applied one year before were found to have a greater effect on seed yields than the nutrients which were applied in the spring of the year in which the seed crop was harvested.

3. The plots on which the forage was removed in June and August of the year preceding the seed harvest produced significantly lower seed yields than the plots from which the forage had not been removed. The response to applied N was greater on the plots from which the forage had been removed
than on the plots where the aftermath remained throughout the previous season.

4. In years of heavy rainfall the seed which was harvested with a header and cured in piles in the field had a heavy buildup of seed fungi and low germination resulted. When the drying of the seed heads was not interrupted by rain the quality of the seed which was cured in the field was as high as that from seed heads cured under cover.

5. The moisture loss was more rapid from seeds dried on wood floors than on concrete. The 3-inch storage depth was superior to the 6-inch depth and stirring of the seed promoted more rapid drying than seed which was left undisturbed.

6. The germination percentage was significantly higher for seeds dried in shallow layers and the stirred samples had a higher germination than the unstirred lots.

7. There was no difference in the germination percentage between seed lots harvested from plots of varying fertility levels.

8. The fungi which are present in many lots of reed canarygrass seed cause molds to develop during the germination tests and accurate tests are not always possible. Treatment with mild fungicides such as Captan-75, Orthocide-75, and Panoram inhibits some of the mold development, resulting in higher germination readings in seed lots which are infested with fungi. The use of strong fungicides such as Ceresan-M resulted in severe injury to normal germination of reed canarygrass seed.
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