Effect of Nitrogen Fertilization on the Establishment, Density, and Strength of Merion Kentucky Bluegrass Sod Grown on a Mineral Soil

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EFFECT OF NITROGEN FERTILIZATION ON THE ESTABLISHMENT, DENSITY, AND STRENGTH OF MERION KENTUCKY BLUEGRASS SOD GROWN ON A MINERAL SOIL

by

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Kent W. Kurtz

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INTRODUCTION

With the advances in technology of the last few decades, the shortened work week and increased leisure time, there has appeared an ever increasing demand for recreational facilities, many of which require turf. Added to this are the increased activities revolving around the lawn and garden of the suburbanite and the Federal government's emphasis on beautification. Thus, in a few short years, the demand for and the production of sod has evolved into a large industry.

Over one-half of the commercial sod produced is grown on well-drained, organic soils (muck and peat). Sod grown on these soils is lighter to handle, is produced in twelve months or less, and has well-developed roots and rhizomes. However, sod produced on mineral soils (sand, clay, loam) is superior to that grown on organic soils because it has greater cohesiveness and does not readily separate from the soil beneath. Therefore, sod grown on mineral soils is used more extensively for athletic fields, golf greens, public parks, and recreation areas where traffic is heavy.

Most grasses grown for sod purposes are seeded in the fall rather than in the spring. Fall rains, reduced weed competition, and favorable weather for both seedbed preparation and bluegrass production are the main reasons for this cultural practice.

The purpose of this investigation is to determine: 1) the specific level of nitrogen necessary to establish a spring-seeded, quality Merion bluegrass sod on a mineral soil in one season (less than twelve months), and 2) to determine what variations if any exist between the different nitrogen levels in relation to topgrowth, density, rhizome development, sod strength, and general appearance.

HISTORICAL REVIEW

Introduction

Most of the origins and migrations of Kentucky bluegrass are obscure. It was believed to have been known in Europe near the dawn of recorded history. By the time it was named *Poa pratensis* by Linnaeus it was widely spread through all of northern Europe. Per Kalm in 1749 reported that bluegrass was widely spread throughout the St. Lawrence Valley and French Canada. Moreover, it is not unlikely that Kentucky bluegrass descended via a Great Lakes route to Illinois, Ohio, Indiana, and Kentucky. Hence, the early history of bluegrass was associated with the movement of settlers, and its early use and adaptation in Kentucky were responsible for its common name (Daniel 1966, Schery 1959).

According to Jackson (1967) the invention of the cylinder mower in the 1830's was the most important single factor in lawn history giving impetus by providing an alternative to mowing with the sickle and the scythe. Daniel and Roberts (1966) and Jackson mention that the first attempts to apply scientific principles to the cultivation of turf began in the United States in Rhode Island in 1894.

Root, Rhizome and Foliar Studies of
Common Kentucky Bluegrass

Exhaustive studies by Fitts (1925), Laird (1930), Graber (1931), Harrison (1931), Sprague (1933), and Brown (1939) in the United States, and Evon (1931), Troughton (1956, 1957), and Baker (1957) in Great Britain provide a thorough background on turfgrass root response to clipping, fertilization, temperature, light, and moisture.

Early workers such as Harrison (1931), Darrow (1940), and Spencer, et. al. (1949) showed that continuous clipping of grass below three-fourths inches was detrimental to the production of roots, rhizomes, tops, and seeds of Kentucky bluegrass. Crider (1955) reported that the growth of roots ceased after forty to fifty percent of the foliage had been removed, and that defoliation of grasses caused serious restrictions in the development of the root system. Troughton (1957) states that turfgrasses must be tolerant of frequent, close clipping and must respond to this treatment by developing tillers to form a tight cover over the soil surface. Roberts and Bredakis (1960) point out that all clipping inhibits root development when compared with turf that has not been clipped. They also indicate that if turf is clipped at reasonable heights it will stimulate the production of rhizomes and tend to encourage the formation of sod. Daniel (1964) cites the inability of bluegrass to tolerate low heights of cut as one of its major limitations for lawn and sports use. He indicates that all varieties of bluegrass, except Merion, should be clipped no closer than one and one-half inches.

Sprague (1933) found in Kentucky bluegrass, that most of the roots occurred in the upper nine inches, the abundance decreasing rapidly with depth. It was discovered by Stuckey (1941) that the roots of Kentucky bluegrass remain functional for more than one year. Dittmer (1938) calculated that Kentucky bluegrass contains approximately two thousand roots and one million root hairs per cubic inch of soil with a combined length of over four thousand feet and a surface area of about sixty-five square inches. The work of Bosemark (1954) and Troughton (1957) reveals that long slender roots result when nitrogen levels are low; whereas short thick roots are evident when nitrogen levels are higher.

The greatest growth of Kentucky bluegrass herbage, as reported by Brown (1939), usually occurs during the late spring. Further research indicates that the late spring period of active growth of above ground parts of bluegrass is followed by the development during the summer of rhizomes and the storage of nutrients in them. Evans and Watkins (1939) found that under long days the shoots of bluegrass grow upright while under short days they grow in a decumbent manner. They conclude that day length has a greater influence on this phase of growth than temperature.

According to the investigations by Evans (1949), a greater number of branches developed rhizomes when the plants were grown under long days, and fewer rhizomes developed when the plants were grown under short days. Also, when average temperatures range from about thirty-five to fifty degrees in the early spring and late autumn, leafy shoots develop, but when average temperatures range from sixty to seventy degrees during the summer, rhizomes develop. Finally, both shoots and rhizomes develop in late spring and early autumn when average temperatures range between sixty and seventy degrees.

Harrison (1934) grew Kentucky bluegrass plants in glazed pots filled with sand. He observed that the rhizomes developed in the greatest numbers during the summer. He also found that production of above-ground stems was somewhat retarded, and that larger numbers of rhizomes developed when the days were long and bright.

Some of the branches of Kentucky bluegrass, as reported by Evans and Ely (1935), assume the form of underground rhizomes, by means of which the plant gradually spreads and occupies an increasingly large area. The first rhizomes which develop on a young plant originate from the axil of the above-ground leaves. A rhizome which develops in this manner turns downward and completes its development in the soil. However, most rhizomes originate beneath the soil surface as branches of older rhizomes and may branch and rebranch several times during one year.

Pellett and Roberts (1963) point out that during the summer, when lawns and recreational areas are used the most, bluegrasses are least aggressive. When the soil temperatures reach ninety degrees, the vigor of the grass declines. Daniel and Roberts (1966) mention that cessation of root development occurs when soil temperatures are in the eighties and nineties.

Nitrogen Fertilization Studies

Graber (1931) found that the food reserves of turfgrass are reduced by nitrogen fertilization and clipping. Nitrogen fertilization, according to Sprague (1933), stimulates the replacement of foliage removed in clipping and further restricts root development. Moreover, the responses of turfgrass to fertilizer are governed to a large extent by temperature and moisture conditions. He also reports that nitrogen is used by turfgrass in larger quantities than are the other plant nutrients.

Monteith (1929), Graber (1931), Harrison (1931), Noer (1942), and Stanford (1950) all indicate that proper nitrogen management is important to turf quality. Studies by Musser and his associates (1951) indicate that to obtain steady growth, good density, and a pleasing and durable condition throughout the growing season, a constant and liberal supply of plant nutrients must be available at all times.

Several investigators have studied the effects of the source of nitrogen and periodicity of application on turf quality. Sprague and Evaul (1930) report that a more vigorous turf was achieved by using slowly available nitrogen sources. Bengston and Davis (1939) conclude that soybean and cotton seed meals produced a more vigorous, weed-free turf than the turf produced by ammonium sulphate. DeFrance and Odland (1939) state that inorganic nitrogen did not produce a uniform turf throughout the season. Monteith and Welton (1939) found no differences in turf quality for either organic or inorganic forms when the applications were made at monthly intervals. The work of Welton and Carroll

(1940) also support this conclusion. In addition, Darrow (1940) found that the best leaf, rhizome, and root development occurred at pH 6.5 with monthly applications of ammonium nitrate. Musser and his colleagues (1951) showed more uniform, slow release of nitrogen throughout the season when urea - formaldehyde, a synthetic nitrogen source, was employed. Investigations by Gilbert, et. al. (1953) indicate that readily available nitrogen sources applied early in the spring may be partly wasted. Therefore, in order to maintain turf growth during the summer, smaller amounts of nitrogen must be added at intervals or the initial application should contain most of the nitrogen in a slowly available form. Bredakis and Steckle (1963) found that the natural organic nitrogen sources, such as activated sewerage sludge and processed tankage, released nitrogen more slowly to the turf, and that they could be applied at higher rates and at less frequent intervals. They discovered that fast-acting nitrogen sources such as ammonium sulphate, ammonium nitrate, sodium nitrate, and urea burned the foliage when left on the leaf tissue and concluded that the fast-acting sources should not exceed one pound per thousand square feet per application.

Mantell and Stanhill (1966) feel that quality and yield are of major importance in the production of economic crops such as corn and wheat, but that the aesthetic quality of a lawn is the main concern in turfgrass culture. Daniel (1950), Hagan (1955), Madison (1960, 1962), Goss (1960), and Madison and Hagan (1962) showed that aesthetic quality depends upon soil water, nitrogen fertilization, and mowing frequency and height. Pellett and Roberts (1963) found that when temperatures are high, growth is poorer and foliage is yellow green. Lobenstein (1967) reports that the yield of turfgrass, as determined by foliage production and dark green color, are in themselves poor indicators of quality. In his research with Kentucky bluegrass, the plots that received the highest nitrogen rates in monthly increments always rated highest from the viewpoint of color. However, after drouth had taken its toll, the high nitrogen plots lost most of their grass, and by the end of the season were the lowest in measured shoot density.

Merion Kentucky Bluegrass

Merion Kentucky bluegrass was discovered in 1936 by Joseph Valentine, superintendent of the Merion Golf Club near Philadelphia, in a patch of bluegrass on the country club site. Merion bluegrass, as reported by Schery (1936) and Daniel and Roberts (1966), was first released as an improved bluegrass variety in 1947. Merion was called B-27 by the USGA Green Section and was incorporated along with other varieties in the Arlington Research Center plots near Washington, D.C. The first seed was produced in 1950.

Lobenstein (1936) reports that Merion bluegrass is a rhizomatous grass, as it develops shoots at the underground nodes. Further, Merion spreads by underground, horizontal rhizomes, by upright tillers, and by dissemination of seed. Schery reports that Merion bluegrass, as well as other varieties of Poa pratensis, is apomictic. Reproduction occurs without fertilization and/or meiosis and facilitates the development of an exceptional plant that is identical to the parent one. Apomictic seed formation in Poa pratensis was discovered by Muntzing in 1933.

Juska, et. al. (1955) found that Merion was slow to germinate and that the seedlings were slow to become established as compared to other bluegrass varieties. Madison and Hagan (1962) report that after Merion is established, it may be encouraged to become dominant by regular heavy fertilization and irrigation. Further investigations by Juska and Hanson (1961) reveal that the nitrogen level has an important bearing on varietal performance. They found that the maintenance of a high quality Merion bluegrass turf often requires annual applications of six to eight pounds of actual nitrogen per one thousand square feet. Moreover, Merion is superior to common Kentucky bluegrass when topdressed annually with six pounds of nitrogen per one thousand square feet. Davis (1965) concludes: 1) any form of nitrogen in adequate amounts and used properly on Merion bluegrass will do a good job of supplying nitrogen to the grass, and 2) split applications of ammonium nitrate will usually give a more uniform response, but the heaviest application should be made in the fall. Research conducted by Daniel (1957), in which he compared Merion with eleven other lawn grasses, revealed that Merion always produced a denser, more uniform turf when well fertilized. However, when unfertilized, Merion was little better than the other grasses since weeds and clover were dominant. Daniel concludes that Merion was best only when fertilized three to six times per year with chemical fertilizers.

As reported by Roberts (1967), Merion bluegrass is very susceptible to stem rust, *Puccinia graminis*. This reduces its persistence and limits the usefulness of this variety in areas where rust is severe. The infection of leaf blades occurs during the hot weather of mid to late summer. Rapidly growing turf during this period suffers less disease injury as clipping removes much of the infection. Roberts found that a well fertilized and watered turf has fewer infection sites per plant or per area of sod than turf grown under low nitrogen and water conditions. Therefore, he concludes that to keep Merion bluegrass most resistant to rust, additional nitrogen should be applied during mid-summer and water should be applied frequently. Daniel (1966) further reports that rust infections are seldom damaging if Merion bluegrass receives four to six pounds of actual nitrogen per year and is irrigated to force new growth. Field observations by Cheesman (1965), supported by solution culture results, indicate that physiological processes within the plant may affect rust infection more than the growth rate of the turf.

The use of Merion bluegrass for sod has been instrumental in promoting both the Merion variety and the sod business. The factors that have contributed to its acceptance are its ability to form a dense sod, its shallow rhizomes, and its bright green color.

Sod Production

According to Mueller (1965), pasture grass was sold for sod forty years ago. Sod people would tour the countryside looking for sod that had some quality and a small percentage of weeds.

Indyke (1967) states that the efficient production of high quality sod involves the same basic principles and practices used in other areas of turfgrass culture. A quality sod, as specified by Miner (1967), consists of healthy, living plants of uniform density, texture, and color which is free of weeds and objectionable grasses. Mueller feels that a quality sod should be disease free, weed free, and have a heavy development of roots and rhizomes, a thick topgrowth, and a lush green color.

Studies by Musser (1957) indicate that one of the most important economic factors in commercial sod production is to mature the sod as rapidly as possible. If it is to be matured and cut as soon as possible, it is necessary that one follows a much more intensive maintenance program of clipping, watering, and fertilizing. This means that bluegrass sod should be clipped regularly at a height of one and one-half to two inches, watered during drouth periods, and fertilized at least once between seeding and harvesting. Roberts (1964) proposes that one inch of water per week and twenty pounds of nitrogen per acre per week may be necessary to establish a good sod.

Indyk reports that for most situations a 1:1:1 fertilizer can be used at a rate of one hundred pounds of actual material per acre. Moreover, when phosphorus and potassium are adequate, nitrogen should be applied in increments of fifty to sixty pounds per acre to maintain the color and growth. Also, soluble nitrogen sources are most commonly used in lieu of organic forms.

Roberts states that mineral soils with a sandy loam classification are good to use, but that highly sandy soils fail to hold together under common handling practices. He feels that heavier soils with good structure are suitable, but that the best sod is grown on muck soils.

Ruthven (1957) indicates that a Merion bluegrass sod can be produced in one year by using irrigation and proper methods of fertilization. The time of seeding, according to Indyk, is primarily confined to the late summer or early fall periods. Experience has shown that successful seedings can be made during the spring, but that in most instances sod from late summer or early fall seedings will mature and be ready for harvesting sooner than seedings made in the spring of the same growing season.

Lage and Roberts (1964) indicate that turf cut for sod should be at least one year old to give adequate time for the development of rhizomes and crowns. Musser reports that sod can be harvested as soon as it has knit sufficiently to permit handling without excessive loss; under favorable growing conditions sod can sometimes be cut when it is ten to twelve months old. Indyk states that the thickness of cut is determined by the type of soil, evenness of soil, density of sod, and the development of roots and rhizomes. Several methods have been used in the past to determine whether sod was ready to harvest. One method is to grasp two handfuls of grass and lift upward. If the grass parts from the roots without the roots being disturbed a potential supply of sod is available. The other method is to place a sod cutter in the field and cut a few yards of sod. The sod is then rolled and unrolled four times; if it holds together, it is satisfactory.

MATERIALS AND METHODS

Site Preparation, Treatment, and Maintenance

The site selected for this investigation was located between fairways on the Kalamazoo Country Club grounds. The area had received regular mowings but no fertilizer for several years.

The soil in the experimental area as determined by mechanical analysis is a Fox sandy clay loam consisting of twenty-three percent clay, fifty percent sand, and twenty-seven percent silt. A pH of 6.2 obviated the necessity of liming. Further analysis showed P_2O_5 to be in the high range. An application of one pound per one thousand square feet of potassium chloride (0-0-62) disced to a depth of five inches corrected the medium level of K_2O.

Preparation of the area included discing, rotovating, floating, and raking. Seeding was accomplished at the rate of two pounds per one thousand square feet with Blue Tag Merion on May 8,1967. Seeding was followed by light raking and rolling. A straw mulch was used to cover the area for approximately thirty days.

The seeded area was marked off into twenty-eight plots each of which measured ten feet by twenty feet (see Illustration 1). A randomized complete block design was employed, each treatment level was replicated four times.

Golden Uran, a commercial nitrogen solution containing twenty-eight percent nitrogen, was used as the nitrogen source (Table 1). Application of Golden Uran was made with a sprayer after dilution with one and one-half gallons of water.

Seven rates of nitrogen were tested. The rates tested, their equivalents in pounds per one thousand square feet and their schedules of applications, are shown in Table 2. Initial applications were made on July 1, 1967. All applications were followed by irrigation to prevent leaf burning.

The turf was irrigated uniformly as needed to supplement rainfall. Using rain guages as an aid, a minimum of at least one inch of water was applied to the area each week.

Evaluation Methods

Visual rating

A judging panel composed of agronomy students from Western Michigan University visited the plots on October 2, 1967 (Illustration 2). Each plot was assigned one of seven ranks ranging from one (least desirable) to seven (most desirable) on the basis of color, density, texture, plant vigor, percentage bare areas, and general appearance.

Clipping weights

The effectiveness of the various levels of nitrogen in producing topgrowth was measured by clipping weight yields taken at weekly intervals throughout the entire experiment, except for the period from July 22 to August 21, 1967. During this period weed control measures were taken. Disodium methyl arsonate (DSMA) and the amine form of 2,4-D were used for the control of crabgrass and broadleaf weeds, respectively. Adverse effects were mild and turf recovery was uniform.

Eight clipping weight determinations were made with a reel-type mower set at a height of one and one-half inches. All clipping samples were collected in a mower attachment, placed in brown paper bags, and weighed within two hours after mowing. Dry weight determinations in grams were made after the clippings were air-dried for one month. Both fresh and dry clipping weights were recorded.

Plant density

On August 13, and at the termination of the project on October 10, 1967, plant density was measured by the procedure described by Mahdi and Stoutemeyer (1953). Two turf cores, obtained by driving a four inch steel cylinder into the soil, were removed from each of the twenty-eight plots. All soil was gently washed from the roots and rhizomes. After the soil had been removed, the seedlings were dissected and the individual plants counted. A single stem was counted as one plant, and the results expressed in number of plants per twelve and one-half square inches. In addition, all rhizomes were counted and measured in inches; tillers present were merely counted.

Sod strength determinations

Sod strength determinations were made on October 11, 1967. A sod cutter was used to cut two pieces of sod, each sixteen inches wide, one inch thick, and thirty-six inches long. A piece of plywood was used to carry the sod to the stretching apparatus.

The sod stretching apparatus, an innovation of the Soil Science and Agricultural Engineering Departments of Michigan State University, was loaned for this investigation. The apparatus consists of a table approximately six feet in length, twenty-one inches in width, and four feet in height. There are two sixteen inch square plywood covered platforms on the top of the table. One is stationary and the other is equipped with wheels. The mobile platform is connected to a cable which runs over a pulley. A metal pail is attached to the other end of the cable. Sod to be tested is placed on the platforms which at the beginning of the test are together. Spikes and hooks secure the sod. Sand is slowly added to the metal pail, the platforms separate, and the sod stretches and eventually breaks. After breakage, the amount of sand in the pail is weighed and the weight is recorded in pounds.

Disease evaluation

The plots were evaluated visually for stem rust, *Puccinia graminis*, on October 5, 1967. Plots were ranked on a scale of zero to ten with zero assigned to plots exhibiting no rust, and with ten assigned to plots totally infested.

Statistical evaluation

All of the data derived from the research plots were computerized and analyzed statistically by the Mathematics Department of Western Michigan University. The Friedman Test was used for analysis of variance for ranked data (Winer, 1962). All other evaluations were derived using Duncan's Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION[1]

Visual Rating Results

A judging panel of agronomy students ranked each of the plots on several criteria. Friedman's Test, which is used to analyze variances between ranked data by utilizing two methods of agreement between judges (coefficient of concordance and average intercorrelation), revealed significant differences between the treatments. The data from these evaluations are found in Table 3.

The control plots were ranked "least desirable" and the plots of treatment four (4.0 lbs. nitrogen) "most desirable" on the basis of color, texture, density, thin and bare areas, and general appearance. The other plots were ranked as follows beginning with "least desirable" and continuing to "most desirable": plots of treatment one (1.0 lb. nitrogen, five (1.3 lbs. nitrogen), two (2.0 lbs. nitrogen), three (3.0 lbs. nitrogen), and six (2.6 lbs. nitrogen).

Visual Rating Discussion

Visual evaluation of turf quality provides valuable supplementary information to a research investigation. However, since such evaluations are often subjective, the appraisal methods used in this study were designed to be objective but yet convenient to apply. Even though the incidence and severity of stem rust in the plots caused some con-

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[1]Data from replication number three are not included in any of the statistical analysis due to erratic plot responses stemming from the presence of two soil types and an error in applying the nitrogen.

fusion among the observers, the judges' evaluations were quite consistent.

As the levels of nitrogen were increased on plots, the quality of the turf also increased. The control plots exhibited the lowest turf quality; the grass plants were chlorotic, sparse, stunted, and lacked sufficient root systems to extract adequate moisture and nutrients from the soil. Conversely, the treatment four plots (4.0 lbs. nitrogen) were ranked highest in turf quality. The plants of these plots had well-developed root systems which enabled them to maintain vigor and dark green color, and to increase in plant numbers by developing tillers (see Illustration 3).

Plots of treatments five and six received one-half of the nitrogen in the fall. Plots of treatment five (1.3 lbs. of nitrogen) did not respond to the additional nitrogen. However, plots of treatment six (2.6 lbs. nitrogen) responded to the fall application and surpassed plots of treatment three (3.0 lbs. nitrogen) in all quality ratings. It appears that the large nitrogen application in September accompanied by favorable temperatures (mean daily temperatures of 74 degrees) and optimum soil moisture caused the pronounced response of plots of treatment six.

The amounts of nitrogen applied to plots of treatments one (1.0 lb. nitrogen), two (2.0 lbs. nitrogen), and three (3.0 lbs. nitrogen) were not sufficient to stimulate and maintain the quality of the turf. These plots exhibited green color for the first one to two weeks following the monthly applications; but thereafter, they lost their green color and showed a decline in growth.

Clipping Weight Determination Results

Dried clipping weight yields taken on six harvest dates are grouped under three periods of growth: late August, early September, and late September. Duncan's Multiple Range Test was used to analyze the data.

The data indicate that the control plots are lowest while the plots of treatment four (4.0 lbs. nitrogen) are highest in clipping weight yields for the three growth periods (see Table 4). The clipping weight yields from plots of treatments one (1.0 lb. nitrogen), two (2.0 lbs. nitrogen), three (3.0 lbs. nitrogen), five (1.3 lbs. nitrogen) and control decreased after the last harvest date in August. Plots of treatments four (4.0 lbs. nitrogen) and six (2.6 lbs. nitrogen) showed increases in dry weight yields until mid-September; however, dry weight yields for these plots then decreased. The additional nitrogen applied in September to plots of treatment six increased the foliage production, but had no effect on foliage production on plots of treatment five.

Clipping Weight Determination Discussion

Clipping weight yields provide a means whereby growth responses can be measured and evaluated. Foliage growth, as measured by clipping weight yields, declines with decreasing nitrogen levels and with time. One exception is noted: foliage production in plots of treatment six increased after receiving one-half of the nitrogen in September.

The foliage from sod treated with low and medium concentrations of nitrogen became chlorotic with the passing of time. Chlorosis was most pronounced at low nitrogen levels. Chlorosis may be due to the following factors: 1) excessive leaching after rainfall or irrigation, 2) low residual nitrogen following application of Golden Uran, and 3) environmental stress resulting from low nutrition levels. The results suggest that higher rates of nitrogen (4.0 lbs. nitrogen, applied at monthly intervals, are necessary to replace nitrogen lost due to one or all of the above factors.

Plant Density Results

Plant density is determined by recording the number of plants, rhizomes, and tillers, and by measuring the length of rhizomes per twelve and one-half square inches of sod. Duncan's Multiple Range Test was used to analyze the plant density data (Table 5).

Comparison of the October density data with that recorded on June 30, 1967, prior to the first nitrogen application (177.0 plants per 12.5 square inches of sod), reveals that all plots except the control plots increased in plant number. Plots of treatment four have the greatest number of plants per area (238.7) followed by plots of treatment three (222.7). The control plots contained the least number of plants (169.7).

The number of rhizomes per twelve and one-half square inches of sod were greatest in plots of treatments three and four (31.0). Control plots had the least number of rhizomes (9.83). No significant differences are evident from the groups of plots which received additional nitrogen in the fall, namely plots of treatments five and six.

Plots of treatment six exhibited the longest total rhizome length

(28.7 inches) followed by plots of treatments four and three (26.3 and 25.0 inches, respectively). The control plots contained the shortest total rhizome length (5.13 inches) followed by the plots of treatment one (6.90).

Moreover, the plots of treatment six contained the longest average rhizome length (1.17 inches) while the control plots contained the shortest average rhizome length (.48 inches).

No significant differences are evident from the data relating to the number of tillers per area of sod. The F-Test was non-significant at the five percent level.

Plant Density Discussion

Nitrogen fertilization increased the density of plants in all plots except controls in proportion to the amount of nitrogen applied. The presence of fewer plants per area of sod indicates the interaction of both environmental stress and plant competition. Where stess and competition are lessened, plant vigor and plant number are increased.

The absence of high plant population in plots receiving low rates of nitrogen (treatments one, two, and three), may be the result of moisture stress. Plants in these plots were not able to absorb the available nitrogen from the soil in the absence of adequate moisture. Plots of treatments five and six received one-half of the allotted nitrogen in the fall; however, the additional nitrogen did not facilitate an increase in plant population. Rather, the additional nitrogen resulted in plants of larger size when compared with plants from plots receiving similar nitrogen levels but at monthly intervals.

Plots of treatment four (4.0 lbs. nitrogen) exceeded all other plots in respect to population number and size of individual plants because they received the highest rate of nitrogen.

The plots receiving three pounds and four pounds of nitrogen per one thousand square feet (treatments three and four) produced the greatest number of rhizomes because they received higher rates of nitrogen prior to September 1, 1967, and because the plants had sufficient leaf area for optimum photosynthesis.

Plots of treatment six produced the longest total rhizome length as a result of the large nitrogen application in September. Also, during this period cooler temperatures and optimum soil moisture conditions existed. These conditions favored not only the development of rhizomes but also the production of foliage. Conversely, plots of treatment five did not receive enough additional nitrogen in September to maintain adequate foliage. As a result, a few medium size rhizomes were produced but at the expense of foliage.

Sod Strength Determination Results

Sod strength determinations are significant at the one percent level using the F-Test (Table 6). No further statistical analysis of the sod strength data was possible because a significant interaction was present.[2]

The control plots could not be evaluated on the basis of stress

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[2]This interaction is believed to be due to variation in soil type.

since the sod within them could not be lifted from the place of growth. Plots of treatment four (4.0 lbs. nitrogen) required the most stress to stretch and separate the sod (44.3 lbs. stress). With the exception of the plots that received one-half of their nitrogen in the fall (treatments five and six), all plots increased in sod strength according to increasing rates of nitrogen. Moreover, plots of treatment five (1.3 lbs nitrogen) exceeded those of treatment two (2.0 lbs. nitrogen) in sod strength (27.4 compared with 26.0 lbs. stress) and plots of treatment six (2.6 lbs. nitrogen) exceeded those of treatment three (3.0 lbs. nitrogen) with thirty-eight pounds compared with thirty pounds of stress, respectively.

Sod Strength Determination Discussion

The sod stretching apparatus (see Illustration 4) proved to be a valuable instrument in determining that nitrogen is indirectly responsible for the production of roots and rhizomes which are essential to the strength of sod. As the level of nitrogen is increased, the density and development of roots, rhizomes, and crowns is also increased. The development of underground plant parts adds to sod strength and more stress is required to break such sods.

Nitrogen was deficient in the control plots and in the plots of treatment one (1.0 lb. nitrogen) as evidenced by the chlorotic appearance of leaves and in the number of plants. These plots were low in sod strength as available nitrogen was used in the formation of new leaves; there was little rhizome development.

Plots of treatments five (1.3 lbs. nitrogen) and six (2.6 lbs.

nitrogen) were equivalent to plots of treatments one (1.0 lb. nitrogen) and two (2.0 lbs. nitrogen), respectively, prior to the September nitrogen applications. However, sod strength determinations indicate that additional nitrogen applied in the fall, results in the production of shoots and rhizomes which enhance the sod strength.

Disease Evaluation Results

On September 21, 1967, a small area in one of the research plots appeared reddish-yellow in color compared with the other treatment areas. This was the initial infestation of stem rust, *Puccinia graminis*. It was identified by the small, raised red pustules that covered the entire leaf area. The disease spread to the other treatments, and by October 5, 1967, every plot, except the control plots, showed the disease.

Visual observations made on October 5 are found in Table 7. The control plots exhibited no symptoms of the rust, while plots of treatments six and four had the least amount of infestation, respectively. Plots of treatment five exhibited the greatest infestation followed by plots of treatments two, one and three.

Disease Evaluation Discussion

Control plots contained no stem rust due to sparse populations and contained more weeds than Merion bluegrass plants. Plots of treatments one, five, two, and three were heavily infested because they did not receive ample amounts of nitrogen and were under considerable stress for moisture since adequate moisture is essential for the absorption of nitrogen. The well-fertilized plots of treatments four and six were able to obtain adequate moisture and thus had fewer infection sites per plant and per area of sod. Heavy nitrogen fertilization, cool temperatures, and adequate moisture stimulate the growth of grass below the mowing height, and therefore, tend to reduce the severity of the disease as the infected grass blades grow fast enough and are removed during the mowing process.

CONCLUSIONS

The establishment of a quality Merion bluegrass sod on a mineral soil, with spring seeding, is possible only when intensive management practices are followed. The formation of a dense sod requires high nitrogen levels and favorable growing conditions.

When sod is irrigated frequently, soluble nitrogen cannot be stored in the soil for long periods of time. Therefore, nitrogenous solutions should be applied every three to four weeks. Moreover, the nutrient balance of Merion bluegrass may be upset by withholding nitrogen even though other plant nutrients are available in sufficient amounts for plant growth. When nitrogen is withheld, the growth rate of sod is severely retarded and the foliage becomes chlorotic.

Formerly, sod development was evaluated solely on the characteristics of color, texture, density, topgrowth, and root and rhizome development. However, the sod stretching apparatus designed by Michigan State University scientists provides a means of measuring the stress that must be exerted on sod to separate it which is an indirect indication of root, rhizome, and crown development.

In these studies four pounds of actual nitrogen per one thousand square feet (treatment four), applied over a period of three months, produced the most desirable sod. Four pounds of nitrogen also produced the most topgrowth, initiated the most rhizomes, and had the greatest sod density. In addition, four pounds of nitrogen produced sod that was rated "most desirable" by a judging panel on the basis of color, density, plant vigor, and over-all pleasing appearance. Furthermore, the sod grown under the four pound rate of nitrogen was most cohesive and resistant to separation.

The treatment that ranked second in almost every category was treatment number six in which plots received one-half of the nitrogen in the fall, and a total of two and two-thirds pounds of actual nitrogen per one thousand square feet. It surpassed treatment number four in resistance to disease and exhibited the longest rhizomes.

Nitrogen research studies on the establishment of quality Merion bluegrass sod are never complete. The creation of new materials, uses, techniques, demands, and tools for application continually present new problems to be solved.

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Table 1. The composition and physical properties of Golden Uran*.

Constituents	Percentage
Ammonium nitrate	39.5
Urea	30.5
Water	30.0
Total nitrogen	28.05
Nitrate nitrogen	6.91
Urea nitrogen	6.91
Physical properties	
Approximate specific gravity at 60 degrees F	1.28
Weight per gallon (lbs.)	10.67
Pounds of nitrogen per gallon soluble	2.99

* Golden Uran is the trade name for the nitrogen solution used in this investigation, manufactured and sold by the Allied Chemical Company.

Table 2. The levels of Golden Uran applied to the research plots according to the application dates.

Date	Treatment	Amount of N mls.	lbs./1000 sq. ft.	Total lbs./1000 sq. ft.
7-1-67	1	84.13	.33	.33
	2	168.26	.66	.66
	3	252.39	1.00	1.00
	4	336.52	1.33	1.33
	5	84.13	.33	.33
	6	168.26	.66	.66
	CK	-----	---	---
8-1-67	1	84.13	.33	.66
	2	168.26	.66	1.32
	3	252.39	1.00	2.00
	4	336.52	1.33	2.66
	5	84.13	.33	.66
	6	168.26	.66	1.32
	CK	-----	---	---
9-1-67	1	84.13	.33	1.00
	2	168.26	.66	2.00
	3	252.39	1.00	3.00
	4	336.52	1.33	4.00
	5	168.26	.66	1.33
	6	336.52	1.33	2.66
	CK	-----	---	---

Table 3. Visual turf rating according to color, density, plant vigor, thin and bare areas, and over-all evaluation by a judging panel of agronomy students.

Treatment	Color	Texture	Density	Plant Vigor	Thin & Bare Areas	Over-all Evaluation
CK	1.2*	1.0	1.0	1.1	1.1	1.1
1	2.1	2.1	2.2	2.3	2.3	2.2
2	3.6	4.1	4.1	3.9	4.2	4.0
3	4.6	4.5	4.4	4.4	4.4	4.5
4	6.6	6.5	6.4	6.6	6.4	6.5
5	3.5	3.5	3.6	3.6	3.7	3.6
6	6.3	6.2	6.2	6.2	5.8	6.1

Analysis of ranked data utilizing Friedman's Test.

*The above numbers signify the average of all replications expressed as 1.0 (least desirable) and 7.0 (most desirable).

Table 4. Effect of nitrogen fertilization on dry weight yields of clippings.

Treatment Number	lbs. N. per 1000 sq. ft.	Late Aug.** Clipping wts. (Grams)	Early Sept.** Clipping wts. (Grams)	Late Sept.** Clipping wts. (Grams)
CK	0.00	1.50 a	.71 a	.74 a*
1	1.00	3.10 a	2.44 ab	2.22 a
2	2.00	8.88 ab	7.55 ab	5.66 ab
3	3.00	16.79 bc	9.06 ab	6.38 ab
4	4.00	22.76 c	25.00 c	15.00 c
5	1.33***	3.46 a	3.35 ab	2.83 ab
6	2.66***	7.79 ab	11.85 b	8.85 b

* Mean values followed by the same letter do not differ significantly at the 5% level using Duncan's Multiple Range Test.

** Mean values represent two harvest dates for late August (August 21 & 31), early September (September 8 & 15), and late September (September 21 & 28).

*** Split nitrogen applications ¼ July 1, ¼ August 1, and ½ September 1). All other treatments received 1/3 July 1, August 1, and September 1, respectively.

Table 5. Plant density as expressed by plant population, rhizomes, and tillers.*

Treatment	(1) Average Total Plants (numbers)	(2) Average Total Rhizomes (numbers)	(3) Total Rhizome Length (inches)	(4) Average Rhizome Length (inches)	(5) Total Tillers on Rhizomes (numbers)
CK	169.7 a	9.83 d	5.13 a	.48 a	8.3
1	192.7 ab	14.2 cd	6.90 a	.52 a	11.5
2	213.5 bc	21.2 bc	12.4 ab	.57 ab	15.0
3	222.7 bc	31.0 a	25.0 cd	.81 abc	17.2
4	238.7 c	31.0 a	26.3 d	.84 abc	19.5
5	204.0 abc	17.8 bcd	16.7 bc	.95 bc	19.8
6	209.2 bc	26.0 ab	28.7 d	1.17 c	16.3

(1, 2, 3, 4)--Mean values followed by the same letter do not differ significantly at the 5% level using Duncan's Multiple Range Test.

(5)--The F Test was not significant at the 5% level.

* Two soil cores each 12.5 square inches in area per plot were analyzed.

Table 6. Strength of Merion Kentucky bluegrass sod following various applications of nitrogen.

Treatment Number	Total Pounds Actual Nitrogen per 1000 sq. ft.	Average Pounds Stress Required to Separate Sod.
CK	0.00	00.00
1	1.00	22.83
2	2.00	26.00
5	1.33 *	27.42
3	3.00	30.00
6	2.66 *	38.00
4	4.00	44.33

* Split applications of nitrogen, ¼ on July 1, ¼ of August 1, and ½ on September 1. All other treatments received 1/3 on July 1, 1/3 on August 1, and 1/3 on September 1, respectively.

The F-Test was significant at the 1% level.

The sod strength determinations were made on October 5, 1967.

Table 7. Visual disease evaluation for stem rust (<u>puccinia graminis</u>) on Merion bluegrass thirty-two days after the final nitrogen application.

Treatment Number	lbs. Actual N per 1000 sq. ft.	Total Percentage Disease	Average ** Percentage Disease
1	1.00	7.50	2.50
2	2.00	12.00	4.00
3	3.00	7.00	2.33
4	4.00	5.00	1.66
5	1.33 *	16.50	5.50
6	2.66 *	4.50	1.50
CK	____	____	____

* Split applications of nitrogen.

** The percentage of plants infested with rust as expressed by 1 (10%) - best; 10 (100%) - poorest.

Illustration 1. Randomized complete block design of the research plots between fairways on the Kalamazoo Country Club site.

1	2	3	4	5	6	ck	Replication I
3	6	ck	1	2	4	5	Replication II
4	5	2	6	ck	1	3	Replication III
ck	4	1	5	3	2	6	Replication IV

The symbols in the above boxes express the lbs. of nitrogen/1000 sq. ft./year: ck(0.0), 1(1.0), 2(2.0), 3(3.0), 4(4.0), 5(1.3), 6(2.6)

Illustration 2. Aerial view of the research plots at the time of evaluation by the judging panel of agronomy students.

Illustration 3. A view of the plot receiving four pounds of nitrogen per one thousand square feet (foreground) and the plot receiving one pound of nitrogen per one thousand square feet (right).

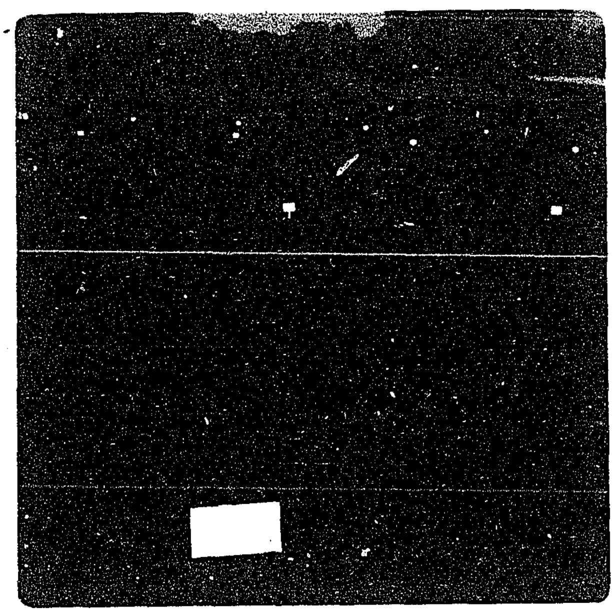
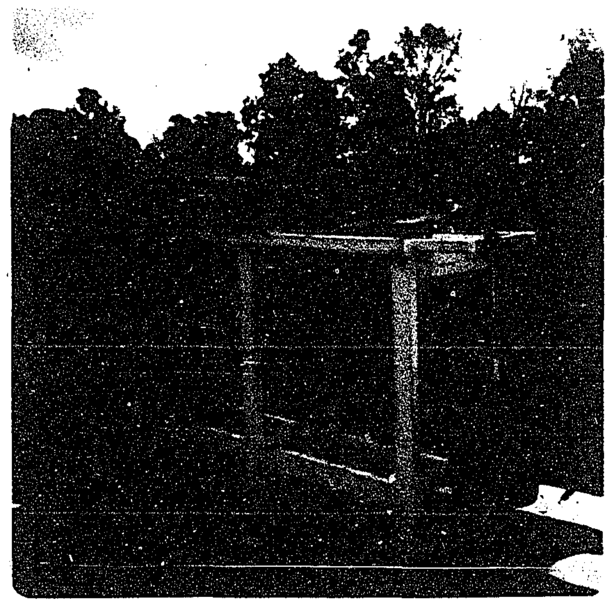


Illustration 4. Sod stretching apparatus showing the sod prior to (1) and after (2) the stress is administered.



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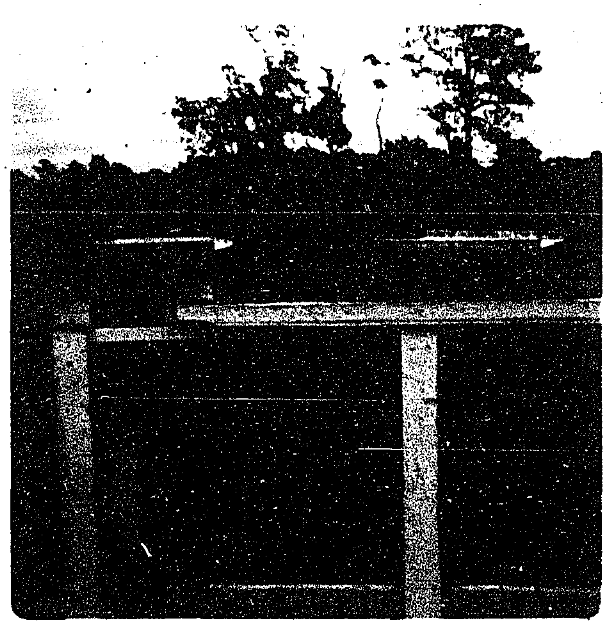

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