ACKNOWLEDGEMENTS

The author extends appreciation to Dr. William H. Mitchell for his guidance and assistance during the conduct of this experiment. Sincere appreciation is extended to Dr. R. W. Lighty for his suggestions in the preparation of this manuscript. Special appreciation is extended to Dr. R. Smith for his guidance in the statistical analysis of this project.

Appreciation is also extended to the Longwood Foundation for the financial support of this experiment and for granting the fellowship which made graduate study possible.

Sincere appreciation is extended to my devoted wife for her assistance in the preparation of this manuscript.

TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ABSTRACT

Studies involving the growth and development of a Kentucky bluegrass-red fescue turf under varying levels of irrigation, shade, nitrogen, and species association were conducted at Newark, Delaware during 1968. The Kentucky bluegrass cultivars studied were 'Windsor', 'Merion', and 'Kenblue', and the red fescue cultivar studied was 'Pennlawn'. Comparisons involving these species included dry matter production, density measurements, and chemical composition of the plant tissue.

Irrigation studies indicated that the dry weight production of a Kentucky bluegrass-red fescue turf is significantly reduced during periods of high moisture stress. Studies involving subsurface irrigation indicated that additional information is needed to judge its effectiveness for irrigationg turf.

Shade studies indicated that sixty (60%) percent shade significantly reduces the dry weight production of Kentucky bluegrass-red fescue turf. At medium shade levels the dry weight production of the turf was favored by low nitrogen and low moisture regimes.

Nitrogen studies indicated that dry matter production increases when water and nitrogen are not limiting factors. Studies also indicated that high nitrogen levels tended to reduce dry matter production under shade.

The studies involving a comparison of the Kentucky bluegrass cultivars indicated that the percent chemical composition of nitrogen and phosphorus and the dry weight production of 'Windsor', and 'Merion', bluegrass were greater than 'Kenblue' bluegrass.

The studies involving the competition of Kentucky bluegrass in a bluegrass-fescue turf showed that the 'Windsor' and 'Merion' bluegrass increased in density under all treatments of this experiment.

## INTRODUCTION

The need for knowledge of turf grass culture became apparent in the 1930's. Researchers and extension agents realized that accurate and reliable information for the public was not available. Questions pertaining to the cultural requirements of turf grasses, turf diseases, turf insects, and weed problems of the recommended species were considered. With the development of each new turf grass cultivar it was important to know how it would respond to the principle growth factors.

In the Northeast, Kentucky bluegrass, Poa pratensis, was recognized to have many of the qualities desirable in a turf grass. Its ability to persist under regular mowing, the rather broad cultural requirements, the availability of seed, and its outstanding appearance were a few of its desirable characteristics. Unfortunately, bluegrass has a high susceptability to certain diseases and a tendency to perform poorly at low nitrogen levels or high moisture stresses. During the summer periods of high temperatures and high moisture stress the plant goes into a semi-dormant growth condition. Since under these conditions bluegrass has a tendency to turn brown, the appearance of the turf is lowered.

To compensate for these less desirable traits of Kentucky bluegrass, other species are often included in the planting. The grass most often recommended to be included is red fescue, Festuca rubra. Its overall appearance and growth habit are similar to Kentucky bluegrass and it will compliment bluegrass in a turf. In addition, fescue will persist under low nitrogen and moisture regimes and remain green during periods of high temperatures. Because fescue is not susceptable to some of the pathogens that effect bluegrass, its presence will reduce the severity of the infection and mask the degree of the infection. Thus, the combination of Kentucky bluegrass and red fescue has become one of the most commonly recommended mixtures.

The management of a Kentucky bluegrass-red fescue turf is essentially a compromise of their individual cultural requirements. Kentucky bluegrass grows best under high moisture regimes; red fescue grows best under relatively low moisture regimes. Bluegrass requires high nitrogen levels for optimum growth; red fescue prefers low levels of nitrogen. Kentucky bluegrass prefers a less acidic soil reaction; red fescue tolerates a more acidic soil reaction. Hence, the maintenance program for one species is not conductive to the best performance of the other.

One unsolved problem of turf culture is the management of turf in a shaded area. Often Kentucky bluegrass grows poorly under shaded conditions. The plants become less dense and gradually die out. Red fescue, on the other hand, grows and persists. This situation is commonly encountered under shallow-rooted trees. Buildings, fences, and deep-rooted trees are other elements that cast shade as well, and under these conditions the growth and development of Kentucky bluegrass is variable and not predictable.

Because the structures casting shade differ from each other, their environments will differ. Light, temperature, and wind are some climatological elements that will differ. The competition between grass roots or grass roots and tree roots for water and nutrients will differ with the area. Consequently, cultural practices must vary from situation to situation.

To develop a fine turf in this area, irrigation must be practiced. To date, the most commonly used method is overhead irrigation. Watering by permanent or moveable sprinklers poses several problems. In the case of the permanent sprinklers, dirt and grass can cause mechanical failure by plugging or interfering with the sprinkler head. With the moveable sprinklers, the hose must be carried and placed into position and then removed after watering is completed. Particularly for large areas of turf, this routine takes time and energy that could be devoted to other useful tasks. In addition, overhead irrigation creates, during use, an unusable area.

A watering system for turf that would be efficient, economical, reliable, and provide the necessary water has not yet been developed. One method now being studied to meet these requirements is subsurface irrigation. Plastic pipes, which are perforated at set intervals, are installed underground at set intervals. This permits even wetting of the soil volume contained within the rooting zone of the turf.

The pipe, which is long-lasting, is not difficult to install. A tractor-mounted machine that can travel two or three miles per hour can lay up to four hundred feet of pipe per length at a depth of six to eight inches. Three lines can be laid simultaneously. Once operating, the system can be automated to a daily or weekly irrigation schedule. Except for routine checks, the irrigation system would be essentially self-sufficient. From a central location soluble fertilizers could be injected into the system, eliminating the need for applying fertilizers mechanically. In the future, as systemic insecticides and fungicides are developed for turf, they might be applied through the system too. Furthermore, evaporation, wind drift, and run-off, the products of surface irrigation, are eliminated, thus conserving water. In more arid regions this could be a significant advantage in favor of subsurface irrigation.

This study was initiated to resolve some of the questions pertaining to the cultural practices of a Kentucky bluegrass and red fescue turf. The specific objectives of this study were (1) to observe the growth of bluegrass as influenced by water, nitrogen, and cultivars under varying light intensities, (2) to observe the competition between Kentucky bluegrass and red fescue, and (3) to compare the dry weight production of Kentucky bluegrass under surface and subsurface irrigation.

# LITERATURE REVIEW

Temperature and day length are environmental factors governing the growth and development of a Kentucky bluegrass (Poa pratensis) turf. Under controlled environmental conditions, Baker (1) demonstrated that the optimum day-time temperatures for herbage production were between 64.9°F and 70.8°F; as the temperatures increased above 70.8°F, the herbage yields gradually decreased. Brown (3) observed in field experiments that herbage production declined at temperatures above 80°F. At super optimal temperatures the growing meristems became disorganized and died.

Day length, Evans (7) observed, influenced tiller and rhizome development. Plants grown under 8½ hours of light developed 33 percent more shoots than plants grown under 18 hours of light. Where short-day periods favored shoots, long-days favored rhizomes. He observed that "the ratios of shoots to rhizomes were 100:67 and 100:190 under short-days and long-days, respectively." Etter (6) observed, also, that tillers developed under short-day lengths and rhizomes developed under long-day lengths; however, Etter studied the crown of a bluegrass plant and observed a relationship between tiller and rhizome development. If tiller development was favored in the fall then a relatively fewer number of rhizomes developed the following season. Likewise, if tiller development was not favored in the fall, a relatively greater number of rhizomes developed the following year. The conditions, according to Etter, that favored a larger number of tillers to develop under short days were mowing, adequate water and nitrogen, and light.

When daylight and temperatures are favorable for the development of bluegrass, the soil moisture regimes will influence vegetative growth. Lucey (11) observed that under moisture regimes below forty (40) percent field capacity, the herbage production was significantly reduced. He observed that moisture regimes of forty to sixty percent favored growth. Stanhill (15) concluded that the greatest growth was with higher soil moisture regimes.

When nitrogen was limiting, Baker (1) observed that increased frequency of irrigation did not increase yields greatly. In field tests, the yield of bluegrass increased only with available water and nitrogen. Mantell (12) observed that stand density increased when nitrogen and water were available for growth.

In pot cultures in greenhouse tests Brown (3) studied the influence of nitrogen on vegetative growth. Under a low level of nitrogen, vegetative growth was less than under higher levels of nitrogen at a 2" clipping height. With adequate nitrogen, carbohydrate reserves accumulated, and with the carbohydrate reserves, vegetative growth was favored. Skogley (14) observed in a greenhouse experiment, that higherlevels of nitrogen favored dry matter production. In field tests with 'Merion' bluegrass, Juska (8) observed that when the turf was clipped to a 2" height, six to eight pounds of nitrogen promoted a higher quality turf than lower levels of nitrogen did.

During periods of high temperature and moisture stress, bluegrass becomes dormant. Pellet (13) observed that bluegrass was able to adapt to high temperatures and drought conditions for short periods of time. He suggested that for the plant to survive these conditions, high carbohydrates were necessary. Juska (8) observed that plants having a well-developed root and rhizome system were better able to withstand drought conditions.

During periods when the plant is dormant, excessive watering and nitrogen can result in stand depletion. Carrol (5) observed that high levels of nitrogen tended to promote growth during periods of high temperatures. When bluegrass was in a dormant growth condition, Brown (3) observed that rhizome development was hindered.

Under low light intensities, the development of a bluegrass-red fescue turf has only been casually investigated. Beard (2) studied the development of bluegrass and red fescue under 95% shade.

The turf was fertilized yearly with two pounds of nitrogen, and received only water from natural rainfall. The turf was grown under Acer saccharum trees.

In the spring of the first season, diseases were the single most important factor influencing the growth of red fescue and Kentucky bluegrass. Pure stands of red fescue were infected by Helminthosporium sativum and Kentucky bluegrass was infected by Erysiphe graminis; in both cases, the turf was severely thinned. In the following years, the red fescue increased in density more than Kentucky bluegrass, but neither grass improved to its original condition.

Beard (2) concluded that the intensity of the diseases was due to the effects of the microclimate. Under the Acer saccharum trees the higher relative humidities, extended dew periods, and lower light intensities favored a more succulent growth. This condition lowered the resistance of the grasses and encouraged infection by the causal organisms.

Juska (9) observed the growth of six turf grasses under 80% shade. His purpose was to determine which of the grasses maintained as turf, were tolerant of shade. The turf was fertilized yearly with three pounds of nitrogen, and it received only water from natural rainfall. The shading meterial was black plastic net. The grasses were rated visually on a quality scale.

He observed that the grasses under shade were a lighter green, less dense, and more succulent. Under the conditions of his experiment, he observed that the appearance of 'Kentucky 31' tall fescue was outstanding in both the shade and the sun, but 'Pennlawn' red fescue was also outstanding. The appearance of Kentucky bluegrass was not as outstanding either in the shade or in the sun as 'Pennlawn' red fescue.

Below is Juska's ranking of the grasses studied according to shade-tolerance:

(1) Tall fescue

(2) 'Pennlawn' red fescue

(3) Chewings fescue

(4) Common Kentucky bluegrass

(5) Common red fescue

(6) Experimental red fescue

## METHODS

The experiment was conducted at the University Farm in Newark, Delaware. It involved a four-factor split plot design. The plots were randomly placed and replicated three times. The main effect was irrigation, the sub-effect was shade, the sub-sub-effect was nitrogen, and the sub-sub-sub-effect was cultivar and cultivar association. The treatments began on 15 June 1968. See Appendix V for a schematic drawing of the experimental area.

Three irrigation treatments were used consisting of natural rainfall, surface irrigation, and subsurface irrigation. The plastic pipes were installed in September 1968 prior to seeding. From the water source to the treatments a main line two inches in diameter was laid approximately eight inches deep. To accurately measure the rate of the water flow, a pressure gauge and flow meter were placed near the water source. Connecting the main line with the treatments was a submain which was one-and-a-half inches in diameter.

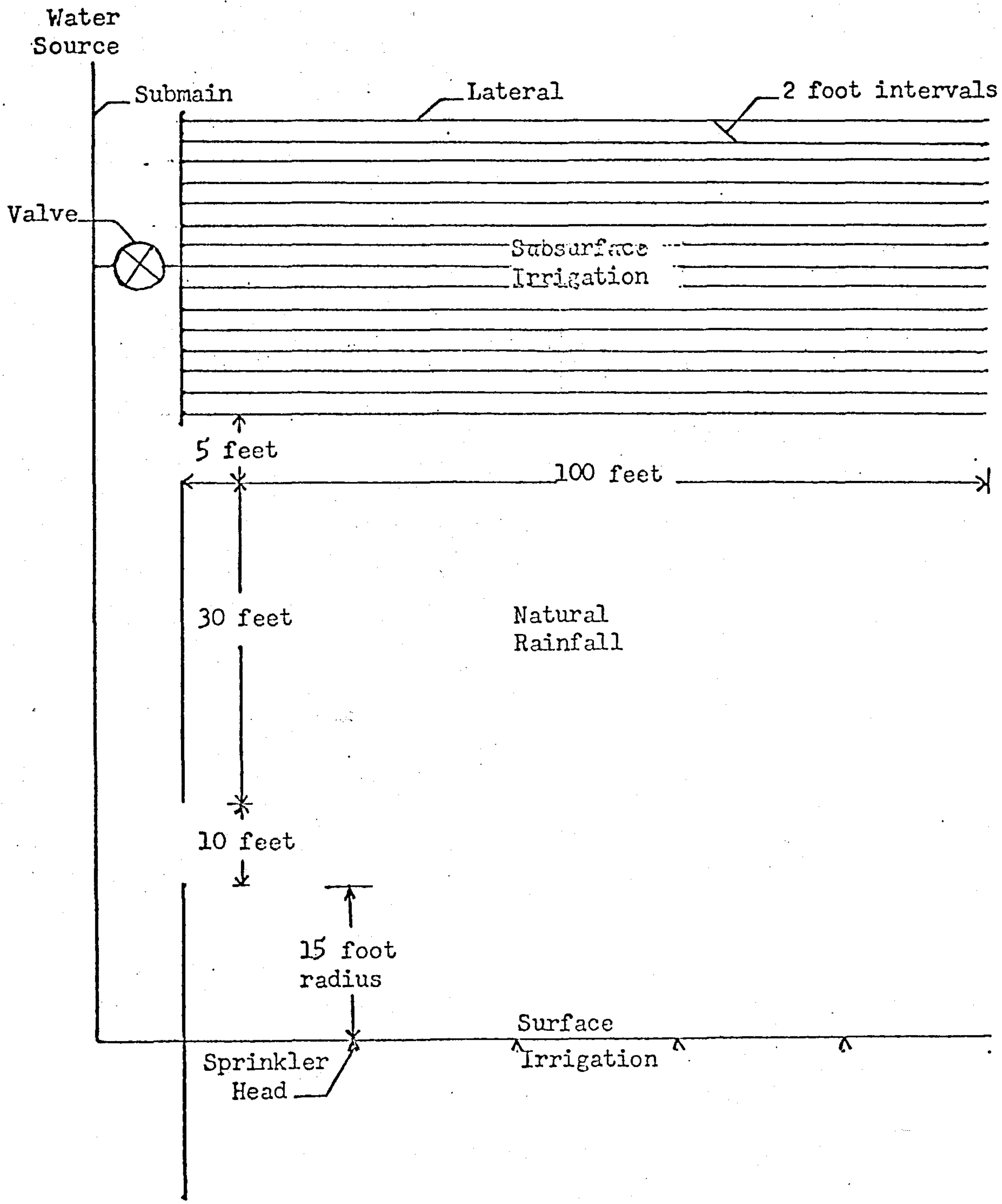
From the submain, laterals were installed for the subsurface irrigation treatments. They were placed eight inches deep and were spaced two feet apart. On each lateral orifices .030 inches in diameter were spaced on two foot centers. The flow of water was adjusted for each replication to insure a uniform pressure and flow rate for the treatment. To provide control, a valve was installed at the beginning of each subsurface irrigation treatment and a water manometer was placed at the end of one of the laterals of each replication. The flow rate was adjusted to read two pounds of pressure per square inch. The three replications were irrigated at the same time.

A single lateral was installed from the submain for the surface irrigation treatment. The diameter of this pipe was one inch and the pipe was installed about eight inches underground. Quick-coupling valves were spaced every ten feet. The full circle sprinklers with a break-up nozzle had a flow rate of 3.8-4.9 gpm at 30-35 psi and could be adjusted to wet an area from twenty to eighty-five feet in diameter. One replication was irrigated at a time.

See Figure 1 for a schematic drawing of the irrigation facility.

The irrigation schedule was based on the Water Balance Tables of Thornthwaite and Mather (17). The plots were irrigated when a water deficiency of 1.80 inches existed. On the average, the plots were irrigated every two weeks and two inches of water were applied each time. The irrigation schedule is shown in Appendix I.

SCHEMATIC DRAWING OF
IRRIGATION FACILITY OF
ONE REPLICATION



Three shade treatments, full sun intensity, sixty percent (60%) sun intensity, and forty percent (40%) sun intensity, were used. The shaded section was thirty feet by twenty-four feet and covered by a polyvinyl, woven net. The nets were placed twenty-four inches above ground level. To reduce the amount of light entering from the sides, the borders of the shaded sections were extended two feet beyond the area needed to gather data. The nets were supported by tightly-drawn twine that was tied to metal poles. To provide more support, the twine was criss-crossed. To reduce the sagging of the nets, wooden poles were placed under the nets in the center of the section, paralleling the metal poles. The simplicity and flexibility of this system provided easy handling and storage of the large nets. The nets were removed only during maintenance and irrigation periods.

Three nitrogen treatments were used consisting of ten (10) pounds, five (5) pounds, and one (1) pound of elemental nitrogen per one thousand (1000) square feet. To all the plots, a 10-10-10 fertilizer was applied at the rate of one pound of nitrogen per one thousand (1000) square feet. To the higher level nitrogen treatments, the appropriate amount of nitrogen was applied in the form of ammonium nitrate. The fertilizer was hand-broadcast to each individual treatment.

The experimental area was seeded on 17 October 1967. The rate of seeding was two pounds per one thousand (1000) square feet.

In the Kentucky bluegrass-red fescue treatment, one pound of bluegrass and one pound of fescue were mixed together to seed two pounds per one thousand (1000) square feet. The area was broken down to one hundred and sixty-two seeding sections. The seed for one section was weighed out and then placed in a drop-type seeder. The seeding pattern was back and forth the length of the section. This procedure was followed until all sections were sown. Three cultivars of Kentucky bluegrass (Windsor, Merion, and Kenblue) and one cultivar of red fescue (Pennlawn) were sown. Each cultivar of bluegrass was sown once by itself and once in association with red fescue.

To control crabgrass, Tupersan was broadcast at the rate of six ounces per one thousand (1000) square feet on 20 April 1968. Disease and insect control was not practiced.

The turf was mowed at weekly intervals although weather and irrigation periods did not always permit a scheduled mowing. The turf was cut to a two inch height for the entire season.

To measure the nutrient status of the soil of the experimental area, a soil test was conducted in April of 1968 (Appendix IV).

Climatological observations were recorded to provide data for the computation of the water balance and for supplementary interpretative data. The rainfall and air temperatures were recorded daily. Soil temperature and temperature-humidity data were periodically recorded. Light measurements were taken in September to confirm the light intensity levels of the shaded treatments.

Commencing with the second cutting following the initiation of the treatments, dry weight and nutrient observations were taken. The grass clippings were collected in a wire basket attached to a rotary lawn mower. After a sample from an individual plot was taken, the clippings were placed in a perforated paper bag. The bags were then oven dried. After the cuttings dried for several weeks, the clippings were weighed and the weight recorded. From the July and September harvests, tissue samples were removed from the one pound and five pound nitrogen treatments of the Kentucky bluegrass plots for chemical analysis. The nitrogen analysis was conducted according to the modified Keldhal-Gunning Procedure, while Phosphorus, potassium, calcium, and magnesium were analyzed according to the procedures set forth by Steckel and Flannery (16).

The density of stand was observed twice. Once on July 15th and again on September 30th. A ten-point quadrat was the instrument used.

## MATERIALS

The materials and quantity used were as follows:

IRRIGATION EQUIPMENT

| Item | Quantity |
|---|---|
| 1. ½" perforated plastic tubing .030" holes on 12" centers | 10,000 feet |
| 2. 1" plastic tubing | 300 feet |
| 3. 1½" plastic tubing | 750 feet |
| 4. Quick coupling valves Valves 3/4" IPS Metal cover Model number: 30A | 12 each |
| 5. Long shank couplers 3/4" MPT and ½" FPT Model number: 30AC | 4 each |
| 6. Full circle irrigation sprinklers 20-85 feet dia., 3.8-4.9 ggm @ 30-35 psi, ½ male, IPS breakup nozzle, Model number: 856. PBU | 4 each |
| 7. Brass saddle tees for 1½" plastic pipe, 1" threaded outlet Model number: 5-1144 | 9 each |
| 8. Brass saddle tees for 1" plastic pipe with 3/4" female threaded outlet. Model number: 1175. | 12 each |

[1]The plastic tubing for subsurface irrigation was purchased from Perma-Pipe Corporation, Stone Mountain, Georgia.

The sprinkler irrigation equipment was supplied by Buckner Manufacturing Co., Inc. Fresno, California.

(MATERIALS)

IRRIGATION EQUIPMENT

| | Item | Quantity |
|---|---|---|
| 9. | 1½" Brass gate valve<br>Jenkins Number: 370 | 1 each |
| 10. | 1" Brass gate valve<br>Jenkins Number 370 | 9 each |
| 11. | 1" Styrene plastic adaptors | 18 each |
| 12. | 1½" x 1½" x 1½" Styrene plastic tees | 3 each |
| 13. | 1½" x 1½" Slip Elbow Styrene Plastic | 1 each |
| 14. | 1½" Stainless Steel Clamps | 12 each |
| 15. | 1" Stainless Steel Clamps | 12 each |
| 16. | 1" Close Nipples, 1½" long | 18 each |
| 17. | ½" Galvanizing Plugs | 120 each |
| 18. | 1½" Galvanizing Plugs | 6 each |
| 19. | 1" Galvanized Plugs | 12 each |
| 20. | Threaded Galvanized Pipe<br>Nipple 3/4" x 6" long | 24 each |
| 21. | 3/4" Galvanized Elbow | 36 each |
| 22. | 3/4" Galvanized Nipples 1½" long | 24 each |
| 23. | Tygon Tubing, I. D., 5/8", OD ½" | 50 feet |

---

[1]The Tygon Tubing was purchased from the Kaufman Glass Co., 1209-21 French Street, Wilmington, Delaware.

(MATERIALS)

SHADE MATERIAL[1]

| Item | Quantity |
| --- | --- |
| 24. 30% Actual Shade, Saran cloth, green, size 30 feet x 24.5 feet, 2% shrinkage | 9 each |
| 25. 60% actual shade, Saran cloth, green, size 30 feet x 24.5 feet, 2% shrinkage | 9 each |

GRASS SEED

| | |
| --- | --- |
| 26. 'Windsor' Kentucky bluegrass | 35 pounds |
| 27. 'Merion' Kentucky bluegrass | 35 pounds |
| 28. Common Kentucky bluegrass | 35 pounds |
| 29. 'Pennlawn' Red Fescue | 35 pounds |

[1]The shade cloth was purchased from the American Associated Co., P. O. Box 272, Red Bank, New Jersey.

## RESULTS

### Water

Water, as a factor, increased the yield of the turf in June and August, see Table I. (For a complete listing of the F values see Appendix II). Only for these two months did the irrigated treatments yield more than the non-irrigated treatment (natural rainfall). Although the dry matter yield for the season tended to be greater under surface irrigation, subsurface irrigation was not significantly different from it. (Table I).

TABLE I. INFLUENCE OF WATER
ON DRY MATTER PRODUCTION

| | Yield in Pound per 1000 sq ft | | | |
|---|---|---|---|---|
| Water | June | July | August | September |
| Subsurface Irrigation | 2.991 | 3.709 | 9.491 | 7.452 |
| Natural Rainfall | 1.990 | 3.212 | 3.432 | 5.792 |
| Surface Irrigation | 3.059 | 3.628 | 10.804 | 7.199 |
| LSD (05) | .416 | - | 3.808 | - |
| LSD (01) | .689 | - | 6.316 | - |

In September the plants under surface irrigation absorbed a greater amount of phosphorus than the plants under subsurface irrigation, and greater amounts of phosphorus were absorbed by the plants under the irrigated treatments than under the non-irrigated treatment (Table II).

TABLE II. PHOSPHORUS CONTENT OF THE BLUEGRASS UNDER IRRIGATION TREATMENTS IN SEPTEMBER

| Irrigation | %P |
|---|---|
| Subsurface Irrigation | .443 |
| Natural Rainfall | .384 |
| Surface Irrigation | .483 |
| LSD (05) | .029 |
| LSD (01) | .048 |

Shade

The effect of shade on the growth of Kentucky bluegrass suggested a seasonal variation, Table III. In June the yield under hewvy shade (40% full sun intensity) was greater than the yield under medium shade (60% full sun intensity), and the yield under medium shade was greater than the yield under full sun. Associated with increasing shade levels was an increase in the percent mineral composition of the plant tissue. Phosphorus, potassium and magnesium content of the plants was the highest under heavy shade (figures 2, 3). Under medium shade, calcium content of the tissue exhibited a reduction, but under heavy shade the content increased (figure 4).

In July and August, shade as a factor did not significantly influence yield. Although dry matter yields associated with the three shade levels were not significantly different at the five percent level of probability, there was some evidence that heavy shade depressed yields, Table III.

POTASSIUM CONTENT OF TURF
UNDER THREE SHADE LEVELS
JUNE

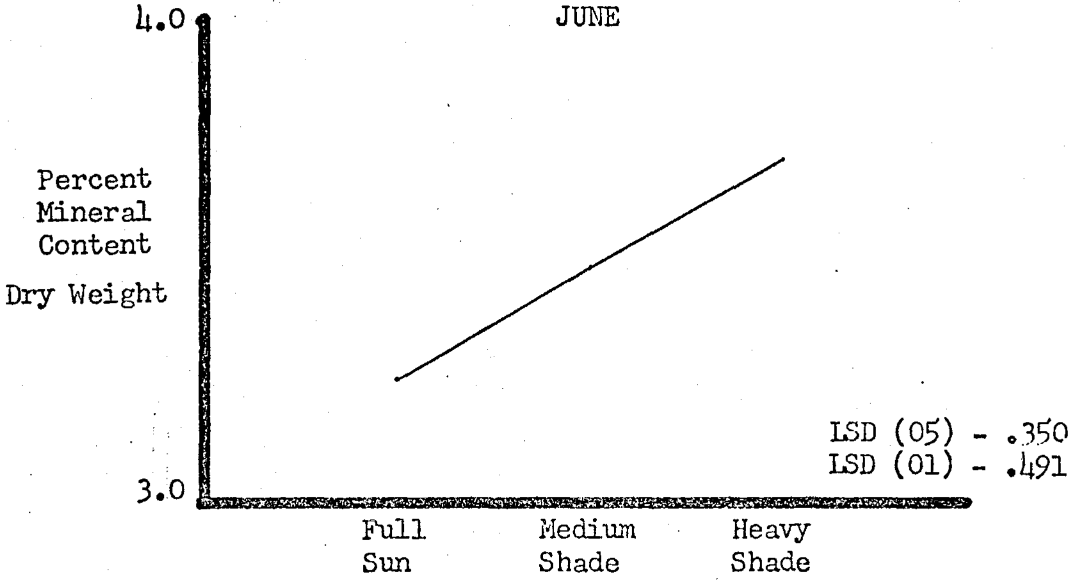



FIGURE 2

PHOSPHORUS AND MAGNESIUM CONTENT
OF TURF UNDER THREE SHADE LEVELS
JUNE

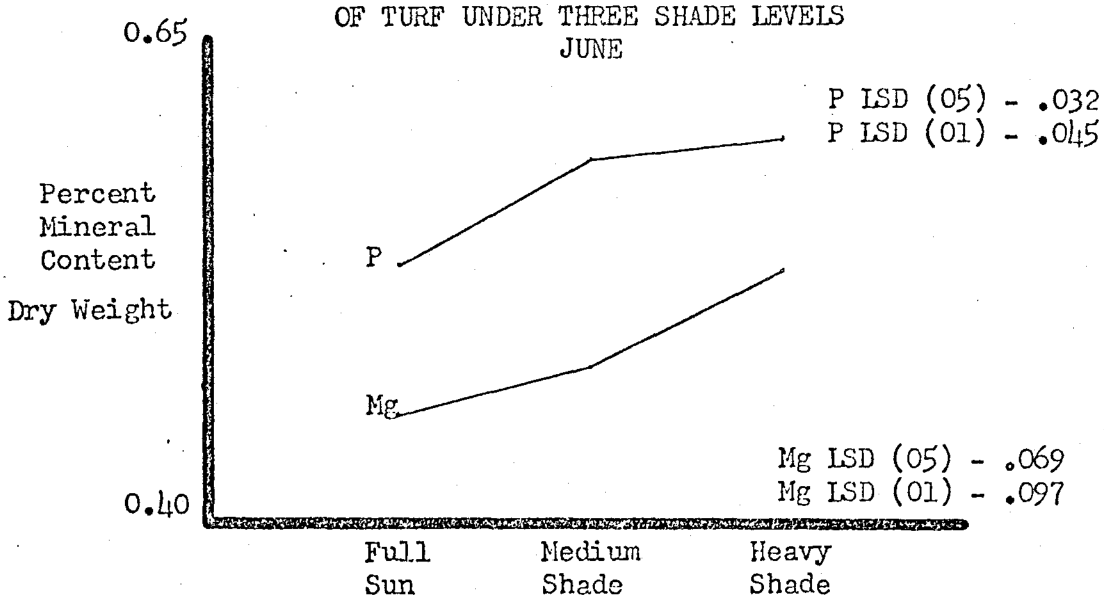



FIGURE 3

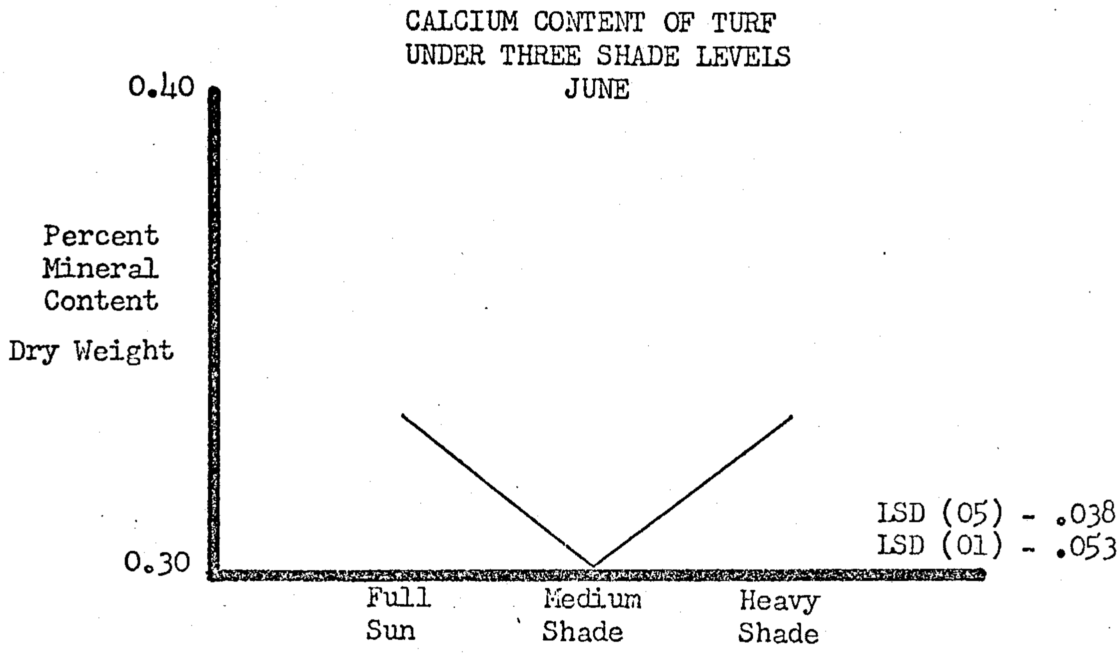

CALCIUM CONTENT OF TURF
UNDER THREE SHADE LEVELS
JUNE
0.40
Percent
Mineral
Content
Dry Weight
0.30
LSD (05) - .038
LSD (01) - .053
Full
Sun
Medium
Shade
Heavy
Shade

FIGURE 4

In September the yield in full sun or medium shade was only slightly different. In the fall, however, heavy shade significantly lowered yield. These trends are observed in Table III. The potassium content of the turf increased with increasing shade (figure 5).

TABLE III. THE INFLUENCE OF SHADE ON DRY MATTER PRODUCTION

Yield in Pounds per 1000 sq ft

| Shade | June | July | August | September |
|---|---|---|---|---|
| 100% Full Sun | 2.323 | 3.443 | 8.121 | 7.439 |
| 60% Full Sun | 2.798 | 3.665 | 7.968 | 7.206 |
| 40% Full Sun | 2.925 | 3.441 | 7.619 | 5.797 |
| LSD (05) | .400 | - | - | .756 |
| LSD (01) | .561 | - | - | 1.060 |

The growth of the turf was influenced by an irrigation-shade interaction. In June the nonirrigated and subsurface irrigated treatments increased yield as the level of shade increased, but the surface irrigated treatment depressed yield (figure 6).

In July the yield of the nonirrigated treatment significantly increased under medium or heavy shade. The yield from the surface irrigated treatment decreased slightly under shade but increased in full sun. These trends are observed in figure 7.

In August the yield under heavy shade increased in the nonirrigated treatment but decreased under subsurface irrigation (figure 8). The yield of the subsurface irrigated treatment was greater, however, than the yield of the nonirrigated treatment

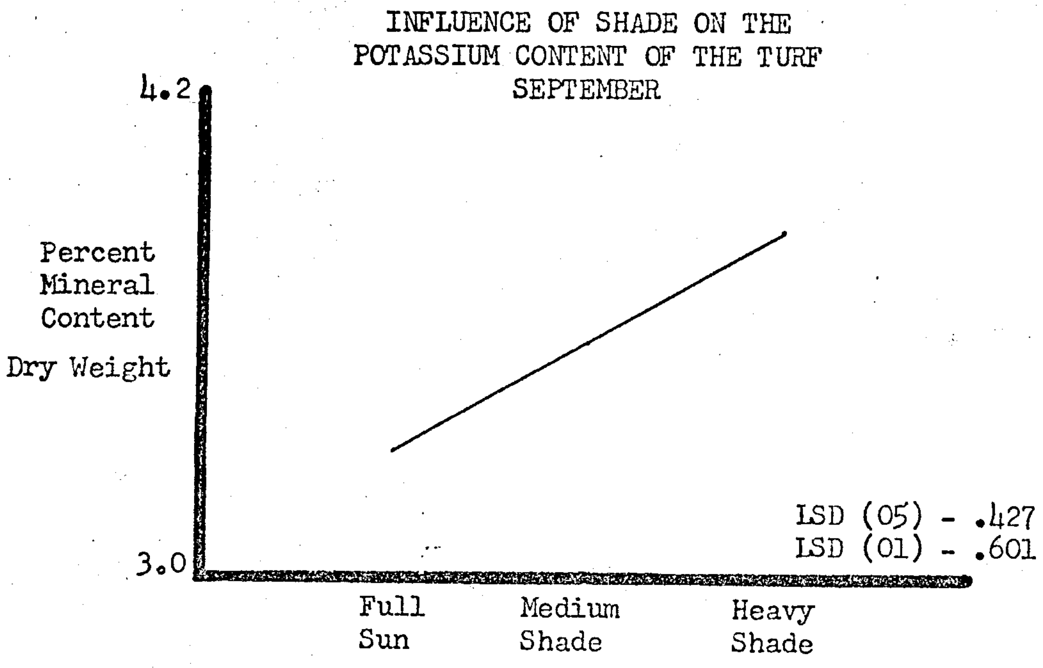



FIGURE 5

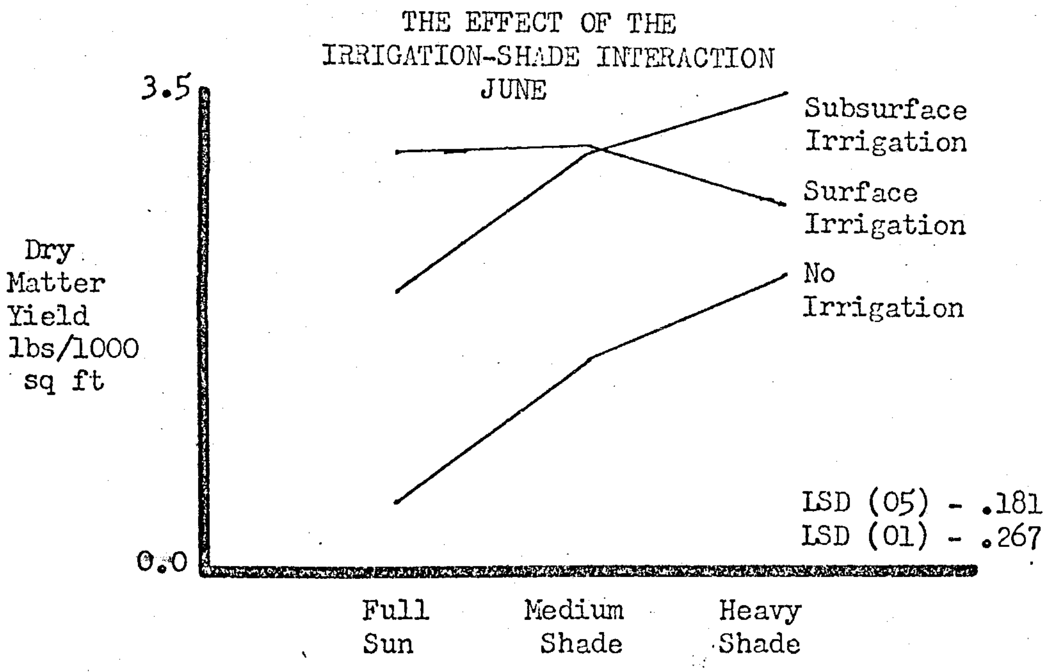



FIGURE 6

THE EFFECT OF THE IRRIGATION-SHADE
INTERACTION ON YIELD
JULY

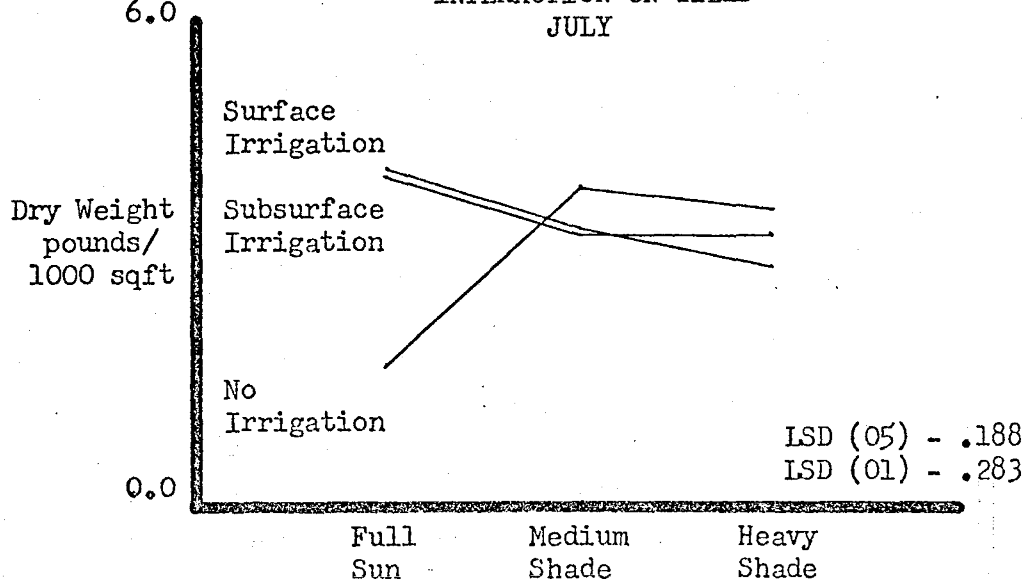



FIGURE 7

THE EFFECT OF THE IRRIGATION-SHADE
INTERACTION ON YIELD
AUGUST

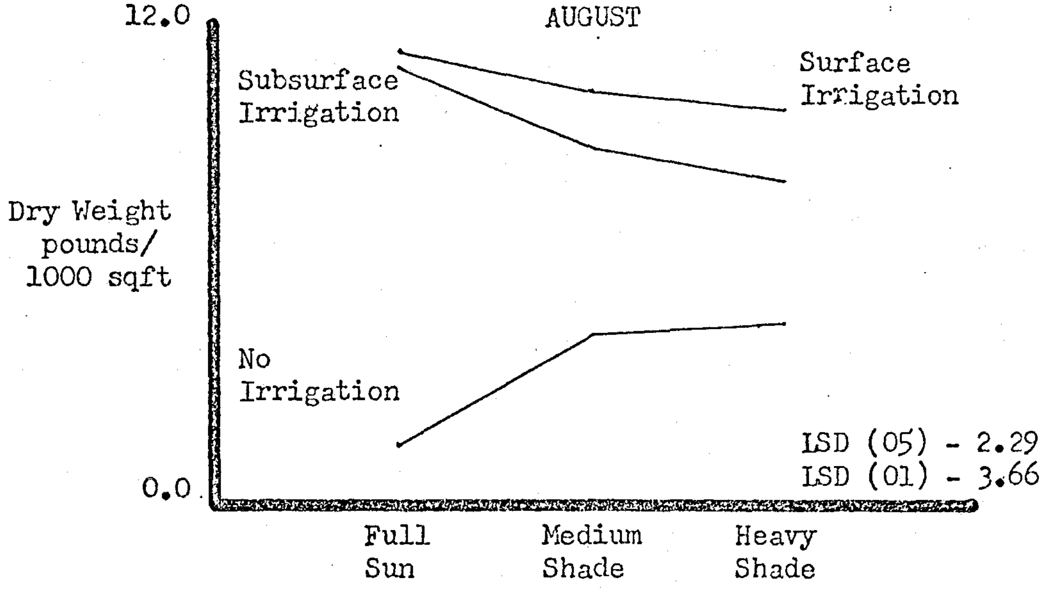



FIGURE 8

(figure 8).

In full sun, the yield was affected during the season by the type of irrigation system employed (Table IV). For example, the yield in June under subsurface irrigation and surface irrigation was 2.433 and 3.160 pounds respectively, and these differences were significant at the 5% level of probability. Under shaded conditions the yields under the different systems differed from each other only in June. The yield under surface irrigation was 3.160 pounds in full sun and 2.833 pounds in heavy shade. Under subsurface irrigation the yield was, in contrast, 2.433 pounds in full sun and 3.432 pounds in heavy shade (figure 9).

TABLE IV. A COMPARISON OF SURFACE AND SUBSURFACE IRRIGATION IN FULL SUN

| | Yield in Pounds per 1000 sq ft | | |
|---|---|---|---|
| Irrigation | June | July | August |
| Subsurface Irrigation | 2.433 | 4.225 | 11.176 |
| Surface Irrigation | 3.160 | 4.275 | 11.691 |
| LSD (05) | .696 | .186 | .772 |
| LSD (01) | 1.045 | .283 | 1.235 |

In September the phosphorus content of the plants was influenced by the irrigation-shade interaction. Under heavy shade the phosphorus uptake of the plant was nearly the same for surface irrigation and subsurface irrigation; however, in full sun or medium shade the plants under subsurface irrigation absorbed significantly less phosphorus than the plants under surface irrigation (figure 10).

The bluegrass cultivars responded, during the season,

THE INFLUENCE OF IRRIGATION AND
SHADE TREATMENTS ON DRY MATTER PRODUCTION
JUNE

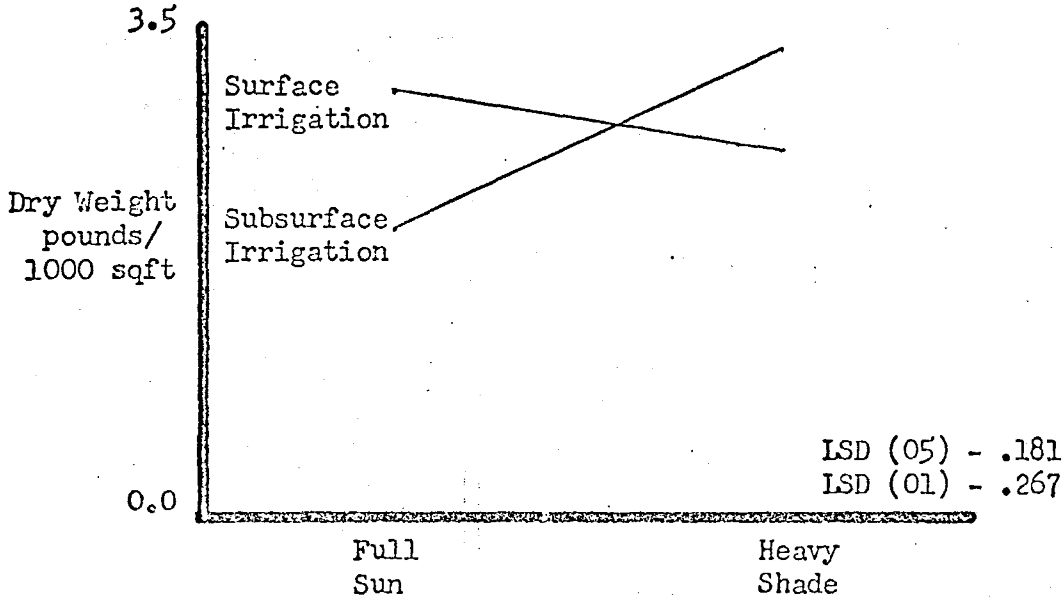



FIGURE 9

THE EFFECT OF THE IRRIGATION-SHADE
INTERACTION ON THE PHOSPHORUS CONTENT
OF THE TURF
SEPTEMBER

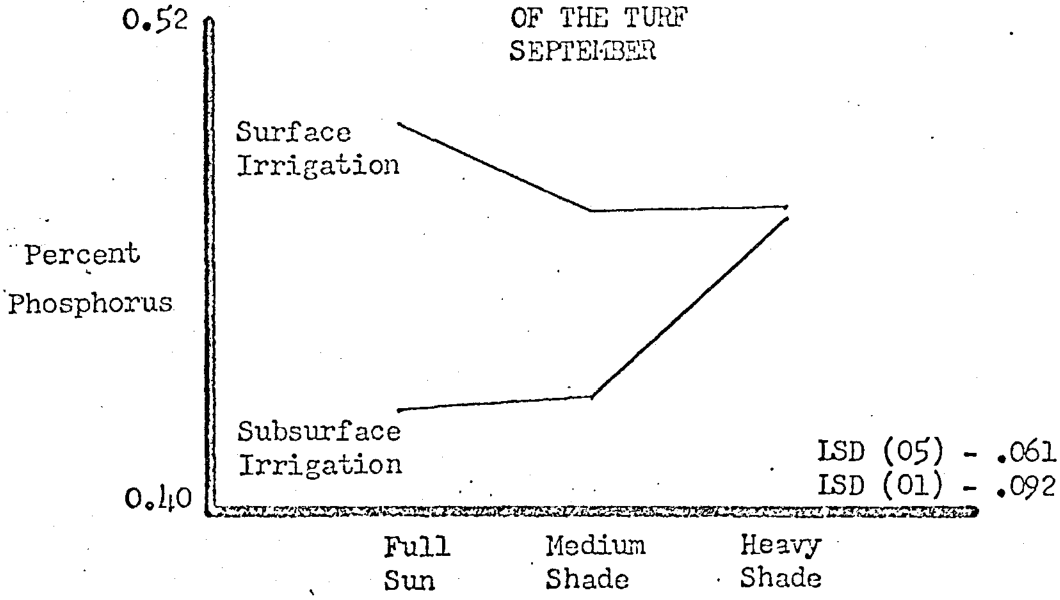



FIGURE 10

differently to shade. In June 'Merion' yielded 2.99 pounds under medium shade and 2.20 pounds in full sun; in contrast, 'Kenblue' was unresponsive to shade (figure 11). Under heavy shade in September, the yield of 'Merion' was depressed to a greater degree than the yield of 'Kenblue' (figure 12).

Nitrogen

Nitrogen contributed importantly to the yield of the turf, Table V. In June and July the medium level of nitrogen (five pounds of elemental nitrogen) promoted growth significantly more than the low level of nitrogen (one pound of elemental nitrogen). The plant nitrogen composition was higher as shown in figure 13. Because of injury to stand when nitrogen was applied, the high rates of nitrogen (ten pounds of elemental nitrogen) depressed yield.

TABLE V. THE INFLUENCE OF NITROGEN ON DRY MATTER PRODUCTION

| | Yield in Pounds per 1000 sq ft | | | |
|---|---|---|---|---|
| Nitrogen | June | July | August | September |
| 1 lb. Nitrogen | 2.102 | 3.526 | 7.687 | 5.213 |
| 5 lbs. Nitrogen | 3.432 | 3.847 | 8.269 | 6.952 |
| 10 lbs. Nitrogen | 2.512 | 3.202 | 7.770 | 8.215 |
| LSD (05) | .224 | .271 | - | .705 |
| LSD (01) | .300 | .364 | - | .946 |

In September the yield increased with increasing nitrogen levels (Table V). The high rates of nitrogen promoted growth too. The plant nitrogen composition was, however, less in September than in June (figure 13).

THE EFFECT OF THE SHADE-SPECIES
INTERACTION ON YIELD
JUNE

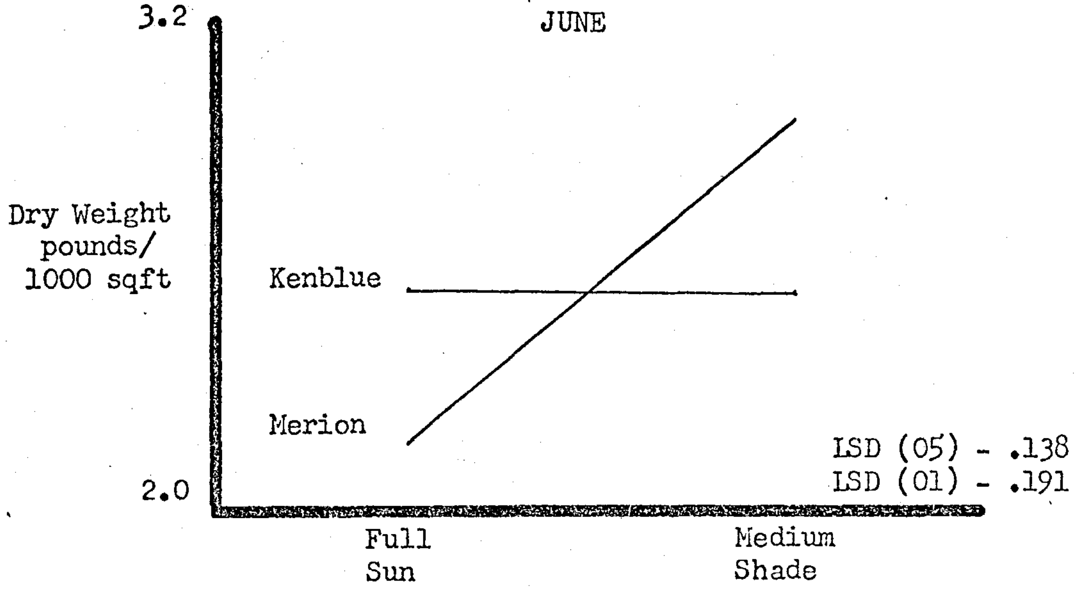



FIGURE 11

THE EFFECT OF THE SHADE-SPECIES
INTERACTION ON YIELD
SEPTEMBER

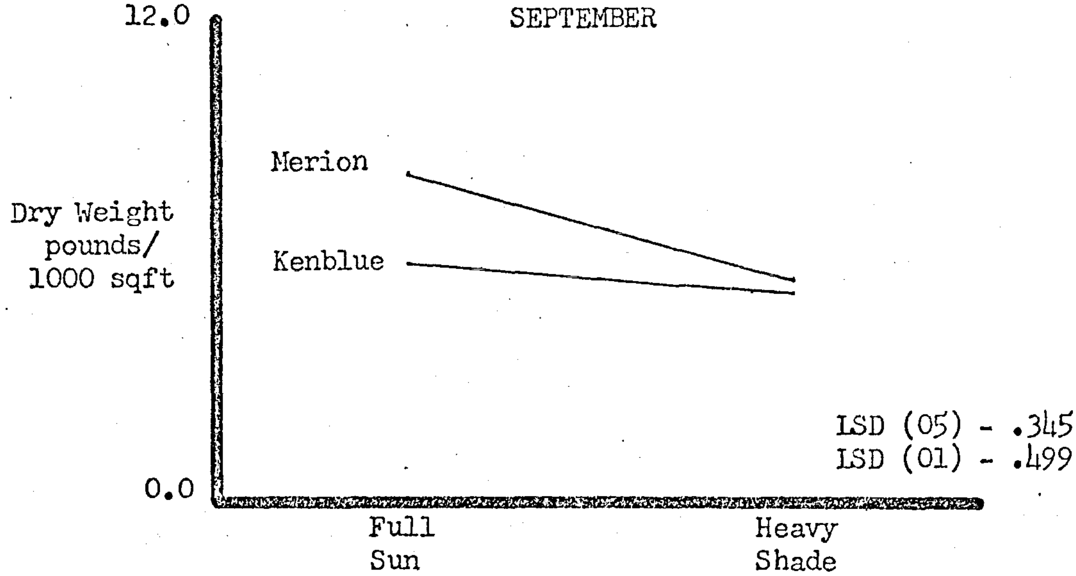



FIGURE 12

THE INFLUENCE OF HARVEST DATE AND NITROGEN TREATMENTS ON NITROGEN CONTENT OF CLIPPINGS

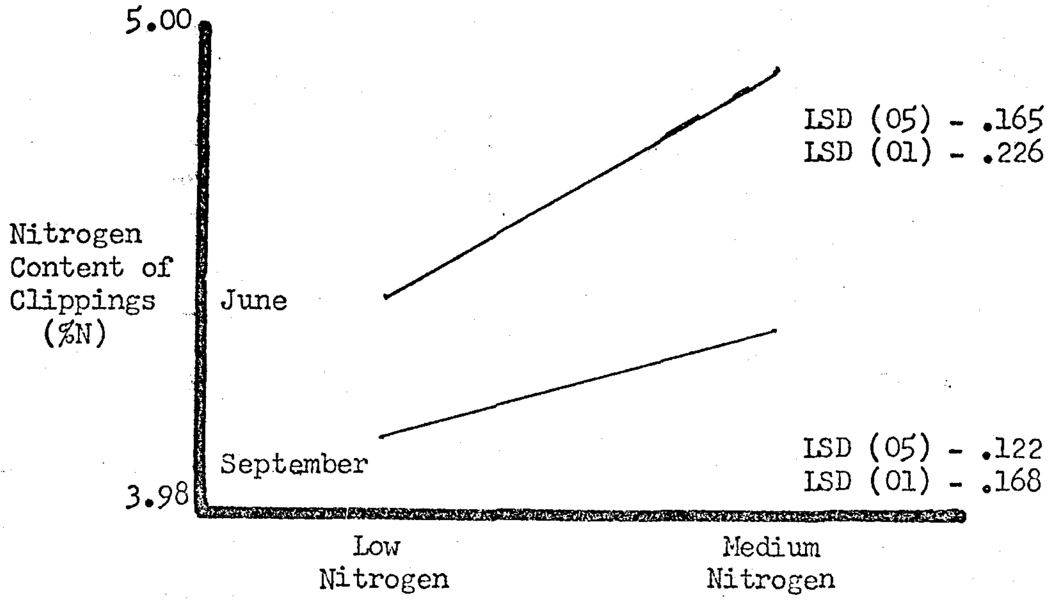



FIGURE 13

In July medium rates of nitrogen promoted a denser turf (Table VI). The density of the turf was 75.30 percent with medium nitrogen levels and only 70.60 percent with low nitrogen levels. In September the high level of nitrogen promoted a denser turf, 86.30 percent, than did the low level, 80.80 percent, or the medium level, 83.20 percent.

TABLE VI. THE INFLUENCE OF NITROGEN ON THE DENSITY OF THE TURF

| Nitrogen | July | September |
|---|---|---|
| 1 lb. Nitrogen | 70.60% | 80.80% |
| 5 lbs. Nitrogen | 75.30 | 83.20 |
| 10 lbs. Nitrogen | 67.60 | 86.30 |
| LSD (05) | .303 | .314 |
| LSD (01) | .406 | .422 |

When water and nitrogen interacted in June, there was a consistant increase in yield (figure 14). At the low level of nitrogen, however, the yield was not greatly affected by irrigation treatments. At the medium nitrogen level, the yield increase was greater under surface irrigation than under no irrigation. As compared to the non-irrigated treatment subsurface irrigation tended to increase yield, but the increase was not significant.

In September the yield from medium and high levels of nitrogen increased more under surface irrigation than under no irrigation. Subsurface yields increased but the differences were not significant at the five percent level of probability (figure 15).

THE EFFECT OF THE IRRIGATION-NITROGEN
INTERACTION ON YIELD
JUNE

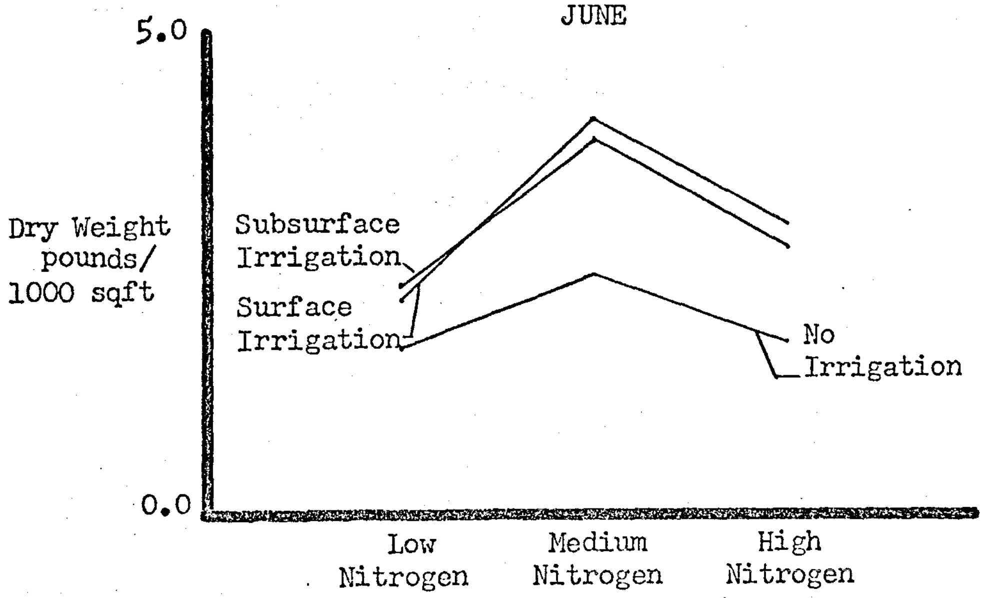



FIGURE 14

THE EFFECT OF THE IRRIGATION-NITROGEN
INTERACTION ON YIELD
SEPTEMBER

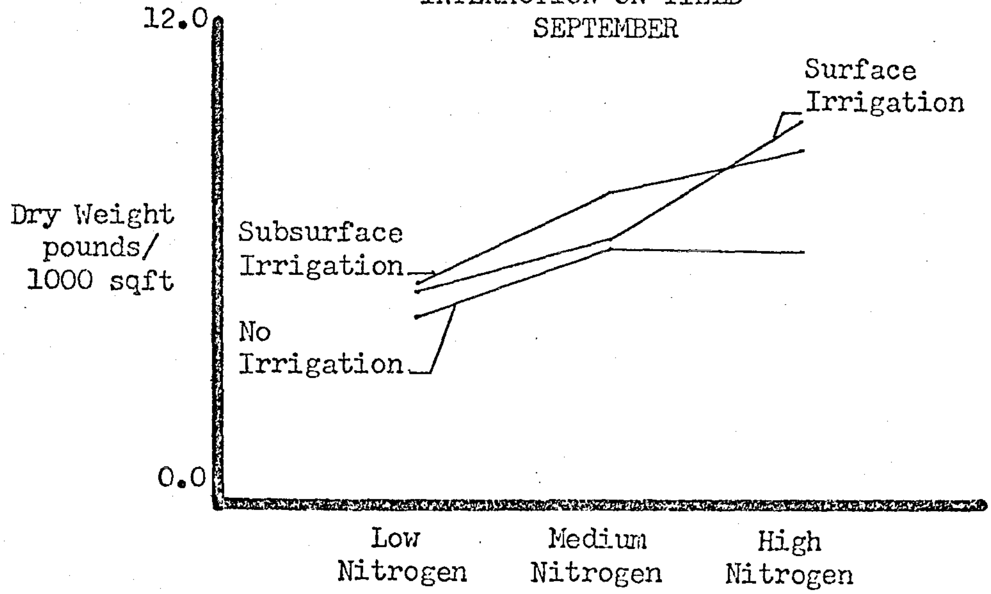



FIGURE 15

The effect of nitrogen on yield under varying shade levels was consistant for the season. Low rates of nitrogen increased yield with increasing shade levels, whereas high rates of nitrogen reduced yield as shade increased. This trend was observed in June, July, August, and September. See figures 16, 17, 18, 19 for the trends. In September under heavy shade, high levels of nitrogen decreased yields more than low levels of nitrogen (figure 19).

Species

Until September, there was a successive monthly increase in dry matter production of the Kentucky bluegrass cultivars. In August the yield was the maximum, then in September the yield declined. Refer to figure 20.

The month-to-month growth pattern of the Kentucky bluegrass cultivars differed from one another. In June and August, 'Merion' yielded more than 'Windsor', but 'Windsor' yielded more in July. In September the yield for 'Merion' and 'Windsor' was approximately the same. 'Kenblue' yielded less than 'Merion' for the season, except for the month of July. These trends are observed in Table VII.

TABLE VII. DRY MATTER YIELD OF
<u>POA PRATENSIS</u> CULTIVARS

Yield in Pounds per 1000 sq ft

| Cultivars | June | July | August | September |
|---|---|---|---|---|
| Windsor | 2.457 | 4.135 | 9.239 | 6.941 |
| Merion | 2.831 | 3.759 | 10.221 | 7.349 |
| Kenblue | 2.662 | 4.565 | 8.468 | 6.001 |
| LSD (05) | .232 | .268 | .711 | .594 |
| LSD (01) | .308 | .355 | .939 | .785 |

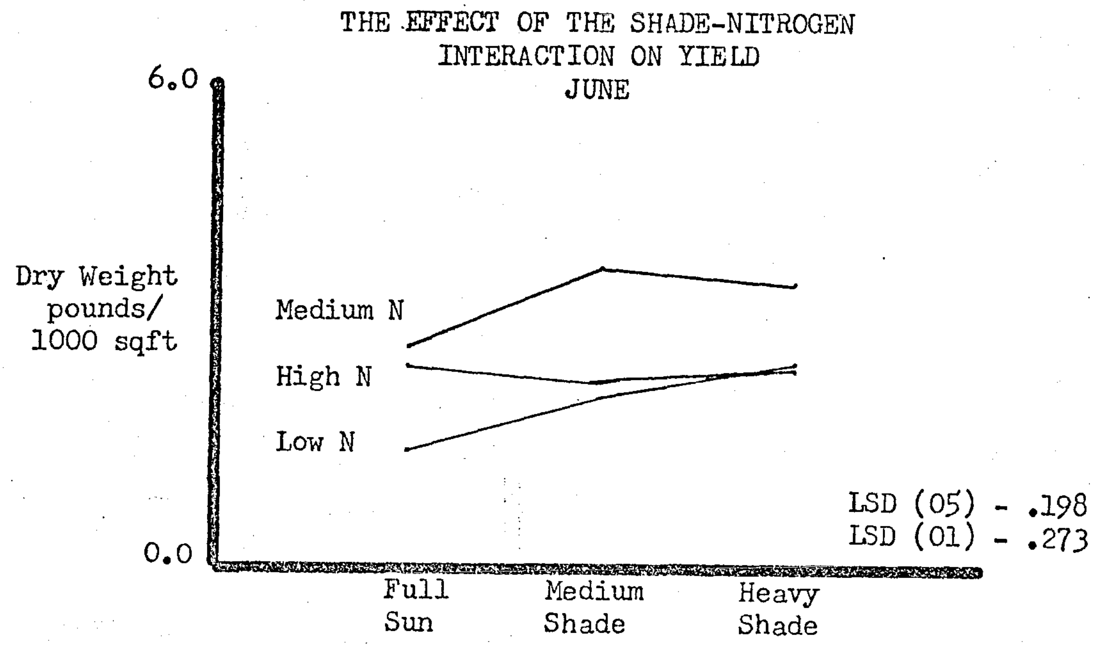



FIGURE 16

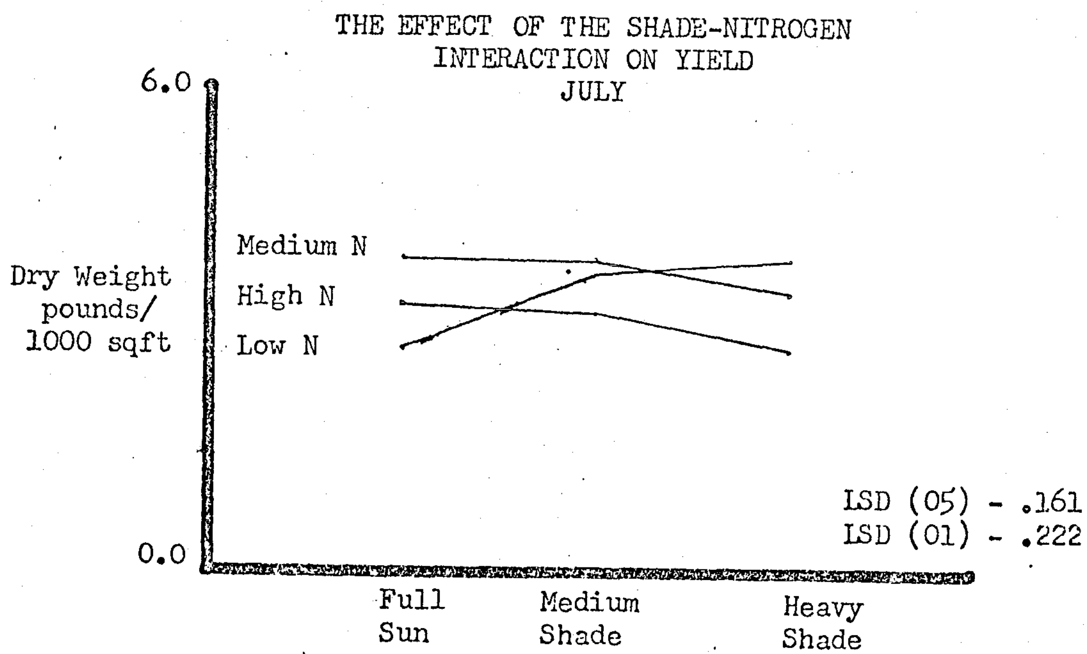



FIGURE 17

THE EFFECT OF THE SHADE-NITROGEN
INTERACTION ON YIELD
AUGUST

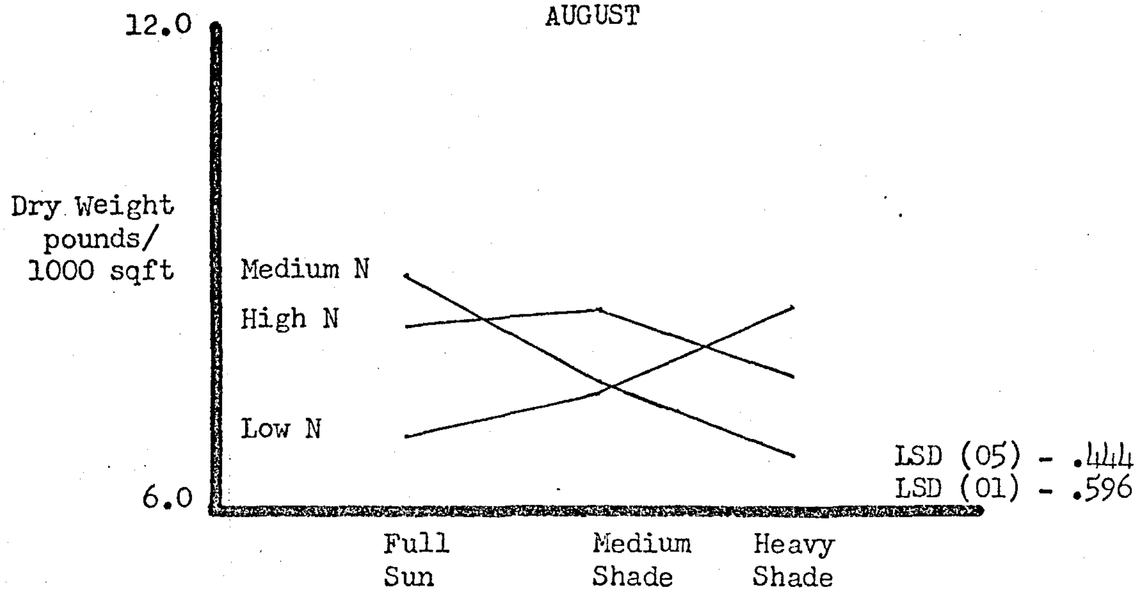



FIGURE 18

THE EFFECT OF THE SHADE-NITROGEN
INTERACTION ON YIELD
SEPTEMBER

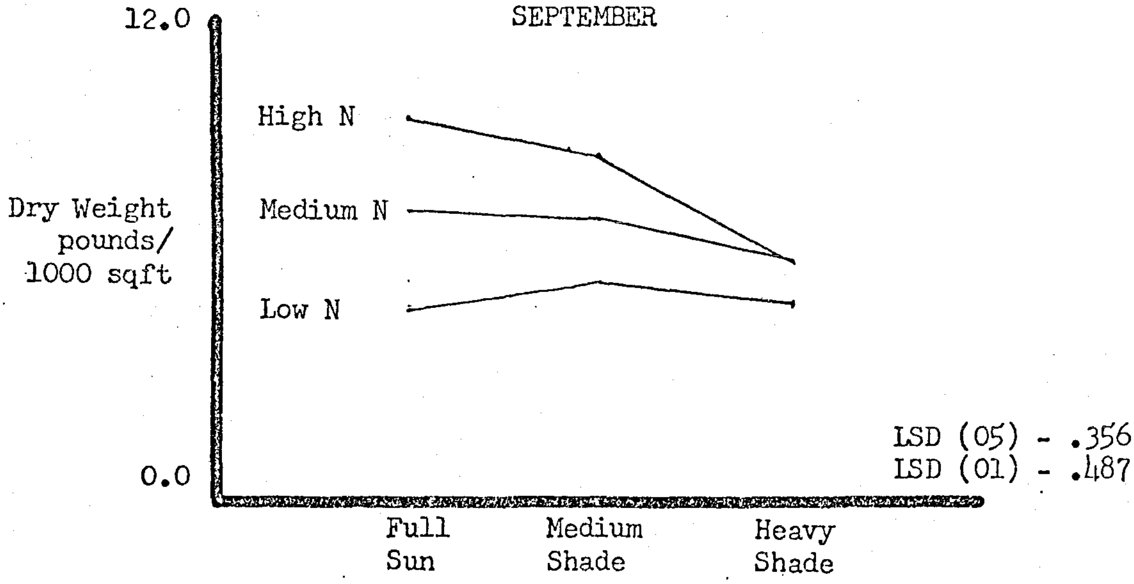



FIGURE 19

DRY MATTER YIELD OF
POA PRATENSIS AT FOUR HARVESTS

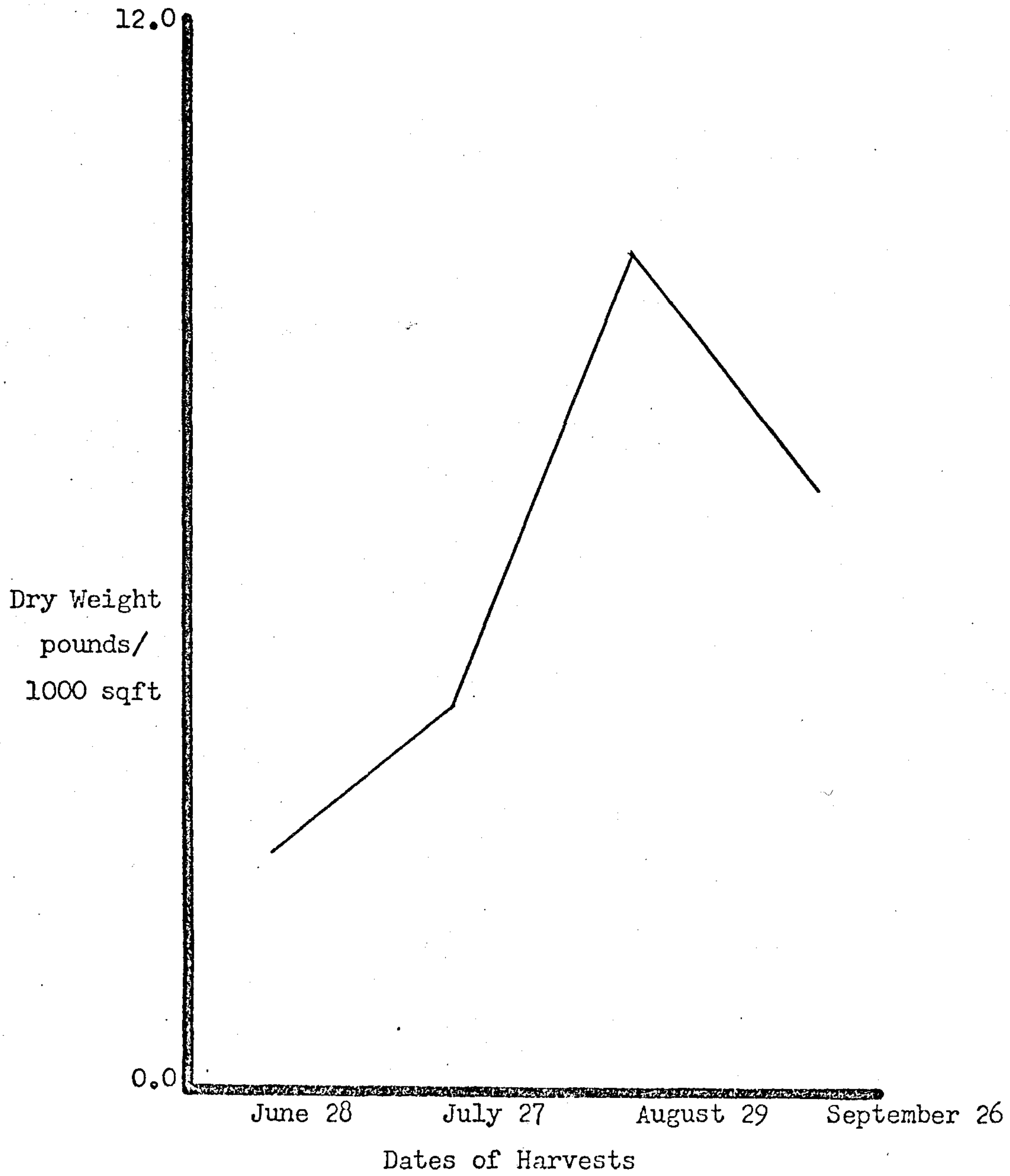



FIGURE 20

In June the leaf analysis for minerals provided further evidence of the vigorous growth of both 'Windsor' and 'Merion' bluegrass. There was little difference between 'Merion' and 'Windsor' in plant composition of nitrogen and phosphorus, but the two cultivars contained more nitrogen, phosphorus and potassium than 'Kenblue'. See Table VIII.

TABLE VIII. MINERAL CONTENT OF POA PRATENSIS CULTIVARS IN JUNE

| Cultivars | %N | %P | %K |
|---|---|---|---|
| Windsor | 4.82 | .590 | 3.81 |
| Merion | 4.72 | .590 | 3.74 |
| Kenblue | 4.42 | .537 | 3.26 |
| LSD (05) | .200 | .0266 | .360 |
| LSD (01) | .266 | .0353 | .477 |

In September 'Merion' and 'Windsor' bluegrass also contained more nitrogen and phosphorus than 'Kenblue'. 'Windsor' contained a greater amount of potassium than 'Kenblue' or 'Merion' bluegrass (Table IX).

TABLE IX. MINERAL CONTENT OF POA PRATENSIS CULTIVARS IN SEPTEMBER

| Cultivars | %N | %P | %K |
|---|---|---|---|
| Windsor | 4.23 | .450 | 3.89 |
| Merion | 4.17 | .453 | 3.59 |
| Kenblue | 4.00 | .421 | 3.47 |
| LSD (05) | .12 | .017 | .165 |
| LSD (01) | .16 | .023 | .219 |

The Kentucky bluegrass and red fescue dry matter production conformed to the general pattern of the Kentucky bluegrass dry matter production. The yield increased monthly until September when the yield declined. The August harvest was the highest. The monthly yield of the bluegrass-fescue treatment was less than the yield of the bluegrass treatment. See Table X.

TABLE X. DRY MATTER YIELD OF THE GRASS SPECIES

| | Yield in Pounds per 1000 sq ft | | | |
|---|---|---|---|---|
| Cultivars | June | July | August | September |
| Windsor | 2.457 | 4.135 | 9.239 | 6.941 |
| Windsor & Pennlawn | 2.552 | 3.032 | 6.523 | 6.829 |
| Merion | 2.831 | 3.759 | 10.221 | 7.349 |
| Merion & Pennlawn | 2.850 | 2.530 | 6.815 | 7.219 |
| Kenblue | 2.662 | 4.565 | 8.468 | 6.001 |
| Kenblue & Pennlawn | 2.738 | 3.131 | 6.148 | 6.583 |
| LSD (05) | .232 | .268 | .711 | .594 |
| LSD (01) | .308 | .355 | .939 | .785 |

The yield of the 'Merion-Pennlawn' treatment tended to be larger than the 'Windsor-Pennlawn' treatment. In Table X this trend is observed for the month of August. In September the yield of the 'Kenblue-Pennlawn' treatment was lower than the yield of either the 'Merion-Pennlawn' or the 'Windsor-Pennlawn' treatments, but the yield was greater than was the yield of 'Kenblue' alone (Table X).

Kentucky bluegrass competed favorably with red fescue as shown by the density measurement, Table XI. For example, in July the density of the 'Merion' bluegrass was 50.30 percent, in September the density of 'Merion' was approximately 64.70 percent. By the end of the 1968 season, 'Merion' did not perform as well as either 'Windsor' or 'Kenblue' in the bluegrass-fescue treatments.

TABLE XI. DENSITY OF KENTUCKY BLUEGRASS IN THE BLUEGRASS-FESCUE TREATMENTS

| Cultivars | July | September |
|---|---|---|
| Windsor & Pennlawn | 47.70% | 68.90% |
| Merion & Pennlawn | 50.30 | 64.70 |
| Kenblue & Pennlawn | 47.50 | 68.60 |
| LSD (05) | .397 | .382 |
| LSD (01) | .525 | .505 |

Water tended to increase the density of Kentucky bluegrass in the bluegrass-fescue treatments. In July and September the density of 'Merion' bluegrass was increased significantly by surface irrigation (figures 21, 22 respectively). The density of 'Merion' under subsurface irrigation also increased in July but the increase was not significant at the five percent level of probability. In September, the density of 'Windsor' increased from 61.80 percent in the non-irrigated treatments to 73.20 percent in the surface irrigated treatment, but again the increase was not significant at the five percent level of probability.

The bluegrass cultivars in the bluegrass-fescue plots responded differently to shade in July (figure 23). With increasing shade levels, 'Windsor' bluegrass increased in density. 'Kenblue,' on the other hand, decreased in density under heavy shade.

Higher levels of nitrogen tended to favor Kentucky bluegrass in the bluegrass-fescue treatments only late in the season. In July there was not a significant difference in the density of the bluegrass cultivars at the five percent level of probability (figure 24). In September the density of the bluegrass in the

THE EFFECT OF THE IRRIGATION-CULTIVAR INTERACTION
ON THE DENSITY OF THE BLUEGRASS-FESCUE TREATMENT
JULY

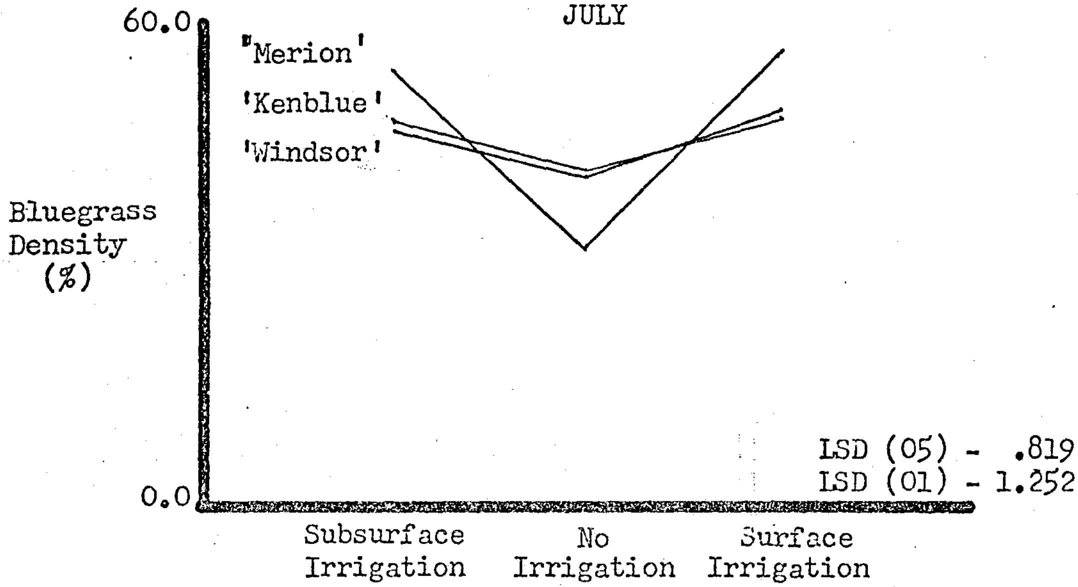



FIGURE 21

THE EFFECT OF THE IRRIGATION-CULTIVAR INTERACTION
ON THE DENSITY OF THE BLUEGRASS-FESCUE TREATMENTS
SEPTEMBER

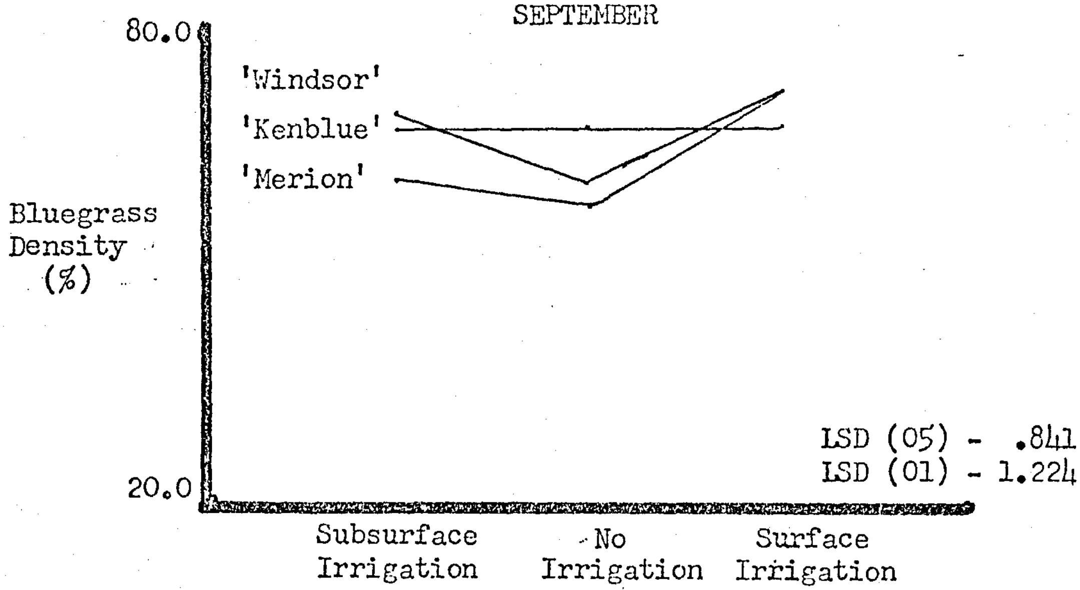



FIGURE 22

THE EFFECT OF THE SHADE-SPECIES INTERACTION
ON THE DENSITY OF THE BLUEGRASS-FESCUE TREATMENTS
JULY

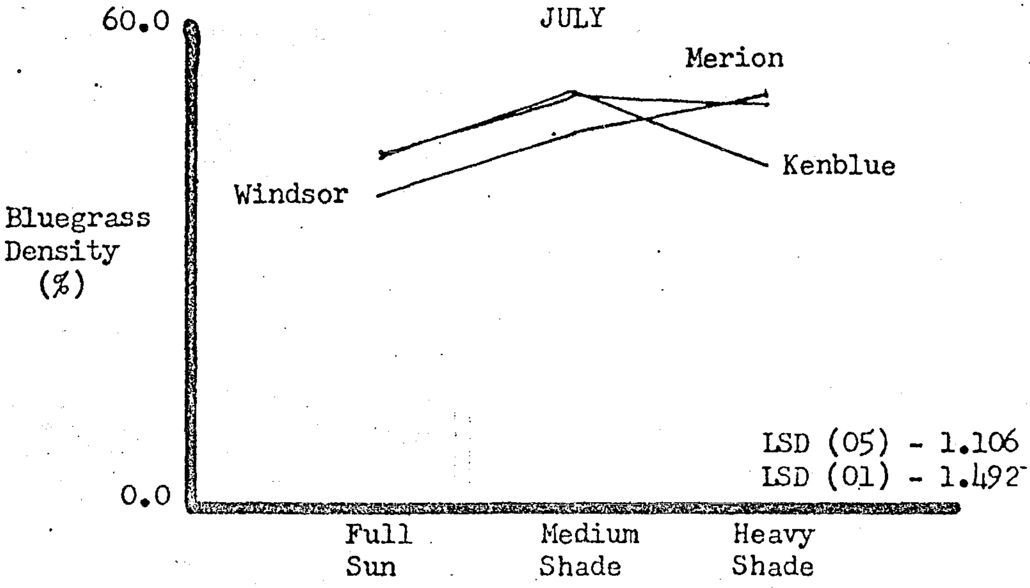



FIGURE 23

THE EFFECT OF THE NITROGEN-SPECIES INTERACTION
ON THE DENSITY OF THE BLUEGRASS-FESCUE TREATMENTS
JULY

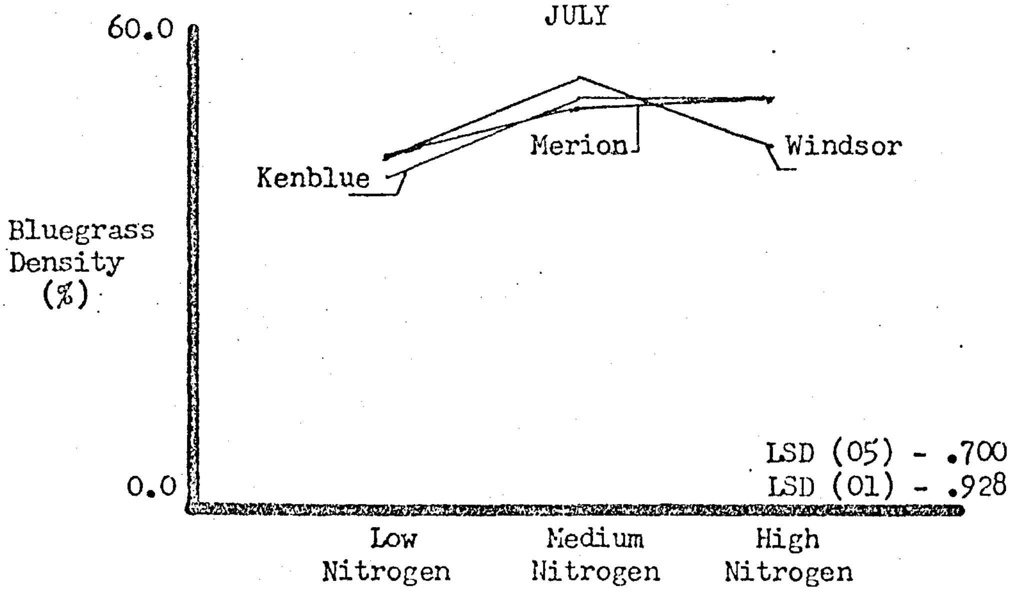



FIGURE 24

bluegrass-fescue treatments increased with increasing rates of nitrogen (figure 25).

THE EFFECT OF THE NITROGEN-CULTIVAR INTERACTION
ON THE DENSITY OF THE BLUEGRASS-FESCUE TREATMENTS
SEPTEMBER

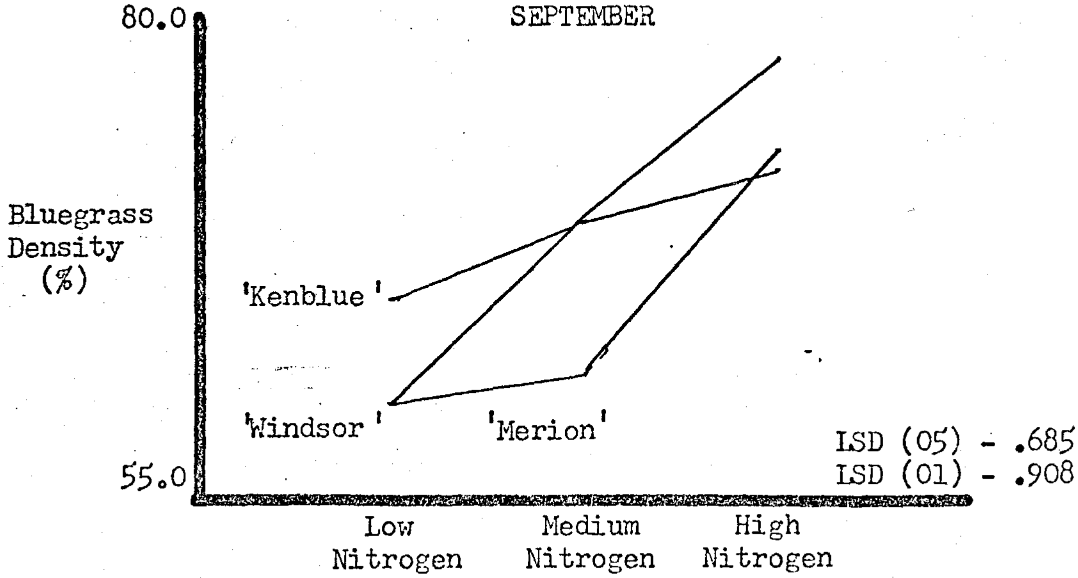



FIGURE 25

# DISCUSSION

## Water

Water was an important factor for promoting dry weight production in June and August. As observed in Table IV, the yield of the non-irrigated treatments was significantly lower than the irrigated treatments. The rainfall during June and August was only 1.70 inches and 1.90 inches respectively. In contrast, the rainfall for July and September was 3.34 and 2.70 inches respectively. This past season, the data showed that bluegrass will become dormant and inactive under high moisture stresses. For satisfactory mid-summer growth and development of bluegrass under these conditions, it will be necessary to use supplemental irrigation.

The results of the different methods of irrigation did not differ significantly. For example, the yield in August of surface irrigation was 10.804 pounds while for subsurface irrigation it was 9.491 pounds per one thousand (1000) square feet (Table IV).

The nutrient compostion of the plants was not greatly influenced by the type of irrigation system employed. In June there was not a significant difference in the mineral composition of the plants. In September only phosphorus absorption was significantly increased by surface irrigation (figure 8). Because this was the first season, any conclusions relating to phosphorus mobility are difficult to state, but this observation does indicate that the type of irrigation system employed can influence mineral absorption. This relationship needs to be more thoroughly investigated in the future.

Shade

In June dry matter production increased with increasing shade levels (Table XII). The high light intensities during this time enabled a high rate of photosynthesis to be carried on. Also, Brown (3) observed that vegetative growth is associated with temperatures under 80°F. The ambiant air temperatures for a six day period are in Table XIII, and the air temperature was in the range favorable for the growth of Kentucky bluegrass.

TABLE XIII. AMBIANT AIR TEMPERATURE AT EXPERIMENTAL LOCATION °F

| | |
|---|---|
| 24 June | 77.6°F |
| 25 June | 79.0°F |
| 26 June | 79.0°F |
| 27 June | 61.0°F |
| 28 June | 64.0°F |
| 29 June | 76.6°F |

To further support the observation that dry matter production was improved with increasing shade levels is the tissue mineral content of the plants (figures 9, 10). The higher content of minerals in the tissue is strongly associated with the higher growth rates of the plants under medium and heavy shade.

In July and August, shade did not significantly influence yield. This occurrence suggested that during the summer months the light intensities under 40 percent and 60 percent shade levels were not limiting growth.

In September, heavy shade did limit growth but medium shade did not. Under the heavy shade levels, the reduced light intensity was probably limiting photosynthesis, whereas under medium shade there was sufficient light for food production. This supported the field observation that the turf did not grow as vigorously under heavy shade as it did under medium shade.

The yield of the plants was influenced by a shade-water interaction. Over all the treatments, the yield in the non-irrigated shade treatments increased when comparing the yield in full sun (figures 13, 14, 15). In the shade, the rate of evaporation from the soil surface was less due to lower incident energy and a higher relative humidity. Since water loss was reduced, the soil did not dry out as quickly as it did in full sun; thus, the plant was not under as great a water stress in the shade as in full sun. Also, the soil temperature, at least during the month of July, was lower under the shaded treatments than the full sun treatment (Table XIV). Under water

TABLE XIV. SOIL TEMPERATURE READINGS
AT A SIX INCH DEPTH, JULY 1968

| | | Full Sun | Medium Shade | Heavy Shade |
|---|---|---|---|---|
| July 14 | 2:00 pm | 81.5°F | 80.5°F | 77.5°F |
| | 5:00 pm | 86.0 | 81.5 | 79.0 |
| | 7:00 pm | 84.5 | 81.0 | 78.0 |
| July 15 | 11:00 am | 79.0°F | 78.0°F | 77.0°F |
| | 1:00 pm | 79.5 | 79.0 | 78.0 |
| | 3:00 pm | 82.0 | 79.5 | 79.0 |
| July 16 | 12:00 | 80.5°F | 78.5°F | 77.5°F |
| | 2:00 pm | 83.0 | 80.0 | 78.5 |
| | 5:00 pm | 86.0 | 82.0 | 81.0 |

stress the increased rate of respiration of the plants in full sun consumed the available food reserves necessary for the growth and development of the turf.

The influence of surface and subsurface irrigation systems under shaded conditions on the growth of the turf cannot be easily interpreted with one seasons growth. One condition that is influencing the growth of the grass in shade is the practice of mowing. Nitrogen was available and sufficient water was present to promote vegetative growth. In turn, this dry matter was removed with each mowing. The regular mowing removed a portion of the leaf area needed for the production of food reserves, which were necessary for additional growth.

Another condition influencing the response of the turf is that with the over-head irrigation the shade cloth was removed to ensure even distribution of the water. To minimize run-off, only one inch of water was applied at a given time. It, therefore, took three days to irrigate all the replications, and during this time the shade cloths were not covering the plots.

Nitrogen

The effects of nitrogen on plant growth have been well-documented ( 3 ). The effects of high levels of nitrogen on dry matter production, however, needs to be explained. In June the turf was injured by the ten pound rate of nitrogen. The source of nitrogen was ammonium nitrate. Although the nitrogen was watered-in, the action was not completely successful and some burning resulted. In September, the increase in herbage growth under the ten pound rate of nitrogen was mainly due to the residual nitrogen.

The occurence of interactions involving nitrogen were more interesting to the investigator. In the interaction of nitrogen and water, water did not increase yields under the one pound rate of nitrogen because nitrogen was the limiting factor. This effect does support Carroll's (4 ) observation that water alone is not sufficient for promoting the growth of Kentucky bluegrass.

With surface irrigation and medium levels of nitrogen, growth in June was improved. The overhead irrigation system leached the fertilizer into the root zone at a faster rate than subsurface irrigation. Since water movement under subsurface irrigation is largely by capillary action, the ions did not move as quickly into the root zone as when they were removed by gravitational water. In this area, however, irrigation is used to suppliment natural rainfall for promoting growth during periods of high moisture stress. Nitrogen is more often applied earlier in the spring, and the spring rains would have leached the nitrogen into the root zone prior to the need for supplimental irrigation.

In July the yield of the turf under low and medium levels of nitrogen was not increased by irrigation. The air temperatures were slightly higher, reducing the growth rate, and the available soil nitrogen was less than in June as it had been used in growth. The yield increased under high levels of nitrogen in the presence of irrigation.

In September the yield of the turf increased with increasing levels of nitrogen in the presence of irrigation. In this season the air temperature was within the range that encourages vegetative growth of bluegrass, and the water was available for the growth of the turf. In this season also, tiller development is initiated. There was a greater leaf area present for the production of food materials, hence, vegetative growth was encouraged. Because nitrogen was limiting, the dry matter production was not as great as it might have been if nitrogen were available for growth.

The nitrogen also interacted with shade. During the season, low levels of nitrogen significatnly increased growth under shade. This observation is not fully explainable with only the results of the first seasons' growth. The lower temperatures recorded under shade (Table XIV), would reduce the rate of respiration and less food material would be metabolized. Consequently, carbohydrate reserves should have increased. The lower light intensities, however, would have tended to reduce the rate of photosynthesis. In addition, low levels of nitrogen tended to reduce the vegetative growth under these conditions, thus there would be a lower amount of photosynthate produced and with each mowing less food reserves would be removed from the plant. As long as the rate of photosynthesis was greater than the rate of respiration, the carbohydrate reserves would increase, and the plant would continue to grow and develop.

Medium and high levels of nitrogen under shade depressed yields. The higher levels of nitrogen stimulated succulent growth, and as compared to the one pound rate of nitrogen, each mowing removed a greater portion of the leaf blade. Consequently, with each mowing a greater amount of food material was removed from the plant; over the season the carbohydrate reserves were not able to increase and this reduced the regrowth of the plant.

Cultivars

The monthly increase in the dry matter production of the Kentucky bluegrass treatment was due to several factors.

The nitrogen was applied in June, and the grass was encouraged to grow during the summer. The soil volume was not root bound due to the presence of existing plant roots and rhizomes. Etter ( 6 ) has observed that the dry weight production is often the greatest in the first year and it is related to the number of rhizomes present. Finally, although the turf was to be mowed once a week the weather and the scheduling of irrigations on several occasions prevented the grass from being mowed on the scheduled day.

For the 1968 season, the dry matter production of the cultivars indicated 'Merion' and 'Windsor' bluegrass were more productive than 'Kenblue' (Table I). Although the total yield differences did not appear to be great, visual observations during the growing season supported this trend. In addition, 'Merion' and 'Windsor' contained greater amounts of nitrogen, phosphorus, and potassium than 'Kenblue' in June (Table II), and greater amounts of nitrogen and phosphorus in September (Table III).

Kentucky bluegrass in the bluegrass-fescue treatments competed favorably, as measured by density, with fescue. For example, over all the treatments 'Windsor' in the bluegrass-fescue treatments increased in density from 47.70 to 68.90 percent.

Water and nitrogen were the two main factors that favored the growth of the bluegrass in the bluegrass-fescue treatment. Mantell (12) observed that Festuca rubra is tolerant of and will persist under drought conditions. Lucey (11), on the other hand, observed that a moisture regime of 40 percent or higher is more favorable for the growth and development of bluegrass than lower moisture regimes. In this experiment, the irrigated treatments were watered when the soil moisture deficit was fifty percent of field capacity.

In September, the density of the bluegrass increased significantly more under the higher rates of nitrogen. Juska (8) observed that at five pounds of nitrogen fertilization, red fescue will not persist. Skogley (14), in field tests, concluded that five pounds of nitrogen favors the growth and persistance of bluegrass. The findings of this experiment (figure 25) indicates also that higher rates of nitrogen favor bluegrass when in competition with red fescue.

A shade-cultivar interaction, as measured by density, was significant only in the month of July. 'Windsor' increased in density under increasing shade levels, but 'Kenblue' decreased in density under heavy shade. This observation suggests, possibly, that there are differences between bluegrass cultivars in their tolerance to shade. This is an area that needs further investigation to determine bluegrass' tolerance of shade.

In August, an infection of rust, Puccina graminus, was first noted on 'Merion' bluegrass in the low nitrogen and the non-irrigated medium shade treatment. In two weeks, this disease had spread to all the treatments in the first two replications. Under heavy shade, however, the incidence of the rust was negligible, whereas under medium shade and full sun the infection was severe. The pattern of infection can best be explained by the mode of entry of the rust organism. According to Cheeseman (5), the organism infects the host either through direct penetration of the plant cell or through an open stomata. Direct penetration is more commonly associated with plants of weakened vigor, and stomatal entry when the stomates are open. Under heavy shade the guard cells of the plant would be flacid and the stomates closed. Thus, this observation suggests that shaded conditions can either increase or, at least modify, the severity of disease in a Kentucky bluegrass turf.

## CONCLUSIONS

1. The dry matter production of 'Merion' bluegrass and 'Windsor' bluegrass was, respectively, ten (10) percent and five (5) percent greater than the dry weight production of 'Kenblue.' 'Merion' and 'Windsor' bluegrass also contained eight (8) percent more nitrogen, nine (9) percent more phosphorus and fourteen (14) percent more potassium than 'Kenblue' contained under the conditions of this experiment.

2. The dry weight production of the turf in full sun and medium shade was respectively, 7.3 percent and 8.7 percent greater than the dry weight production under heavy shade for the 1968 season.

3. In the non-irrigated treatment, the dry weight production of the turf in the sun, 1.887 pounds per 1000 square feet, was less than the dry weight production under either medium shade, 3.407 pounds per 1000 square feet, or heavy shade, 3.597 pounds per 1000 square feet for the 1968 season.

4. The dry weight production of the turf increased with the low level of nitrogen under medium shade or heavy shade, but with higher rates of nitrogen the dry weight production decreased

under medium or heavy shade for the 1968 season.

5. The Kentucky bluegrass cultivars increased in density in the bluegrass-fescue treatments under all conditions of this experiment; however, further field tests are required in order to evaluate the competition between *Poa pratensis* and *Festuca rubra*.

6. Additional field tests are required to reliably judge the effectiveness of subsurface irrigation on turf grass under varying environmental conditions.

## LITERATURE CITED


1. Baker, B. S. and G. A. Jung. Effect of Environmental Conditions on the Growth of Four Perennial Grasses. Agron. Jour. 60 (2): 158. 1968.

2. Beard, James S. Factors in the Adaptation of Turf Grass to Shade. Agron. Jour. 57 (5): 457. 1965.

3. Brown, E. Marion. Seasonal Variation in the Growth and Chemical Composition of Kentucky Bluegrass. Miss. Agron. Exp. Sta. Bull. 360. 1943.

4. Carrol, J. C. Effects of Drought, Temperature, and Nitrogen on Turf Grasses. Plant Physiology 18:19. 1943.

5. Cheesman, Roberts. Effects of Nitrogen Level and Osmotic Pressure on the Nutrient Solution on Incidence of Puccinia graminis and Helminthosporium sativum Infection in Merion Kentucky Bluegrass. Agron. Jour. 57 (6): 599. 1965.

6. Etter, Alfred Gordon. How Kentucky Bluegrass Grows. Annuals of Missouri Botanical Garden. 18(3): 293. 1951.

7. Evans, Morgan W. Kentucky Bluegrass. Ohio Agr. Exp. Sta. Bull. 681. 1949.

8. Juska, F. V. and A. A. Hanson. Evaluation of Cool-Season Turf Grasses Alone and in Mixtures. Agron. Jour. 51(9):597. 1959.

9. __________ and A. A. Hanson and A. W. Hovin. Kentucky 31 Tall Fescue- A Shade Tolerant Turf Grass. Weeds, Trees, and Turf. 1: . 1969.

10. __________ and J. Tyson and C. H. Harrison. The Competitive Relationship of Merion Bluegrass as Influenced by Various Mixtures, Cutting Heights, and levels of Nitrogen. Agron. Jour. 47 (11): 513. 1955.

11. Lucey, Robert F. and Milo B. Tesar. Frequency and Rate of Irrigation as Factors in Forage Growth, and Water Absorption. Agron. Jour. 57 (6): 519. 1965.

12. Mantell, A. and E. Stanhill. Comparison of Methods of Evaluating the Response of Lawn-Grasses to Irrigation and Nitrogen Treatments. Agron. Jour. 58 (5): 465. 1966.

13. Pellet, Harold M. and Eliot C. Roberts. Effects of Mineral Nutrition and High Temperatures Induced Growth Retardation of Kentucky Bluegrass. Agron. Jour. 55 (5): 473. 1963.

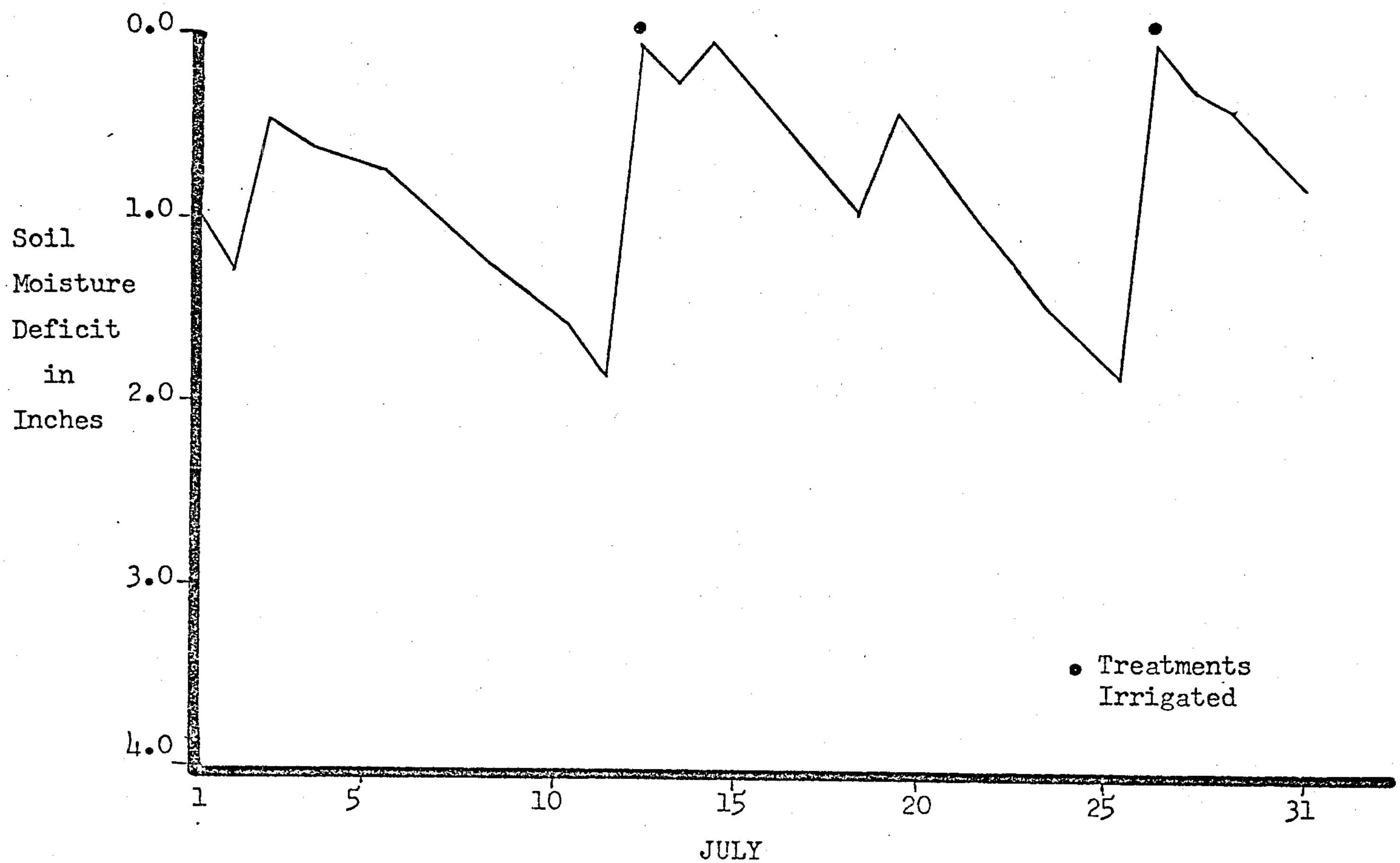
14. Skogley, C. R. and F. B. Lederoer. Evaluation of Several Kentucky Bluegrasses and Red Fescue Strains Maintained as Lawn Turf Under Three levels of Fertility. Agron. Jour. 60 (1): 47. 1968.

15. Stanhill, G. The Effect of Differences in Soil-Moisture Status on Plant Growth. Soil Sci. 84. 1957.

16. Steckel, Joseph E. and Royal Flannery. Automatic Determination of Phosphorus, Potassium, Calcium, and Magnesium in Wet Digestion Solutions of Plant Tissue. Technitian Symposium. September, 1965.

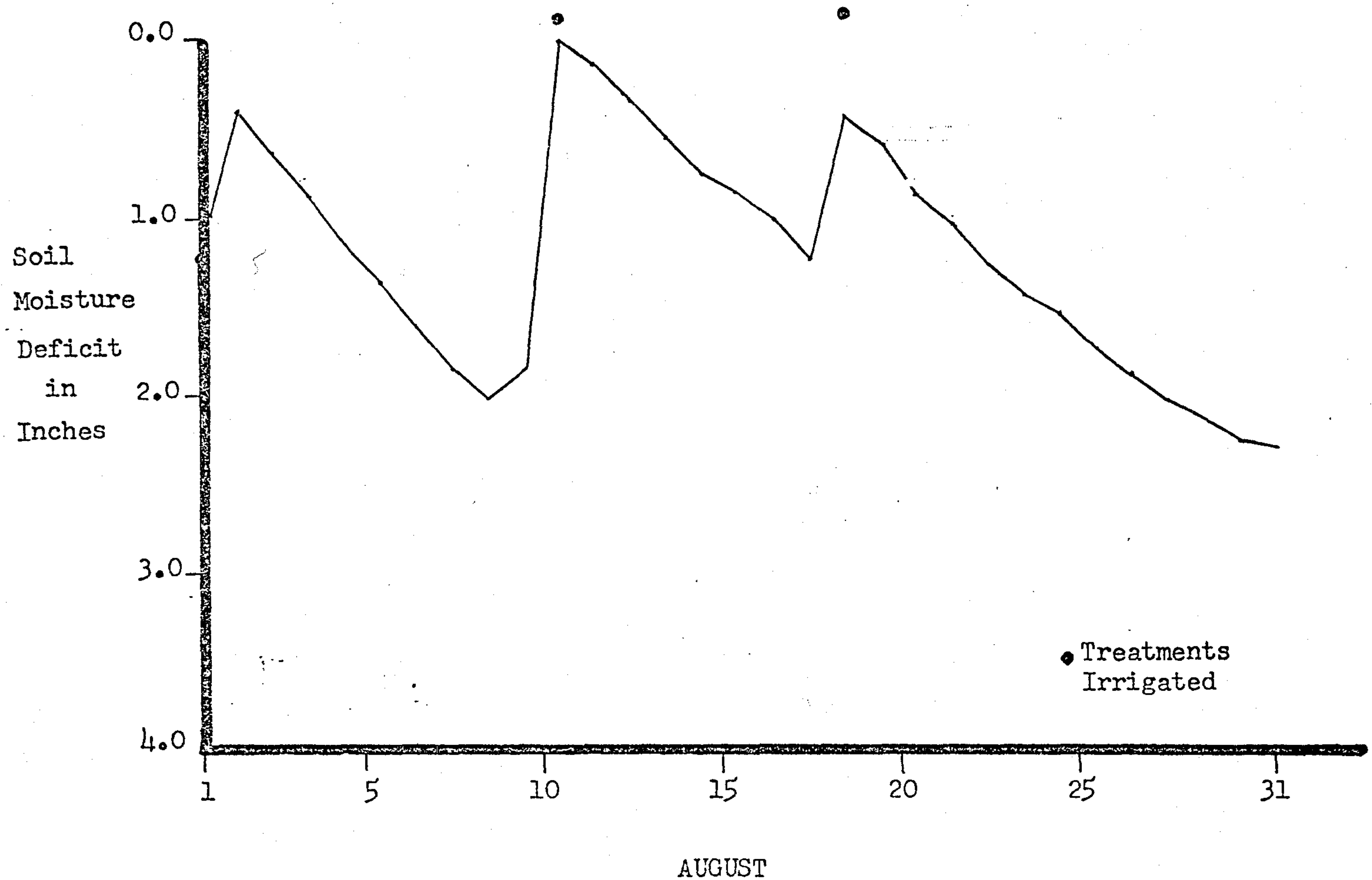
17. Thornthwaite, C. W. and J. R. Mather. The Water Balance. Publications in Climatology. 8(1). 1955.

DAILY SOIL MOISTURE BALANCE DETERMINED
ACCORDING TO THORNTHWAITE AND MATHER (17)



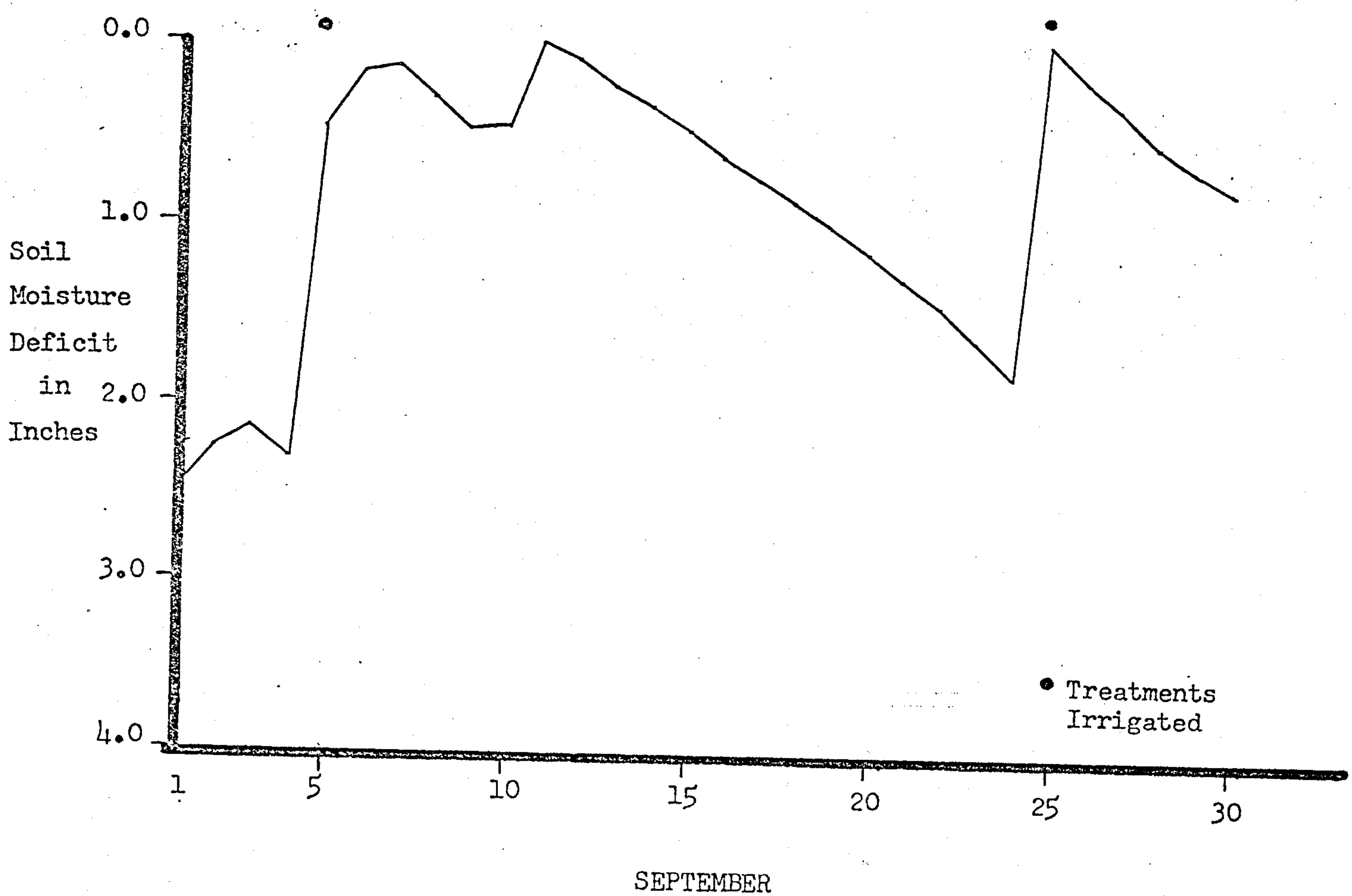

APPENDIX I

DAILY SOIL MOISTURE BALANCE DETERMINED
ACCORDING TO THRONTHWAITE AND MATHER (17)



APPENDIX I

DAILY SOIL MOISTURE BALANCE DETERMINED
ACCORDING TO THORNTHWAITE AND MATHER (17)



# APPENDIX II

## TABLE VIII
## F VALUE SIGNIFICANCE
## DRY WEIGHT

| | June | July | August | September |
|---|---|---|---|---|
| A | .01 | N.S. | .05 | N.S. |
| B | .05 | N.S. | N.S. | .01 |
| C | .01 | .05 | N.S. | .01 |
| D | .01 | .01 | .01 | .01 |
| AB | .05 | .01 | .05 | N.S. |
| AC | .05 | .05 | .01 | .01 |
| BC | .01 | .01 | .01 | .01 |
| AD | N.S. | N.S. | N.S. | .05 |
| BD | .05 | .05 | N.S. | .01 |
| CD | N.S. | .05 | N.S. | .01 |
| ABC | .01 | N.S. | N.S. | N.S. |
| ABD | N.S. | .01 | N.S. | .01 |
| ACD | N.S. | N.S. | N.S. | N.S. |
| BCD | N.S. | N.S. | N.S. | N.S. |
| ABCD | N.S. | N.S. | N.S. | N.S. |

## TABLE IX
## F VALUE SIGNIFICANCE
## DENSITY

| | July | September |
|---|---|---|
| A | N.S. | N.S. |
| B | N.S. | N.S. |
| C | .01 | .01 |
| D | .01 | .01 |
| AB | N.S. | N.S. |
| AC | .01 | N.S. |
| BC | .05 | N.S. |
| AD | .01 | .01 |
| BD | .01 | N.S. |
| CD | .01 | .01 |
| ABC | N.S. | N.S. |
| ABD | N.S. | N.S. |
| ACD | N.S. | N.S. |
| BCD | N.S. | N.S. |
| ABCD | N.S. | N.S. |

A - water B - shade C - nitrogen D - cultivars

Multinumbers Indicate Interactions

# APPENDIX II

## TABLE X
## F VALUE SIGNIFICANCE
## NUTRIENTS

| | CALCIUM | | MAGNESIUM | | NITROGEN | | PHOSPHORUS | | POTASSIUM | |
|---|---|---|---|---|---|---|---|---|---|---|
| | J. | S. | J. | S. | J. | S. | J. | S. | J. | S. |
| A | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | .01 | N.S. | N.S. |
| B | .01 | N.S. | .05 | N.S. | N.S. | N.S. | .05 | N.S. | .01 | .05 |
| C | N.S. | .01 | N.S. | N.S. | .01 | .01 | N.S. | N.S. | N.S. | N.S. |
| D | .01 | .01 | N.S. | N.S. | .01 | .01 | .01 | .01 | .05 | .01 |
| AB | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | .05 | N.S. | N.S. |
| AC | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| BC | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| AD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| BD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| CD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| ABC | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| ABD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | .01 | N.S. |
| ACD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| BCD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |
| ABCD | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. | N.S. |

J - June S - September

A - water B - shade C - nitrogen D - cultivars

N.S. - Not Significant

Multinumbers Indicate Interactions

# APPENDIX III

## RAINFALL CHART 1968[1]

| | | | |
|---|---|---|---|
| January | 1.47 | July | 3.34 |
| February | 1.09 | August | 1.90 |
| March | 5.21 | September | 2.70 |
| April | 1.97 | October | 3.47 |
| May | 4.80 | November | 3.54 |
| June | 1.76 | December | 2.62 |

[1]Climatological Data, US Dept. of Commerce, Environmental Science Services Administration, Environmental Data Service, Jan. 1968, vol. 72, 1-12.

# APPENDIX IV

## CHEMICAL AND PHYSICAL MEASUREMENTS OF THE SOIL PROFILE

| | 0-8" | 8-12" | 12-16" |
|---|---|---|---|
| Field capacity % moisture (Dry wt. Basis) | 26.8 | 23.9 | 23.9 |
| Wilting point % moisture (Dry wt. Basis) | 6.1 | 8.8 | 10.8 |
| Bulk density | 1.27 | 1.39 | 1.44 |
| Available moisture holding capacity in inches of water | 2.1 | .8 | .8 |
| % Sand .05 mm. | 28.0 | 27.0 | 27.0 |
| % Silt .002 - .05 mm. | 59.0 | 55.0 | 52.8 |
| % Clay .002 mm. | 13.0 | 18.0 | 20.2 |

| | 4" | 8" | 12" |
|---|---|---|---|
| Phosphorus Lbs. $P_2O_5$ per acre | 726.5 | 678.9 | 297.9 |
| Potassium Lbs. $K_2O$ per acre | 371.7 | 257.1 | 202.5 |
| Calcium Lbs. CaO per acre | 1340.0 | 1191.7 | 1008.1 |
| Magnesium Lbs. MgO per acre | 160.1 | 130.0 | 127.4 |
| Organic matter | 2.36 | 1.71 | .06 |
| pH | 6.1 | 6.0 | 5.7 |

# APPENDIX V

## A SCHEMATIC DRAWING OF THE IRRIGATION, SHADE, NITROGEN AND CULTIVAR TREATMENTS OF ONE REPLICATION