# A STUDY OF THE EFFECT OF NITROGEN CARRIERS ON TURFGRASS DISEASES

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## INTRODUCTION

Nitrogen has been recognized as being the key element in the relationship between soil fertility and disease of turfgrasses. The importance of utilizing any such potential becomes apparent when the overwhelming nature of disease problems is considered. The most disease resistant grasses can never be developed to give complete resistance to the more than 100 turfgrass pathogens (8). Also, the saprophytic nature of many of these fungi provides a continual source of inoculum which makes an intensive and expensive fungicide program a prerequisite in the maintainance of fine turf (11). Even with the best fungicide programs, some disease may occur. In view of this, potential management aids in turfgrass disease control should be discovered and utilized. Putting greens fertilized with activated sewage sludge have had a relatively low incidence of disease. This study was undertaken to determine if the specific nitrogen source could serve as a deterrent to disease and to obtain information on factors associated with nitrogen fertilization which might produce measurable disease reduction.

## REVIEW OF LITERATURE

Research reports and field observations of disease reduction associated with activated sewage sludge fertilization indicated need for further study of disease and nitrogen carrier relationships. Davis and Engel (5) used curative and preventative fungicide treatments with three rates of activated sewage sludge and one rate of an 8-6-4 fertilizer. They reported lower readings for large brownpatch on Colonial bentgrass fertilized with activated sewage sludge than with 8-6-4 or no fertilizer treatment. Seaside bentgrass showed higher large brownpatch readings when fertilized with the 8-6-4. Copperspot incidence with the various fertilizer types was not consistent, but the plots fertilized with activated sewage sludge at the highest rate show lower disease readings.

Wells (21) reported that ryegrass plots receiving heavy rates of activated sewage sludge showed less damage from Cottony blight than those receiving other sources of organic and inorganic nitrogen.

Watson, Jr. (18) designed a test to study the effect of carriers of phenyl mercuric acetate and mercuric + mercurous chloride for control of snowmold. The carriers were water, sand, topdressing and activated sewage sludge; the fungicides were tested at two rates. The low rate of phenyl mercuric acetate was effective only when applied with activated sewage sludge as a carrier. All other fungicide treatments were effective in controlling snowmold.

Several theories could explain an inhibitory effect of a nitrogen carrier on disease. Fertility level has long been associated with disease severity. Large brownpatch usually increases when the nitrogen level is high and creates a soft succulent growth. In contrast, dollarspot is usually more severe on turf that shows symptoms of nitrogen deficiency, although succulent turf produced by excessive nitrogen fertilization can be severely attached (11). Couch (3) reported the severity of dollarspot, on seaside creeping bentgrass in a greenhouse study, was directly related to nitrogen level. This is not contradictory since the levels of nitrogen fertility used in this study might be considered excessive in field practice.

A second possible explanation for nitrogen carriers affecting turfgrass disease incidence is suggested by a study of the constituents and elements of activated sewage sludge by Rehling and Truog (12). The product was found to contain appreciable amounts of highly available iron, manganese, sodium, copper, zinc, sulfur, chlorine, chromium, and many other elements. Several of the elements found in activated sewage sludge also are constituents of some fungicides (7).

The activity of soil microflora offers a third explanation for nitrogenous materials affecting disease incidence. Wells (21) concluded that activated sewage sludge favored the development of cottony blight of ryegrass. However, he also reported that activated sewage sludge seemed to encourage soil micro-organisms, antagonistic to *Pythium*, which decreased the severity of cottony blight.

This was indirectly supported by Johnson (10) who reported that high soil nitrogen and high organic matter encourage microflora which are antagonistic to *Sclerotium rolfsii*. Davey (4) and Wilhelm (22) reported similar findings with *Rhizoctonia solani* and *Verticillium* sp., respectively.

Other reports of soil microorganisms antagonistic to plant pathogens are widespread in the literature (1,2,9,13,16,17,19, 20,23).

Trace elements present in nitrogen carriers may offer a fourth explanation for a fertilizer affecting turf disease. Schutte (14) reported that resistance to moisture stress was affected by certain trace elements that also are found in appreciable quantities in activated sewage sludge. He found that radish seedlings were more susceptible to wilting when grown in nutrient solutions deficient in copper, zinc or boron than in complete solution. Couch (3) reported that dollarspot development was greater when soil moisture was allowed to become limiting.

## METHODS AND PROCEDURES

Experiments were designed to test the hypothesis that nitrogen carriers do influence disease incidence and to explore the basis for any such effects that might be observed. The effect of activated sewage sludge on disease incidence was tested with a field experiment and two laboratory studies; the same field experiment, two other laboratory experiments and a greenhouse study were used to investigate possible mechanisms by which nitrogen carriers affect disease incidence on turfgrasses.

### Tests of nitrogen carriers for their influence on disease incidence

The field experiment was established on one-year-old seaside and Penncross bentgrass turf maintained at one quarter inch cutting height. Sources of nitrogen were urea, ammonium nitrate, ammonium sulfate, ureaform [1], process tankage [1], and activated sewage sludge [1].

The soluble carriers, urea, ammonium nitrate and ammonium sulfate, were applied at rates of 3.75 and 6.75 pounds of nitrogen per one thousand square feet per growing season[2]. The insoluble carriers, ureaform, process tankage, and activated sewage sludge,

[1] Commercial products known as Uramite, Agrinite and Milorganite, respectively.

[2] Unless otherwise stated, all rates will be given as pounds of elemental nitrogen per one thousand square feet.

were applied at rates of 3.75, 6.75, and 11.25 pounds of nitrogen per growing season. All treatments totaling 3.75 pounds of nitrogen per season were applied in five applications of 0.75 pound each at four week intervals. Seasonal totals of 6.75 pounds of nitrogen were applied in nine applications of 0.75 pound each at two week intervals. Nine applications of 1.25 pounds each were applied at two week intervals for the seasonal totals of 11.25 pounds of nitrogen from insoluble sources. In addition to the split application treatments, there was a single spring application of 11.25 pounds of ureaform nitrogen, and the process tankage treatment of 3.75 pounds of nitrogen was omitted. All treatments were replicated four times in a randomized block design. Each plot was three by fifteen feet, with a nine-inch buffer strip between plots. All fertilizer applications were made by hand. A box-like structure of wood and polyethylene film was used to outline and isolate the individual plots when applying treatments. The ureaform for these split application treatments was ground in a Wiley mill to pass through a 0.5 mm opening. The soluble materials and the split application treatments of ureaform were applied with a garden sprinkling can in one gallon of water. The single application of ureaform and other insoluble materials were applied dry without modification or special treatment.

The test area was mowed three times a week and all clippings were removed. The area was irrigated regularly to prevent dryness from becoming a limiting factor for growth. This particular test area was maintained on a minimum type fungicide program, using thiram (Tersan) and phenyl mercuric acetate (PMAS) at twenty-day intervals or longer.

Two laboratory experiments were conducted to study the effect of nitrogen sources on turf pathogens in pure culture. In the first, commercial potato dextrose agar (Difco) was used as the base culturing medium; to this a water extract of activated sewage sludge and unmodified activated sewage sludge were added. Twenty grams of unmodified activated sewage sludge were added to each preparation of potato dextrose agar (39 g agar in 1000 ml distilled water). The activated sewage sludge extract was prepared by boiling 100 g of the raw material in 500 ml of distilled water for one hour. The resultant slurry was allowed to cool over night and was filtered. The filtrate was then brought up to 500 ml and used as a substitute for distilled water in preparation of media.

The media were prepared in flasks and autoclaved at 15 pounds pressure for 20 minutes. Approximately 10 ml of the finished medium was used in each standard size (10 cm) petri dish.

The test organisms used in this test were _Curvularia_ sp., *Helminthosporium carbonum*, and *Stemphilium* sp. Each of the test organisms was introduced at four loci on each of four plates of each treatment. When no additive was used, only one plate was inoculated. At three-day intervals during the next nine days, the diameter of each colony was recorded.

In the second laboratory test, an attempt was made to maintain a constant nitrogen level. Three different nitrogen sources in Czapek's medium were compared with potato dextrose agar. The three sources were ammonium nitrate, activated sewage sludge and an extract of activated sewage sludge. Except for quantity, the preparation of the extract was similar to that of the previous experiment. The test organisms were:

1. *Corticium fuciforme*
2. *Curvularia* sp.
3. *Fusarium nivale*
4. *Helminthosporium carbonum*
5. *Pythium aphanidermatum*
6. *Rhizoctonia solani*
7. *Sclerotinia homoeocarpa*

In this experiment the test organisms were introduced to each plate at one point only. Each treatment was replicated four times.

During the next three weeks, notes on growth rate (diameter of colony), growth habit, longevity and number of sclerotia were made to measure the effect of the different media on the fungi.

Study of factors related to nitrogen carriers' influence on disease.

The growth patterns, induced by the several nitrogen treatments made in the field, were studied by means of weekly color ratings and clipping weights. A rating system of 0 to 4 was used to measure color response. The clippings were collected from one of three mowings per week. They were oven-dried 48 hours at 72 degrees centigrade before weighing. Data on color and clipping weights were analysed and presented graphically to show the patterns of nitrogen stimulation.

The clippings harvested in 1957 were analysed for nitrogen content by the Milwaukee Sewerage Commission.

A preliminary survey was made of the number of soil microorganisms of selected treatments in the field experiment. Soil samples were collected in March 1958 from the following fertilizer treatments:

1. Check
2. Activated sewage sludge at 6.75 and 11.25 pounds of nitrogen
3. Ureaform at 3.75 and 6.75 pounds of nitrogen
4. Process tankage at 11.25 pounds of nitrogen

5. Urea at 6.75 pounds of nitrogen

6. $(NH_4)SO_4$ at 6.75 pounds of nitrogen

One ml aliquots from dilution of 1-1000, 1-10,000 and 1-100,000 were cultured on potato dextrose agar. Counts of the colonies were made to estimate the numbers of microorganisms in the soil.

A laboratory experiment was conducted to investigate the comparative effects of the trace nutrients and other elements of activated sewage sludge on Sclerotinia homoeocarpa. Chromium ($CrO_3$), iron ($Fe_2(SO_4)_3$), aluminum ($Al_2O_3$), copper ($CuSO_4$) and sulfur (wettable powder) were tested. Totals of 578, 57.8, and 5.78 gms of activated sewage sludge per liter of media were used as standards. The higher rate would supply nitrogen per unit area of a petri dish at the equivalent of ten pounds per 1000 square feet. The trace elements were added in the same amounts as they are found in activated sewage sludge. The lowest rate of activated sewage sludge approximates the level in the second laboratory study. This experiment was replicated five times. Either the bulk of the additives or other effects on the gelling properties of the agar made it necessary to omit the high rate treatments of activated sewage sludge, iron and copper, and the medium rate of iron. After the fungus was introduced, growth rate, as expressed by the diameter of the colony, was measured periodically for the next three weeks.

A greenhouse study was established to measure the effect of trace elements on disease. The more promising elements from the laboratory test were added to ureaform and used to fertilize pots seeded to a mixture of seaside and Highland bentgrasses. The test was completely randomized and had four replications. The soil was a mixture of one part sand and two parts loam soil by volume. The seed mixture was 33 percent seaside creeping bentgrass and 67 percent Highland colonial bentgrass at 5.18 pounds per 1000 square feet. The following fertilizer treatments were made 23 days after seeding:

1. Check, no fertilizer
2. $CdNH_4PO_4$
3. $CuNH_4PO_4$
4. $FeNH_4PO_4$
5. $MgNH_4PO_4$
6. $MnNH_4PO_4$
7. $NiNH_4PO_4$
8. $ZnNH_4PO_4$
9. Ureaform + $CuSO_4$
10. Ureaform + $CrPO_4$
11. Ureaform + Sulfur, wettable
12. Ureaform + $FeCl_3$, $FeSO_4$, $Fe_2O_3$

13. Activated sewage sludge at four pounds of nitrogen per 1000 square feet.

The ureaform treatments received the same quantities of trace elements that were contained in the activated sewage sludge treatment. The pots were clipped to three fourths inch, 8 and 19 days after fertilization and inoculated with Sclerotinia homoeocarpa after 21 days. An aqueous suspension of the pathogen, made from approximately 31 square centimeters of an active colony of the organism in 100 ml of distilled water, was sprayed on the crowns of the plants. Sixty-one ml of the suspension were used to treat each of two pots of each fertilizer treatment, leaving two as checks. Clipping weights were taken again seven days after inoculation, and disease ratings were made 5 and 70 days after inoculation. In addition, color ratings were made 6, 13 and 19 days after fertilization.

## RESULTS AND DISCUSSION

Field Test on the effect of nitrogen carriers on disease incidence.

Dollarspot (*Sclerotinia homoeocarpa*) was present through the 1957 and 1958 seasons and it was the only disease present in epiphytotic proportions. Significantly less disease was observed both years (95% level of probability) on the treatment of 11.25 pounds of nitrogen from activated sewage sludge (Table 1). In 1957 the 11.25-pound rate of activated sewage sludge reduced disease incidence to 13% of the check. This treatment showed significantly less disease than any other treatment. No statistically significant differences occurred among other treatments. Comparing transformed data, activated sewage sludge at the 6.75-pound rate ranked second only to the 11.25-pound rate.

In 1958, the 11.25-pound rate of activated sewage sludge reduced disease severity to 20% of the check. In contrast with 1957, other statistically significant reductions in disease incidence were obtained. At the 6.75-pound rate, activated sewage sludge resulted in significantly less disease than ureaform, ammonium sulfate or ammonium nitrate at the comparable rate; the disease incidence of this activated sewage sludge treatment was 42% less than the average of the significantly higher disease readings. Only the activated sewage sludge at 6.75 and 11.25 pounds of nitrogen

Table 1. Incidence of dollarspot on 1/4 inch creeping bentgrass turf for two growing seasons under different nitrogen treatments. New Brunswick, New Jersey.

| Treatment [1] | Dollarspot incidence | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1957 | | | 1958 | | | Average | |
| | No. of Spots | | Rank [2] | No. of Spots | | Rank [2] | No. of Spots | Rank |
| No nitrogen check | 314 | b[3] | 15 | 515 | cd | 14 | 414.5 | 16 |
| 3.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 121 | b | 7 | 378 | bcd | 7 | 249.5 | 7 |
| Ureaform | 224 | b | 14 | 518 | cd | 15 | 371.0 | 15 |
| Urea | 205 | b | 13 | 404 | bcd | 9 | 304.5 | 11 |
| Ammonium nitrate | 157 | b | 8 | 474 | cd | 13 | 315.5 | 12 |
| Ammonium sulfate | 166 | b | 12 | 532 | d | 16 | 349.0 | 14 |
| 6.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 94 | b | 2 | 256 | b | 2 | 175.0 | 2 |
| Ureaform | 247 | b | 16 | 422 | cd | 10 | 334.5 | 13 |
| Process tankage | 211 | b | 11 | 393 | bcd | 8 | 302.0 | 10 |
| Urea | 75 | b | 3 | 360 | bcd | 5 | 190.5 | 3 |
| Ammonium nitrate | 144 | b | 6 | 452 | cd | 11 | 298.0 | 9 |
| Ammonium sulfate | 140 | b | 9 | 450 | cd | 12 | 295.0 | 8 |
| 11.25 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 42 | a | 1 | 106 | a | 1 | 74.0 | 1 |
| Ureaform | 184 | b | 10 | 305 | bc | 3 | 244.5 | 5 |
| Ureaform [4] | 129 | b | 4 | 362 | bcd | 6 | 245.5 | 6 |
| Process tankage | 114 | b | 5 | 312 | bcd | 4 | 213.0 | 4 |

[1] Quantity of nitrogen is given as pounds per 1000 square feet per season.

[2] Based on transformed data.

[3] Figures followed by the same letter are not significantly different from each other at the 5% level of probability by Hartley's method of sequential testing (15).

[4] Single spring application.

resulted in significantly less disease than the check treatment.

Except for one comparison in 1957, the disease ratings were inversely proportional to nitrogen level; the exception was a reversal for the 6.75 and 3.75 pounds of ureaform nitrogen. The average number of disease spots from each nitrogen carrier at the 11.25-pound rate in 1958, were significantly lower than those of the same carriers applied at lower rates. There were, however, no significant differences between the 3.75 and 6.75-pound rates of nitrogen fertilization.

Dollarspot counts were made four times during each season. Both years the majority of the treatments ranked similarly throughout the season. An exception was the 11.25-pound rate of activated sewage sludge; this treatment ranked ninth for freedom of disease in the first counts of 1957, but was given top rank on the basis of counts (Table 2) made in July, August and October. In 1958, activated sewage sludge ranked second in May and first (Table 3) for the remainder of the season. Ureaform at 11.25 pounds of nitrogen ranked sixteenth at the first count of 1957, but fifteenth, ninth and third at succeeding counts. In 1958, this treatment ranked third to fifth throughout the entire season. The single application of ureaform in 1957 ranked eleventh at the first count and sixth or seventh in following evaluations. In contrast, this treatment in 1958 ranked

Table 2. First season incidence of dollarspot on 1/4 inch creeping bentgrass turf under different nitrogen treatments. New Brunswick, New Jersey, 1957.

| | Dollarspot incidence | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | June 18 | | July 30 | | Aug. 20 | | Oct. 14 | |
| Treatment | No. of Spots | Rank | No. of Spots | Rank | No. of Spots | Rank | No. of Spots | Rank |
| No nitrogen check | 188 | 15 | 233 | 16 | 627 | 16 | 228 | 15 |
| 3.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 62 | 7 | 84 | 5 | 226 | 6 | 111 | 8 |
| Ureaform | 64 | 8 | 140 | 11 | 452 | 14 | 240 | 16 |
| Urea | 83 | 10 | 154 | 13 | 434 | 13 | 149 | 9 |
| Ammonium nitrate | 53 | 4 | 81 | 4 | 345 | 11 | 149 | 9 |
| Ammonium sulfate | 47 | 2 | 93 | 7 | 316 | 10 | 209 | 14 |
| 6.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 40 | 1 | 95 | 8 | 200 | 3 | 40 | 2 |
| Ureaform | 109 | 12 | 186 | 14 | 515 | 15 | 177 | 13 |
| Process tankage | 146 | 13 | 152 | 12 | 372 | 12 | 175 | 12 |
| Urea | 47 | 2 | 17 | 1 | 105 | 2 | 74 | 4 |
| Ammonium nitrate | 156 | 14 | 110 | 10 | 213 | 4 | 96 | 6 |
| Ammonium sulfate | 60 | 6 | 79 | 3 | 250 | 8 | 171 | 11 |
| 11.25 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 75 | 9 | 17 | 1 | 55 | 1 | 20 | 1 |
| Ureaform | 182 | 16 | 198 | 15 | 287 | 9 | 67 | 3 |
| Ureaform[1] | 91 | 11 | 85 | 6 | 241 | 7 | 100 | 3 |
| Process tankage | 55 | 5 | 102 | 9 | 223 | 5 | 78 | 5 |

[1] Single spring application

Table 3. Second season incidence of dollarspot on 1/4 inch creeping bentgrass turf under different nitrogen treatments. New Brunswick, New Jersey, 1958.

| | Dollarspot incidence | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | May 26 | | July 7 | | Sept. 12 | | Sept. 25 | |
| Treatment | No. of Spots | Rank | No. of Spots | Rank | No. of Spots | Rank | No. of Spots | Rank |
| No nitrogen check | 195 | 6 | 499 | 6 | 743 | 16 | 624 | 16 |
| 3.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 251 | 9 | 550 | 8 | 355 | 8 | 356 | 5 |
| Ureaform | 303 | 12 | 702 | 13 | 560 | 15 | 506 | 13 |
| Urea | 282 | 10 | 636 | 10 | 325 | 6 | 372 | 6 |
| Ammonium nitrate | 348 | 14 | 643 | 11 | 456 | 14 | 449 | 11 |
| Ammonium sulfate | 387 | 16 | 726 | 14 | 417 | 12 | 508 | 15 |
| 6.75 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 174 | 4 | 318 | 2 | 225 | 2 | 305 | 2 |
| Ureaform | 314 | 13 | 726 | 14 | 321 | 5 | 327 | 3 |
| Process tankage | 283 | 11 | 506 | 7 | 377 | 9 | 405 | 9 |
| Urea | 225 | 8 | 576 | 9 | 238 | 3 | 401 | 8 |
| Ammonium nitrate | 352 | 15 | 645 | 12 | 382 | 11 | 428 | 10 |
| Ammonium sulfate | 178 | 5 | 786 | 16 | 377 | 9 | 455 | 12 |
| 11.25 lbs. nitrogen | | | | | | | | |
| Act. sew. sludge | 75 | 2 | 132 | 1 | 90 | 1 | 125 | 1 |
| Ureaform | 158 | 3 | 459 | 5 | 260 | 4 | 344 | 4 |
| Ureaform[1] | 66 | 1 | 342 | 4 | 447 | 13 | 594 | 14 |
| Process tankage | 204 | 7 | 332 | 3 | 325 | 6 | 386 | 7 |

[1] Single spring application

first at the beginning of the season, but its rank decreased through the summer and it had dropped to thirteenth in the September ratings. Ammonium sulfate, at 3.75 and 6.75 pounds of nitrogen in 1957 and at 6.75 pounds in 1958, ranked sixth or better at the first count. However, disease increased through the season until these treatments ranked eleventh or poorer at the close of both seasons.

Laboratory Tests on the effect of nitrogen carriers on disease incidence.

When activated sewage sludge was added to potato dextrose agar, *Stemphylium* sp. and *Helminthosporium carbonum* were inhibited but *Curvularia* sp. was stimulated, as measured by diameter of the colonies (Table 4). After six days of incubation at room temperature, the addition of unmodified sewage sludge reduced the growth of *Helminthosporium carbonum* 15% and *Stemphylium* sp. 19% when compared with the check. Growth of *Curvularia* sp. was 128% of the check. The extract of activated sewage sludge inhibited growth of *Helminthosporium carbonum* 8% and *Stemphylium* sp. 54%. The growth inhibition of *Stemphylium* sp. was the only significant effect produced by the extract.

Differences were noted in growth habit and sporulation. The addition of unmodified activated sewage sludge induced *Curvularia* sp. and *Helminthosporium carbonum* to form a compact mat of

Table 4. The effect of activated sewage sludge added to potato dextrose agar on growth rate of turf pathogens at room temperature in pure culture.

| | Diameter of Colony in cm | | | |
|---|---|---|---|---|
| | Curvularia sp. | Helminthosporium carbonum | Stemphylium sp. | Av. |
| Potato dextrose agar (PDA) | 2.49 | 4.29 | 2.28 | 3.02 |
| PDA + unmodified sewage sludge | 3.18 | 3.62 | 1.85 | 2.88 |
| PDA + extract of act. sew. sludge | 2.60 | 3.95 | 1.05 | 2.54 |
| Average | 2.85 | 3.84 | 1.54 | 2.74 |

prostrate mycelium with a lighter colored cotton-like aerial growth (Figure I). Both of these organisms showed a thin, light-colored growth when treated with the extract of sewage sludge. Stemphylium sp. showed a higher proportion of aerial growth with both sewage sludge treatments.

Helminthosporium carbonum appeared to produce the most spores on potato dextrose agar, less with addition of unmodified activated sewage sludge, and least with the extract of activated sewage sludge. Most spores of Curvularia sp. were found with the addition of unmodified activated sewage sludge. The unmodified potato dextrose agar and the extract of activated sewage sludge produced fewer spores.

The second laboratory experiment with nitrogen sources was an attempt to improve on the first test by equalizing the nitrogen variable. The several test organisms responded to nitrogen sources differently. Corticium fuciforme produced 48% as much growth in ten days on the ammonium nitrate treated medium as on the potato dextrose agar check. The growth of this organism, with the unmodified activated sewage sludge as the nitrogen source, was 72% of the check (Table 5). The extract of sewage sludge increased growth 7% (not significant).

After 10 days the unmodified activated sewage sludge and the

Figure I. The effect of sewage sludge in potato dextrose agar (PDA) on Helminthosporium carbonum. Top, check PDA; bottom left, PDA plus unmodified sludge; bottom right, PDA plus sludge extract.

Table 5. The effect of culture media with varied nitrogen sources on the growth rate of turfgrass pathogens.

| Organism and treatment | Diameter of colony in cm |
|---|---|
| <u>Corticium fuciforme</u> | |
| Check potato dextrose agar | 2.20 |
| Unmodified act. sew. sludge | 1.58 |
| Extract of activated sew. sludge | 2.35 |
| Ammonium nitrate | 1.05 |
| <u>Fusarium nivale</u> | |
| Check potato dextrose agar | 6.35 |
| Unmodified act. sew. sludge | 6.63 |
| Extract of activated sew. sludge | 7.10 |
| Ammonium nitrate | 2.25 |
| <u>Sclerotinia homoeocarpa</u> | |
| Check potato dextrose agar | 4.60 |
| Unmodified act. sew. sludge | 4.68 |
| Extract of activated sew. sludge | 2.95 |
| Ammonium nitrate | Trace |

extract of activated sewage sludge increased the growth of Fusarium nivale 4% and 12%, respectively, as compared to the potato dextrose check. The latter value differed significantly. Media containing ammonium nitrate gave 60% as much growth as produced on the check.

As a nitrogen source, unmodified sewage sludge had little effect on Sclerotinia homoeocarpa for the first 10 days (Table 5), as compared with potato dextrose agar. The extract of sewage sludge reduced growth of this organism to 64% of the check. Ammonium nitrate prevented new growth the first few weeks; this severe inhibition was temporary and by six weeks the colonies were fully as large as those under other treatment and appeared to be covered with large numbers of microsclerotia (Figure II).

Neither preparation of activated sewage sludge affected Curvularia sp. or Helminthosporium carbonum. The growth of these organisms was reduced approximately 50% for six days on ammonium nitrate media. Thereafter the growth became irregular and the main growth was in several radial rays in which the mycelium was limited to a more compact mat on the surface of the substrate rather than the typical ramification throughout the media.

The isolate of Pythium aphanidermatum used in this study is normally a very fast growing and short-lived fungus. It completely covered the area of the petri dish in less than three days regardless

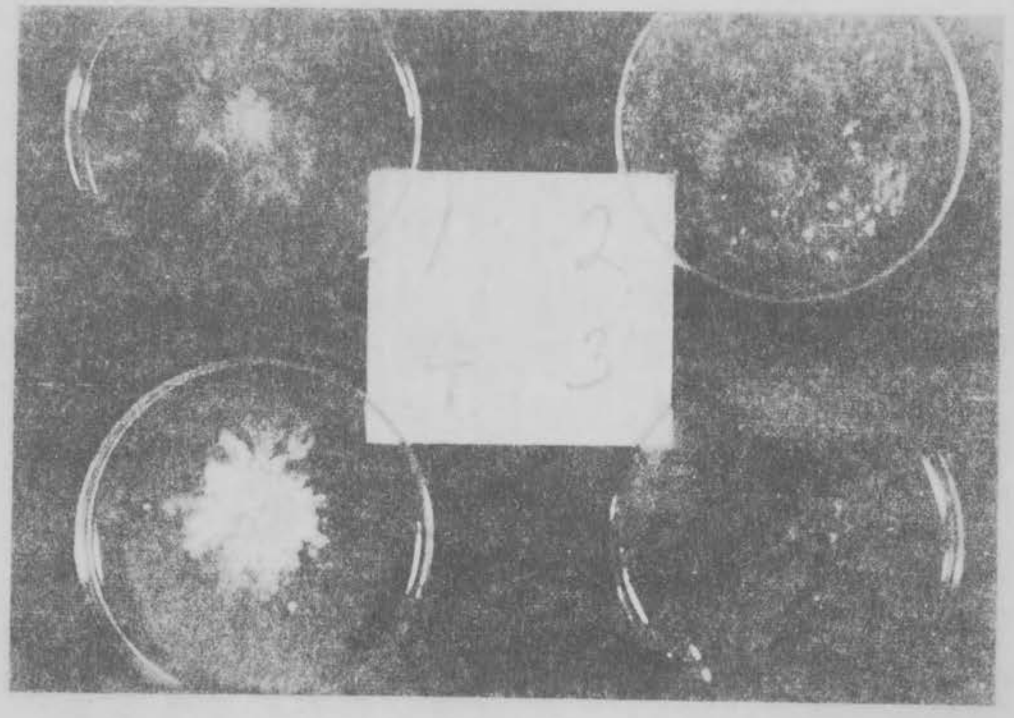


Figure II. The effect of nitrogen source on growth of Sclerotinia homoeocarpa. 1. Potato dextrose agar; 2. Czapek's medium with unmodified activated sewage sludge; 3. Czapek's medium with sludge extract; 4. Czapek's medium with ammonium nitrate. Note the thin growth with either activated sewage sludge media and the very dense growth with ammonium nitrate media.

of nitrogen source (Table 6 and Figure III). Differences were noted in the longevity of this fungus, as indicated by an upright cottony appearance as opposed to a prostrate bacteria-like habit. P. aphanidermatum lived six days when grown on a medium containing nitrogen from activated sewage sludge, four days on the potato dextrose agar check and 14 days on media containing ammonium nitrate.

The growth rate of Rhizoctonia solani was relatively independent of nitrogen source used in the culture media. However, this organism produced an average of 16.2 sclerotia per colony (Table 7) on potato dextrose agar. Approximately twice this quantity was formed on media containing unmodified sewage sludge. The medium containing the extract of sewage sludge produced 75% fewer sclerotia and the medium containing ammonium nitrate produced 12.7 times that of the potato dextrose agar check.

Growth patterns produced by nitrogen carriers in relation to disease incidence.

Growth patterns, of the turf, for the different nitrogen carriers were developed from clipping weights and color ratings. The turfgrass responses to nitrogen carriers varied considerably and there appeared to be a relationship between Sclerotinia homoeocarpa development and pattern of nitrogen response. The approximate dates of new outbreaks of dollarspot in 1957 were June 18, July 30,

Table 6. The effect of culture media with varied nitrogen sources on the longevity of *Pythium aphanidermatum* at room temperature.

| Media | Life in days |
|---|---|
| Check potato dextrose agar | 4 |
| Unmodified activated sewage sludge | 6 |
| Extract of activated sewage sludge | 6 |
| Ammonium nitrate | 14 |

Table 7. The effect of culture media on the formation of sclerotia by *Rhizoctonia solani* at room temperature.

| Media | No. of Sclerotia |
|---|---|
| Check potato dextrose agar | 16 |
| Unmodified activated sewage sludge | 32 |
| Extract of activated sewage sludge | 4 |
| Ammonium nitrate | 206 |

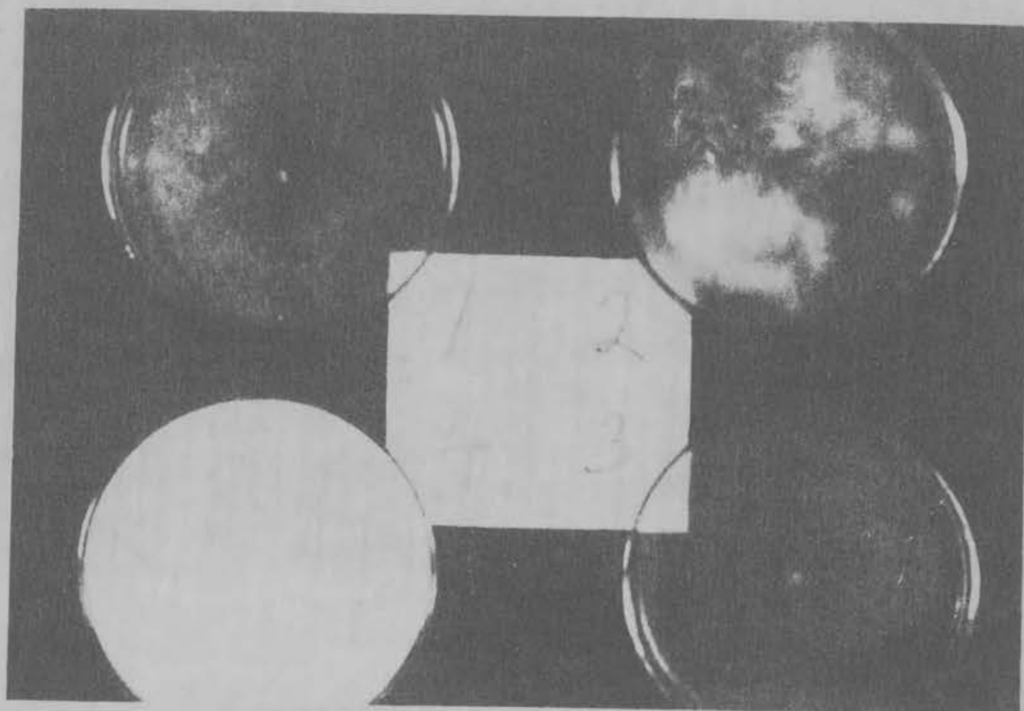

Figure III. The effect of nitrogen source on growth of Pythium aphanidermatum. 1. Potato dextrose agar; 2. Czapek's medium with unmodified activated sewage sludge; 3. Czapek's medium with extract of activated sewage sludge; 4. Czapek's medium with ammonium nitrate. Note that the growth of all cultures covers the entire petri dish, but differences exist in density of growth.

August 20 and October 14. The corresponding dates in 1958 were May 26, July 7, September 12 and September 25 (Tables 2 and 3).

GROWTH PATTERNS WITH 3.75 POUNDS OF NITROGEN: Activated sewage sludge, which had the lowest number of dollarspots of all materials at 3.75 pounds of nitrogen, gave a very uniform color response during the 1957 season (Figure 1). In contrast, ureaform had the highest disease incidence rating and gave a highly variable color response. The June outbreak occurred in a period of declining color response. The dollarspot outbreak of July and August coincided closely with periods of low color response. The 1957 clipping weights showed little variation that could be correlated with disease incidence (Figure 2).

The soluble materials, urea, ammonium nitrate and ammonium sulfate, applied at 3.75 pounds of nitrogen gave color responses that were more cyclic in nature (Figures 1, 3 and 7). Except for the June 18, 1957, outbreak of dollarspot, all attacks were associated with periods of declining or minimum color response (Figure 3). Also, clipping weights indicated a correlation of dollarspot incidence with reduced growth from ammonium nitrate in July and August, and from ammonium sulfate in August (Figure 4).

In 1958, there was less uniformity of color response than in 1957 from activated sewage sludge and a closer relationship between

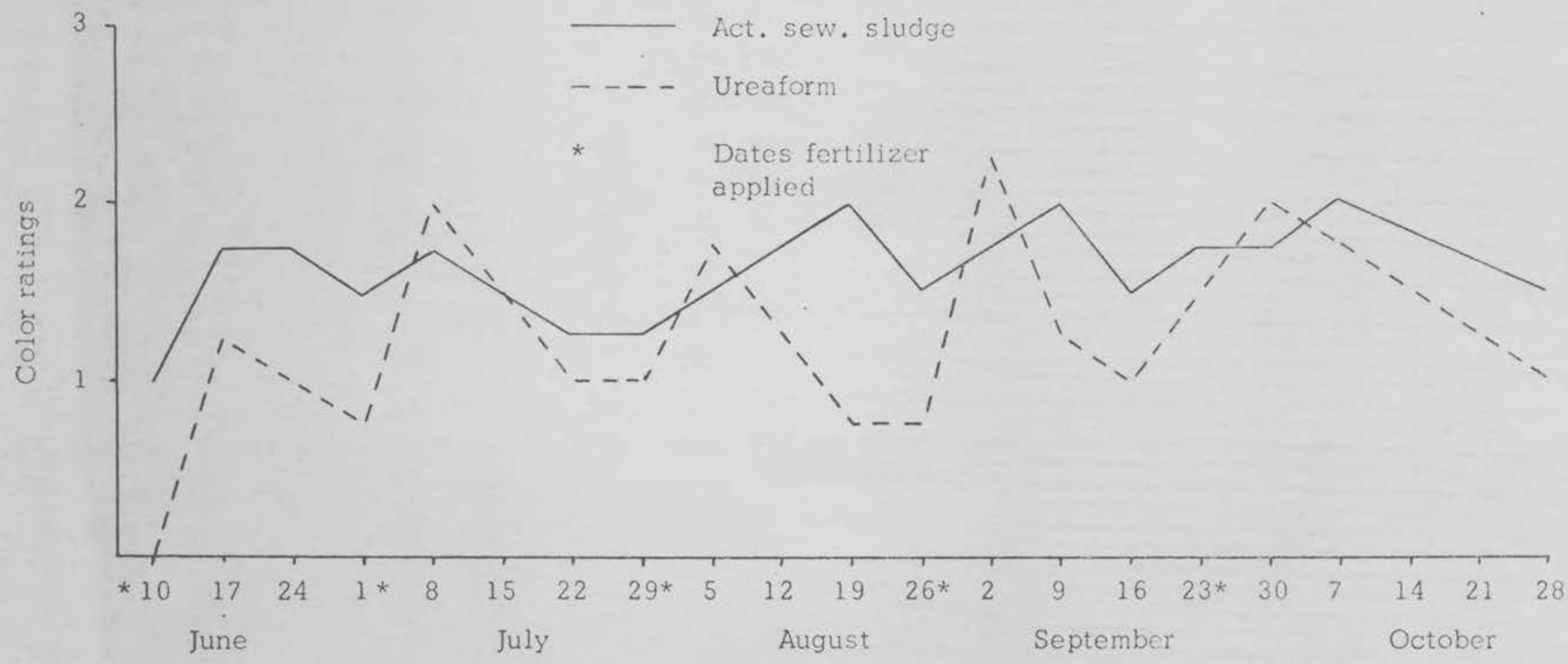


Figure 1. Color ratings of 1/4 inch bentgrass turf fertilized with two different insoluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

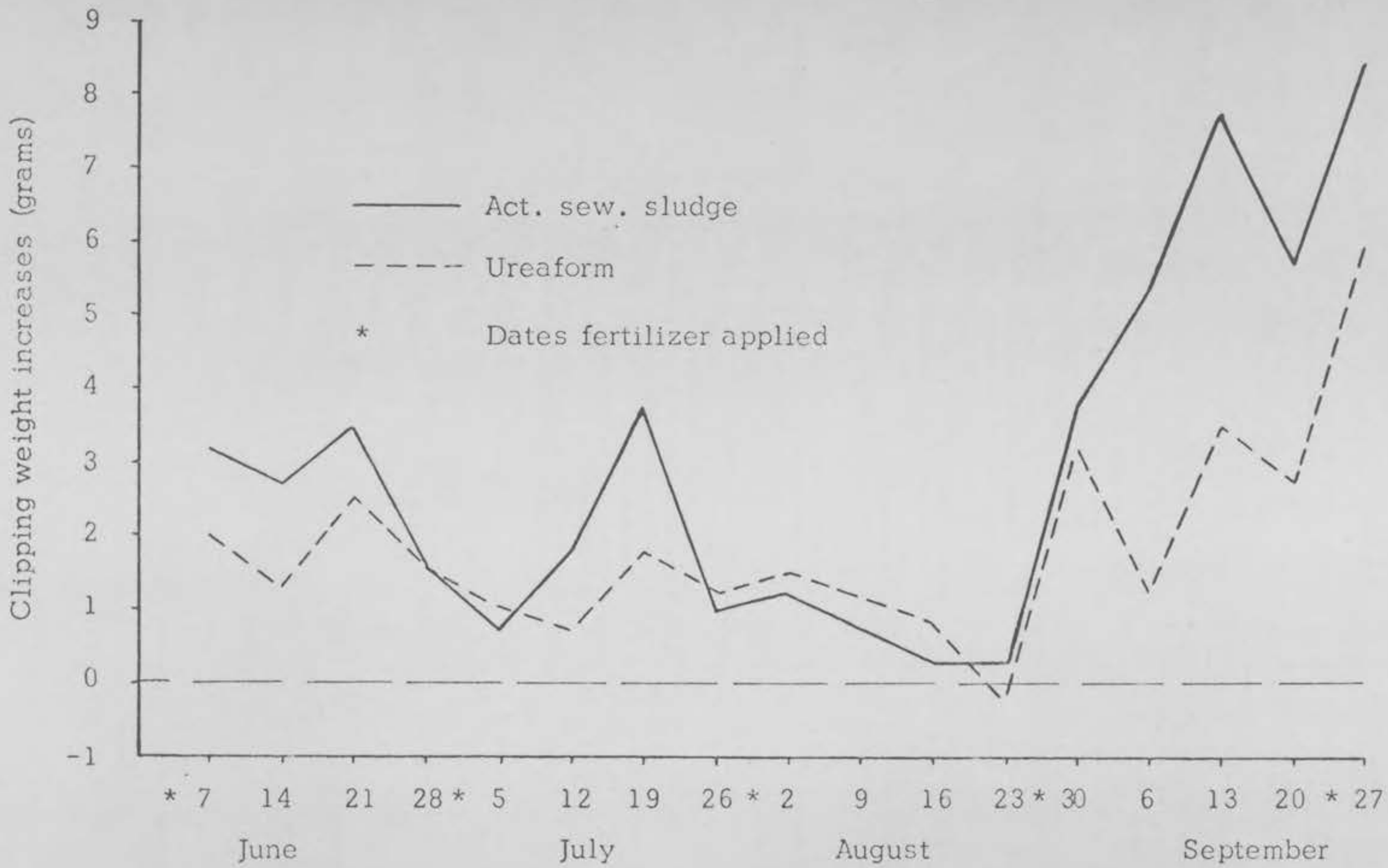


Figure 2. Clipping weight increases over check from two different insoluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1957.

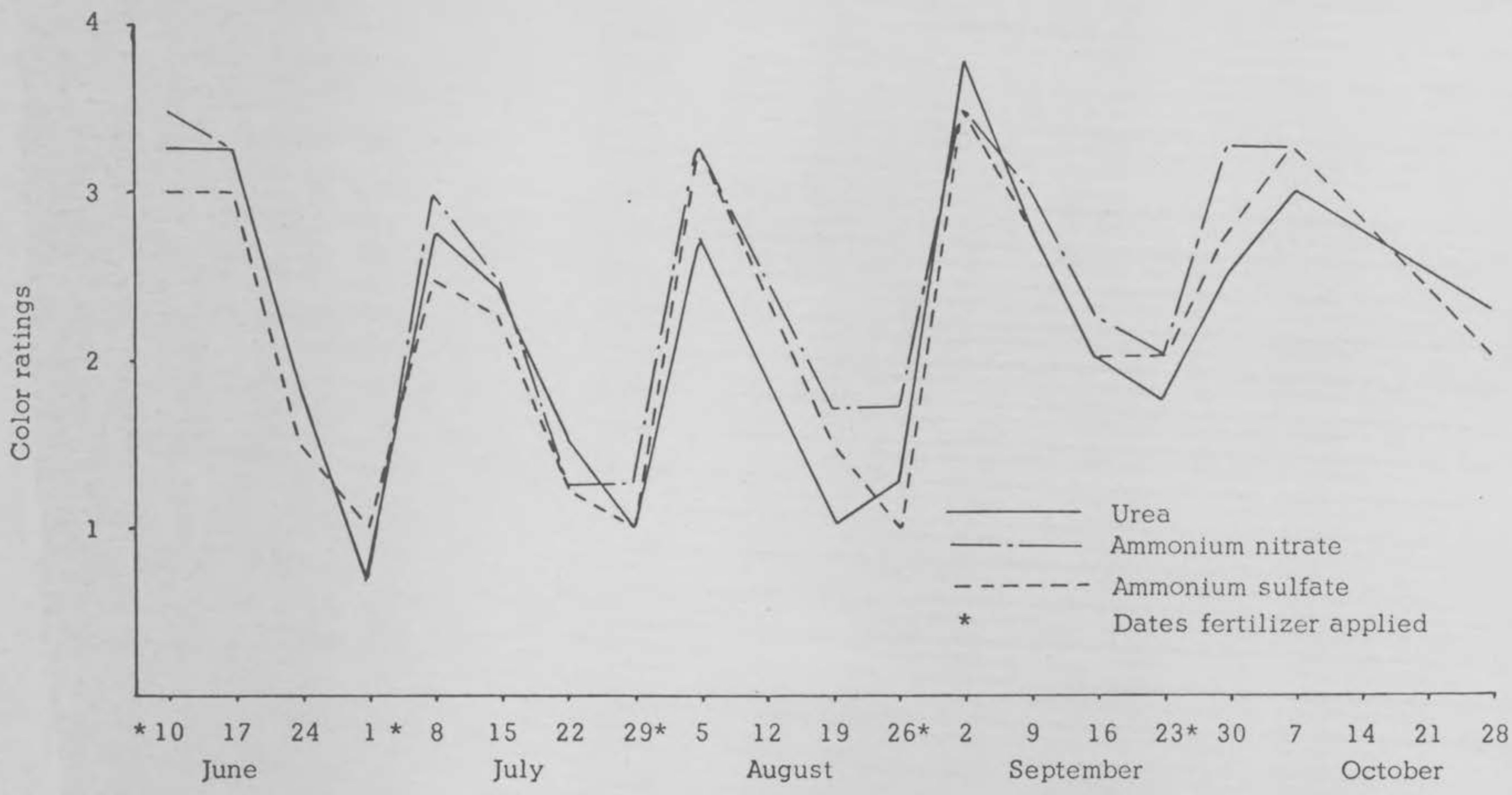


Figure 3. Color ratings of 1/4 inch bentgrass turf fertilized with three different soluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

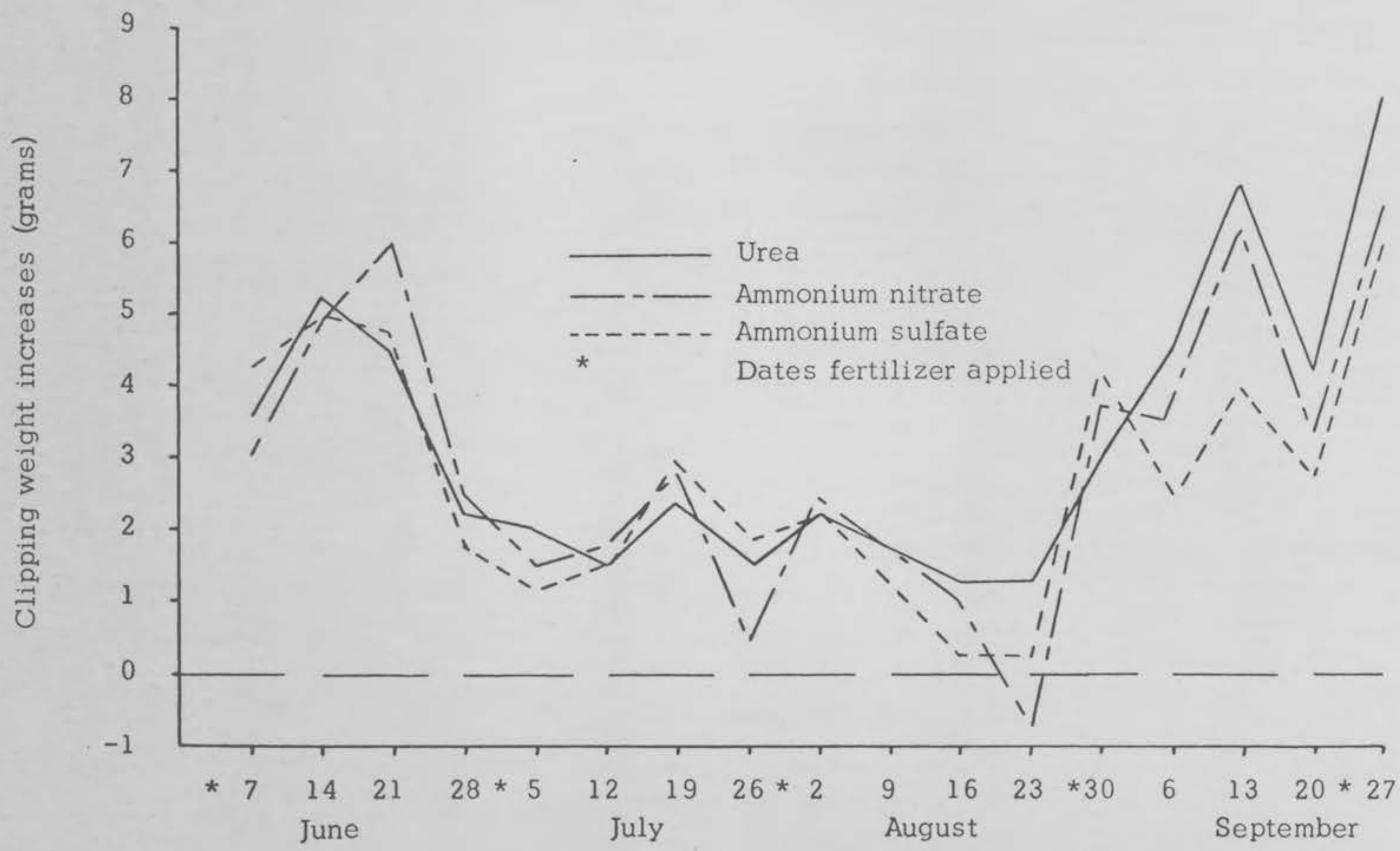


Figure 4. Clipping weight increases over check from three different soluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1957.

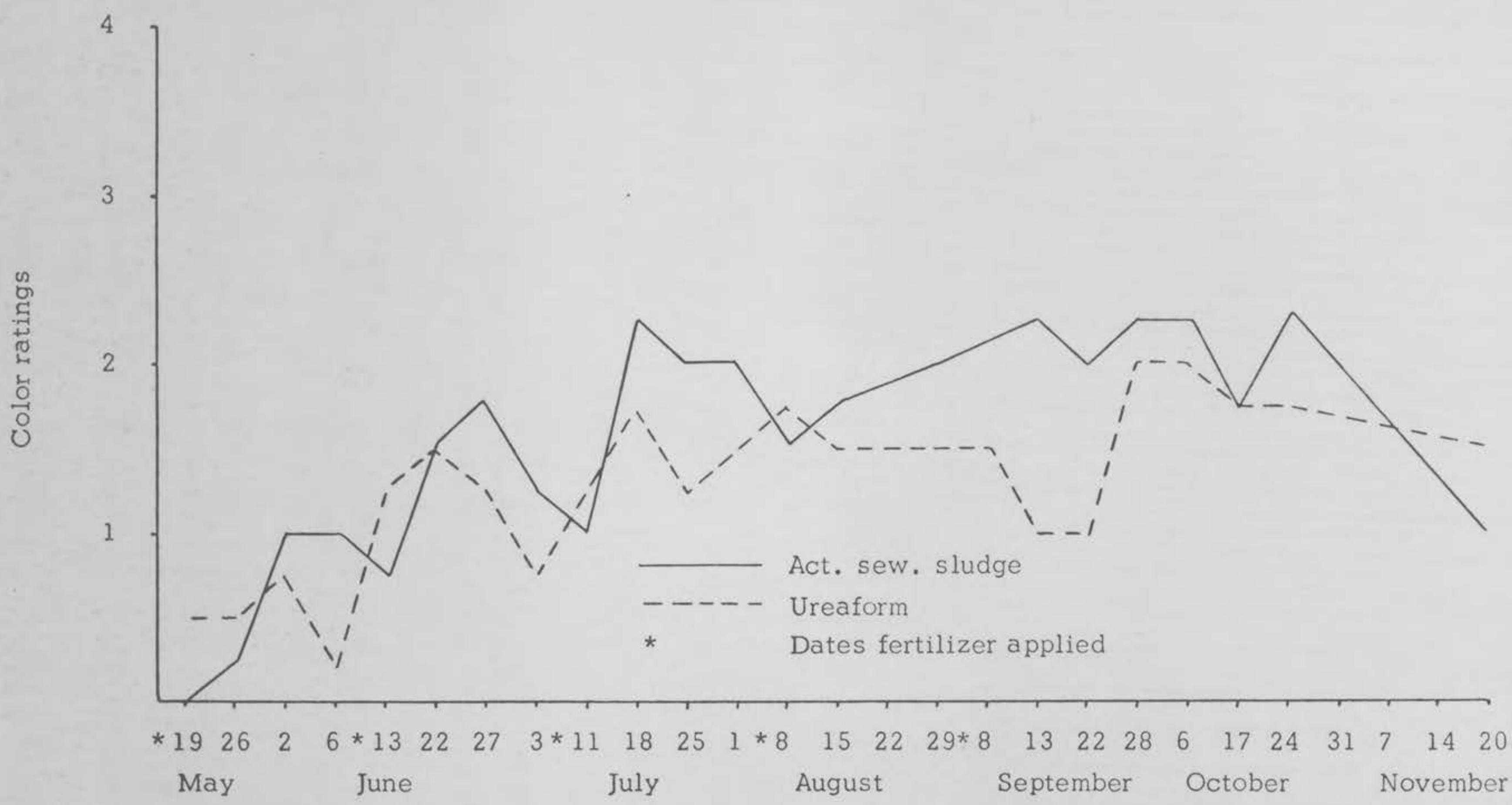


Figure 5. Color ratings of 1/4 inch bentgrass turf fertilized with two different insoluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1958.

low response periods and disease occurrence (Figure 5); this was most noticeable in May, July and September. The variation in color response from ureaform and the association between disease and low color response were greater than for activated sewage sludge. Again, activated sewage sludge rated considerably better in inhibition of disease than ureaform. There was little variation in clipping weights in 1958 that could be correlated with disease incidence (Figure 6).

The outbreak of dollarspot of May 26 and the outbreak of July 7, 1958, appear to be correlated with low color response from the soluble carriers (Figure 7). There was little difference among the three soluble carriers in May, June and early July in color response, clipping weights or disease incidence. In September, the color and clipping weight responses to ammonium sulfate had declined (Figures 7 and 8); this was accompanied by an increase in dollarspot incidence. Urea gave the best color response during this period and showed 17% and 39% less disease than ammonium nitrate and ammonium sulfate, respectively. The increased color response from urea over ammonium sulfate in September was reflected in increased clipping weights.

GROWTH PATTERNS WITH 6.75 POUNDS OF NITROGEN: The color response at 6.75 pounds of nitrogen was more uniform than at 3.75 pounds; this is explained by the respective two and four-week

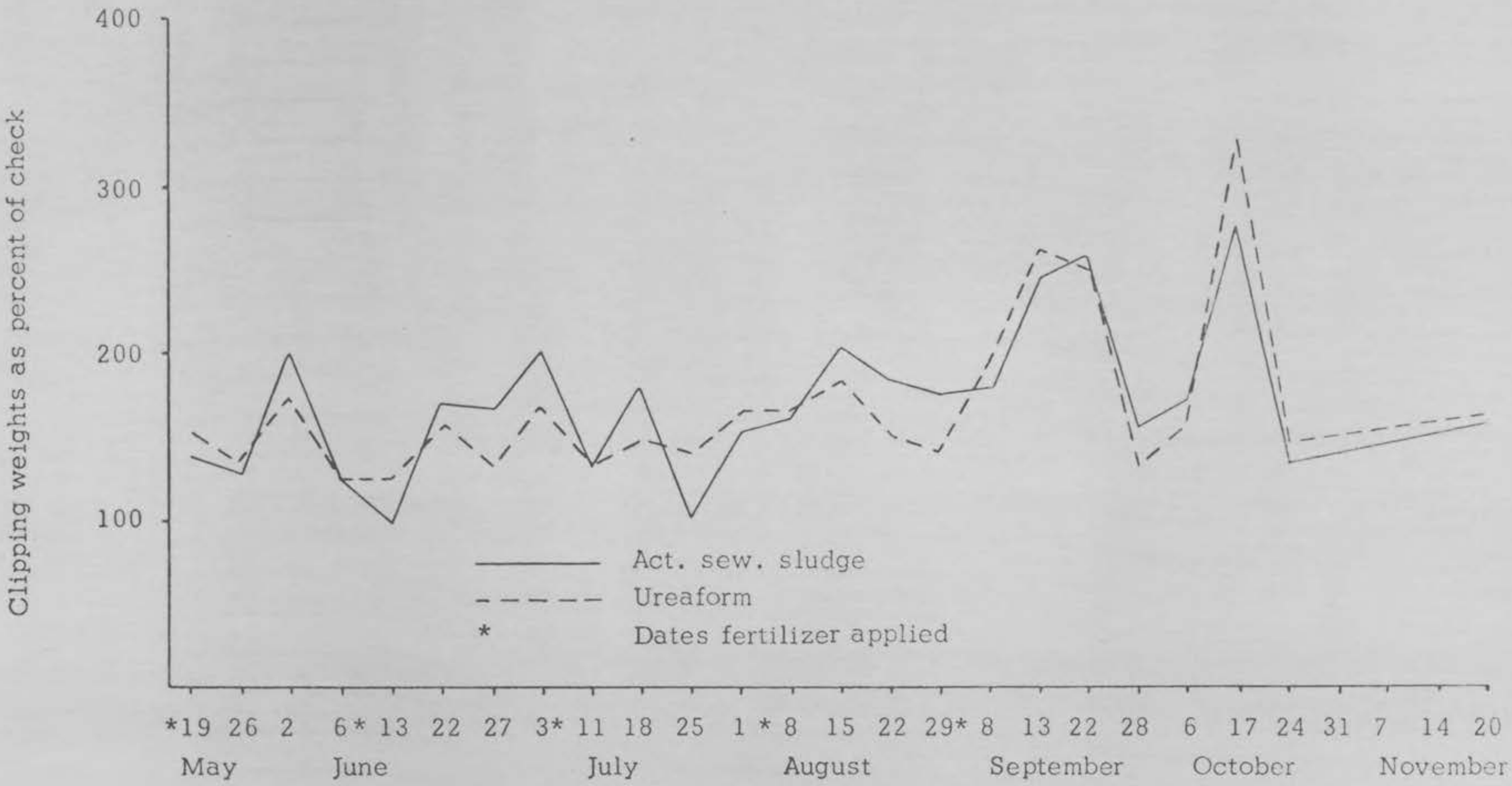


Figure 6. Clipping weights, as percent of check, from two different insoluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1958.

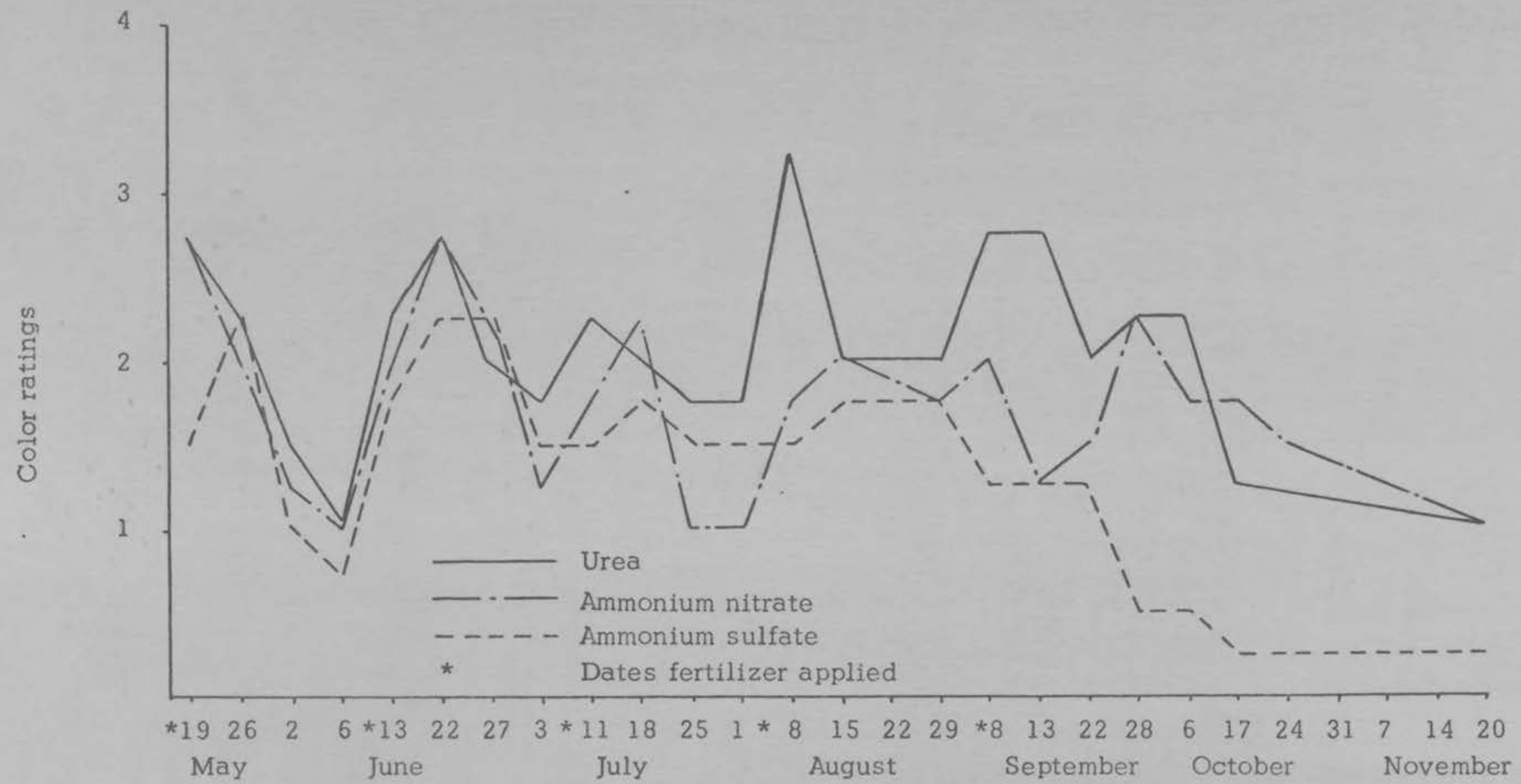


Figure 7. Color ratings of 1/4 inch bentgrass turf fertilized with three different soluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1958.

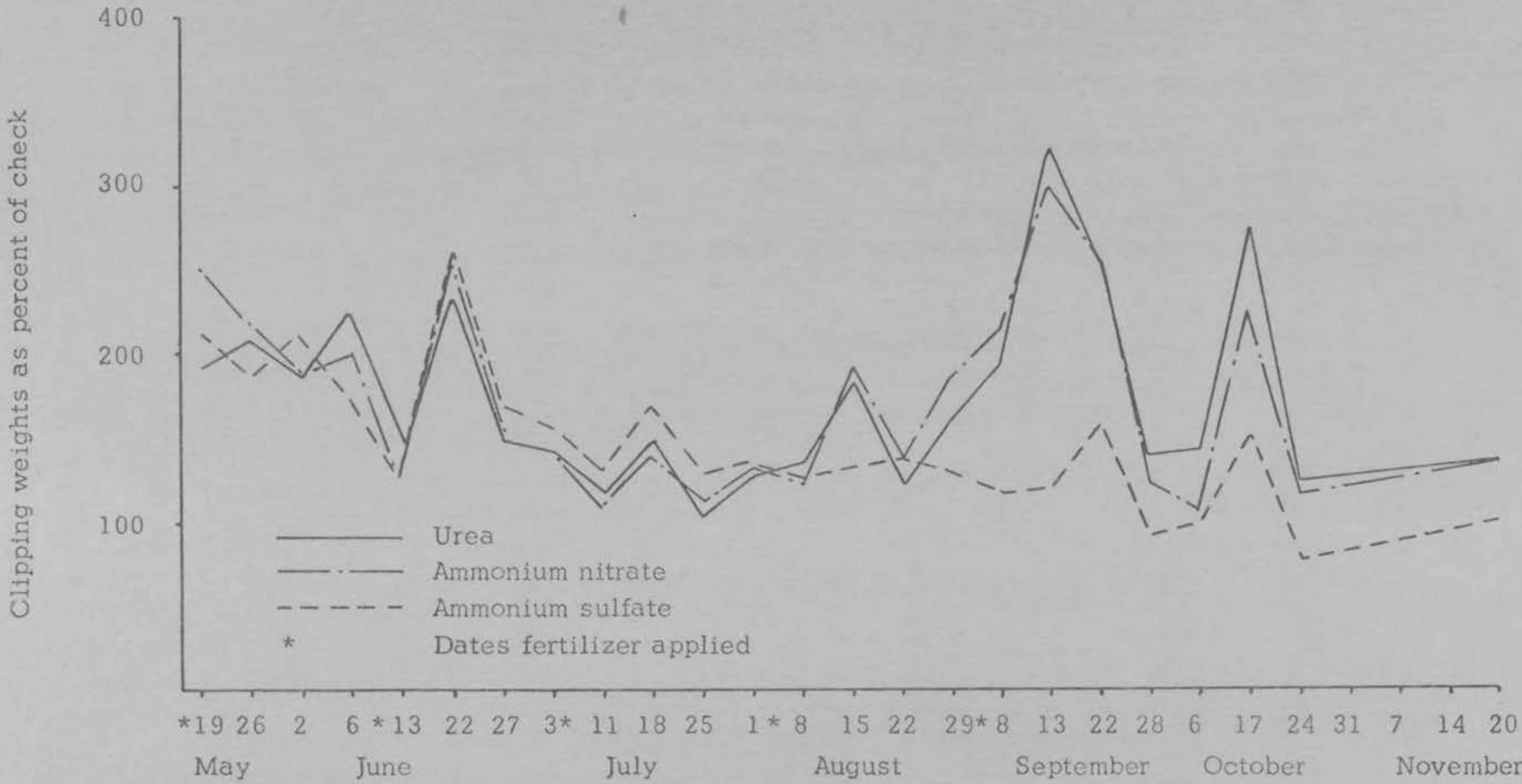


Figure 8. Clipping weights, as percent of check, from three different soluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1958.

intervals of application. Activated sewage sludge generally had a slight advantage over ureaform in stimulation of color, but a greater advantage in disease control (Figure 9). Process tankage consistently gave good uniformity of color response, but it was poorest in color stimulation. Its dollarspot readings compared with those of ureaform. The clipping weight responses from the insoluble carriers were similar at the times of dollarspot attacks and offer no apparent explanation for differences in disease incidence (Figure 10). No dollarspot data were available later in the season when clipping weights differed.

Urea consistently resulted in lower disease reading than any of the soluble carriers and the highest color response in 1957. The latter response had good uniformity (Figure 11) and showed no variation that could be correlated with disease. The clipping weight responses from the three soluble carriers were similar throughout the 1957 season (Figure 12) and cannot be used to explain the lower disease readings of urea. There was an indication that disease incidence from the soluble carriers was correlated with low growth in July and August.

Except for less uniformity, the clipping weight and color responses to the insoluble carriers in 1958 were similar to those of 1957 (Figures 13 and 14). During the 1958 season, periods of low

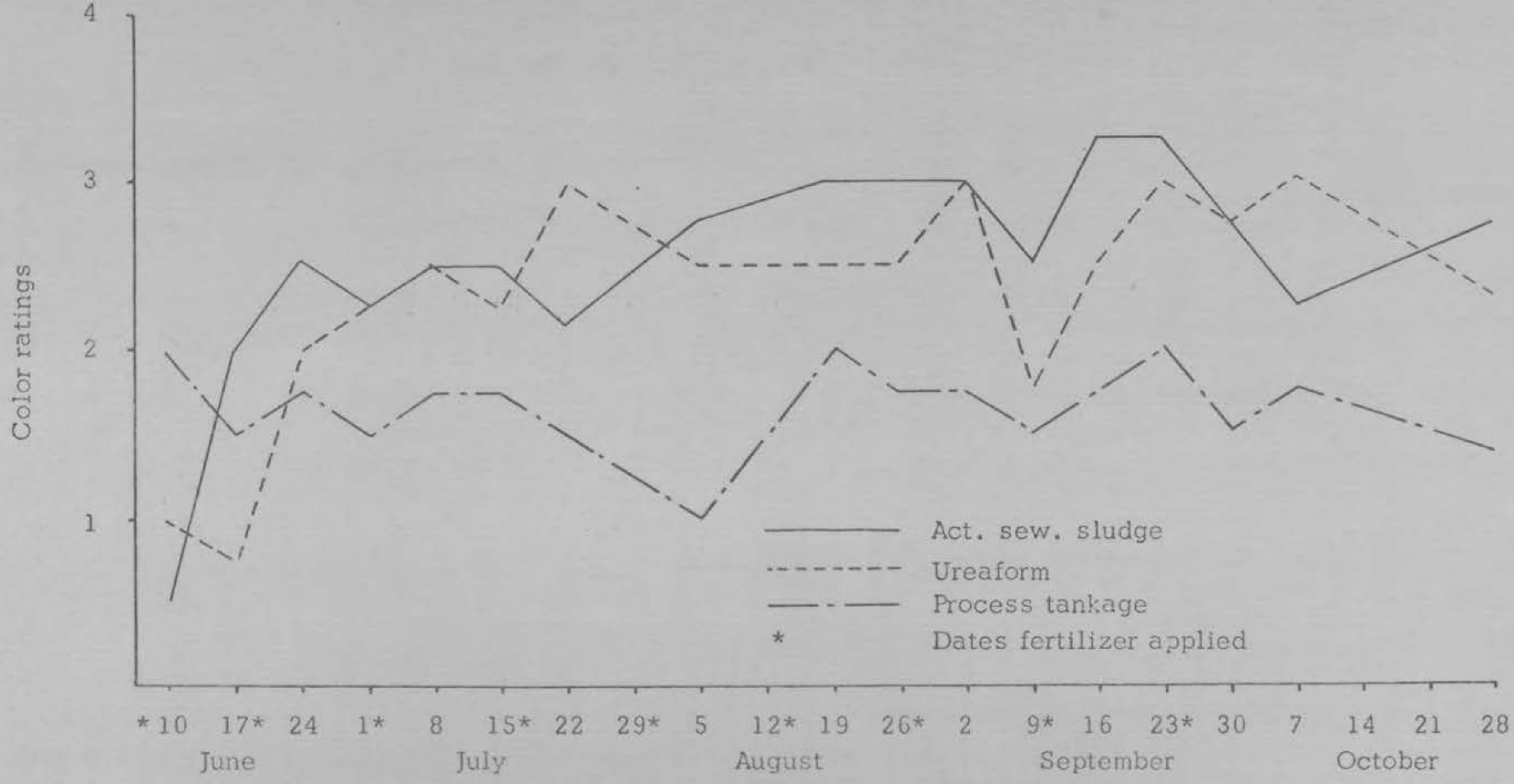


Figure 9. Color ratings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

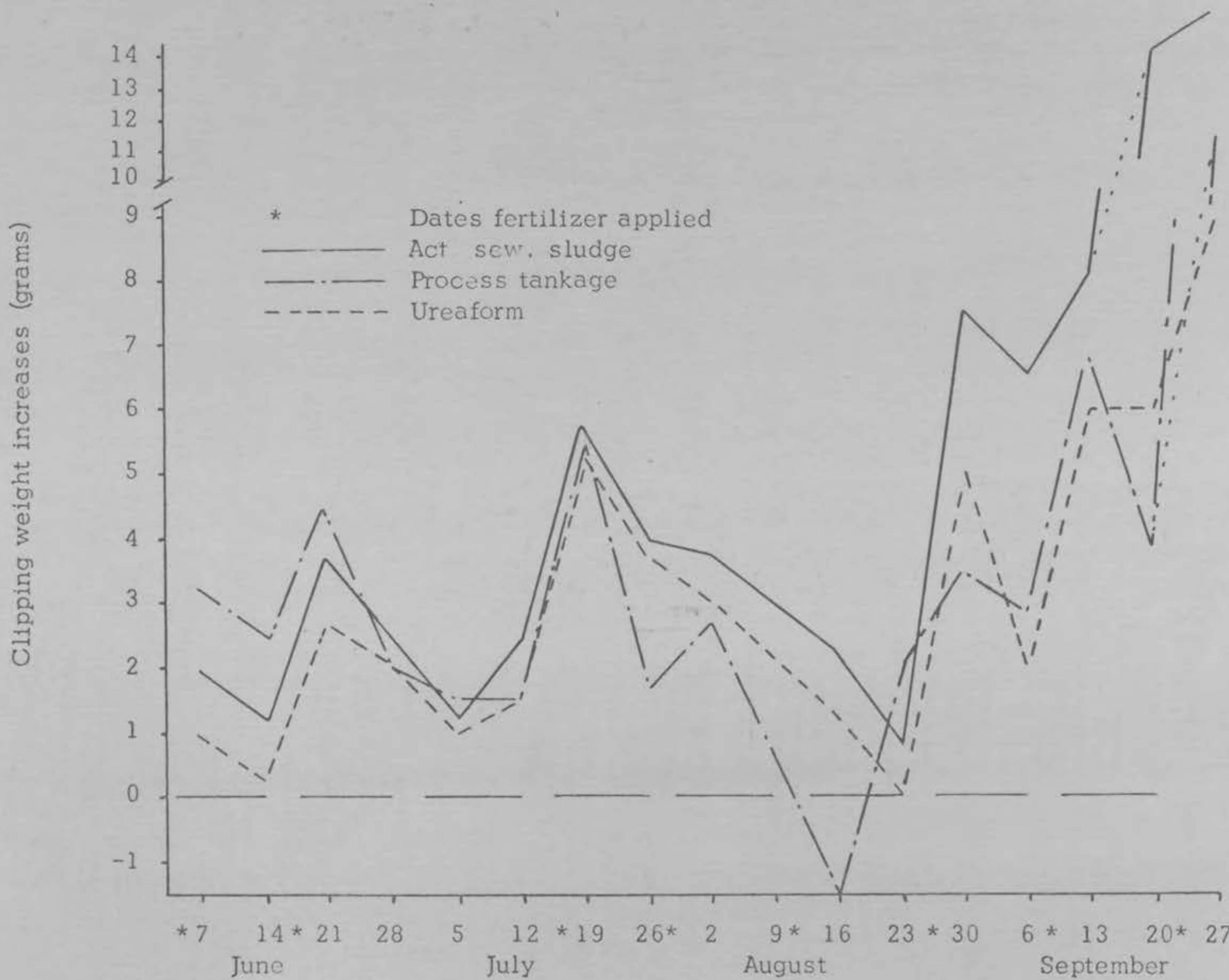


Figure 10. Clipping weight increases over check from three different insoluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1957.

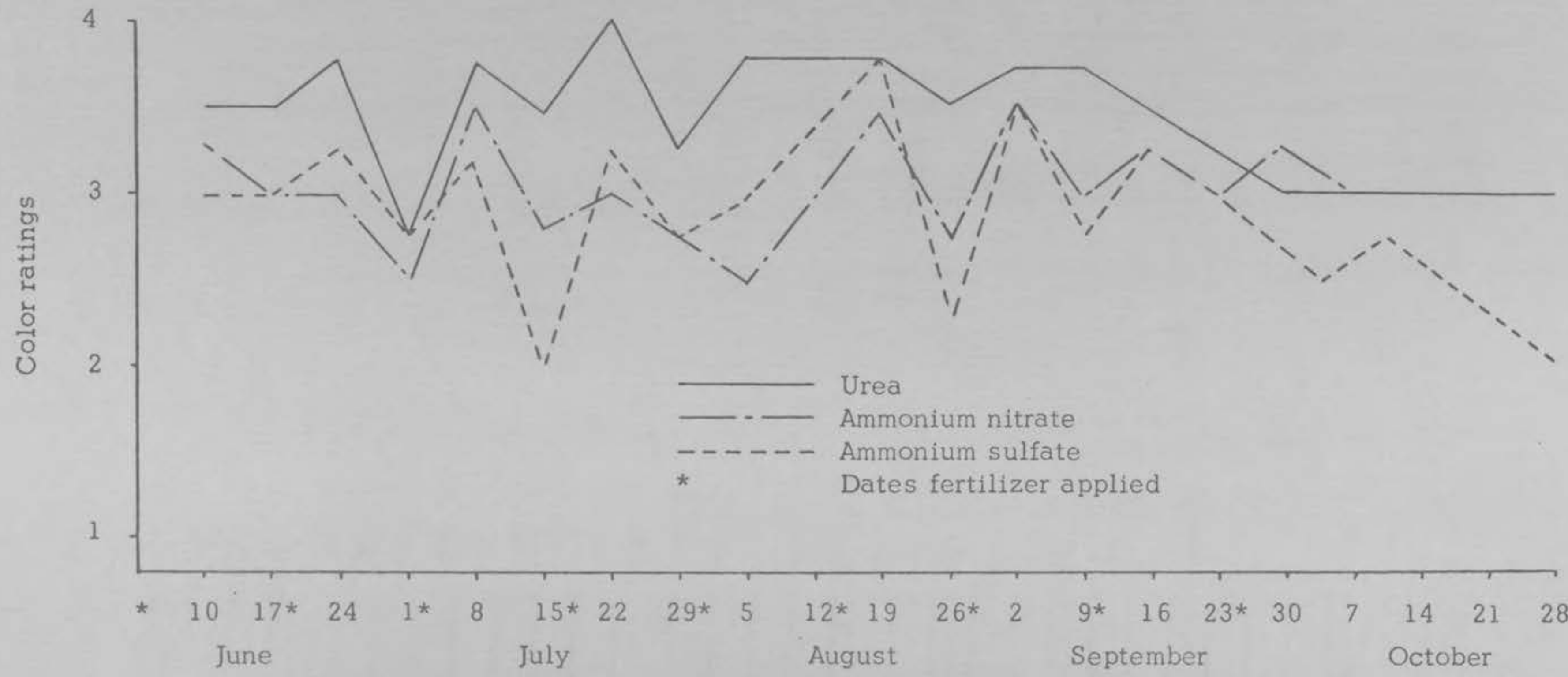


Figure 11. Color ratings of 1/4 inch bentgrass turf fertilized with three different soluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

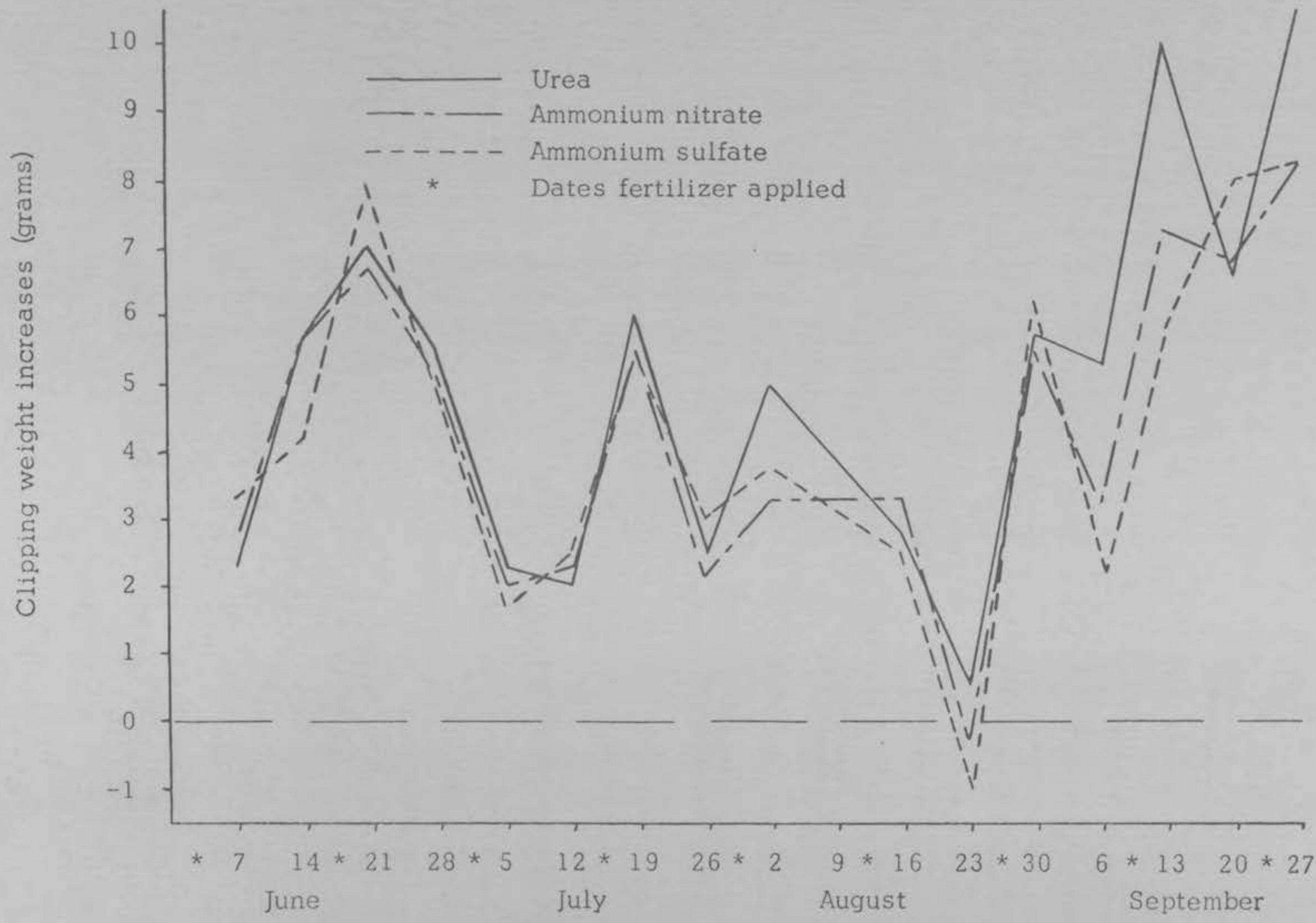


Figure 12. Clipping weight increases over check from three different soluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1957.

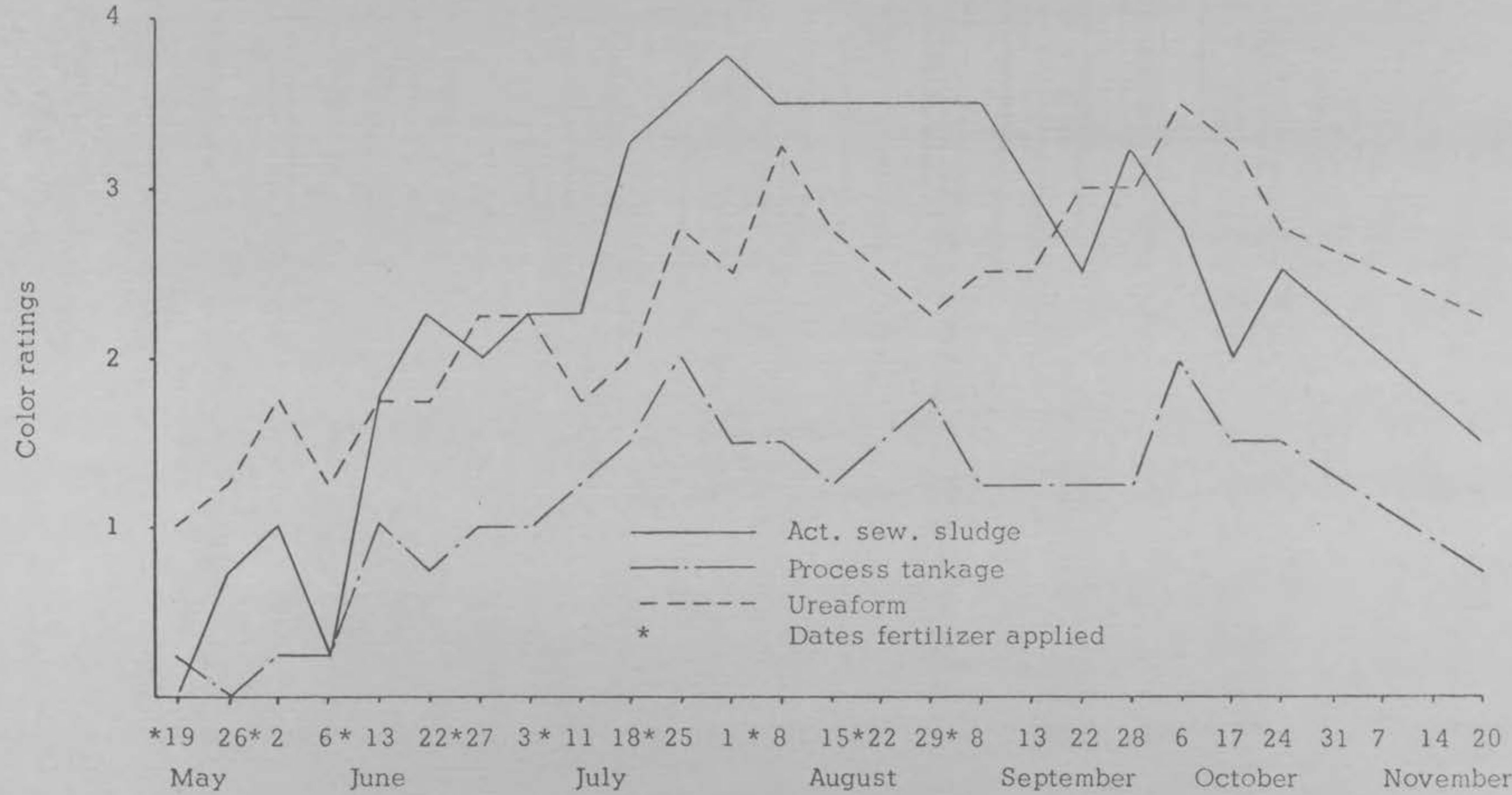


Figure 13. Color ratings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1958.

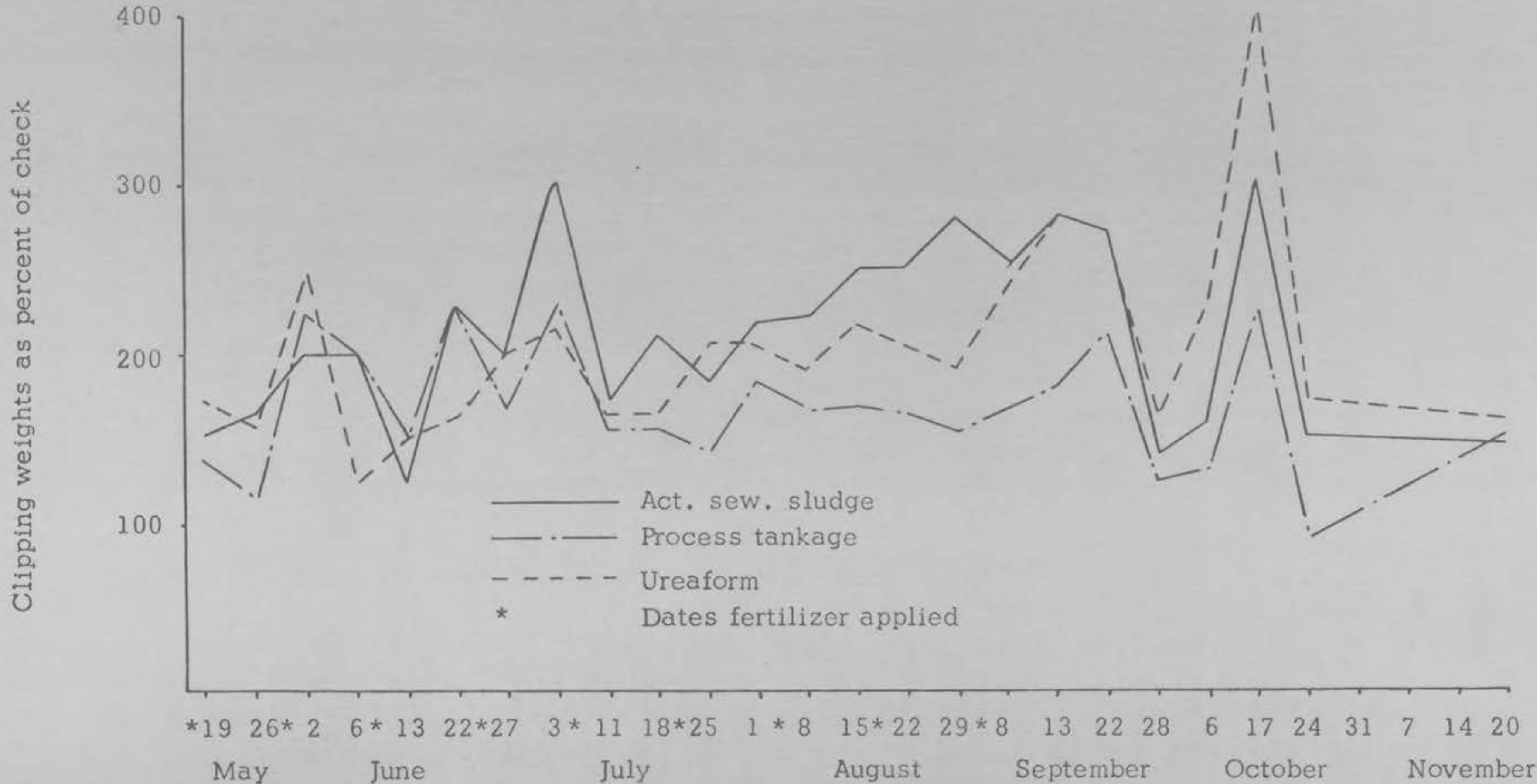


Figure 14. Clipping weights, as percent of check, from three different insoluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1958.

clipping weight response appeared to be associated with dollarspot outbreaks in May, July and late September with all three materials. Both color and clipping weight responses from ammonium sulfate declined as the season progressed (Figures 15 and 16). However, ammonium sulfate treatments did not show a proportionate increase in disease.

GROWTH PATTERNS WITH 11.25 POUNDS OF NITROGEN: The insoluble carriers, activated sewage sludge, process tankage and ureaform, gave among the most uniform color responses and lowest dollarspot readings when applied at two-week intervals to give a total of 11.25 pounds of nitrogen (Figures 17 and 19). As indicated at the lower levels of nitrogen fertility, there was more variation in clipping weights than in color response (Figures 18 and 20).

In 1957, three periods of low clipping response occurred; they were July 5 to 12, July 26, and August 23. Those of late July and August appear to have some correlation with dollarspot outbreaks. Low response periods of 1958 were not as pronounced as in 1957. However, there were periods of declining growth, in July and September, which appear to be associated with disease incidence.

Activated sewage sludge generally gave the best color response and high, moderately uniform clipping weights after the first

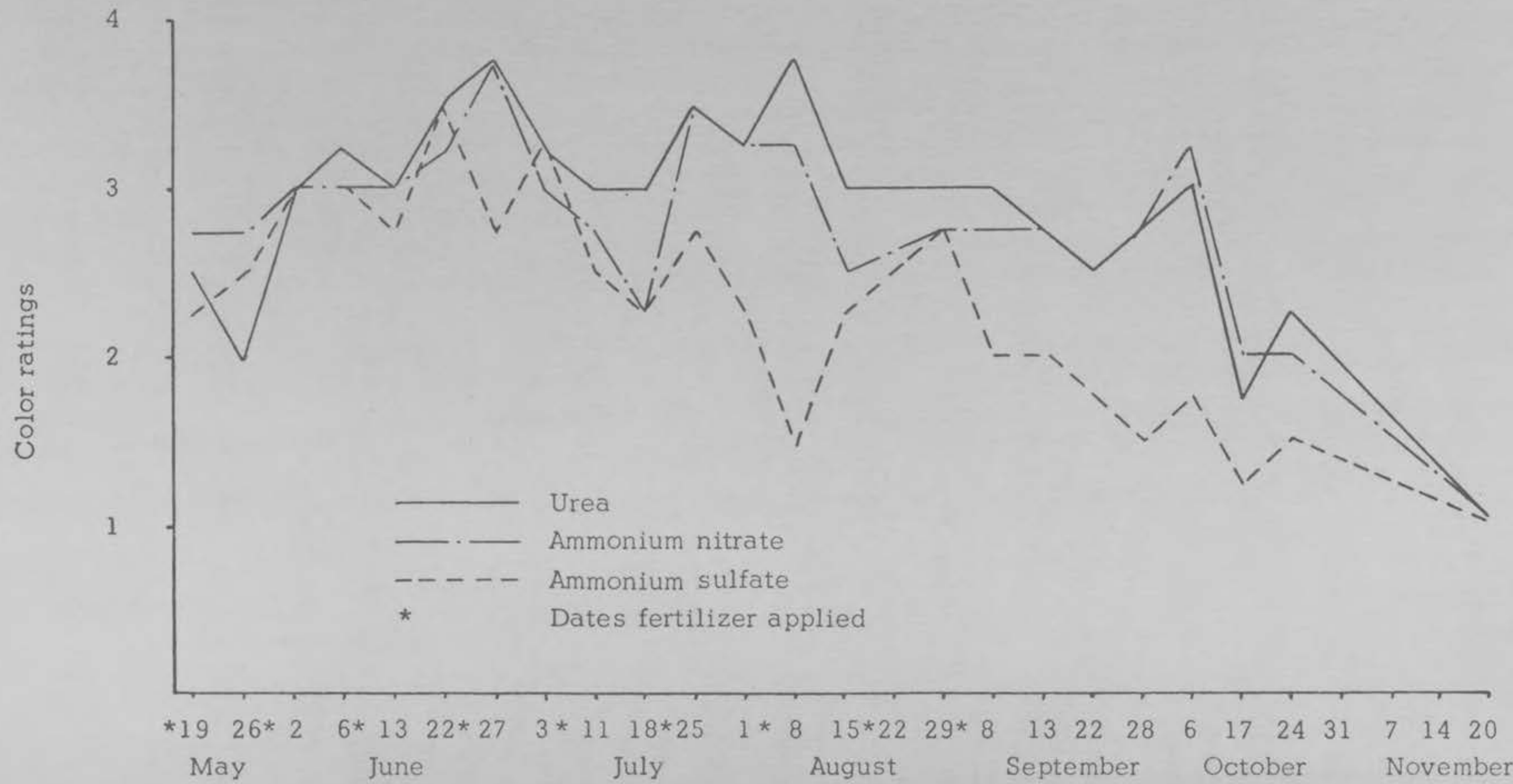


Figure 15. Color ratings of 1/4 inch bentgrass turf fertilized with three different soluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1958.

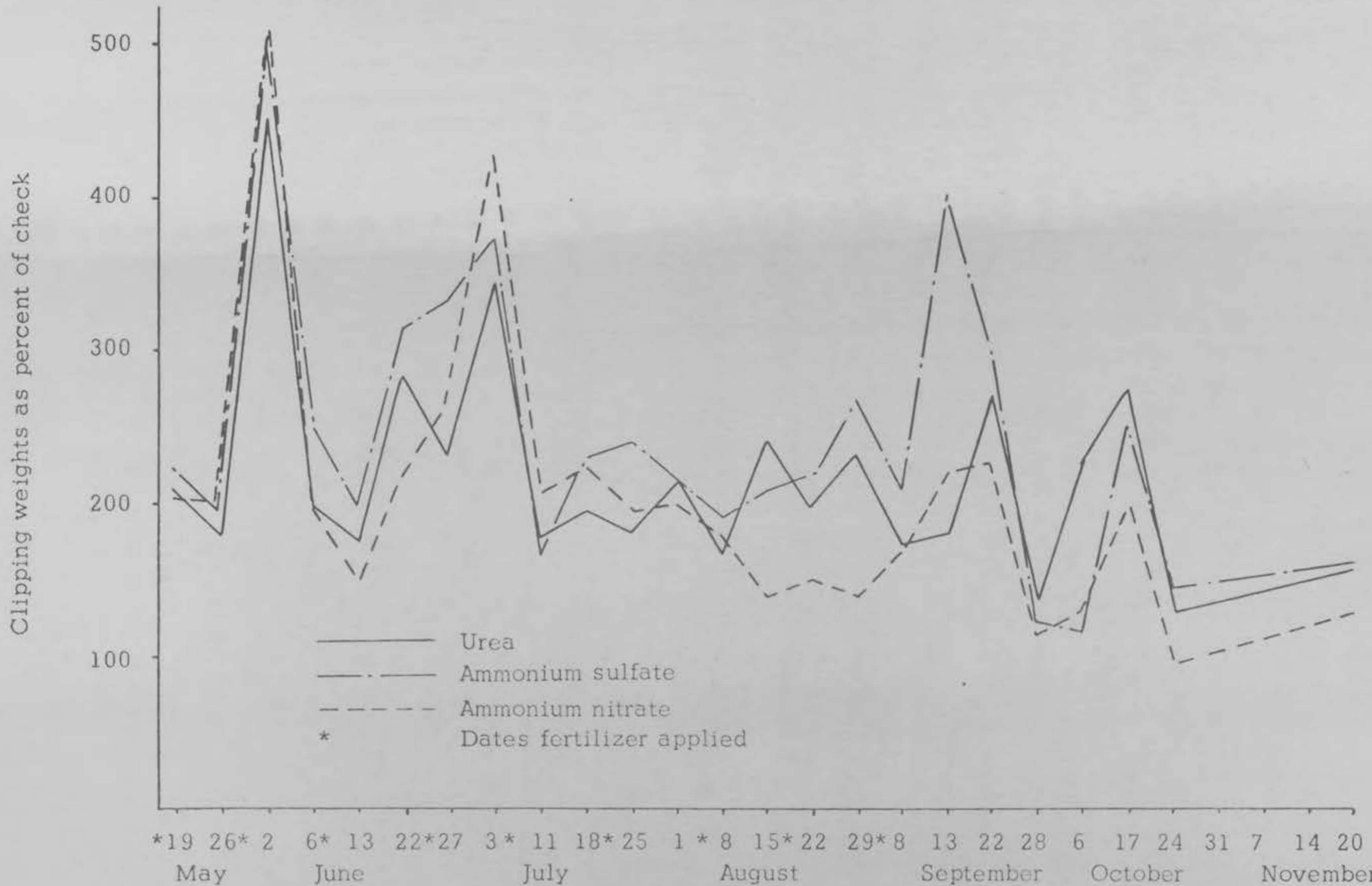


Figure 16. Clipping weights, as percent of check, from three different soluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1958.

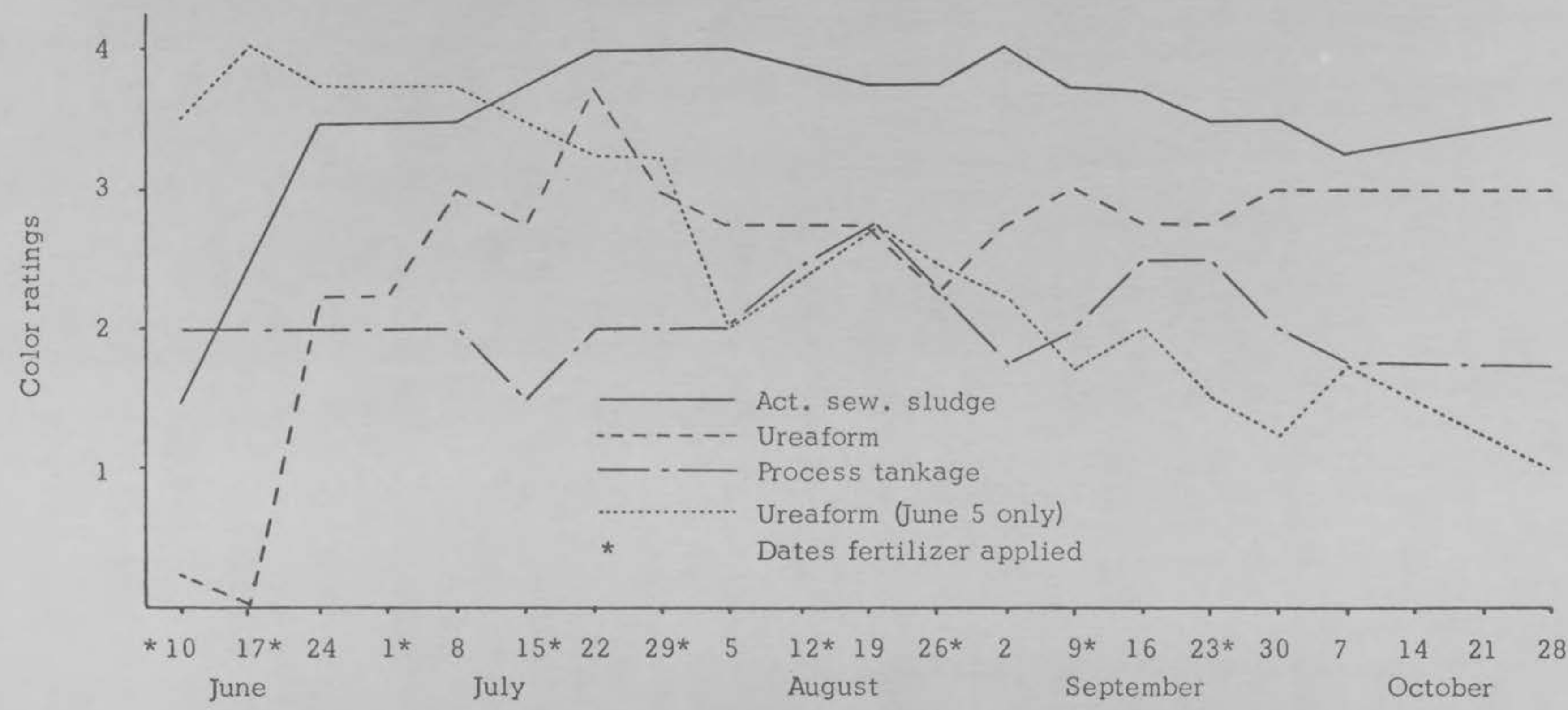


Figure 17. Color ratings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 11-1/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

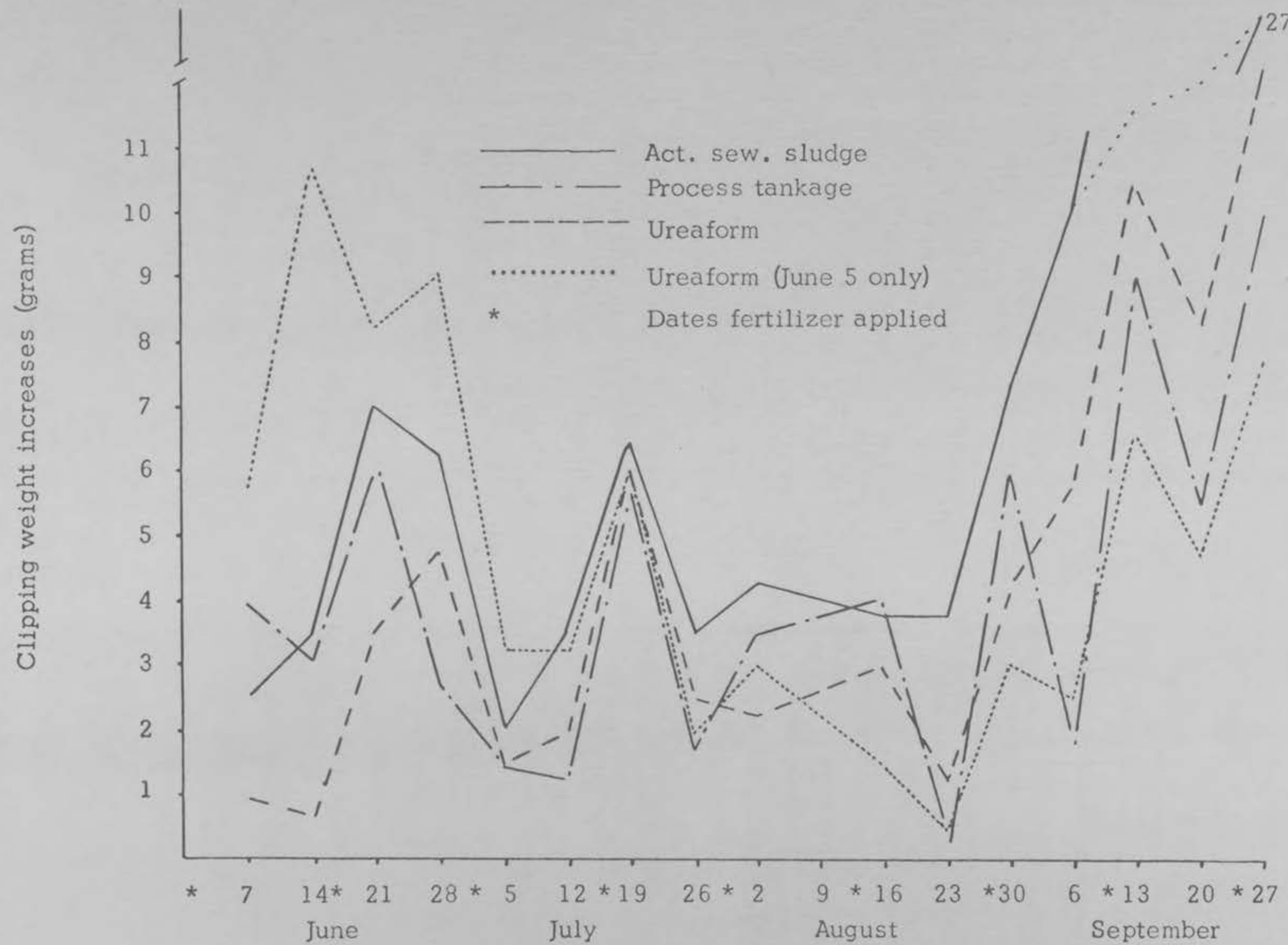


Figure 18. Clipping weight increases over check from three different insoluble nitrogen sources at 11-1/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch creeping bentgrass turf. New Brunswick, New Jersey, 1957.

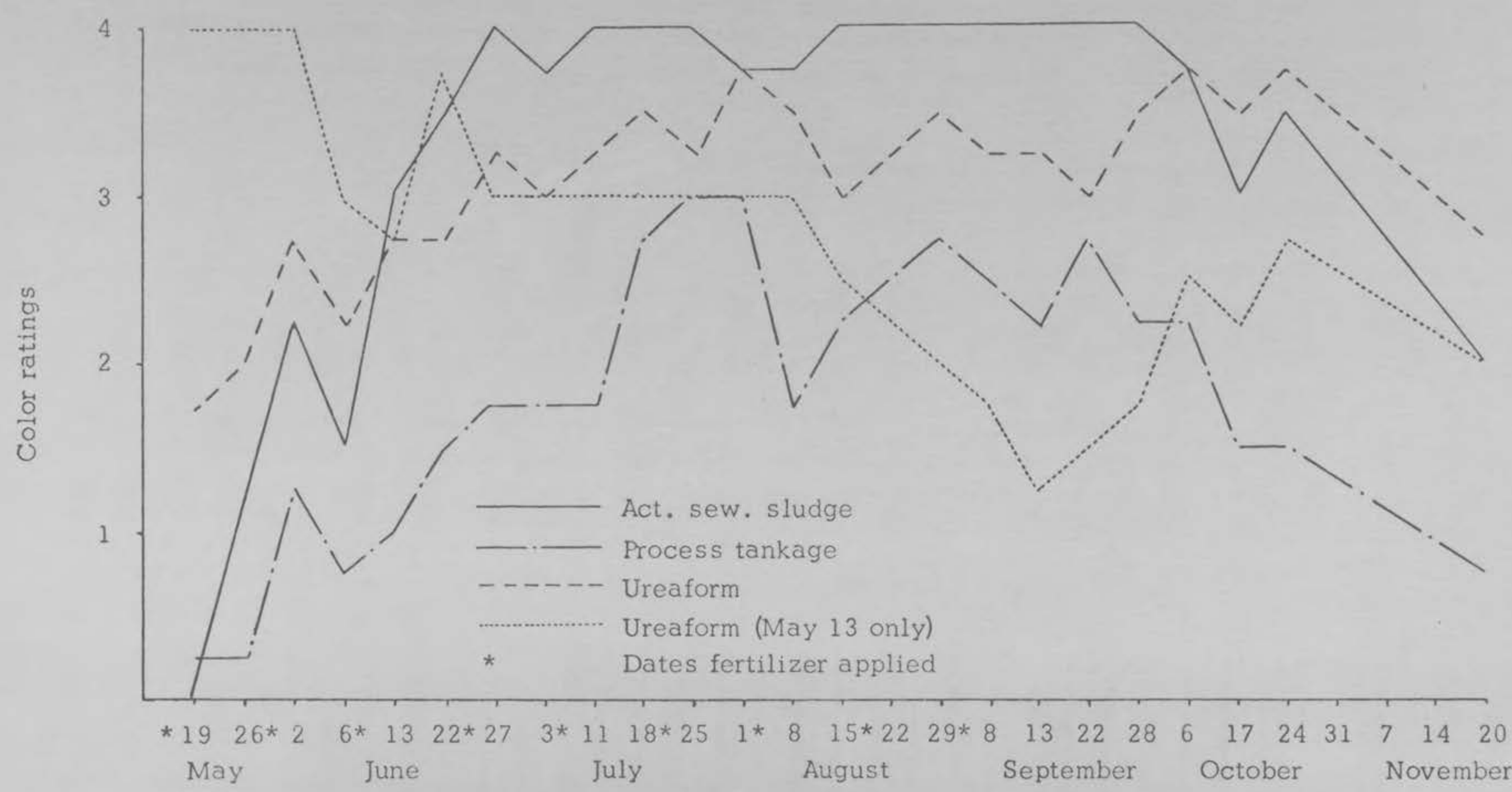


Figure 19. Color ratings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 11-1/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1958.

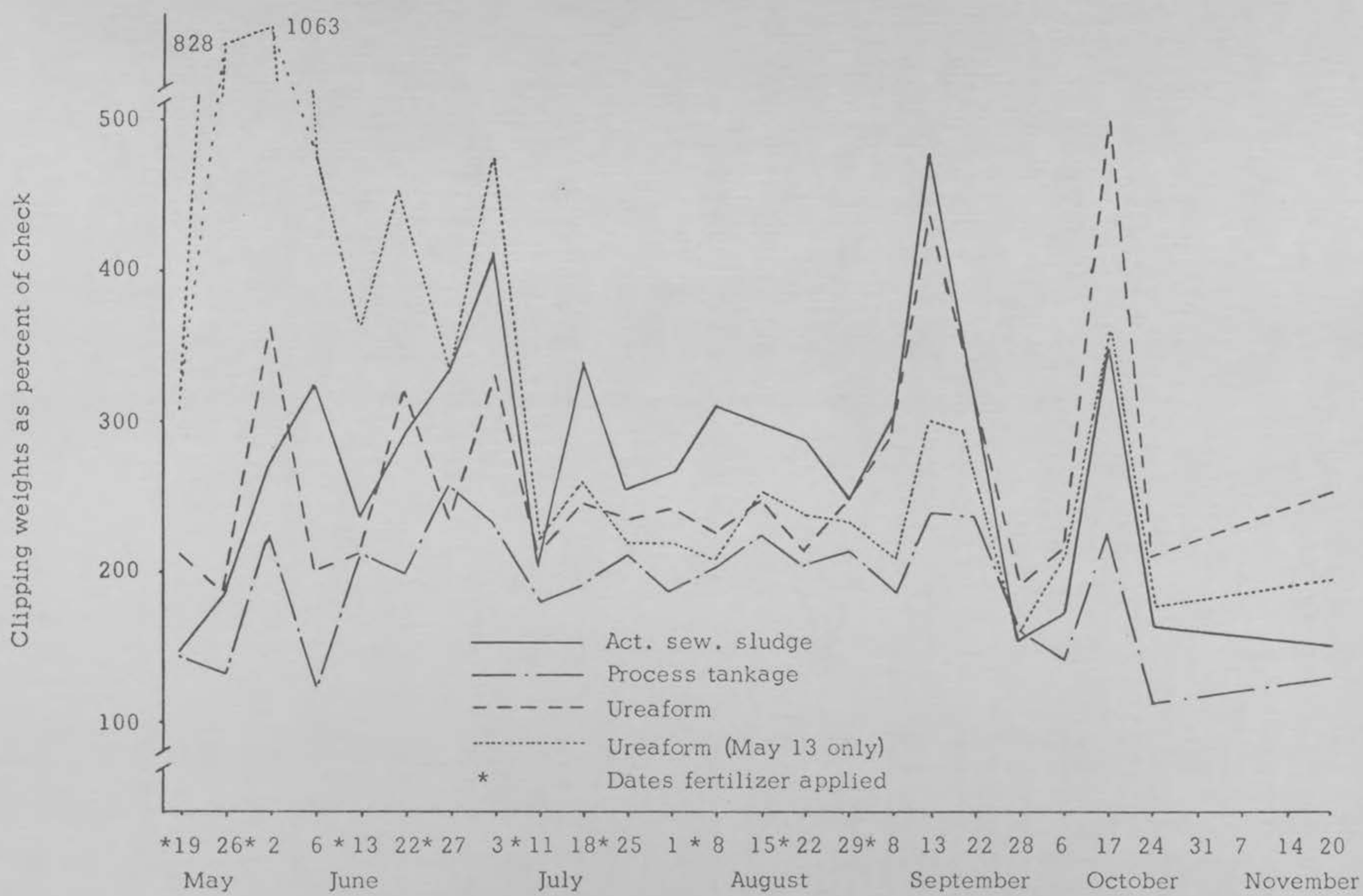


Figure 20. Clipping weights, as percent of check, from three different insoluble nitrogen sources at 11-1/4 pounds of nitrogen per 1000 sq. ft. per season on 1/4 inch bentgrass turf. New Brunswick, New Jersey, 1958.

few weeks of both seasons. Except for the first outbreak of dollar-spot at the start of each season, activated sewage sludge at the 11.25 pound rate had the lowest rating in disease incidence both years.

The color and clipping weight responses to process tankage were very uniform but were lowest. In spite of the low level of response, there was a relatively small amount of disease in both 1957 and 1958. There was considerably less dollarspot with this treatment than would be expected considering the "low nitrogen" appearance of the plots.

In 1957, the color and clipping weight responses to the split application treatment of ureaform were very low at the start of the season and dollarspot was consistently most severe. In 1958, the responses were more uniform and this was reflected in lower disease incidence.

The single application of 11.25 pounds of ureaform nitrogen produced a very high clipping weight and color response the first three to six weeks of both seasons. These high responses decreased rapidly, and this treatment was among the lowest in clipping weight and color response the last half of each season. The flush growth appeared to aid the turf in resisting dollarspot by "out growing" the disease early in the season. In June 1957, the single application treatment of ureaform showed one half the number of disease spots as the split application treatment; by October this reversed and the split application treatment had only two thirds as many spots as the single application treatment of ureaform. This difference in performance of the ureaform treatments was more clearly shown in 1958. Dollarspot in May was least severe under the single application of ureaform and by September the number of disease spots was the highest of any treatment at 11.25 pounds of nitrogen and among the highest of the entire test. Among all carriers at the 11.25 pound split-application rate, disease incidence was fairly uniform throughout the season.

SUMMATION OF GROWTH PATTERNS: Raising the level of color or clipping weight response from a given nitrogen carrier by increasing the rate of nitrogen fertilization from 3.75 to 6.75, or from 6.75 to 11.25 pounds resulted in a decrease in dollarspot incidence. Within a given rate of nitrogen fertilization there was a tendency for the dollarspot attacks to appear in periods of low or declining color and clipping weight responses. Total nitrogen response alone cannot explain differences in disease incidence; activated sewage sludge, though at a disadvantage in terms of level of color and clipping weight responses, resulted in lowest disease readings. Also, process tankage treated plots which showed a low color response had only a moderate amount of dollarspot.

Color and clipping weight responses from the insoluble carriers tended to be more uniform than those from soluble carriers. Activated sewage sludge and urea gave the most uniform color and clipping weight responses of the insoluble and soluble carriers, respectively. These carriers also resulted in the lowest dollarspot readings for their respective groups. Uniformity is not enough to insure low dollarspot incidence, as evidenced by comparing activated sewage sludge and ureaform both of which stimulated growth curves of similar uniformity but dollarspot was more prevalent on the ureaform treated plots.

Nitrogen content of clippings.

None of the fertilizer treatments produced clippings with a significantly higher nitrogen content than the no nitrogen check when using all dates of clippings as replications, but highly significant differences were found by using the last five dates only (Table 8). Increasing the rate of nitrogen fertilization gave consistently higher nitrogen readings. The nitrogen content appeared to increase with the increase in clipping weights. The nitrogen content of clippings grown during the last five weeks with 3.75, 6.75 and 11.25 pounds of nitrogen were 14, 21 and 23% higher, respectively, than that of the no nitrogen check. The average nitrogen content of clippings from soluble nitrogen treatments at 3.75 and

Table 8. The effect of various nitrogen carriers on the nitrogen content and total clipping weights of 1/4 inch creeping bentgrass turf. New Brunswick, New Jersey, 1957.

| Treatment | Percent Nitrogen Season | Percent Nitrogen Aug. 30-Sept. 27 | Total clipping weights (grams) |
|---|---|---|---|
| No nitrogen check | 4.87 | 5.13 | 88 |
| 3.75 lbs. nitrogen | | | |
| Act. sew. sludge | 5.07 | 5.54 | 138 |
| Ureaform | 5.15 | 5.61 | 120 |
| Av. ins. carriers | 5.11 | 5.58 | 129 |
| Urea | 5.55 | 6.05 | 141 |
| Ammonium nitrate | 5.52 | 5.96 | 136 |
| Ammonium sulfate | 5.54 | 6.07 | 133 |
| Av. sol. carriers | 5.54 | 6.03 | 137 |
| Av. 3.75 lbs. | 5.37 | 5.86 | 134 |
| 6.75 lbs. nitrogen | | | |
| Act. sew. sludge | 5.50 | 6.00 | 168 |
| Ureaform | 5.42 | 6.01 | 135 |
| Process tankage | 5.27 | 5.75 | 145 |
| Av. ins. carriers | 5.40 | 5.92 | 149 |
| Urea | 5.89 | 6.47 | 167 |
| Ammonium nitrate | 5.94 | 6.52 | 158 |
| Ammonium sulfate | 6.01 | 6.57 | 156 |
| Av. sol. carriers | 5.95 | 6.52 | 160 |
| Av. 6.75 lbs. | 5.58 | 6.22 | 155 |
| 11.25 lbs. nitrogen | | | |
| Act. sew. sludge | 5.82 | 6.39 | 208 |
| Ureaform | 5.67 | 6.42 | 157 |
| Ureaform[1] | 5.84 | 5.73 | 164 |
| Process tankage | 5.52 | 6.05 | 153 |
| Av. 11.25 lbs. | 5.76 | 6.29 | 173 |
| D | N.S. | 0.44 | 10 |

[1] Single spring application

6.75 pounds of nitrogen was 9% higher than the corresponding insoluble carrier treatments. With one exception, there was a gradual and significant (5% level) increase in nitrogen content of the clippings as the season progressed (Figures 21, 22, 23 and 24). The single application of ureaform gave a very uniform level of nitrogen content the entire season (Figure 25).

Other than the increase in total nitrogen as the season progressed, the nitrogen content of the clippings failed to have any marked variation from week to week as shown by the calculation of the variance ($s^2$) for each treatment. The single application of 11.25 pounds of ureaform showed the lowest variance. There was no difference in uniformity or in the variance among all other treatments. A comparison among pooled variances indicated that variation in nitrogen content with 3.75 pounds of nitrogen fertilization was less than with 6.75 or 11.25 pounds. A decrease in dollarspot incidence appears to have occurred with high nitrogen content of the host.

Other observations.

No formal study was undertaken on drought resistance but it was observed, particularly during 1957, that activated sewage sludge appeared to increase drought resistance. The first replication of the field test was on a drier soil and the activated sewage sludge plots

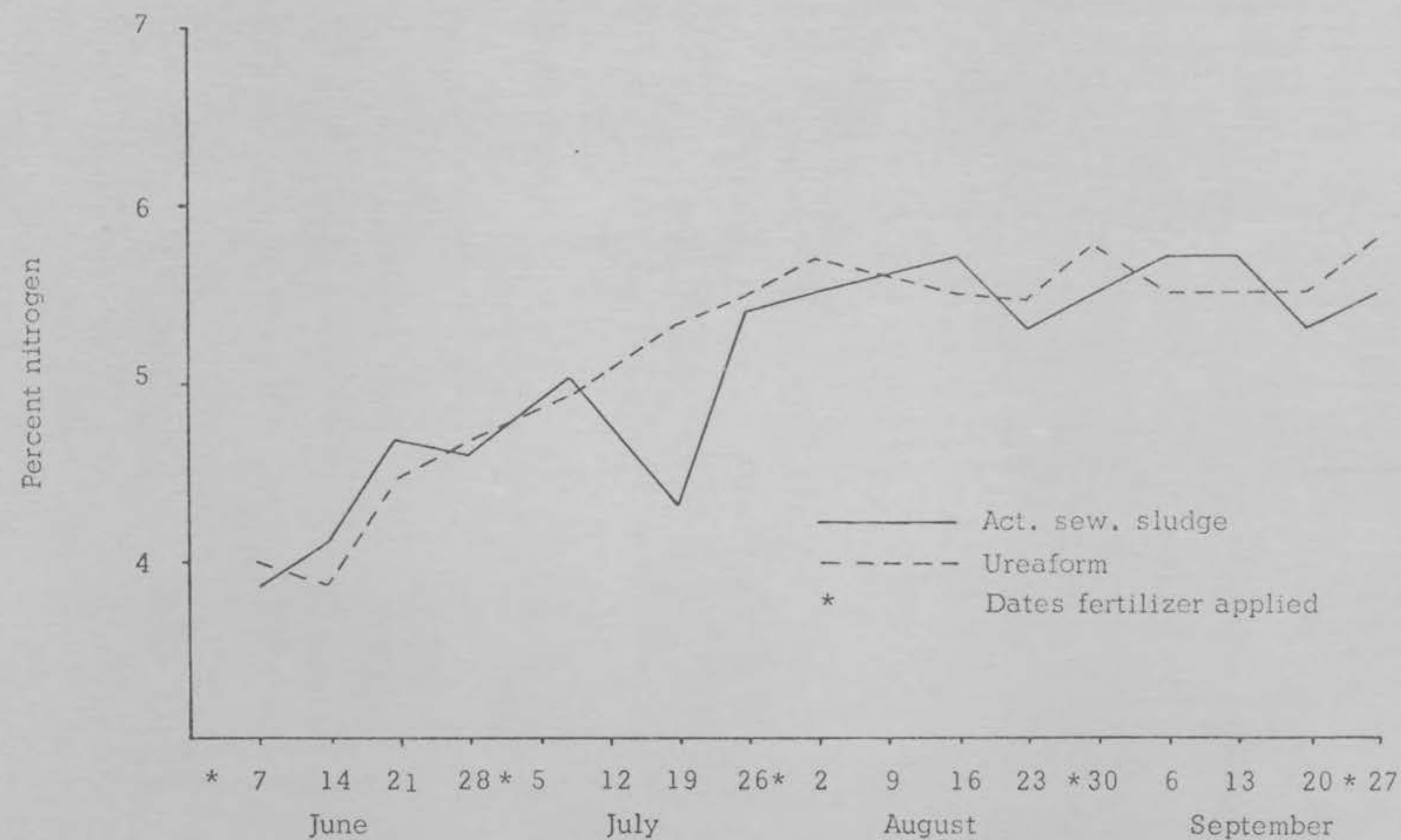


Figure 21. Nitrogen content of clippings of 1/4 inch bentgrass turf fertilized with two different insoluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

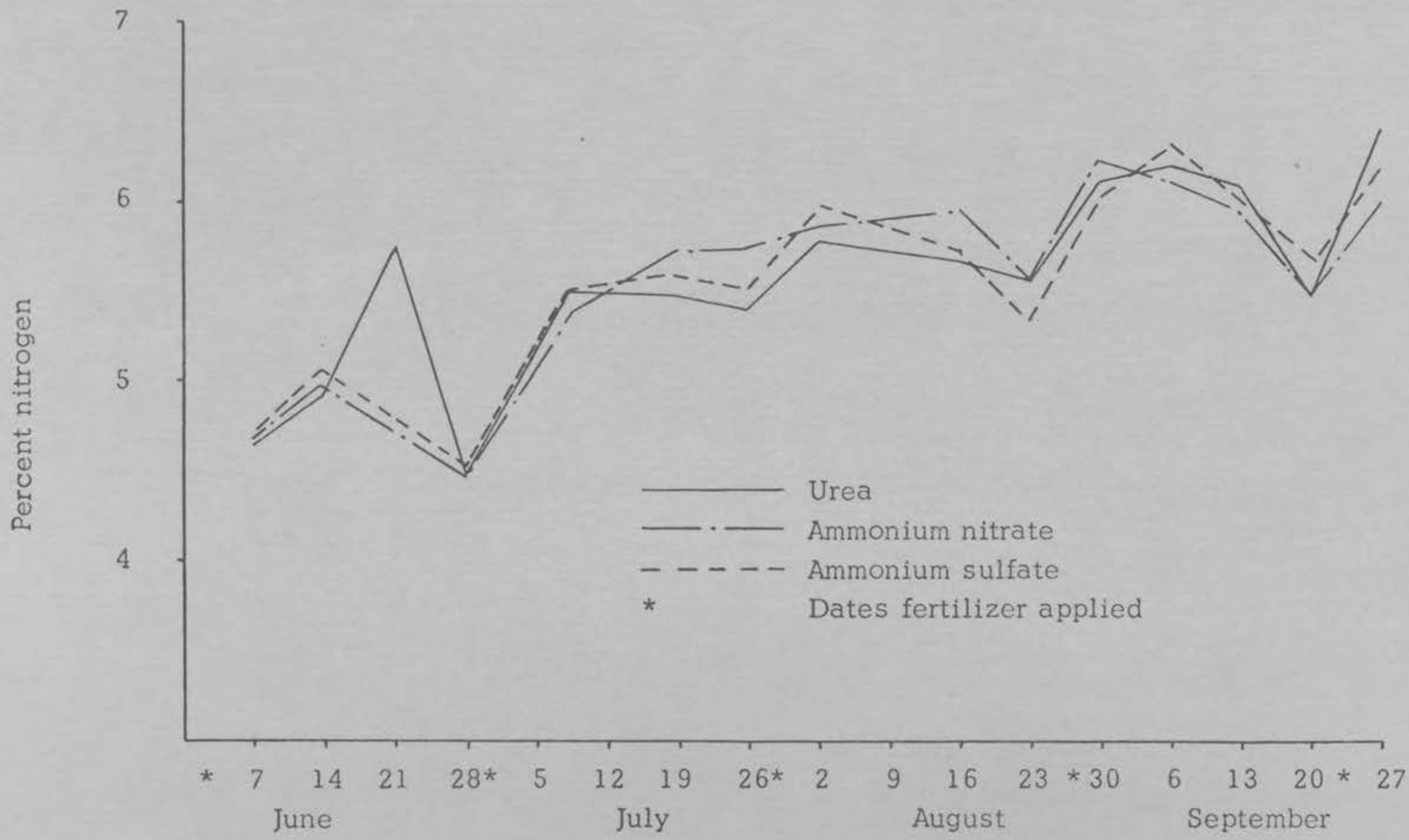


Figure 22. Nitrogen content of clippings of 1/4 inch bentgrass turf fertilized with three different soluble nitrogen sources at 3-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

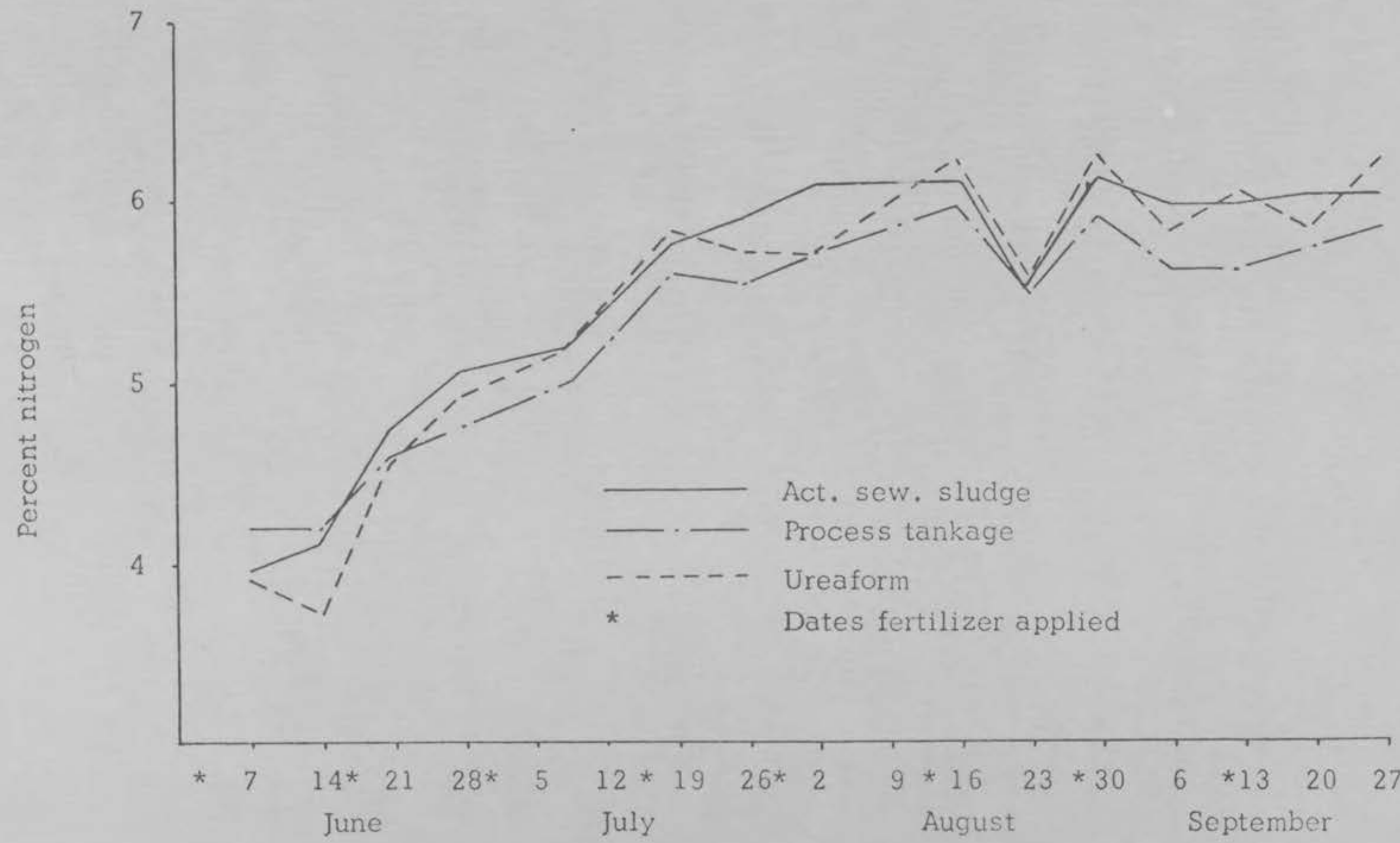


Figure 23. Nitrogen content of clippings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

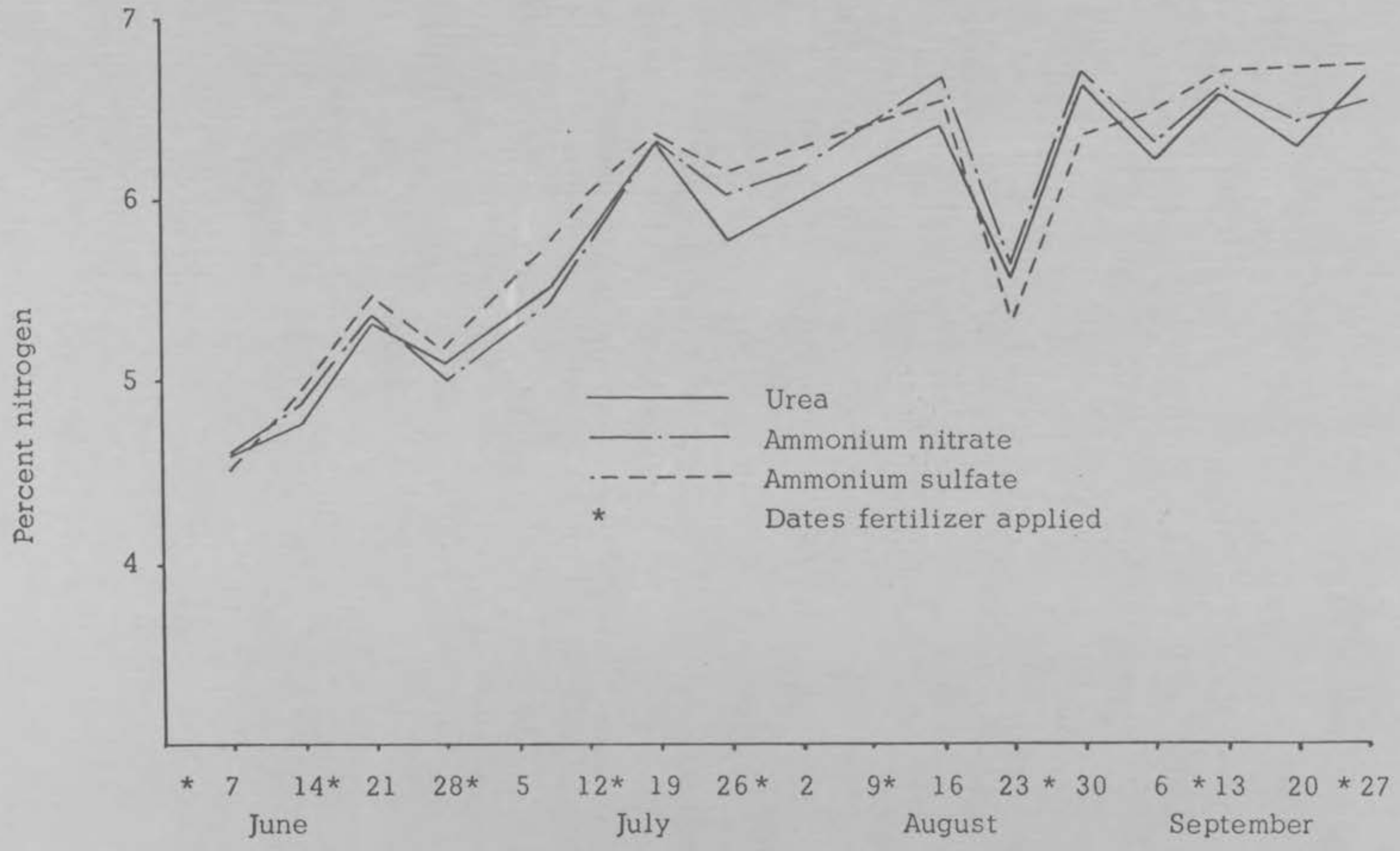


Figure 24. Nitrogen content of clippings of 1/4 inch bentgrass turf fertilized with three different soluble notrogen sources at 6-3/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

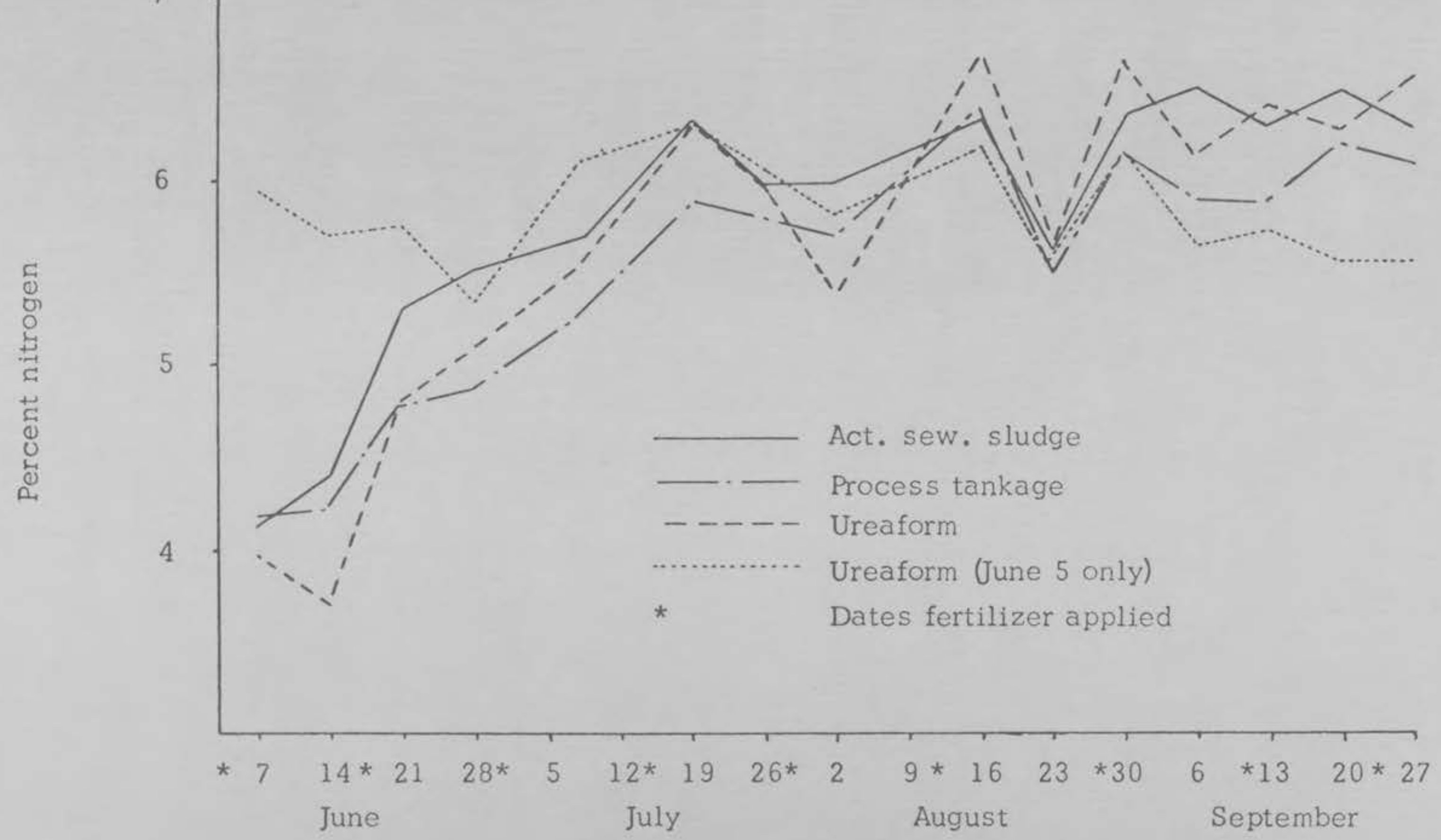


Figure 25. Nitrogen content of clippings of 1/4 inch bentgrass turf fertilized with three different insoluble nitrogen sources at 11-1/4 pounds of nitrogen per 1000 sq. ft. per season. New Brunswick, New Jersey, 1957.

were noticeably less droughty than the other nitrogen treatments. Occasional field reports claim the activated sewage sludge fertilizer reduces the tendency to wilt.

The survey of soil microflora indicated that activated sewage sludge might increase the number of organisms present. Since an abundant population of microorganisms could have the potential to suppress the facultative saprophytic pathogens by "sheer weight of numbers", as well as by other more direct antagonistic methods, this seems to be a possible area for further study. This also suggests that any effect of accumulated metallic substances would have to be highly specific in mode of action.

Effect of nitrogen source on pathogen in pure culture.

The 8-15% and 19-54% inhibition of growth of *Helminthosporium carbonum* and *Stemphylium* sp. by activated sewage sludge suggests this material may have the potential to reduce the severity of disease in the field (Table 4). The effect of sewage sludge on sporulation of these pathogens could have an indirect effect by reducing the supply of inoculum.

One-sixth the number of sclerotia of *R. solani* were produced on activated sewage sludge medium as on the ammonium nitrate medium. This type reaction of *Sclerotinia homoeocarpa* and *R. solani* to soluble and insoluble nitrogen in pure culture (Figure II and Table 7) suggests that continued use of activated sewage sludge in the field could decrease the number of sclerotia in the soil. Hence, less inoculum would be available when conditions were favorable for disease.

*Pythium aphanidermatum* showed increased vigor and twice the longevity (Table 6) on medium containing soluble nitrogen. This could be correlated with increased vigor and pathogenicity of the organism in the field when soluble nitrogen is abundant.

*Trace and mineral elements in relation to disease inhibitions*.

*Laboratory*: Both the high rate of wettable sulfur and the low rate of iron reduced the growth of *Sclerotinia homoeocarpa* by 94% when added to potato dextrose agar as compared with the standard potato dextrose agar (Table 9). Also copper and sulfur, at the low rate, reduced the growth by 42% and at the medium rate by 75% when compared with the standard potato dextrose agar check. At the high rate of chromium, growth was limited to the plug of agar used to propagate the fungus. However, at the low and medium rates, chromium had no significant effect on the growth of *S. homoeocarpa*. At no rate did the aluminum treatment of potato dextrose agar have any significant (5% level) effect on growth of this fungus. The addition of activated sewage sludge at both the low and medium rates gave a 15% increase (not significant at 5%)

Table 9. The effect of trace elements, in quantities comparable to amounts found in activated sewage sludge, on *Sclerotinia homoeocarpa* in pure culture on potato dextrose agar at room temperature.

| Treatment | Diameter of colony in mm | | |
|---|---|---|---|
| | Low Rate | Medium Rate | High Rate |
| Aluminum | 73 ef* | 68 e | 70 e |
| Copper | 45 d | 19 c | -- |
| Chromium | 72 ef | 78 ef | 0 a |
| Iron | 4 b | -- | -- |
| Sulfur | 44 d | 20 c | 5 b |
| Act. sew. sludge | 89 f | 89 f | -- |
| Check | 78 ef | 78 ef | 78 ef |

* Figures followed by the same letter are not significantly different from each other at the 5% level of probability by Hartley's method of sequential testing (15).

in growth, as expressed by diameter of colony. The extra nitrogen in the sewage sludge could be responsible for this increase. These results suggest the possibility of fungitoxic proportions of trace elements accumulating from continued use of activated sewage sludge.

Greenhouse: Attempts to induce infection of bentgrass with *S. homoeocarpa* under greenhouse conditions were not successful. A large brown patch-like disease was very severe on all but the no-nitrogen check pots. This does not nullify the hypothesis that the trace elements in activated sewage sludge can affect disease incidence. Possibly it suggests a very complex relationship.

## SUMMARY AND CONCLUSIONS

A review of literature and field observation suggested that different nitrogen carriers affect turfgrass disease incidence. Three insoluble carriers, sewage sludge (Milorganite), process tankage (Agrinite), and ureaform (Uramite), and three soluble carriers, urea, ammonium nitrate and ammonium sulfate, were applied at rates of 3.75, 6.75 or 11.25 pounds of nitrogen per 1000 square feet in the field to determine if they affected disease incidence. In the laboratory, media containing both unmodified and extracts of activated sewage sludge and ammonium nitrate were compared with a standard culture medium (potato dextrose agar) for their effect on turf pathogens in vitro.

In an attempt to explain the effect of nitrogen carriers on disease incidence, the growth patterns and nitrogen content of clippings from the field test of nitrogen carriers were studied. Also, the effect of selected trace elements in amounts comparable to those found in activated sewage sludge was studied on Sclerotinia homoeocarpa. Soil from plots receiving nitrogen from selected sources was sampled to estimate their effect on the microbial population.

The results of these tests are the basis for the following conclusions:

1. Activated sewage sludge was the most outstanding

nitrogen carrier in inhibiting outbreaks of dollarspot. This effect was greater than the normal reduction of this disease due to nitrogen stimulation and was in evidence at every level of nitrogen fertility.

2. When in pure culture, the response of the fungi to the more soluble nitrogen carriers appeared to be favorable to the fungi as pathogens. Nitrogen source was observed to affect:

   a. the growth rate of Curvularia sp., Helminthosporium carbonum, Stemphylium sp., Corticium fuciforme and Fusarium nivale,

   b. sporulation of H. carbonum and Curvularia sp.,

   c. sclerotia production of Sclerotinia homoeocarpa and Rhizoctonia solani,

   d. the growth habit of H. carbonum and Curvularia sp. and

   e. longevity of Pythium aphanidermatum.

3. Soluble carriers, applied at intervals of two weeks tended to produce a cyclic pattern of growth which indicates "feast" the first week after application and relative "famine" the second. The more even stimulation of the insoluble carriers with the same application rate and

interval may keep the nitrogen level within safer limits. The majority of dollarspot outbreaks were associated with periods of "famine".

4. Growth produced by the single application of ureaform reached a peak during the first three weeks following application. During this peak the turf was relatively free of disease. Following this, the growth rate decreased as compared with the equivalent total amount of ureaform applied at frequent intervals. Later in the season, the grass grown on this single application treatment of ureaform was more susceptible to dollarspot disease.
5. Nitrogen content of the host appeared to be correlated with incidence of dollarspot.
6. Elements (iron, copper and sulfur) in quantities comparable to those in activated sewage sludge reduced the growth of _Sclerotinia homoeocarpa_ by 25% to 95%. Attempts to demonstrate this on turf grown in the greenhouse were inconclusive.
7. Activated sewage sludge stimulated abundant growth of soil microorganisms in field plots compared with other nitrogen carriers.
8. The relationship between nitrogen carriers and disease

incidence of turf is exceedingly complex. Further study of the following seems justified:

a. the significance of activated sewage sludge stimulated soil microorganisms as disease antagonists,

b. the effects of trace elements found in activated sewage sludge on the physiology of the grass, particularly in terms of drought resistance and fungitoxants, and

c. the effect of nitrogen carriers on turf diseases other than dollarspot.

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# APPENDIX

Table A 1. Miscellaneous effects of various nitrogen carriers on 1/4 inch bentgrass turf. New Brunswick, New Jersey.

| Treatment | dollarspot incidence 1957 No. of Spots | 1957 Log | 1958 No. of Spots | 1958 Log | Total clipping weights (gms.) 1958 | Variance of nitrogen content 1957 |
|---|---|---|---|---|---|---|
| No. nitrogen check | 314 | 2.29 | 515 | 2.70 | 101[1] | 0.3554[2] |
| 3.75 lbs. nitrogen | | | | | | |
| Act. sew. sludge | 121 | 2.00 | 378 | 2.57 | 166 | 0.3980 |
| Ureaform | 224 | 2.27 | 518 | 2.70 | 164 | 0.4204 |
| Urea | 205 | 2.20 | 404 | 2.60 | 167 | 0.3263 |
| Ammonium nitrate | 157 | 2.04 | 474 | 2.66 | 177 | 0.3263 |
| Ammonium sulfate | 166 | 2.17 | 532 | 2.72 | 150 | 0.3313 |
| 6.75 lbs. nitrogen | | | | | | |
| Act. sew. sludge | 94 | 1.75 | 256 | 2.39 | 205 | 0.5572 |
| Ureaform | 247 | 2.31 | 422 | 2.61 | 199 | 0.6854 |
| Process tankage | 211 | 2.17 | 393 | 2.58 | 160 | 0.3583 |
| Urea | 75 | 1.85 | 360 | 2.54 | 218 | 0.4588 |
| Ammonium nitrate | 144 | 1.97 | 452 | 2.64 | 217 | 0.4487 |
| Ammonium sulfate | 140 | 2.10 | 450 | 2.65 | 193 | 0.5097 |
| 11.25 lbs. nitrogen | | | | | | |
| Act. sew. sludge | 42 | 1.24 | 106 | 1.95 | 253 | 0.5669 |
| Ureaform | 184 | 2.11 | 305 | 2.48 | 250 | 0.9744 |
| Ureaform[3] | 129 | 1.95 | 362 | 2.56 | 298 | 0.0760 |
| Process tankage | 114 | 1.97 | 312 | 2.49 | 184 | 0.5364 |

[1] D=10 [2] F=2.48 [3] Single spring application