Life history studies and the control of northern nutgrass (Cyperus esculentus L.).

LIFE HISTORY AND THE CONTROL OF NORTHERN NUTGRASS

CYPERUS ESCULENTUS L.

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LIFE HISTORY STUDIES AND THE CONTROL OF NORTHERN NUTGRASS

(Cyperus esculentus L.)

BY

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LIFE HISTORY STUDIES AND THE CONTROL OF NORTHERN NUTGRASS (Cyperus esculentus L.)

INTRODUCTION

Northern nutgrass (Cyperus esculentus L.) is now a very serious weed in the Northeast. It is found on many of our fertile productive soils and is exceedingly difficult to eradicate once it becomes established. Present control methods involve removing the infested land from production and disking continuously for two or more years. This results in a decrease in crop production and a loss of farm income.

The seriousness of this problem makes it desirable to study the life history and control of this plant in the hope that an eventual method of eradication will be found.

REVIEW OF LITERATURE

Introduction

Fernald (12) reported that C. esculentus is distributed widely in North America, where its chief habitat appears to be damp, sandy soil and cultivated ground. Contrary to its name, nutgrass belongs to the sedge family, Cyperaceae, rather than to the grass family, Gramineae. Nutgrass is a herbaceous perennial which is propagated by means of seeds, as well as tubers that are produced on the ends of weak filiform stolons. The simple to compound yellowish to golden-brown umbel blooms from July to September. Mature seeds are produced from August to November.

According to Georgia (17) C. esculentus is known by such common names as: northern nutgrass, yellow nutgrass, yellow galingale, and chufa. The common names: coco, coco-sedge, rush nut, nut sedge, edible galingale, and earth almond are added by Muenscher (25).

Seed Germination

In the past few years there has been an increasing interest in weed seed germination studies, in an attempt to overcome the lack of knowledge in this field. Workers involved in weed seed germination follow closely the rules prescribed in 1954 by the Association of Official Seed Analysts (2) for testing seeds. Studies of laboratory methods for weed seed germination have also been carried out by Cross (1), Everson (11), and Steinbauer, et al (33). Steinbauer, et al (33) state that there is not always one best method for testing a particular seed. Some seeds germinate readily under a variety of conditions, whereas others have much more definitely defined requirements.

In a later paper, Steinbauer and Grigsby (34) indicated that three sets of environmental factors must be controlled accurately to insure complete germination. These three factors are suitable temperature, light, and moistening agent. Dormancy in most cases is overcome by the proper control of these three environmental factors. They found that a large proportion of the seeds of weed plants are dormant at maturity. The most common cause of this primary dormancy is the need for complex physico-chemical changes within the seed known as "after-ripening". In many cases the need for after-ripening can be overcome by exposing moist seeds to low temperatures for one or two weeks. After the seeds have been in dry storage for a few weeks the need for after-ripening usually disappears.

"The optimum range of temperatures within which germination occurs varies with the age, physiological state, and kind of seed". The range of 20°C to 30°C appears favorable for germination of most weed seeds. Seeds germinate more promptly with daily alternation of temperature, than with constant temperature.

Some seeds germinate poorly or fail to germinate when deprived of light completely. About 35 per cent of the seeds tested germinated more rapidly in light than in darkness.

Water is the chief moistening agent for seed germination, but many seeds germinate better with nitrate solutions.

Studies of C. esculentus seed by Isely and Wright (20) indicate that they are yellowish to medium-brown in color, with no scurfy gray coating, as in C. rotundus. The seed is usually broader above the middle and gradually tapering to the base. Cellular reticulations are quite coarse and frequently transluscent and bulbous.

Additional seed studies by Justice and Whitehead (23) show that the achenes are approximately 1.5 mm by 0.8 mm in size and the embryos are 100 X 300 microns. The relatively hard and thick pericarp encloses a thin seed coat. The endosperm is differentiated into starchy endosperm and a peripheral oil layer. The microscopic, globular to ovate embryo is in contact with the starchy endosperm and an oil layer at the base of the seed. The apical end of the embryo elongates into the sucker or absorbing organ during germination. Outside the seed coat an enlargement occurs from which the primary root and shoot appear.

In further work Justice (22) states that the seeds of many Cyperus species were dormant at maturity and required a period of after-ripening for germination. After-ripening occurred most rapidly when seeds were stored between moist substrata at low temperatures. It was found that of the four temperatures used for after-ripening, 10°C constant was best and in the following order were 10-20°C alternating, 2-20°C alternating, and 2°C constant. Once dormancy was overcome the seeds germinated readily on blotters moistened with a 0.2 per cent potassium nitrate solution at an alternating temperature of 20-30°C in diffuse light.

Cyperus species range in condition from no dormancy to extreme dormancy. When stored dry, and depending on the species, the seed remains viable for three to twelve years.

Justice and Whitehead (23) found that seed production in C. esculentus was quite variable. An infestation located in Alabama was examined for two consecutive years with only a few viable seeds developing. Seeds collected from greenhouse plantings at Orono, Maine, and from a field at Fryeburg, Maine were highly viable. The Maine seed lots were divided into four weight fractions. It was found that the seed grown in the greenhouse varied in germination from 2.5 per cent for the lightest seed to 62 per cent for the heaviest seed. The Fryeburg lot varied in germination from 20 per cent for the lightest to 95 per cent for the heaviest seed lot with an overall average of 75.6 per cent with the equivalent of 1,521 seedlings per inflorescence. Other tests by Justice and Whitehead (23) showed that the viability of heavier seeds was retained longer than that of lighter seeds.

When four week old seeds were sown in sterilized soil in a greenhouse no seedlings were produced within a three month period. Seeds placed between blotters increased in germination from 4 per cent in two months to 79 per cent in four months and to 89 per cent in twelve months. There was a great variation in the germination percentages of the various lots of seed.

By moistening the substratum with a 0.2 per cent solution of potassium nitrate the germination of dormant seeds was increased significantly, while seeds stored dry at room temperature after-ripened as soon as those stored moist at 10°C.

Bell and Larssen (5) also found that Northern nutgrass seeds would germinate readily. Their work indicated that 70°-95°F was the optimum temperature for germination. Seeds treated with a 0.2 per cent potassium nitrate solution failed to show a significant increase over the check. They also indicated that seed storage at 36°F was unfavorable for seed germination.

Leighty and Love (24) found that treating clover and alfalfa seeds with concentrated sulfuric acid increased germination. This method was tested by Justice (21) using C. rotundus seeds, but it did not promote increased germination.

Ranade and Burns (27) report that C. rotundus seeds heated for three hours at 51°C germinated much higher than the controls. Justice (21) also states that dormancy in C. rotundus seed was broken by heating the seeds to approximately 40°C on a moist substratum for three to six weeks followed by exposure to 20-30°C.

Tuber Dormancy

Very little work has been done on tuber dormancy of Northern nutgrass. An abstract published recently by Bundy, Donnally and Rhan (6) indicated that newly formed tubers were dormant. These tubers germinated as low as 4 per cent, whereas, tubers stored at 48°F for thirty days germinated at the rate of 95 per cent. Dormancy was also broken partially by treatments with thiourea and ethylene chlorohydrin solutions. Tubers failed to germinate when treated with Eptam (ethyl di-n-propylthiol-carbamate), while tubers treated with Atrazine (2-chloro-4-isopylamino-6-ethylamino-5-triazine) germinated normally but the resulting plants eventually died.

Denny (8), (9), (10) found an effective means of shortening the rest period of potatoes. The effect of two hundred and twenty-four chemical substances on potato germination was studied and in these tests ethylene chlorohydrin and potassium and sodium thiocyanate were found to be the most effective in hastening germination. Denny (9) also found that tubers developed multiple sprouts after being soaked in a dilute solution of thiourea.

Photoperiodic Response

Garner and Allard (15) observed that day length had a profound effect on plant growth and flower initiation. Later work by these workers (16) showed that day length was also an important factor in the formation of potato tubers.

Bundy, Donnally, and Rhan (6) report that increased photoperiod, light intensity, soil temperature and soil moisture were favorable for plant growth and development of vegetative shoots in plants that developed from

tubers. On the other hand, decreasing photoperiod as well as low light intensity promoted tuber development on nutgrass plants.

Chemical Control

Many of the currently recommended methods for nutgrass control are expensive as well as relatively ineffective. Orsenigo and Smith (26) report that rotations with pasture and potato plantings were not effective in controlling nutgrass. A field severely infested with nutgrass was planted to permanent pasture. In the eight years that followed, the only nutgrass plants to be found were small and chlorotic and deemed to be of little importance. After this time, a section of the field was plowed and fitted. In one month nutgrass shoots were evident and by fall there were from ten to fifteen nutgrass shoots per square foot. These men reported further that nutgrass control was not obtained effectively by using other cultural methods such as fallowing or regular cultivation and harrowing operations.

The relative ineffectiveness of cultural practices to control nutgrass have led to research in chemical control. Orsenigo and Smith (26) state that the rates (2 to 5 pounds per acre) of 2,4-D (2,4-dichlorophenoxyacetic acid) used to control C. rotundus do not appear to control C. esculentus. They found that 15 pounds of 2,4-D per acre applied in a 5 per cent emulsion of aromatic oil was needed for an 80 per cent reduction in stand. TCA (Trichloroacetic acid) at 75 pounds per acre and CMU (3-(p-chlorophenyl)-1,1-dimethyl urea) at 20 or more pounds per acre also had a measurable effect on nutgrass retardation.

Work reported by Frans and Aldrich (14) in 1952 indicated that TCA and CMU were effective in controlling one season's growth of nutgrass. A few years leter Bell and Bannister (3) soreened the following chemicals: CMU, Dalapon (2,2-dichloropropronic acid), PMAS (phenyl mercuric acetate), TCA, Chloro IPC (isopropyl N-(3-chlorophenyl) carbamate), Maleic Hydrazide and 2,4-D alone and as combinations of these materials. They found that none of these chemicals eradicated Northern nutgrass, although they believed that CMU at low rates might be effective if applied over a period of years.

In 1958, Veatch (38) found that a post-emergence application of DNBP (4,6-dinitro ortho secondary butylphenol) at 3 to 4 pounds per acre controlled nutgrass in corn. Meanwhile, studies by Saidak (30) at Cornell University indicated that Eptam suppressed the growth of nutgrass significantly. Pre-emergence and post-emergence applications at 15 pounds per acre resulted in significantly better control than applications of 10, 5 or 2.5 pounds per acre.

Several workers (1, 18, 19, 28, 29, 31, 36) have found Eptam to be effective in controlling Northern nutgrass. Sweet, Rubatzky and Cialone (35) also tested Eptam as well as several of its analogs. They found that treatment with Eptam and analog 1607 (propyl di-n-propylthiol-carbamate) resulted in commercially acceptable control of nutgrass. Havis, Ticknor and Bobula (18) have found Eptam to be less effective when applied to wet soils. Weed control was enhanced on dry soil by either cultivation or irrigation after application of Eptam.

Top growth and tuber production of nutgrass were reduced drastically when plants were grown in soil treated with CMU at 5 pounds per acre according to Bell, Bannister and Tisdell (4). Simazine (2-chloro-4, 6-bis (ethylamino)-s-triazine), at 2 and 4 pounds per acre, was reported by Indyk (19) to be promising in the control of nutgrass when used as a pre-emergence spray. Atrazine, was found to be more active on emerged weeds than Simazine in New York by Flanagon (13). This chemical was also found to be effective in the control of Northern nutgrass by Springer (32) and Trevett and Gardner (36).

MATERIALS AND METHODS

Seed Germination

Several different seed collections of C. esculentus were made because of the dearth of information on seed germination of this plant. The seeds were subjected to various conditions and tested for germination. All of the seeds were harvested and threshed by hand. The seeds harvested in 1958 were oven-dried at 100°F for five days with the exception of lot number 7 of which one-half were air-dried for several days. Seeds collected in 1959 were all air-dried for several days after harvest. The inert material and lighter seeds were removed by a tobacco seed cleaning machine. Table I shows the pertinent data relating to the harvest of the seeds.

TABLE I

Location and Date of Harvest of Cyperus esculentus L. Seed Lots

Lot	Location	Habitat	Date
1	Kingston, R. I.	Unknown	Sept. 57
2	Granby, Mass.	Corn Field	Sept. 11, 58
3	Granby, Mass.	Potato Field	Sept. 20, 58
4[1/]	Granby, Mass.	Potato Field	Sept. 30, 58
5	Kingston, R. I.	Unknown	Sept. 58
6	Kings Ferry, N. Y.	Unknown	Oct. 10, 58
7[1/]	Granby, Mass.	Potato Field	Oct. 11, 58
8[2/]	Amherst, Mass.	Nutgrass Planting	Aug. 12, 59
9[2/]	Amherst, Mass.	Nutgrass Planting	Aug. 20, 59
10	Granby, Mass.	Nutgrass Field	Aug. 21, 59
11	Granby, Mass.	Nutgrass Field	Aug. 27, 59
12[2/]	Amherst, Mass.	Nutgrass Planting	Aug. 27, 59

1/ Collected after a heavy frost
2/ Rhode Island Strain

The germination tests were conducted in the seed laboratory at the University of Massachusetts in the manner prescribed by the Official Seed Analysts (2). All treatments were replicated four times with 100 seeds in each replication. The germination substrate consisted of two discs of germination blotters placed in the bottom of covered Petri dishes. The seeds were germinated in standard seed germination chambers. All seeds were subjected to a forty-five day germination period. The germination was considered to be the total percentage of germinated seedlings without regard for normal and abnormal seedlings. The seeds were dusted with Arason seed protectant before each treatment. Unless otherwise specified all tests were subjected to 16 hours of darkness and 8 hours of light. When an alternating temperature was used the seeds received 8 hours at the high temperature and 16 hours at the low temperature.

The data collected were analyzed by the usual statistical procedures and are presented in appropriate tables.

This initial project was designed to determine whether newly harvested nutgrass seed were dormant as indicated by Justice and Whitehead (23). Seed lots 2, 3, 4, and 7 were germinated in Petri dishes on germination blotters moistened with tap water at alternating temperatures of 20-30°C as indicated in Table II.

Seeds selected at random from each of the above lots were divided into five replications of one hundred seeds each and weighed to the nearest tenth of a milligram.

A second experiment was started on October 24, 1958 to determine the effects of stratification on seed germination. Seed from lots 1, 3, and 4 were placed on germination blotters moistened with tap water in Petri

dishes and subjected to a temperature of 10°C for one, two and three month periods. After each stratification period expired the seeds were transferred to an alternating germination temperature of 20-30°C for forty-five days.

Results by Justice and Whitehead (23) indicate that seed germination declines as the storage temperature decreases. To check these results, seeds of lot number 8 were subjected to room temperature 10°C, 5°C, and -10°C for one and two months before they were germinated at 20-30°C.

In the late winter and early spring of 1959 seed lots 1, 3, and 6 were subjected in the usual manner to the following temperatures: 30°C, 35°C, 20-30°C, and 20-35°C to determine the effect of temperature on the germination of nutgrass seed.

On March 9, 1959, a project was started to determine the effects of light, darkness, potassium nitrate, and tap water at three different temperatures on the germination of seed lot 3. The check consisted of germinating the seeds in the normal manner; each Petri dish receiving 8 hours of light, and 16 hours of darkness. Tap water was used to moisten the substrate. The same method was used in the second treatment except the substrate was moistened with a 0.2 per cent solution of potassium nitrate. Petri dishes were wrapped in aluminum foil to prevent any light from reaching the seeds in the third test and the substrate was moistened with tap water. The fourth and final test was also subjected to complete darkness but here the substrate was moistened with a 0.2 per cent solution of potassium nitrate. Each of the four treatments mentioned above were subjected to the following germination temperatures: 30°C, 20-30°C, and 20-35°C.

Because of the noteworthy results obtained in previous tests it was deemed important to expand further and retest the effects of light and darkness, potassium nitrate, and stratification at various temperatures. The seed from lot number 12 was tested for dormancy. The test was begun on September 14, 1959, eighteen days after the seed was harvested. The seeds were subjected to light, darkness, potassium nitrate, tap water, and stratification at two different temperatures. The methods used are the same as those described for previous tests.

A test to compare the germination rate of two different seed strains of nutgrass was started on September 30, 1959. The Rhode Island strain (lot No. 12) and the Massachusetts strains (lot No. 11) both arose from the previous year's tubers, and grown under similar conditions without disturbance to maturity. Both lots were collected on the same day with identical harvest methods. The seeds were placed in Petri dishes, and subjected to the following four treatments: alternating 20-30°C; alternating 20-30°C in complete darkness; alternating 20-35°C; and alternating 20-35°C in complete darkness.

Ranade and Burns (27) indicated that C. rotundus seed heated for 3 hours at 51°C gave a highly significant increase in germination as compared to a control sample. The purpose of this investigation was to determine the effects on germination of heating after-ripened and newly harvested C. esculentus seed for 3 hours. Seed lot 3 and the eight day old lot 8 were subjected to 50°C $\pm$ 1, 60°C $\pm$ 1, and 70°C $\pm$ 1 in an oven for three hours on August 20, 1959. A sample of lot 3 was also soaked in boiling water for two, five, and ten minutes. The treated seeds along with a check were then placed in Petri dishes and germinated in the usual method at 20-30°C.

The following test was initiated to determine the effect of freezing dry and wet seeds on subsequent germination: wet, dry, and untreated seeds of seed lot numbers 3 and 5 were used. Wet seeds were obtained by placing the seeds in a beaker of water. Since the seeds did not readily absorb water it was necessary to add a drop of emulsifier (phthalic glycerol alkyd resin) to the water before saturation was complete. The untreated seeds or checks were held at room temperature, while on June 17, 1959 the wet and dry seeds were placed in envelopes and subjected to -15°C for one month in a domestic type refrigerator. At the end of the storage period the seeds were placed in Petri dishes and germinated at 20-30°C.

The seeds from lot number 3 were stored at room temperature and germinated many times in numerous tests over an eleven month period to determine their variability in germination. The usual germination method with an alternating temperature of 20-30°C was used as indicated in Table XI.

The following experiment was designed to determine the effects of ethylene chlorohydrin on seed germination. On September 30, 1959, seeds from lot 8 were placed in folded filter paper and suspended in a 50 ml. flask containing 20 ml. of ethylene chlorohydrin solution. After the filter paper was moistened with the solution a gas tight stopper was inserted in the flask. The flasks were then maintained at 30°C for 24 hours. After this treatment the seed were placed in Petri dishes and germinated at 20-30°C.

Leighty and Love (24) reported that seed germination may be increased by scarification with sulphuric acid and so an experiment was designed to determine the effect of scarification of nutgrass seed by this method.

Seeds from lot 3 were soaked in concentrated sulphuric acid for two, five, and ten minutes, then rinsed in cold tap water and placed in Petri dishes. The germination blotters were moistened with tap water and the seeds were germinated at 20-30°C.

The effects of a base, an oxidizing agent, and a reducing agent on seed germination were also tested in this experiment. For this purpose 12.5 M sodium hydroxide was selected as the base, 0.1 M potassium permanganate as the oxidizing agent, and a 0.1 M solution of pyrogallic acid as the reducing agent. The seeds of lot 3 were soaked in the various solutions for a period of two, five, or ten minutes, then removed and washed thoroughly in tap water. The seeds were germinated in the usual manner at 20-30°C in July, 1959.

On September 16, 1959, seeds from lot 12 were placed in Petri dishes and germinated at 20-30°C. The substrates were saturated with potassium nitrate, potassium nitrite, ammonium nitrate, and mixtures of manganese sulfate and potassium nitrate, and manganese sulfate and ammonium nitrate at concentrations of 1, 0.5, 0.02, and 0.01 per cent to determine their effects on germination.

Tuber Dormancy

The Massachusetts strain of nutgrass seed was planted in number 10 cans on March 7, 1958. In four weeks the new seedlings were thinned to one plant per can. The plants were fertilized with an aqueous solution of 20-20-20, and grew well, producing numerous vegetative shoots; by mid-July the plants had matured.

Over three thousand tubers were harvested from one-half of these plants on July 21. All vegetation was removed to the soil surface from

the remaining unharvested plants; one-half of them were subjected to a temperature of 10°C, and the other half exposed to normal greenhouse temperature.

Treatment I

Each treatment was composed of four replications of thirty tubers each. On July 22, the tubers were placed in Petri dishes on two thicknesses of germination blotters which were moistened with either water or 0.2 per cent potassium nitrate solution. The tests were conducted in standard germinators which received 16 hours of darkness and 8 hours of light. The four germinating temperatures used were: 15-25°C and 20-30°C alternating, 25°C, and 35°C constant. Four treatments were carried out at each of these temperatures. The first treatment consisted of placing the tubers on blotters moistened with tap water. The second treatment was similar to the first except a 0.2 per cent potassium nitrate solution was used to moisten the blotters. In treatment number three the tubers were treated in a manner similar to the check, except the Petri dishes were wrapped in aluminum foil to eliminate light. In the fourth treatment the tubers were placed on blotters moistened with tap water and stratified at 10°C for five days. At the end of five days the tubers were removed from the 10°C temperature and placed in each of the four germinating temperatures. Tubers were also placed in -12°C and 10°C temperatures for one and two months and at the end of the stratification period these tubers were placed in a 20-30°C temperature for germination. The test was conducted over a period of seventy-five days with counts and observations made at intervals throughout this period.

Treatment II

The purpose of this treatment was to determine the effects of various chemicals on tuber dormancy. The tubers exposed to the greenhouse temperatures were harvested on July 26 for this experiment. Each of the treatments consisted of four replications of thirty tubers each. The tubers were tested in Petri dishes on germination blotters at 20-30°C.

Two checks were used in this experiment; the first consisted of tubers soaked in tap water for one hour before being placed on the germination blotters, the second consisted of tubers dipped in water and then placed in an air tight jar for 24 hours at 30°C.

In treatments 4 through 6 the tubers were soaked for one hour in a 1, 2, and 4 per cent potassium thiocyanate solution respectively before being placed in the germinator. Tubers were also treated with thiourea using the same method, at 1, 2, 4, and 8 per cent concentrations in treatments 11 through 14. Concentrations of ethylene chlorohydrin at 0.5, 1, 2, and 4 per cent were used in treatments 7 through 10. In these tests the tubers were put into a 250 ml. flask and enough of each solution was poured into the flasks to cover the tubers. The solution was then poured off immediately and the flask sealed air-tight with a rubber stopper. They were then subjected to 30°C constant temperature for 24 hours before the tubers were removed and placed in the Petri dishes for germination.

The experiment was started on August 26, 1959 and concluded on September 10, 1959. At the end of the test each tuber was examined, and the shoot growth was measured from the base to the tip of the longest leaf. The roots were also measured from the base to the tip of the long-

est root. The number of shoots present on each tuber, and the number of tubers that sprouted in each replication was also determined.

The data were then analyzed statistically, and are presented in Table No. XV.

Treatment III

The tubers subjected to the 10°C temperature were harvested on September 20, 1959. The following day a new experiment involving the use of ethyl ether was begun. The same procedure was followed as was described with ethylene chlorohydrin in the preceding experiment. All counts and measurements were made two weeks after the start of the treatment.

Photoperiodic Response

The Massachusetts strain of Northern nutgrass was germinated in four Petri dishes. The substrate, which consisted of two thicknesses of germination blotters and one thickness of filter paper, was moistened with tap water. One hundred seeds were placed in each dish on January 27, 1959. These seeds were placed in a germinator and subjected to a germination temperature of 20-30°C. Twenty-four days later the resulting seedlings averaged 2 to 4 centimeters in height with a substantial number of roots varying from 0.5 to 1 mm in length.

The seedlings were removed carefully from the Petri dishes on February 20, and transplanted in number 10 cans containing a fertile sandy loam soil with a pH of 5.6. Three seedlings were transplanted to each of the sixty cans and were thinned later to one seedling per can. These cans were placed in a greenhouse with an average night temperature of 70°F and a day temperature of 85 to 100°F. They were exposed to the prevailing day length period which was slightly less than 12 hours.

On March 21 the plants were divided among three groups; group one was subjected to a 12 hour photoperiod, group two received a 16 hour photoperiod, while the third group received normal daylight. Normal day length consisted of 12 hours of light gradually increasing to over 15 hours of light on June 21, with decreasing day length from that time on. Five of the plants subjected to a 16 hour photoperiod were removed on May 21, and placed in the 12 hour day length period.

Measurements of plant height, and number of leaves and vegetative shoots per plant were recorded weekly. One plant from each treatment was removed at biweekly intervals and the soil washed carefully from the roots in order to determine the extent of tuber formation and growth.

Chemical Control

The plots were located out of doors on a fine sandy loam with a pH of 4.5, and an organic matter content of 4 to 5 per cent. All treatments were replicated four times in a randomized block design. The plot dimensions were 12 feet by 15 feet. All chemicals were diluted with water and applied at the rate of 100 gallons per acre. The sprays were applied with a Brown Open-Hed No. 4 hand pressure sprayer fitted with a No. 8004 Spraying Systems Tee Jet, flat fan-type nozzel. The area was populated with a dense stand of Northern nutgrass.

The first of several different spray applications was begun on July 21, 1958, as post-emergence treatments. The field had been disked four weeks prior to treatment. The hot, humid weather during the day of application was followed by rain in the evening. The following chemicals were applied: Dowpon at 10 and 20 pounds, Amino triazole at 1, 2, 4 and 8 pounds, Eptam at 10 and 20 pounds, Kuron (2-(2,4,5-Trichlorophenoxy)

propionic acid) at 10 and 20 pounds and T.C.A. at 50 and 100 pounds. The plots were rated numerically for control of weeds on a basis of one, indicating poor control to five, indication excellent control.

A few weeks later a second post-emergence treatment was applied. In this test the nutgrass averaged 3 inches in height. These plots had been disked only two weeks before treatment with the following chemicals and their respective per acre rates: CMU at 8 and 16 pounds, Zobar (Polychlorobenzoic acid) at 30 pounds, T.B.A. at 10 pounds, Eptam at 20 pounds, Amino triazole at 4 and 8 pounds, T.C.A. at 50 pounds and Dowpon at 20 pounds.

On September 4, 1958, several chemicals were incorporated into a relatively dry soil by disking. The nine treatments consisted of spraying the plots with Eptam at 10, 20, and 40 pounds, Dowpon at 10, 20, and 40 pounds, T.C.A. at 50 and 100 pounds and Simazine at 10 pounds. These plots were rated later for weed control on a basis of from one to nine.

Four chemicals were applied as pre-emergence sprays to a dry soil on May 21, 1959. The soil was disked twice, the second disking at right angles to the first, within 2 hours after spraying. The chemicals used were: Eptam at 6 and 10 pounds, Atrazine at 4 and 8 pounds, Dowpon at 5 and 10 pounds, and Amino triazole at 4 and 8 pounds.

On June 24, 1959, the following treatments were applied: Zobar at 10, 20, 30, and 40 pounds, T.B.A. at 10, 20, and 30 pounds, Fenac (2,3,-6-trichlorophenylacetic acid) at 5 and 10 pounds, and Atrazine at 5, 10, and 20 pounds. A rain followed soon after application of the herbicides and at this time the nutgrass plants averaged 12 inches in height.

Six days later Dicryl (N-(3,4-dichlorophenyl) methacrylamide) and Karsil (N-(3,4-dichlorophenyl)-2 methylpentanamide) were applied at 4 and 6 pounds per acre and repeat treatments were applied to one-half of the plots on July 16. A 10 pound rate of both of these materials was also applied to previously untreated plots.

Soil samples were collected at random from the plots of the most promising weed control treatments on June 2, 1959. Four samples of the top 4 inches of soil from each replication were tested. Those treatments are presented in Table XXII.

Each soil sample collected was distributed among eight 3 inch pots. Fifteen sweet corn seeds (variety Golden Beauty) were planted in four of the pots, and fifteen oat seeds (variety Clinton) were planted in the other four pots. The pots were than placed at random with respect to treatment on a greenhouse bench. When the seedlings emerged they were thinned to ten oat seedlings per pot, and five corn seedlings per pot.

On June 23, the seedlings were harvested and weighed to the nearest tenth of a gram. The data were analyzed statistically, and the results presented in Table XXII.

RESULTS

Seed Germination

The effect of harvest date and seed weight on the germination of nutgrass is presented in Table II.

TABLE II

Effect of Harvest Date and Seed Weight on the Germination of Nutgrass Seed (Per Cent Germination)

Germination Dates	Seed Lot Number 2	3	4	7	7*	Means
October 17, 1958	73.7	88.0	46.7	39.5	28.0	55.2
October 31, 1958	80.5	87.2	50.5	37.0	36.5	58.3
November 14, 1958	72.5	82.0	43.5	28.7	27.7	50.9
November 28, 1958	71.7	83.0	41.5	29.5	25.2	50.2
December 12, 1958	74.0	77.2	36.5	24.2	26.0	47.6
January 23, 1959	72.7	87.2	46.2	29.7	27.2	52.6
L.S.D. .05	6.7	6.7	6.7	6.7	6.7	4.5
.01	8.8	8.8	8.8	8.8	8.8	5.9
Seed Source Means	74.2	84.1	44.1	31.5	28.5	
L.S.D. .05 - 2.7						
.01 - 3.6						
Seed Weight Means	18.4	19.9	16.5	14.8	15.2	
L.S.D. .05 - 0.7						
.01 - 0.9						

r = 0.9992 -- L.S.D. = 0.878 - 0.959

* Seed was air dried.

There was little or no difference in germination rates among the lots treated on October 17, at the beginning of the tests, and those noted on January 23, at the conclusion of the experiment. The individual seed lots showed little variation throughout the germination period, but the seed sources and the seed weights were significantly different with lot number 3 being outstanding in both per cent germination and seed weight. There was a highly significant correlation coefficient, r= ⁄ 0.9992, between seed weight and seed germination.

The results of the test started on October 24, 1958 to determine the effect of cold storage on the germination of nutgrass seeds are presented in Table III.

TABLE III

Effect of Storage at 10°C on the Germination of Nutgrass Seeds (Per Cent Germination)

Months Stored	Seed Lot Number 1	3	4	Means
1	80.0	88.0	47.0	71.7
2	78.7	86.7	49.0	71.5
3	88.7	87.7	43.5	73.3
L.S.D. .05	6.9	N.S.	N.S.	N.S.
.01	9.3	N.S.	N.S.	N.S.
Seed Source Means	82.5	87.5	46.5	
L.S.D. .05 - 4.0				
.01 - 5.4				

There was no significant difference between the individual treatments or total treatments at one, two or three months, but a highly significant difference did exist among seed lots 1, 3, and 4.

Further results of cold storage on seed germination are presented in Table IV.

TABLE IV

Effect of Cold Storage on the Germination of Seed Lot 8 at 20-30°C

Months Stored	Temperature Room	10°C	5°C	-10°C	Means
1	43.0	50.5	44.7	34.0	43.0
2	58.0	54.7	39.7	37.2	47.4
L.S.D. .05	7.2	N.S.	N.S.	N.S.	3.6
.01	9.8	N.S.	N.S.	N.S.	N.S.
Temperature Means	50.5	52.6	42.2	35.6	
L.S.D. .05 - 5.1					
.01 - 6.9					

It should be noted that storage for two months at room temperature promoted significantly higher germination than did seeds stored at room temperature for one month. As the storage temperature was decreased from 10°C the germination percentage decreased significantly. There was also a significant difference existing between the total storage means of the one and two month treatments.

Results of germination tests showing the effect of temperatures on seed germination are presented in Table V.

TABLE V

Effect of Temperature on the Germination of Northern Nutgrass Seed (Per Cent Germination)

	Seed Lot Number			
Temperature	1	3	6	Means
30°C	7.0	7.7	21.2	12.0
35°C	93.7	84.2	90.2	89.4
20-30°C	85.2	86.5	89.7	87.1
20-35°C	94.7	90.2	89.7	90.7
L.S.D. .05	5.3	5.3	5.3	3.0
.01	7.1	7.1	7.1	4.1
Seed Source Means	69.6	67.2	72.7	
L.S.D. .05 - 2.6				
.01 - 3.5				

All seeds germinated significantly better at 35°C, 20-30°C, and 20-35°C than at constant 30°C. Seed lot 6 (New York strain) germinated significantly higher than lot 3 (Massachusetts strain) and lot 1 (Rhode Island strain); however, there was no significant difference between lot 3 and lot 1.

Further effects of temperature as well as the effects of light, darkness, and 0.2 per cent potassium nitrate solution on seed germination are presented in Table VI.

TABLE VI

Effects of Light, Darkness and Potassium Nitrate at Three Different Temperatures on the Germination of Seed, Lot 3 (Per Cent Germination)

	Treatments				
Temperature	Light & Dark	Light, Dark and KNO_3	Dark	Dark & KNO_3	Means
30°C	15.7	18.0	0.0	1.2	8.8
20-30°C	83.0	87.0	48.0	53.7	67.9
20-35°C	93.5	96.2	95.5	94.7	95.0
L.S.D. .05	4.7	4.7	4.7	4.7	2.4
.01	6.4	6.4	6.4	6.4	3.2
Total Treatment Means	64.1	67.1	47.9	49.9	

L.S.D. .05 - 2.7
.01 - 3.7

Germination in all treatments at alternating 20-35°C was significantly better than those seeds germinated at alternating 20-30°C and constant 30°C, while seeds subjected to 20-30°C germinated significantly better than those at 30°C. It is interesting to note that the effect of darkness was negligible at the higher alternating temperature. The potassium nitrate increased germination significantly when used in conjunction with light and dark.

Additional effects of temperature combined with light, dark, potassium nitrate, and stratification on seed germination are presented in Table VII. All treatments at 20-35°C were significantly better than those subjected to 20-30°C, including the stratified seed. It is evident that seeds stratified for five days at 10°C germinated better than those stratified for thirty days. An outstanding increase in germination was obtained in this test with the use of potassium nitrate at 20-35°C.

TABLE VII

Effects of Light, Darkness, Potassium Nitrate and Stratification at 20-30°C and 20-35°C on the Germination of Seed Lot 12 (Per Cent Germination)

	Treatments					
Temperature	Check	Dark	KNO_3	Strat. 5 Days at 10°C	Strat. 30 Days at 10°C	Means
20-30°C	36.0	1.5	45.0	55.0	37.7	36.8
20-35°C	59.2	46.2	70.0	63.5	56.2	59.3
L.S.D. .05	6.6	6.6	6.6	6.6	6.6	3.0
.01	8.9	8.9	8.9	N.S.	8.9	4.0
Total Treatment Means	47.6	23.9	57.5	59.2	52.2	

L.S.D. .05 - 4.7
.01 - 6.3

The effects of light and dark in conjunction with two germination temperatures on two seed strains are indicated in Table VIII.

TABLE VIII

Comparison of Two Seed Strains at Two Temperatures in Alternating Light and Dark and in Complete Darkness

	Seed Lot Number		
Treatments	11	12	Means
20-30°C	74.0	37.5	55.7
Dark 20-30°C	9.0	0.7	4.9
20-35°C	88.7	56.0	72.4
Dark 20-35°C	85.0	49.7	67.4
L.S.D. .05	5.8	5.8	4.1
.01	8.0	8.0	5.6
Seed Source Means	64.2	36.0	

L.S.D. .05 - 2.9
.01 - 4.0

Nearly twice as many seed of the Massachusetts strain (lot 11) germinated as did the Rhode Island strain (lot 12). Other treatment effects are comparable to results obtained in previous tests.

Heating after-ripened and newly harvested seeds had no significant effect on increasing germination as is shown in Table IX.

TABLE IX

Effects of Heating After-Ripened and Newly Harvested Seeds for Three Hours on Their Germination (Per Cent Germination)

	Seed Lot Number		
Treatments	3	8	Means
Check	75.7	30.7	53.2
50°C ± 1	79.5	19.5	49.5
60°C ± 1	75.2	22.0	48.6
70°C ± 1	78.0	25.0	51.5
L.S.D. .05	N.S.	7.0	N.S.
.01	N.S.	9.5	N.S.
Seed Source Means	77.1	24.3	
L.S.D. .05 - 3.5			
.01 - 4.7			

Seeds soaked in boiling water failed to germinate.

Table X indicates that seed viability was reduced when wet seeds were frozen. Little difference existed between dry seeds frozen for one month and the checks.

TABLE X

Effect of Storage at -15°C for One Month Followed By a Germination Temperature of 20-30°C on Both Wet And Dry Nutgrass Seeds (Per Cent Germination)

Treatments	Seed Lot Number 3	5	Means
Check	88.5	73.2	79.4
Dry	86.5	73.7	80.1
Wet	29.2	38.2	33.7
L.S.D. .05	7.6	7.6	5.3
.01	10.5	10.5	7.4
Seed Source Means	67.8	61.7	
L.S.D. .05 - 4.4			
.01 - 6.0			

In another test seeds of lot 3 showed little variability in germination over a period of eleven months as shown in Illustration I. During this period the seeds germinated in a range of 77.2 and 88.2 per cent with a mean of 84.9 per cent.

Low concentrations of ethylene chlorohydrin promoted increased seed germination as indicated in Table XI. Seeds treated with 0.2 and 0.5 per cent solutions of this chemical were increased in germination over the check, while seeds treated with higher concentrations showed a significant decrease in germination.

ILLUSTRATION I

Variation in the Germination of Seed Lot 3

Over an Eleven Month Period at 20-30°C

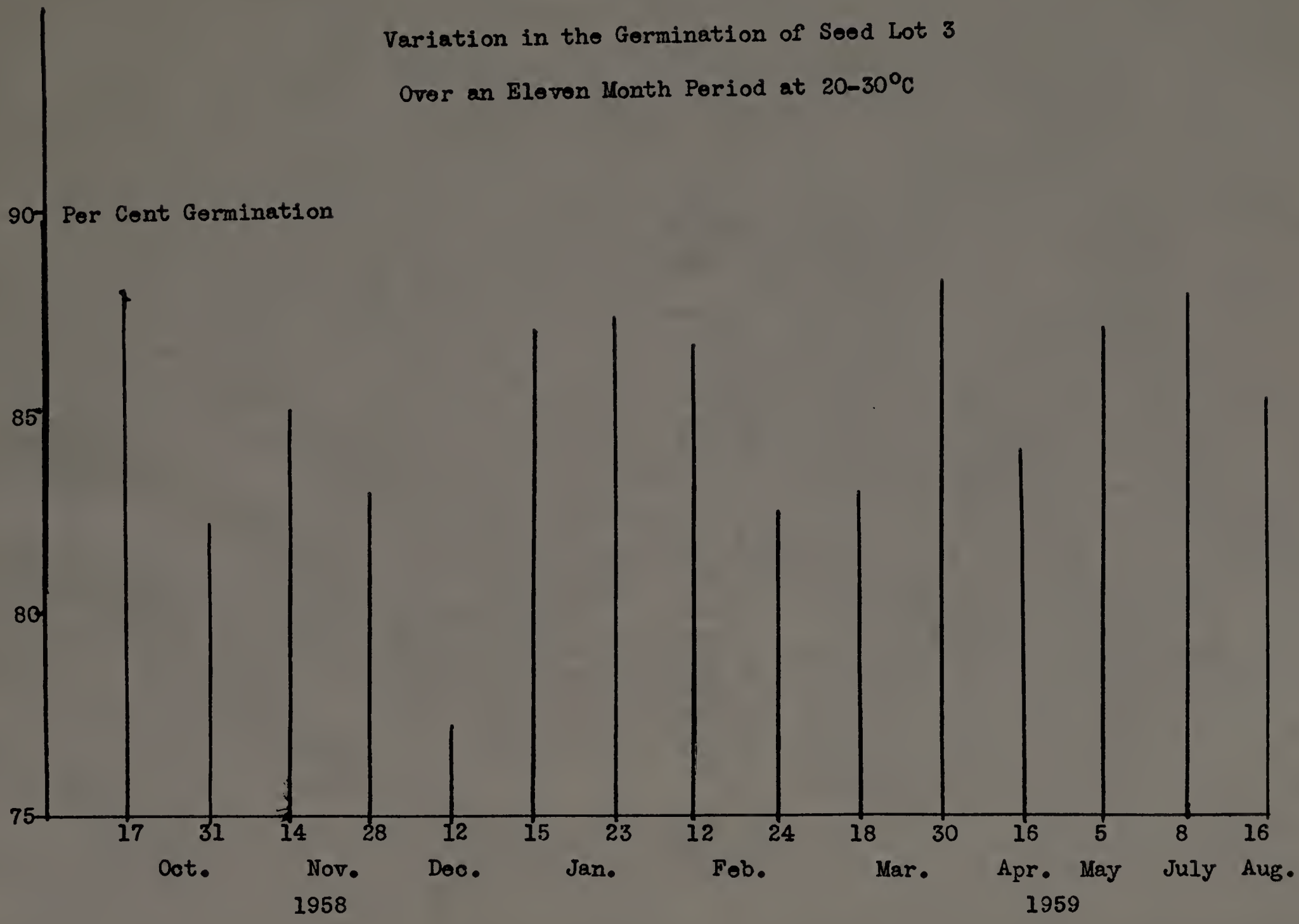


TABLE XI

Effect of Ethylene Chlorohydrin on Seed Germination

Treatment			Seed Lot Number 8
Check			29.7
0.2%	Ethylene	Chlorohydrin	50.7
0.5%	"	"	46.0
1%	"	"	8.7
2%	"	"	0.0
5%	"	"	0.0
L.S.D.	.05		4.9
	.01		6.8

The data in Table XII shows that germination was increased when seeds were scarified with concentrated sulphuric acid for two, five, and ten minutes.

TABLE XII

Effect of Seed Scarification with Concentrated Sulphuric Acid on the Initial Germination Count at Eighteen Days and the Final Germination Count at Forty-Five Days of Seed Lot 3

Treatment		Days 18	45
Check		71.7	84.0
2 Minutes		88.0	91.0
5	"	87.7	90.0
10	"	90.7	91.0
L.S.D.	.05	7.5	6.5
	.01	10.7	N.S.

Counts made after eighteen days showed that the scarified seed germinated significantly better than the control at both the .05 and .01 levels, but after forty-five days significance was evident only at the .05 level.

The results of seed treatments with a strong base, an oxidizing agent, and a reducing agent are presented in Table XIII. None of the chemicals used produced any effects on seed germination which differed significantly from the check.

TABLE XIII

Effect of Seed Treatment with Various Chemicals on the Germination of Seed Lot Number 3

Treatment	12.5M NaOH	0.1M $KMnO_4$	0.1M $C_6H_6O_3$
Check	87.7	82.7	85.7
2 Minutes	85.2	82.5	86.0
5 "	85.0	87.0	84.7
10 "	90.0	82.7	84.7
L.S.D. .05	N.S.	N.S.	N.S.

Further results from several chemical treatments are shown in Table XIV. Seeds treated with a 0.1 per cent potassium nitrite solution and a 0.2 per cent ammonium nitrate solution excelled in germination. Other chemicals and combinations of chemicals failed to increase seed germination to any marked extent.

TABLE XIV

Effects of Various Chemicals on the Germination of Seed Lot 12 at 20-30°C

Treatments	Per Cent Germination	Treatments	Per Cent Germination
Check	47.7	0.2% $MnSO_4$/KNO_3	46.5
1% KNO_2	--	0.1% " "	49.5
0.5% "	4.7	1% $MnSO_4$/NH_4NO_3	1.0
0.2% "	49.0	0.5% " "	40.2
0.1% "	56.0	0.2% " "	43.5
1% NH_4NO_3	26.0	0.1% " "	44.0
0.5% "	53.2	1% KNO_3	42.0
0.2% "	57.2	0.5% "	45.5
0.1% "	54.2	0.2% "	45.7
1% $MnSO_4$/KNO_3	33.2	0.1% "	47.7
0.5% " "	46.7		
L.S.D. .05	5.9	L.S.D. .05	5.9
.01	7.8	.01	7.8

Tuber Dormancy

TREATMENT I

The tubers appeared to be dormant with little or no sprouting at any of the temperatures used. The following treatments appeared to have no effect on per cent germination: darkness, five day stratification period, and potassium nitrate solution.

Stratification for one and two months at 10°C was the only treatment used that gave results significantly better than the check. Tubers stratified for one month and then subjected to 20-30°C for forty-eight days sprouted at 42 per cent. After being stratified for two months at 10°C, followed by only thirteen days at 20-30°C, 77.5 per cent sprouting was obtained.

TREATMENT II

It is evident from observing Table XV that the results from this experiment were extremely variable.

TABLE XV

Germination Results Obtained by Several Chemical Treatments on Dormant Northern Nutgrass Tubers

Figures Are The Means Of Four Replications

Treatment	Mean Shoot Length	Mean Root Length	Mean No. Sprouts/Tuber	Per Cent Germination
Check	2.35	4.19	1.05	15.0
" *	3.45	3.36	1.00	13.3
" **	3.59	5.15	1.00	15.8
1% KSCN	0.58	1.96	1.28	79.2
2% "	0.54	1.52	1.67	90.8
4% "	0.49	0.41	1.47	65.8
0.5% Ethylene Chlorohydrin	5.59	5.68	1.14	100.0
1% "	4.63	5.10	1.17	90.0
2% "	3.20	3.36	1.07	65.0
4% "	1.32	1.03	1.12	36.7
1% Thiourea	2.29	2.18	1.22	80.0
2% "	0.96	0.18	1.97	97.5
4% "	0.52	--	2.27	86.7
6% "	0.50	--	2.23	34.2
L.S.D. .05	1.06	1.12	0.14	22.6
.01	1.42	1.51	0.19	30.3

* Tubers soaked in water for 1 hour.
** Tubers dipped in water then placed in an air tight jar for 24 hours at 30°C.

PHOTOGRAPH I

Tubers treated with ethylene chlorohydrin.
Upper left to right: Check, 0.5% E.C.
Lower left to right: 1% E.C., 2% E.C., 4% E.C.

The effect of ethylene chlorohydrin on tuber sprouting is illustrated in Photograph I. All the tubers treated with a 0.5 per cent ethylene chlorohydrin solution germinated and produced the longest root and shoot lengths. As the concentration of ethylene chlorohydrin was increased, the germination, as well as root and shoot lengths decreased significantly.

Potassium thiocyanate and the thiourea increased tuber germination when compared with the untreated tubers, but root and shoot lengths were reduced by these treatments. Both of these chemicals also increased substantially the number of vegetative shoots per tuber. Tubers treated with 2, 4, and 8 per cent thiourea averaged two or more sprouts each, as compared to the untreated tubers which averaged one sprout each.

TREATMENT III

The data in Table XVI present the results obtained from tubers stored at 10°C for two months; later the tubers were transferred to various concentrations of ethyl ether and held in a closed container for 24 hours at 30°C. The root and shoot length increased proportionately as the concentration of ether was increased from 0.1 to 2 per cent. When the ethyl ether concentration was increased to 4 per cent a highly significant decrease in root and shoot length resulted, while the germination percentage and the number of sprouts per tuber increased significantly. Stratification for two months in soil at 10°C without the ether treatment resulted in only 48 per cent germination.

TABLE XVI

Germination Results Obtained With Northern Nutgrass Tubers Stored in Soil at 10°C For Two Months Followed by Treatment with Ethyl Ether to Break Dormancy

Figures Are The Means Of Four Replications

Treatment	Shoot Length	Root Length	Sprouts/ Tubers	Germination
Check	3.86	4.76	1.12	48.35
0.1% Ethyl Ether	4.30	4.59	1.08	60.00
0.2% " "	5.08	4.95	1.05	65.00
0.5% " "	5.50	5.23	1.01	50.82
1% " "	5.83	5.67	1.04	61.67
2% " "	6.25	6.15	1.08	59.17
4% " "	3.84	3.79	1.78	100.00
L.S.D. .05	0.77	0.84	0.12	12.28
.01	1.06	1.15	0.17	16.82

Photoperiodic Response

The newly transplanted seedlings developed four leaves and reached a height of nearly four centimeters after three weeks had elapsed. While the seedlings were exposed to short day conditions prior to March 21, small tubers began to form on the stolons.

The plant heights and number of leaves and vegetative shoots are shown as they developed at weekly intervals in Illustrations II, III, and IV respectively. Photographs II, III, IV, and V show the root and subsequent tuber development at biweekly intervals.

It is readily seen in the Illustrations and Photographs that the 12 hour photoperiod was unfavorable for vegetative growth of Northern nutgrass. The plants receiving this treatment eventually attained a maximum height of thirteen centimeters with eight leaves. No vegetative shoots were produced, but tuber production continued throughout the growing period, increasing gradually to twenty-eight tubers per plant.

Plants exposed to a 16 hour photoperiod made a noteworthy vegetative response. Vegetative shoots first made their appearance in ten weeks and increased throughout the growing period until the twenty second week when there was an average of forty large, vigorously growing shoots per plant. The growth of these plants was rapid with the height gradually increasing to 111 centimeters and the leaf number to thirteen per plant. Tuber formation ceased when this long-day photoperiodic treatment began. It was not until the plants approached maturity in their twentieth week that tuber formation was again initiated. In the following two weeks over one hundred tubers developed on each plant.

The five nutgrass plants that were moved from the 16 hour photoperiod to the 12 hour photoperiod on May 21 made little or no additional vegetative top growth. In less then three weeks, however, tuber formation was initiated. By the fourth week the stolons were covered with a mass of mature brown tubers. The tubers were larger and more mature appearing than those found on the plants receiving sixteen hours of light. Over two hundred and fifty tubers were counted on an individual plant.

Plants grown under normal daylength developed slowly at first, but gradually increased in height and number of vegetative shoots as the daylength increased. These plants produced many more leaves than either of the other treatments. Tuber development increased slowly until the sixteenth week at which time development was rapidly accelerated. These plants ultimately produced over one hundred and fifty tubers each.

At no time during the entire experiment was there any evidence of flower formation.

ILLUSTRATION II

Height Response of Nutgrass to Photoperiod

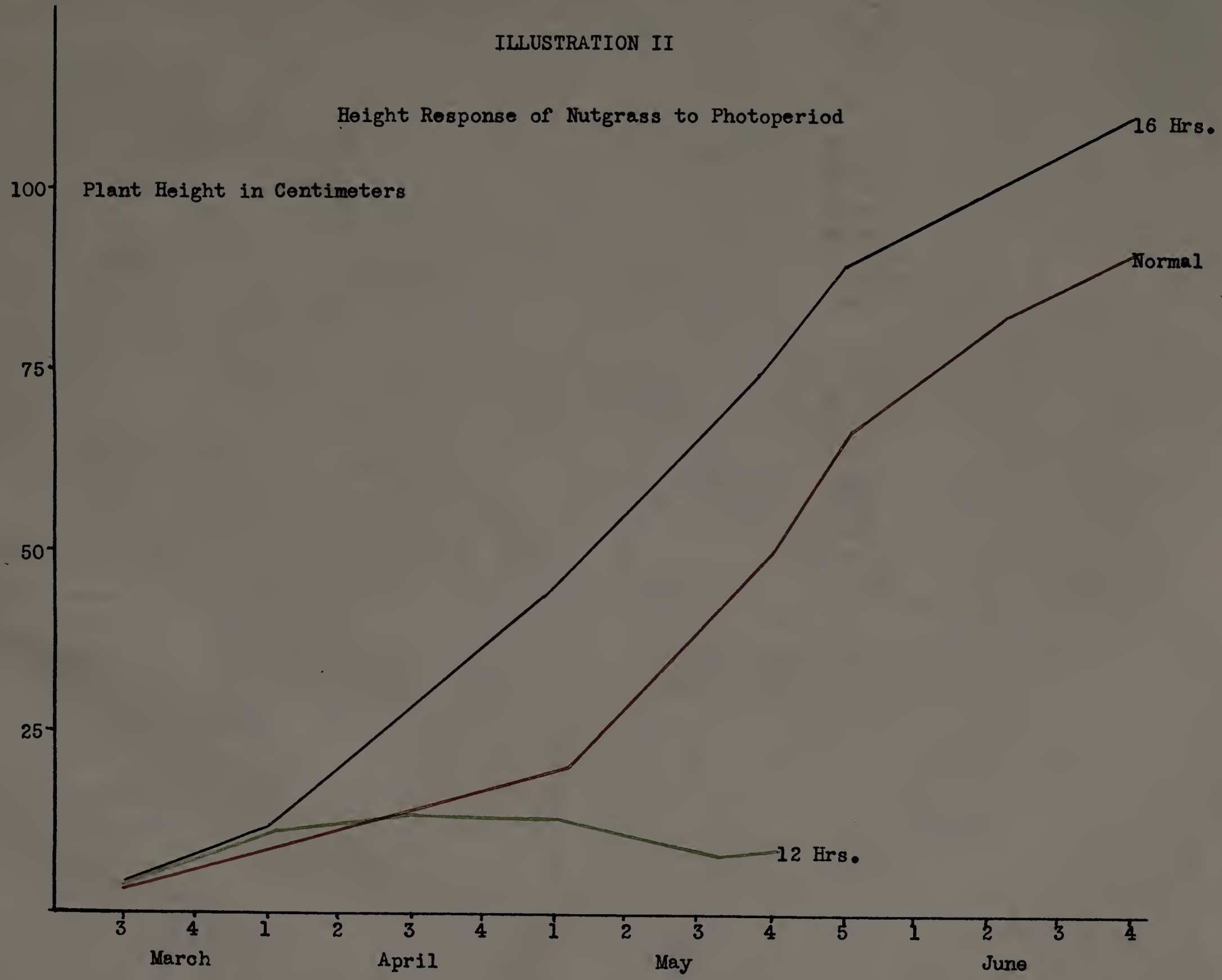


ILLUSTRATION III

Rate of Leaf Development of

Nutgrass to Photoperiod

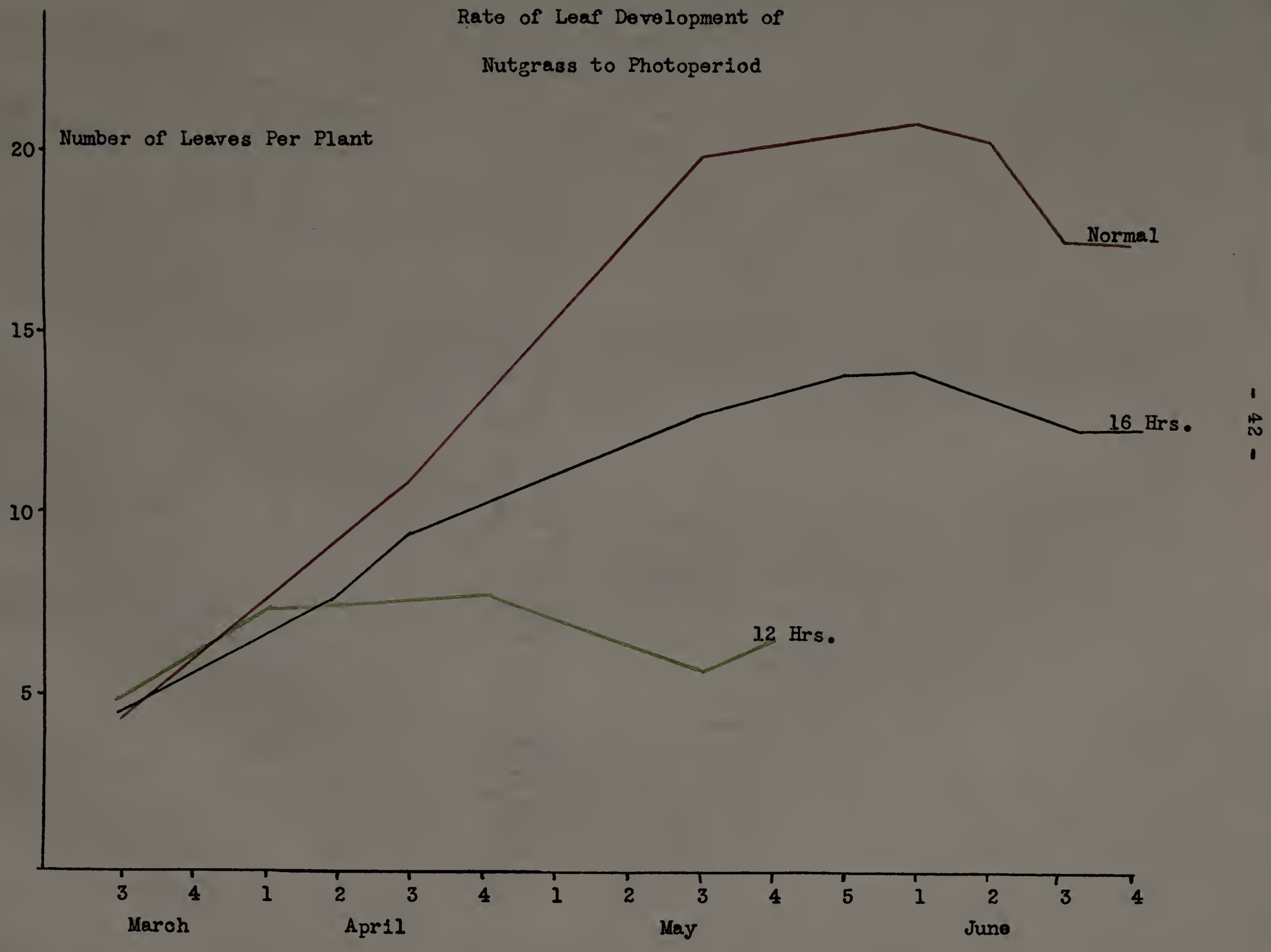
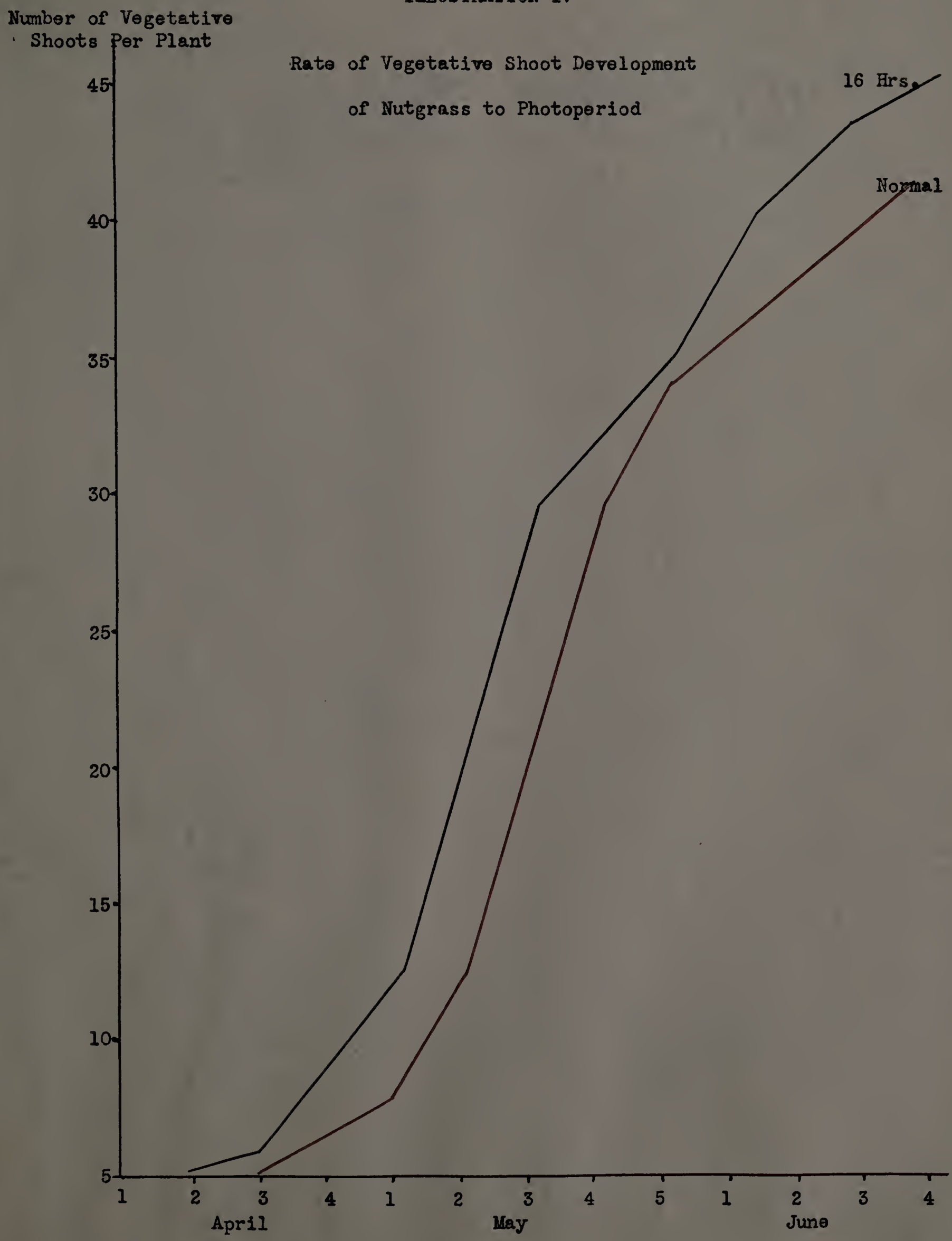


ILLUSTRATION IV

Rate of Vegetative Shoot Development of Nutgrass to Photoperiod



PHOTOGRAPHS II and III

Seven week-old seedlings after exposure
to a short-day period.

Twelve week-old nutgrass plants after
exposure to various daylength periods.

Left to right: 12 hours, normal and 16 hours.

PHOTOGRAPHS IV and V

Eighteen week-old nutgrass plants after exposure to various daylength periods. Left to right: 12 hours, normal, 16 hours, and 16 hours for 16 weeks followed by 12 hours for 2 weeks.

Twenty week-old nutgrass plants after exposure to various daylength periods. Left to right: 12 hours, normal, 16 hours, and 16 hours for 16 weeks followed by 12 hours for 4 weeks.

Chemical Control

The results of the first post-emergence chemical control experiment are presented in Table XVII.

TABLE XVII

Effect of Various Herbicides on Nutgrass

Applied on 7/21/58 and 8/5/58

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Ratings-1 Poor to 5 Excellent 8/20/58	9/23/58	5/28/59
1	Dowpon	10.0	4.75	3.75	1.00
2	"	10.0	2.50	2.25	1.00
3	"	20.0	5.00	4.75	1.25
4	"	20.0	3.25	2.75	1.25
5	Amino Triazole	1.0	2.50	2.00	1.00
6	" "	2.0	3.25	3.00	1.00
7	" "	4.0	3.25	2.75	1.00
8	" "	8.0	4.25	4.25	1.25
9	" "	2.0	4.25	4.75	1.00
10	" "	4.0	5.00	4.75	1.00
11	Eptam	10.0	3.00	3.50	1.00
12	"	20.0	3.75	4.00	1.00
13	Kuron	2.0	1.75	1.75	1.00
14	T.C.A.	50.0	4.25	4.00	1.25
15	"	100.0	5.00	4.00	1.50
16	Control	--	1.00	1.00	1.00
L.S.D.	.05		0.80	0.74	0.37
	.01		1.06	0.99	0.49

A double application of Dowpon decimated the entire nutgrass stand in four weeks time. New plants began to appear in all the plots before the end of the season, however, by the next spring these plots were comparable to the checks.

The plants sprayed with Amino Triazole began to show the characteristic leaf blanching eleven days after treatment. These plots as well as those treated with Eptam and T.C.A. showed promise in 1958, but gave little or no control the following year.

The second post-emergence treatment gave results similar to the first treatment, as shown by Table XVIII; CMU and Zobar treatments are exceptions.

TABLE XVIII

Effect of Various Herbicides on Nutgrass

Applied on 8/22/58

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Ratings-1 Poor to 5 Excellent 9/23/58	5/28/59	7/7/59
1	CMU	8.0	5.00	2.00	1.00
2	"	16.0	5.00	2.50	3.25
3	Zobar	30.0	1.75	4.00	2.50
4	T.B.A.	10.0	1.50	2.25	1.00
5	Eptam	20.0	1.00	1.00	1.00
6	Amino Triazole	4.0	4.00	1.00	1.00
7	" "	8.0	4.50	1.00	1.00
8	T.C.A.	50.0	4.25	1.00	1.00
9	Dowpon	20.0	3.75	1.00	1.00
10	Control	--	1.00	1.00	1.00
L.S.D.	.05		0.43	0.48	0.38
	.01		0.59	0.65	0.52

Zobar appeared to retard temporarily tuber sprouting in the spring following a summer application, however, by mid-summer the effect of Zobar on tuber sprouting had disappeared. CMU at the higher level gave better control as the season progressed.

The data presented in Table XIX indicate that significant control was not obtained with Eptam at the 10 pound rate. Numerous tubers sprouted throughout the plots early in the year producing a heavy stand of nutgrass. The 20 pound rate resulted in some reduced growth of the weed while 40 pounds resulted in practically complete control. Photographs VI and VII show the effect of Eptam at the 40 pound rate in the spring following the fall application, as compared with the control. Simazine was the only other treatment in this test that showed any control the following year, however, the nutgrass recovered markedly as the season progressed.

TABLE XIX

Effect of Various Herbicides Incorporated

in the Soil on Nutgrass

Applied on 9/4/58

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Ratings- 1 Poor to 9 Excellent 5/28/59	7/15/59	8/21/59
1	Eptam	10.0	2.25	1.00	1.00
2	"	20.0	6.00	6.00	5.00
3	"	40.0	8.75	8.50	8.25
4	Dowpon	10.0	1.00	1.00	1.00
5	"	20.0	1.00	1.00	1.00
6	"	40.0	1.00	1.00	1.00
7	T.C.A.	50.0	1.00	1.00	1.00
8	"	100.0	1.00	1.00	1.00
9	Simazine	10.0	3.25	1.00	1.00
10	Control	--	1.00	1.00	1.00
L.S.D.	.05		0.56	0.18	0.44
	.01		0.76	0.24	0.60

Pre-emergence treatments with Eptam and Atrazine gave excellent nutgrass control, as shown in Table XX.

TABLE XX

Effects of Eptam and Atrazine on Nutgrass

Applied on 5/21/59

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Date Cultivated	Ratings-1 Poor to 9 Excellent 7/15/59	8/21/59
1	Eptam	6.00	6/22/59	7.50	7.00
2	"	10.00	"	8.50	7.50
3	Atrazine	4.00	"	7.00	6.75
4	"	8.00	"	8.50	8.75
5	Control	—	"	1.00	1.00
L.S.D.	.05			1.54	1.89
	.01			2.16	2.65

There was little or no significant difference between the Eptam and Atrazine irrespective of rate although the 8 pound application of Atrazine appeared to be the most promising. Neither the Amino Triazole nor Dowpon treatments resulted in any indication of control.

PHOTOGRAPHS VI and VII

Nutgrass check plot on June 3, 1959.

Eptam at the 40 lb. rate on June 3, 1959
following the fall applications.

A post-emergence treatment of Atrazine was applied to nutgrass plants which averaged ten inches in height on June 24. This treatment proved to be very effective since nearly all the top growth of these plants was dead or dying within two weeks after treatment. Shortly after this time, however, newly sprouted basal lateral plants began appearing in the plots that received the 5 pound application. This sprouting continued as the season progressed, but the plots treated with 10 and 20 pounds of Atrazine showed no such basal growth or recovery of the nutgrass. Control appeared to be maintained completely throughout the remainder of the summer, as indicated in Table XXI.

TABLE XXI

Effects of Atrazine on Nutgrass

Applied on 6/24/59

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Ratings-1 Poor to 9 Excellent 7/15/59	8/21/59
1	Atrazine	5.0	7.0	5.0
2	"	10.0	8.0	9.0
3	"	20.0	9.0	9.0
4	Control	--	1.0	1.0
L.S.D.	.05		1.6	1.6
	.01		2.3	2.3

The only visible control obtained where Zobar was used was a slight stunting of the nutgrass plants with little or no mortality. T.B.A. applied at the 10 pound rate showed results similar to those attained with Zobar.

The nutgrass plants treated with 20 and 30 pounds of active material resulted in 70 per cent control two months after application.

At no time did Fenac at 5 and 10 pounds show any indication of control other than a very slight yellowing at the leaf tips.

The final post-emergence treatment of 1959 included Dicryl and Karsil at 10 pounds, as well as double application at the rate of 4 and 6 pounds. These materials had only slight effects on well-developed nutgras plants, since the only symptoms observed were tip burning followed by a slight reduction in growth.

The effects of the soil bio-assay made in the spring of 1959 are presented in Table XXII.

TABLE XXII

Soil Bio-assay With Corn and Oats

Samples Collected 6/2/59

Figures Are The Means of Four Replications

Plot No.	Herbicide	Rate/Acre Lbs. Active	Date Applied	Corn Weight	Oat Weight
1	Eptam	20.0	9/4/58	19.45	2.45
2	"	40.0	"	20.75	0.07
3	Zobar	30.0	8/27/58	16.30	7.17
4	T.B.A.	10.0	"	17.70	6.55
5	Atrazine	10.0	9/30/58	17.35	0.20
6	Control	--	--	17.15	9.27
L.S.D.	.05			N.S.	2.53
	.01			N.S.	3.50

It is evident that there was no significant difference in the weight of corn plants among the treatments and the check. A slight twisting and stunting was evident on a few of the plants grown in the soils treated with T.B.A. and Zobar.

Eptam at both levels, Atrazine and T.B.A. produced a substantial loss in weight of oat plants as compared to the plants in the check.

The symptoms produced on the oat plants by the various chemicals may be observed in Photographs VIII and IX.

PHOTOGRAPHS VIII and IX

The effects of a soil bio-assay using oats as an indicator crop; 1, check; 19, Eptam at 20 lbs. per acre; 39, Eptam at 40 lbs. per acre.

The effects of a soil bio-assay using oats as an indicated crop; 60, Zobar at 30 lbs. per acre; 75, T.B.A. at 10 lbs. per acre; 88, Atrazine at 10 lbs. per acre.

DISCUSSION

Seed Germination

The results presented in Table II indicate that the seed dormancy found to be present by Justice and Whitehead (23) in both Alabama and New York seeds is not present in the Massachusetts seed. It is possible that the plants of various areas have some genetic differences which might account for specific strains of nutgrass. The lack of dormancy in the Massachusetts strain might also be attributed to a difference of some genetic characters.

The time of harvest does appear to be extremely important when collecting seeds for germination. There is a significant reduction in germination when the seeds are harvested as little as ten days before or immediately after a frost. In this particular case, those seeds collected just before the first frost were the heaviest and germinated best. The tremendous reduction in weight and germination of seeds collected after the frost appears to be caused by the heavier and more mature seeds dropping from the inflorescence, with the lighter more immature seeds remaining. It was observed that fewer seeds were obtained per inflorescence in collections made after the first frost as compared to collections of twelve hundred or more seeds per inflorescences made prior to the frost.

The highly significant positive correlation obtained between seed weight and germination indicates a close association between these factors. Similar results were also obtained by Justice and Whitehead (23) in their germination studies.

The fact that no substantial increase in germination was obtained by stratifying seeds at 10°C shows further the lack of dormancy in this newly harvested seed.

Further observations on seeds of the Rhode Island strain, harvested in early August of 1959, indicate that storage temperatures lower than 10°C are detrimental to seed germination. The increase in germination of seeds stored for two months at various temperatures over those stored for one month is due to the increase in germination of those seeds stored at room temperature. This increase appears to be due to a breaking of dormancy, since the Rhode Island strain exhibits partial primary dormancy. This dormancy is overcome to some extent by after-ripening the seeds in dry storage for two months. Steinbauer and Grigsby (34) indicate that the need for after-ripening is common in many plant families.

Nutgrass appears to be very specific in its temperature requirements for seed germination. Of the treatments tried, either a high constant temperature of 35°C or an alternating temperature of 20-35°C resulted in optimum germination. A reduction in temperature from 35°C to 30°C reduces germination greatly, but a decrease from 20-35°C to 20-30°C has no such effect on mature seed. The New York strain (Lot 6) appears to be less specific in its germination requirements.

Seeds germinate poorly when subjected to complete darkness at a temperature considered to be slightly lower than optimum. This darkness effect is readily offset by germinating the seeds at their optimum temperature. It is evident that potassium nitrate does promote increased seed germination when used in conjunction with alternating light and darkness, but has no effect on seeds germinated in complete darkness.

Temperature appears to be a factor of even greater importance when testing newly harvested seeds. These seeds require a higher alternating temperature (20-35°C) for optimum germination, but fully after-ripened seeds germinate equally well at a lower alternating temperature (20-30°C). A better response is obtained when newly harvested seeds are treated with a potassium nitrate solution or stratified for five days. The inhibiting effect of darkness is even more pronounced at other than optimum temperatures when this seed is used.

Both the Massachusetts and Rhode Island strains of seed appear to react similarly under various temperature and light conditions, but ordinarily the Massachusetts strain germinates at a much higher rate. The lower rate of germination of the Rhode Island strain seems to indicate further that partial primary dormancy may be present, as indicated previously.

Subjecting seeds to high temperatures (50, 60 and 70°C) for three hours prior to germination had little effect on seed germination. The germination of imbibed seeds, subjected to a low temperature of -15°C for one month, was effectively reduced.

Nutgrass seed is stimulated by several different chemicals in that seed germination is greatly enhanced when partially dormant seeds are subjected to ethylene chlorohydrin gas. The significant increase in germination by seeds which had been soaked in concentrated sulphuric acid was probably due to the ability of the acid to make the seed coat more permeable to water and oxygen. The hardness or impermeability of this seed coat is shown by its ability to withstand a concentrated acid

for a relatively long period of time. A concentrated solution of sodium hydroxide failed to produce similar results.

Tuber Dormancy

Failure of freshly harvested tubers to germinate under the various growing temperatures indicated that dormancy was present. The fact that the germination rate was not altered by the use of a 0.2 per cent potassium nitrate solution or by the stratification of tubers at 10°C for five days indicate further their extreme dormant condition. The importance of subjecting the tubers to a long cool period of 10°C for one and two months in breaking dormancy was indicated by the resulting 42 and 77.5 per cent germination respectively. Further work is necessary to determine the length of stratification and other factors necessary to obtain 100 per cent tuber germination.

It was found that the long period of cold exposure needed to break tuber dormancy could be eliminated by using potassium thiocyanate, ethylene chlorohydrin, thiourea, and ethyl ether. Applications of these chemicals induced 90 to 100 per cent tuber germination within two weeks. A 0.5 per cent solution of ethylene chlorohydrin appeared to be the most effective treatment for promotion of germination and root and shoot growth. This treatment had little or no effect on the apical dominance of the terminal bud. Both the potassium thiocyanate and thiourea solutions were capable of breaking the apical dominance, which resulted in the production of one to four vegetative shoots per tuber. Denny (9) found that potato tubers soaked in a dilute solution of thiourea developed multiple sprouts. Although high germination was induced with these two chemicals it was evident that root and shoot growth were seriously affected. It has not

been determined whether the reduced development of tubers would terminate and be followed eventually by normal growth.

It was evident that a two month stratification period in soil did partially break tuber dormancy, while a further treatment of 4 per cent ethyl ether broke it entirely. This concentration gave the highest rate of germination and number of sprouts per tuber, as well as the shortest root and shoot lengths. This would seem to indicate that root and shoot growth were retarded by this particular ether concentration even though germination was stimulated.

In future tests it would be desirable to plant the treated tubers in soil, and observe their growth habits over a longer period of time to indicate possible prolonged effects.

Photoperiodic Response

It is evident that the length of the daily photoperiod has a definite effect on the vegetative development of nutgrass, but appears to have no effect on flower initiation. When short day conditions prevail, very little plant growth is made as compared to the abundant vegetation produced by the plants exposed to the long day photoperiod.

Tubers develop continuously throughout the entire short day period, whereas, tuber formation in long day plants does not occur until very late in the growth cycle. Any abrupt shortening of the day length period appears to hasten tuber formation. Garner and Allard (16) indicate that short days are an important factor in the formation of potato tubers, and the data presented here is in agreement with their findings.

Chemical Control

It is evident that several different chemicals will kill the top growth of Northern nutgrass. In most cases, basal lateral sprouting occurs within a short time after the application of the chemical and in the following spring new plants appear thereby terminating any semblance of control.

When incorporated in the soil at high rates in the fall, Eptam treatments promoted practically complete control throughout the following year. A soil bio-assay test made the spring following the application showed that the higher rates of Eptam had little or no effect on the growth of sweet corn, but affected seriously the growth of oats. These results indicate that careful screening for tolerant crops would be necessary before planting on soils that have been treated with Eptam.

Eptam and Atrazine applied at low rates in the spring, and incorporated in the soil appeared to give excellent seasonal control.

Atrazine was also very effective when applied as a post-emergence spray to relatively well-developed plants. At the higher rates, no basal lateral sprouting developed, and the plots remained free of nutgrass for the entire season.

SUMMARY

All seed germination studies were made in the Seed Laboratory on the University of Massachusetts campus under the carefully controlled conditions considered optimum by the Association of Official Seed Analysts. Seeds were harvested at several different stages in the field each year and germinated shortly after harvest.

In the Massachusetts strain of nutgrass a highly significant correlation exists between seed weight and seed germination. There is no evidence of dormancy present in this strain, but the Rhode Island strain does appear to be partially dormant. Seeds of the Massachusetts strain exhibit a little variability in germination over an extended period of time.

Optimum germination results are obtained with an alternating temperature of 20-35°C. Mature seeds seem to be less exacting in temperature requirements than do newly harvested seeds. The New York strain appears to be a little more variable in its germination requirements than doseeds of either the Massachusetts or Rhode Island strain.

Stratification at 10°C resulted in inoreased germination in several tests, while temperatures lower than 10°C were detrimental to seed germination. There was no increase in germination when seeds were stratified for more than five days.

Seeds subjected to high temperatures for a short period failed to increase in germination.

Germination is inhibited by complete darkness at other than optimum temperatures.

Seed germination is stimulated by several chemicals such as; potassium nitrate, potassium nitrite, sulphuric acid, ethylene chlorohydrin, and ammonium nitrate.

Freshly harvested nutgrass tubers were found to be dormant. This dormancy was broken partially by stratification at 10°C for one and two months and was broken completely by chemical treatment. The per cent germination, number of sprouts per tuber, root length and shoot length varied considerably with the chemical and the concentration used. The most pronounced results were obtained from tubers treated with a 0.5 per cent solution of ethylene chlorohydrin and a 4 per cent ethyl ether solution.

Nutgrass plants subjected to a sixteen hour daylight period grew rapidly producing numerous vegetative shoots. Tubers were not produced until the plants approached maturity. Plants which received only twelve hours of daylight made little top growth and no vegetative shoots were produced, but tubers were formed continuously throughout the growing period. Flowers were not initiated in any of the tests.

Eptam and Atrazine appear to be the most promising of the chemicals tested for nutgrass control. Excellent control of Northern nutgrass resulted where 20 to 40 pounds of Eptam was incorporated thoroughly in the soil. At 40 pounds per acre recovery of this weed was practically nil the year following application. Excellent seasonal control was also obtained at the rates of 6 to 10 pounds per acre.

Atrazine at the rate of 10 to 20 pounds per acre appeared to be especially effective in post-emergence treatments. Pre-emergence treatments were also very effective at 4 to 8 pounds per acre when incorporated with the soil. The potential recovery of nutgrass has not been ascertained in the year subsequent to Atrazine treatment.

A soil bio-assay revealed that Eptam and Atrazine were still actively present the spring following a summer application.

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