# Germination Studies on Buffel Grass Seed

By

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## PREFACE

A large number of the forage plants of the United States have a period of seed dormancy that must be broken before maximum germination is obtained. Much research has been done on seed dormancy of many species, but very little has been done on delayed germination in Pennisetum ciliare.

Before a study of dormancy in Pennisetum ciliare could be made, it was necessary to know the various factors that inhibit or prevent germination. Cause of dormancy varies widely with the different species and each type of dormancy requires a specific treatment or treatments to induce germination. The methods used in breaking dormancy in other species should be studied and incorporated into the tests run on a new species to increase germination. The purpose of this study is to determine the cause of dormancy in Pennisetum ciliare and to find a treatment that will increase germination of freshly harvested seed.

My thanks are extended to Dr. J. R. Harlan and other members of my graduate committee of Oklahoma Agricultural and Mechanical College for their patience and help in completing my thesis. Acknowledgement is due Drs. E. C. Holt, E. C. Bashaw, R. C. Potts, and other members of the Department of Agronomy, Texas Agricultural and Mechanical College for their invaluable aid and advice in establishing the germination tests on Pennisetum ciliare.

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# INTRODUCTION

Buffel grass, Pennisetum ciliare L., has recently received much publicity as a forage grass for the Southern United States. This grass is apparently adapted to light sandy soils where minimum temperatures do not go below 5°F.

Considerable difficulty has been experienced in establishing buffel grass from freshly harvested seed. Summer seeding of spring harvested seed give very poor results but seed carried over from the previous year have given excellent stands. Many seeds are harvested in the spring in the southern section of the region of adaptation and these are sent to the more northern growing regions, to be planted during the same growing season.

Delayed germination in seeds has long been a problem in establishment of many species. In many instances dormancy is helpful in maintaining a seed supply in the soil from one season to another. Griswold (16) found that many western range plants of the United States depend on seed dormancy for survival.

Dormancy is detrimental in some of our field crops and pasture plants where the seeds are harvested in the spring and seeded in the fall. The period between harvest and seeding date may be insufficient for the dormancy to be well broken. The result is a poor stand and loss in production. According to Bass (3) many varieties of oats fall into this category. Buffel grass, if seeded the same season it is harvested will give low germination.

There are numerous forms of dormancy in the seeds of various species of grasses. It was necessary to know these forms of dormancy to determine the cause of inhibition of germination in buffel grass seeds. In establishing the cause of dormancy, tests were run to determine the source and exact nature of the inhibitor. After it was established that an inhibitor was present, treatments were set up to find a means of breaking dormancy. The treatments used were all based on previous work with seeds of other species. The data presented here are concerned with the various means of breaking dormancy with chemicals, temperature and moisture variations, solvents, and adsorbents.

## LITERATURE REVIEW

The literature on seed germination is extremely voluminous, therefore most of the references used here will deal only with dormancy and germination of forage grass seeds.

The cause of delayed germination in seeds may vary with the different species. Crocker (7) made an extensive study on the role of the seed coat in dormancy. He found that the seed coat could interfere with imbibition of water or normal exchange of gases. In this work he also found that encasing structures interfere with absorption of water, per cent gas exchange, and may also produce an inhibitor to germination. Evenari (10) and Evenari, Konis and Ullman (11) found in their studies on dormancy, that the seedcoat, enclosing structures and the embryo itself might inhibit germination. They found that the glumes, lemma, and palea could produce substances such as HCN or ammonia thus retarding germination. Nazarenko and Djadjun (17) obtained results very similar to Crocker and Evenari. Laibach and Keil (15) found that hulls of certain plants produce HCN to cause delayed germination.

In many species the simplest type of seed treatment to induce germination is soaking the dormant seed in water. Akamine (1) reported an increase from 6.7 per cent to 49 per cent in Panicum prolutum when soaked 4 days in tap water. Wenger (26) found that soaking the burs of buffalo grass in water from 2 to 4 hours, followed by drying at room temperature, increased the germination from 7 per cent to 43.6 per cent. In studying the effect of alternate soaking and drying on 42 western range plants, Griswold (12) found that the effects were variable with the species. The

germination was increased in some species while in others it was retarded by wetting. Some species were not affected in any way by this treatment.

The use of chemicals in breaking dormancy and inducing germination of seeds has been widely used. The chemicals most commonly used for grass seeds are nitrogen carrying compounds such as $KNO_3$, $NaNO_3$, $NaNO_2$, $HNO_3$, and $NH_4SCN$. Akamine (1) found that 1 per cent $NH_4SCN$ increased the germination of feathery pennisetum from 44.5 per cent to 92.4 per cent. Toole (22) and Toole and Toole (25) observed that a 0.2 per cent solution of $KNO_3$ stimulated germination when used as a germinating medium. Canada bluegrass seed germinated 60 to 70 per cent in a dilute solution of $HNO_3$, while the control germinated only 20 to 30 per cent.

Scarification of seeds is one of the most widely used methods in increasing germination. This is used on seeds that have encasing structures or seed coats that prohibit absorption of water or the proper exchange of gases necessary for germination. They may also prevent the subsequent expansion of the embryo, thus hindering germination. Many methods have been used to break or scratch the seed coat, or to destroy enclosing structures that prevent germination. Some of the most commonly used methods include acids, bases, and mechanical scratching of seed coats. The acid most widely used and the one that has been most successful is $H_2SO_4$. Akamine (1) observed that Bahia grass germination was increased from 0.2 per cent to 72 per cent when treated with concentrated $H_2SO_4$ for 30 minutes. Bryan (5) used concentrated $H_2SO_4$ for 20 minutes on Bermudagrass, and increased germination from 22.5 per cent to 71 per cent. Hodgson (14) reported a definite increase in the germination of freshly harvested Bahia grass when treated with $H_2SO_4$. Using the same species

as Hodgson, Morinaga (16) found that treating the seeds with concentrated $H_2SO_4$ for 3 to 9 minutes and germinating at a constant temperature of 27°C, gave the same increase in germination as seed treated with light and alternating temperatures. According to Stoddart and Wilkinson (19), the germination of Indian ricegrass was definitely increased by the use of $H_2SO_4$ and complete removal of the seed coat. Toole (21) reported a decline in germination of poverty grass seed when treated with concentrated $H_2SO_4$ but a 71 per cent solution would readily increase germination. Toole (22) also observed that a 71 per cent solution of $H_2SO_4$ gave better germination in Indian ricegrass seed than concentrated $H_2SO_4$ treatments. Burton (6) found that a 5 minute treatment with concentrated HCl increased germination of Bermudagrass seed while the same treatment with concentrated $H_2SO_4$ decreased germination and apparently killed most of the embryos. Burton (6) also reported that concentrated $H_2SO_4$ and 35 per cent NaOH increased and hastened the germination of Dallis grass and Bahia grass. The removal of the lemma and palea, by hand, from Bahia grass and Dallis grass served the same purpose as acid scarification. According to Akamine (1) the germination of Urochloa pullulans could be increased from 0 per cent to 90 per cent by the removal of the lemma and palea.

Alternating temperatures have been used extensively to break dormancy and increase germination. Anderson (2) found that the germination of Kentucky bluegrass and Canada bluegrass was increased with the use of alternating temperatures. The best results were obtained with the high temperature at 30°C for 8 hours and the lower temperature at 20°C for 16 hours. According to Blake (4) the seeds from many native prairie plants increased the germination from very low at harvest to a maximum in mid-spring. A lowering of germination in the summer months was followed by

a marked rise in early autumn. Davis (9) found the use of alternating temperatures of special value in studying the germination of seeds with a membranous structure that restricts gas exchange. He reported that alternating temperatures increase respiration and catalase activity throughout the period of germination. Harrington (13) did extensive work with alternating temperatures on grass seeds. He obtained the best germination for redtop, orchard grass, and Kentucky bluegrass seeds by using temperatures of 20°C for 16 to 18 hours and 30°C for 6 to 8 hours. Bermudagrass germinated best at 20°C and 35°C. A daily alteration of 30°C for 18 to 22 hours and 45°C for 2 to 6 hours, was considered to be optimum for Johnson grass seeds. Harrington (13) states that the beneficial effect of alternating temperatures on germination is not due to the specific effect of extreme temperatures but to the changes in the temperatures. Morinago (16) used a wide spread of temperatures and found that a daily alteration of 10°C for 18 hours and 38°C for 6 hours, was beneficial to the germination of Bermudagrass seeds. The optimum condition for Canada bluegrass was a daily alteration of 15°C to 32°C. Pladeck (18) found that burs of Buffalo grass germinated best in sterilized soil with daily alterations of 20°C and 35°C. According to Toole (22), daily alterations of 20°C and 30°C is as effective in producing germination in Indian ricegrass, as scarification with 71 per cent $H_2SO_4$. Excellent germination was obtained in several species of Poa and Orchard grass with daily alterations of 10°C and 30°C or 15°C and 30°C. Toole (23) states that the germination of vine mesquite and plains bristle-grass was increased with alternating temperatures. According to Toole and Toole, the germination of carpet grass seed (24) and goosegrass seed (25) responded well to alternating temperatures. They used 35°C for carpet grass and 40°C for goosegrass as the higher temperature in the alteration.

Oxygen plays an important role in seed germination. Morinago (16) found that excellent germination could be obtained in Bermudagrass under reduced oxygen pressure. In air diluted with 40 to 60 per cent $H_2$ or $N_2$ by volume, the germination was approximately 90 per cent after 10 days, as compared with 73.5 per cent in water sealed containers and 24.5 per cent in loosely covered petri dishes. Thornton (20) found that the per cent of oxygen present around the germinating seed, directly affected the per cent of germination.

Cold is necessary for proper germination of seeds from certain species of plants. Blake (4) stated that germination was increased in some of the forty-two species of tall grass prairie plants when subjected to freezing. Bass (3) found that the germination of oats rose from 0 to 90 per cent when chilled at 15°C for seven days.

## MATERIALS AND METHODS

Germination studies on the seed of buffel grass, Pennisetum ciliare L., were conducted on seed harvested at College Station, Texas, on June 22, July 22, August 15 and September 15, 1952 and 1953. Two strains were used in these tests, however there was no strain difference in germination or length of dormancy.

The spikelets of buffel grass are borne in clusters of three or more, as shown in Figure 3, and each group is completely surrounded by rather stiff bristles as indicated by Figure 2. These clusters are called fascicles and each may contain from none to three caryopses. From each harvest, a count was made of 1,000 fascicles to determine the per cent of fascicles containing caryopses, Figure 5. These counts were used as a basis for determining the per cent germination for each treatment.

Germination tests were carried out under alternating temperatures of 20°C for 16 hours and 30°C for 8 hours. The germinations in soils were run in the greenhouse without a temperature control. Acid treatments were replicated 8 times in the germinator and soil germinations were replicated twice. All other treatments had 4 replications for germination. Each replication consisted of 100 fascicles or caryopses. Each replication was rotated daily to different parts of the germinator, to minimize the effects of moisture, light, and temperature on germination. These factors in germination varied to some degree within a single germinator and by daily rotation, the variation of germination between replications was held to a minimum.

Preliminary Trials. Preliminary trials were run on buffel grass seeds to determine the cause of delayed germination. It was necessary to determine what structure caused dormancy and if it prevented water absorption, gas exchange or was producing a chemical inhibitor.

Fascicles were thoroughly soaked in water for 48 hours and the caryopses were removed. The weight of 100 wet caryopses was compared with the weight of 100 dry caryopses and it was found that the weight of wet caryopses had increased 85 per cent over the dry weight. When examined under binoculars, it was found that the endosperm and embryo were sufficiently swollen for germination.

Caryopses of freshly harvested material were germinated to determine if other factors were preventing proper germination. The caryopses were placed in the germinator until sufficiently swollen for germination. Half the replications were removed and the seed coats were cut just above the embryo. Caryopses that were not treated, germinated 47 per cent while those with the cut seed coats germinated 64 per cent. Akamine (1) says this is probably due to improper gas exchange through the seed coat. He obtained almost perfect germination by cutting the seed coat, thus giving better exchange of gases. Caryopses germinated 90 days after harvest had an increase from 47 per cent to 58.5 per cent, indicating that time destroys the inhibitor in the seed coat.

In these preliminary tests, some caryopses of freshly harvested material were germinated without treatment while other caryopses had the bristles, lemma, and palea included on the blotters. The caryopses that received no treatment germinated 47 per cent while those with the enclosing structures included germinated only 24 per cent. Freshly harvested fascicles, germinated in this same test, gave only 1 per cent

Figure 1 Inflorescence of Buffel Grass

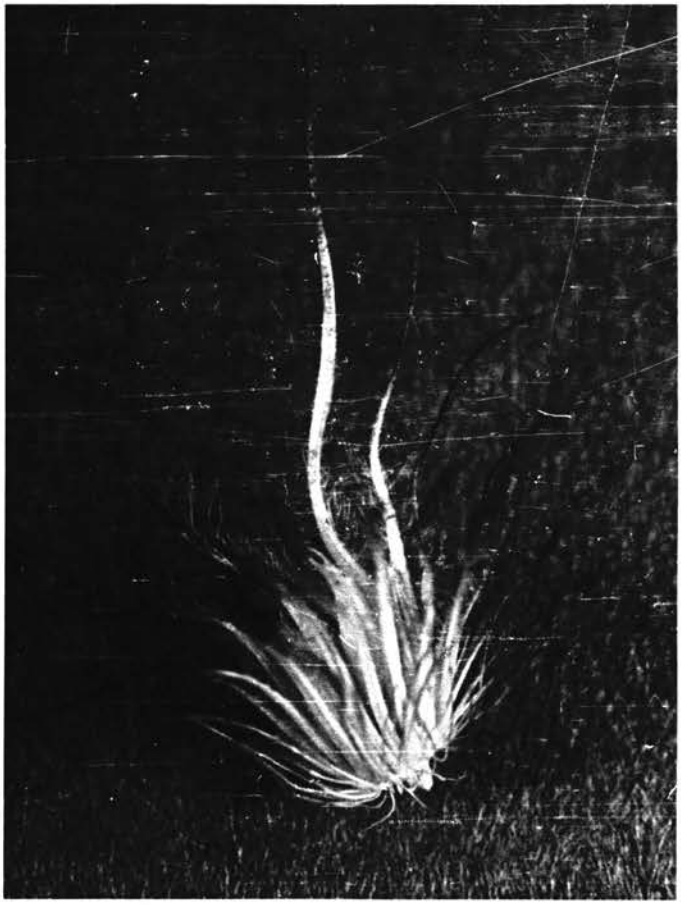

Figure 2 Fascicle of Buffel Grass Showing Bristles that Surround the Spikelets

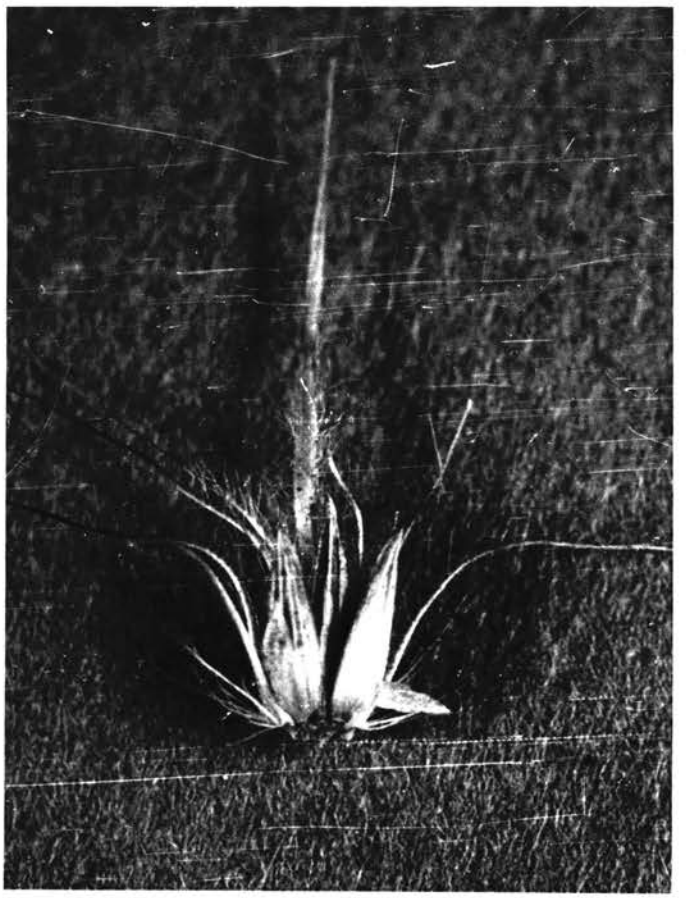

**Figure 3** Cross-section of a Buffel Grass fascicle Showing the Cluster of Spikelets

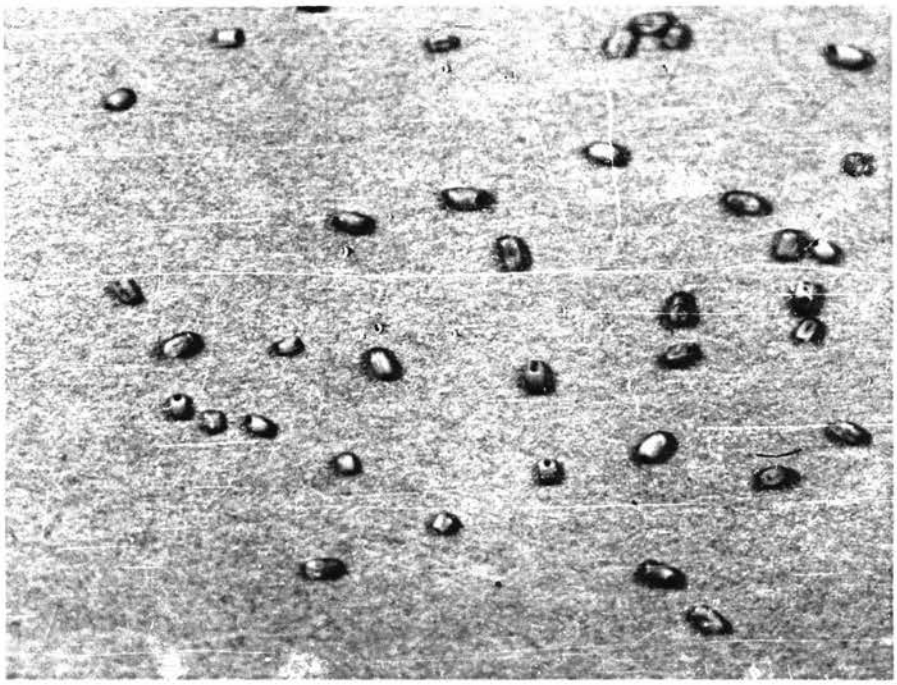

Figure 4 Caryopses of Buffel Grass

germination. The enclosing structures were thoroughly boiled and placed on the buffel grass caryopses. This gave no increase in germination over those treated with non-boiled material. Bermudagrass and wheat caryopses were treated with the enclosing structures from buffel grass seed to determine if there was any inhibiting effect on germination. The untreated Bermudagrass germinated 70 per cent and the treated caryopses germinated 55 per cent. The germination of treated wheat seeds dropped from 90 per cent to 75 per cent. This would seem to indicate the presence of a chemical inhibitor in the lemma, palea, and bristles of buffel grass fascicles.

Breaking dormancy. A series of treatments were conducted with seeds of buffel grass to determine the best method of breaking dormancy. The treatments were divided into the following groups; scarification, temperature, moisture, adsorbents, solvents, and soils.

A. Scarification and removal of enclosing structures

1. Mechanical

   a. Caryopses removed from lemma, palea and bristles by hand.

   b. Naked caryopses - rubbed between hands.

   c. Naked caryopses - rubbed on sandpaper.

   d. Caryopses removed from lemma, palea and bristles with rub-board made of corrugated rubber.

2. Acid

   a. Concentrated $H_2SO_4$.

      Length of treatment in minutes - 1, 3, 5, 10, 15, 30.

   b. 50 per cent $H_2SO_4$.

      Length of treatment in minutes - 10, 20, 30, 40, 50, 60.

B. Temperatures

1. Constant temperatures.

a. Dry fascicles stored at 47°, 5°, -20°C for 15 days.

b. Wet fascicles stored at 5° and -20°C.

2. Alternating temperatures.

a. Dry and wet fascicles - stored at -10°C for 48 hours and room temperature for 48 hours.

b. Fascicles soaked in water at 20°C for 48 hours - dried at 47°C for 48 hours.

C. Fascicles placed in germinator for 45 days at 20°C for 8 hours and 30°C for 16 hours.

C. Moisture

1. Alternate wetting and drying.

a. Fascicles soaked for 48 hours and dried at room temperature for 48 hours. Length of treatment - 16 days.

b. Fascicles soaked for 48 hours and dried at 47°C for 48 hours. Length of treatment - 16 days.

2. Wetting.

a. Fascicles soaked in water at room temperature for seven days then germinated.

D. Solvents.

1. Three treatments; fascicles emersed in benzol, 95 per cent ethyl alcohol and ether for 2 hours then thoroughly washed with water.

E. Adsorbents.

1. Three treatments; fascicles soaked in a suspension of animal charcoal, wood charcoal and Darco for 48 hours then washed with water.

2. One treatment; fascicles soaked in suspension of organic soil for 48 hours then washed with water.

F. Soils

1. Germinated in greenhouse in sand, sandy loam, and organic soil.
   a. Immediately after harvest.
   b. 60 days after harvest.
   c. 360 days after harvest.

## EXPERIMENTAL RESULTS

Effect of dry storage on germination. Each storage period of fascicles over 16 days resulted in a significant increase in germination, Table 1. Freshly harvested fascicles germinated 1.5 per cent with the maximum germination of 83.0 per cent being obtained approximately 180 days after harvest. After 46 days in storage, there was a sharp rise in the germination, that continued until maximum germination was obtained.

Each storage period of caryopses up to 150 days resulted in a significant increase in germination, Table 2. The germination of freshly harvested caryopses was 47.5 per cent and rose to 80.5 per cent 150 days after harvest. Caryopses germinated 360 days after harvest dropped to 54.5 per cent germination. This would seem to indicate a rather rapid break down of the embryo when caryopses are stored under ordinary conditions.

Effect of scarifying and removal of enclosing structures. Freshly harvested fascicles germinated 1 per cent, Table 1. Mechanical removal of the enclosing structures from the caryopses increased the germination to 47.5 per cent, Table 2. The scarification of caryopses with sandpaper resulted in a significant decrease in germination, Table 3. The germination dropped from 47.5 per cent to 42.5 per cent with this treatment. This drop in germination is thought to be due to embryo injury during the treating process. The caryopses were examined under binoculars and it was observed that the germ face of a large number of seeds were badly mutilated.

Treatment of fascicles with concentrated $H_2SO_4$ was significant in all tests, Table 4. Germination increased from 0.5 per cent to 47.5 per cent when treated 5 minutes with concentrated $H_2SO_4$. Treatments of more than 5 minutes gave a rapid decline in germination, with the 30 minute treatment giving only 20.5 per cent germination, Table 4. The indications are that the embryo is killed when treated too long with the concentrated acid. The 50 per cent $H_2SO_4$ gave very little increase in germination; however only one treatment was not significant, Table 4.

Effect of temperature on dormancy. Temperatures used in this test were not significant, Table 5 and 6. Seed were stored under alternating and constant temperatures with the spread between the low and high temperature being approximately 40°C. Fascicles were placed in the germinator for 45 days under high humidity and alternating temperatures of 20°C for 16 hours and 30°C for 8 hours, but no appreciable increase in germination occurred.

Effect of wetting and drying on dormancy. Alternate wetting and drying of fascicles was significant statistically, Table 7, however due to the low per cent germination, no importance should be placed on this variation. Moisture was used as a factor for alternating temperature treatments with no significant increase in germination. It can be assumed that moisture has no direct effect on breaking dormancy in buffel grass seed.

Effect of solvents and time on dormancy. Fascicles thoroughly washed in alcohol, ether, and benzol gave no significant increase in germination, Table 8. This seems to indicate that the inhibitor found in the enclosing structures is not soluble in the solvents used in this test; however it might be removed with other solvents not used in these

experiments. Fascicles, germinated 90 days after the initial treatment with solvents, gave the same germination as untreated seed. This indicates that the embryo was not injured by the solvents used in these tests.

The effect of adsorbents on dormancy. The use of adsorbents in water suspension gave a significant increase in germination over untreated fascicles and those treated with solvents, Table 8. Animal charcoal gave an increase from 1 per cent for untreated fascicles to 8.0 per cent while the organic soil suspension gave no increase in germination. Darco, a petroleum by-product, and wood charcoal gave an increase from 1 per cent to 3.5 and 4 per cent. The data in Table 8 seem to indicate that the inhibitor in the enclosing structures is adsorbed by charcoal particles when in a water suspension.

The effect of soil on dormancy. The germinating media produced no significant effect on caryopses; however time was significant at different germination dates, Table 9. Media and time gave significant increases for fascicles with the exception of organic soil, Table 9. Sands and sandy loam gave an increase in germination over those in the germinator but organic soils had a decrease in seedlings emerging above the soil surface. In comparing these treatments with adsorbents, it is observed that they correspond within certain limits. Akamine (1) suggests that the colloids found in soils might adsorb the inhibitor from the fascicles.

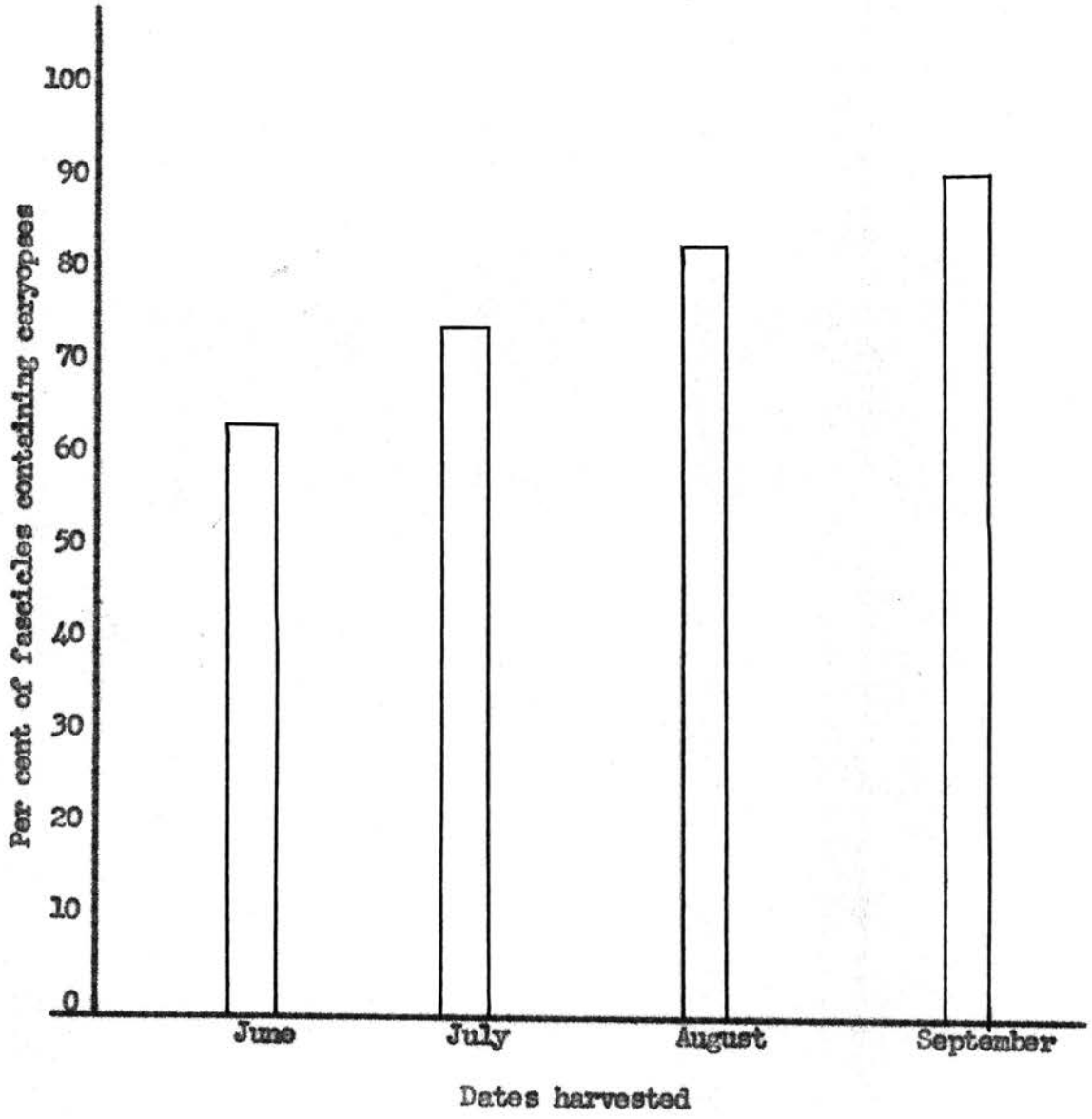


Figure 5. Per cent of fascicles containing caryopses at different dates of harvest.

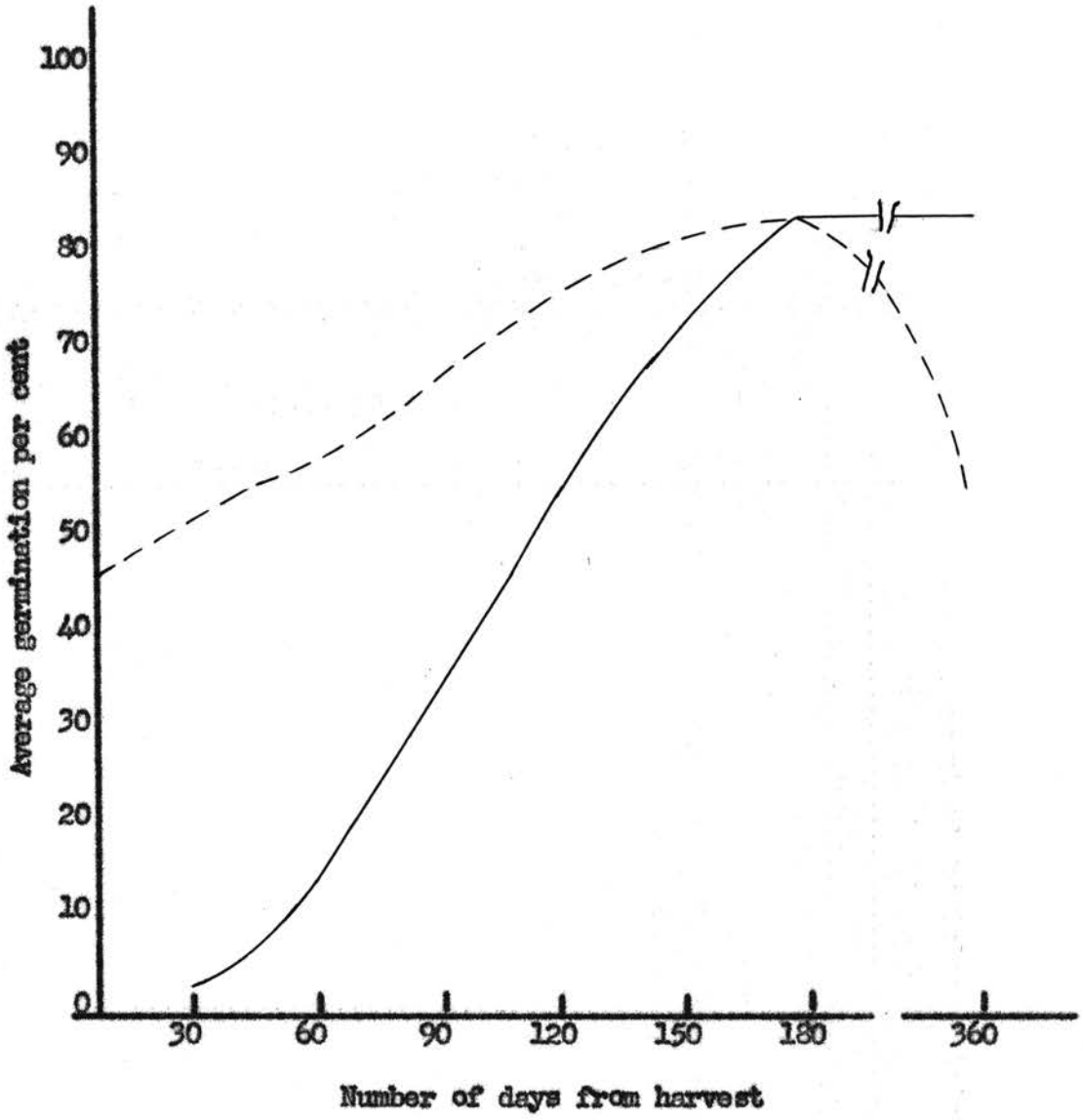


Figure 6. Length of time required for buffel grass seed, in fascicles, to reach maximum germination from date of harvest.

Caryopses - - -

Fascicle ———

Table 1 The effect of dry storage on germination of untreated buffel grass seed in fascicles.

| Days from date of harvest | Per cent germination: 7 days | 21 days | Total per cent germination |
|---|---|---|---|
| 0 | 0.5 | 0 | 0.5 |
| 4 | 0.5 | 0.5 | 1.0 |
| 8 | 1.0 | 0.0 | 1.0 |
| 12 | 1.0 | 0.5 | 1.5 |
| 16 | 1.5 | 0.5 | 2.0 |
| 46 | 5.5 | 1.0 | 6.5 |
| 76 | 12.0 | 3.5 | 15.5 |
| 106 | 28.0 | 8.0 | 36.0 |
| 136 | 46.5 | 7.5 | 54.0 |
| 166 | 63.0 | 12.0 | 75.0 |
| 360 | 68.0 | 15.0 | 83.0 |

Difference required for significance 1/

.05 level - 2.02
.01 level - 2.70

1/ Table 10 Analysis of variance

Table 2 The effect of dry storage on germination of caryopses of buffel grass at 20°C.

| Number of days from harvest | Per cent germination: 7 days | 21 days | Total per cent germination |
|---|---|---|---|
| 0 | 36.0 | 11.5 | 47.5 |
| 30 | 38.5 | 12.5 | 51.0 |
| 60 | 48.5 | 12.0 | 58.5 |
| 90 | 53.5 | 12.5 | 66.0 |
| 120 | 60.5 | 14.5 | 75.0 |
| 150 | 65.5 | 15.0 | 80.5 |
| 360 | 49.0 | 5.5 | 54.5 |

Difference required for significance 1/

.05 level - 3.0
.01 level - 4.2

1/ Table 11 Analysis of variance

Table 3 Mechanical scarification of freshly harvested buffel grass seed and effect of dry storage on germination of the caryopses.

| Treatment | Per cent germination |
|---|---|
| Caryopses | 47.0 |
| Caryopses plus scarification with sandpaper | 42.5 |
| Caryopses plus rubbing with hands | 46.0 |
| Caryopses plus chilling at 5°C | 46.5 |
| Caryopses plus heating at 47°C | 45.5 |
| Caryopses 90 days in dry storage at room temperature | 58.5 |
| Caryopses 360 days in dry storage at room temperature | 24.5 |

Difference required for significance 1/

.05 level - 1.9
.01 level - 2.8

1/ Table 12 Analysis of variance

Table 4 The influence of sulphuric acid scarification on germination of buffel grass seed in fascicles.

| Treatment Concentrated $H_2SO_4$ | Per cent germination: 7 days | 21 days | Total per cent germination |
|---|---|---|---|
| No treatment | 0.0 | 0.5 | 0.5 |
| 1 minute | 19.0 | 0.0 | 19.0 |
| 3 minutes | 34.5 | 2.0 | 36.5 |
| 5 minutes | 44.0 | 3.5 | 47.5 |
| 10 minutes | 30.0 | 3.0 | 33.0 |
| 15 minutes | 30.0 | 1.0 | 31.0 |
| 30 minutes | 17.0 | 3.5 | 20.5 |
| 50 per cent $H_2SO_4$ | | | |
| 10 minutes | 0.0 | 0.0 | 0.0 |
| 20 minutes | 0.0 | 2.0 | 2.0 |
| 30 minutes | 1.0 | 1.5 | 2.5 |
| 40 minutes | 2.0 | 3.0 | 5.0 |
| 50 minutes | 2.5 | 3.5 | 6.0 |
| 60 minutes | 3.0 | 3.5 | 6.5 |

Difference required for significance 1/

| | | |
|---|---|---|
| Concentrated $H_2SO_4$ | .05 level | - 1.49 |
| | .01 level | - 2.0 |
| 50 per cent $H_2SO_4$ | .05 level | - .89 |
| | .01 level | - 1.2 |

1/ Table 13 Analysis of variance

Table 5 Influence of constant temperatures on germination of freshly harvested seed.

| Treatment | Per cent germination: 7 days | Per cent germination: 21 days | Total per cent germination |
|---|---|---|---|
| Dry fascicles - 20°C for 15 days | 0.5 | 0.5 | 1.0 |
| Wet fascicles - 20°C for 15 days | 0.0 | 0.5 | 0.5 |
| Dry fascicles 5°C for 15 days | 1.0 | 0.0 | 1.0 |
| Wet fascicles 5°C for 15 days | 1.0 | 0.5 | 1.5 |
| Dry fascicles 47°C for 15 days | 0.5 | 0.5 | 1.0 |

Not significant 1/

1/ Table 14 Analysis of variance

Table 6 The effect of alternating temperatures on the germination of wet and dry buffel grass seed.

| Length of treatment 1/ | Per cent germination : 7 days | : 21 days | Total per cent germination |
|---|---|---|---|
| Dry fascicles | | | |
| 5 days | 1.0 | 0.0 | 1.0 |
| 10 days | 0.5 | 0.0 | 0.5 |
| 15 days | 0.5 | 0.5 | 1.0 |
| 20 days | 1.0 | 0.5 | 1.5 |
| 30 days | 1.0 | 0.0 | 1.0 |
| Wet fascicles | | | |
| 5 days | 0.5 | 0.0 | 0.5 |
| 10 days | 0.5 | 0.0 | 0.5 |
| 15 days | 1.0 | 0.0 | 1.0 |
| 20 days | 0.5 | 0.0 | 0.5 |
| 30 days | 1.0 | 0.5 | 1.5 |

1/ Seed treatment - 10° for 24 hours
room temperature 24 hours

Not significant 2/

2/ Table 15 Analysis of variance

Table 7 The effect of alternate wetting and drying upon the germination of buffel grass seed.

| Length of treatment 1/ | Per cent germination: 7 days | Per cent germination: 21 days | Total per cent germination |
|---|---|---|---|
| 0 days | 0.0 | 1.0 | 1.0 |
| 5 days | 0.0 | 1.0 | 1.0 |
| 10 days | 0.0 | 0.5 | 0.5 |
| 15 days | 0.5 | 0.5 | 1.0 |
| 20 days | 0.0 | 0.0 | 0.0 |
| 30 days | 0.5 | 1.5 | 2.0 |

1/ Seed soaked - 24 hours
dried - 48 hours at 47° C

Difference required for significance 2/

.05 level - 1.02
.01 level - 1.4

2/ Table 16 Analysis of variance

Table 8 The influence of several adsorbents and solvents on the germination of freshly harvested buffel grass seed.

| Treatment 1/ | Per cent germination |
|---|---|
| 48 hours in wood charcoal suspended in water | 4.0 |
| 48 hours in animal charcoal suspended in water | 8.0 |
| 48 hours in darco suspended in water | 3.5 |
| 48 hours in organic soil suspended in water | 1.0 |
| 2 hours benzol | 1.0 |
| 2 hours alcohol | 1.5 |
| 2 hours ether | 1.0 |
| Control | 1.0 |

1/ Caryopses in fascicles

Difference required for significance 2/

.05 level - 1.0
.01 level - 1.4

2/ Table 17 Analysis of variance

Table 9 The effect of dry storage on per cent germination of buffel grass seed when germinated in different soils.

| Treatment in soil | Per cent germination | |
|---|---|---|
| | Caryopses | Fascicles |
| Germinated at harvest: | | |
| A0 - Blotter paper in germinator | 40.0 | 1.5 |
| A1 - Organic soil in greenhouse | 39.5 | 1.5 |
| A2 - Sandy loam in greenhouse | 42.0 | 13.5 |
| A3 - Sand in greenhouse | 43.5 | 12.5 |
| Germinated 60 days after harvest: | | |
| B0 - In germinator | 58.5 | 30.5 |
| B1 - Organic soil in greenhouse | 53.0 | 5.5 |
| B2 - Sandy loam in greenhouse | 63.0 | 46.5 |
| B3 - Sand in greenhouse | 64.5 | 47.0 |
| Germinated 360 days after harvest: | | |
| C0 - In germinator | 80.5 | 81.0 |
| C1 - Organic soil in greenhouse | 75.0 | 25.0 |
| C2 - Sandy loam in greenhouse | 82.5 | 81.0 |
| C3 - Sand in greenhouse | 81.5 | 80.0 |

Difference required for significance 1/

| | | |
|---|---|---|
| Caryopses | .05 level | - 4.06 |
| | .01 level | - 10.5 |
| Fascicles | .05 level | - 6.1 |
| | .01 level | - 8.8 |

1/ Table 18 Analysis of variance

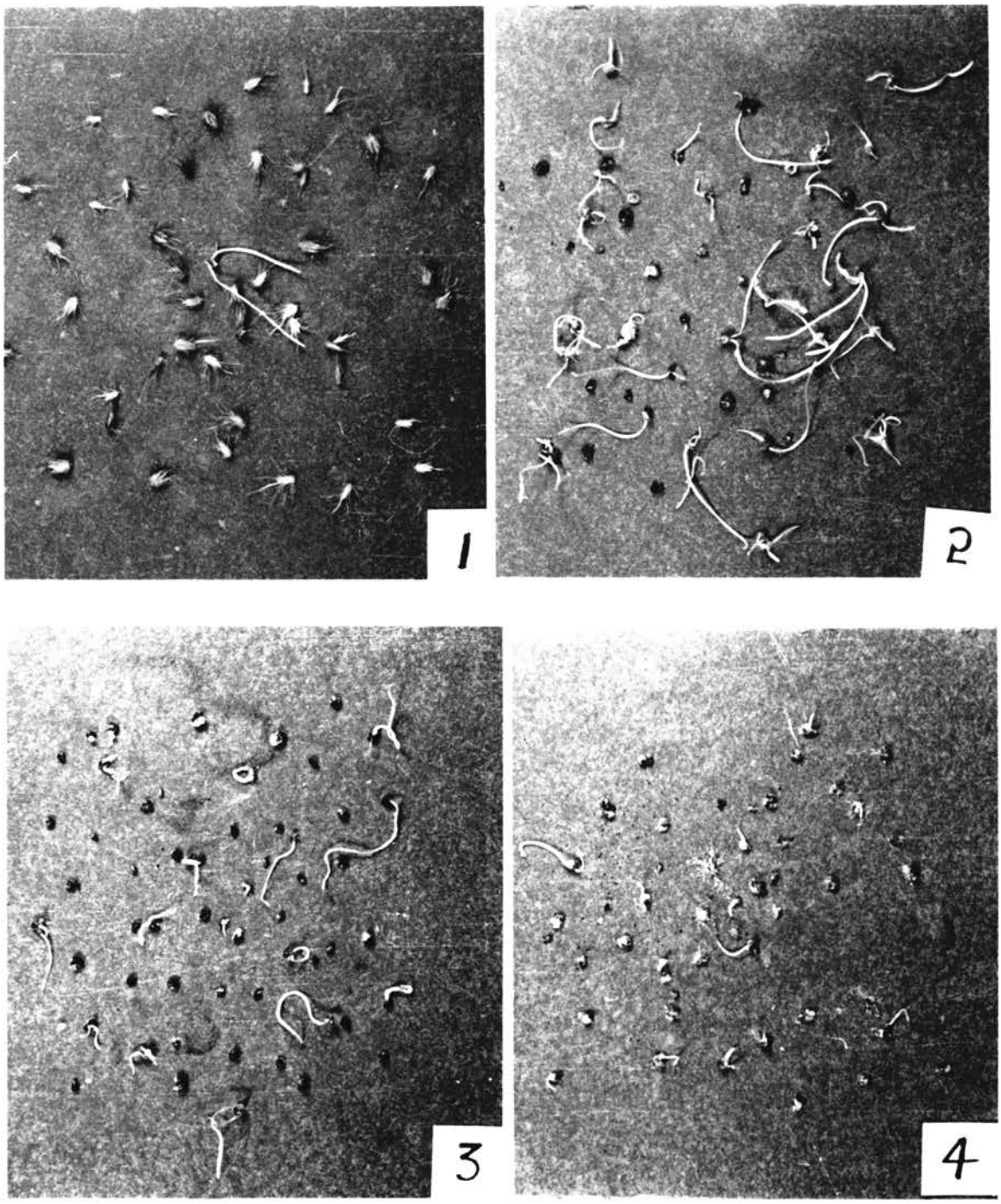


Figure 7 The effect of Varying Lengths of Treatment With Sulfuric Acid on the Germination of Buffel Grass Seed

1 - No treatment
2 - 10 minutes
3 - 30 minutes
4 - 60 minutes

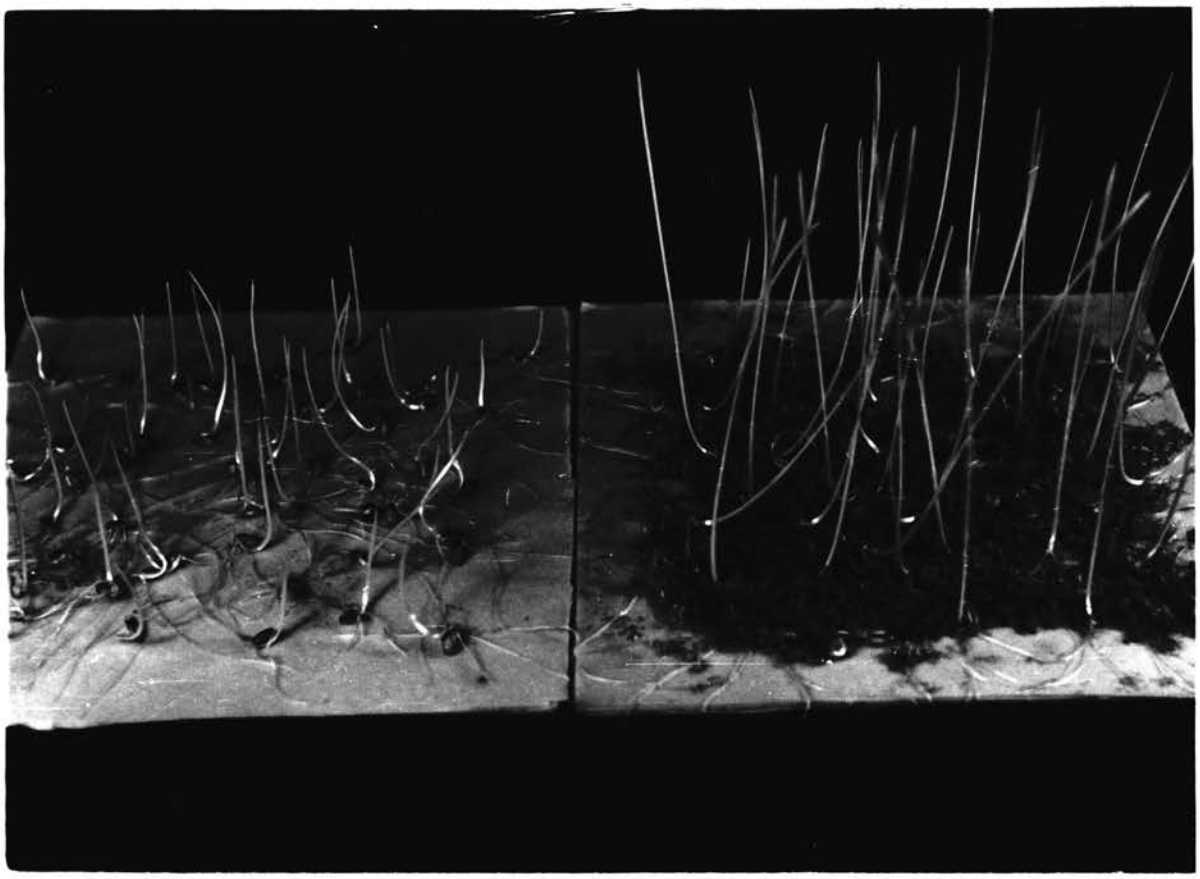

Figure 8 The Influence of the Bristles, Lemma, and Palea From Buffel Grass Seed on the Germination of Wheat Seed

Left - No treatment
Right - Treated

## DISCUSSION

The dormancy or delayed germination of seed may be caused by one or more of the following, according to Crocker (7) (8):

1. Rudimentary embryos that must mature before germination can begin;
2. Structures inhibiting imbibition of water;
3. Enclosing structures preventing expansion of embryo and endosperm;
4. Structures preventing proper gaseous exchange;
5. Embryo dormancy that fails to germinate even under proper germination conditions;
6. Combination of two or more of these;
7. Secondary dormancy.

The delayed germination in buffel grass seed is thought to be due partly to Crocker's fourth cause of dormancy and in part to the production of an inhibitor by the enclosing structures of the caryopses. The exact chemical nature of the inhibiting substance was not determined. The inhibitor is heat stable; therefore is not ammonia as found in the seeds of many plants. Akamine (1) tested buffel grass seed for HCN but all tests were negative; therefore he assumed HCN was not the inhibitor. In preliminary trials it was observed that water was readily absorbed by caryopses in the fascicles. Moisture is not the limiting factor to germination in this species. The removal of enclosing structures around the caryopses caused an immediate increase in germination. From these observations, it can be seen that an inhibiting substance is given off by the enclosing structures. The removal of the caryopses did not

produce maximum germination and since moisture is not a controlling factor, it is thought that insufficient gas exchange might be occurring through the seed coat. The two controlling factors in germination of buffel grass seed are destroyed rather rapidly, with maximum germination in caryopses and fascicles occurring about 6 months after harvest.

In scarification treatments, it was observed that any method which removed the enclosing structures gave an increase in germination. Mechanical removal of the enclosing structures and breaking the seed coat, produced no higher germination than did concentrated $H_2SO_4$. The concentration of the acid treatment had to be sufficiently high to destroy the enclosing structures before germination was increased.

Temperatures used in this study did not effect germination of buffel grass seed. Seed stored under high, low and alternating temperatures gave a slight increase in germination, but these increases were attributed to length of time from harvest.

Moisture treatments produced no increase in germination, either alternate wetting and drying or continuous wetting. Since there might be an improper gas exchange occurring through the seed coat, it was thought moisture would cause a more rapid exchange of gases.

Solvents were unable to remove the inhibitor from the enclosing structures; however, other solvents not used in these experiments might dissolve the substance. The inhibitor might have been attracted to particles of charcoal and soils for some increase in germination occurred when treated with these materials.

In the preliminary trials, wheat seeds were covered with the enclosing structures removed from buffel grass caryopses. There was a definite influence on the germination as shown in Figure 7, but the author was unable to explain the results. It was observed that a decrease in germination occurred in the treated seed, but the seedlings on the treated blotter were more vigorous than on the untreated. Moisture was not the factor inducing vigorous growth since both treatments were given sufficient water. The inhibitor in the bristles of buffel grass seed might act as a growth stimulus to seedlings when in a weak solution.

In this study there appeared to be an abnormally high per cent of twin seedlings. A count was made on 1,000 caryopses to determine the per cent twin embryos that might be expected to appear in this species and of this amount 20 per cent showed twin seedlings. All questionable caryopses were examined under binoculars to be sure twin seedling were present. This compares favorably with data from an unpublished thesis in which the relatively high per cent twining was used as one of the means to support the postulation of apomixis in buffel grass.

SUMMARY

Poor germination in the seed of Pennisetum ciliare is due partly to an inhibitor from the enclosing structure of the caryopses and partly to the seed coat, which could possibly be improper gas exchange. Removal of the source of the inhibitor by $H_2SO_4$ acid or mechanical removal of the caryopsis from the fascicles results in increased germination. Soil or charcoal attracted the inhibitor from the fascicles but did not give as much increase in germination as acid or mechanical scarification. The inhibitor was non-volatile in boiling water; therefore assumed to be heat stable. Solvents such as alcohol, ether, and benzol would not remove the inhibitor from the fascicles. Moisture and temperatures had no direct effect in breaking dormancy in this species.

Freshly harvested caryopses did not give maximum germination although there was a definite increase over the germination of fascicles. Caryopses in dry storage gave an increase in germination with the maximum being reached six months after harvest.

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# APPENDIX

## Analysis of Variance

Table 10 Analysis of variance of the effect of dry storage on germination of untreated buffel grass seed in fascicles.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 43 | 40,429.64 | | |
| Reps | 3 | 3.27 | 1.09 | - |
| Treatments | 10 | 40,367.64 | 4,036.76 | 2,059.57** |
| Reps x Treatments | 30 | 58.73 | 1.96 | |

Difference required for significance

.05 level - 2.02
.01 level - 2.70

Table 11 Analysis of variance of the effect of dry storage on germination of caryopses of buffel grass.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 27 | 3,786.43 | | |
| Reps | 3 | 3.72 | 1.24 | - |
| Treatments | 6 | 3,707.43 | 617.90 | 147.82 |
| Reps x Treatments | 18 | 75.28 | 4.18 | |

Difference required for significance

.05 level - 3.0
.01 level - 4.2

Table 12 Analysis of variance of mechanical scarification of freshly harvested buffel grass and effect of dry storage on germination of the caryopses.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 27 | 2,490.43 | | |
| Reps | 3 | 4.14 | 1.38 | - |
| Treatments | 6 | 2,453.43 | 408.90 | 223.44 |
| Reps x Treatments | 18 | 32.86 | 1.83 | |

Difference required for significance

.05 level - 1.9
.01 level - 2.8

Table 13 Analysis of variance of the influence of sulphuric acid scarification on germination of buffel grass seed in fascicles.

Concentrated $H_2SO_4$

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 55 | 11,099.71 | | |
| Reps | 7 | 6.28 | .90 | - |
| Treatments | 6 | 11,001.71 | 1,833.62 | 841.11** |
| Reps x Treatments | 42 | 91.72 | 2.18 | |

Difference required for significance

.05 level - 1.49
.01 level - 2.0

50 per cent $H_2SO_4$

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 47 | 290.67 | | |
| Reps | 7 | 1.00 | .143 | - |
| Treatments | 5 | 262.67 | 52.54 | 68.23 |
| Reps x Treatments | 35 | 27.00 | .77 | |

Difference required for significance

.05 level - .89
.01 level - 1.2

Table 14 Analysis of variance of the influence of constant storage temperatures on germination of freshly harvested seed.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 19 | 8.00 | | |
| Reps | 3 | 1.40 | .47 | 1.24ns |
| Treatments | 4 | 2.00 | .50 | 1.32ns |
| Reps x Treatments | 12 | 4.60 | .38 | |

Table 15 Analysis of variance of the effect of alternating temperatures on the germination of wet and dry buffel grass seed.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 47 | 25.67 | | |
| Reps | 3 | .50 | .167 | 2.93ns |
| Wet vs dry | 1 | .33 | .33 | 5.79ns |
| Error (a) | 3 | .17 | .057 | |
| Time | 5 | 2.67 | .534 | - |
| Time x wet vs dry | 5 | 2.67 | .534 | - |
| Error (b) | 30 | 19.33 | .644 | |

Table 16 Analysis of variance of the effect of alternate wetting and drying on the germination of buffel grass seed.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 23 | 15.83 | | |
| Reps | 3 | .16 | .053 | - |
| Time | 5 | 8.83 | 1.77 | 3.85* |
| Reps x time | 15 | 6.84 | .46 | |

Difference required for significance

.05 level - 1.02
.01 level - 1.4

Table 17 Analysis of variance of the influence of several adsorbents and solvents on the germination of freshly harvested buffel grass seed.

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 27 | 173.43 | 1.14 | |
| Reps | 3 | 3.43 | 26.90 | 2.38 |
| Treatments | 6 | 161.43 | 29.07 | 56.04** |
| (1) Chemicals | 5 | 145.34 | 24.33 | 60.56** |
| (a) Adsorbents | 2 | 48.67 | 0.33 | 50.68** |
| (b) Solvents | 2 | 0.67 | 96.00 | - |
| (c) Adsorbents vs solvents | 1 | 96.00 | 16.09 | 200.00** |
| (2) Chemicals vs control | 1 | 16.09 | 0.48 | 33.52** |
| Reps x Treatments | 18 | 8.57 | | |

Difference required for significance

.05 level - 1.0
.01 level - 1.4

Table 18 Analysis of variance of the effect of dry storage on germination of buffel grass seed when germinated in different soils.

Caryopses

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 23 | 6,282.50 | | |
| Reps | 1 | 1.50 | 1.5 | 1.33 |
| Time | 2 | 5,986.25 | 2,986.125 | 2,654.33** |
| Error (a) | 2 | 2.25 | 1.125 | |
| Media | 3 | 194.83 | 64.94 | 8.69[1]/ |
| Time x media | 6 | 44.42 | 7.40 | - |
| Error (b) | 9 | 67.25 | 7.47 | |

1/ Requires 8.81 for significance

Difference required for significance

.05 level - 4.6
.01 level - 10.5

Fascicles

| Source of variation | D.F. | S.S. | M.S. | F value |
|---|---|---|---|---|
| Total | 23 | 7,003.33 | | |
| Reps | 1 | 0.66 | 0.66 | - |
| Time | 2 | 4,046.65 | 2,023.33 | 1,006.63** |
| Error (a) | 2 | 4.02 | 2.01 | |
| Media | 3 | 2,051.66 | 683.89 | 94.20** |
| Time x media | 6 | 835.02 | 139.17 | 19.17** |
| Error (b) | 9 | 65.32 | 7.26 | |

Difference required for significance

.05 level - 6.1
.01 level - 8.8

# VITA

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