CORRELATION OF SORGHUM GERMINATION FOLLOWING AMMONIUM CHLORIDE TREATMENT WITH FIELD ESTABLISHMENT

by 2214

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INTRODUCTION

The increasing complexity of agriculture and the need for information on the performance potential of seed requires that more consideration be made to determine seed quality. In addition to germinability, the seed industry and farmers need information on total viability, potential stand establishment, uniformity, storability, and any loss of yield potential attributable to seed deterioration.

One of the important steps in profitable sorghum production is that of securing proper stands. Stands may be altered by a number of factors, a few which are due to the peculiar characteristics of the seed. Other hazards are a poor seedbed, planting too early, or the use of improper planting plates. Some of these hazards may be more easily controlled if the characteristics of the seed are considered.

As better seedbed preparing machines and methods became available, diseases, and pests were feasible to control, the climatic factor in relation to the seed itself became the only one left. Some seed lots are more capable than others to withstand adverse conditions. Seed vigor is the capacity of seed to survive and emerge under adverse field conditions. Standard germination tests may fail to predict field stand with sufficient accuracy, usually because of their failure to detect weakness which may be present in the seed. Consequently, such tests sometimes overestimate the performance that can be expected from a given lot of seed, especially when field conditions are less than optimum. For this reason vigor tests have been devised for nearly all crops. Vigor tests provide information on how a particular seed lot may perform in the field. This information is valuable not only to seed producers, but to farmers who may adjust their planting rate to obtain the desired plant population. The fundamental objectives of seed testing with amonium chloride (NH_4Cl) are to predict the field performance of grain sorghum, to establish the level of seed quality, and to provide a basis for consumer discrimination among seed lots.

LITERATURE REVIEW

Clark (8), and Isely (20) pointed out there is a great need for vigor tests due to discrepencies between field emergence and standard laboratory germination because of environmental and seed factors affecting field germination.

Perry (32) and Wellington (47) found when peas were sown in cold wet conditions some lots showed much lower emergence than might be anticipated from the laboratory germination, the depression in emergence did not affect all lots evenly and thus laboratory germination could not be used to predict relative field performance.

Swanson and Hunter (41) found that discrepency between laboratory and field germination of sorghum seed frequently ranges from 30 to 50% even with seed of high viability. They further pointed out that seed of some sorghum varieties show inherently better ability to germinate under unfavorable planting conditions than seed from other varieties. The differences seem to be due to in part to the relative thickness of starchy layer located in the seed coat.

The moderating effect of soil and climatic factors on stand establishment has been studied intensively (Schooler 37). Field emergence is often lower than laboratory germination, and much evidence indicates that seed kinds and lots differ widely in their ability to germinate in unfavorable conditions in the seedbed.

Bradnock (6) stated that seed lots which fail to come up to the laboratory expectations when planted in the field are considered to lack vigor.

Helmer, Delouche, and Lienhard (19) pointed out that seed vigor, properly evaluated, is not only a measure of the capacity of seed to survive and emerge under adverse field conditions, but is also a measure of storability of seed, i.e., the keeping quality of seed. Seeds low in vigor are as susceptible to adverse storage conditions as they are to adverse field conditions.

Douglas, Brooks, and Winstead (11) emphasized the importance of high quality seed which will germinate uniformily and produce vigorous seedlings that grow and mature at a uniform rate.

A seed lot may have a relatively high germination percentage but be almost worthless for planting purposes. Vigor, then, is perhaps a more realistic measure of the degree of seed deterioration according to Helmer (18).

Isely (20) suggested that adverse temperature and moisture relationship do not in themselves result in the death of weak seeds but shift the ecological balance in favor of the microorganisms. Furthermore, vigor of the seeds in the sense that it relates to the rapidity or strength of growth is important only as it affects or correlates with other characters which favor the emerging seed over the fungus.

Delouche and Caldwell (9) suggested that the rapidity and uniformity of emergence are becoming prime considerations along with the percentage emergence or stand. This is particularly true in crops where the application of herbicides is timed to stage of development. A plant low in vigor that matures late contributes little to yield and may actually detract from the quality of the crop as a whole.

Grobe (17) reported for corn and oats that delayed emergence, slower growth, fewer tillers and seed per head were produced by less vigorous seeds.

McDaniel (28) reported that seedling-fresh weight, seedling mitochondrial biochemical activity were positively correlated with seed weight. The increased quantity of mitochondrial protein of seedlings produced from heavy seed was indicative of higher respiratory rates and greater energy production. Thus, these seedlings have a greater growth potential than seedlings produced from lighter seeds of the same pure line of barley.

Suzuki (40) pointed out the viability and longevity of seed vary according to the species and variety of the plant. He worked with tomato, potato, and eggplant and concluded that there was no clear relation between germinability and seed weight.

In experiments with crimson clover, Schmidt (36) found that 86.6% of the heavy seed germinated while only 53.3% of the light seed germinated. He also observed that heavy seed germinated more rapidly than did light seed.

Vaughan and Delouche (45) found that weight seemed to be more consistently related to viability than was seed size. Weight differences among kinds of seed are related to chemical composition and morphology of the seed. Within a crop, however, weight differences are probably more related to change occuring in the seed during maturation and storage. Seed stored at high temperature and moisture content respire at a rapid rate. Loss of carbohydrate reserves during respiration without corresponding decrease in seed size lowers the weight.

Sung and Delouche (39) emphasized that the vigor of rice seed, in percentage germination, rate of germination, seedling growth in the laboratory, and percentage emergence from soil under greenhouse conditions, was closely related to seed weight.

Finfrock (15) has suggested that in addition to germination, rice growers should consider individual seed weight as a criterion of seed quality.

Oexeman (31) found a close relationship between seed weight and seedling vigor on soybeans.

Seed maturity is closely related to vigor. Mature seeds contain more food reserves. They produce seedlings from greater depths, and they can produce seedlings with a better chance for survival (Erickson 13). Since mature seeds are heavier than immature seeds, seed weight can be used to estimate maturity.

Govedrov (16) stated that larger and heavier sunflower seeds used for planting resulted in strong plants, thus increasing yields.

Trupp and Carlson (43) found that selection for increased seed weight resulted in superior seedling vigor as measured by ability to emerge from a 5-cm planting depth, weight per seedling, and seedling yield per unit area.

Significant positive correlations between seed weight and seedling vigor were reported for bromegrass by Tossell (42).

Scaife and Jones (35) worked on the effect of seed weight on lettuce growth, he concluded that under uniform conditions, and in the absence of interplant competition, a linear relationship was found to exist between the fresh weight of the plant tops at harvest and the weight of the seed sown.

Bleak and Keller (5) found that rate of emergence and rate of root and shoot elongation were strongly associated with the age of seed.

Dungan and Koehler (12) found that yellow dent corn yielded progressively less as the age of the seed increased. The yield reductions were related to reduction in field stands. Old seed produced plants lacking the vigor of new seed.

McNeal (28) pointed out that the use of seed that is viable at planting time is a major factor in all agronomic production. Various lots of seeds may have high germination when harvested but germinate relatively poor at planting time because they have been stored under adverse conditions of moisture and temperature.

Robertson et. al (33) reported that seed of about 10% moisture stored in a dry unheated room germinated 32% after 21 years and that there had been a gradual decline in viability. A dry climate was considered as contributing much to the longevity of seeds.

Sayre (34) tested seed after storage by planting in the field at normal corn planting time a, seed was stored at room temperature. Seed at 18% moisture was dead in one year or less, seed at 14% moisture had decreased in germination in 3 or 4 years, seed at 7.5 and 11.0% moisture germinated satisfactorily after 7 years.

Robertson, Lute, and Kreuger (33) found that a dry, arid climate preserves germination in the farm crops studied so that stocks of sorghum, wheat, oat, barley, and corn can be stored for 20 years and still have enough viable seed to maintain the stocks. They further suggested that Black Amber sorghum still maintained an excellent germination percentage after being stored for 10 years.

Kearns and Tool (22) stated that within a seed lot, there are some seeds that will produce normal seedlings after stoarge under adverse conditions for a long period of time, while others will be killed or produce abnormal seedlings after only a short period of storage under such conditions. Thus, there are both inter-lot and intra-lot differences with respect to seed vigor.

Helmer (18) recently advocated the use of stress storage conditions as a means of evaluating vigor of crimson and red clover seed. He reported that under stress storage conditions, seed lots low in vigor decreased very rapidly in viability, while lots high in vigor were relatively unaffected.

Planting of sorghum at soil temperatures below 18°C usually has resulted in poor seedling stands. Leukel (25) showed that seed- and soil-born fungi may cause reduction of germination and emergence of sorghum, and that this reduction increased with decrease of soil temperature.

Stoffer and Van Riper (38) found that the highest percent emergence was obtained in the field on June 2 and June 12, soil temperatures were 18.3°C and 21.1°C respectively, at time of planting. A specific date for planting cannot be established, however, because of the high degree of variability of temperature.

Leukel (25), in controlled greenhouse studies with sorghum seed of high viability, found that the best temperature for germination ranged from 25.0 to 30.0°C and that the best planting depth was 3.75 cm.

Evans and Stickler (14) pointed out that an important aspect of seed germination studies used in determining variety superiority is the extent to which seed source might influence results. The range in difference found in 4 sources of RS 610 produced in different areas of Kansas, was nearly as great as that noted when 4 widely different genotypes were used. This suggests that a single seed lot could not be expected to truely represent the variety.

Casady and Urich (7) observed that hybrids of similar parentage (genetically the same) grown from seed produced under different conditions and of different seed quality often differed significantly in yield in the same yield trial.

John and West (21) collected seed from 4 native stand of winter fat (Eurotia lanata) in Utah were germinated at the 6 levels of NaCl under 2 temperature regimes. Germination percentage differed significantly between seed source and also between NaCl levels. Each seed source decreased in germination percentage as the NaCl level increased. Genetic differences within species enabled some strains to germinate more successfully than other strains at certain levels of temperature and sodium chloride.

Keller and Bleak (23) found that seed of crested wheat grass, Fairway wheatgrass, and their hybrid were subjected to pre-planting wetting treatments for various durations. Rate of water absorption within the temperature range 4.5 and 27.8°C absorption appeared directly proportional to temperature. Rate of absorption differed significantly with different strain and seed lots. Breeder seed produced in different years on a single field, yielded significantly different, only partially explained by age, size and seed or precipitation the year the seeds were produced.

Barnes (3) found that soaking sorghum seeds in 5% NaOH solution for 5 minutes before standard germination was one of the most effective tests for differentiating vigor among seed lots. And the 5% NaOH test best approximated field emergence.

Danovan and Day (10) reported that differences in barley tolerance may be due to imbibitional differences and a selective permeability of seed to salts.

Uhvits (44) studied the effect of NaCl on the germination of alfalfa seed. Rate and percent of seed germinating were decreased by the use of solutions of increased osmotic pressures. The more severe reduction in germination percentage brought about by the use of NaCl can be attributed to injury caused by accumulation of toxic amounts of chloride within the seed.

Berstein and Hayward (4) suggested that the effects on plant growth of excessive concentrations of soluble salts in the root medium may be mediated by osmotic inhibition of water absorption, by specific effects of the constituent ion(s) in the saline media, or combination of the two. Furthermore, specific ion effects may involve direct toxicity or a variety of nutritional effects.

Kofrank, Lunt, and Hart (24) observed specific ion effects on growth of chrystanthemums associated with high level of ammonium.

Barker and Maynard (2) reported that seed (Cucumis sativa) germination was totally inhibited by high (0.1N) concentrations of potassium or ammonium salts. Partial inhibition of germination occurred with low (0.01N) concentrations of ammonium salts, but low concentrations of potassium salts did not affect germination.

Mooring, Cooper, and Seneca (30) stated that germination response to salinity was an inverse curvelinear relationship with germination inhibition at high salinities apparently due to osmotic affects. The maximum tolerance limit for germination lies between 6 and 8% sodium chloride.

Ammonium ions are usually toxic to most plants. Some specific toxicity mechanisms are know for ammonium according to Vines and Wedding (46).

Salt effects on seed germination are reported as a result of osmotic effects although specific ion effects are recognized (Mayer and Poljakoff-Mayber 26).

Helmer, Delouche, and Lienhard (19) soaked crimson clover seeds in 2% and 4% solutions of ammonium chloride at $40^{o}C$ for 1 and 2 hours. Of the ammonium chloride treatments, the two hour soak in 2% NH_4Cl at $40^{o}C$ appeared to most effectively differentiate among high and low vigor seed lots. The differential response of seed lots to the NH_4Cl treatment can perhaps be attributed to the differences in permeability. Seed of low vigor are more permeable than seeds of high vigor. Hence more of the chemical was absorbed under conditions of treatment resulting in a considerable toxic effect.

Abdullahi (1) and Barnes (3) have compared and evaluated various vigor tests for sorghum.

One of the methods used by Abdullahi was an ammonium chloride test which consisted of soaking seeds in 2% NH_4Cl for 2 hours at 40°C. All methods were compared to standard germination and field emergence, although correlation with field emergence were highly significant for all treatments, the NH_4Cl test produced the highest correlation and ranked the seed lots best.

Mockel (29) conducted NH_4Cl test using the techniques used by Abdullahi. Twenty-one different hybrids and two seed ages were used in this study. He concluded that NH_4Cl test was highly satisfactory in providing a seed vigor measurement, and he also emphasized that standard germination did not give consistent correlation with field establishment.

METHODS AND MATERIALS

In 1970, fifty-four lots of sorghum seeds were tested. These were made up of 18 hybrids, with each hybrid represented by seed submitted for the 1967, 1968 and 1969 Kansas Sorghum Performance Tests. Each seed lot was divided into 3 replication and the following determinations made:

1. Standard Germination:

Fifty seeds were germinated at 25-26°C and 90-95% relative humidity and germinated seeds were recorded after 5 days.

2. Ammonium Chloride Test:

Two percent NH_4Cl solution was warmed to 40°C and seed samples in nylon bags were soaked for 2 hours, flushed and rinsed for 30 seconds. Seeds were then germinated and counts were recorded at two and four days.

3. Seed Weight:

Two hundred seeds from each lot were counted by electronic seed counter, dried and weighed.

4. Field Emergence:

A field emergence study was conducted at the Agronomy Farm, Manhattan, Kansas. A randomized complete block design was used with 3 replications.

The seed was sown in 15 foot plots, two rows 30 inches apart, and 50 seeds per row on June 23, 1970. Emerged plants were counted on July 7, 1970.

In 1971 some modifications were made by increasing temperature, time of soaking, and levels of concentrations of NH_4Cl treatments, and selection of hybrids on the basis of their responses to the stress effects of ammonium chloride solution.

This study was initiated with 25 hybrids of 1970 seeds which were provided by Mr. Ted Walter. Three replications of these hybrids were subjected to 4% NH_4Cl stress and water treatments (Table 1).

Table 1. Percent Germination of 25 Hybrids, 1970 Seeds

Hybrid No.	Hybrids	Treatment Water	Treatment 4% NH_4Cl salt	Diff-erence
1	DeKalb C-42a	84.6	72.0	12.6
2	DeKalb C-42y	46.0	27.2	18.8
3	DeKalb F-61L	82.0	66.6	15.4
4	DeKalb F-65a	62.0	34.0	28.0
5	Excell 707A	81.2	57.2	24.0
6	Excell 733	92.6	83.2	9.4
7	Excell 808	88.6	82.6	6.0
8	Frontier 410E	48.0	24.0	24.0
9	Pioneer 828	60.6	51.2	9.4
10	Pioneer 820	72.0	34.0	38.0
11	Coop. SG-40	74.0	50.6	23.4
12	Coop. SG-30	55.2	30.6	24.6
13	Coop. SG-20	81.2	68.0	13.2
14	DeKalb C-48A	74.6	61.2	13.4
15	Pioneer 845	74.6	58.0	16.6
16	Pioneer 846	77.2	58.6	18.6
17	Niagara Chula	82.0	64.0	18.0
18	Pioneer 848	75.2	64.0	11.2
19	NB 505	55.2	54.6	0.6
20	NC+ T700	26.0	20.0	9.0
21	Asgrow Jumbo	86.6	72.6	14.0
22	DeKalb $C_{44}C$	82.0	73.2	8.8
23	RS 610 Dorman Co. (Texas)	56.0	54.6	1.4
24	RS 610 Priary Valley(Kansas)	63.2	32.0	31.2
25	Pioneer 845	59.2	42.6	16.6

Eight hybrids were selected to represent the whole range of responses of the 25 hybrids to ammonium chloride treatment.

Two hybrids each were selected from classes which showed minimum and maximum differences between NH_4Cl and water treatments and four hybrids were selected from medium responses to NH_4Cl treatment stress (Table 2).

Table 2. The Percent Difference in Responses as a Result Water and Ammonium Chloride Tests on 25 Sorghum Hybrids

Hybrid No.	Min. diff.	Hybrid No.	Med. diff.	Hybrid No.	Max. diff.
19	.6	18	11.2	11	23.4
23	1.4	1	12.6	8	24.0
7	6.0	13	13.2	5	24.0
20	6.0	14	13.4	12	24.6
22	8.8	21	14.0	4	28.0
9	9.4	3	15.4	24	31.2
6	9.4	15	16.6	10	38.0
		25	16.6		
		17	18.0		
		16	18.6		
		2	18.6		

The list of hybrids selected is shown in Table 3. Four replicates of fifty randomly selected seeds in each hybrid were treated with ammonium chloride at 4 levels of concentrations: 0, 2, 4, and 8%. Samples were soaked for time periods of 1 hour and 2 hours at temperatures of 40°C and 50°C. After soaking the seeds were rinsed with distilled water for 30 seconds and then placed in petri dishes. In each petri dish 7 ml. of distilled water which contained 3 ml. chlorox per liter was used to control fungal growth.

Table 3. Eight Selected Sorghum Hybrids Used in This Study

1 - DeKalb C-42a	5 - Pioneer 820
2 - DeKalb C-42y	6 - Coop SG-40
3 - DeKalb F-61L	7 - Pioneer 845
4 - Excell 733	8 - RS 610 (Texas)

The petri-dishes with seed were kept in a germinator maintained 25-26°C and 90-95% relative humidity. Germinated seeds were recorded after 2 and 5 days.

Field Emergence

Field emergence studies were conducted in 1971 at three locations: Sandyland Experiment Field, St. John; South Central Kansas Experiment Field, Hutchinson; and Agronomy Farm, Manhattan, Kansas. A randomized complete block design was used for the first two locations, and a split plot design* was used for Manhattan. Each study consisted of 4 replications.

Plots consisted of two 25 foot rows 30 inches apart and 50 seed planted per row. Planting and stand count dates are presented in Table 4.

*At Manhattan each replication consisted of two randomized planting dates. At time of writing this thesis data for the second planting was not available.

Table 4. Locations, Planting, and Counting Dates for Field, Emergence Trial 1971

Location	Planting date	Stand counting date
St. John	April 13	May 3
Hutchinson	May 26	June 8
Manhattan (Date 1)	May 17	June 9

RESULTS AND DISCUSSION

1970 Field Study

Correlation coefficients between weight per 200 seed, standard germination, two- and four-day count ammonium chloride laboratory tests and field establishment of three seed ages and combined over seed ages are presented in Table 5.

Table 5. Correlation of the Vigor Tests and Field Emergence

Vigor test	1967	Entry Year 1968	1969	Combined
Standard germination	0.377**	0.477**	0.460**	0.451**
Two-day count NH_4Cl	0.400**	0.477**	0.408**	0.450**
Four-day count NH_4Cl	0.424**	0.526**	0.450**	0.487**
Weight/200 seed	-.074	-0.174	-0.343*	-0.164

**Significance at the 1% level.

*Significance at the 5% level.

Data from standard germination and ammonium chloride treatments (2- and 4-day counts) were positive and highly significantly correlated with field establishment with all three sets of seed, but there was no correlation between weight/200 seed and field stand counts except for the negative correlation for 1969 seed.

Correlation of standard germination and 2- and 4-day counts of NH_4Cl treatments with field establishment were positive and highly significant for all three seed ages when they were considered together, but there was no significant correlation between weight/200 seed and field stand counts when all three seed ages were considered together.

The following conclusions can be drawn from these data:

The standard germination test gave highly significant and positive correlation with field counts, two possible reasons can be suggested here.

1- Standard germination tests were determined in 1970 with seeds from 1-3 years old. During these periods of storage weak and non-vigorous seeds died and standard germination test could provide information about field emergence.

2- Highly significant and positive correlations were obtained probably because there was no severe moisture and temperature stress during June planting.

The ammonium chloride test showed positive and highly significant correlation with field stands probably because weak, non-vigorous seeds were more permeable to NH_4Cl salts and were killed and the remaining seeds germinated to provide correlation with field establishment.

In this study weight/200 seed was not a good indicator of field establishment probably due to wide genetic variability of seed weight of the hybrids tested.

1971 Laboratory Study

Ammonium chloride concentration and time and temperature of soaking were varied to find out which combination would give the highest and most consistent correlation with field establishment. Analysis of variance of germination data indicated that the two day count showed the same results as five day count Table 6, and appendix Tables 12 and 13.

For total count, highly significant differences (at 1% level) were found among hybrids, concentrations, time of soakings, and temperatures.

Table 6. Analysis of Variance for Germination After Ammonium Chloride Treatments

Source of variation	d. f.	Mean Squares 2 day	5 day	Total
Replicates	3	2.710	3.734	1.111
Hybrid	7	6044.09**	563.50**	4233.61**
Concentration	3	892.22**	39.78	1194.95**
Time	1	970.75**	23.63	1259.39**
Temperature	1	1222.03**	2.53	1297.31**
Hybrid x conc.	21	41.64*	39.15	96.56**
Hybrid x time	7	65.88*	45.73	60.50**
Hybrid x temp.	7	114.93**	20.85	135.03**
Conc. x time	3	137.51**	6.12	130.68**
Conc. x temp.	3	37.93	16.70	24.30
Time x temp.	1	139.24*	48.76	307.83**
Hybrid x conc. x time	21	32.37	21.16	25.24
Hyb. x conc. x temp.	21	25.60	25.50	16.25
Hyb. x time x temp.	7	25.26	31.31	49.54
Conc. x time x temp.	3	37.90	28.12	44.93
Hyb. x conc. x time x temp.	21	10.01	23.22	17.04
Error	381	26.38	25.51	20.27

Also highly significants hybrid x concentration, hybrid x time, hybrid x temperature, concentration x time, and time x temperature interaction effects were indicated in the analysis.

These data suggest that genotype can have a highly important influence on results of seed germination studies.

The hybrid x concentration interaction is due to the different behavior of the hybrids within the various concentrations.

The general trend that germination decreased with increased concentration was not consistent for all eight hybrids (Figure 1).

Hybrids 1, 3, and 4 were superior to the other hybrids in tolerance and showed no significant effect due to concentration of NH_4Cl. The average germination for these hybrids was 89.55, 86.35, and 90.75 percent, respectively.

Hybrids 2, 6, and 8 reacted in a similar manner at 0, 2, and 4% concentrations, but differed highly significantly at 8% concentration. Among these three hybrids, hybrid 2 had the lowest average germination 25.90%. This suggested that this hybrid might be poor in viability. Average germination of hybrids 6 and 8 was 74.90 and 56.10 percent, respectively.

In case of hybrid 7, germination at 0 and 2% were not significantly different, and the 2, 4 and 8% showed no significant differences, but 0% was highly significantly different from 8%. Average germination was 79.20 percent.

Hybrid 5 responded differently from all other hybrids. It showed highly significant germination differences between each concentration increase. Increasing concentration from 0 to 8% dropped germination from 83.80 to 48.00 percent. The difference in germination due to salt treatment was 35.80 percent indicating the susceptibility of this hybrid to stress.

The interaction between hybrids and soaking times is shown in Figure 2. Hybrids 2, 5, and 8 gave lower germination with 1 hour soaking than the other hybrids, and also showed highly significant differences between 1 and 2 hour soaking times. The adverse effects on germination for 2 hour soaking could be attributed to accumulation of more salt due to length of imbibition period. Average germination for these hybrids was 46.4, 56.6, and 56.0 percent. Hybrids 1, 3, 4, 6, and 7 did not differ significantly due to soaking time. The hybrid x time of soaking interaction might be due to imbibitional differences within various soaking times.

Effects of temperatures on hybrids are shown in Figure 3. Hybrids 2, 5, and 8 gave lower germination with 50°C soaking temperature than the other hybrids, and also showed highly significant differences between 40°C and 50°C soaking temperatures. At the higher temperature reduction in germination may be due to increasing reaction activity of NH_4Cl salt which presumeably caused the seed injury.

Highly significant hybrid x temperature interactions were found possibly due to different responses to ionic activities of NH_4Cl solution at different temperatures.

A highly significant interaction between time of soaking and concentration of ammonium chloride was found (Figure 4).

At low concentrations the effect of time of soaking was not significant, but it was significant at concentrations of 4 and 8%.

With 1 hour of soaking the difference among the 0, 2, and 4% concentrations were not significant, but all were significantly higher than germination at 8 percent.

With 2 hours, significant differences were found between each

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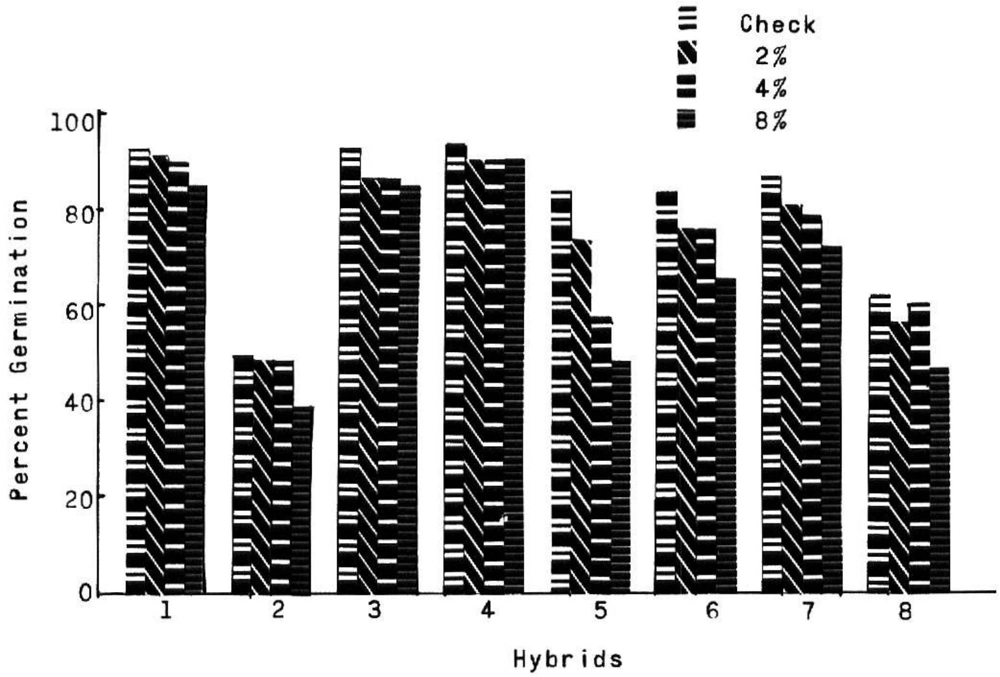

Figure 1. Effect of hybrids and NH_4Cl concentration on germination of grain sorghum

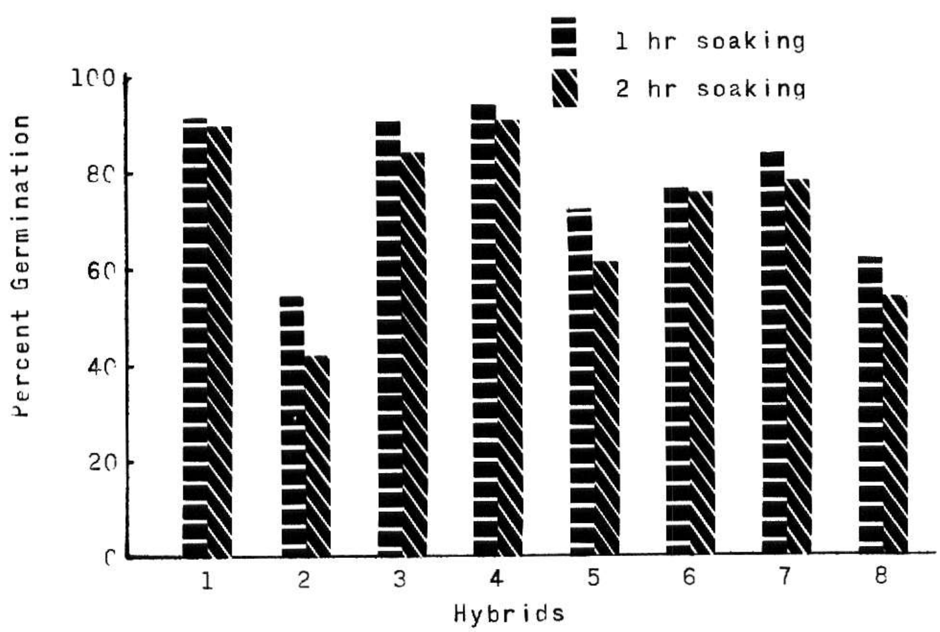

Figure 2. Effect of hybrids and soaking times on germination of grain sorghum

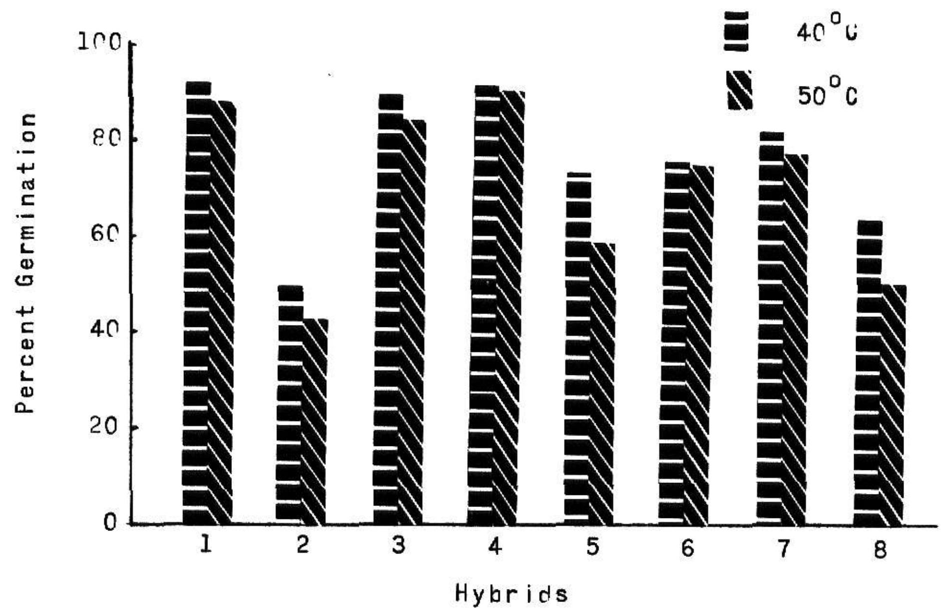

Figure 3. Effect of hybrids and soaking temperatures on germination of grain sorghum

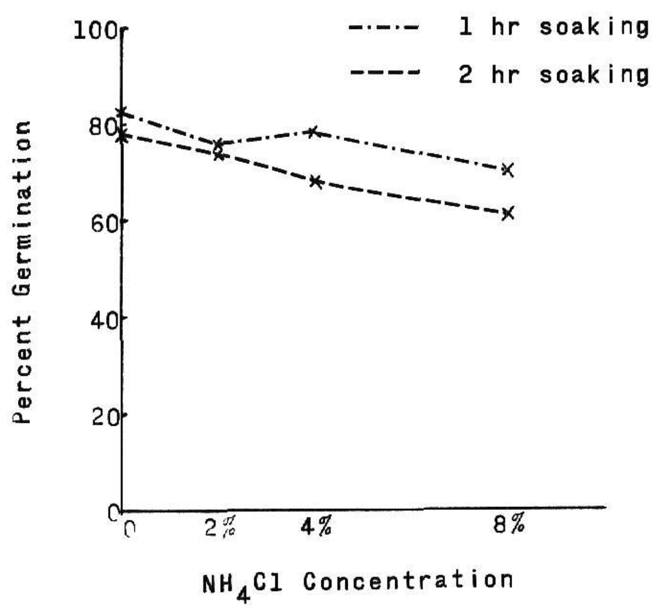

Figure 4. Effect of concentrations and soaking times on germination of grain sorghum

increasing level of concentration.

Possible reasons for the observed decrease in germination as the salt concentration was increased may be the osmotic effect which made it difficult for the seed to absorb water necessary for germination or the direct effect of NH_4Cl which is considered to be toxic or poisonous to the seed or a reaction could occur between NH_4^+ or Cl^- or both with various nutrient reserves in the seed.

It was noticed as the time of soaking was increased from 1 hour to 2 hours the results were more striking.

Higher temperatures retarded germination at both times of soaking Table 7, however, the effect of raising temperature from 40 to 50°C was greater with the 2 hour soaking than the 1 hour period.

Table 7. Effect of Soaking Times and Temperatures on Germination of Grain Sorghum

Temperature C°	Time 1 hour	2 hour
40	78.420	75.250
50	75.156	65.780

L.S.D at the 1% level = 2.832

The average total count after ammonium chloride stress test classified hybrids 1, 3, 4, and 7 the best; and 2, 5, 6, and 8 as poor performance hybrids under laboratory conditions.

Two day count of ammonium chloride classified the hybrids close to the total count except a slight change in the position of hybrids 7 and 6.

1971 Field Establishment

With the objective of testing the results of laboratory germination studies, the eight hybrids were planted in the field at three locations: Hutchinson, St. John, and Manhattan. Results obtained from these locations are shown in Table 8.

Table 8. Field Emergence in Percent

Hybrid	Location		
	Hutchinson	St. John	Manhattan Date 1
1. DeKalb C-42a	90.50	58.50	53.75
2. DeKalb C-42y	37.25	16.25	17.25
3. DeKalb F-61L	89.25	53.75	55.75
4. Excell 733	91.75	50.00	55.00
5. Pioneer 820	76.75	42.25	51.50
6. Coop SG-40	80.75	39.50	50.00
7. Pioneer 845	86.25	57.50	59.75
8. RS 610 (Texas)	63.75	33.00	47.25
Average	77.03	43.84	48.78

Hutchinson:

The eight hybrids were planted May 26 and field establishment counts were recorded June 8, 1971. This location had the most favorable climatic conditions and hence the field establishment was better than the other two locations. The soil temperature at time of planting was 21.1°C. Percent field establishment ranged from 37.25 to 91.75 for hybrids 2 and 4 with an average of 77.03 percent.

St. John:

The hybrids were planted April 13 and stand counts were recorded May 3, 1971. Establishment in the field ranged from 16.25 for hybrid 2 and 58.50 percent for hybrid 1 with an average of 43.84 percent. The low performance of the hybrids at this location can be attributed to the prevailing weather conditions following planting. At planting time the soil temperature was 4.4°C. This low temperature during the germination time might have decreased rate of germination. The seedlings which were established and counted also turned purple due to unfavorable climatic conditions.

Manhattan:

At this location the hybrids were planted May 17 and establishment counts were recorded June 9, 1971. Due to unfavorable moisture conditions crusting of soil surface decreased establishment. Also difficulties were encountered in planting, hence the results have to be considered with caution.

Field establishment ranged between 17.25 for hybrid 2 and 59.75 for hybrid 7 with an average of 48.78 percent. Hybrid 2 consistently recorded the poorest establishment at all locations.

Correlation of Field and Laboratory Data

As mentioned earlier, the objective of modifying the ammonium chloride laboratory test was to find the treatments which give the highest and most consistent correlation with field establishment.

Among sixteen ammonium chloride treatments for both 2 day and total counts the following four treatments gave the highest correlations for combined or individual location data:

0% NH_4Cl, 1 hour soaking at 40°C; 0% NH_4Cl, 2 hour soaking at 50°C;

2% NH_4Cl, 1 hour soaking at 40°C; and 8% NH_4Cl, 1 hour soaking at 40°C.

Correlations between laboratory germination and field establishments are shown in Table 9. Most of the germination counts were significantly correlated with field establishment at the individual locations. Germination counts for all treatments were significantly correlated with establishment when data were combined over locations.

Total counts gave higher correlations with field emergence than did 2 day counts.

It is worthwhile to consider the degree of consistence of the above four treatments' correlations with field establishment.

Both the 1 hour at 40°C and 2 hour at 50°C, 0% NH_4Cl treatments showed high correlation values, but neither of these treatments were consistent. They fluctuated in their correlation not only one over the other, but also between the 2 day and total count at the same location or at different locations.

The 2% NH_4Cl, 1 hour at 40°C treatment was not consistent in its correlation with field emergence when compared with other treatments of the same concentration. It was also observed that this treatment was not consistent between 2 day and total counts at the same location.

The 8% NH_4Cl, 1 hour soaking at 40°C always gave consistent, positive and highly significant correlations with field establishments when it was compared with the other treatments either at the same level or with other treatments at different levels of NH_4Cl concentrations both at 2 day and total count at combined or each location separately.

Germination results obtained in the laboratory under various levels of NH_4Cl stress conditions were in agreement with the field establishment data

Table 9. Correlation Between Field Establishment and Germination Following Ammonium Chloride Treatments

Location	Control				2% NH_4Cl				4% NH_4Cl				8% NH_4Cl			
	1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		1 hr		2 hr	
	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hutchinson																
Two day count	.92**	.86**	.95**	.88**	.88**	.83**	.81*	.79*	.85**	.83**	.83**	.79*	.89**	.80*	.76*	.74*
Total count	.95**	.82*	.83**	.99**	.88**	.97**	.94**	.87**	.94**	.72*	.87**	.87**	.92**	.80*	.88**	.82*
St. John																
Two day count	.86**	.78*	.86**	.79*	.82*	.72*	.81*	.71*	.79*	.74*	.73*	.69	.85**	.72*	.67	.67
Total count	.92**	.77*	.70	.94**	.90**	.90**	.96**	.83*	.91**	.72*	.85**	.83**	.91**	.79*	.83**	.78*
Manhattan																
Two day count	.78*	.67	.83**	.71*	.72*	.63	.67	.59	.65	.63	.64	.59	.73*	.57	.55	.54
Total count	.93**	.62	.71*	.89**	.78*	.84**	.81*	.68	.81*	.50	.70*	.76*	.81*	.58	.71*	.63
Combined																
Two day count	.60**	.54**	.62**	.56**	.57**	.41*	.54**	.49*	.54**	.52**	.52**	.50*	.58**	.49*	.47*	.46*
Total count	.65**	.52**	.53**	.65**	.60**	.63**	.63**	.53**	.62**	.45*	.57**	.58**	.62**	.51*	.57**	.52**

**Significance at the 1% level.
*Significance at the 5% level.

from optimum and sub-optimum field conditions.

Hence by following laboratory technique, grain sorghum seed lots can be evaluated on the basis of their germination percentages in the laboratory without trying them in the field. This method may prove a very useful tool for screening sorghum seed.

Laboratory germination (Figure 1) indicated that hybrids 4, 1, 3 and 7 had comparatively high germination percentages, 90.75, 89.55, 86.35, and 79.20, respectively. The same four hybrids recorded consistently higher percentages of field establishment than the other hybrids at all locations.

Figure 1 indicated that hybrids 2, 6, and 8 were sensitive to stress conditions. The sensitiveness of these hybrids increased in proportion to the increased of stress due to ammonium chloride concentrations of 0 to 8%. Under optimum conditions hybrid 6 recorded 83.4% at 0% NH_4Cl against 65.0% germination at 8% NH_4Cl, a difference in germination of 18.4%. Establishment data obtained from the three locations indicated the sensitive hybrids mentioned above in the laboratory experiments have shown depressed field emergence by recording more than 20% decrease in stand at St. John (sub-optimum) compared to Hutchinson (optimum) conditions.

For example, hybrid 5 (sensitive to stress under laboratory conditions) had 83.8, 57.4, and 48.0 percent germination at 0, 4, and 8% of NH_4Cl. The reduction in germination due to NH_4Cl was 26.4 and 35.8 percent for the 4 and 8 percent solutions, respectively. Field establishment of this hybrid was 76.5 at Hutchinson (most favorable condition), 51.50 at Manhattan (less favorable condition), and 42.25 percent at St. John (least favorable condition) clearly indicated the same trend of results as obtained in the laboratory. The differences in emergence (using Hutchinson as the basis) were found to be 25.25 and 34.50 percent which agreed with the laboratory results.

Ranking of Hybrids Criterion

In this test the eight hybrids were ranked according to how well they germinated in ammonium chloride treatments or emerged at different locations (Tables 10 and 11).

By comparing each column the average total count of laboratory germination best ranked the hybrids in order of their performance at all locations.

Average total count ranked the hybrids at Hutchinson perfectly, and also classified the hybrids better on the basis of their ability to establish in the field into two classes at the other two locations (sub-optimum conditions).

At St. John hybrids 1, 7, 3, and 4 were found to be the best performing hybrids. The difference between hybrids 1 and 4 was only 8.5 percent. The other four hybrids, 5, 6, 8, and 2 were stress sensitive hybrids. The difference between two extremes, hybrids 5 and 2 was 26.0 percent.

At Manhattan the first four hybrids, 7, 3, 4, and 1 were rated as the best performing hybrids. The difference between hybrids 7 and 1 was 6 percent. The rest of the hybrids, 5, 6, 8, and 2 were catagorized as poor hybrids on the basis of their establishment in the field. The difference between hybrids 5 and 2 was 34.25 percent.

Among other ammonium chloride treatments, as shown in Table 10, the total count of 8% NH_4Cl, 1 hour soaking at 40°C best ranked the hybrids on the basis of their performances.

Not only the total count of 8% NH_4Cl, 1 hour soaking at 40°C ranked the hybrids, but also the 2 day count of the same treatment ranked the hybrids

Table 10. Ranking of Hybrids According to Their Performance at Total Count Lab. and Field Germination

Germination					Establishment		
Control 1 hr 40°C	Control 2 hr 50°C	2% 1 hr 40°C	8% 1 hr 40°C	Total Count (Av.)	Hutchinson	St. John	Manhattan
1	1	1	4	4	4	1	7
7	4	4	1	1	1	7	3
3	3	3	3	3	3	3	4
5	7	5	7	7	7	4	1
4	6	7	6	6	6	5	5
6	5	6	5	5	5	6	6
8	8	8	8	8	8	8	8
2	2	2	2	2	2	2	2

the best as shown in Table 11.

Eight percent ammonium chloride for 1 hour soaking at 40°C revealed its outstanding ability among other treatments in ranking the hybrids on the basis of their performances and consistent, positive, and highly significant correlations under all circumstances.

Talbe 11. Ranking of Hybrids According to Their Performance at Two Day Count Lab. and Field Germination

Germination					Establishment		
Control 1 hr 40°C	Control 2 Hr 50°C	2% 1 hr 40°C	8% 1 hr 40°C	2 day Count (Av.)	Hutchinson	St. John	Manhattan
1	4	4	4	4	4	1	7
4	1	1	1	1	1	7	3
6	6	6	3	3	3	3	4
7	3	7	7	6	7	4	1
3	7	3	6	7	6	5	5
5	5	5	5	5	5	6	6
8	8	8	8	8	8	8	8
2	2	2	2	2	2	2	2

CONCLUSIONS

Standard germination was highly significantly correlated with field stand when seed ages were considered together or separately. These data suggest that storage of seed for one year or more might have eliminated the low vigor or weak seed, leaving only vigorous seeds which have given relative information of field emergence, or favorable conditions following the planting made it possible for the weak and non-vigorous seed to emerge.

Both 2 and 4 day counts of NH_4Cl test gave consistent, positive and highly significant correlations in all circumstances probably because weak seeds with high permeability were killed or rendered incapable of normal germination by the NH_4Cl treatment, while vigorous seeds were left relatively unaffected.

Weight per 200 seed was not a promising indicator of field establishment potential.

Laboratory germination after ammonium chloride treatments were in close agreement with field stands at all locations. This means laboratory germination after the ammonium chloride stress test may predict with accuracy the field performances of grain sorghums both under optimum and sub-optimum conditions.

The ammonium chloride test classified the hybrids' germination potential the same as field establishment performance.

Among sixteen NH_4Cl laboratory stress treatments, four revealed the highest correlation with field establishment. However, among these four treatments: 0% NH_4Cl, 1-hour soaking at $40^{\circ}C$, 0% NH_4Cl, 2-hour soaking at $50^{\circ}C$, and 2% NH_4Cl, 1-hour soaking at $40^{\circ}C$ were not consistent in their correlation with field establishments. But 8% NH_4Cl, 1-hour soaking at

40°C, both for 2 day and total count, gave consistent, positive and significant correlation with field establishment either combined over locations or separately.

Average total count of NH_4Cl test ranked the hybrids the best according to their field performances. Among the four best NH_4Cl treatments, 8% NH_4Cl, 1-hour soaking at 40°C ranked the hybrids the best. Both 2 day and total count of 8% NH_4Cl 1-hour at 40°C ranked the hybrids the best.

These results suggest that sorghum in 8% NH_4Cl solution at 40°C for 1-hour can be utilized to screen the non-vigorous from vigorous seed, and may predict with accuracy the field establishment values. This technique can also be used as a tool by the breeder in screening before evaluating varieties.

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APPENDIX

Table 12. Two Day Count Laboratory Germination in Percentage for Each NH_4Cl Treatments

	Control				2% NH_4Cl				4% NH_4Cl				8% NH_4Cl				Average
	1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		
	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.DeKalb C-42a	84.00	79.50	83.00	73.50	82.50	72.00	82.50	80.00	86.00	79.00	72.00	68.50	80.50	68.00	73.00	66.00	76.84
2.DeKalb C-42y	38.50	32.00	35.00	20.50	36.00	30.00	35.50	26.50	39.00	30.00	27.50	19.50	24.00	30.50	25.50	15.50	29.08
3.DeKalb F-61L	70.50	73.00	80.50	69.50	62.50	69.00	56.50	61.50	68.00	78.00	65.50	59.00	69.50	65.00	66.00	43.00	66.06
4.Excell 733	78.00	89.50	92.00	84.50	83.00	91.50	75.50	83.50	82.50	85.00	86.50	78.00	83.00	79.00	83.50	80.00	83.42
5.Pioneer 820	66.50	46.50	59.50	35.50	57.00	53.00	43.50	30.50	51.00	38.00	39.00	24.50	40.50	36.00	28.00	14.50	41.46
6.Coop SG-40	77.00	77.50	74.50	70.00	63.00	60.50	64.50	74.50	71.50	70.50	59.00	56.00	58.00	61.00	57.50	53.00	65.42
7.Pioneer 845	73.00	71.00	72.00	61.50	62.50	52.00	71.00	61.50	64.50	57.00	52.00	43.00	61.00	54.00	45.00	48.00	59.34
8.RS 610 (Texas)	45.50	33.00	58.50	32.00	47.00	33.00	45.00	31.50	44.50	40.50	38.50	33.00	40.50	25.50	35.00	19.50	37.64

Table 13. Total Laboratory Germination in Percentage for Each NH_4Cl Treatments

	Control				2% NH_4Cl				4% NH_4Cl				8% NH_4Cl				Average
	1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		
	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.DeKalb C-42a	94.0	90.50	94.50	91.50	95.00	90.00	93.00	88.50	95.50	91.50	88.50	84.00	87.00	85.50	83.50	81.50	89.52
2.DeKalb C-42y	53.00	63.50	53.00	28.00	53.50	40.00	53.50	46.00	55.50	64.00	48.00	29.50	41.00	50.00	42.00	22.00	46.40
3.DeKalb F-61L	92.00	92.00	98.00	87.00	87.50	89.00	87.50	80.00	91.00	89.00	85.50	81.50	84.50	84.50	84.00	67.00	86.24
4.Excell 733	86.50	98.00	98.50	90.00	91.50	94.50	84.00	89.50	96.50	89.50	90.00	82.00	94.00	90.50	91.50	86.50	90.80
5.Pioneer 820	91.00	80.50	91.00	73.00	83.50	72.50	74.00	63.50	74.00	56.50	58.50	40.50	60.50	52.50	53.50	25.50	65.64
6.Coop SG-40	87.00	85.00	85.50	76.50	67.50	76.00	78.00	81.00	78.00	81.00	69.50	74.00	65.00	67.00	69.50	58.50	74.92
7.Pioneer 845	93.00	86.00	69.00	84.50	81.00	76.50	85.50	79.50	83.50	82.50	73.00	73.00	80.00	75.50	72.00	61.00	79.30
8.RS 610 (Texas)	72.50	53.00	71.50	50.00	64.50	57.00	60.50	42.50	71.00	59.00	58.00	54.00	59.50	44.00	52.00	30.50	56.20

Table 14. All Possible Correlations Between Two Day Count Following NH_4Cl Treatments and Field Establishment Emergence

	Control				2% NH_4Cl				4% NH_4Cl				8% NH_4Cl				Hutchinson	St. John	Manhattan
	1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		1 hr		2 hr				
	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		.92	.88	.89	.91	.85	.87	.87	.92	.84	.82	.80	.87	.86	.77	.80	.92	.86	.78
2			.92	.98	.90	.91	.90	.97	.96	.94	.93	.92	.93	.98	.90	.94	.86	.78	.67
3				.96	.93	.91	.86	.89	.92	.94	.95	.93	.97	.90	.91	.88	.95	.86	.83
4					.91	.91	.90	.97	.96	.97	.96	.96	.96	.97	.94	.94	.88	.79	.71
5						.92	.92	.89	.96	.88	.93	.90	.95	.89	.89	.90	.88	.82	.72
6							.78	.86	.91	.91	.96	.91	.91	.94	.92	.87	.83	.72	.63
7								.93	.94	.85	.86	.87	.92	.86	.84	.93	.81	.81	.67
8									.97	.95	.93	.95	.93	.95	.93	.97	.79	.71	.59
9										.95	.94	.95	.96	.95	.93	.95	.85	.79	.65
10											.97	.98	.96	.96	.98	.92	.83	.74	.63
11												.98	.97	.96	.98	.95	.83	.73	.64
12													.96	.94	.99	.95	.79	.69	.59
13														.93	.95	.93	.89	.85	.73
14															.95	.94	.80	.72	.57
15																.94	.76	.67	.55
16																	.74	.67	.54
17																		.94	.94
18																			.90

Table 15. All Possible Correlations Between Total Counts Following NH_4Cl Treatments and Field Establishment Emergence

	Control				2% NH_4Cl				4% NH_4Cl				8% NH_4Cl				Hutchinson	St. John	Manhattan
	1 hr		2 hr		1 hr		2 hr		1 hr		2 hr		1 hr		2 hr				
	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C	40°C	50°C			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1		.75	.79	.98	.84	.88	.90	.79	.81	.55	.72	.73	.78	.64	.72	.64	.95	.92	.93
2			.73	.89	.81	.89	.89	.96	.83	.81	.84	.74	.82	.91	.87	.83	.82	.77	.62
3				.83	.83	.89	.76	.71	.82	.53	.77	.64	.73	.64	.75	.64	.83	.70	.71
4					.91	.98	.96	.92	.94	.76	.89	.86	.92	.85	.90	.85	.99	.94	.89
5						.92	.89	.79	.91	.64	.85	.71	.89	.79	.82	.75	.88	.90	.78
6							.94	.91	.97	.79	.94	.88	.94	.88	.94	.88	.97	.90	.84
7								.93	.93	.83	.90	.87	.90	.88	.89	.86	.94	.96	.81
8									.88	.89	.89	.86	.86	.93	.91	.91	.87	.83	.68
9										.83	.97	.92	.98	.90	.96	.92	.94	.91	.81
10											.91	.91	.84	.95	.92	.95	.72	.72	.50
11												.94	.97	.95	.99	.96	.87	.85	.70
12													.91	.88	.94	.94	.87	.83	.76
13														.91	.96	.93	.92	.91	.80
14															.96	.96	.80	.79	.58
15																.97	.88	.83	.71
16																	.82	.78	.63
17																		.94	.94
18																			.90

CORRELATION OF SORGHUM GERMINATION FOLLOWING AMMONIUM CHLORIDE TREATMENT WITH FIELD ESTABLISHMENT

by

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In 1970 fifty-four lots of sorghum seeds were tested. These were made up of 18 hybrids, with each hybrid represented by seed submitted for the 1967, 1968 and 1969 sorghum performance tests. Each seed lot was divided into 3 replications and the following determinations were made:
Standard germination; ammonium chloride test; seed weight; and field emergence.

Data from standard germination and ammonium chloride treatments (2- and 4-day counts) were positive and highly significantly correlated with field establishment with all three sets of seed, but there was no correlation between weight/200 seeds and field counts except for a negative correlation for the 1969 seed.

In 1971 some modifications were made by increasing temperature, time of soaking, and level of concentration of ammonium chloride treatments, and selection of hybrids on the basis of their response to the stress effect of ammonium chloride.

Seeds of eight hybrids were treated with NH_4Cl at 4 levels of concentration: 0, 2, 4, and 8 percent. Samples were soaked for time periods of 1 and 2 hours at temperatures of 40 and 50°C. After soaking, the seeds were rinsed and then germinated.

Field emergence studies were conducted in 1971 at three locations: Sandyland Experiment Field, St. John; South Central Kansas Experiment Field, Hutchinson; and Agronomy Farm, Manhattan, Kansas. A randomized complete block design was used for the first two locations, and a split-plot design was used for Manhattan.

The objective of modified ammonium chloride treatment was to find out which combination would give the highest and most consistent correlation with field establishment.

Laboratory germination after NH_4Cl treatments were in close agreement with field stands at all locations. This means laboratory germination after ammonium chloride stress may predict with accuracy the field performances of grain sorghums both under optimum and sub-optimum conditions.

Among sixteen NH_4Cl laboratory stress treatments, 8 percent NH_4Cl, 1-hour soaking at 40^oC, both for 2-day and total counts gave consistent, positive and significant correlation with field establishment, either combined over locations or separately. Both 2-day and total count of 8 percent NH_4Cl, 1-hour at 40^oC ranked the hybrids the best.

It seemed, therefore, that soaking sorghum seeds in 8 percent NH_4Cl solution at 40^oC for 1 hour can be utilized to screen the non-vigorous from vigorous seed lots and may predict with accuracy field establishment.