RELATIONSHIP OF SEED VIGOR AMONG GRAIN SORGHUM HYBRIDS AND FIELD ESTABLISHMENT

by

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INTRODUCTION

Since seed testing began with the turn of the century, it has been noted that many seed lots that were satisfactory from the viewpoint of standard germination tests, did not perform well under actual field conditions. This poor field performance was generally attributed to soil, climatic and biotic factors.

As better seedbed preparing machines and methods became available and diseases and pests were feasible to control, the climatic factor in relation to the seed itself became the only one left. Then it was noted that some seed lots were more capable than others to withstand adverse field conditions. "Vigor" is this ability of seed to overcome an environment which is not ideal and produce a plant that will complete its cycle and yield.

It is well known that in the obtention of high yields, good seed quality is a prerequisite in order not only to obtain purity, but to produce a uniform and ideal stand of plants conductive to this goal.

Standard germination tests fail to show "weak" seeds (the ones that lack vigor) which will not germinate and produce a normal plant under field conditions. For this reason "vigor tests" have been devised for nearly all crops and ornamental plants.

Vigor tests should provide information on how a particular seed lot may perform in the field, which is not given by the standard germination test, in a consistent way and should be easy to perform.

This information is valuable not only to seed producers in order to determine which lots are best for carryover but to farmers who may adjust their planting rates to obtain the ideal stand for that environment. It also may be useful in selecting a vigorous seed lot for early plantings of sorghum where they have been shown to produce higher yields.

Standard germination does not provide this information for it is conducted in ideal conditions of temperature, moisture, mold control, light, etc., which are standardized in order to be reproducible. Reproducibility is the main problem of vigor tests, many of which try to reproduce field conditions, such as the commonly used cold test for corn. Field conditions are variable according to locations and years, so a test that is efficient in one case may not be in another and/or produce non-repeatable data.

Seed vigor is particularly important in the case of sorghum which is variable in comparison to corn, wheat and other cereal grains.

Paradoxically little research has been done with grain sorghum, while there is abundant literature for other crops.

This research was conducted in an attempt to establish: a) if the methods used by other researchers are consistentfor a large number of hybrids and different seed ages, and b) to compare the tests to provide information as to which is most satisfactory.

LITERATURE REVIEW

Isley (29, 30) discussed the necessity, future and limitations of vigor tests. In his opinion these tests are the major breakthrough in seed quality testing since germination tests were incorporated into the seed testing rules. He also classified them in two categories: 1) direct tests and 2) indirect tests. The direct tests simulate unfavorable field conditions. The advantage is that they are easy to perform, but they present the disadvantage of being difficult to standardize and are useful only in limited areas according to the variation of field conditions. Indirect methods can be reproduced because all variables can be controlled and are good for large areas.

Delouche and Caldwell (14) state that vigor is also important in producing uniform and rapid emergence, besides ideal stand, for proper application of herbicides that are related to plant development. Uniform maturation is also mentioned as an advantage produced by vigorous seeds. They also point out that all seed storage studies should take in consideration vigor besides germination for the work to be more critical.

In this same work a graph is presented to explain the difference between germination and vigor and the meaning of vigor tests. The decline in vigor is much faster than the decline of standard germination and the difference between both curves is the gap covered by vigor tests. This gap is greatest just before deterioration is reflected in viability. Niffeneger (42) states that germination seed test reports do not provide the information necessary to determine seeding rate which is considered fundamental since this is the ultimate purpose of all seed produced. Relative seeding value could be provided by vigor tests and a method is proposed using the number of normal sprout-producing seeds planted per square foot from a seeding rate of one pound per acre. He further states that where vigor tests are not available an estimate of vigor based on seed size could be used.

Moore (40) also discusses the evaluation of the dying seed and some methods of determining deterioration.

Clark (9) points out the practical importance of vigor tests in crop production.

As was mentioned in the introduction, there is a great need for a vigor test due to discrepancies between field emergence and standard germination even from lots with high germination percentage. Swanson and Hunter (52) found discrepancies in field emergence and standard germination tests for sorghum that ranged from 30 to 50%. Vinall (55) in Texas also found large differences between field and laboratory results. These were more marked for cold, wet soils than for moist soil and higher temperatures.

Evans, Stickler and Laude (17) after comparing emergence from soil and standard germination concluded that no one lot of of seed is representative of a variety or hybrid due to their variation in response to different temperatures.

Evans and Stickler (16) report that four lots of RS610 from different parts of Kansas responded to moisture and temperature stress very differently. In fact they behaved in a manner equal to widely different genotypes.

Swanson and Hunter (52) concluded that the discrepancy between field emergence and laboratory germination is probably greater for sorghum than for most crops. They arrived to this conclusion after extensive studies in Hays, Kansas, in which the discrepancies for sorghum were compared to results for corn in the same location and from the data of other researchers.

Some of the causes for this variability in sorghum are: environmental conditions during maturation of seed; mechanical damage during harvest; and, handling and storage conditions.

Several authors have studied the environmental conditions during seed maturation. Carlson and Atkins (8) studied the effect of freezing temperatures on grain sorghum with varying moisture contents and concluded that even though there was a reduction in viability there was no reduction in vigor. The reduction in germination was affected by genotype, freezing temperature and duration and grain moisture content.

Gritton and Atkins (23) arrived at the same conclusion. Rosenow, Casady and Heyne (47) found that seeds from plants produced by good quality seed are less susceptible to freezing injury, they also found varietal differences in susceptibility. Kantor and Webster (33) also studied the effect of freezing.

Jones, Cobb and Hay (31) point out the importance of mechanical injury during harvest and handling in viability and storage qualities. Seeds that were cracked over the germ did not germinate because of fungus infection. Douglas, Brooks and Winsted (15) report correlation between seed injury and decrease of germination and vigor in the case of cotton.

Kantor and Webster (33) report that higher cylinder velocities produce not only higher percentage of cracking in sorghum but also lowered the germination of the sound seed and increased abnormal seedlings possibly by damage to the radicule and plumule.

Moore (40) reports that tensions produced during alternate dry and humid periods during maturation can cause crushing of the germ in the same way that occurs during mechanical harvest.

McNeal and York (38) have reported a study concerning the conditioning and storage of grain sorghum for seed. Clark (10) studied the effect of several types of bags on viability and vigor. Sorghum germination was not affected by the bag type but vigor was lowered when measured by the cold test in some cases.

It is interesting to note that plants produced by seeds of a higher germination percent produce more grain per plant and are earlier than the same hybrid but of a lower germination (4). This effect has also been reported for corn and oats (22). Also delayed emergence, slower growth, fewer tillers and seeds per head were produced by less vigorous seeds.

Several reports have been made on sorghum seed longevity. Robertson, Lute and Kroeger (46) reported that black amber sorghum maintained its germination for a period of 17 years. Thornton (54), with the same variety, in 1962 obtained 89.5%, 50% and 73.5% germination for seed lots produced in 1925, 1926 and 1927 respectively. Karper and Jones (34) obtained a loss of 12% in viability after 7 years. By the end of the 10th year half of the seeds were still viable but after that germination fell quickly and the ones that did germinate were weak. Plotting these results, a curve was obtained which he called the "death curve" and corresponded to the right half of a bell shaped one.

Ayyangar and Ayyar (5) found that sorghum seeds preserved in the head retained viability at 90% during 7 years but the threshed ones stored in a bottle germinated only 10% after 4 years. Undoubtedly temperature, moisture content, and air humidity are important factors affecting deterioration.

The cold test for corn is the most commonly used vigor test. For this reason several attempts to adapt this method to sorghum havo been made with mixed results.

Pinthus and Rosenblum (44) in Israel obtained similar germinations between checks and cold treatment when the seeds were protected with a fungicide while in the case of untreated seeds significant differences were obtained. From these results they conclude that this would be a suitable method to evaluate fungicides but fails as a vigor test.

Sirvastava and Pinnell (48) using three dates of planting and two years data found that cold tests could not predict field stand better than standard germination tests especially if the season was not cold and damp. They also point out the importance of seed treatment especially for the early plantings which are likely to encounter cool damp conditions. They also found significant variety by lot interactions indicating the importance of the environment in which the seed was produced.

Adams (2) using several types of mulches and seedbed configurations reported increased germination of sorghum in Texas and concluded that the soil was too cool at normal planting time for maximum emergence and stand.

Lancaster (36) in 1958-59 conducted the first cold tests with sorghum in an attempt to devise a standard cold test. Nine lots of RS610 were used and laboratory tests were compared to field emergence. All lots were treated and planted in the field at two dates. The results obtained showed high correlations between cold test and field emergence as well as standard germination and field emergence. No significant difference was noted in the four temperatures used in the cold test and again pointed out the importance of seed treatment.

Evans et al (17) compared emergence from soil at three different temperatures with standard germination and found very marked temperature effects. Varietal differences and a lot by variety interaction were highly significant.

Abdullahi (1) conducted an intensive study of several vigor tests one of which was the cold test. Plants were grown at 55-56° F for seven days after which it was raised to 79-80° F until completion of emergence. Dry matter of the fraction above the soil was determined. Percent seedling emergence from cold soil was the closest to field emergence but presented a low correlation when compared to the other vigor tests used.

Crosier (13) recognizes the importance of molds in cold tests. Other authors (9, 25, 26, 37, 39 and 43) also point out the importance of fungi and fungicides in field and laboratory germination.

Abdullahi (1) and Barnes (6) have compared and evaluated various vigor tests for sorghum which constitute the basic research work done for this crop.

The methods used by Barnes were: a) Hot water treatment in which seeds were soaked in hot water at 65°, 70° and 80° for 2 to 30 minutes and 90° and 100° C for 5 to 45 seconds. b) Sodium hydroxide treatment: seeds were soaked from 1 to 20% concentration solution from 2 to 65 minutes after which they were flushed with tap water. c) Heat treatment: dry seeds were exposed for periods of 60 to 360 minutes to temperatures of 80 to 100° C. After all these treatments seeds were germinated. d) Sterile sand test: Seeds were germinated in sterile sand with a moisture content from saturation to 10% and temperatures of 20° to 35° C. All these were compared to standard germination and field emergence. Results showed that a 5 second soak in 100° C water ranked and correlated the 32 lots best with field emergence, the 5% sodium hydroxide test approximated best field emergence.

Abdullahi used as vigor test: a) Artificial aging of seeds: seeds were held at 100° F and relative humidities between 95 and 100% for ten days. b) Ammonium chloride treatment: seeds were soaked in a 2% solution of NH_4Cl for 2 hours at 40° C then flushed with tap water. Germination followed these two treatments. c) The cold test already mentioned. These methods were compared to standard germination and field emergence of two different planting dates. Although correlations with field emergence were highly significant for all treatments the ammonium chloride test produced the highest correlation and ranked the seed lots best. This last author also tested the effect of seed size on field emergence and laboratory tests. Seed lots were divided into those retained by a 10/64 round hole sieve those passing a 10/64 and retained on a 9/64 and those passing a 9/64 sieve. Only the smaller size group produced significantly lower emergences.

On the other hand Swanson and Hunter (52) reported that smaller seeds show a tendency to germinate better than the large seeded varieties.

Tetrazolium tests have been reported as vigor tests for other crops but not for sorghum. Thorneberry and Smith (53) report a close relationship between respiration activity and ability to germinate. Isley (28) published a review of the use of tetrazolium salts in determining viability.

Highly satisfactory results were obtained for wheat by Kittock and Law (35) when extracting the red colored, reduced form of tetrazolium and correlating it with vigor determined by emergence tests in the greenhouse.

Similarily good results were obtained by Moore and Goodsell (41) with corn when they attempted to predict cold test results with tetrazolium.

Dormancy has been reported by several researchers (7, 11, 12, 18, 24, 45, 49, 50, 54 and 56). Although it does not present a problem to the farmer, for it is present for a short period of time following maturity, it might be an inconvenience in testing seeds for vigor immediately after harvest. This is a varietal character in forage sorghums. Several methods for breaking dormancy are presented in those same papers.

Harmond (27) suggests that vigor could also be measured by respiration rate using gas chromatography or a Warburg apparatus, using electromagnetic waves to distinguish dead from live seeds or x-rays to detect mechanical injury, live or dead seeds, partially filled seeds and presence of fungi infection. The latter method providing a photographic record of the seed. All these methods would take only a few hours.

Strong and Lindgrem (42) report that after fumigation with methyl bromide differences in emergence and growth were noted and attributed to differences in seed quality. This also could be used as a vigor test.

Gopalachari (19) and Grabe (20 and 21) have studied enzyme activity during germination and the second author used glutamic acid decarboxylase activity as an index of vigor.

METHODS AND MATERIALS

The seed used in this research was provided by Mr. Ted Walter and consisted of 21 different hybrids and two seed ages: the seed utilized in the 1967 Kansas grain sorghum performance test and that used in the 1968 test. In addition the nine sources of RS610 tested by Abdullahi (1) were used in the 1967 seed age. The list of hybrids is given in Table 1. The seed lots received had all been treated with fungicides. They were divided into three replications of 80 grams each and used for all the experiments.

LABORATORY TESTS

The following tests were selected from the literature.

1. Sodium hydroxide treatment. Two different tests were performed within this treatment as reported by Barnes (6). The first consisted of soaking 50 random seeds placed in test tubes in a 5% NaOH solution for five minutes. After this period of time seeds were rinsed and flushed in tap water for about 30 seconds and were put to germinate immediately, following standard rules (3). All seed counting was done at random with a vacuum counter.

The second test was identical except for only a 2 minute soaking period.

2. Ammonium chloride treatment. This vigor test used by Abdullahi's work (1), consisted of soaking 50 random seeds placed in a cheese cloth bag for 2 hours in a 2% NH_4Cl solution

at a temperature of 40^{o} C that was obtained with a water bath. Previous to soaking the solution was also preheated to that temperature. After this period seeds were flushed, rinsed and germinated according to standard rules.

TABLE 1. LIST OF HYBRIDS FROM WHICH SEEDS WERE USED DURING THIS STUDY

Hybrids for which 1967 and 1968 Seed Ages Were Obtained

NK 280	Excel 707
NK 265	Excel 505
NK 275	T. E. Grainmaster A
RS 626	T. E. Mucho
RS 671	Asgrow Ranger B
RS 702	DeKalb F 64
RS 610	DeKalb E 57
Pioneer 820	DeKalb F 61
Pioneer 845	NC + T - 700
Pioneer 828	PV 685
Pioneer 846	

Various Sources of RS 610 Seed Used

1. Anderson Seed Co., Texas
2. Dorman and Co., Texas
3. W. R. Grace and Co., Mo.
4. Henry and John Bunk, Ks.
5. NC - Hybrids, Kansas
6. Prairie Valley Inc., Ks.
7. Prairie Valley Inc., Nebr.
8. Richardson Seed Farms, Texas
9. Star Seed and Produce Co., Texas

3. Tetrazolium test. This test was adapted from the one devised for wheat by Kitlock and Law (35). It consisted of placing 10 random seeds in a test tube and soaking them in a 0.2% aqueous solution of 2, 3, 5 - triphenyl tetrazolium chloride (T.T.C.) for a period of twenty-four hours to obtain good staining. After this period seeds were flushed, rinsed and placed in the same test tube. Then the red colored 1, 3, 5 - triphenyl formazan was extracted from the intact seeds with 5 ml of ethylene glycol monomethyl ether for a period of five hours and optical density measured with a Beckman spectrophotometer at 480 mμ against a blank conducted in the same way except that it was soaked in water instead of the tetrazolium solution. This was done to eliminate possible interference from the color of the seed treatment.

4. Percentage Small Seed. Data obtained by Abdullahi (1) indicated that the amount of small seeds present in a seed lot could be an index of vigor. Seed samples of about 60 grams were passed through a 9/64 inch diameter round hole sieve. The fraction not retained was considered small seed and calculated as a percentage of the total.

5. Standard Germination. This test was conducted following the rules for testing seed (3) except for temperature that fluctuated between 24° and 31° C. A random sample of 50 seeds was placed in a petri dish with two layers of filter paper and watered periodically as needed. Normal seedlings were counted from the fourth to the tenth day.

FIELD EMERGENCE

Field emergence studies were conducted at the Agronomy Farm, Manhattan, Kansas, in 1968 and 1969 and at the North-central Kansas Experiment Fields, Bellville, Kansas, in 1968. A randomized complete block design was used with three replications.

Plots consisted of two rows separated 30 inches in each of which 50 random seeds were placed. Planting was done with a vacuum planter and plots were approximately 15 feet long. Herbicide was applied and insecticide when needed.

Plants were counted by hand and the center 10 feet of each row was harvested. Heads harvested per plot also were counted.

Planting, counting and harvesting dates are presented in Table 2. At the time this thesis was written data were not available for yield and heads per plot for the Manhattan, 1969 planting.

TABLE 2. LOCATIONS, PLANTING, COUNTING AND HARVESTING DATES FOR FIELD EMERGENCE TRIALS

Location	Planting Date	Counting Date	Harvest Date
Manhattan 1968	6-3-68	6-21-68	10-3-68
Belleville 1968	6-20-68	7-10-68	10-28-68
Manhattan 1969	6-4-69	6-25-69	---

RESULTS AND DISCUSSION

Field Emergence

Data obtained for field emergence are shown in Table 3. Analysis of variance showed highly significant differences for seed ages, hybrids and the interaction of these two factors for both years at Manhattan. At Belleville, hybrids and seed age differences were highly significant, but their interaction was significant at the 5% level only.

These results indicate that seed age undoubtedly is an important factor in field emergence and also in seed vigor.

It is important to notice that since one seed sample is not representative of a hybrid, the differences obtained are to be interpreted as different seed lots and not be extended to the whole hybrid.

Interaction effects signify that some samples lost vigor from one year to the other of storage, while others did not and apparently some gained vigor.

Laboratory Tests

Correlations obtained between laboratory and field emergence tests are presented in Tables 4 and 5, pages 18 and 19.

1. Standard Germination test results are summarized in Table 6, page 20. Analysis of variance indicates highly significant differences for hybrids and years and a highly significant interaction, both for the fourth and tenth day count as in the case of field emergence.

TABLE 3. FIELD EMERGENCE FOR ALL LOCATIONS, HYBRIDS & SEED AGES (IN PERCENTAGE), AVERAGE OF THREE REPLICATES

	Manhattan 1968		Belleville 1968		Manhattan 1969	
Hybrids	Seed Age 1967	1968	Seed Age 1967	1968	Seed Age 1967	1968
NK 280	76.6	88.6	64.0	77.6	66.0	85.6
Pioneer 820	79.3	77.6	65.3	61.6	69.6	65.3
Pioneer 845	78.6	84.0	70.6	65.6	80.6	75.6
Excel 707	95.3	88.6	77.6	66.3	79.0	79.6
RS 626	87.0	77.6	67.0	66.0	71.0	67.3
NK 265	71.3	84.0	51.0	71.6	59.6	74.6
Pioneer 828	84.6	87.0	65.3	66.0	69.3	70.3
RS 671	74.0	89.0	59.0	72.6	70.6	77.0
T.E. Grainmaster A	69.6	80.0	50.6	60.6	55.3	72.3
T. E. Mucho	83.0	89.3	62.0	66.3	72.0	71.6
Pioneer 846	70.0	86.3	51.0	64.0	61.0	72.6
Asgrow Ranger B	95.6	88.6	80.6	75.6	81.6	79.6
Excel 505	60.3	83.6	52.6	65.3	45.3	77.0
DeKalb F 64	92.0	91.3	63.6	68.0	82.6	80.0
NK 275	88.3	91.0	68.3	63.3	78.0	81.6
DeKalb E 57	75.3	84.0	61.3	75.3	69.0	78.0
NC + T - 700	80.6	82.6	54.3	65.6	70.6	76.6
Pv 685	83.6	86.0	70.6	65.6	71.3	67.0
DeKalb F 61	86.0	88.3	68.0	71.3	74.3	81.3
RS 702	63.0	83.0	50.0	57.6	53.3	64.0
RS 610						
Source 1	87.0	--	57.0	--	74.0	--
Source 2	80.3	--	65.3	--	66.6	--
Source 3	83.3	--	72.6	--	75.0	--
Source 4	71.0	82.0	46.0	56.3	49.6	68.6
Source 5	71.6	--	57.6	--	62.0	--
Source 6	72.0	--	54.6	--	55.0	--
Source 7	76.0	--	52.6	--	60.6	--
Source 8	75.6	--	58.3	--	69.6	--
Source 9	80.6	--	64.0	--	68.6	--
Mean	79.0	85.3	61.5	66.3	67.6	74.7
Location Mean	81.7		63.5		70.6	
Hybrid LSD 0.05:	2.1		3.1		2.2	
Seed Age* LSD 0.05:	2.0		2.8		2.0	

*Excluding All Sources of 1967 RS 610 Except Source 4

TABLE 4. CORRELATIONS OF VIGOR TESTS AND FIELD EMERGENCE WHEN BOTH SEED AGES ARE CONSIDERED TOGETHER

Location	Standard Germination		NH_4Cl Test		5 Minute NaOH Test		2 Minute NaOH Test		Percent Small Seed Test	Tetra-Zolium Test
	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count		
Manhattan 1968	0.472**	0.456**	0.597**	0.600**	0.298**	0.257**	0.453**	0.446**	-0.008	0.102
Belleville 1968	0.401**	0.381**	0.479**	0.469**	0.262**	0.226**	0.355**	0.361**	-0.135	0.032
Manhattan 1969	0.600**	0.577**	0.611**	0.613**	0.406**	0.365**	0.520**	0.511**	0.002	0.081

* Significant at the 5% Level

** Significant at the 1% Level

TABLE 5. CORRELATIONS OF VIGOR TESTS AND FIELD EMERGENCE WHEN BOTH SEED AGES ARE CONSIDERED SEPARATELY

Location	Standard Germination		NH_4Cl Test		5 Minute NaOH Test		2 Minute NaOH Test		Percent Small Seed Test	Tetrazolium Test
	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count		
1967 SEED AGE										
Manhattan 1968	0.530**	0.507**	0.608**	0.619**	0.165	0.127	0.392**	0.387**	-0.036	0.028
Belleville 1968	0.480**	0.447**	0.490**	0.481**	0.146	0.131	0.316**	0.315**	-0.221*	0.075
Manhattan 1969	0.612**	0.580**	0.571**	0.573**	0.228*	0.184	0.443**	0.436**	-0.126	0.024
1968 SEED AGE										
Manhattan 1968	0.030	0.032	0.385**	0.384**	0.323**	0.302*	0.309*	0.303*	0.046	0.001
Belleville 1968	0.142	0.143	0.366**	0.354**	0.286*	0.236	0.280*	0.301*	-0.054	-0.120
Manhattan 1969	0.400**	0.379**	0.534**	0.547**	0.539**	0.525**	0.454**	0.442**	0.198	-0.048

* Significant at the 5% Level
** Significant at the 1% Level

TABLE 6. STANDARD GERMINATION TEST RESULTS FOR SEED AGES, HYBRIDS AND DAY OF COUNT EXPRESSED IN PERCENTAGE (AVERAGE OF THREE REPLICATES)

Hybrid	1967 Seed Age 10 Day Count	1967 Seed Age 4 Day Count	1968 Seed Age 10 Day Count	1968 Seed Age 4 Day Count
NK 280	95.3	94.6	98.6	98.6
Pioneer 820	90.0	88.6	94.0	94.0
Pioneer 845	98.0	96.6	96.0	94.0
Excel 707	95.3	94.6	95.3	95.3
RS 626	96.0	95.3	94.0	93.3
NK 265	86.6	86.6	94.6	93.3
Pioneer 828	92.6	90.0	94.6	94.0
RS 671	90.6	90.6	96.6	96.6
T. E. Grainmaster A	83.3	82.0	88.6	88.6
T. E. Mucho	87.3	87.3	92.6	89.3
Pioneer 846	84.0	82.0	93.3	92.0
Asgrow Ranger B	98.0	94.6	90.6	90.6
Excel 505	80.6	80.6	98.6	98.6
DeKalb F 64	97.3	97.3	94.6	94.6
NK 275	97.3	97.3	94.6	94.0
DeKalb E 57	82.6	81.3	96.6	96.6
NC + T - 700	88.0	88.0	94.0	94.0
Pv 685	93.3	92.6	92.6	92.6
DeKalb F 61	90.0	86.0	96.0	96.0
RS 702	92.0	91.3	82.0	81.3
RS 610				
Source 1	90.6	90.0	--	--
Source 2	91.3	90.6	--	--
Source 3	96.6	96.0	--	--
Source 4	80.6	69.3	88.0	86.0
Source 5	85.3	83.3	--	--
Source 6	87.3	87.3	--	--
Source 7	88.0	86.6	--	--
Source 8	90.6	88.6	--	--
Source 9	91.3	91.3	--	--
Mean:	90.3	89.3	93.6	93.2

10 Day Count Mean (Both Seed Ages): 91.7
4 Day Count Mean (Both Seed Ages): 90.9

LSD 0.05 for Hybrids 10 Day Count: 1.4
LSD 0.05 for Hybrids 4 Day Count: 1.5
LSD 0.05 for Seed Ages, 10 Day Count:* 1.1
LSD 0.05 for Seed Ages, 4 Day Count:* 1.2

* Excluding all Sources of 1967 RS 610 Except Source 4

Correlations between standard germination and field emergence tests were highly significant for all three locations when both seed ages were considered together, but when considered separately they were still highly significant for the 1967 seed age but were not significant for 1968 except the Manhattan 1969 planting where the seed lots were one year older. Standard germination tests were conducted during the 1968 field trials.

This difference probably exists because during one year of storage, weak seeds died and standard germination tests could provide information about field emergence as compared to the 1968 seed age, where weak seeds were still alive and capable of germinating under the favorable conditions of the standard germination test but failing to emerge under field conditions. In the case of the Manhattan 1969 planting high correlations were obtained probably due to the fact that there was no moisture and temperature stress rather than the fact of one year older seed lots because germination tests were performed almost a year earlier.

These results are in accordance with the criticism that standard germination tests fail to provide information on field performance of a particular seed lot. Means for the 10 and 4 day standard germination count were 91.2 and 90.9 as compared to 71.9 average field emergence for all three locations and 63.5% for Belleville which was the most unfavorable location.

The differences noted in correlations when both seed ages are considered together or separately indicate that in the long run, standard germination tests, for a large number of hybrids and seed ages on the average may approximate actual field emergence but fails to identify low vigor lots with accuracy.

Fourth day count failed also as a measure of seed vigor, in fact correlations were lower than for the complete standard germination test (10 days). Presumably a shorter period would have favored only more vigorous seeds while weak seeds would not have time to germinate.

No dormancy was present in the seed lots used as demonstrated by the high germination percentages obtained.

2. Ammonium Chloride Test: Results obtained are presented in Table 7. Analysis of variance reveals highly significant differences for hybrids and years and a highly significant interaction of year x hybrid for both 10 and 4 day counts. These analyses indicate differences in vigor detected by the test on the different hybrid seed lots, seed age, and the interaction present between age and seed lot meaning that some seed lots lose vigor in storage more rapidly than others.

Highly significant correlations were obtained in all cases when seed ages were considered together or separately. These results indicate that this test is highly satisfactory in providing a seed vigor measurement. Fourth day count is as good as a tenth day count permitting an appreciable reduction in the test length. It was noted that seeds germinated very rapidly after this treatment, possibly this could be attributed to high temperature that caused higher embryo activity and

TABLE 7. AMMONIUM CHLORIDE TEST RESULTS FOR SEED AGES, HYBRIDS AND DAY OF COUNT EXPRESSED IN PERCENTAGE OF SEEDS GERMINATED AFTER TREATMENT (AVERAGE OF THREE REPLICATES)

Hybrid	1967 Seed Age		1968 Seed Age	
	10 Day Count	4 Day Count	10 Day Count	4 Day Count
NK 280	75.3	73.3	91.3	91.3
Pioneer 820	76.3	74.0	75.8	74.3
Pioneer 845	82.5	82.5	82.6	81.3
Excel 707	92.6	92.6	90.0	90.0
RS 626	93.3	93.3	78.6	78.0
NK 265	79.1	79.1	91.3	91.3
Pioneer 828	76.0	76.0	86.6	84.0
RS 671	82.9	82.9	87.3	86.6
T. E. Grainmaster A	67.8	67.0	81.2	81.2
T. E. Mucho	76.8	76.8	90.0	90.0
Pioneer 846	70.2	69.3	78.0	77.3
Asgrow Ranger B	94.6	94.0	92.6	91.3
Excel 505	62.0	61.3	94.0	91.3
DeKalb F 64	89.3	89.3	87.3	87.3
NK 275	77.4	76.0	89.9	89.9
DeKalb E 57	67.6	66.3	89.4	58.6
NC + T - 700	67.3	67.3	88.6	86.0
Pv 685	82.5	82.0	71.1	69.6
DeKalb F 61	84.6	82.6	90.1	88.6
RS 702	57.4	53.3	62.4	71.0
RS 610				
Source 1	84.6	84.6	--	--
Source 2	73.4	73.3	--	--
Source 3	79.8	78.6	--	--
Source 4	54.3	51.6	66.6	66.6
Source 5	71.4	71.4	--	--
Source 6	58.6	58.6	--	--
Source 7	78.0	77.3	--	--
Source 8	67.1	66.3	--	--
Source 9	77.7	75.3	--	--
Mean:	75.7	75.1	84.0	83.2

10 Day Count Mean (Both Seed Ages): 79.2
4 Day Count Mean (Both Seed Ages): 78.5

LSD 0.05 for Hybrids 10 Day Count: 2.5
LSD 0.05 for Hybrids 4 Day Count: 2.5
LSD 0.05 for Seed Ages 10 Day Count:* 2.2
LSD 0.05 for Seed Ages 4 Day Count:* 2.2

* Excluding all Sources of 1967 RS 610 Except Source 4

water absorption. Radicules started breaking the pericarp only a few hours after the soaking was completed.

This test with 79.2% for the average of the ten day count and 78.5% for the four day count approximates the actual field emergence value of 71.9% for all three locations.

Correlations with field emergence were the highest obtained for all the tests used. Highly significant correlations were also obtained with standard germination (general table of correlation in the appendix).

3. Sodium Hydroxide Tests. Results for this vigor test are given in Table 8.

a) 5 minute soak in 5% NaOH solution: Analysis of variance indicates highly significant differences for years and hybrids and also highly significant interaction for both the fourth and tenth day count.

Again analysis of variance points out that the test was effective in detecting differences in vigor and interactions for all factors included. Correlations with field emergence when all seed ages are considered together are highly significant but again, like standard germination, when seed ages are considered separately this test was inconsistent.

Tenth day count performed better than the fourth day count not only because it was somewhat more consistent but because of slightly higher correlation. This test seems to detect vigor differences better on recently produced seed lots than

TABLE 8. SODIUM HYDROXIDE TESTS RESULTS FOR SEED AGE, HYBRIDS AND DAY OF COUNT EXPRESSED IN PERCENTAGE OF SEEDS GERMINATED AFTER TREATMENT (AVERAGE OF THREE REPLICATES)

Hybrids	5 MINUTE TEST				2 MINUTE TEST			
	1967 Seed Age		1968 Seed Age		1967 Seed Age		1968 Seed Age	
	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count
NK 280	39.3	34.3	75.9	74.0	56.3	55.0	75.3	75.3
Pioneer 820	17.0	14.6	36.8	35.3	44.6	44.0	75.0	64.3
Pioneer 845	57.7	52.6	34.0	30.3	73.3	73.3	58.6	58.6
Excel 707	50.1	47.3	55.7	51.0	75.0	75.0	85.0	85.0
RS 626	85.1	85.3	39.2	33.3	85.3	85.3	50.3	50.3
NK 265	45.9	45.3	69.4	64.0	53.6	53.0	78.3	77.6
Pioneer 828	14.9	15.0	37.4	34.0	31.3	21.3	65.0	65.0
RS 671	54.6	51.3	74.1	67.6	53.0	53.0	72.0	72.0
T. E. Grainmaster A	17.5	16.3	63.1	58.3	23.0	23.3	65.3	65.3
T. E. Mucho	47.4	46.0	64.8	58.6	37.6	37.0	68.6	34.6
Pioneer 846	24.0	24.0	56.5	53.6	44.6	44.6	64.6	64.6
Asgrow Ranger B	4.7	2.0	54.4	53.0	50.6	49.3	82.0	81.0
Excel 505	26.2	25.3	65.7	58.0	44.0	44.0	80.3	80.3
DeKalb F 64	45.9	32.6	74.1	67.6	82.6	79.3	85.3	84.6
NK 275	49.3	42.3	80.5	80.0	70.6	70.6	68.0	66.0
DeKalb E 57	44.8	43.0	72.7	64.6	71.0	69.0	86.3	84.3
NC + T - 700	16.6	15.3	52.2	45.3	25.0	25.0	66.0	63.3
Pv 685	39.3	36.0	9.8	8.6	42.6	42.6	46.3	45.0
DeKalb F 61	55.4	52.6	52.7	41.3	76.3	75.6	81.3	81.3
RS 702	32.2	27.6	20.2	16.6	43.6	43.6	47.0	45.6

TABLE 8. (Continued)

Hybrids	5 MINUTE TEST				2 MINUTE TEST			
	1967 Seed Age		1968 Seed Age		1967 Seed Age		1968 Seed Age	
	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count	10 Day Count	4 Day Count
RS 610								
Source 1	55.5	54.3	--	--	73.6	73.0	--	--
Source 2	34.5	34.3	--	--	42.0	42.0	--	--
Source 3	59.3	58.0	--	--	74.0	74.0	--	--
Source 4	40.0	38.0	30.1	28.0	44.6	44.6	45.3	45.3
Source 5	36.2	35.6	--	--	36.0	34.6	--	--
Source 6	31.3	28.0	--	--	66.3	66.3	--	--
Source 7	49.0	42.3	--	--	51.3	51.3	--	--
Source 8	41.6	39.0	--	--	57.0	56.3	--	--
Source 9	54.7	51.3	--	--	61.3	60.0	--	--
Mean	40.4	37.9	53.7	49.0	53.9	53.4	68.5	67.6

10 Day Count Mean (Both Seed Ages): 5 Minute Test: 46.0; 2 Minute Test: 60.0

4 Day Count Mean (Both Seed Ages): 5 Minute Test: 42.5; 2 Minute Test: 59.4

10 Day Count LSD 0.05 (Both Seed Ages): 5 Minute Test: 3.8; 2 Minute Test: 3.4

4 Day Count LSD 0.05 (Both Seed Ages): 5 Minute Test: 3.7; 2 Minute Test: 3.5

10 Day Count LSD 0.05 for Seed Ages*: 5 Minute Test: 4.0; 2 Minute Test: 3.9

4 Day Count LSD 0.05 for Seed Ages*: 5 Minute Test: 3.3; 2 Minute Test: 3.3

* Excluding all Sources of 1967 RS 610 Except Source 4

with those which have been stored for a year where it fails to produce significant correlations with field emergence.

This method was found to be very harsh on seeds. Another inconvenience was that even after thorough flushing and rinsing sodium hydroxide could not be removed completely and seeds retained a soapy film around them. This remaining sodium hydroxide may have caused alkalinity problems in the germination medium and prolonged its effect on the seed for more than the five minutes of soaking. It also presents the inconvenience of possible experimental errors due to the short time of soaking that may have a high incidence if surpassed or shortened even by half a minute.

Field emergence is severely underestimated by this vigor test, average for the ten day count is 46.0% and 42.5% for the fourth day count as compared to 71.9% field emergence average for all three locations.

b) Two minute soak in 5% NaOH solution: Again this test produced an analysis of variance highly significant for hybrids, years and interaction for both counts.

Highly significant correlations were obtained in all cases (all locations and 4th and 10th day count) when both seed ages were considered together. When considered separately, results show highly significant correlations with field emergence for the 1967 seed lots of all three locations.

Correlations for the 1968 seed lot show a highly significant linear relationship for the 1968 Manhattan planting but only significant for Belleville 1968 and Manhattan 1969.

These data suggest that these inconsistencies may be attributed to different field conditions that this test failed to anticipate.

Although the two minute soak was not so harsh on the seed and much less sodium hydroxide was retained after rinsing and flushing this method also presents the inconvenience of possible experimental errors due to an even shorter soaking period.

It was noted during this test that germination was very rapid in the first day similar to the ammonium chloride test and after the first count, during the fourth day of germination, very few seeds germinated. This may be why the fourth day count performed as well as the 10 day count as a vigor test therefore permitting an appreciable reduction in the time necessary to conduct the test.

One might speculate that the apparent difficulty of both sodium hydroxide tests in detecting seed age differences or anticipate different field conditions may be attributed to the mechanical effect of NaOH rather than the physiological effect of NH_4Cl.

Correlations with standard germination follow the same pattern as with field emergence for both tests. Correlations with the ammonium chloride test results are highly significant which indicates that this is not a satisfactory evaluation method for a vigor test for it is incapable of distinguishing a relatively good test like the 2 minute test from an unsatisfactory one like the 5 minute test. This is an important fact for several authors have evaluated vigor tests against others as checks and these results indicate that no relative or absolute value of a test is given.

4. Small seed percentage. Results from this test are presented in Table 9.

Analysis of variance shows no significant differences for seed ages but highly significant ones for hybrids and a highly significant interaction of these two factors indicating different proportions of small seed in the different hybrid sorghum lots and that these proportions varies in each hybrid according to the environment in which that seed was produced.

Correlations with field emergence for this test have all proven insignificant except in the case of the Belleville planting where a greater stress existed. There is a general trend towards negative correlations that indicate there is a positive relationship between small seed and low vigor, although insignificant, and therefore unacceptable as a test of field performance.

Correlations with standard germination are all negative and insignificant except for the 1968 seed lots where positive insignificant correlations were obtained. This is also true for field emergence correlations (except for Belleville) which

TABLE 9. PERCENTAGE OF SMALL SEED FOR SEED AGES AND HYBRIDS (AVERAGE OF THREE REPLICATES)

Hybrid	Seed Age 1967	Seed Age 1968
NK 280	1.2	1.8
Pioneer 820	1.5	1.5
Pioneer 845	5.6	0.7
Excel 707	0.8	5.4
RS 626	18.0	9.6
NK 265	2.7	3.6
Pioneer 828	1.6	2.8
RS 671	1.2	4.5
T. E. Grainmaster A	16.4	1.9
T. E. Mucho	3.3	3.6
Pioneer 846	3.4	1.8
Asgrow Ranger B	1.3	5.7
Excel 505	3.1	3.9
DeKalb F 64	13.4	17.4
NK 275	1.9	1.5
DeKalb E 57	10.2	7.1
NC + T - 700	1.7	28.6
Pv 685	2.2	3.4
DeKalb F 61	1.8	1.5
RS 702	0.6	0.3
RS 610		
Source 1	11.9	--
Source 2	4.8	--
Source 3	4.2	--
Source 4	10.4	2.7
Source 5	5.2	--
Source 6	9.3	--
Source 7	6.6	--
Source 8	2.9	--
Source 9	4.8	--
Mean	5.0	4.9

Mean for Both Seed Ages: 5.0

LSD 0.05 for Hybrids (Both Seed Ages): 0.6

LSD 0.05 for Seed Ages:* 0.6

* Excluding all Sources of 1967 RS 610 except Source 4

might indicate that during the first year much of the small seed are alive and vigorous losing this condition during one year of storage.

5. Tetrazolium Test. Results obtained are summarized in Table 10. Although this method detected highly significant differences in hybrids and seed ages and their interaction, it failed to be associated with field emergence.

Respiration activity as measured by reduction of tetrazolium is correlated with vigor and used satisfactorily as a vigor test for other crops. For this reason and the rapidity and simplicity of this method, is justification for further research with tetrazolium.

Tetrazolium work with sorghum is quite difficult because of impermeable waxes in the pericarp that require long soaking periods to obtain staining of the germ. Possibly using an apparatus of the "vitascope" type would shorten this period and produce better staining.

Another possibility to improve this technique would be to use samples larger than the ones used (ten seeds), at least one hundred without any complication in the method. Testing seed without color from seed treatment would also help.

Correlations with all other tests are also insignificant.

6. Harvest results. These results are presented in Tables 11 and 12, pages 33 and 34.

a) Yield: Analysis of variance shows only highly significant differences for hybrids in the case of Manhattan and

TABLE 10. ABSORBANCE RESULTS OBTAINED FOR THE TETRAZOLIUM TEST FOR SEED AGES AND HYBRIDS (AVERAGE OF THREE REPLICATES)

Hybrid	Seed Age 1967	Seed Age 1968
NK 280	.098	.050
Pioneer 820	.137	.099
Pioneer 845	.126	.317
Excel 707	.126	.179
RS 626	.085	.113
NK 265	.069	.171
Pioneer 828	.152	.174
RS 671	.080	.137
T. E. Grainmaster A	.029	.201
T. E. Mucho	.095	.125
Pioneer 846	.166	.193
Asgrow Ranger B	.144	.167
Excel 505	.118	.115
DeKalb F 64	.100	.127
NK 275	.139	.101
DeKalb E 57	.078	.113
NC + T - 700	.118	.116
PV 685	.175	.122
DeKalb F 61	.099	.026
RS 702	.120	.142
RS 610		
Source 1	.119	--
Source 2	.054	--
Source 3	.052	--
Source 4	.114	.035
Source 5	.095	--
Source 6	.099	--
Source 7	.098	--
Source 8	.105	--
Source 9	.076	--
Mean	0.114	0.134

Mean for Both Seed Ages: 0.117

LSD 0.05 for Hybrids (Both Seed Ages): 0.017

LSD 0.05 for Seed Ages:* 0.016

* Excluding all Sources of 1967 RS 610 except Source 4

TABLE 11. YIELD RESULT IN BUSHELS PER ACRE FOR MANHATTAN 1968 AND BELLEVILLE 1968 LOCATIONS AND HYBRIDS (AVERAGE OF THREE REPLICATES)

Hybrid	Manhattan 1967 Seed Age	Manhattan 1968 Seed Age	Belleville 1967 Seed Age	Belleville 1968 Seed Age
NK 280	57.4	60.4	41.1	57.4
Pioneer 820	53.7	56.5	48.4	42.9
Pioneer 845	55.6	57.0	55.1	55.0
Excel 707	51.5	53.9	49.8	50.6
RS 626	42.8	46.4	49.1	49.0
NK 265	51.5	50.7	52.1	61.3
Pioneer 828	65.1	66.9	52.3	60.5
RS 671	60.7	54.6	42.3	54.5
T. E. Grainmaster A	46.3	44.1	49.3	53.5
T. E. Mucho	45.4	45.9	50.4	52.3
Pioneer 846	53.3	51.9	44.9	45.9
Asgrow Ranger B	49.6	54.5	55.4	48.6
Excel 505	51.2	61.0	52.5	53.6
DeKalb F 64	56.5	53.2	52.2	56.3
NK 275	60.8	48.7	55.3	48.5
DeKalb E 57	53.0	53.0	52.0	53.3
NC + T - 700	59.4	49.8	36.9	40.9
PV 685	52.6	50.3	52.2	48.9
DeKalb F 61	58.0	59.5	43.2	47.1
RS 702	57.8	60.9	39.0	32.3
RS 610				
Source 1	46.0	--	55.4	--
Source 2	49.6	--	56.1	--
Source 3	45.3	--	56.0	--
Source 4	48.8	49.7	48.7	50.7
Source 5	46.3	--	54.6	--
Source 6	48.3	--	51.2	--
Source 7	45.1	--	49.4	--
Source 8	46.7	--	56.8	--
Source 9	47.4	--	55.4	--
Mean:	51.4	53.9	51.0	50.6
Mean for Both Seed Ages:	52.0		50.8	

LSD 0.05 for Hybrids (Both Seed Ages): Manhattan: 2.8, Belleville: 2.2

LSD 0.05 for Seed Ages:* Manhattan: 2.2, Belleville: 2.0

* Excluding all Sources of 1967 RS 610 except Source 4

TABLE 12. NUMBER OF HEADS PER PLOT FOR MANHATTAN 1968 AND BELLEVILLE 1968 AND HYBRIDS (AVERAGE OF THREE REPLICATES)

Hybrid	Manhattan 1967 Seed Age	Manhattan 1968 Seed Age	Belleville 1967 Seed Age	Belleville 1968 Seed Age
NK 280	62.0	69.0	58.0	61.3
Pioneer 820	64.0	61.3	59.0	64.6
Pioneer 845	64.0	62.3	61.0	56.6
Excel 707	75.6	71.0	58.6	60.3
RS 626	73.0	74.3	58.0	58.0
NK 265	61.0	58.0	52.0	61.3
Pioneer 828	64.3	70.0	58.3	59.6
RS 671	70.0	70.6	51.0	62.0
T. E. Grainmaster A	69.0	66.3	71.5	58.3
T. E. Mucho	67.6	72.0	60.6	59.0
Pioneer 846	62.6	69.5	50.6	56.6
Asgrow Ranger B	74.6	75.5	68.3	69.0
Excel 505	60.6	75.5	50.3	57.3
DeKalb F 64	71.0	72.0	55.6	59.0
NK 275	72.0	62.5	59.6	54.3
DeKalb E 57	73.0	55.3	58.6	59.6
NC + T - 700	53.6	62.0	48.3	47.0
PV 685	68.6	68.3	58.6	55.3
DeKalb F 61	65.0	71.6	56.0	56.3
RS 702	65.6	73.6	53.0	59.0
RS 610				
Source 1	71.6	--	60.0	--
Source 2	71.0	--	60.0	--
Source 3	70.6	--	60.6	--
Source 4	65.3	72.5	54.0	53.0
Source 5	66.5	--	54.6	--
Source 6	75.5	--	60.0	--
Source 7	63.5	--	56.0	--
Source 8	69.3	--	59.0	--
Source 9	69.3	--	61.3	--
Mean:	66.9	69.1	56.9	58.0
Mean for Both Seed Ages	68.0		57.4	

LSD 0.05 for Hybrids (Both Seed Ages): Manhattan: 3.4; Belleville: 2.1

LSD 0.05 for Seed Ages:* Manhattan: 2.6; Belleville: 1.9

* Excluding all Sources of RS 610 except Source 4

Belleville, seed ages were not significant and hybrid x age interactions were only significant for Manhattan.

Correlation results show no significant relationship between field emergence and yield for Manhattan, but this relationship is highly significant for Belleville. This is noticed both where the two seed ages are considered together or separately. This effect may be attributed to different field conditions, pointing out the increasing importance of seed vigor as field conditions become limiting.

Correlations of yield with standard germination show only a significant relationship between ten day count and Belleville yield when both seed ages are considered together. When the seed ages are considered separately there is no correlation for the 1967 lots, but the 10 day count and the 4 day count are highly significant and significant, respectively, for the 1968 seed lots, Belleville planting only. This result may indicate that under unfavorable conditions relatively younger seed had more vigor and therefore was capable of producing higher yields.

The same results were obtained when yield was correlated with ammonium chloride test results. The 5 minute NaOH test did not produce any correlations with yield when both seed ages are considered. When the 1967 seed age is considered separately significant correlations were obtained with Manhattan yields, but with the 1968 seed age, only Belleville yields are significantly correlated with this method. A similar trend was obtained with the 2 minute sodium hydroxide treatment.

Percentage of small seed showed significant negative correlation with Manhattan yield when both seed ages were considered together and for the 1967 seed age separately but not for the 1968 seed age possibly indicating the death of small seed during one year of storage and higher yield produced by the big vigorous seeds left. The same results were obtained for the tetrazolium test.

These results are highly erratic and no conclusion can be extracted from them. However, if an experiment were conducted to express yield per plant instead of per acre, maybe an association between vigor as measured by some vigor test and yield could be found, expanding even further the future of vigor tests. Higher yield produced by relatively more vigorous seeds has been shown by some authors as expressed in the literature review.

b) Heads produced: Analysis of variance shows only highly significant differences for hybrids in both locations.

In all cases highly significant correlations were obtained between yield and heads per plot. If we assume that each plant produces only one head, which is the normal and ideal, then heads per plot should be correlated with field emergence and with yield, but as in the case of this last one significant correlations were obtained only for the results obtained in the Belleville planting, possibly because of higher stress on the seedlings.

All other correlations are erratic as in the case of yield and follow the trend as of this last one: correlations being significant for the Belleville planting in most cases.

SUMMARY AND CONCLUSIONS

This study was conducted to establish which of the vigor tests for sorghum was the one most capable of providing field performance information.

The tests selected were the ones found best by other authors and two others included because data was found that suggested they might be effective.

Twenty-one hybrids and two seed ages were used. The two seed ages corresponded to the ones used in the 1967 and 1968 Kansas Grain Sorghum Performance Test. Seed lots were divided into 3 replicates and tested by the following methods:

a) Standard germination, according to the rules for testing seed of the Association of Official Seed Analysis. Four and ten day counts were used.

b) Ammonium Chloride Test. Fifty random seeds were soaked in a 2% NH_4Cl solution for 2 hours at a temperature of 40° C after which seeds were flushed, rinsed and germinated immediately following standard rules.

c) Sodium Hydroxide. Fifty random seeds were soaked in a 5% NaOH solution for two different periods of time. One test consisted of a 5 minute soaking time and the other of a

2 minute period. After this they were flushed and rinsed and germinated immediately following standard procedures.

d) Percentage small seed. Samples of approximately 60 grams were passed through a 9/64 round hole sieve and the amount that passed expressed as percent of the total.

e) Tetrazolium Test. Ten random seeds were soaked for a period of 24 hours in a 0.2% aqueous solution of 2, 3, 5 - triphenyl tetrazolium chloride. After this period seeds were flushed and rinsed and color extracted with 5 ml of ethylene glycol monomethyl ether on the intact seeds for a period of 5 hours after which optical density was measured at 480 mμ.

All these tests were compared to field emergence. Plots were located at Manhattan and Belleville, Kansas in 1968 and in Manhattan in 1969. A randomized complete block design was used with 100 seeds planted per 2 row plot. Stands were counted by hand. The center ten feet of each row was harvested and heads counted.

Results obtained show the discrepancies between field emergence and standard germination which give support to the criticism that the latter fails to provide information on the performance of a certain seed lot under field conditions.

Standard germination correlated significantly when seed ages were considered separately only with the 1967 seed age. This suggests that during one year of storage, seed of low vigor died leaving only the vigorous ones that would emerge under field conditions, therefore standard germination tests, could provide vigor information on a seed lot at least one year old.

From all the vigor tests used in this research ammonium chloride treatment gave the best results. It not only gave the highest correlations with field emergence consistently in all cases but best approximated field emergence. Results also suggest that the length of the test can be shortened to 4 days, instead of the regular 10 day germination test, without any decrease in accuracy.

Both sodium hydroxide tests proved inconsistent. Like standard germination they correlated highly significantly with field emergence when both seed ages were considered together, but when considered separately they failed. The five minute soaking time test only detected vigor differences in the 1968 seed lots while the two minute test detected vigor better in the 1967 seed age with variation in the 1968 seed lots according to location.

The two minute sodium hydroxide test appears to be a good test although it underestimates field emergence and is difficult to use due to the short time of soaking in which slight variations in soaking periods could produce large experimental errors. This method too could be shortened to germination for four days without large loss in correlation.

The five minute test is too harsh and severely underestimates field emergence. The variations in detecting vigor according to seed ages and location of these two tests could possibly be attributed to the more mechanical effect rather than physiological like in the case of ammonium chloride test. They also present the inconvenience of transporting sodium hydroxide to the germination medium which may cause pH problems even after thorough rinsing.

The sodium hydroxide tests are very simple but time consuming even in the case of a shortened four day method. For this reason percentage of small seed and the tetrazolium tests were considered attractive for their capability of yielding information in a few hours. Results show that these two methods were unacceptable for predicting field emergence and did not correlate with the other vigor tests used. Percentage of small seed showed a trend towards negative correlations with field emergence indicating that large seeds possess more vigor.

Although the tetrazolium test failed, more work is necessary because of its speed and highly satisfactory results obtained for wheat and corn. This method could be improved by using larger and untreated samples of seeds.

It is interesting to notice that the two best tests of ammonium chloride and 2 minute sodium hydroxide produce germinations that are virtually completed at the fourth day.

Even though some significant correlations between vigor and yield were obtained, they were erratic and no conclusion can be drawn from them. Possibly this effect existed but was not detected by this study because the harvest method did not take into account the number of plants harvested.

Results show that some lots did not lose vigor during one year of storage and could possibly be stored for a longer time without deterioration. Also the effect of environment on field emergence was demonstrated when the three locations are compared. Since the ammonium chloride test was consistent for all seed ages and locations, it could be used to select seed lots that would store well, withstand early plantings and adjust seeding rates.

The author believes that the ammonium chloride test is the best from the presently available vigor tests for sorghum and further standardization of this technique is needed which would prove satisfactory for a large range of field situations and emergence approximations. This study showed it to be easy to perform, reliable, consistent and present the advantage of needing only four days to provide results.

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APPENDIX

CODE FOR TABLES 1, 2 AND 3

1	:	Field Emergence 1968 Manhattan
2	:	Field Emergence 1968 Belleville
3	:	Field Emergence 1969 Manhattan
4	:	Standard Germination 10 Day Count
5	:	Standard Germination 4 Day Count
6	:	Ammonium Chloride Test 10 Day Count
7	:	Ammonium Chloride Test 4 Day Count
8	:	5 Minute Sodium Hydroxide Test 10 Day Count
9	:	5 Minute Sodium Hydroxide Test 4 Day Count
10	:	2 Minute Sodium Hydroxide Test 10 Day Count
11	:	2 Minute Sodium Hydroxide Test 4 Day Count
12	:	Percentage of Small Seed Test
13	:	Tetrazolium Test
14	:	Yield Manhattan 1968
15	:	Yield Belleville 1968
16	:	Heads Per Plot Manhattan 1968
17	:	Heads Per Plot Belleville 1968

TABLE 1. ALL POSSIBLE CORRELATIONS BOTH SEED AGES CONSIDERED TOGETHER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		.495	.688	.472	.456	.598	.601	.299	.257	.454	.446	-.008	.102	.017	.124	.062	.251
2			.457	.402	.382	.480	.469	.263	.227	.355	.361	-.135	.032	.038	.294	.078	.527
3				.601	.577	.611	.614	.407	.366	.520	.511	.003	.081	-.074	.137	-.072	.234
4					.969	.561	.571	.318	.279	.480	.477	-.067	.078	.049	.188	.018	.209
5						.548	.555	.369	.326	.497	.492	-.029	.054	.038	.157	.018	.202
6							.988	.498	.449	.586	.584	.062	.157	.030	.160	.049	.214
7								.506	.460	.577	.575	-.055	.146	.030	.181	.054	.210
8									.968	.677	.676	.184	.008	-.073	.156	-.018	.156
9										.623	.623	.157	-.029	-.098	.157	-.041	.148
10											.997	.159	.066	-.094	.169	.068	.270
11												.146	.061	-.083	.168	-.062	.270
12													-.131	-.192	-.020	-.108	-.139
13														.181	.013	.119	.092
14															-.036	.919	.048
15																.025	.525
16																	.142
17																	

TABLE 2. ALL POSSIBLE CORRELATIONS FOR THE 1967 SEED AGE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		.557	.733	.531	.508	.608	.620	.166	.127	.392	.387	-.037	.029	-.011	.136	.077	.317
2			.574	.481	.448	.490	.481	.146	.131	.316	.315	-.222	.075	-.028	.335	.066	.626
3				.612	.580	.571	.574	.229	.184	.444	.437	-.126	.025	-.186	.094	-.154	.310
4					.963	.520	.539	.178	.135	.381	.378	-.197	.052	.011	.108	.008	.281
5						.495	.511	.232	.189	.394	.390	-.164	.016	-.034	.083	-.022	.269
6							.985	.289	.262	.470	.467	-.056	.162	.005	.056	.068	.215
7								.287	.262	.457	.454	-.053	.128	-.007	.068	.058	.186
8									.981	.650	.656	.218	-.130	-.258	.075	-.165	.115
9										.602	.610	.199	-.184	-.284	.075	-.184	.112
10											.998	.176	-.046	-.230	.154	-.156	.260
11												.168	-.039	-.228	.145	-.153	.255
12													-.230	-.273	.061	-.143	-.050
13														.250	-.148	.146	.033
14															-.026	.919	-.060
15																.078	.553
16																	.072
17																	

TABLE 3. ALL POSSIBLE CORRELATIONS FOR THE 1968 SEED AGE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		.270	.356	.030	.033	.385	.384	.324	.302	.309	.304	.047	.002	-.057	.168	-.082	.098
2			.120	.143	.144	.367	.354	.287	.236	.280	.302	-.055	-.120	.078	.274	.049	.390
3				.400	.380	.534	.547	.539	.525	.454	.442	.198	-.048	.013	.269	-.026	.065
4					.978	.508	.510	.399	.384	.513	.513	.112	-.050	.035	.380	-.046	.043
5						.492	.490	.419	.395	.506	.499	.148	-.081	.075	.323	.008	.051
6							.990	.655	.590	.627	.628	.222	-.011	-.033	.351	-.071	.181
7								.678	.618	.631	.630	.198	.009	-.006	.379	-.034	.212
8									.972	.632	.618	.182	-.062	.069	.270	.097	.166
9										.572	.558	.140	-.030	.061	.269	.082	.156
10											.992	.193	-.016	-.003	.255	-.036	.270
11												.168	-.030	.023	.260	-.021	.274
12													-.063	-.114	-.088	-.075	-.225
13														.070	.160	.053	.119
14															-.045	.918	.178
15																-.037	.503
16																	.227
17																	

TABLE 4. FIELD EMERGENCE MANHATTAN 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F
Seed Ages	1	1158.13	35.68**
Hybrids	20	220.48	6.79**
Seed Ages x Hybrids	20	116.34	3.58**
Error	82	32.46	

LSD 0.05 Rep. : 2.469
" Seed Ages: 2.016
" Hybrids : 6.533

TABLE 5. FIELD EMERGENCE BELLEVILLE 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F
Seed Ages	1	582.86	9.16**
Hybrids	20	260.23	4.09**
Seed Ages x Hybrids	20	116.60	1.83*
Error	82	53.64	

LSD 0.05 Rep. : 3.457
" Seed Ages: 2.823
" Hybrids : 9.147

TABLE 6. FIELD EMERGENCE MANHATTAN 1969

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	1386.70	40.92**
Hybrids	20	5912.86	8.72**
Seed Ages x Hybrids	20	2860.63	4.22**
Error	82	2778.62	

LSD 0.05: Rep. : 2.52
" Seed Ages: 2.06
" Hybrids : 6.67

TABLE 7. STANDARD GERMINATION 10 DAY COUNT

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	336.79	30.07**
Hybrids	20	1589.71	7.10**
Seed Ages x Hybrids	20	1335.87	5.96**
Error	82	918.29	

LSD 0.05: Rep. : 1.45
" Seed Ages: 1.18
" Hybrids : 3.84

TABLE 8. STANDARD GERMINATION 4 DAY COUNT

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	457.14	34.48**
Hybrids	20	1702.54	6.42**
Seed Ages x Hybrids	20	1341.52	5.06**
Error	82	1087.17	

LSD 0.05: Rep. : 1.58
" Seed Ages: 1.29
" Hybrids : 4.17

TABLE 9. AMMONIUM CHLORIDE TEST 10 DAY COUNT

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	1730.12	41.85**
Hybrids	20	436.19	10.55**
Seed Ages x Hybrids	20	189.67	4.59**
Error	82	41.34	

LSD 0.05: Rep. : 2.79
" Seed Ages: 2.28
" Hybrids : 7.37

TABLE 10. AMMONIUM CHLORIDE TEST 4 DAY COUNT

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	1677.90	41.72**
Hybrids	20	470.76	11.70**
Seed Ages x Hybrids	20	199.90	4.97**
Error	82	40.22	

LSD 0.05: Rep. : 2.75
" Seed Ages: 2.24
" Hybrids : 7.27

TABLE 11. 5 MINUTE SODIUM HYDROXIDE TEST 10 DAY COUNT

Three Way Analysis of Variance			
Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	7211.03	81.50**
Hybrids	20	1154.54	13.05**
Seed Ages x Hybrids	20	1074.70	12.15**
Error	82	88.47	

LSD 0.05: Rep. : 4.08
" Seed Ages: 3.33
" Hybrids : 10.79

TABLE 12. 5 MINUTE SODIUM HYDROXIDE TEST 4 DAY COUNT

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	5553.43	63.38**
Hybrids	20	1064.99	12.15**
Seed Ages x Hybrids	20	1074.36	12.26**
Error	82	87.62	

LSD 0.05: Rep. : 4.06
" Seed Ages: 3.31
" Hybrids : 10.73

TABLE 13. 2 MINUTE SODIUM HYDROXIDE TEST 10 DAY COUNT

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	7314.29	86.60**
Hybrids	20	1041.76	12.33**
Seed Ages x Hybrids	20	589.97	6.99**
Error	82	84.46	

LSD 0.05: Rep. : 3.98
" Seed Ages: 3.25
" Hybrids : 10.54

TABLE 14. 2 MINUTE SODIUM HYDROXIDE TEST 4 DAY COUNT

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	6908.64	78.39**
Hybrids	20	1023.04	11.61**
Seed Ages x Hybrids	20	576.49	6.54**
Error	82	88.13	

LSD 0.05: Rep. : 4.07
Seed Ages: 3.32
Hybrids : 10.76

TABLE 15. PERCENTAGE SMALL SEED TEST

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	3.27	1.07
Hybrids	20	106.84	34.84**
Seed Ages x Hybrids	20	88.21	28.76**
Error	82	3.07	

LSD 0.05: Rep. : .76
" Seed Ages: .62
" Hybrids : 2.01

TABLE 16. TETRAZOLIUM TEST

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	0.02	7.93**
Hybrids	20	0.01	3.77**
Seed Ages x Hybrids	20	0.01	3.47**
Error	82	0.002	

LSD 0.05: Rep. : 0.02
" Seed Ages: 0.01
" Hybrids : 0.05

TABLE 17. YIELD MANHATTAN 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	0.39	0.01
Hybrids	20	205.37	5.06**
Seed Ages x Hybrids	20	69.71	1.72*
Error	82	40.58	

LSD 0.05: Rep. : 2.76
" Seed Ages: 2.25
" Hybrids : 7.30

TABLE 18. YIELD BELLEVILLE 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	35.52	1.09
Hybrids	20	171.12	5.24**
Seed Ages x Hybrids	20	45.12	1.38
Error	82	35.66	

LSD 0.05: Rep. : 2.48
" Seed Ages: 2.02
" Hybrids : 6.55

TABLE 19. HEADS PER PLOT, MANHATTAN 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	67.17	1.21
Hybrids	20	216.94	3.91**
Seed Ages x Hybrids	20	61.07	1.10
Error	82		

LSD 0.05: Rep. : 3.23
" Seed Ages: 2.63
" Hybrids : 8.53

TABLE 20. HEADS PER PLOT, BELLEVILLE 1968

Three Way Analysis of Variance

Source of Variation	d.f.	Mean Sq.	F.
Seed Ages	1	99.56	3.32
Hybrids	20	89.77	3.00**
Seed Ages x Hybrids	20	32.44	1.08
Error	82	29.94	

LSD 0.05: Rep. : 2.37
" Seed Ages: 1.93
" Hybrids : 6.27

RELATIONSHIP OF SEED VIGOR AMONG GRAIN SORGHUM HYBRIDS AND FIELD ESTABLISHMENT

by

FEDERICO E. MOCKEL

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The purpose of this research was to compare the effectiveness of several vigor tests in predicting sorghum field emergence. Twenty-one hybrids and two seed ages were used to test the value of the different tests.

The two seed ages used corresponded to the 1967 and 1968 Kansas Grain Sorghum Performance tests. Vigor tests used were: a) Ammonium chloride test. Fifty random seeds were soaked in a 2% solution of ammonium chloride for two hours at 40° C, then rinsed and germinated according to standard rules. b) Sodium hydroxide tests. Two different tests were performed the first consisted in soaking 50 seeds in a 5% sodium hydroxide for 5 minutes then rinsed and germinated, the second one was identical except for a two minute soaking. c) Percentage of small seed: The amount of seed that was not retained by a 9/64 round hole sieve were calculated as percentage of the total. d) Tetrazolium test: Ten seeds were soaked in a 0.2% solution of 2,3, 5 - triphenyl tetrozolium chloride for twenty-four hours after which the red colored formaean was extracted with ethylene glycol monomethyl ether and optical density measured at 480 mμ in a spectrophotometer. Standard germination tests were also conducted.

Laboratory results were compared with field trials located at Manhattan in 1968 and 1969 and in Belleville in 1968. Field emergence was counted by hand and yield and heads harvested were recorded.

A randomized complete block design with three replicates was used for all laboratory tests and field trials.

Results obtained show that the ammonium chloride test was the most satisfactory. Correlations obtained with field emergence show that this method held consistent when both seed ages were considered separately and for all locations. This test also possessed the advantage of most closely approximating field emergence. Results show that the test could be shortened to four days without any deterioration in correlation or field emergence approximation.

The five minute sodium hydroxide test proved not satisfactory for it was inconsistent when seed ages were considered separately. It also underestimated field emergence severely.

The two minute sodium hydroxide test was good although some inconsistencies were noted for the different locations. It also underestimated field emergence but not so severely as the five minute test. This test can also be shortened to 4 days.

Percentage of small seed and tetrazolium tests failed completely as estimates of field emergence.

Standard germination results show high discrepancies with field germination and was of little value as a vigor test, thus supporting the need for other methods.

No correlations were observed between vigor tests and yield.

It is concluded that ammonium chloride test is the best vigor test for sorghum and presents the advantages of being simple, consistent and relatively short, even though more work is necessary to prove it effective in all possible situations for standardization.