Chapter IV

Use of Standard Germination Data and Seed Mass to Predict Field Emergence of Sorghum

Introduction

Typically, a standard germination test presents seeds with an essentially optimal environment for germination. Under such conditions, seedlots with poor vigor or genotypes with sensitivity to stresses may perform well. Perhaps as a consequence, seedlots that score high in a standard germination test in the laboratory can perform poorly under field conditions, i.e., the standard germination test is a poor predictor of field emergence. Part of the work to be reported here has examined possible correlations between data obtained from a standard germination test and field emergence observed in the Virginia Sorghum Trials.

Seed size was perhaps the first characteristic used by ancient producers in the agricultural selective process. Hyoung et al. (1974) observed "If the seed weight has influence on the grain yield, this result should interest the sorghum producer; it would be advantageous to plant the seed weight that gives greatest yields". The research results are ambiguous in relation this variable. Some have found correlations among sorghum seed size, emergence, and productivity (Maranville and Clegg, 1977; Abdullahi and Vanderlip,1972), while others (Hyoung et al.,1974; Trabanino et al.,1989) did not find such agreement. This research also examines correlations between seed mass of several hybrids and their emergence in field.

Materials and Methods

Standard germination

A "standard germination test" with amplifications was performed to provide laboratory seed performance data that might be compared with field emergence results from the same seedlots. The basic procedure was the standard germination test for sorghum (AOSA, 1983) with some modifications and extensions. A constant 25°C was used instead of a cycling 30°C and 20°C, and four replications of 50 seeds each were used rather than four replications of 100 seeds each.

Seedlot samples were taken from 24 hybrids of grain sorghum out of the 32 hybrids planted in the 1995 Virginia Sorghum Trials (see Chapter III) and from all 30 planted in 1996. The seeds were obtained from different commercial seed producers (Table 4.1). Subsamples for laboratory testing were taken from the same seedlots planted in field emergence studies (Chapter III) and held at 5°C until laboratory tests were performed. Fifty seeds from each hybrid were counted into each of four replications to represent the seedlot. The seeds were initially imbibed in a 9-cm Petri dish on germination blotter paper (Packaging Converts) and 7 ml of distilled water. The "imbibition period'' in the Petri dish was 24 hr at 25°C in darkness. After the imbibition period, the 50 seeds were placed on 40 cm X 25 cm germination toweling (Seedburo) and moistened with 10 ml of distilled water. The toweling was folded once and then rolled to make a "ragdoll", and ragdolls were placed inside plastic zip-closure bags. The subsequent "incubation period" was for 48 hr at 25°C in darkness. Percentage of germination was measured 72 hr after imbibition began. A seedling that produced a normal coleoptile and >3 mm of root length was considered germinated.

Table 4.1. Sorghum hybrids from the Virginia Sorghum Trials that were tested in laboratory studies in 1995 and/or 1996.

Company	Hybrid	Tested in	
		1995	1996
Cargill Hybrid Seeds	CAR577	*	
	CAR627		*
	CAR630	*	
	CAR647		*
	CAR730		*
	CAR737	*	
	CAR775	*	*
	CAR837	*	*
	CAR1922	*	
	CAR12027		*
Pioneer Hi-Bred International, Inc.	P8118	*	*
	P8212	*	*
	P8282		*
	P8305	*	*
	P8310	*	*
	P8414		*
	P8446	*	*
	P8699	*	
	XS345	*	*
Crosbyton Seed Company, Inc.	GW6089	*	
	GW8046	*	
	GW9089		*
	GW1114	*	
Southern States Cooperative, Inc.	FFR321	*	*
	SS115	*	*
	SS160	*	*
	SS1211	*	*
	SS1313	*	*
Northrup King Company	KS711		*
	KS714	*	*
	KS735		*
	KS936	*	
	X604	*	
Dekalb Genetics Corp.	DK18		*
	DK36		*
	DK40		*
	DK45		*
	DK47		*
	DK54		*
	DK55		*

Seedling fresh weight

The total fresh weight of the seedlings in each ragdoll was determined immediately after the ragdoll (replication) was opened. The seedlings were separated from nongerminated seeds before weighing. The total fresh weight was divided by the number of seedlings to determine the average for the replication.

Seed dry weight

The mass of unimbibed seeds was determined by weighing four, 50-seed samples of each seedlot. The total weight (average of four replications) was divided by 50, and this average was used in the computation of the data as "dry weight " of the seeds. These seeds were not truly "dry", since they had not been oven-dried; however all were at a low and approximately uniform equilibrium moisture content.

Radicle length estimation

The radicle length of each 3-day-old seedling from the ragdolls was quickly approximated using a graduated ruler. Each seedling was grouped into a 10-mm decade (3 to 10 mm; 11 to 20 mm; 21 to 30 mm, etc.). The number of seedlings in each cohort was multiplied by the midpoint of the decade (5, 15, 25, etc.), and the total root lengths for all cohorts were added together. The radicle length average was determined by dividing the grand total root length (all cohorts) by the number of seedlings.

Data analysis

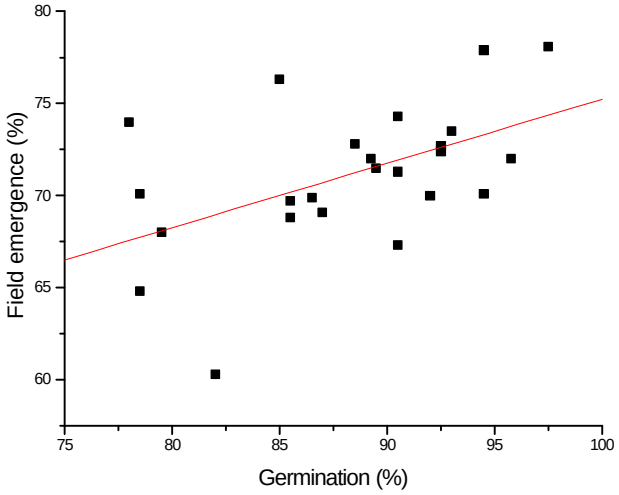
Analysis of variance was done as appropriate using the SAS software package (SAS Institute, 1993) to test for differences between hybrids in germination, radicle length, seedling fresh weight, and seed mass. Mean separations were performed by Tukey's test, if the ANOVA F-statistic indicated significant effects at the 0.05 probability level (SAS Institute, 1993). Germination percentage data were arcsine transformed (Sokal and Rohlf, 1995) before ANOVA and back transformed for reporting.

Regression analyses were performed using the SAS software package (SAS Institute, 1993) to test the correlation between the laboratory test variables and field emergence (see Chapter III). The field emergence data used for this comparison were the two-site averages (Warsaw and Blacksburg) for each hybrid within each year (see Tables 3.5 and 3.7). Arcsine transformed data were used for regression analyses where percentage data were the parameter tested. The regression figures (scatter plots) and equations were generated using Microcal Origin 3.5 (1995) software.

Results and Discussion

Germination of 24 hybrids in 1995 Virginia Sorghum Trials

The hybrids from 1995 differed in laboratory germination (P< 0.0006) (Table 4.2). The hybrids FFR321, SS160, and CAR775 were superior to KS714, XS345, and X604. The mean germination for all hybrids was 88.5%, and the CV was 6.4%. When 1995 field emergence was regressed against standard germination (arcsine data), there was a linear association between the variables (P= 0.007 and r^2 = 0.283) (Figure 4.1). The regression equation using arcsine transformed values is y = 0.678 + 0.263x, where x is germination and y is field emergence. The formula derived using nontransformed data is y = 40.35 + 0.348x.



P<0.007 **r^2 = 0.283** **y = 40.35 + 0.0.348x**

Figure 4.1. Linear regression of laboratory germination and field emergence for 24 hybrids in the 1995 Virginia Sorghum Trials.

Radicle length of 24 hybrids in the 1995 Virginia Sorghum Trials

Average radicle lengths of the 3-day-old seedlings were not significantly different among hybrids (Table 4.2). The mean for all hybrids was 49.8 mm, and the CV was 12.9%. When 1995 field emergence was regressed against radicle length, there was no significant linear association between variables (P = 0.18) (Figure 4.2).

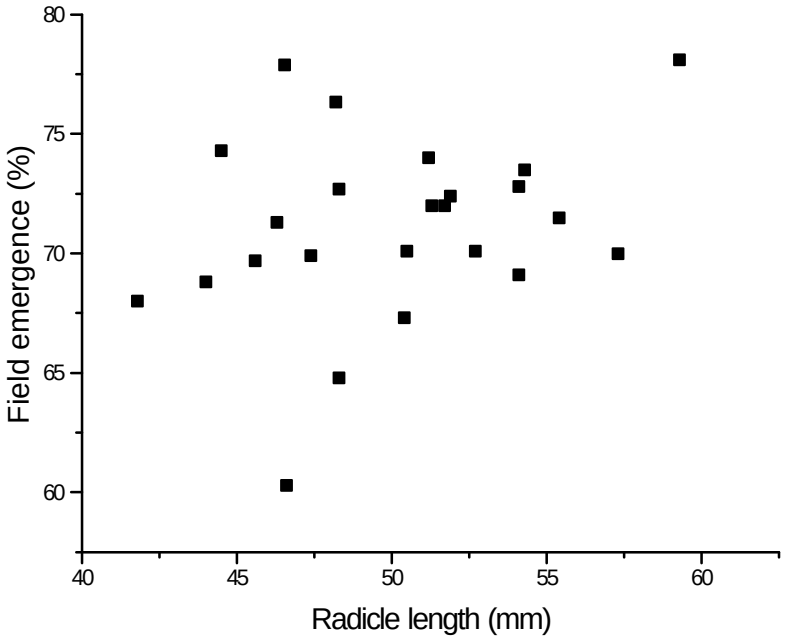


Figure 4.2. Linear regression (ns) of 3-day-old seedling radicle length and field emergence for 24 hybrids in the 1995 Virginia Sorghum Trials.

Fresh weight of seedling for 24 hybrids in the 1995 Virginia Sorghum Trials

Differences among hybrids for average fresh weight of the 3-day-old seedlings were detected ($P < 0.001$). The top six ranked hybrids were significantly heavier than the bottom 14 ranked ones (Table 4.2). The mean of seedling fresh weight was 71.7 mg, and the CV was 5.8%. In 1995, emergence did not show a linear association with fresh weight of the seedlings ($P=0.17$ and $r^2 = 0.083$) (Figure 4.3).

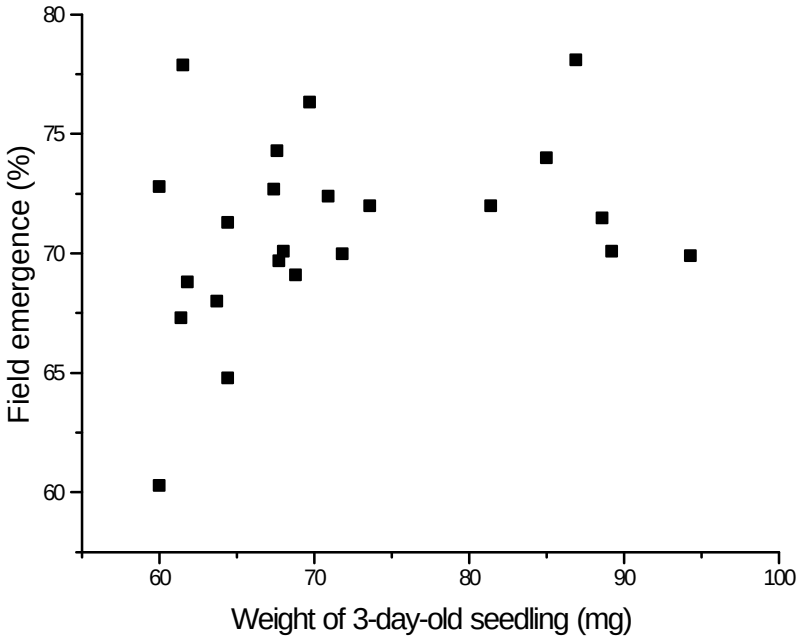


Figure 4.3. Linear regression (ns) of 3-day-old seedling fresh weight and field emergence of 24 hybrids in the 1995 Virginia Sorghum Trials.

Mass of the seeds for 24 hybrids in the 1995 Virginia Sorghum Trials

Seed mass differed among hybrids ($P < 0.001$). Means of six hybrids with values above 33 mg were superior to 12 hybrids with means below 28 mg (Table 4.2). The seed mass average for all hybrids in 1995 was 30.2 mg, and the CV was 4.8%. When field emergence was regressed against seed mass, there was not a significant linear association between variables ($P = 0.17$) (Figure 4.4).

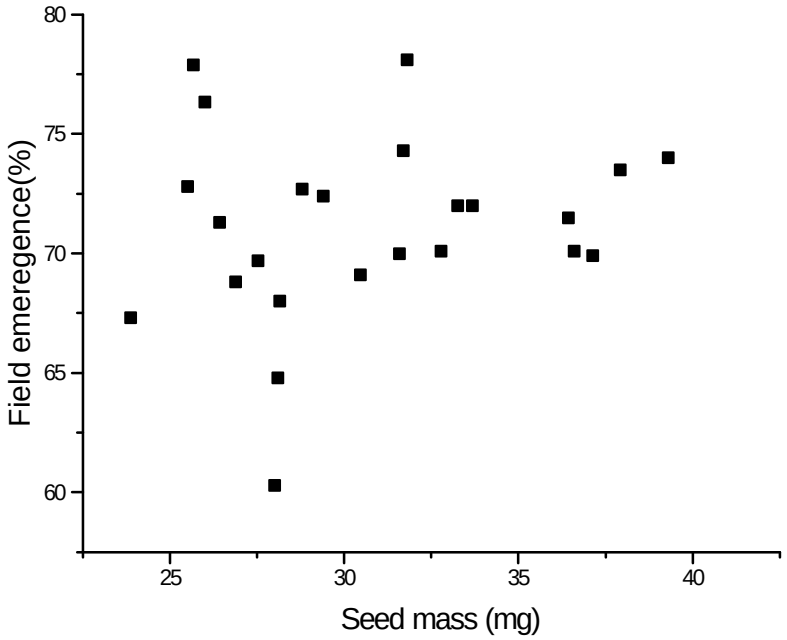


Figure 4.4. Linear regression (ns) of seed mass of and field emergence of 24 hybrids in the 1995 Virginia Sorghum Trials.

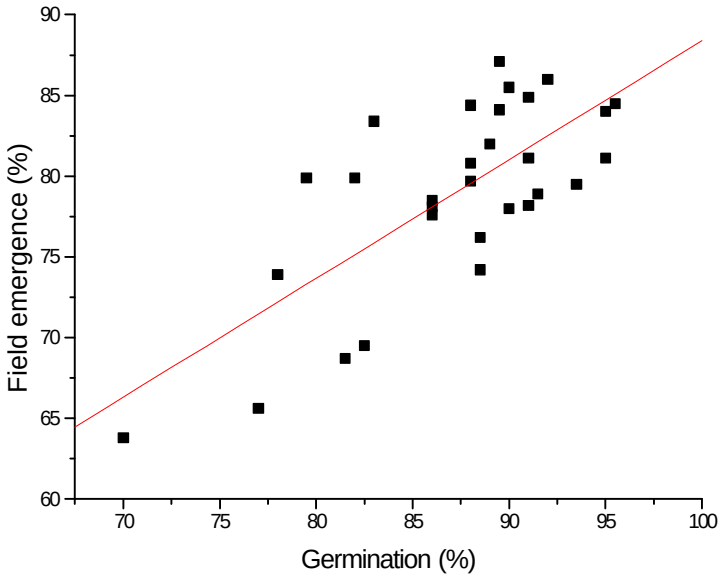
Table 4.2. Germination, radicle length and fresh weight of 3-day-old seedlings, and seed mass for 24 hybrids in the 1995 Virginia Sorghum Trials.

Hybrid	Germination		Radicle length		Seedling fresh weight		Seed mass	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank
	%		mm		mg		mg	
FFR321	96.5 ^{a*}	1	58.9^{a}	1	86.9^{ab}	4	31.8^{def}	9
SS160	96.0^{a}	2	48.3^{a}	14	67.^{def}	14	28.8^{fgh}	14
CAR775	94.5^{a}	3	51.7^{a}	9	73.6^{cd}	7	33.6^{bcd}	6
CAR837	94.0^{ab}	4	46.5^{a}	18	61.5^{ef}	20	25.6^{hi}	22
SS1313	93.5^{ab}	5	53.8^{a}	6	-	-	37.9^{ab}	2
SS115	92.5^{ab}	6	52.7^{a}	8	89.2^{ab}	2	36.6^{abc}	4
GW8046	92.5^{ab}	7	45.1^{a}	22	68.8^{def}	11	30.4^{defg}	12
CAR630	92.0^{ab}	8	50.4^{a}	12	61.4^{ef}	21	23.8^{i}	24
SS1211	91.5^{ab}	9	50.7^{a}	10	85.0^{ab}	5	39.3^{a}	1
P8305	91.0^{ab}	10	53.5^{a}	7	70.9^{cdef}	9	29.4^{efgh}	13
CAR1922	90.5^{ab}	11	45.6^{a}	21	67.7^{def}	12	27.5^{fghi}	18
GW1114	90.5^{ab}	12	55.4^{a}	2	88.6^{ab}	3	36.4^{abc}	5
GW6089	89.5^{ab}	13	47.4^{a}	16	94.7^{a}	1	37.1^{ab}	3
P8699	89.0^{ab}	14	46.3^{a}	19	64.4^{def}	15	26.4^{hi}	20
P8310	88.0^{ab}	15	45.7^{a}	20	67.6^{def}	13	31.7^{def}	10
P8212	88.0^{ab}	16	44.0^{a}	23	61.8^{ef}	19	26.8^{ghi}	19
P8118	87.5^{ab}	17	54.1^{a}	5	60.0^{f}	23	25.5^{hi}	23
CAR737	87.0^{ab}	18	48.2^{a}	15	69.7^{def}	10	26.0^{hi}	21
P8446	87.0^{ab}	19	54.8^{a}	3	71.8^{cde}	8	31.5^{def}	11
CAR577	86.0^{ab}	20	54.4^{a}	4	81.4^{bc}	6	33.2^{bcde}	8
KS936	83.0^{ab}	21	48.3^{a}	13	64.8^{def}	18	28.1^{fgh}	16
KS714	78.5^{b}	22	50.5^{a}	11	68.0^{def}	16	32.7^{cde}	7
XS345	77.0^{b}	23	41.8^{a}	24	63.7^{def}	17	28.1^{fgh}	15
X604	76.5^{b}	24	46.6^{a}	17	60.0^{f}	22	28.0^{fgh}	17
Average	88.5	-	49.8	-	71.7	-	30.2	-

* Means in a column followed by the same letter are not significantly different at 0.05 probability level.

Germination of seeds from the 1996 Virginia Sorghum Trial

Hybrids from 1996 differed in laboratory germination (P< 0.001). The hybrids CAR775, CAR12027, CAR647, and P8282 were superior to DK40 and KS714 (Table 4.3). The mean of all hybrids was 87.2%, and the CV was 6.6%. Regression of field emergence against percent of germination showed a linear association between variables (P< 0.001 and $r^2 = 0.520$). The distribution of the data is shown in Figure 4.5. A prediction of field emergence (y) for a given percent germination (x) using arcsine transformed data for each variable can be made employing an empirical linear equation $y = 0.364 + 0.608x$, where y is field emergence and x is laboratory germination percent. The formula derived using nontransformed data is $y = 14.79 + 0.753x$.



P<0.001 $r^2 = 0.520$ $y = 14.79 + 0.735x$

Figure 4.5. Linear regression of laboratory germination and field emergence for the hybrids in the 1996 Virginia Sorghum Trials.

Radicle length of seedlings for hybrids in the 1996 Virginia Sorghum Trials

Average radicle length of 3-day-old seedlings differed among hybrids (P< 0.001). The top ten ranked hybrids were superior to XS345, DK40, and CAR837 (Table 4.3). The mean of all hybrids was 41.9 mm, and the CV was 12.1%.

When field emergence was regressed against radicle length, there was no significant linear association between variables (P=0.15) A scatter diagram is shown in Figure 4.6

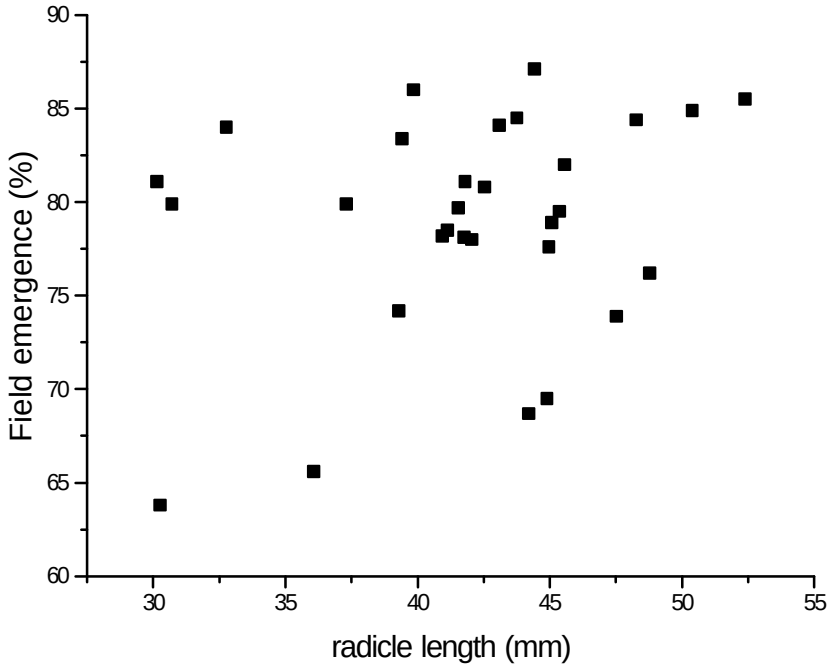
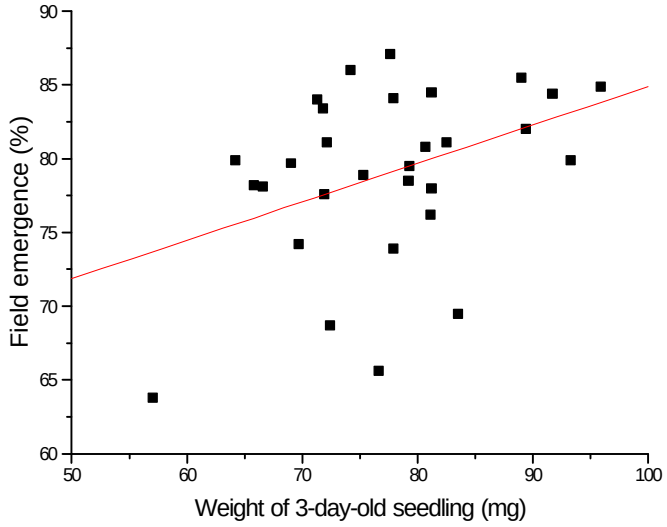


Figure 4.6. Linear regression (ns) of 3-day-old seedling radicle length and field emergence of the hybrids in the 1996 Virginia Sorghum Trials

Fresh weight of seedlings of hybrids in the 1996 Virginia Sorghum Trials

Hybrids differed in fresh weight of 3-day-old seedlings ($P < 0.001$). The hybrids SS1211, FFR321, SS1313, CAR647, GW9089, SS115, DK18, and CAR12027 were heavier than CAR730, P8212, P8118, KS711, XS345, and DK40 (Table 4.3). The general mean of seedling weight was 77.3 mg, and the CV was 6.3%. When field emergence was regressed against fresh weight of the seedlings, there was a linear association between variables ($P < 0.039$ and $r^2 = 0.156$). A prediction of field emergence (y) for a given weight of 3-day-old seedling (x) using arcsine transformed data can be made employing an empirical linear equation $y = 0.845 + 0.0303x$ where y is field emergence and x is weight of 3-day-old seedling. The formula derived using nontransformed data is $y = 58.85 + 0.260x$. A scatter diagram is shown in Figure 4.7.



P < 0.039 **r^2 = 0.156** **y = 58.85 + 0.260x**

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Figure 4.7. Linear regression of 3-day-old seedling fresh weight and field emergence of the hybrids in the 1996 Virginia Sorghum Trials.

Mass of the seeds used in the 1996 Virginia Sorghum Trials

Sorghum hybrids differed (P< 0.001) in seed mass. Seed mass of four hybrids with values greater than 35 mg (FFR321, SS1313, SS1211, and KS714) was significantly greater than 20 hybrids with means below 31.5 mg (Table 4.3). FFR321 was in fact heavier than all of the others hybrids. The general mean of seed mass was 31 mg, and the CV was 3.3%.

When field emergence was regressed on mass of the seeds, there was no significant linear association between variables(P = 0.058 and an r^2 = 0.121). The distribution of the data is shown in a scatter diagram (Figure 4.8).

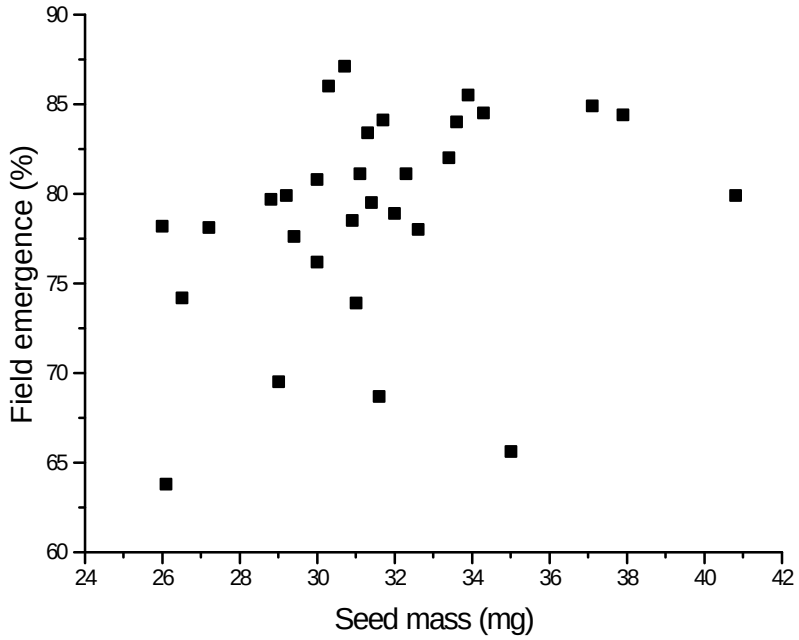

Figure 4.8. Linear regression (ns) of seeds mass and field emergence from the 1996 Virginia Sorghum Trials.

Table 4.3. Germination, radicle length and fresh weight of 3-day-old seedlings, and seed mass of the hybrids in the 1996 Virginia Sorghum Trials.

Hybrid	Germination		Radicle length		Seedling fresh weight		Seed mass	
	Value	Rank	Value	Rank	Value	Rank	Value	Rank
	%		mm		mg		mg	
CAR647	95.50[a*]	1	43.71[abcdef]	13	89.4[abcd]	4	34.3[cde]	5
CAR12027	95.0[ab]	2	41.79[abcdef]	17	82.5[abcdef]	8	31.1[fghijkl]	17
CAR775	95.0[ab]	3	32.78[def]	27	71.3[efghij]	24	33.6[defg]	7
P8282	94.5[ab]	4	45.37[abcd]	7	79.3[cdefgh]	12	28.8[lmnop]	15
SS160	92.0[abc]	5	39.84[abcdef]	22	74.2[efghij]	19	30.3[ijkl]	20
DK45	91.5[abc]	6	45.07[abcd]	8	75.3[efghij]	18	32.0[efghij]	11
KS711	91.0[abc]	7	40.93[abcdef]	21	65.8[jik]	28	26.0[p]	28
CAR837	91.0[abc]	8	30.14[f]	30	72.1[efghij]	21	32.3[defghi]	10
SS1211	91.0[abc]	9	50.63[ab]	2	95.9[a]	1	37.1[bc]	3
P8212	90.0[abc]	10	41.59[abcdef]	19	67.9[ghijk]	26	28.8[lmnop]	26
CAR627	90.0[abc]	11	42.05[abcdef]	16	81.2[bcdef]	9	32.6[defghi]	9
SS115	90.0[abcd]	12	52.38[a]	1	89.0[abcd]	6	33.9[def]	6
DK47	89.5[abcd]	13	40.08[abcdef]	14	77.4[defghij]	16	31.7[efghijk]	13
P8305	89.5[abcd]	14	44.42[abcde]	11	77.6[defghij]	15	30.7[hijkl]	19
GW9089	89.0[abcd]	15	45.56[abcd]	6	89.4[abcd]	5	33.4[defgh]	8
DK55	88.5[abcd]	16	48.78[abc]	3	81.1[bcdefg]	10	30.0[ijklm]	21
CAR730	88.5[abcd]	17	39.28[abcdef]	24	69.7[fghijk]	25	26.5[nop]	29
P8414	88.0[abcd]	18	42.52[abcdef]	15	80.7[bcdfg]	11	30.0[ijklm]	22
SS1313	88.0[abcd]	19	48.27[abc]	4	91.7[abc]	3	37.9[b]	2
P8118	86.0[abcd]	20	41.75[abcdef]	18	66.6[hijk]	27	27.2[mnop]	27
P8446	86.0[abcd]	21	41.13[abcdef]	20	79.2[cdeghi]	13	30.9[ghijkl]	18
KS735	86.0[abcd]	22	44.96[abcd]	9	71.9[efghi]	22	29.4[jklm]	23
P8310	83.0[abcd]	23	39.41[abcdef]	23	71.8[efghi]	23	31.3[fghijkl]	16
DK18	82.5[abcd]	24	44.88[abcd]	10	83,5[abcde]	7	29.0[klmno]	25
XS345	82.0[abcd]	25	30.71[ef]	28	64.2[ijk]	29	29.2[jklmn]	24
DK36	81.5[abcd]	26	44.19[abcde]	12	72.4[efghi]	20	31.6[efghikl]	14
FFR321	79.5[abcd]	27	37.86[bcdef]	25	93.3[ab]	2	40.8[a]	1
DK54	78.0[bcd]	28	47.51[abc]	5	77.9[defghi]	14	31.8[efghijk]	12
KS714	77.0[cd]	29	36.07[cdef]	26	76.6[dfghij]	17	35.0[bcd]	4
DK40	70.0[d]	30	30.26[f]	29	57.0[k]	30	26.1[op]	30
Average	87.2	-	41.9	-	77.3	-	31.5	-

* Means in a column followed by the same letter are not significantly different at 0.05 probability level.

Laboratory germination versus field emergence

Differences between performance in "optimal-condition" laboratory tests and field emergence have been observed by several researchers whose work ha included different genotypes (Table 4.4)

Table 4.4. Comparison between field emergence and standard germination test made by several researchers working with grain sorghum.

Researcher(s)	Field emergence	Laboratory germination
	----------%----------	
Ahmed (1977)	73.5	88.8
Brar and Stewart (1994)	59.0	91.6
Baskin et al. (1993)	85.8	89.5
Srivastava and Pinnell (1963)	71.6	91.6
Vanderlip et al.(1973)	79.0	90.3
Vanderlip et al.(1973)	85.0	93.6

Khosla (1995), working in Virginia with sorghum, followed the instructions on the label of the seed company and planted 20% more seeds than the desired stand, based on the 85% germination reported on the seed tag from a standard test. The field emergence observed was only 80% of the predicted stand, i. e., 66% of the seeds emerged.

The results found in this work agree generally with the cited research. For 1995, the general mean of field emergence was 66.1%, and the mean standard germination was 87.9%. In 1996, 69.3% emergence in the field compared with 87.3 % for the standard germination test. This suggests that the laboratory tests were consistently over-predicting emergence by about 20%.

The variance analysis showed that, under the standard germination conditions and in the field, the hybrids were significantly different from one another in percent germination and emergence in 1995 and 1996 (Tables 4.2 and 4.3). The correlation between the laboratory germination and field emergence showed a significant linear relationship. However the r^2 was low in 1995 (0.283). In 1996 the correlation between standard germination and field emergence was somewhat stronger ($r^2 = 0.520$), (Figures 4.1 and 4.5).

Simple correlations (r values) between field emergence and standard germination test were sought by Srivastava and Pinnell (1963), and they found similar results. A significant correlation was seen in two of three fields. Baskin et al. (1993) found high correlations between the same variables, and they explained their results based on near-optimal conditions of temperature and moisture during the emergence period. Abdullahi and Vanderlip (1972) found positive and significant correlations between standard germination and field emergence over two years and two

planting dates. High correlation coefficients were also found by Krishnasamy and Ramaswamy (1987) with $r^2 = 0.738$ and Vanderlip et al. (1973) with $r^2 = 0.634$.

Radicle length correlations with field emergence

Root length has been previously examined as an indicator of vigor of grain sorghum. Garcia and Lasa (1991), working with 10 genotypes, found length averages from 16 mm to 56 mm after 7 day. The correlations between root length and field emergence were not significant in their two trials. Ahmed (1977) used the rate of root growth and shoot length as criteria to evaluate seed vigor. His measurements were made 4 days after the seeds were imbibed, and the values ranged from 84 to 151 mm. He concluded that some seedlots are superior to others in the rate of root growth.

Krishnasamy and Ramaswamy (1987) examined the mean length of the root and shoot of normal seedlings in 30 sorghum varieties. They found that standard germination test value were positively correlated with root length. Gelmond et al. (1978) obtained six different levels of vigor from a single seedlot of sorghum seeds using accelerated aging. Their results suggested that vigor within genotype is well correlated with root growth in the laboratory as well as with field emergence. In the present study, some differences between genotypes likely reflected vigor differences.

The results of both years of this research agree with those of Garcia and Lasa (1991), where the genotypes showed significant differences in radicle length. However there was no correlation with field emergence in either year. The average length (16 to 56 mm after 7 days) found by Garcia and Lasa (1991) seems not agree with this results, where after 3 days incubation the average ranged from 41 mm to 49 mm. Similarly Ahmed (1977), who found a range of 84 to151 mm in 4 days incubation at 20 to 30°C. He also found significant differences among hybrids in average root length. Positive correlations were exhibited between root length and both standard germination and field emergence in research by Krishnasamy and Ramaswamy (1987) using a single sorghum hybrid.

Fresh weight of seedlings and correlation with emergence

Seedling fresh weight was measured by Garcia and Lasa (1991), and the weights of the genotypes were significantly different. The same result was found in this research; genotypes were significantly different in both years at $P < 0.0001$ (Tables 4.2 and 4.3). The association with field emergence was weakly correlated in 1996 ($r^2 = 0.156$) but not significant in 1995 (Figures 4.3 and 4.7).

Dry weight of seeds and correlations with emergence

Hyoung et al. (1974) compared two seedlots with different seed weights and concluded that seed mass did not affect ultimate grain yield. Maranville and Clegg (1977), found seed size to be highly influential in determining germinability and seedling vigor of grain sorghum. They

used large and small seeds from the same genotype and concluded that larger and denser seeds had a higher percent germination. Trabanino et al. (1988) found that variation in seedling emergence in their study was a reflection of many seeds being removed from the hill by ants and other insects and that seed size did not affect seedling emergence and stand establishment. Abdullahi and Vanderlip (1972) found that seed size had an effect on vigor and field establishment; however larger seeds tended to perform better in laboratory tests but not necessarily in the field. Mortlock and Vanderlip (1989) concluded that larger and/or denser seeds have improved field establishment under temperate conditions.

In this research, comparing 24 seedlots in 1995 and 30 seedlots in 1996, the variance analysis showed there were significant differences between hybrids in both years. Regressing the seed mass with field emergence revealed no correlations ($P<0.05$) for either year.

Relation between mass of seeds, fresh weight of seedlings, and radicle length

Correlation tests between dry weight of the seeds and the fresh weight of the seedlings for all genotypes tested in this research revealed a highly significant correlation, with P values lower than 0.0001 (Table 4.5). Similar results were found by Borikar et al. (1985), where seedling dry weight revealed a positive correlation with fresh weight. The correlation between seed weight and radicle length was not significant in 1996 but was in 1995 (Table 4.5). Seedling weight and radicle length were significantly correlated in both years.

Table 4.5. Regression analysis of dry weight of the seed, seedling fresh weight, and radicle length of the hybrids used in both years in Virginia Sorghum Trials.

Regression	Year	P	r^2
Seed weight vs seedling weight	1995	0.001	0.61
	1996	0.001	0.35
Seed weight vs radicle length	1995	0.050	0.16
	1996	0.257	0.05
Seedling weight vs radicle length	1995	0.045	0.16
	1966	0.001	0.66

Contrast of the hybrids used in both years trials

Each of the fourteen hybrids that were tested in both years was analyzed and contrasted one year against the other for each of the laboratory test parameters (Table 4.6). The objective of this analysis was to see if seedlots showed significant differences in test parameters between years, where differences might signify vigor or testing variance.

Assuming the standard germination test procedures did not vary, the hybrid KS714 did not maintain the same germination level between years. The other 13 hybrids did not show significant differences in percent germination between years. A difference in germination between years suggests significant vigor differences between the two seedlots.

Contrasts of radicle lengths of the seedlings were also done to observe differences in each year's seedlot of the same hybrid. Significant differences were seen seven of the 14 hybrids analyzed.

Table 4.6. Contrasts between 1995 and 1996 seedlots for germination, radicle length, fresh weight of 3-day-old seedlings, and seed mass of 14 hybrids in the Virginia Sorghum Trials.

	Germination		Radicle length		Fresh weight		Seed mass	
Hybrid	F value	P value	F value	P value	F value	P value	F value	P value
CAR775	0.01	0.9081	20.98	0.0001	0.67	0.4137	3.72	0.0554
CAR837	1.77	0.1869	1.74	0.1907	5.36	0.0231	8.31	0.0045
FFR321	0.48	0.4892	15.55	0.0002	13.47	0.0004	61.75	0.0001
KS714	10.73	0.0016	14.01	0.0003	4.95	0.0287	13.69	0.0003
P8118	0.12	0.7292	12.11	0.0008	13.88	0.0004	37.77	0.0001
P8305	1.93	0.1686	8.82	0.004	5.44	0.0221	0.51	0.4764
P8212	0.34	0.5643	0.01	0.9326	0.24	0.6252	0.07	0.7979
P8310	0.34	0.5643	0.36	0.5482	9.66	0.0026	4.23	0.0412
P8446	0.15	0.6953	3.90	0.0518	29.65	0.0001	45.73	0.0001
SS115	0.01	0.9081	1.41	0.2383	5.62	0.0201	1.05	0.3064
SS160	1.48	0.2280	1.33	0.2532	0.10	0.7487	99.99	0.0001
SS1211	1.09	0.3006	0.01	0.9326	35.41	0.0001	12.46	0.0005
SS1313	0.34	0.5643	7.20	0.0089	-	-	1.91	0.0007
XS345	2.04	0.1569	13.50	0.0005	5.62	0.0201	6.47	0.0119

This observation suggests three hypothesis for those different seedlots. The first is that the seedlots were unequal from their origin. Some environmental factor could have affected the intrinsic characteristics of the seeds during their formation. The second is that some post-harvest treatment could have differed between the seedlots before the seeds were tested. The third is that some differences in laboratory test routines (experimental error) could cause this result. There was approximately 20% higher mass radicle length for all seedlots in 1995.

The contrasts between the 13 hybrids compared for both years showed a high sensitivity for seedling mass (Table 4.6). Ten hybrids differed between years (the hybrid SS1313 was not measured in this variable). The approximately 10% higher fresh weight for all seedlots in 1996 suggests some possible variation in procedures between years.

Seed mass also had a high sensitivity, the contrast between seedlots showed significant differences for ten hybrids. This differences are a strong indicator that the seeds for this hybrids varied from one year to the next. A higher 1996 seed moisture content might account for part of this difference.