Chapter III

Influence of Genotype and Location on Grain Sorghum Field Emergence

Introduction

Virginia Tech (1995) and Khosla (1995) have cited poor field emergence as a problem in sorghum stand establishment in Virginia. Establishment of a good stand is, of course, an important factor for satisfactory yield of any crop. As part of the Virginia Sorghum Trials of 1995 and 1996, the field emergence of several hybrids of sorghum was counted at three locations. These observations determined the percentage of seeds that were able to germinate, emerge, and survive during the first 30 days after planting. The hybrids tested showed a range in percentage emergence across locations. These data will be used to determine if the differences observed are related to genotype and/or planting environment. In addition, these data will be used to examine possible correlations with data from various laboratory seed tests.

Materials and Methods

Field experiments

Field emergence data were collected from three sites that were part of the Virginia Sorghum Trials in 1995 and 1996. The hybrids planted and their sources are shown in Table 3.1. The precounted seeds were planted at two locations (Warsaw and Blacksburg) with a tractor-mounted planter at a target depth of 2.5 cm and a target population of 247,000 seeds/ha. At Orange, the planting was done by hand at the same density and depth. Seeds were treated with a seed safener product, Concept, to allow the use of pre-emergence atrazine herbicide. The herbicide program at Orange did not include atrazine in 1995, but there was a higher than recommended rate of metolachlor applied. Plot sizes differed by location. In Blacksburg, plots were four rows 0.35 m apart X 8.25 m long. In Orange, there were three rows of 0.30 m X 5.0 m; and in Warsaw six rows of 0.30 m X 6.0 m.

The field emergence data were collected 30 days after planting. All live seedlings that had two or more leaves were considered emerged. All plants within each plot were counted. The percentage emergence was determined by dividing the number of plants by the number of seeds that had been planted in each plot.

In 1995 and 1996, 32 and 30 sorghum hybrids were planted, respectively. The location, planting date, and soil classification are given in Table 3.2. Rainfall during the 30-day emergence periods and cultural practices before planting that could affect emergence are shown in the Tables 3.3 and 3.4. Additional climatic data for each year are included in the appendix.

Table 3.1. Sorghum hybrids in the Virginia Sorghum Trials in 1995 and/or 1996.

Company	Hybrid	Planted in	
		1995	1996
Asgrow Seed Company	A298	*	
	A531	*	
	A7712	*	
	Seneca	*	
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		*
	DK51	*	
	DK54	*	*
	DK55	*	*

Table 3.2. Location, planting date, and soils for each of the three locations of the Virginia Sorghum Trials used in field emergence studies.

	Planting date		Soil	
Location	**Year**	**Day**	**Type**	**Family**
Blacksburg	1995	May 31	Hayter fine loam	Fine loamy, mixed mesic ultic,
	1996	May 23		Hapludalfs
Orange	1995	May 18	Starr clay loam	Fine loamy, mixed, thermic
	1996	May21		fluvenitic, Dystrochrepts
Warsaw	1995	May 19	Kempsville sandy	Fine loamy, siliceous, thermic
	1996	May 14	loam	typic, Hapludults

Table 3.3. Fertilization, herbicide application, and rainfall during the emergence period at three 1995 locations of sorghum field emergence studies.

	Pre plant fertilization			Herbicide		Rainfall during 30-day
Location	**N**	**P**	**K**	**Brand**	**Rate**	**emergence period**
	----------kg/ha----------				l/ha	cm
Blacksburg	44	89	89	Bicep*	5.6	10.5
Orange	55	111	111	Dual R	4.6	23.5
Warsaw	145	67	89	Bicep	5.6	9.4

Source: Virginia Tech (1995)

*Bicep = Dual + Aatrex (3.7 + 3.0 AI kg/ha)

Dual R = Metolachlor (9.0 AI kg/ha)

Aatrex = Atrazine (2.2 A I kg/ha)

Table 3.4. Fertilization, herbicide application, and rainfall during the emergence period at three 1996 locations of sorghum field emergence studies.

Location	Pre plant fertilization			Herbicide		Rainfall during 30-day emergence period
	N	P	K	Brand	Rate	
	----------kg/ha----------				l/ha	cm
Blacksburg	55	78	78	Bicep*	5.1	14.0
Orange	111	111	33	Bicep	7.0	7.0
Warsaw	22	67	66	Bicep	7.0	14.6

Source: VirginiaTech (1996)
*Bicep = Dual + Aatrex (3.7 + 3.0 kg AI/ha)

Data analysis

A randomized-complete-block design was applied with four replications at each location, and an analysis of variance of transformed data (arcsine of square root of percent emergence) (Sokal and Rohlf, 1995) was performed. SAS (1993) was used to test for differences among hybrids and possible interactions of year, hybrid, and location. Mean separation was done using Tukey's test. Data were back-transformed for reporting.

Results and Discussion

Field emergence in 1995

Emergence in Blacksburg (Table 3.5) revealed differences between hybrids ($P < 0.01$). Tukey's test showed DK51 and CAR837 to be superior to X604. The mean emergence for all hybrids at Blacksburg was 71.0%, and the CV was 9.0%. There were also differences in emergence among the hybrids in Warsaw ($P < 0.01$). The top six ranked hybrids at this site were superior to X604 (Table 3.5). The mean emergence at Warsaw was 72.7%, and the CV was 8.5%. The hybrids also differed in emergence at Orange ($P<0.01$), where the hybrid SS1211 was superior to KS714. The mean emergence at Orange was 54.7%, and the CV was 17.0% (Table 3.5).

The lowest overall emergence was seen at Orange (54.7%), while Warsaw (72.7%) and Blacksburg (71%) were very similar in mean emergence. There was no interaction between hybrids and location at $P < 0.1$ when Orange was included (Table 3.6). Pooling the Orange data for subsequent analyses is therefore inappropriate. Significant differences among hybrids were observed when data were pooled across the remaining two locations (Blacksburg and Warsaw) ($P<0.01$), and there was no interaction between hybrid and location (Table 3.7). When considering these two locations, the top four hybrids were superior to X604 and KS936. The general mean across all hybrids at these two locations was 71.8%, and the CV was 8.8%.

Table 3.5. Field emergence of the 32 sorghum hybrids tested at three locations of the Virginia Sorghum Trials in 1995.

Hybrid	Blacksburg		Warsaw		Average (Blacksburg + Warsaw)		Orange	
	%	Rank	%	Rank	%	Rank	%	Rank
DK51	79.4 [a*]	2	76.8 [ab]	7	78.1 [a]	1	53.9 [ab]	17
FFR321	77.2 [ab]	4	78.9 [a]	2	78.1 [a]	2	64.6 [ab]	2
CAR837	80.6 [a]	1	75.3 [ab]	11	77.9 [a]	3	50.3 [ab]	24
DK54	73.8 [ab]	8	80.7 [a]	1	77.3 [a]	4	46.4 [ab]	30
CAR737	77.0 [ab]	5	75.6 [ab]	9	76.3 [ab]	5	61.7 [ab]	7
DK55	75.3 [ab]	6	75.4 [ab]	10	75.3 [ab]	6	57.5 [ab]	13
P8310	78.9 [ab]	3	69.7 [ab]	25	74.3 [ab]	7	60.3 [ab]	8
SS1211	73.8 [ab]	9	74.1 [ab]	12	74.0 [ab]	8	66.0 [a]	1
SS1313	69.4 [ab]	20	77.7 [a]	5	73.5 [ab]	9	50.0 [ab]	26
A531	68.1 [ab]	23	78.6 [a]	3	73.3 [ab]	10	56.7 [ab]	14
P8118	74.8 [ab]	7	71.2 [ab]	20	73.0 [abc]	11	52.8 [ab]	20
DK45	68.6 [ab]	21	77.2 [a]	6	73.0 [abc]	12	62.5 [ab]	3
SS160	67.1 [ab]	26	78.2 [a]	4	72.7 [abc]	13	62.1 [ab]	4
A298	71.8 [ab]	13	73.4 [ab]	15	72.6 [abc]	14	61.7 [ab]	6
P8305	70.9 [ab]	16	74.0 [ab]	13	72.5 [abc]	15	59.6 [ab]	9
CAR577	72.9 [ab]	11	71.2 [ab]	19	72.1 [abc]	16	58.2 [ab]	10
CAR775	70.9 [ab]	15	73.1 [ab]	17	72.0 [abc]	17	53.5 [ab]	18
GW1114	66.9 [ab]	27	76.1 [ab]	8	71.5 [abc]	18	51.0 [ab]	23
P8699	71.6 [ab]	14	67.2 [ab]	30	71.4 [abc]	19	55.3 [ab]	15
A7712	73.3 [ab]	10	69.2 [ab]	28	71.2 [abc]	20	52.1 [ab]	21
Seneca	67.3 [ab]	25	73.8 [ab]	14	70.6 [abc]	21	62.1 [ab]	5
KS714	72.9 [ab]	12	67.2 [ab]	30	70.1 [abc]	22	40.0 [b]	32
SS115	69.5 [ab]	19	70.6 [ab]	22	70.1 [abc]	23	58.2 [ab]	12
P8446	70.5 [ab]	17	69.6 [ab]	26	70.0 [abc]	24	52.1 [ab]	22
GW6089	69.5 [ab]	18	70.3 [ab]	23	69.9 [abc]	25	54.6 [ab]	16
CAR1922	67.5 [ab]	24	72.0 [ab]	18	69.8 [abc]	26	47.5 [ab]	28
GW8046	65.1 [ab]	29	73.1 [ab]	16	69.1 [abc]	27	53.2 [ab]	19
P8212	68.6 [ab]	22	69.0 [ab]	29	68.8 [abc]	28	47.1 [ab]	29
XS345	66.6 [ab]	28	69.5 [ab]	27	68.0 [abc]	29	58.2 [ab]	11
CAR630	64.7 [ab]	31	70.0 [ab]	24	67.3 [abc]	30	47.5 [ab]	27
KS936	64.9 [ab]	30	64.7 [ab]	31	64.8 [bc]	31	50.3 [ab]	25
X604	61.5 [b]	32	59.1 [b]	32	60.3 [c]	32	44.6 [ab]	31
Average	71.0	-	72.7	-	71.8	-	54.7	-

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

Table 3. 6. Analysis of variance of field emergence for 32 sorghum hybrids planted at three Virginia locations in 1995.

Source of Variation	Degrees of freedom	Mean square	F value	P value
Hybrid (Hyb)	31	0.03325336	3.32	0.0001
Location (Loc)	2	2.12247073	211.95	0.0001
Hyb*Loc	62	0.01284681	1.28	0.0922
Rep (Loc)	9	0.15112241	15.09	0.0001
Error	279	0.01001410		
Total	383			

Table 3. 7. Analysis of variance of field emergence for 32 sorghum hybrids planted at two Virginia locations (Warsaw and Blacksburg) in 1995.

Source of Variation	Degrees of freedom	Mean square	F value	P value
Hybrid (Hyb)	31	0.02435810	2.79	0.0001
Location (Loc)	1	0.03426252	3.93	0.0490
Hyb*Loc	31	0.01125529	1.29	0.1548
Rep (Loc)	6	0.08620639	9.88	0.0001
Error	176	0.00872891		
Total	383			

Field emergence in 1996

Thirty days after planting in 1996, field emergence of the 30 hybrids was counted at each of three locations. There were differences between hybrids at Warsaw ($P<0.001$). The top nine hybrids were superior to DK18, DK36, KS714, and DK40 (Table 3.8). The mean emergence at Warsaw was 84.2%, and the CV was 5.7%.

The variance analysis for field emergence in Blacksburg in 1996 revealed marked differences between hybrids ($P< 0.001$). The hybrids P8282 and P8305 showed a higher percent emergence than DK54, DK18, DK36, KS714, and DK40. The emergence mean at Blacksburg was 74.3%, and the CV was 8.1%.

At Orange, emergence again differed between hybrids ($P<0.001$). The hybrid P8282 and CAR775 produced more surviving seedlings than did the bottom six ranked hybrids. The mean emergence at Orange was 49.5 %, and the CV was 15.5%.

The combined ANOVA of field emergence for the three 1996 locations (Table 3.9) revealed differences between hybrids and each location and an interaction between hybrid and location. A two-location analysis of variance was then performed using data only from Blacksburg and Warsaw (Table 3.10). The mean emergence across these two locations was 79.2%, and the CV was 6.8%. More importantly, there was no interaction between hybrid and location. As with 1995 data, this finding will allow us to pool data from the two locations for subsequent analyses and comparisons with laboratory data.

Table 3.8. Field emergence of the 30 sorghum hybrids tested at three locations of the Virginia Sorghum Trials in 1996.

Hybrids	Blacksburg		Warsaw		Average(Blacksburg + Warsaw)		Orange	
	%	rank	%	rank	%	rank	%	rank
P8282	84.5 [a*]	1	90.6 [a]	6	87.6 [a]	1	63.3 [a]	1
P8305	84.0 [ab]	2	90.2 [a]	8	87.1 [ab]	2	54.4 [abcd]	11
SS160	80.6 [abc]	3	91.5 [a]	3	86.0 [abc]	3	49.7 [abcde]	18
SS115	78.7 [abcde]	9	92.4 [a]	1	85.5 [abc]	4	56.8 [abc]	8
SS1211	78.8 [abcde]	7	91.0 [a]	4	84.9 [abc]	5	57.1 [abc]	5
CAR647	80.4 [abcd]	4	88.5 [a]	9	84.5 [abcd]	6	55.0 [abcd]	10
SS1313	78.7 [abcde]	8	90.1 [a]	7	84.4 [abcd]	7	57.7 [abc]	4
CAR775	79.6 [abcde]	6	88.3 [ab]	10	84.0 [abcde]	8	60.7 [ab]	2
DK47	79.9 [abcd]	5	87.2 [abc]	13	83.5 [abcde]	9	53.8 [abcd]	12
P8310	77.8 [abcde]	11	89.1 [a]	5	83.4 [abcde]	10	53.5 [abcd]	14
GW9089	78.0 [abcde]	10	85.9 [abc]	14	82.0 [abcde]	11	58.0 [abc]	3
CAR837	75.0 [abcdef]	16	87.2 [abc]	12	81.1 [abcde]	12	53.2 [abcd]	15
CAR12027	70.6 [abcdef]	23	91.5 [a]	2	81.1 [abcde]	13	53.8 [abcd]	13
P8414	76.1 [abcde]	13	85.6 [abc]	16	80.8 [abcde]	14	37.5 [cde]	27
XS345	75.0 [abcdef]	15	84.8 [abcd]	17	79.8 [abcdef]	15	55.9 [abcd]	9
FFR321	71.8 [abcdef]	21	87.7 [ab]	11	79.7 [abcdef]	16	50.3 [abcde]	17
P8212	76.7 [abcde]	12	82.7 [abcde]	21	79.7 [abcdef]	17	43.7 [abcde]	23
DK45	74.7 [abcdef]	17	83.2 [abcde]	20	78.9 [abcdef]	18	52.7 [abcd]	16
P8446	73.3 [abcdef]	19	83.7 [abcde]	19	78.5 [abcdef]	19	38.7 [cde]	26
KS711	72.1 [abcdef]	20	84.3 [abcd]	18	78.2 [abcdef]	20	36.9 [cde]	28
P8118	74.4 [abcdef]	18	81.8 [abcde]	22	78.1 [abcdef]	21	57.1 [abc]	7
CAR627	70.4 [abcdef]	24	85.7 [abc]	15	78.0 [abcdef]	22	47.3 [abcde]	19
KS735	75.7 [abcdef]	14	79.5 [abcde]	26	77.6 [bcdef]	23	57.1 [abc]	6
DK55	71.8 [abcdef]	22	80.6 [abcde]	23	76.2 [cdefg]	24	41.0 [bcde]	24
CAR730	68.6 [bcdef]	25	79.8 [abcde]	24	74.2 [defgh]	25	45.8 [abcde]	20
DK54	68.1 [cdef]	26	79.8 [abcde]	25	73.9 [efgh]	26	44.9 [abcde]	22
DK18	63.6 [ef]	29	73.9 [bcde]	27	68.8 [fgh]	27	30.0 [e]	30
DK36	65.5 [cdef]	27	71.9 [cde]	28	68.7 [fgh]	28	38.9 [cde]	25
KS714	64.1 [def]	28	67.0 [e]	30	65.5 [gh]	29	44.9 [cde]	21
DK40	58.5 [f]	30	69.1 [de]	29	63.8 [h]	30	35.1 [de]	29
Average	74.3	-	84.0	-	79.2	-	49.5	-

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

Table 3.9. Analysis of variance of field emergence of the 30 sorghum hybrids planted at three Virginia locations in 1996.

Source of variation	Degrees of freedom	Mean square	F value	P value
Hybrid (Hyb)	29	0.10589023	12.71	0.0001
Location (Loc)	2	7.54253522	905.33	0.0001
Hyb*Loc	58	0.01344792	1.61	0.0064
Rep(Loc)	9	0.10502965	12.61	0.0001
Error	261	0.00833124		
Total	359			

Table 3.10. Analysis of variance of field emergence of the 30 sorghum hybrids planted at two Virginia locations (Blacksburg and Warsaw) in 1996.

Source of variation	Degrees of freedom	Mean square	F value	P value
Hybrid (Hyb)	29	0.08233576	9.46	0.0001
Location (Loc)	1	1.76905994	203.27	0.0001
Hyb*Loc	29	0.00948710	1.09	0.3543
Rep(Loc)	6	0.05804749	6.67	0.0001
Error	174	0.00870315		
Total	239			

Seventeen hybrids were used in both years, and a combined analysis of variance for those hybrids, the two years, and the three locations was performed (Table 3.11). There were differences between hybrids, years, and locations. Because of interactions between hybrid and year and between location and year, it is not appropriate to pool these multiple-year data for further analysis.

Table 3.11. Analysis of variance of field emergence of 17 hybrids planted at three Virginia locations in both 1995 and 1996.

Source of variation	Degrees of freedom	Mean square	F value	P value
Hybrid (Hyb)	16	319.1523	6.27	0.0001
Location (Loc)	2	25426.7192	499.52	0.0001
Year (Y)	1	1450.2345	28.49	0.0001
Rep (Loc)	9	789.7502	15.69	0.0001
Hyb*Loc	32	81.9623	1.61	0.0230
Loc*Y	2	2035.5920	39.99	0.0001
Hyb * Y	16	133.5735	2.62	0.0007
Hyb* Y * Loc	32	83.8170	1.65	0.0182
Error	296	50.9020		
Total	407			

The results from this field study generally agree with research cited in the literature review (Chapter II). Distinct differences among hybrids were observed, and location had an effect on total emergence. An interaction between location and hybrid was observed when the Orange location was included. Some differences in methodology used in Orange and in soil and climate may have caused this result. The planting by hand may have caused differences in seed distribution. When using a tractor-mounted planter, the soil compression by the planter wheel increases the soil contact with the seed. Environmental effects also may help explain the very different results. Orange has a soil type with more clay content than the others (Table 3.2). It is consequently heavier and more subject to soil crusting. Additionally, rainfall (Tables 3.3 and 3.4) was strikingly different in Orange in both years during the emergence period. In 1995, the Orange rainfall amount was twice as much, but in 1996 only one-half of the other two locations. The low percentage of emergence in Orange was also perhaps related to a problem in herbicide application in 1995. As a consequence of perhaps a variety of factors, the mean emergence of all hybrids in Orange was much lower than at the other two locations in both years. Because of this difference and because of the interaction between hybrid and location, it was necessary to take the Orange location out of further analyses.

The two-location (Blacksburg and Warsaw) analysis in 1995, revealed the hybrids FFR321, DK51, DK54, and CAR837 were superior to KS936 and X604. Emergence means among all hybrids across two locations ranged from 78.1% to 60.3%. In 1996, the emergence percentages were significantly different, and the range was from 87.6 % to 63.8%. In 1996 P8282, P8305, SS160, SS115, and SS1211 were superior to CAR730, DK54, DK18, DK36, KS714, and DK40.

Locations showed significant differences in mean emergence in1995 and 1996 (Tables 3.6, 3.7, 3.9, and 3.10) and when the 17 hybrids tested in both years were analyzed separately (Table 3.11).

There was no interaction at $P<0.05$ level between hybrid and location in the two-location (Blacksburg and Warsaw) variance analyses for 1995 or 1996. This result allows us to conclude that these 17 hybrids were not affected differentially by these two locations but that the locations did affect their overall emergence.

Differences in field emergence among hybrids of grain sorghum have been observed by other researchers. Garcia and Lasa (1991) compared four genotypes under saline conditions and found a difference of 21% between the highest and the lowest field emergence. Similar results were obtained by Somman and Peacock (1985), who worked with 24 genotypes and concluded that emergence was affected differentially by temperature with considerable genotype X temperature interaction. Baskin et al. (1993) used 35 different genotypes and observed that, even under favorable conditions, the genotypes were not equal in emergence. Emergence of the different hybrids ranged from 97% to 69%. Ahmed (1977) also found differences among genotypes when testing nine genotypes of sorghum; his results showed a range from 91% to 58%. Baskin et al. (1993) reported emergence differences among hybrids that ranged from 97% to 67%. Maiti and Gutierrez (1989) tested 100 sorghum genotypes for their capacity to emerge from different planting depths and found a great variability among genotypes in seedling emergence.

The differences among genotypes in their emergence may be related not to genotype *per se* but to several other intrinsic factors of the seed. Some of them are associated with the seed history; for example, stress suffered during seed formation, storage, and chemical treatments can affect vigor and reduce field emergence. Miranda (1967), Abdullahi (1968), and Camargo and Vaughan (1971) artificially aged seeds to stimulate the deterioration process and found differences among genotypes in emergence and seed quality. Using electron microscopy, Paliwal et al. (1991) observed anatomical differences among genotypes that had different seed densities. Low density was correlated with low vigor and embryo axes that were not well developed. Other, genetically determined differences between hybrids might be related to morphology or biochemistry.

The average percent of emergence for all hybrids planted in 1995 at three sites was 66.2% and for 1996 was 69.3%, which means essentially one-third of the seeds planted did not became established in the field. When comparing the 17 hybrids planted in both years, the means increased to 67.1% in 1995 and 71.2% in 1996. For this subset, the difference between years was significant ($P< 0.05$). The interaction between hybrid and year in the combined variance analysis suggests the hybrids may have behaved differentially between years due to environmental factors. Alternatively, the differences may have been due to vigor differences between the seedlots for each cultivar. Srivastava and Pinnell (1963) found significant differences among years for the same seedlots in field germination percentage when they worked with 25 cultivars and three field trials.

Genotypes can react differently when submitted to emergence stresses such as insect damage, soil crusting, wet or dry seedbeds, warm or cool soil temperature, diseases, and planter problems, and these can result in a stand reduction. Larson and Vanderlip (1994) studied yield compensation in reduced grain sorghum stands in two medium-maturity sorghum hybrids. They concluded that yield reductions were 5 to 10% when the plant spacing was severely nonuniform. Also Camargo and Vaughan (1973) found that seedlots with lower vigor showed lower field emergence and final stands

and yields. Focusing on the differences among genotypes, the laboratory studies that follow could help find a test to identify better seedlots and predict field emergence.