THE RELATIONSHIP OF HCN CONTENT TO DISEASE RESISTANCE AND CERTAIN MORPHOLOGICAL CHARACTERS IN VARIOUS STRAINS OF SUDANGRASS

by

BEDFORD WALTER JACKSON

B. S., Tennessee Polytechnic Institute, 1949

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

TABLE OF CONTENTS

INTRODUCTION

The purpose of this experiment has been to study the potential HCN content of several strains of sudangrass, *Sorghum vulgare* var. *sudanense* (Piper) Hitchc., and to determine whether or not relationships existed between this character and certain others such as disease reaction, height, vigor, tillering, leafiness, and coarseness.

Sudangrass is adapted to many regions and soils and is one of the most valuable of summer annual forage grasses as a supplementary pasture crop, but it possesses certain agronomic characters which may reduce its value as a forage grass. Some of these characters are susceptibility to disease and potential HCN content as well as lack of leafiness, vigor, and fine stems. HCN which exists in the plant as a cyanogenetic glucoside, dhurrin, may be toxic to ruminants. Horses and swine are not effected by HCN in the plant. Susceptibility to diseases may be so great that the plant may be defoliated.

Sudangrass grows from 4 to 12 feet in height, depending on the variety, method and time of planting, and fertility of the soil. The tillers arise from a single clump, some varieties having a tendency to produce a larger number of tillers than others. The culms are usually relatively fine and erect. The leaves are long and narrow and the seeds are borne in panicles which may be loose or compact, depending on the strain.

Sudangrass is usually grown alone, the yields of forage, depending upon rainfall and soil fertility, ranging from 1 to 7 tons per acre. A good growth of sudangrass will provide 4 to 6 animal months of grazing if properly managed. Seed yields may vary from less than 250 pounds to more than 1000 pounds per acre.

LITERATURE REVIEW

Studies of the Potential HCN Content of Sudangrass

Avery, according to Vinall (8), found that 0.4 g of prussic acid was sufficient to make an animal very sick. Therefore, it is probable that 0.5 to 0.6 g would in most cases be fatal to a mature animal. Vinall stated that 19.9 pounds of green sudangrass were required to provide sufficient prussic acid to be fatal to cattle. Recent work tends to indicate that the amount required to be fatal to an animal depends on the amount of potential HCN in the plant.

The presence of HCN in sorghums was not discovered until 1902. Vinall (8) has stated that it was first reported by Dunstan and Henry of England, although Slade, a chemist at the Nebraska Agricultural Experiment Station, suggested the possibility of such a poison in 1901, and he actually isolated prussic acid from a sample in 1902.

The theory of Dunstan and Henry, according to Vinall, was that sorghum poisoning was due to the release of HCN by an enzyme. Slade and Avery arrived independently at the same conclusions. The amount of prussic acid liberated will depend on the amount of dhurrin in the plant and on the action of an enzyme. Several investigators, according to Ahlgren (1), have reported that danger of prussic acid poisoning can be eliminated by delaying grazing until the plants are 2 to 3 feet in height, at which stage they are relatively free of the cyanogenetic glucoside.

Factors Influencing the Potential HCN Content of Sudangrass

Inheritance studies involving the production of HCN in sorghums have been reported by Franzke (3), Hogg and Ahlgren (6), and others. They have stated that low HCN content appears to be partially dominant over high HCN, and that one or two main genetic factors and several modifying factors may be involved.

Several environmental factors influence the potential HCN content of sudangrass, the most important being stage of growth, time of day, fertility of the soil, climatic conditions, and genetic factors (4). Short, stunted plants usually contain more prussic acid than normal ones (2).

Williaman and West (9) found that heavy applications of nitrogen fertilizer increased the potential HCN content of sudangrass. Peters, Slade, and Avery have stated, according to Garner and Atwood (4), that growth arrested by drought presents a favorable condition for the elaboration of the poison. Stunting by too much water, shade, or hardening of the soil does not result in a higher HCN content. Vinall (8) has concluded from a critical survey of literature that drought injury to growing sorghum plants increases the HCN content, but that growth stunted from a lack of plant food in the soil contains less of the glucoside. Hogg and Ahlgren (6) stated that Peters, Slade, and Avery found young vigorous plants to contain more prussic acid than plants approaching maturity. They further concluded that second growth was no more dangerous than first growth.

Williaman and West (10) and Martin, Couch, and Briese (7) have stated that the glucoside is concentrated in the stems during the first 3 or 4 weeks, but then decreases and disappears, persisting in the leaves in decreasing amounts until maturity.

Vinall (8) found that the glucoside increased to a certain extent as the moisture concent of the soil decreased. Young actively growing tillers were found to be uniformly and consistently high in the glucoside.

MATERIALS AND METHODS

Methods of Planting and a Description of the Material Used

The sudangrass in this experiment was planted June 2, 5, and 6, 1950 in rows 25 feet in length and 3 feet apart. It was thinned June 20, leaving the plants approximately 6 inches apart in the row, and received no cultivation except hoeing and hand weeding. The origin of the strains included in this experiment is shown in Table 1.

Eight check blocks of sudangrass were planted at various intervals in the nursery, each containing the following strains which have been under observation at the Kansas Agricultural Experiment Station for several seasons: Wheeler, Tift, Sweet, Piper, KS 1044

Table 1. Groups of sudangrass in which HCN determinations, disease reactions, and morphological characters were studied.

Group	Source	Row numbers
KS 1044 selections	Leoti-sudan 4 x Leoti-sudan 2	1-164
Tift selections	Tift sudangrass	268-355
4n selections	(Johnsongrass x 4n sudangrass) x (4n sudangrass)	424-617
2n F_2's	Tift x KS 1044	618-718
2n F_1's	Disease resistant sorghum and sudangrass selections x sudangrass selections	718-761
4n F_2's	(Johnsongrass x 4n sudangrass) x (4n sudangrass)	771-818
4n F_1's	(Leafy tillering sudan-grass selections) x (disease resistant sudangrass selections)	830-835
4n F_2's (o.p.)	(Open pollinated Johnsongrass x 4n sudangrass) x (4n sudangrass crosses)	904-916
2n F_2's(o.p.)	Open pollinated (Tift x KS 1044 selections)	934-950
2n and 4n parents	Original source material of many of the 2n and 4n selections	956-994
Checks	Varieties and nursery selections	

selection, and three selections of johnsongrass x 4n sudangrass. The check blocks were replicated and dispersed throughout the nursery in order to determine any possible variation in potential HCN content due to location in the nursery.

The strains of sudangrass included in these trials were extremely variable in disease resistance and morphological characters. The 2n F_1 and 4n F_2 selections of sudangrass exhibited the greatest variability in the characters under observation. These selections were studied more carefully than the others because of their high resistance to disease. Many of them lacked certain other desirable agronomic characters. Their disease resistance was considered to be of importance because of its potential value in the improvement of other strains which are vigorous, leafy, low in potential HCN, and which tiller well.

Emphasis was placed on the 4n material because it contained some of the most vigorous plants, and because of its low degree of natural crossing with the 2n sorghums. This 4n material would be of greater value if its susceptibility to rust could be reduced or eliminated by plant breeding and its high degree of resistance to Helminthosporium leaf blight retained.

Methods Used in Determining the Potential HCN Content

The potential HCN content was determined in the manner described by Hayes and Immer (5). Young, actively growing tillers from 8 to 10 inches in height were removed from the plants. A 0.15 g sample of this green plant material, estimated by comparison with a weighed sample, was cut into short pieces with a pair of scissors and placed in a test tube. Sufficient chloroform was added to cover the pieces of plant material. Above this was suspended a strip of filter paper saturated with sodium picrate solution and held in place by the cork stopper used to seal the tube.

Table 2. Ml of KCN-alkaline picrate solution and equivalent amounts of HCN in mg placed in the various test tubes for making color standards for checking the HCN content of sudangrass samples.

Tube number	ml of solution	mg of HCN
1	0.05	0.0025
2	0.10	0.0050
3	0.15	0.0075
4	0.20	0.0100
5	0.25	0.0125
6	0.30	0.0150
7	0.35	0.0175
8	0.40	0.0200
9	0.45	0.0225
10	0.50	0.0250
11	0.60	0.0300
12	0.70	0.0350
13	0.80	0.0400
14	0.90	0.0450
15	1.00	0.0500
16	1.20	0.0600
17	1.60	0.0800
18	2.00	0.1000

The mixture was incubated from 12 to 24 hours at room temperature. The sodium picrate present on the filter paper was reduced in the presence of HCN liberated as a gas and changed color to some shade of orange-red.

The alkaline picrate solution was prepared by dissolving 25 g of Na_2CO_3 and 5 g of picric acid in 1000 ml of distilled water. The chloroform used was of Merck's U.S.P. grade. The color standards were prepared by dissolving 0.241 g of KCN in 1000 ml of distilled water to give a stock solution containing 0.1 mg of HCN per ml of solution. Equal amounts of the alkaline picrate solution and the KCN solution were placed in a test tube. Table 2 shows the amounts of the KCN-alkaline picrate solution placed in the various test tubes. The volume in each tube was brought up to 10 ml by adding distilled water, and then heated to boiling in a beaker of water. The test tubes were permitted to stand in boiling water for 5 minutes to fix the reduction of the alkaline picrate solution to a stable color and were then labeled as to the number of ml of solution which each one contained.

The test paper consisted of 3/8" x 4½" strips of filter paper saturated in the alkaline picrate solution and kept moist by storing in a closed bottle until needed.

To determine the HCN content of the sudangrass, the pieces of plant material covered with chloroform were allowed to stand for 24 hours, or until all of the HCN had been liberated and the color of the moist filter paper had changed to some shade of orange-red. Its color was then compared with that of the standards, which had been labeled as to their content of the stock solution, and the color which it most nearly matched was concluded to indicate the HCN content in mg of that particular sample.

Several HCN samples were taken from different plants in each row of the various groups of sudangrass. Fewer samples were taken from certain rows not possessing desirable agronomic characteristics than from the superior ones.

Most of the HCN determinations were carried out on 2n F_2 and 4n F_2 selections of sudangrass. Due to segregation in the 4n F_2's considerable variability was observed in the HCN content. The plants selected for HCN tests were those possessing good agronomic characters.

Note Taking Procedure

Detailed field notes were taken on the various strains of sudangrass as to their height, vigor, tillering, leafiness, coarseness, date of heading, and reaction to disease.

The diseases most common in the experimental plots were Helminthosporium leaf blight, _Helminthosporium turcicum_ Pass. rust, _Puccinia purpurea_ Cke., and bacterial stripe, _Pseudomonas andropogonae_ Stapp. Some bacterial spot, _Pseudomonas syringae_ Hall, was observed but it was so limited that it was not considered in these studies. Head smut, _Spacelotheca reliana_ (Kuehn) Clint. was identified in the experimental plots but it was too limited to be considered as a major disease.

The general level of disease occurrence was high. Helminthosporium leaf blight was as prevalent as it had been in past years. The growing season of 1950 was favorable to the development of rust which appeared to be more abundant than in past growing seasons.

Field notes were recorded in terms of the numerals 1 to 6, with 1 representing the most desirable type for each character and 6 the least desirable. In the case of heading dates, the numeral 1 was used to designate the latest and 11 the earliest. This is shown in Table 3.

The height of the various groups of sudangrass was measured in inches. Three height readings were made in each row, the average of the three being taken to indicate the height of that particular row. Each plant was measured in the 2n F_1 group.

Table 3. Dates of heading of the various groups of sudangrass and the code numbers used to represent each date.

1950 heading dates	Code number
7/31 and earlier	11
8/1-8/4	10
8/5	9
8/6	8
8/7	7
8/8	6
8/9-8/10	5
8/11	4
8/12-8/13	3
8/14	2
8/15 and later	1

The height of sudangrass is important from the standpoint of seed production, because of the difficulty in harvesting extremely tall selections. The very short ones, on the other hand, are likely to lack vigor and therefore to be low forage producers.

Field notes on disease and mature plant characteristics were not taken until full maturity had been reached in order to allow each of these characteristics to reach full expression.

Method Used in Determining the Relationship Between HCN, Disease Reaction, and Morphological Characters

The relationships between HCN content, disease resistance, and certain morphological characters such as height, vigor, tillering, leafiness, and coarseness have been studied through the use of correlation coefficients. The formula used in calculating the correlation coefficients is shown as follows:

$$\text{Correlation coefficient} = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

The five items ΣX, ΣY, ΣXY, ΣX^2, and ΣY^2 were obtained for all groups by one series of runs through the IBM tabulator after the data had been transferred from the field notebook to punch cards.

RESULTS

Relationships Between HCN, Disease Reactions, and Certain Morphological Characters as Shown by Correlation Coefficients

Major emphasis in this study has been placed on the two characters, HCN content and disease resistance. The correlation coefficients which show the relationship between HCN, Helminthosporium leaf blight, rust, and certain morphological characters for the various groups of material are shown in Table 4.

No significant correlation coefficients between potential HCN content and Helminthosporium leaf blight were found in any of the groups with the exception of the KS 1044 selections. HCN and rust were not closely related in any of the groups as shown by a lack of correlation coefficients, nor were potential HCN and earliness of heading. HCN showed a significant negative relationship to leafiness in the 4n selections ($r = -0.676$) and in the 2n F_1's ($r = -0.183$), but no such relationship occurred in the other groups. There was no significant relationship between HCN and vigor in any group.

Table 4. Relationships between HCN content and certain other characters in selected groups of sudangrass selection expressed as correlation coefficients.

Characters	Group	d/f	Correlation coefficient
	KS 1044 selections	122	-0.240**
	Tift selections	73	-0.029
HCN x Helminthosporium	4n selections	114	-0.037
leaf blight resistance	2n F_2's	173	0.110
	4n F_2's	108	0.010
	4n F_2's(o.p.)	61	-0.085
	KS 1044 selections	122	0.088
	Tift selections	73	0.021
	4n selections	114	0.020
	2n F_2's	173	-0.004
HCN x rust resistance	2n F_1's	149	-0.002
	4n F_2's	108	0.010
	4n F_1's	23	-0.090
	2n F_2's(o.p.)	20	0.052
	2n and 4n parents	39	0.135
	Checks	73	0.007
	KS 1044 selections	122	0.047
	4n selections	114	0.038
HCN x earliness	2n F_2's	173	0.067
	4n F_2's	108	0.010
	Checks	73	0.018
	KS 1044 selections	122	-0.029
	Tift selections	73	-0.017
	4n selections	114	-0.676**
	2n F_2's	173	-0.005
HCN x leafiness	2n F_1's	149	-0.183*
	4n F_1's	23	-0.004
	2n F_2's(o.p.)	20	-0.006
	2n and 4n parents	39	0.002
	Checks	73	-0.024
	KS 1044 selections	122	-0.031
	4n selections	114	-0.150
	2n F_2's	173	-0.011
	2n F_1's	149	-0.010
HCN x vigor	4n F_2's	108	-0.021
	4n F_1's	23	-0.098
	4n F_2's(o.p.)	61	0.029
	2n F_2's(o.p.)	20	-0.018
	2n and 4n parents	39	0.010
	Checks	73	0.008

Helminthosporium leaf blight resistance and vigor were not closely related in any of the strains of sudangrass, although in the 2n F_2's a negative correlation coefficient of -0.197 was observed. Helminthosporium leaf blight and earliness showed a highly significant positive relationship ($r = 0.440$) in the strains planted in the check blocks, but these two characters did not show a significant relationship in the other groups. Helminthosporium leaf blight and leafiness were significantly related in the KS 1044 selections, 2n F_2's and 4n parents, and in the strains in the check blocks. A high, significant negative relationship ($r = -0.415$) was shown to exist between Helminthosporium leaf blight and tillering in the 4n selections. A negative relationship was found between these characters in the 2n F_2's ($r = -0.390$), and in the 2n and 4n parents ($r = -0.401$). A low, significant positive relationship ($r = 0.378$) was found to exist between these characters in the KS 1044 selections.

A highly significant positive relationship was found between rust resistance and tillering in the 4n selections and in the 2n F_2's. These were the only groups in which a significant relationship between these two characters was observed. Rust resistance and vigor were closely related in the 4n selections and in the open pollinated 2n F_2's, but showed no significant relationship in the other groups of material. Rust resistance and earliness of heading were not significantly related in any of the strains studied. Tables 5 and 6 show the correlation coefficients between Helminthosporium leaf blight, rust, and the various morphological characters.

Table 5. Relationships between Helminthosporium leaf blight and certain other characters in selected groups of sudan-grass selections expressed as correlation coefficients.

Characters	Group	d/f	Correlation coefficient
Helminthosporium leaf blight resistance x vigor	KS 1044 selections	122	0.074
	4n selections	114	0.026
	2n F_2's	173	-0.197
	2n F_1's	149	0.001
	4n F_2's	108	0.034
	4n F_1's	23	-0.030
	4n F_2's (o.p.)	61	-0.024
	2n F_2's (o.p.)	20	0.380
	2n and 4n parents	39	0.023
	Checks	73	0.080
Helminthosporium leaf blight resistance x rust resistance	Tift selections	73	0.050
	4n selections	114	-0.028
	2n F_2's	173	0.011
	2n F_1's	149	0.011
	4n F_2's	108	-0.094
	4n F_1's	23	0.022
	4n F2's (o.p.)	61	-0.012
	2n F 's (o.p.)	20	0.035
	2n and 4n parents	39	0.010
	Checks	73	-0.051
Helminthosporium leaf blight resistance x earliness	KS 1044 selections	122	0.081
	4n selections	114	0.051
	2n F_2's	173	0.069
	4n F_2's	108	0.440**
Helminthosporium leaf blight resistance x leafiness	KS 1044 selections	122	-0.435**
	4n selections	114	-0.227**
	2n F_2's	173	0.270**
	2n F_1's	149	0.006
	4n F_2's	108	0.039
	4n F_1's	23	0.055
	4n F_2's (o.p.)	61	0.201
	2n F_2's (o.p.)	20	0.350
	2n and 4n parents	39	0.375*
	Checks	73	0.819**
	Tift selections	73	0.066

Table 5. (concl.)

Characters	Group	d/f	Correlation coefficient
Helminthosporium leaf blight resistance x tillering	KS 1044 selections	122	0.378**
	Tift selections	73	-0.145
	4n selections	114	-0.415**
	2n F_2's	173	-0.390**
	2n F_1's	149	-0.556**
	4n F_2's	108	0.018
	4n F_1's	23	0.041
	4n F_2's (o.p.)	61	-0.298**
	2n F_2's (o.p.)	20	0.307
	2n and 4n parents	39	-0.401**
	Checks	73	-0.109

Table 6. Relationships between rust and certain other characters in selected groups of sudangrass selections expressed as correlation coefficients.

Characters	Group	d/f	Correlation coefficient
	KS 1044 selections	122	0.022
	Tift selections	73	-0.107
	4n selections	114	0.544**
	2n F_2's	173	0.642**
Rust resistance x tillering	2n F_1's	149	-0.038
	4n F_2's	108	0.015
	4n F_1's	23	0.056
	4n F_2's (o.p.)	61	-0.094
	2n F_2's (o.p.)	20	0.102
	2n and 4n parents	39	-0.283
	Checks	73	0.099
	KS 1044 selections	122	0.312
	Tift selections	73	-0.077
	4n selections	114	0.180
Rust resistance x leafiness	2n F_1's	149	-0.102
	4n F_2's	108	-0.013
	4n F_1's	23	0.168
	2n F 's (o.p.)	20	0.068
	Checks	73	-0.033
	KS 1044 selections	122	0.088
	Tift selections	73	-0.040
	4n selections	114	0.566**
	2n F_2's	173	-0.044
	2n F_1's	149	-0.072
Rust resistance x vigor	4n F_2's	108	0.016
	4n F_1's	23	-0.199
	4n F_2's (o.p.)	61	0.003
	2n F_2's (o.p.)	20	0.658**
	2n and 4n parents	39	0.011
	Checks	73	-0.045
	KS 1044 selections	122	0.001
	Tift selections	73	0.001
Rust resistance x earliness	4n selections	114	0.001
	2n F_2's	173	0.007
	4n F_2's	108	0.087
	Checks	73	0.002

Frequency Distribution of Selected Characters of the Variates Within Each Group

The periods of heading for the various strains of sudangrass varied widely. Some of the strains produced heads almost uniformly throughout the heading period. Other strains had a tendency to produce the majority of the heads early, and others late. Table 7 shows the frequency distribution of heading on the various dates.

The height of most of the strains of sudangrass was between 70 and 100 inches, although a few plants within each strain exceeded this range. Table 8 shows the frequency distribution of heights of the various strains.

The vigor of most of the strains varied from 1 to 5 on the vigor scale, but most of the variates were centered about the mean of the vigor scale. Many of the groups produced plants which were lacking in vigor. The note taking scale is shown in Table 9.

The range of tillering for the various strains is shown in Table 10. Most of the variates were centered about the mean of the tillering scale, but a few strains tended to be extremely high and others low in this respect.

Leafiness of most strains was high, although certain ones were not so leafy as others. Table 11 shows the distribution of leafiness for the various groups. Few groups produced plants which were low in leafiness.

Coarseness was a major factor in some of the strains of sudangrass. Most of the variates were centered about the mean of the coarseness scale, but a few strains produced extremely fine stemmed

Table 7. Frequency distribution of time of heading for rows or individual plants within selected groups of sudangrass.

	Heading dates										
	8/15	8/14	8/12-8/13	8/11	8/9-8/10	8/8	8/7	8/6	8/5	8/1-8/4	7/31
	1	2	3	4	5	6	7	8	9	10	11
	Number										
KS 1044 selections	6	12	23	12	24	14	5	11	1	1	4
Taft selections	13	13	3	—	4	9	2	4	9	14	4
4n selections	10	8	-	2	29	-	8	-	9	25	25
2n F_2's	49	22	6	11	44	7	22	-	13	-	1
4n F_2's	4	5	3	3	33	-	16	-	15	16	15
Checks	1	3	1	1	9	3	5	-	3	10	38

Table 8. Frequency distribution of plant heights of rows or individual plants within each group of sudangrass.

Group	Height of variates in inches				
	50-60	70-80	90-100	110-120	130-145
	Number				
KS 1044 selections	-	14	109	1	-
Tift selections	-	13	61	-	-
4n selections	-	37	76	3	-
2n F_2's 1/	2	8	104	1	-
2n F_1's 1/	-	23	120	8	-
4n F_2's 1/	-	35	72	3	-
4n F_1's 1/	1	4	20	-	-
4n F_2's (o.p.) 1/	1	19	41	2	-
2n F_2's (o.p.)	-	15	7	-	-
Checks	-	-	34	1	1

1/ = Individual plant notes

Table 9. Frequency distribution of vigor ratings of rows or individual plants within each group of sudangrass.

Group	Vigor ratings of variates					
	1	2	3	4	5	6
	Number					
KS 1044 selections	1	30	75	18	-	-
Tift selections	-	2	42	28	3	-
4n selections	6	34	57	19	-	-
2n F_2's 1/	13	74	71	14	2	-
2n F_1's 1/	7	5	84	47	8	-
4n F_2's 1/	19	39	40	14	-	-
4n F_1's 1/	2	3	16	4	-	-
4n F_2's (o.p.) 1/	2	25	33	3	-	-
2n F_2's (o.p.)	2	9	7	4	-	-
2n and 4n parents	4	24	13	-	-	-
Checks	-	31	35	8	-	-

1/ = Individual plant notes

Table 10. Frequency distribution of degree of tillering of rows or individual plants within each group of sudangrass.

Group	Degree of tillering of variates					
	1	2	3	4	5	6
	Number					
KS 1044 selections	11	57	52	4	-	-
Tift selections	--	4	34	34	3	-
4n selections	19	43	50	1	3	-
2n F_2's 1/	14	93	50	17	1	-
2n F_1's 1/	8	6	88	41	8	-
4n F_2's 1/	29	48	23	10	-	-
4n F_1's 1/	2	3	15	1	-	-
4n F_2's (o.p.) 1/	9	38	15	1	-	-
2n F_2's (o.p.)	5	7	6	4	-	-
2n and 4n parents	10	24	5	1	-	-
Checks	--	33	34	7	-	-

1/ = Individual plant notes

Table 11. Frequency distribution of degree of leafiness of rows or individual plants within each group of sudangrass.

Group	Degree of leafiness of variates					
	1	2	3	4	5	6
	Number					
KS 1044 selections	10	41	68	4	1	-
Tift selections	4	41	30	--	-	-
4n selections	3	25	52	33	3	-
2n F_2's 1/	38	55	69	13	-	-
2n F_1's 1/	19	32	74	22	4	-
4n F_2's 1/	40	50	19	1	-	-
4n F_1's 1/	7	15	3	-	-	-
4n F_2's (o.p.) 1/	13	35	15	-	-	-
2n F_2's (o.p.)	6	9	6	1	-	-
2n and 4n parents	15	15	10	1	-	-
Checks	--	35	32	7	-	-

1/ = Individual plant notes

plants and others extremely coarse ones. The frequency distribution for coarseness is shown in Table 12.

Many of the strains of sudangrass were susceptible to Helminthosporium leaf blight while others were extremely resistant. Table 13 shows the range of variation for the different groups. Some of the groups produced both resistant and susceptible plants while others produced resistant plants, but no extremely susceptible ones.

Several of the strains were susceptible to leaf rust but a few strains were fairly resistant. Table 14 shows the frequency distribution of the variates for rust.

The majority of the plants in all of the groups were relatively free from bacterial stripe during the 1950 growing season, but as shown in Table 15, certain ones tended to be slightly susceptible to this disease.

The groups of sudangrass varied in their potential HCN content. The KS 1044 selections fell mostly in the lower classes, although a few fell in the medium class. This was also true of the Tift selections, but they tended to be slightly higher than the KS 1044's. The 4n selections were unusually high in potential HCN, while the 2n F_2's were variable due to the fact that they were still segregating for this and other factors. Among the 2n F_1's there were plants which were low, intermediate, and high in potential HCN. The 4n F_1's and 4n F_2's were similar in their potential HCN content. The 2n F_2's were mostly low while the 2n and 4n parents were high in potential HCN. The strains in the

Table 12. Frequency distribution of degree of coarseness of rows or individual plants within each group of sudangrass.

Group	Degree of coarseness of variates					
	1	2	3	4	5	6
	Number					
KS 1044 selections	3	72	44	5	-	-
Tift selections	1	24	36	14	-	-
4n selections	2	30	69	14	1	-
2n F_2's 1/	3	82	63	27	-	-
2n F_1's 1/	-	51	65	31	4	-
4n F_2's 1/	15	54	36	5	-	-
4n F_1's 1/	5	5	10	5	-	-
4n F_2's (o.p.) 1/	8	41	11	3	-	-
2n F_2's (o.p.)	4	10	6	2	-	-
2n and 4n parents	13	16	12	-	-	-
Checks	--	23	44	7	-	-

1/ = Individual plant notes

Table 13. Frequency distribution of degree of resistance to Helminthosporium leaf blight of rows or individual plants within each group of sudangrass.

Group	Degree of Helminthosporium leaf blight					
	1	2	3	4	5	6
	Number					
KS 1044 selections	5	40	57	21	1	-
Tift selections	6	42	24	2	-	1
4n selections	20	51	35	8	1	1
2n F_2's 1/	77	73	17	4	-	4
2n F_1's 1/	48	64	28	2	-	9
4n F_2's 1/	31	32	13	9	1	29
4n F_1's 1/	18	5	1	-	-	1
4n F_2's (o.p.) 1/	33	20	-	-	-	10
2n F_2's (o.p.)	8	13	1	-	-	--
2n and 4n parents	15	14	3	1	-	8
Checks	--	19	23	13	11	8

1/ = Individual plant notes

Table 14. Frequency distribution of degree of resistance to rust of rows or individual plants within each group of sudangrass.

Group	Degree of rust resistance						
	0	1	2	3	4	5	6
	Number						
KS 1044 selections	2	96	25	1	-	-	-
Tift selections	-	51	23	1	-	-	-
4n selections	4	--	53	39	14	1	-
2n F_2's 1/	-	98	62	13	2	-	-
2n F_1's 1/	3	68	59	17	4	-	-
4n F_2's 1/	-	9	38	45	17	1	-
4n F_1's 1/	4	12	8	1	--	-	-
4n F_2's (o.p.) 1/	-	7	26	22	7	1	-
2n F_2's (o.p.)	-	9	12	1	-	-	-
2n and 4n parents	-	8	12	15	6	-	-
Checks	8	34	15	12	5	-	-

1/ = Individual plant notes

Table 15. Frequency distribution of degree of susceptibility to bacterial stripe of rows or individual plants within each group of sudangrass.

Group	Degree of bacterial stripe susceptibility						
	0	1	2	3	4	5	6
	Number						
KS 1044 selections			none noted				
Tift selections	64	6	5	-	-	-	-
4n selections	77	15	17	7	-	-	-
2n F_2's 1/			none noted				
2n F_1's 1/	151	-	-	-	-	-	-
4n F_2's 1/	101	7	2	-	-	-	-
4n F_1's 1/	24	-	1	-	-	-	-
4n F_2's (o.p.) 1/	46	8	8	1	-	-	-
2n F_2's (o.p.)	21	-	1	-	-	-	-
2n and 4n parents	40	1	-	-	-	-	-
Checks	70	2	2	-	-	-	-

1/ = Individual plant notes

check blocks produced plants in all 3 levels of potential HCN, but most of the plants fell into the medium-high class. Table 16 shows the range of potential HCN for the various groups.

The potential HCN content exhibited a wide frequency distribution within the group, but most of the groups can be classified as being low to medium. The 4n selections however were unusually high in this respect.

DISCUSSION

Helminthosporium leaf blight resistance and tillering showed a significant positive relationship in the KS 1044 selections ($r = 0.378$). Types from this group selected for disease resistance would have a good chance of having many tillers. Rust resistance and tillering were positively related in the 4n selections, with a correlation coefficient of -0.544, suggesting that rust resistant types from this group would at the same time tend to have many tillers.

Potential HCN and leafiness showed a highly significant negative correlation coefficient of -0.676 in the 4n selections, while Helminthosporium leaf blight and tillering showed a highly significant negative correlation coefficient of -0.415 in this group. The correlation coefficient between potential HCN and leafiness suggests that both of these characters could not readily be obtained in the same plant by selection without further breeding. This is also true for Helminthosporium leaf blight resistance and tillering. A highly significant positive correlation coefficient of 0.566 was found in the 4n selections between rust resistance and vigor. Plants in this group which are resistant to

Table 16. Frequency distribution of HCN content expressed as Mg/0.15 g sample for selected plants within each group of sudangrass. Low, medium, and high are arbitrarily designated.

Group	HCN determinations in Mg per 0.15 g sample						
	Low		Medium			High	
	.0025-.0075	.0075-.0125	.0125-.0175	.0175-.0250	.0250-.0300	.0300-.0400	.0400-.100
KS 1044 selections	46	62	33	-	-	-	-
Tift selections	16	40	19	-	-	-	-
4n selections	12	—	—	-	16	30	24
2n F_2's 1/	70	83	—	-	9	9	13
2n F_1's 1/	113	30	—	2	-	2	4
4n F_2's 1/	—	25	—	22	2	-	61
4n F_1's 1/	6	—	—	3	1	-	15
4n F_2's (o.p.) 1/	1	5	6	8	4	10	26
2n F_2's (o.p.)	9	11	-	-	1	—	1
2n and 4n parents	8	5	4	2	1	2	19
Checks	1	13	10	11	4	2	17

1/ = Individual plant notes

rust would also tend to have good vigor. Rust resistance and abundant tillering were also closely correlated in the 4n selections ($r = 0.544$) and the 2n F_2's ($r = 0.642$). There were no significant relation ships between any of the characters studied in the Tift selections.

A highly significant correlation coefficient of -0.556 was found to exist between Helminthosporium leaf blight resistance and tillering in the 2n F_1's. This correlation coefficient suggests these two characters could not readily be combined without further breeding. No significant relationships were found between any of the characters studied in the 4n F_1's. A highly significant negative relationship ($r = -0.298$) was observed between Helminthosporium leaf blight resistance and tillering in the open pollinated 4n F_2's, suggesting that Helminthosporium leaf blight resistance and tillering could not easily be obtained in the same plant by selection. Helminthosporium leaf blight resistance and tillering showed a highly significant negative relationship ($r = -0.390$) in the 2n F_2's. A correlation coefficient of -0.390 may be considered high enough to reduce the chances of obtaining desirable combinations of these characters.

Considerable variability has been shown to exist in most of the groups and in most of the characters studied in these trials, as shown in Tables 7 to 16. Certain of the groups, such as the 2n F_2's and 4n F_2's were resistant to Helminthosporium leaf blight and rust, but they varied in potential HCN content. The 2n F_1's were extremely variable in potential HCN content and in certain morphological characters. The KS 1044 selections were low in potential HCN, produced fine tillers, and were vigorous, but in general they were more susceptible to Helminthosporium leaf blight and rust than any strains reported in those trials. The other groups of sudangrass had a tendency to show the same general reactions to disease as did the 2n F_1's and 4n F_2's.

The frequency distribution of the variates within the various groups of sudangrass is shown in Tables 7 to 16. Some of the variates within the groups were distributed uniformly throughout the range of variability, while in other groups they were grouped closely about the mean of the note taking scale.

The frequency distribution of the variates within certain groups suggests that some of the characters have become uniform through breeding and selection. The frequency distribution of the variates in the KS 1044 selections, with the exception of disease resistance, appears to be uniform. The KS 1044 group of sudangrass possesses the best desirable combinations of HCN level, disease resistance and morphological characters of any group studied. The range of variation is narrow and further selection in this group may not be rapid but it constitutes excellent parental material.

Further selection for the various characters in the groups in which the variates have a wide range of variation would be of potential value. The characters of the 2n F_1's and 2n F_2's showed this wide range of variation. The strains within these groups will require several generations of selection before the characters become recombined as have those of the KS 1044 selections which have been studied for several generations.

SUMMARY

The potential HCN content, disease reactions, and morphological characters of several different strains of sudangrass as well as the relationships between these characters have been studied.

1. The strains of sudangrass under observation during the 1950 growing season proved to be variable in the characters examined.

2. The potential HCN content of the strains was extremely variable. Both the KS 1044 and Tift selections were low in potential HCN. The 4n selections and open pollinated 4n F_2's tended to be high in HCN as did the average of the strains in the checks in spite of the fact that Wheeler and Piper sudangrass, both of which are low in potential HCN, were included.

3. The 1950 heading period extended from July 15 to August 15, but the time of heading differed widely for the various strains. The majority of the KS 1044 selections produced most of their heads from August 8 to August 11. The Tift selections, 4n selections, and the strains in the check blocks produced most of their heads earlier than the other strains, while the 2n F_2's and 4n F_2's produced most of theirs later.

4. The height of the various strains of sudangrass varied from 50 to 150 inches, but the majority of the strains were within the 70 to 100 inch group.

5. The strains of sudangrass included in this study were

vigorous, the plants tending to distribute themselves about the mean of the vigor scale, but a few extremely vigorous plants occurred in most of the strains.

6. The KS 1044 selections, 4n selections, 2n F_2's, 4n F_2's, and the 2n and 4n parents tended to produce more tillers than the other groups.

7. The 2n F_2's, 4n F_2's, KS 1044 selections, and the 4n F_1's were more leafy than the other strains.

8. The KS 1044's, 2n F_2's, 4n F_2's, and the 2n and 4n parents produced finer stems than the other strains of sudangrass.

9. The 4n selections, 2n F_2's, 2n F1's, 4n F1's, and the 2n and 4n parents were more resistant to Helminthosporium leaf blight than the other groups, although susceptible plants were found in each group.

10. Susceptibility to rust varied. Extremely resistant plants were found in the KS 1044's, 4n selections, 2n F_1's, 4n F_1's, and check strains. Although these groups included somewhat susceptible plants, they were, on the whole, more resistant than the other groups.

11. Bacterial stripe was not abundant in these tests during the 1950 growing season, so adequate tests of resistance could not be made.

12. A significant negative correlation coefficient between potential HCN and Helminthosporium leaf blight and a significant positive relationship between Helminthosporium leaf blight and tillering were found in the KS 1044 selections. A significant negative correlation coefficient was observed in the 4n selections

between potential HCN and leafiness, and between Helminthosporium leaf blight and leafiness. A significant positive relationship was also observed in the 4n selections between rust and vigor, and between rust and tillering.

13. A significant positive relationship was found between Helminthosporium leaf blight and leafiness in the check strains, 2n and 4n parents, and 2n F_2's. The 2n F_1's, 2n F_2's, open pollinated 4n F_2's, and the 2n and 4n parents showed significant negative relationships between Helminthosporium leaf blight and tillering. The check strains showed a significant positive relationship between Helminthosporium leaf blight and earliness.

ACKNOWLEDGMENT

The writer wishes to express his appreciation to Professor Kling L. Anderson for counsel and guidance in the course of these studies; to Dr. R. C. Pickett, who supervised the experimental work and aided in tabulating the field data; and to Dr. H. C. Fryer of the statistical laboratory for help in tabulating the data and for the use of IBM punch-card equipment.

LITERATURE CITED

(1) Ahlgren, Henry L.
Some dangers to guard against USDA Yearbook of Agriculture. 892 p. 1948.

(2) Boyd, F. T., O. S. Aamodt, G. Bohstedt, and E. Truog.
Sudangrass management for control of cyanide poisoning. Amer. Soc. Agron. Jour. 30:569-583. 1938.

(3) Franzke, C. J., Leo Puhr, and A. N. Hume.
A study of sorghum with reference to content of HCN. South Dakota State College, Agronomy Department leaflet. pages 1-50. 1939.

(4) Garner, R. J. and S. S. Atwood.
Natural crossing in Sudangrass. Amer. Soc. Agron. Jour. 37:365-369. 1945.

(5) Hayes, H. K. and F. R. Immer.
Methods of plant breeding. New York: McGraw-Hill. 432 p. 1942.

(6) Hogg, Peter and H. L. Ahlgren.
Environmental, breeding, and inheritance studies of HCN in _Sorghum vulgare_ var. _sudanense_. Jour. Agr. Res. 67:195-210. 1943.

(7) Martin, J. H., James F. Couch, and R. R. Briese.
Hydrocyanic acid content of different parts of the sorghum plant. Amer. Soc. Agron. Jour. 30:725-735. 1938.

(8) Vinall, H. N.
A study of the literature concerning poisoning of cattle by the prussic acid in sorghums, sudangrass, and johnsongrass. Amer. Soc. Agron. Jour. 13:267-279. 1921.

(9) Williaman, J. J. and R. M. West.
Effect of climatic factors on the HCN in sorghums. Jour. Agr. Res. 6:261-272. 1916.

(10) Williaman, J. J. and R. M. West.
Notes on the hydrocyanic acid content of sorghums. Jour. Agr. Res. 4:179-185. 1915.

THE RELATIONSHIP OF HCN CONTENT TO DISEASE RESISTANCE AND CERTAIN MORPHOLOGICAL CHARACTERS IN VARIOUS STRAINS OF SUDANGRASS

by

BEDFORD WALTER JACKSON

B. S., Tennessee Polytechnic Institute, 1949

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

The purpose of this experiment was to study the potential HCN content of several strains of sudangrass, Sorghum vulgare var. sudanense (Piper) Hitchc., and its possible relation to disease reactions, and certain morphological characters.

Detailed field notes were taken on morphological characters and disease reactions. The potential HCN content was determined by the green sample tissue test developed at the Wisconsin Agricultural Experiment Station by Hogg and Ahlgren. Numerous samples were taken from each row within each group.

The groups of sudangrass were extremely variable in all characters studied during the 1950 growing season. Leafiness, coarseness, vigor and tillering were more variable than the potential HCN content within the groups.

The potential HCN content of the various groups ranged from low to high, although there was not so great a range in some groups as in others. Some of the groups produced plants which were all low, some which were high, and some groups produced plants that ranged from low to high.

The majority of the sudangrass groups produced plants which varied from 70 to 100 inches in height, although there were a few plants in each group which exceeded this range.

Tillering and vigor of the groups varied in the same manner as the other characters, although the vigor within the group was more uniform than some of the other characters.

The relationship of the various characters to one another has been studied through the use of correlation coefficients. These correlation coefficients have indicated that in many of the cases there was no relationship between the characters under consideration, although in some groups there was a relationship between certain characters.