AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY

1. SUBJECT CLASSIFICATION

A. PRIMARY
Agriculture AF30-0170-0000

B. SECONDARY
Plant breeding--Cereals--Sorghum

2. TITLE AND SUBTITLE
An investigation of the transmission of protein,lysine,oil,and certain other characteristics from sudangrass lines to cultivated grain sorghum

3. AUTHOR(S)
Mukuru,S.Z.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1971	76p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Purdue

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(Thesis M.S.--Purdue)

9. ABSTRACT

10. CONTROL NUMBER
PN-RAA-457

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Hybridization
Sorghum
Sudangrass

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-1175 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

AN INVESTIGATION OF THE TRANSMISSION OF PROTEIN, LYSINE, OIL AND CERTAIN OTHER CHARACTERISTICS FROM SUDANGRASS LINES TO CULTIVATED GRAIN SORGHUM

A Thesis

Submitted to the Faculty

of

Purdue University

by

Samwiri Ziryabareba Mukuru

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

June 1971

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to his major professor, Dr. R. C. Pickett for his advice and guidance in this study, and to the members of his advisory committee, Dr. W. E. Nyquist and Dr. K. J. Lessman. Dr. W. E. Nyquist assisted with the statistical analyses of the data and further appreciation is extended to him.

Sincere gratitude is extended to the Rockefeller Foundation for their financial assistance and to the East African Agriculture and Forestry Research Organisation for granting leave of absence to the author to study in the United States.

Special thanks are extended to the Department of Agronomy for the excellent facilities provided throughout the course of this study.

To his wife, Connie, and sons, Allan, and Andrew, the author wishes to express his sincere love and deepest gratitude for their inspiration, encouragement and cheerfulness and to his parents, Mr. and Mrs. Andereya Mukuru for their patience and understanding.

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	vi
ABSTRACT	vii
INTRODUCTION	1
LITERATURE REVIEW	3
MATERIALS AND METHODS	12
Parental Selection and Field Technique	12
Statistical Analysis	17
RESULTS AND DISCUSSION	20
SUMMARY AND CONCLUSIONS	46
LIST OF REFERENCES	51
APPENDIX	55

LIST OF TABLES

Table		Page
1.	Pedigree and source of each pollinator line used in crosses with male sterile lines	13
2.	Grand means and ranges for five characters of 35 sudangrass parents, 35 Redlan x sudangrass F_1 hybrids, 8 Martin x sudangrass F_1 hybrids, 11 grain sorghum parents, 11 Redlan x grain sorghum F_1 hybrids and 4 Martin x grain sorghum F_1 hybrids	21
3.	Analysis of variance for 9 characters of all 116 sudangrass and grain sorghum lines and hybrids: 1970, Lafayette, Indiana	25
4.	Combining ability analysis of variance of hybrids of eight sudangrass parents with Redlan and Martin for 13 characters	28
5.	Comparisons between the grand mean of eight Redlan x sudangrass F_1 hybrids and eight Martin x sudangrass F_1 hybrids for 6 characters	31
6.	Analysis of variance of 35 sudangrass male parents, Redlan "B" line and 35 Redlan x sudangrass F_1 hybrids for 19 characters	33
7.	Comparisons between the grand mean of Redlan x sudangrass F_1 hybrids and Redlan "B" line for yield in kg/ha, weight in grams of 100 seeds, percent protein, lysine and oil	36
8.	Average performance of 35 sudangrass and 11 grain sorghum lines, their F_1s and percentage heterosis for 7 characters	42
9.	Phenotypic correlation coefficients for parents and hybrids of grain sorghum and sudangrass for a few selected characters	44

Appendix Table

A1.	Mean values of 9 characters recorded on each of all 116 lines and hybrids grown in 1970. Lafayette, Indiana	55
A2.	Mean values of 10 characters recorded on each of 43 sudangrass lines, Redlan x sudangrass F_1 hybrids, Martin x sudangrass hybrids and checks	59

LIST OF TABLES (Cont'd)

Appendix Table | Page

A3. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 11 grain sorghum parents . . . 62

A4. Intercharacter phenotypic, genotypic and environmental correlation coefficients of 11 grain sorghum hybrids 63

A5. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 35 sudangrass lines 64

A6. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 43 Redlan and Martin sudangrass hybrids 66

LIST OF FIGURES

Figure		Page
1	Relationship of male parents and their F_1 hybrids of sudangrass and grain sorghum and with Redlan "B" line for yield, weight of 100 seeds, percent protein and oil. A, C, E and G using grand mean values; B using values of sudangrass line 65007, grain sorghum line 917017 and their F_1 hybrids with Redlan D and H using values of sudangrass line 65143, grain sorghum line 943013 and their F_1 hybrids with Redlan F using values of sudangrass line 65083 and grain sorghum line 943013 and their F_1 hybrids with Redlan	22
2	Regression of Redlan x sudangrass offspring on sudangrass male parents for days to half bloom	37
3	Regression of Redlan x sudangrass offspring on sudangrass male parents for percent protein	38
4	Regression of Redlan x sudangrass offspring on sudangrass male parents for lysine as a percent of protein	39
5	Regression of Redlan x sudangrass offspring on sudangrass male parents for percent oil	40

ABSTRACT

Mukuru, Samwiri Z. M.S., Purdue University, June 1971. An Investigation of the Transmission of Protein, Lysine, Oil and Certain Other Characteristics from Sudangrass Lines to Cultivated Grain Sorghum. Major Professor: Robert C. Pickett.

Eleven grain sorghum and thirty five sudangrass lines were each crossed to Redlan cytoplasmic male sterile line. Four of the grain sorghum lines and eight of the sudangrass lines were also crossed to Martin cytoplasmic male sterile line. All the F_1 hybrids, pollinator lines, Redlan and Martin "B" lines and four checks were planted in 1970 at the Purdue University Agronomy Farm. There were three replications in a randomized complete block design. Several agronomic characteristics were recorded in the field and laboratory on a plot basis.

There were significant differences between grain sorghum male parents and sudangrass male parents for most characters recorded. Sudangrass pollinator lines had significantly more panicles per plot, percent protein and oil than grain sorghum male parent lines. However sudangrass lines were significantly less than grain sorghums in yield, weight per 100 seeds and percent lysine. The superiority or inferiority of sudangrass for most traits was transmitted and maintained in their offsprings.

Variation among sudangrass male lines ranged from 10.47 to 16.53 for percent protein; 3.60 to 6.02 for percent oil. However these

ranges were reduced among their F_1 hybrids and were 8.83 to 13.67 for percent protein 3.69 to 4.59 for percent oil. The genetic factors which control several traits in grain sorghum and sudangrass appear to be similar in the manner in which they are transmitted to their offspring but are different in magnitude.

The Redlan x sudangrass F_1 hybrids per se were significantly better than the Redlan "B" line for percent protein and percent oil but significantly less for weight of 100 seeds. No significant differences were obtained for yield and percent lysine though there were some individual F_1s that outyielded Redlan "B" line by far.

In general the Redlan x sudangrass F_1 hybrids had longer and broader leaves and thicker stems than their male sudangrass progenitors. However panicle shape resembled that of sudangrass lines though weight of seeds approximated that of the grain sorghum parent.

Significance was indicated more often for G.C.A. than for S.C.A. indicating that additive gene action was more important in the expression of most traits studied. However for weight of 100 seeds, days to half bloom and percent oil, S.C.A. was also significant which suggests that both additive and non-additive gene action appeared to influence the expression of these traits.

The expression of hybrid vigor for grain sorghum and sudangrass was similar for each character studied except that the mean percent heterosis was higher for sudangrass than for grain sorghum with the exception of lysine. This is probably to be expected because of the genetic diversity between the two groups.

Percent protein and lysine were negatively and significantly correlated for sudangrass F_1 hybrids ($r = -.766$) and sudangrass male parents. Percent protein and oil were significantly correlated for grain sorghum male parents ($r = .487$). A positive and significant association was obtained between protein and weight of 100 seeds for sudangrass F_1 ($r = .571$) and grain sorghum parents ($r = .566$). Oil content and weight of 100 seeds were negatively and significantly correlated among sudangrass male parents ($r = -.341$) but positively and significantly correlated among grain sorghum male parents ($r = .707$). All correlations were computed using nonsegregating populations and may be somewhat different in segregating populations.

INTRODUCTION

Sorghum is an important food crop to millions of people in Africa and Asia who subsist on it, and its importance in cattle farming particularly in areas liable to water stress, is gaining momentum all over the world. Unfortunately the nutritional value of sorghum grain is still low and all attempts are being made by plant breeders throughout the world to improve it. The limiting amino acids are lysine and tryphophan , as is the case with other cereals, excepting high lysine corn.

Variability for grain type and chemical composition in the world sorghum collection is tremendous. The sorghum project at Purdue University has carried out chemical analyses of several hundred lines in the world sorghum collection and the preliminary results are encouraging. They have obtained wide ranges in percent protein (7 to 20), in percent lysine (.5 to 3.8) and in percent oil (1.2 to 5.7) and most of the oil is believed to be in the embryo.

Most of the screening for high protein and high lysine genotypes has been primarily limited to grain sorghum types and very little attention has been paid to sudangrass and other grass sorghum relatives. However a few hundred sudangrass lines have been analysed by the sorghum project at Purdue University and the results they obtained indicated a similar range in protein as in grain sorghum. A few genotypes were up to 20 percent protein which stimulated interest in this study.

The sudangrass lines have slender stems, narrow leaves, numerous tillers and small spikelets and seeds as compared to grain sorghum and except as a forage crop they are not used for human consumption. However, any desirable agronomic quality that might be found in sudangrass could be utilised in the improvement programs of grain sorghum.

The primary objectives of this study were:

1. To investigate the transmission of several characters with special emphasis on protein, lysine and oil from sudangrass to their Redlan x sudangrass F_1 hybrids.
2. To determine whether there is any significant genetic variability among the sudangrass lines studied with special emphasis to protein, lysine and oil.
3. To find out whether there is any significant difference between sudangrass and grain sorghum male parents used in this study for protein, lysine, oil and several other characteristics.

LITERATURE REVIEW

The great potential of the sorghum species both as a human food crop and cattle feed lies in its tremendous genetic diversity. Significant diversity exists in the sorghum species for almost any characteristic one can think about ranging from seed size to herbicide tolerance; from heterosis to sterility systems. Miller (35) observed a wide variation in seed size (0.7 to 6.1 grams per 100 seeds) within the 585 exotic lines of sorghum he studied. Numerous workers have reported significant variation in many other agronomic characteristics: embryo size, percent protein, lysine as percent of protein, oil content, head size, seed size just to name a few. Pickett (40,41,42) has reported a considerable range of variation from 7 to 25 for percent protein 0.5 to 3.8 for lysine as percent of protein and 1.2 to 5.7 for oil percent of the whole grain in several entries from the World Sorghum Collection that were analysed at Purdue. He observed that most of the oil was in the embryo.

Not much work has been done on the inheritance of protein in sorghum but the little that has been done suggests that additive as well as non-additive gene action influence protein and lysine (16). Collins studied the inheritance of protein in five segregating populations of sorghum, their F_1s and parents. The F_2 variances he obtained indicated that all the lines had different genes for protein which were few in number and appeared to be partially dominant for

high protein. Frey (26) studied the inheritance of protein in corn and his results indicated that low protein percentage is completely dominant. He suggested, however, that the dominance of low protein percentage may be confounded by hybrid vigour. He was led to this conclusion by earlier work done by Hayes et al (28) who found that hybrid vigor is more pronounced in the non-protein than in the protein part of the corn kernel, thus tending to lower the protein percentage in the F_1 hybrids. Chapman (15) studied the gene effects for grain protein in five spring wheat crosses. His results indicated additive genetic effects to be highly significant in all crosses while significant epistasis was absent in all crosses. Dominance effects were significant in only two of the five crosses.

Abifarin (1) obtained significant differences for protein content among the 56 hybrids of 14 diverse imbred sorghum lines crossed to 4 male sterile. Most of the hybrids were much less than the better parents for protein percent.

Collins (16) reported that though many sorghum F_1 hybrids in his study yielded significantly more than either parent, only a few had significantly higher levels of protein than their parents. Bartel (6) found that most of the 19 sorghum F_1 hybrids he studied had lower percentage protein content than either parent. Liang (30,31) also found that protein content of sorghum hybrid were significantly lower than that of the mid-parent. Mahaderappa (33) studied the inheritance of protein content in Pennisehim typhoides using a diallel cross involving five parents which ranged in percent protein from 12.40 to 14.95. He observed that, in general, the performance of hybrids was either equal to or above the mid-parent value in most cases.

Chakravorty (14) reported that protein content in grain sorghum is dependent on variety rather than seed size, i.e., he obtained no significant correlations between seed size and protein content. However he found that within a variety large, well developed grains had higher levels of protein than in small underdeveloped grains, but the reverse held for hybrids. He also noted that, in general, protein content was higher in colored than in white grains.

Normand et al (37) analysed successive peripheral layers milled from grain sorghum by tangential abrasion. Their results indicated that protein distribution was heterogeneous in the sorghum kernel. The protein content of the fractions with the exception of the first fraction (which was almost entirely bran layer along with some embryo) decreased as scouring progressed from the outer to the inner most portions of the kernel. Altaf et al (3) found small differences in protein content in different parts of the wheat spike, though the grain from the central florets had significantly higher protein content than grain from the top third of the spike and significantly lower than the grain from the bottom third. However the bottom third which was the highest in protein content was not significantly different from the check (entire spike).

Malm (34) reported significant differences among hybrids of different female parents. He found that Martin contributed more to the protein of hybrids than the other female parents he used (Wheatland, combine Kafir 60 and Redlan).

The inheritance of seed size in sorghum has been studied by Voigt et al (48). They showed that gene action appeared to be almost

entirely additive but they found no evidence for dominance or epistasis as an important contributor to seed size. They suggested that a minimum of 3 or 4 genetic factors or blocks of genes, primarily additive in their effect, appear to control seed size. They obtained 60% heritability for seed size which indicated that considerable progress could be made in selecting for larger seed size. Studying the inheritance of quantitative characters in grain sorghum, Beil et al (8) observed transgressive segregation beyond both the high and low for days to mid-bloom and plant height. They obtained segregates which exceeded the high parent for 100 seed weight and grain yield but did not observe transgressive segregation for tillering. They noted a marked heterosis for 100 seed weight which they believed indicated a gross deviation from a strictly additive gene action. Phul et al (38) studied the inheritance of grain size and grain hardness among segregating generations of a cross between small, soft grain and bold, hard grains of Pearl millet lines. Both additive and non-additive variation were involved. However they reported that the inter-allelic interaction of additive x dominance type accounted for most of non-additive variation for grain size while dominance effects were relatively more important in the case of grain hardness. The overdominance they observed in F_1 generation appeared to be partly the results of genic interaction.

Bartel (5) reported that the seed size of the sorghum F_1 he studied was intermediate or was as large as or larger than that of the larger seeded parent and Liang (31) reported that the kernel weight of the sorghum F_1 in his study was significantly greater than

the superior parents. In wheat Altaf Ali (3) showed that 1000 kernel weight, seed width and length/width ratio varied considerably in different parts of the wheat spike.

Niehaus (36) obtained striking heterosis for grain yield in a diallel cross with 8 parents. He showed that seeds per head were the most important influence of yield. Quinby (43) noted that heterosis in sorghum hybrids was expressed in earlier blooming, increased tillering, height, longer stems, larger leaves, larger heads and greater production of grain. The increase in grain production in the two highest yielding hybrids came from greater tillering and a larger increase in the number of seeds per plant. Very little increase came from hybrid seed size. Doggett(20,21,22) confirmed that the main expression of heterosis for yield in sorghum is due to increased grain number, which may almost be doubled relative to the better parent. He suggested that part of the genetic effect on heterosis seemed to be due to the production of a rather constant number of extra spikelets per unit area per plant under a wide range of conditions. Blum (9) also noted that most hybrids evidenced significant heterosis for yield in the number of grains per panicle, reaching an average of 134.4 percent of their respective better parent.

Karper et al (30) indicated that heterosis for seed size among crossed seeds of sorghum was due to increased growth of the endosperm. They found that increased size of the endosperm was correlated with the expression of vigor in the F_1 plants. Their results indicate that the increases in size of endosperm were in part, the effect of the hybrid vigour.

Sprague (45) working with corn did not agree with the suggestion reached by Ashby in his earlier work on corn that hybrid vigor was nothing more than a maintenance of an initial difference in embryo size. Instead he explained the differing growth rates on the basis of complementary action of dominant genes.

The interrelationships among several traits in corn, sorghum and the small grains have been given considerable attention. Of particular interest are yield, seed size, percent protein, lysine as percent of protein, percent oil, proportion of embryo of whole grain. Liang et al (32) studied the interrelationship among several agronomic characteristics in segregating populations and pure lines of grain sorghum. They obtained a positive significant correlation between yield and head weight, kernel number, half bloom date and leaf number but a negative correlation with germination percentage and protein percent. The inverse relationship between kernel weight and kernel number per plant was thought to arise from either developmentally induced relationships or thought to be genetically dependent.

Negative correlation between protein and lysine as percent of protein in the seeds of five sorghum varieties was obtained by Vinipaksha et al (47). The analysis of the solubility fractions of the five varieties indicated that prolamine and glutelin are the principal proteins of the sorghum endosperm and it was found that high protein levels were correlated with high levels of prolamine. Grain size and percent protein of grain sorghum were reported to be positively and significantly correlated at the one percent level i.e. as seed size increased, protein percent increased (Worker et al 51).

Abifarin (1) obtained a positive correlation though nonsignificant between 100 seed weight and percent protein. However this was mainly attributed to environmental correlations. Rodriguez (44) observed in grain sorghum that the genotype with the heaviest embryo had the highest proportion of embryo and highest percent of oil in the seed; and the genotype with the highest percent protein in embryo free seed was also highest in percent protein in the whole seed. He obtained positive and significant correlation between the weight of embryo and percent oil in the seed, weight of 100 seeds, and embryo as percent of the whole seed. The percent protein in the whole seed was significantly and positively correlated with percent protein in the embryo free seed (endosperm). Ayyangar et al (5) studied the relationship between seed size and seed weight and found them to be highly positively correlated. Seed size was also found to be positively correlated with embryo size.

Bremner et al (10) studying the relative importance of embryo size and endosperm size in causing the effects associated with seed size in wheat, reported that embryo size has a negligible effect on growth while endosperm size has a considerable effect. They suggested that the relationship between seed size and plant size is governed by the amount of reserve material in the seed. They observed a higher relative growth rate for small embryos than largerones within the first 6 days of growth, apparently regardless, within limits of the amount of reserve material in the seed. Thereafter until the exhaustion of reserves, growth appeared to be related to the amount of reserve material present. Brown et al (12) observed significant

negative correlations between oil content and protein content in spring and winter oats. There appeared, also, to be a slightly but not significant negative association between kernel weight and oil content especially in the winter oats. In pearl millet, grain size and grain hardness were found to be positively correlated but they had a weak and strong negative correlation respectively with protein content.

Studying the composition of the component parts of the corn kernel, Earle et al (23) obtained a high positive correlation between the amount of oil in the whole grain and the amount in the germ and the correlation between protein in the endosperm and that in the whole grain was equally good. Brunson et al (13) obtained similar results among segregating F_2 corn plants. He also obtained highly significant and positive correlations between germ oil in total kernel and proportion of germ in the kernel. They reported that the size of the kernel had relatively little influence on the composition of the sample they investigated. Alexander et al (2) found that oil content in the two synthetic varieties of corn previously selected for oil content in the grain, was independent of kernel weight.

Vaughan (47) investigating the relationship between seed size and seed viability and vigour in clover found that larger seeds in red clover and white clover were generally better while in crimson red increase in seed size tended to decrease germination. However the larger seeds that germinated were more vigorous.

Sudangrass is primarily a cattle feed crop and almost all the research that has been done on it is on this aspect. Almost all the research work on protein content and quality and oil content and other

grain quality characteristics found in the literature are exclusively on grain sorghum.

Pickett (40,41,42) screening the sorghum world collection to identify superior genotypes with high protein content and lysine, has reported a wide range in protein content (7 - 25%) of several hundred samples analysed. Several of these genotypes showing percent protein above 18 are sudangrass which stimulated interest in this study.

Farhoomand et al (25) observed that the heads of both sudangrass and forage sorghum decreased with maturity and at a relatively greater rate in sudangrass than forage sorghum. This was explained as having arisen from the rapid development and greater rate of starch accumulation in the seeds of sudangrass as compared with forage sorghum. In the hay managed plots, he found that heads of sudangrass were higher in percent crude protein than the heads of forage sorghum. Craig-miles (17) found that at each location the F_1 hybrids of Sorghum vulgare x Sorghum sudanense were statistically better than their parents for dry matter production. The F_1 hybrids were not as leafy as sudangrass but were similar to sudangrass in appearance although they possessed broader leaves and thicker stems. The F_1 hybrids were characterised by an open panicle type head with seed which approximate the shape, size and appearance of the sorghum parent.

MATERIALS AND METHOD

Parental Selection and Field Technique

The grain sorghum and sudangrass male parental entries used in this study were selected from the world collection that flowers at Purdue University and the Purdue Sudangrass Breeding Nursery, respectively. Selections were made by the Sorghum Project at Purdue in the summer of 1969 when an attempt was made to cross each selection to both Redlan and Martin cytoplasmic male steriles. The pedigree and source of each male parent lines plus checks are presented in table 1.

In the fall of 1969 the crossed seed as well as the parental selections were made available for this study. Thirty-five sudangrass and 11 grain sorghum Redlan crosses; and 8 sudangrass and 4 grain sorghum Martin crosses were included in this study.

During the summer of 1970, the male parental entries together with their F_1 hybrids plus Redlan and Martin "B" lines were planted in a replicated experiment at the Purdue University Agronomy Farm on May 30, 1970. Greenleaf, Forage Farmers 66, Regional Sorghum 610 and Hydrabad 0819 were used as checks in this study. Redlan "B", Martin "B" and all check varieties were replicated each two times in every block.

The 116 total entries were replicated three times in randomized complete blocks. Each plot consisted of four rows 30 inches apart and 15 feet long. Each plot was hand thinned to a stand of

Table 1. Pedigree and source of each pollinator line used in crosses with male sterile lines

Code	P.N.S.[1]	Pedigree and Source
1	65021	KS 1044 Selection
3	65062	Tift Selection
5	65083	Wisc. Selection
7	65039	KS 1044 Selection
9	65084	Wisc. Selection
11	65025	KS 1044 Selection
13	65038	Beltsville Selection
15	65055	Beltsville Selection
17	65066	KS 1044 Selection
19	65007	Beltsville Selection
21	65035	KS 1044 Selection
23	65041	Greenleaf Selection
25	65098	KS 1044 Selection
27	65143	Tift Selection
29	65156	Tift Selection
31	65014	Greenleaf Selection
33	65011	Beltsville Selection
35	65153	Wisc. Selection
37	65017	Wisc. Selection
39	65155	KS 1044 Selection
41	65148	KS 1044 Selection
43	65037	Beltsville Selection
45	65097	KS 1044 Selection
47	65110	KS 1044 Selection
49	65056	Wisc. Selection
51	65015	KS 1044 Selection
53	65018	KS 1044 Selection
55	65028	Beltsville Selection
57	65046	Wis. Selection
59	65052	Greenleaf Selection
61	65105	Unknown
63	65061	Beltsville Selection
65	65022	Wisc. Selection
67	65023	Greenleaf Selection
69	65053	Greenleaf Selection

[1]Purdue Nursery Number

Table 1 (Cont'd)

Grain Sorghum

Code	Pedigree		Source
71	943	018	EC 18103 - Nepal
73	943	003	Dawa UAR Busiri - UAR
75	943	013	PI 217837 Lwali White Q 2/3/26 - USA
77	943	009	AS 5227 Tsinan, India
79	943	004	Msumbji red - Tanganyika
81	917	008	RFYE 3-4-2, Mexico
83	917	017	FC 16208 Club - USA
85	917	024	Unknown
87	954	050	Tx-4433-4
89	954	148	Tx-4423-2
93	954	031	Tx-2537

Checks and "B" Lines

97	Greenleaf
99	Forage farmers 66
101	Regional Sorghum 610
103	Redlan "B" line
105	Martin "B" line
107	Hydrabad 0819

approximately 220,000 plants per acre. Hand thinning was carried out when the plants were about 4 inches high.

The soil type was a Chalmers silt clay loam. The field was plowed during the spring and anhydrous ammonia at the rate of 150 pounds of N per acre and 175 pounds per acre of 8-30-16 distributed in the row were applied prior to planting. Weed control was by both cultivation and Atrazine at the rate of seven pounds per acre applied when the plants were about two inches tall.

The following characters were measured in each plot:

Heads per plot - Number of panicle harvested per plot.

Grain yield - Kilograms per hectare based on harvesting 3.05 meters taken from the center of each of the two center rows of the plot. For every plot a sample was taken, oven dried, threshed, weighed and its moisture content determined. Yield was then computed at 13 percent moisture.

Threshing Percent - Percentage of the weight of threshed grain to the weight before threshing.

Weight of 100 seeds - Weight of 100 seeds in grams randomly selected from each plot were accurately weighed.

Days to half bloom - The number of days from planting to the time when 50 percent of the panicles per plot were in bloom.

Plant height - The average height in centimeters on a plot basis at maturity.

Percent protein - The proportion of nitrogen content on a fat free basis determined by microkjeldahl multiplied by 6.25.

Percent lysine - Lysine determined by ion-exchange column chromatography and reported as a percentage of the protein.

Percent oil - Percent oil in the kernel determined by the "nuclear magnetic resonance (N.M.R.) Spectroscopy method".

The following characters were measured on sudangrass male parents, their Redlan and Martin hybrids and the "B" lines:

Panicle Length - Average length in centimeters of five panicles per plot measured from the lowermost node to the tip of the panicle.

Panicle Branch Length at first node - Average length in centimeters of five primary branches at first node one from each of five different panicles per plot.

Panicle Branch Length at first node excluding racemes - The length in centimeters of the first primary branch from the basal attachment on the rachis to the first node on the primary branch. The average of five primary branches each in a different panicle was taken per plot.

Ratio of Primary Branch at first node - The primary branch length at first node excluding racemes was divided by the whole length of the primary branch length at the first panicle node.

Panicle Branch Length at third node - Average length in centimeters of five primary branch lengths at third node of different panicles per plot.

Panicle Branch Length at third node excluding racemes - The length in centimeters of the third primary branch from the basal attachment on the rachis to the first node on the third primary branch. The average of five branches each on a different panicle were taken per plot.

Ratio of Primary Branch at third node - The primary branch length at third node excluding racemes was divided by the whole length of the primary branch at the third panicle node.

Third Leaf Length - Average length in centimeters of the third leaf from top, measured on five plants per plot.

Third Leaf Width - Average width in centimeters of the third leaf from top measured on maximum leaf width on five plants per plot.

Third Leaf Area - Obtained by multiplying the length by width of the third leaf from top and by 0.6 (7).

Statistical Analysis

The experimental design used was a randomized complete block, replicated three times. Entries were considered fixed and the model assumed for the analysis of variance was:

$$X_{ij} = \mu + \rho_i + T_j + \varepsilon_{ij}$$

where X_{ij} = variable to be analysed for the ith replication and jth treatment

μ = population mean

ρ_i = effect of ith replication

T_j = effect of jth treatment

ε_{ij} = random experimental error

A separate analysis was run for the 16 Redlan and Martin sudangrass hybrids. The model assumed was:

$$X_{ijk} = \mu + \rho_i + \alpha_j + \beta_k + (\alpha\beta)_{jk} + \varepsilon_{ijk}$$

where X_{ijk} = variable to be analysed for ith replication, jth male and kth female

μ = population mean

ρ_i = effect of ith replication

α_i = effect of the jth male parent

β_k = effect of the kth female parent

$(\alpha\beta)_{jk}$ = interaction effect of the jth male parent and kth female parent

ε_{ijk} = random experimental error

In the analysis male and female effects expressed the general combining ability while the male by female interaction expressed the specific combining ability in accordance with the mating Design II procedure of Comstock and Robinson (27).

Phenotypic, genotypic and environmental correlation coefficients between pairs of several characters were calculated separately for sudangrass parents, sudangrass hybrids, grain sorghum parents and grain sorghum hybrids. The following formulae were used for the calculation of the correlation coefficients:

$$\text{Phenotypic correlation} = \frac{M_{g_{12}}}{\sqrt{M_{g_{11}} M_{g_{22}}}}$$

$$\text{Genotypic correlation} = \frac{\hat{Cov}_{g_{12}}}{\sqrt{\hat{\sigma}^2_{g_1} \hat{\sigma}^2_{g_2}}}$$

$$\text{Environmental correlation} = \frac{M_{e_{12}}}{\sqrt{M_{e_{11}} M_{e_{22}}}}$$

where $M_{g_{12}}$ = mean cross products for genotypes in the analysis of covariance between characters 1 and 2

$M_{g_{11}}(M_{g_{22}})$ = mean squares for genotypes in the analysis of variance for character 1 (2)

$\hat{Cov}_{g_{12}}$ = estimated covariance component for genotypes in the analysis of covariance between characters 1 and 2

$\hat{\sigma}^2_{g_1}(\hat{\sigma}^2_{g_2})$ = estimated variance component for genotypes in the analysis of variance for character 1 (2)

$M_{e_{12}}$ = mean cross products for error in the analysis of covariance between characters 1 and 2

$M_{e_{11}}(M_{e_{22}})$ = mean squares for errors in the analysis of variance of character 1 (2).

RESULTS AND DISCUSSION

Data of the average performance of each individual genotype for several characteristics studied are presented in Appendix Table A1 and A2. The grand means and ranges of sudangrass male parents, Redlan x sudangrass F_1 hybrids, Martin x sudangrass F_1 hybrids, grain sorghum parents, Redlan x grain sorghum F_1 hybrids, and Martin x grain sorghum F_1 hybrids for yield, weight of 100 seeds, percent protein, lysine and oil are presented in table 2. The grand mean for weight of 100 seeds of Redlan x sudangrass F_1 hybrids was almost twice that for their sudangrass male parents but the grand mean for protein and oil of Redlan x sudangrass F_1 hybrids was slightly less than the grand mean of the sudangrass male parents. The wide ranges for percent protein and oil of the sudangrass male parents were reduced in their offspring. Figure 1 illustrates in histograms the relationship of parents and hybrids of sudangrass and grain sorghum for yield, weight of 100 seeds, protein and oil using for each character the grand means and the superior cross. It indicates the similarity between sudangrass and grain sorghum for the inheritance of each of these traits. It appears that the genetic factors which control these traits in both sudangrass and grain sorghum are similar in the manner in which they are transmitted to their offspring but not in magnitude. How these genes would behave in advanced segregating populations particularly in sudangrass hybrids remains to be demonstrated.

Table 2. Grand means and ranges for five characters of 35 sudangrass parents, 35 Redlan x sudangrass F_1 hybrids, 8 Martin x sudangrass F_1 hybrids, 11 grain sorghum parents, 11 Redlan x grain sorghum F_1 hybrids and 4 Martin x grain sorghum F_1 hybrids

Characters		Sudangrass			Grain sorghum		
		Parents	Redlan F_1 hybrids	Martin F_1 hybrids	Parents	Redlan F_1 hybrids	Martin F_1 hybrids
Yield in kg/ha	Grand mean	3232	4801	4442	5135	5739	5361
	Ranges	1525 - 4898	1242 - 6915	3288 - 5264	2129 - 7455	4123 - 6707	4921 - 5882
Weight in grams of 100 seeds	Grand mean	1.23	2.09	2.05	2.86	3.00	2.88
	Ranges	0.93 - 2.07	1.51 - 2.61	1.82 - 2.22	2.41 - 3.67	2.67 - 3.45	2.65 - 3.11
Percent Protein	Grand mean	12.39	10.65	11.20	10.47	9.55	10.12
	Ranges	10.47 - 16.53	8.83 - 13.67	10.53 - 12.30	8.27 - 12.57	8.20 - 12.30	8.27 - 11.20
Percent lysine	Grand mean	2.25	2.27	2.24	2.45	2.45	2.32
	Ranges	1.87 - 2.67	1.84 - 2.73	2.00 - 2.38	2.26 - 2.73	2.08 - 2.69	2.03 - 2.52
Percent oil	Grand mean	4.68	4.18	4.36	3.76	3.64	3.61
	Ranges	3.60 - 6.02	3.69 - 4.59	3.97 - 4.59	2.66 - 5.33	3.07 - 4.10	3.57 - 4.10

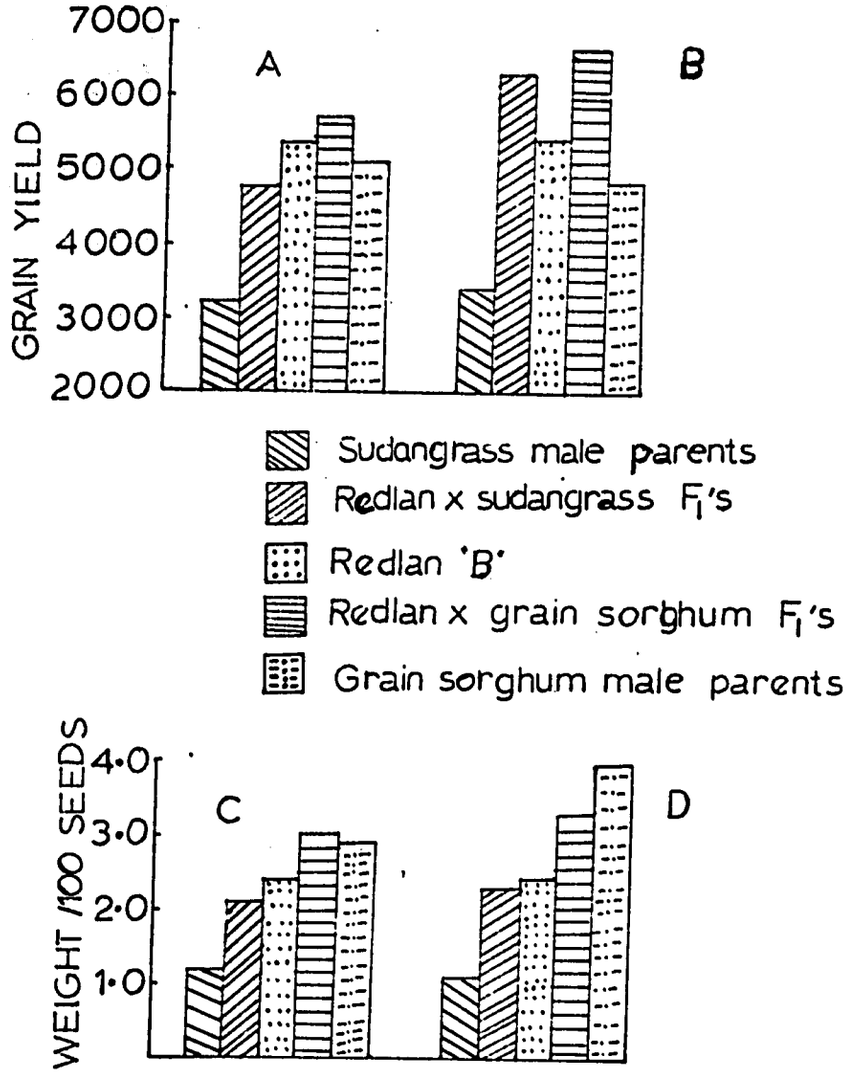

Figure 1. Relationship of male parents and their F_1 hybrids of sudangrass and grain sorghum and with Redlan "B" line for yield, weight of 100 seeds, percent protein and oil. A, C, E and G using grand mean values; B using values of sudangrass line 65007, grain sorghum line 917017 and their F_1 hybrids with Redlan; D and H using values of sudangrass line 65143, grain sorghum line 943013 and their F_1 hybrids with Redlan; F using values of sudangrass line 65083 and grain sorghum line 943013 and their F_1 hybrids with Redlan.

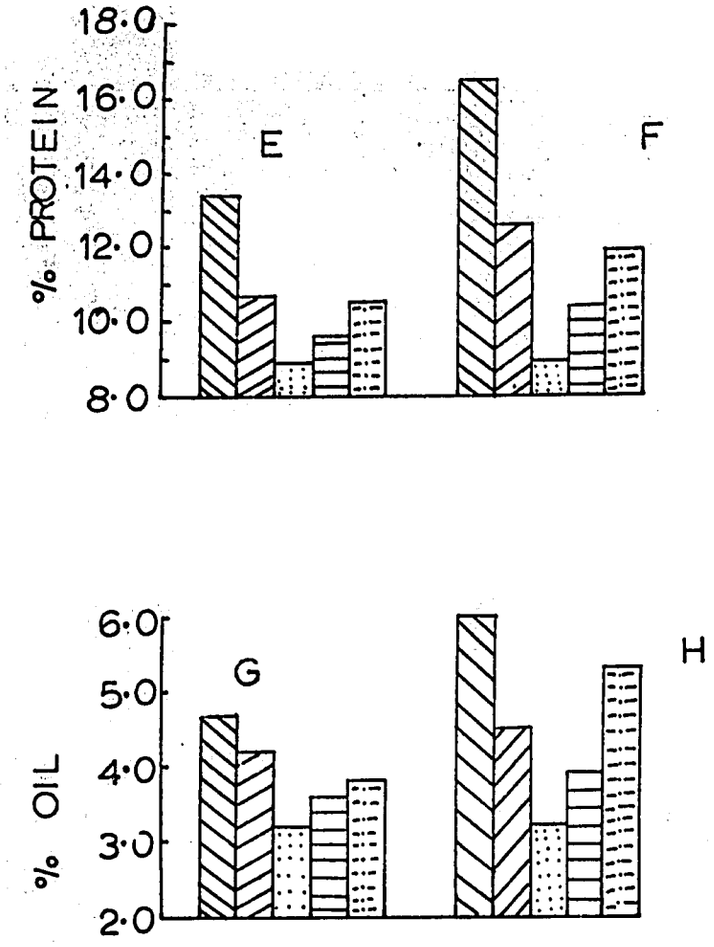

Figure 1 (Cont'd)

The results of the analyses of variance for all the genotypes for nine characters are presented in table 3. Significant differences existed among all the entries for traits listed and among the sudangrass male parents except for lysine. There were no significant differences, however, among grain sorghum male parents for panicles per plot and lysine as a percentage of protein. Redlan x sudangrass F_1 hybrids and Martin x sudangrass F_1 hybrids showed no significant difference for panicles per plot and threshing percentage while the former showed no significant differences for percent protein and the latter for panicles per plot, yield and lysine as a percent of protein. There were significant differences at the one percent level for sudangrass male parents versus grain sorghum male parents for all the characters except for height. The sudangrass male parents produced significantly more than the grain sorghum male parents in panicles per plot, percent protein and oil but significantly less yield, and were lower in threshing percent, weight per 100 seeds, days to half bloom, height and lysine as a percent of protein. The Redlan x sudangrass F_1 hybrids were significantly more than the Redlan x grain sorghum F_1 hybrids in height, percent protein and oil but significantly less in yield, weight of 100 seeds, days to half bloom and percent lysine and not significant for panicles per plot and threshing percent.

It is interesting to note that the superiority of the sudangrass male parents over the grain sorghum male parents or vice versa for several traits is transmitted and maintained in their progeny. In both grain sorghum and sudangrass the average yield and height of their F_1 hybrids was generally higher than the better parent whereas for

Table 3. Analysis of variance for 9 characters of all 116 sudangrass and grain sorghum lines and hybrids: 1970, Lafayette, Indiana

Source of Variation	df	Mean Squares			
		Panicles/Plot	Grain Yield	Threshing	Weight of 100 Seeds
Replication	2	12,880.34**	39,708,857**	6,225.39**	0.0181
Among entries	115	15,393.12**	52,513,391**	179.28**	1.4531**
Among sudangrass male parents	34	10,446.32**	2,226,016**	157.23**	0.1927**
Among Redlan x sudangrass F_1 hybrids	34	1,123.08	3,747,958**	93.95	0.1063**
Among Martin x sudangrass F_1 hybrids	7	431.75	2,308,290**	32.17	0.0669**
Among grain sorghum male parents	10	744.09	6,058,805**	257.87**	0.3068**
Among Redlan x grain sorghum F_1 hybrids	10	7,037.09**	2,141,851*	68.27	0.1706**
Among Martin x grain sorghum F_1 hybrids	3	157.11	478,729	46.93	0.1355**
Among "B" lines	3	484.55	1,757,637	131.54	0.0097
Among checks	7	16,753.80**	5,988,145**	167.79*	2.6661**
Sudangrass male parents vs grain sorghum male parents	1	535,020.19**	90,957,734**	1,210.77**	66.7694**
Redlan x sudangrass F_1 hybrids vs Redlan x grain sorghum F_1 hybrids	1	2,923.04	22,124,495**	55.74	20.8056**
Martin x sudangrass F_1 hybrids vs Martin x grain sorghum F_1 hybrids	1	10,344.01*	6,744,852**	48.18	5.5334**
"B" lines vs checks	1	4,851.12	4,790,028*	51.85	0.0460
Sudangrass and grain sorghum Redlan F_1 hybrids vs sudangrass and grain sorghum Martin F_1 hybrids	1	515.12	2,185,437	0.90	0.0164
Sudangrass and grain sorghum male parents vs Redlan and Martin F_1 hybrids	1	610,975.49**	126,273,393**	5,494.43**	36.7147**
Sudangrass and grain sorghum male parent plus their Redlan and Martin F_1 hybrids vs "B" lines and checks	1	12,184.29**	928,264**	19.17	2.7160**
Error	230	1,674.18	1,004,634	65.61	0.0206
CV		30.72	24.05	12.14	7.12

* Significant at .05 level ** Significant at .01 level

Table 3 (Cont'd)

Source of Variation	Days to Half Bloom	Height	% Protein	% Lysine	% Oil
	Mean Squares				
Replication	387.34**	81.24	61.9472**	8.9877**	0.2447**
Among entries	116.37**	9,977.87**	6.4582**	0.1371**	1.0713**
Among sudangrass male parents	115.92**	1,324.20**	5.4400**	0.1178	0.7569**
Among Redlan x sudangrass F_1 hybrids	150.30**	2,001.84**	3.3391**	0.1565**	0.1485**
Among Martin x sudangrass F_1 hybrids	76.00**	1,114.42*	1.4785	0.0526	0.1424**
Among grain sorghum male parents	120.98**	22,385.53**	4.5335**	0.0574	2.1580**
Among Redlan x grain sorghum F_1 hybrids	56.33**	19,288.00**	1.4675	0.1703*	0.3077**
Among Martin x grain sorghum F_1 hybrids	71.33**	10,642.11**	5.3900**	0.1323	0.4475**
Among "B" lines	57.86**	2,565.33**	7.0475**	0.1258	0.2619**
Among checks	107.66**	11,184.42**	3.0741*	0.1150	1.5142**
Sudangrass male parents vs grain sorghum male parents	381.64**	505.22	91.6696**	1.1914**	21.3257**
Redlan x sudangrass F_1 hybrids vs Redlan x grain sorghum F_1 hybrids	36.41*	24,659.33**	30.5012**	0.8330**	7.3895**
Martin x sudangrass F_1 hybrids vs Martin x grain sorghum F_1 hybrids	56.88**	18,272.34**	9.3168**	0.0496	4.4700**
"B" lines vs checks	17.01	82,215.12**	13.5200**	0.0159	8.6459**
Sudangrass and grain sorghum Redlan F_1 hybrids vs sudangrass and grain sorghum Martin F_1 hybrids	295.11**	6,191.45**	5.8346*	0.0613	0.0973
Sudangrass and grain sorghum male parents vs Redlan and Martin F_1 hybrids	62.34**	326,363.60**	162.9345**	0.0000	11.8338**
Sudangrass and grain sorghum male parent plus their Redlan and Martin F_1 hybrids vs "B" lines and checks	34.94*	34,753.52**	1.2419	0.0663	0.2757**
Error	7.98	423.09	1.3292	0.0835	0.0293
CV	3.48	6.43	10.25	12.49	4.04

* Significant at .05 level ** Significant at .01 level

percent protein, lysine and oil the F_1 hybrids were equal or slightly less than the mid-parents.

For all the genotypes blocking appeared to have removed a considerable source of environmental variation for all the characters except weight of 100 seeds and height.

The Coefficient of Variation (C.V.) ranged from 3.48 for days to half bloom to 30.72 for heads per plot. The low C.V. values for days to half bloom, percent oil, height and weight per 100 seeds indicate that high precision was obtained in the measurements of these characters. The C.V. values for percent protein, percent lysine and threshing percent were moderate which indicates reasonable precision in the measurement of these characters.

The results of the analyses of variance and the combining ability analyses of the sixteen Redlan x sudangrass and Martin x sudangrass F_1 hybrids for 13 characters are presented in table 4. Significant differences were detected among the eight sudangrass male parents for most of the characters except grain yield, threshing percent and lysine. Except for percent lysine significant differences were obtained between sudangrass male parents versus all the F_1 hybrids. There were significant differences among the Redlan and Martin F_1 hybrids for most of the characters except panicles per plot, threshing percent, percent protein and lysine.

The variation among the sixteen Redlan x sudangrass and Martin x sudangrass F_1 hybrids were partitioned further into sources attributable to male, female and male x female interaction. The male and female, estimate general combining ability (G.C.A.) while the male x female

Table 4. Combining ability analysis of variance of hybrids of eight sudangrass parents with Redlan and Martin for 13 characters

Source of Variation	df	Panicles/plot	Grain Yield	Threshing Percentage	Weight per 100 seeds
Replication	2	8,246.68**	20,456,489**	1,798.45**	.0040
Among entries	23	13,784.84**	3,272,296**	106.12	.7515**
Sudangrass male parents vs all F_1s	1	261,461.78**	20,622,195**	1,214.52**	15.7212**
Among sudangrass male parents	7	6,551.18**	942,057	69.13	.0374**
Among Redlan x sudangrass and Martin x sudangrass	15	523.07	3,394,550**	52.08	.0928**
G.C.A. (male)	7	818.32	5,782,844**	47.31	.1617**
G.C.A. (female)	1	2,408.33*	522,501	13.23	.0027
S.C.A. (male x female)	7	227.81	1,006,258	56.86	.0239**
Error	46	1,107.15	678,393	64.45	.0067

Source of Variation	df	Days to half bloom	Height	Panicle Length	3rd Leaf Length
Replication	2	101.43	170.54	3.5876	256.71**
Among entries	23	90.61**	5,082.46**	30.1904**	250.29**
Sudangrass male parents vs all F_1s	1	66.69**	94,249.00**	39.2711**	1,054.63**
Among sudangrass male parents	7	16.57**	701.47*	48.2179**	242.03**
Among Redlan x sudangrass and Martin x sudangrass	15	98.65**	1,038.27**	20.8197**	245.96**
G.C.A. (male)	7	176.99**	1,693.85**	39.9748**	450.66**
G.C.A. (female)	1	520.08**	3,201.33**	26.1075**	36.23
S.C.A. (male x female)	7	20.32**	382.71	1.6646	41.26*
Error	46	5.23	256.76	1.7952	16.63

Table 4 (Cont'd)

Source of Variation	df	3rd Leaf Width	3rd Leaf Area	% Protein	% Lysine	% Oil
Replication	2	0.2524	3,639.52**	11.3872**	2.2629**	.0716*
Among entries	23	2.7893**	8,065.00**	3.4817*	.0666	.9286**
Sudangrass male parents vs all F_1s	1	40.8960**	113,748.80**	16.6736**	.0102	8.1510**
Among sudangrass male parents	7	1.8579**	2,231.10**	3.1095**	.0561	1.5810**
Among Redlan x sudangrass and Mertin x sudangrass	15	.6718**	3,732.48**	2.059	.0771	.1373**
G.C.A. (male)	7	1.2148**	6,830.76**	2.5656	.1158	.2334**
G.C.A. (female)	1	.8480*	3,873.61**	12.8133**	.0501	.2187*
S.C.A. (male x female)	7	.1288	634.20	1.5524	.0384	.0412**
Error	46	.1415	464.28	1.9094	.1109	.0414

interaction estimates specific combining ability (S.C.A.) in accordance with Experiment 2 procedure of Comstock and Robinson (27).

Significance was indicated more often for G.C.A. than for S.C.A. and also for almost all the characters studied the mean squares for G.C.A. were markedly greater than those for S.C.A. G.C.A. mean squares were significant for almost all the characters except threshing percent and percent lysine indicating the influence of additive genes in the expression of the majority of the characters investigated. However significance of S.C.A. mean squares was also obtained for weight of 100 seeds, days to half bloom, third leaf length and percent oil which suggests that additive gene action as well as dominance and expistasis appear to influence the expression of these traits.

The G.C.A. contributed by males was more often significant than that contributed by the females. The mean square for G.C.A. from males were in most cases larger than the G.C.A. from females. However the G.C.A. mean squares from females were more than G.C.A. mean squares from males and were significant for panicles per plot, days to half bloom, height and percent protein. Percent lysine was neither significant for G.C.A. nor for S.C.A.

Grand means of the eight Redlan x sudangrass F_1 hybrids and Martin x sudangrass F_1 hybrids and their differences for six characters are presented in table 5. The Martin female parent contributed significantly more to the percent protein of hybrids than the Redlan female parent. The F_1 hybrids of Redlan female parent reached blooming earlier than F_1 hybrids of Redlan female parent. Redlan x sudangrass F_1 hybrids and Martin x F_1 hybrids were not significantly different for yield, weight of 100 seeds, percent lysine and oil.

Table 5. Comparisons between the grand mean of eight Redlan x sudangrass F_1 hybrids and eight Martin x sudangrass F_1 hybrids for 6 characters

Characters	Redlan x sudangrass F_1 hybrids	Martin x sudangrass F_1 hybrids	Difference
Yield	4651	4442	-209
Weight of 100 seeds	2.04	2.05	.01
Days to half bloom	86.92	80.06	-6.86*
Percent protein	10.16	11.20	1.04*
Percent lysine	2.31	2.24	-0.07
Percent oil	4.23	4.36	0.13

* Significant at .05 level

The results of the analyses of variance for 19 characters of the sudangrass male parents, Redlan x sudangrass and Redlan "B" line are presented in table 6. There were significant differences between sudangrass male parents versus Redlan "B" line for almost all the characters with the exception of panicle branch length at first and third nodes excluding racemes and third leaf length. Table 7 contains the grand means of Redlan x sudangrass F_1 hybrids, Redlan "B" line and their differences for yield, weight of 100 seeds, percent protein, lysine and oil. The Redlan x sudangrass F_1 hybrids per se were statistically significantly superior over their Redlan grain sorghum female parent for percent protein and oil but were significantly inferior for weight of 100 seeds. No significant differences were obtained for grain yield and percent lysine. However some Redlan x sudangrass F_1 hybrids' performance in yield were much higher than the Redlan grain sorghum female parents.

Scatter diagrams illustrating the regression of the offspring on their sudangrass male parents are presented in Fig. 2, 3, 4 and 5 for days to half bloom, percent lysine and percent oil respectively. There appears to be a strong linear relationship between the sudangrass male parents and their offspring for days to half bloom and lysine but the relationship for percent protein and percent oil is not as high. This implies that the heritability for percent protein and oil is low while that for lysine and days to half bloom is high. With a few exceptions, sudangrass male parents with the highest protein, lysine and oil content produced offspring which were highest in protein, lysine and oil content among the Redlan x sudangrass F_1 hybrids.

Table 6. Analysis of variance of 35 sudangrass male parents, Redlan "B" line and 35 Redlan x sudangrass F_1 hybrids for 19 characters

Source of Variation	df	Panicles/plot	Grain yield	Threshing %.	Wt. of 100 seeds	Days to half bloom
Replication	2	16,415.24**	33,634,659**	4,181.61**	0.0046	349.53**
Among entries	71	16,921.62**	4,838,297**	193.15**	0.7285**	131.46**
Among sudangrass parents	34	10,446.32**	2,226,016**	157.23**	0.1927**	115.92**
Among Redlan B line	1	962.66	83,308	17.34	0.0043	0.66
Among Redlan x sudangrass F_1s	34	1,123.08	3,747,958**	93.95	0.1063**	150.30**
Sudangrass parents vs Redlan B line	1	84,859.67**	26,587,138**	512.74**	7.3109**	57.08**
Redlan B + sudangrass parents vs F_1s	1	722,253.23**	113,733,507**	4,643.14**	34.2448**	224.13**
Error	142	1,437.37	1,053,214	80.98	0.0176	9.99
CV		24.41	25.28	13.46	8.21	3.84

Source of Variation	df	Height	Panicle length	Panicle branch length at first node	Panicle branch length at first node excluding racemes
Replication	2	123.50	3.9013	0.7996	2.8558**
Among entries	71	6,589.29**	30.9479**	8.5779**	0.9363**
Among sudangrass parents	34	1,324.10**	47.6102**	13.0806**	1.5734**
Among Redlan B line	1	4.16	1.7067	0.4267	0.0216
Among Redlan x sudangrass F_1s	34	2,001.84**	16.1067	3.5943**	0.3808*
Sudangrass parents vs Redlan B line	1	29,162.52**	13.2284**	18.7215**	0.0028
Redlan B + sudangrass parents vs F_1s	1	519.12	15.9933**	21.1292**	0.0098
Error	142	343.45	1.7997	0.8462	0.2683
CV		8.36	5.81	10.85	25.37

Table 6 (Cont'd)

Source of Variation	df	Ratio[1]	Panicle branch length at third node	Panicle branch length at third node excluding racemes	Ratio[2]
Replication	2	0.0601**	0.0256	0.6892*	0.0235**
Among entries	71	0.0072**	7.1128**	0.6471**	0.0078**
Among sudangrass parents	34	0.0102**	9.8725**	0.8690**	0.0079**
Among Redlan B line	1	0.0017	0.0150	0.3750	0.0081*
Among Redlan x sudangrass F_1s	34	0.0037	3.9177*	0.4123**	0.0061**
Sudangrass parents vs Redlan B line	1	0.0202*	6.0567	0.9103**	0.0683**
Redlan B + sudangrass parents vs F_1s	1	0.0161*	23.8003**	1.0943**	0.0021
Error	142	0.0037	2.5685	0.1538	0.0026
CV		25.06	21.59	24.10	23.02

Source of Variation	df	3rd Leaf length	3rd Leaf width	3rd Leaf area	% Protein	% Lysine
Replication	2	156.1717**	0.7665**	3,480.31**	34.1376**	5.1592**
Among entries	71	181.1199**	3.2209**	6,885.68**	7.0499**	0.1373**
Among sudangrass parents	34	132.4250**	2.2084**	2,694.84**	5.4400**	0.1178**
Among Redlan B line	1	18.7267	0.5643**	2,035.04*	1.2150	0.2646*
Among Redlan x sudangrass F_1s	34	182.2442**	1.1094**	3,705.23**	3.3391**	0.1565**
Sudangrass parents vs Redlan B line	1	37.5012	26.3359**	46,374.22**	71.1062**	0.1530**
Redlan B + sudangrass parents vs F_1s	1	2,119.3519**	88.9773**	256,871.85**	129.7318**	0.0043
Error	142	19.1948	0.1094	445.73	1.0291	0.0597
CV		6.60	7.32	11.59	8.86	11.04

Table 6 (Cont'd)

Source of Variation	df	% Oil
Replication	2	0.1280*
Among entries	71	0.7368**
Among sudangrass parents	34	0.7569**
Among Redlan B line	1	0.0006
Among Redlan x sudangrass F_1s	34	0.1485**
Sudangrass parents vs Redlan B line	1	12.2154**
Redlan B + sudangrass parents vs F_1s	1	9.3179**
Error	142	0.0301
CV		3.93

* Significant at .05 level

** Significant at .01 level

[1]Ratio of panicle branch length excluding racemes to the whole panicle branch length at first node.

[2]Ratio of panicle branch length excluding racemes to the whole panicle branch length at third node.

Table 7. Comparisons between the grand mean of Redlan x sudangrass F_1 hybrids and Redlan "B" line for yield in kg/Ha weight in grams of 100 seeds, percent protein, lysine and oil

Characters	Redlan x sudangrass F_1 hybrids	Redlan "B"	Difference
Yield in kg/Ha	4801	5396	595
Weight of 100 seeds	2.09	2.36	0.27**
% Protein	10.65	8.85	-1.80**
% Lysine	2.27	2.42	0.15
% Oil	4.18	3.21	-0.97**

* Significant at .05 level

** Significant at .01 level

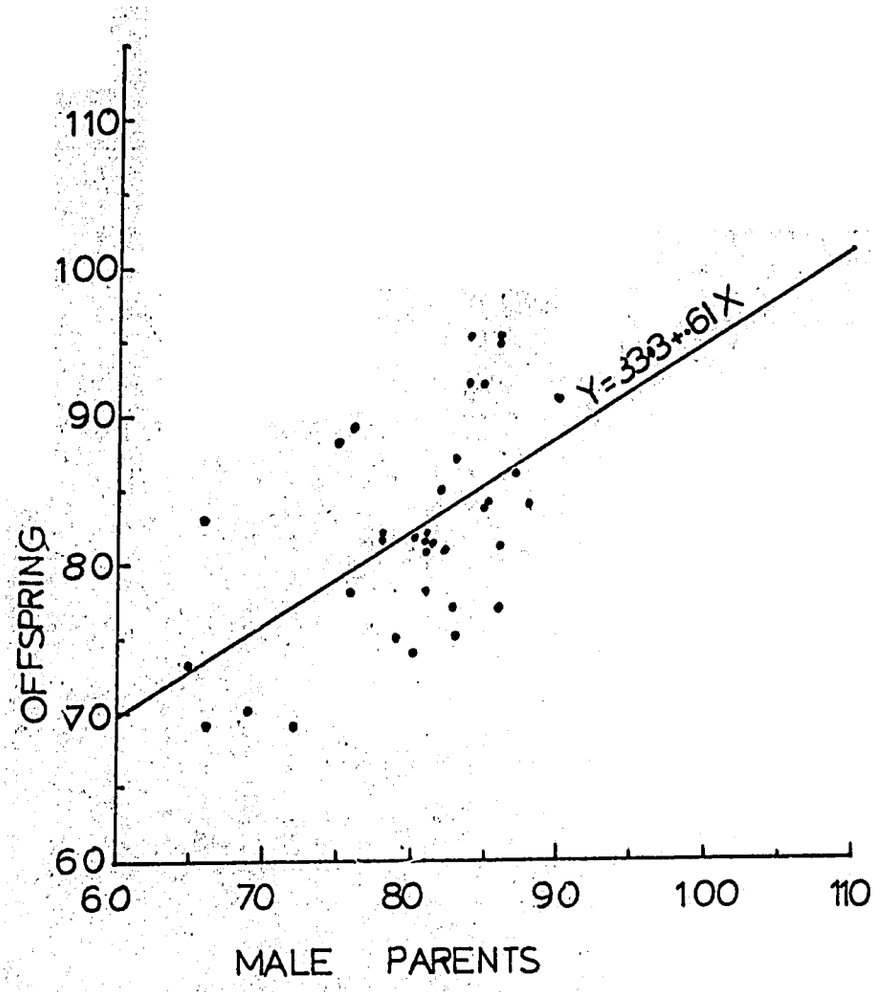

Figure 2. Regression of Redlan x sudangrass offspring on sudangrass male parents for days to half bloom.

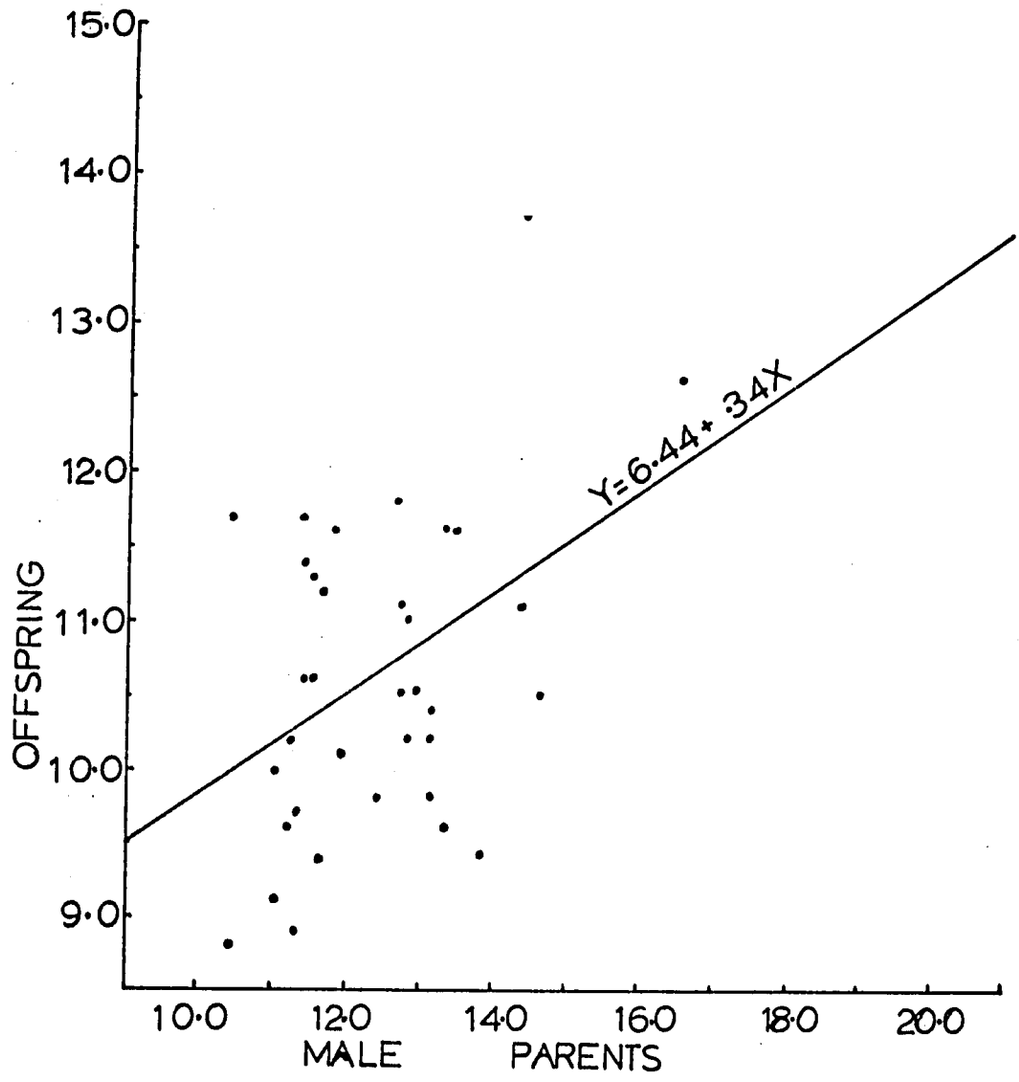

Figure 3. Regression of Redlan x sudangrass offspring on sudangrass male parents for percent protein.

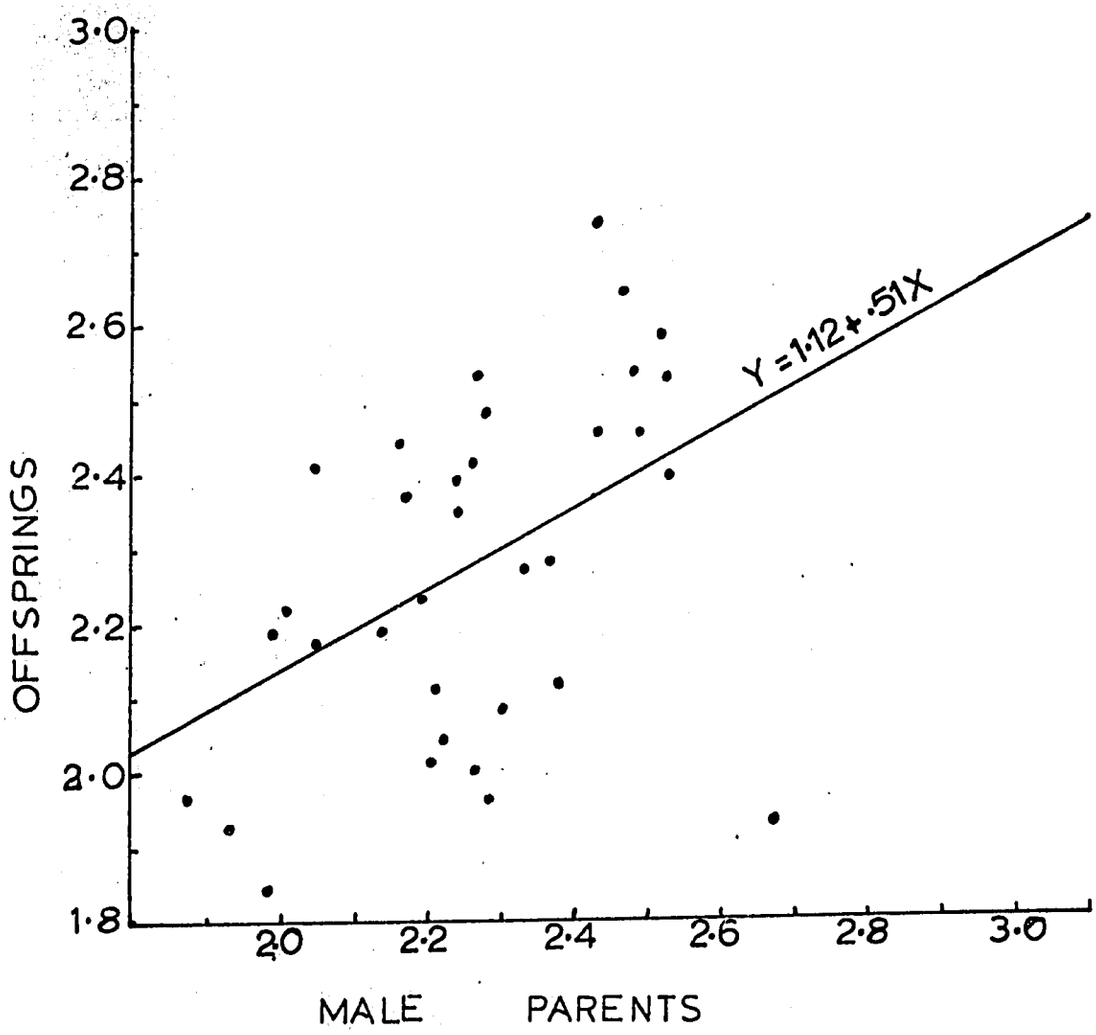

Figure 4. Regression of Redlan x sudangrass offspring on sudangrass male parents for lysine as a percent of protein.

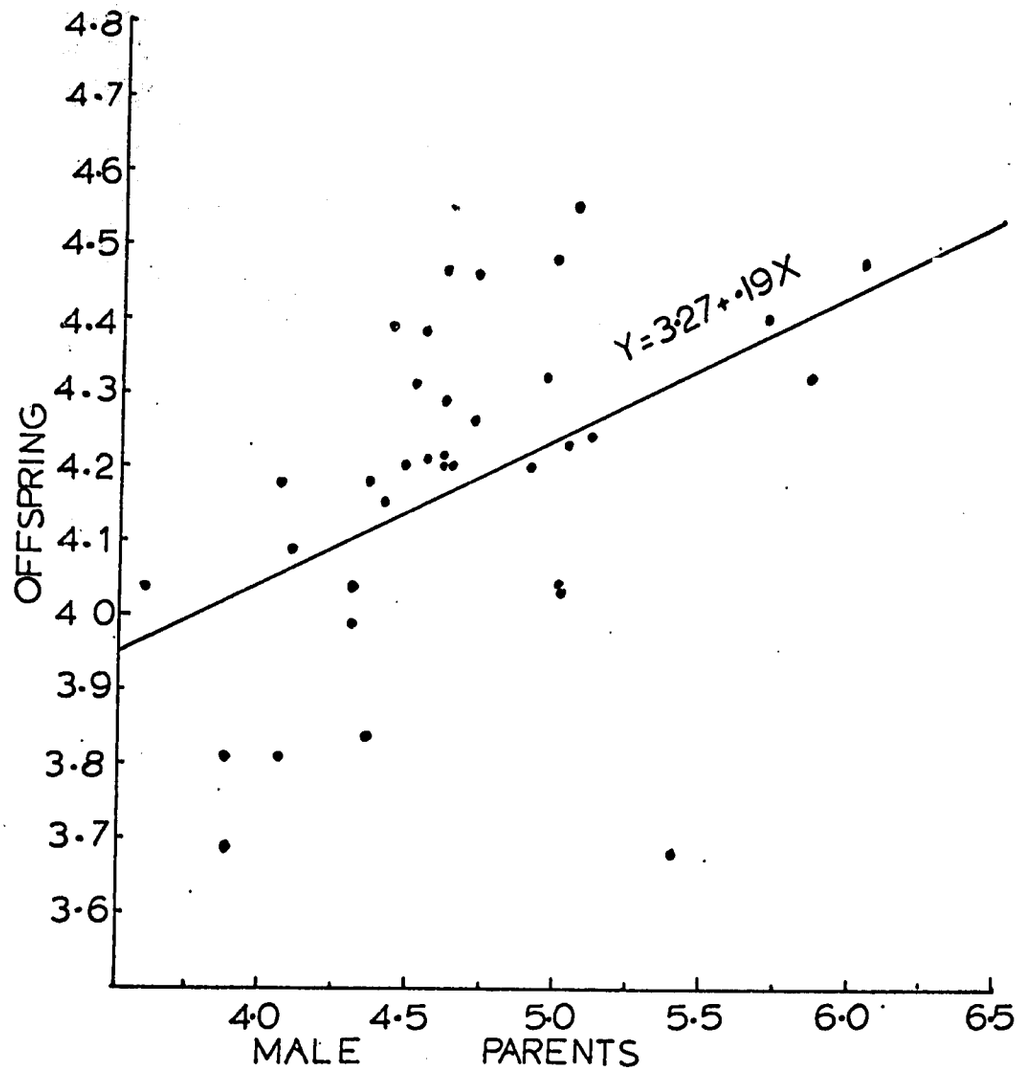

Figure 5. Regression of Redlan x sudangrass offspring on sudangrass male parents for percent oil.

The sudangrass lines are prolific for panicles per plot which is a result of their tillering capacity. On the other hand the sudangrass hybrids produced a small number of heads per plot approximately one-half of the sudangrass entries. However the panicles of Redlan x sudangrass F_1 hybrids were relatively heavier than sudangrass male parent panicles which resulted in their superiority in yield. In general the sudangrass hybrids produced longer and much broader leaves as well as thicker stems in comparison with sudangrass male parents, rather similar to the grain sorghum parent. However the panicle shape characteristics resembled sudangrass though the size, shape, and weight of the seed approximated the grain sorghum female parent.

Indication that heterosis had occurred for yield, weight per 100 seeds, days to half bloom, height, percent protein and lysine and percent oil is indicated in table 8 and was interpreted individually as the increase or decrease of the overall F_1 mean over the overall parental mean. Height registered the highest mean heterosis for both the sudangrass and grain sorghum followed by weight per 100 seeds, yield and percent oil in that order. Mean heterosis was highly significant for weight per 100 seeds, height and percent oil. However for percent protein and lysine, it was not significant for both sudangrass and grain sorghum where as for yield the mean heterosis was significant for sudangrass but not for grain sorghum.

Except for lysine, the mean percent heterosis of sudangrass was higher than that for grain sorghum. This was probably to be expected because of the genetic diversity between the two groups. The grain sorghum male parents and Redlan female parent are more closely related than sudangrass male parent and Redlan female parent. The more closely

Table 8. Average performance of 35 sudangrass and 11 grain sorghum lines, their F_1s and percentage heterosis for 7 characters

		Mid Parents	F_1s	% Heterosis
Yield	Sudangrass	4314.00	4801.00	11.3*
	Grain Sorghum	5266.00	5739.00	9.0
Weight/100 Seeds	Sudangrass	1.80	2.09	16.1**
	Grain Sorghum	2.61	3.00	14.9**
Days to Half Bloom	Sudangrass	81.75	82.37	0.8
	Grain Sorghum	83.70	83.58	-0.1
Height	Sudangrass	183.00	295.00	61.2**
	Grain Sorghum	185.00	264.00	42.7**
% Protein	Sudangrass	10.62	10.65	0.3
	Grain Sorghum	9.67	9.55	-1.2
% Lysine	Sudangrass	2.34	2.27	-3.0
	Grain Sorghum	2.45	2.45	0.0
% Oil	Sudangrass	3.95	4.18	5.8**
	Grain Sorghum	3.48	3.63	4.3**

* Significant at .05 level

** Significant at .01 level

related the female and male parents are the less the chances are of finding high heterosis in their F_1 hybrids and the converse is equally true.

Inter-character associations may be useful in revealing and understanding the relationship that exists among several traits. Hence phenotypic, genotypic and environmental correlations of grain sorghum male parents, grain sorghum F_1 hybrids, sudangrass male parents and sudangrass F_1 hybrids for several characters were computed and are presented in Appendix tables A3, A4, A5 and A6 respectively. The phenotypic correlations of a few characters of special interest in this study are presented in table 9. Percent protein and percent lysine were negatively correlated in all the four groups though significance was only shown for sudangrass male parents ($r = -.700$) and sudangrass F_1 hybrids ($r = -.780$). This seems to indicate that in general as protein content is increased, lysine measured as a percent of protein drops down thus presenting a barrier in the improvement of both protein and lysine in sorghum at the same time. Whereas this seemed true in general, it was not true for some genotypes which showed good combinations of yield, protein, lysine and oil. Percent protein and yield were negatively correlated but significance was only obtained for sudangrass male parents ($r = -.508$) which is in agreement with work done in grain sorghum (1,15,30). Percent protein and weight of 100 seeds were positively and significantly correlated for sudangrass F_1 hybrids ($r = .571$) and grain sorghum parents ($r = .568$) but negatively and nonsignificantly correlated for sudangrass male parents and grain sorghum F_1 hybrids. Protein content and oil content were positively associated in all the four groups but

Table 9. Phenotypic correlation coefficients for parents and hybrids of grain sorghum and sudangrass for a few selected characters

Characters Correlated	Phenotypic Correlation Coefficients			
	Sudangrass		Grain Sorghum	
	Parents	F_1s	Parents	F_1s
Percent protein with lysine	-.700**	-.788**	-.365	-.562*
Percent protein with percent oil	.318	.066	.487*	.417
Percent protein with yield	-.508**	-.193	-.383	-.291
Percent protein with wt of 100 seeds	-.040	.571**	.568*	-.200
Percent protein with days to half bloom	-.467**	-.553**	-.244	-.289
Percent protein with height	-.031	.021	.065	-.127
Percent lysine with yield	.318	.146	.140	-.004
Percent lysine with wt of 100 seeds	-.152	-.545**	.330	.347
Percent lysine with days to half bloom	.393*	.400**	.405	.368
Percent lysine with height	-.178	-.115	.250	.336
Percent oil with lysine	-.134	-.012	.096	.083
Percent oil with yield	-.035	-.143	.041	.291
Percent oil with wt of 100 seeds	-.341*	.253	.707**	.412
Percent oil with days to half bloom	.232	.188	.290	.296
Percent oil with height	-.016	-.008	.755**	.674**
Weight of 100 seeds with yield	.343*	-.011	-.018	-.148
Weight of 100 seeds with half bloom	-.289	-.361*	.456	-.061
Weight of 100 seeds with height	.016	.008	.518**	.560

* Significant at the .05 level

** Significant at the .01 level

only significantly for grain sorghum male parents (r = .467) indicating that protein and oil might be improved together. In oats negative and significant correlations between protein and oil have been reported (12). Oil content and weight of 100 seeds were negatively and significantly correlated for sudangrass male parents (r = -.341) whereas they were positively and significantly correlated for grain sorghum male parents (r = .707). It is important to note that all these correlations were computed in nonsegregating populations and may be somewhat different in segregating populations.

SUMMARY AND CONCLUSIONS

Eleven grain sorghum lines selected from the world collection and thirty five sudangrass lines selected from the Purdue Sudangrass Breeding Nursery were each crossed to Redlan cytoplasmic male sterile line. Four of the grain sorghum and eight of the sudangrass pollinator lines were also crossed to Martin cytoplasmic male sterile line. All the F_1 hybrids, pollinator lines, Redlan and Martin "B" lines and four checks were planted in 1970 at Purdue University Agronomy Farm. There were three replications in a randomized complete block design. Several characteristics, including yield in kg/ha, weight of 100 seeds, days to half bloom, height, percent protein, lysine as a percent of protein and percent oil etc. were recorded. The analysis of variance indicated significant differences among grain sorghum and sudangrass male parents for all the characters except for heads per plot and lysine as a percent of protein for the latter. The differences between grain sorghum pollinator lines versus sudangrass pollinator lines were highly significant for most characters studied. While the sudangrass per se had significantly more panicles per plot, percent protein and oil than the grain sorghum, they were inferior in yield, weight per 100 seeds and lysine as percent of protein. The superiority or inferiority of the sudangrass to grain sorghum was transmitted and maintained in their offsprings. The Redlan x grain sorghum and Redlan x sudangrass F_1 hybrids were generally lower than

the performance of the better parent for most characters though there were several exceptions.

Variation among sudangrass lines ranged from 1525 to 4898 kg/ha for grain yield; 0.93 to 2.07 grams for 100 seed weight; 10.47 to 16.53 percent protein and 3.60 to 6.02 for percent oil. The Redlan x sudangrass F_1 hybrids ranged from 1242 to 6915 kg/ha for grain yield; 1.51 to 2.61 grams per 100 seed weight; 8.83 to 13.67 for percent protein and 3.69 to 4.59 for percent oil.

There were some genotypes among the Redlan x sudangrass F_1 hybrids which had good combinations of yield, weight of 100 seeds, protein, lysine and oil.

It seems that the genes which condition several traits in both grain sorghum and sudangrass are similar in the manner in which they are transmitted to their offspring but are different in magnitude.

There were significant differences among the female parents for some characters. Hybrids with Martin female parent were significantly better for percent protein and reached blooming earlier than hybrids with Redlan female parent. However they were not significantly different for yield, weight of 100 seeds, percent lysine and oil.

The Redlan x sudagrass F_1 hybrids per se were significantly superior over their Redlan female grain parent for percent protein and percent oil but were significantly inferior for weight of 100 seeds. No significant differences were obtained for yield and percent lysine, though some individual F_1s outyielded by far Redlan "B" line.

Regression of Redlan x sudangrass offspring on sudangrass male parents indicate a strong linear relationship for days to half bloom

and lysine but weak for percent protein and percent oil. This implies that the transmission of protein and oil to their offspring is not very high. The tillering ability of the sudangrass appears to be masked by the low tillering ability of Redlan female parent in their F_1 progeny. The yield superiority of the Redlan x sudangrass F_1 hybrids over the sudangrass male parents was as a result of heavier panicles carrying larger seeds.

In general the Redlan x sudangrass hybrids had longer and broader leaves and thicker stems than their male sudangrass proginators. However the panicle shape characteristics resembled sudangrass though the size, shape and weight of the seeds approximated that of the grain sorghum parent.

Significance was indicated more often for general combining ability than for specific combining ability and also for almost all the characters investigated the mean squares for G.C.A. were markedly greater than those for the S.C.A. G.C.A. mean squares were significant for almost all the characters indicating the influence of additive genes in the expression of the majority of the characters investigated. Significance for S.C.A. was also obtained for weight of 100 seeds, days to half bloom, third leaf length and percent oil suggesting that dominance and epistasis together with additive gene action appear to influence the expression of these traits.

The G.C.A. contributed by the males for several characters was more often significant than that contributed by the females. Likewise the mean square for males were generally larger than those for females. There were however a few exceptions.

For a few characters the mean percent heterosis for both grain sorghum and sudangrass was computed. The expression of hybrid vigour for both groups were similar for each character except that the mean percent heterosis was higher for sudangrass than for grain sorghum with the exception of lysine. This is probably to be expected because of the genetic diversity between the two groups.

Phenotypic, genotypic and environmental correlations of grain sorghum male parents, Redlan x grain sorghum F_1 hybrids, sudangrass male parents and Redlan x sudangrass F_1 hybrids for several characters were computed. Percent protein and lysine were negatively correlated in the four groups but were significant for sudangrass F_1 hybrids ($r = -.788$) and sudangrass male parents ($r = -.700$) only. Percent protein and oil content were positively associated in the four groups but only significantly for grain sorghum male parents ($r = .487$). Percent protein and yield were negatively correlated but significance was only obtained for sudangrass male parents ($r = -.508$). Positive and significant correlations were obtained between percent protein and weight of 100 seeds for sudangrass F_1 hybrids ($r = .571$) and grain sorghum parents ($r = .568$).

Oil content and weight of 100 seeds were negatively and significantly correlated for sudangrass male parents ($r = -.341$) but positively and significantly correlated for grain sorghum male parents ($r = .707$).

It is important to realise that these correlations apply to the four groups in general and that there were exceptional genotypes in each of these groups, in that, reasonably good combinations of yield, protein, lysine and oil were observed. A fixed model for the genotypes was used and any inference on any genotypes not included in this study

is not justifiable. All the correlations were in nonsegregating populations and may be somewhat different in segregating populations.

LIST OF REFERENCES

LIST OF REFERENCES

1. Abifarin, A. O. 1969. Combining ability and heterosis for yield, protein, lysine and certain plant characters in 16 diverse imbreds and 56 hybrids in Sorghum bicolor (L.) Moench. Ph.D. Thesis, Purdue University.

2. Alexander, D. E. and R. D. Seif. 1963. Relation of kernel oil content to some agronomic traits in Maize. Crop. Sci. 3:354-355.

3. Altaf, Ali, I. M. Atkins, L. W. Rooney and K. B. Porter. 1969. Kernel dimensions, weight, protein content and milling yield of grain from portions of the wheat spike. Crop. Sci. 9:329-330.

4. Ashby, Eric. 1932. Studies in the inheritance of physiological characters. Annals of Botany 46:1008-1032.

5. Ayyangar, G.N.R., V. Rao and D. S. Rajabhvoshanam. 1932. Sorghum: size relationships of seed embryo, seedling and first seedling leaves. Proc. of Indian Aca. of Sci. Sect. B 8(3): 151-156.

6. Bartel, A. T. 1949. Hybrid vigour in sorghums. Agron. J. 41:147-152.

7. Beckman, W. P. 1969. Leaf characteristics in relation to yield and certain other characters in a diallel cross of eight lines of Sorghum vulgare Pers. Ph.D. Thesis, Purdue University.

8. Bell, G. M. and R. E. Atkins. 1965. Inheritance of quantitative characters in grain sorghum. Iowa State J. of Sci. Vol. 39 No. 3: 345-358.

9. Blum, A. 1970. Nature of heterosis in grain production by the sorghum panicle. Crop Sci. 10:28-30.

10. Bremner, R. N. Sckersall and R. K. Scott. 1963. The relative importance of embryo size and endosperm size in causing the effects associated with seed size in wheat. J. of Agric. Sci. 61:139-145.

11. Bressani, R. and B. R. Rios. 1962. The chemical and essential amino acids of 25 selections of grain sorghum. Cereal Chemistry 39:50-59.

12. Brown, C. M., D. E. Alexander and S. G. Carmer. 1966. Variation in oil content and its relation to other characters in oats (Avena sativa L.) Crop Sci. 6:190-191.

13. Brunson, A. M., F. R. Earle and J. J. Curtis. 1948. Interrelation among factors influencing the oil content of corn. Agron. J. Am. Soc. 40:180-185.

14. Chakravarty, S. C. 1967. Chemical study of sorghum as a staple food in India. 2. Protein content in relation to size of jowar grains. Indian Agric. 11 No. 2, 113-116.

15. Chapman, S. R. and F. H. McNeal. 1970. Gene effects for grain proteins in five spring wheat crosses. Crop Sci. 10:45-46.

16. Collins, F. C. 1969. Genetic and environmental control of protein quantity and quality and their relationships with certain agronomic characters in Sorghum bicolor (L.) Moench.

17. Craig-miles, J. P., H. B. Harris, J. P. Newton and J. W. Dobson. 19. Heterosis in F_1 hybrids of Sorghum vulgare x S. sudanense and S. vulgare x S. arundinaceum. Agron. J. 50(11):714-715.

18. Dalton, L. G. 1967. A positive regression of yield and late maturity in sorghum. Crop Sci. 7:271.

19. Deyoe, C. W. and J. A. Shellenberger. 1965. Amino acids and proteins in sorghum. J. Agricultural Food Chemistry 13:446-450.

20. Doggett, H. 1967. Yield increase from sorghum hybrids. Nature 216:789-799.

21. Doggett, H. 1969. Yield of hybrid sorghum. Expl. Agric. 5:1-8.

22. Doggett, H. 1970. Sorghum. Longmans, Green and Co. Ltd. London and Harlow.

23. Earle, F. R., J. J. Curtis and J. E. Hubbard. 1946. Composition of the component parts of the corn kernel. Cereal Chem. 23:504-511.

24. Falconer, D. S. 1960. Introduction to quantitative genetics. Robert MacLehose and Company Limited, Glasgow.

25. Farhoomand, M. B. and W. F. Wedin. 1960. Changes in composition of sudangrass and forage sorghum with maturity. Crop Sci. 1:459-463.

26. Frey, K. J. 1949. The inheritance of protein and certain of its components in maize. Agron. J. 41:113-117.

27. R. E. Comstock and H. F. Robinson. 1952. Estimation of Average Dominance of Genes. Heterosis ed. by J. W. Gowen, pp. 494-516.

28. Hayes, H. K. and R. J. Gorber. 1919. Synthetic production of high protein corn in relation to breeding. J. Am. Soc. Agron. 11:309-318.

29. Heller, V. G. and J. B. Sieglinger. 1944. Chemical composition of Oklahoma grain sorghum. Oklahoma Exp. Sta. Bul. B-274.

30. Karper, R. E. and J. R. Quinby. 1937. Hybrid vigour in sorghum. J. of Heredity 28:82-91.

31. Liang, G. H. 1967. Diallel analysis of Agronomic characters in grain sorghum, Sorghum vulgare pers. Can. J. Gen. and Cytol. 9:269-276.

32. Liang, G. H., C. B. Overley and A. J. Casady. 1969. Interrelation among agronomic characters in grain sorghum (Sorghum bicolor Moench) Crop Sci. 9:299-302.

33. Mahaderappa, M. 1967. Investigation on the inheritance of protein content in pearl millet (Pennisetum typoides Stapf and Hubb) Current Sci. 36:186-188.

34. Malm, N. R. 1968. Exotic germplasm use in grain sorghum improvement. Crop Sci. 8:295-298.

35. Miller, F. R. 1968. Some diversity in the world sorghum collection. Proceedings of the 23rd Annual corn and sorghum Research Conference.

36. Niehaus, M. H. 1964. Combining ability for grain yield and its primary and secondary components in Sorghum vulgare pers. Ph.D. Thesis, Purdue University.

37. Normand, F. L., J. T. Hogan and H. J. Deobald. 1965. Protein content of successive peripheral layers milled from wheat, barley, grain sorghum and glutinous rice by tangential abrassion. Cereal Chem. 42:359-367.

38. Phul, P. S. and D. S. Athwal. 1969. Inheritance of grain size and grain hardness in pearl millet. Indian J. Gen. and Plant Breeding 29:184-191.

39. Phul, P. S., N. D. Rana and A. K. Goswami. 1969. The effect of heterosis on protein content in pearl millet. Curr. Sci. 38:247-248.

40. Pickett R. C. 1967. Sorghum News Letter 10:67.

41. Pickett, R. C. 1967. Inheritance and improvement of protein quality and content in Sorghum vulgare Pers. Semi-Annual Report No. 2. Contract No. 1175 U.S. Agency for International Development, Purdue University.

42. Pickett, R. C. 1968. Sorghum protein quantity and quality. Proceedings of the 23rd Annual corn and sorghum Research Conference.

43. Quinby, J. R. 1963. Manifestation of hybrid vigour in sorghum. Crop Sci. 3:288-291.

44. Rodriguez, F. 1969. The influence of population density on the embryo, seed size, yield and other agronomic characters in Sorghum bicolor (L.) Moench. M.S. Thesis, Purdue University.

45. Sprague, G. F. 1936. Hybrid vigour and growth rates in maize cross and its reciprocal. J. Agric. Research 53:819-829.

46. Steel, R.G.D., and Torrie, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, New York.

47. Vaughan, C. E. 1961. Seed color and size related to viability, vigour. Miss. Fin. Res. 24 no. 5:3-4.

48. Virupaksha, T. K. and L.V.S. Sastry. 1968. Studies on the protein content and amino acid composition of some varieties of grain sorghum. J. Agricultural and Food Chemistry 16:199-203.

49. Voigt, R. L., C. O. Gardner and O. J. Webster. 1966. Inheritance of seed size in sorghum, Sorghum vulgare Pers. Crop Sci. 6:582-586.

50. Wall, J. S. and C. W. Blessin. 1969. Composition and structure of sorghum grains. Cereal Sci. To-day 14.

51. Worker, G. F. and J. Ruckman. 1968. Variation in protein levels in grain sorghum growth in the southwest desert. Agron. J. 60:485-488.

APPENDIX

Table A1. Mean values of 9 characters recorded on all 116 lines and hybrids grown in 1970. Lafayette, Indiana

Code	Pedigree	No. of Hds/Plot	Yield Kg/Ha	% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height (cm)	% Protein	% Lysine	% Oil
1	65021	302.3	1642	53.9	1.02	75.7	211	14.33	1.91	4.62
2	R x 65021	101.0	4471	75.1	2.03	89.0	325	11.07	2.26	4.46
3	65062	158.0	2431	63.0	1.27	81.0	229	10.43	2.67	4.05
4	R x 65062	111.0	5425	77.0	2.11	76.7	299	11.67	1.93	3.81
5	65083	373.7	1525	43.4	1.08	65.3	216	16.53	1.93	4.62
6	R x 65083	123.3	4673	78.3	2.28	73.3	282	12.60	1.93	4.20
7	65039	281.0	4391	67.9	1.15	83.7	207	13.13	2.27	5.10
8	R x 65039	118.0	5404	63.0	2.11	95.0	293	9.77	2.53	4.24
9	65084	263.7	2097	65.2	0.93	83.7	215	14.63	2.16	5.39
10	R x 65084	94.7	1242	55.4	1.51	92.0	340	10.47	2.44	3.68
11	65025	180.7	4531	77.9	1.04	84.7	199	11.27	2.53	4.94
12	R x 65025	81.0	4177	64.8	2.08	91.3	236	8.93	2.52	4.32
13	65038	190.7	4062	71.7	1.07	83.3	190	11.60	2.28	4.90
14	R x 65038	98.0	5404	78.1	2.12	87.0	284	9.37	2.48	4.20
15	65055	273.7	2704	59.3	1.29	73.0	174	11.83	2.28	5.02
16	R x 65055	132.3	4440	74.1	2.32	69.0	244	11.60	1.96	4.23
17	65066	235.0	1837	49.1	0.94	80.7	226	13.10	2.05	4.44
18	R x 65066	101.7	4277	74.8	2.07	81.7	316	10.43	2.17	4.39
19	65007	314.0	3440	53.6	0.97	82.0	228	11.03	2.43	4.29
20	R x 65007	111.7	6316	72.2	1.91	85.0	317	9.07	2.73	3.99
21	65035	190.7	2746	59.7	1.11	75.0	187	13.33	2.05	5.05
22	R x 65035	85.7	5752	76.1	2.12	88.3	285	9.60	2.41	4.55
23	65041	266.3	2451	54.8	1.21	68.7	150	12.70	2.37	3.88
24	R x 65041	127.3	5645	62.9	2.07	70.3	216	10.47	2.28	3.81
25	65098	183.7	3421	71.6	1.61	79.7	240	13.27	1.99	4.69
26	R x 65098	97.0	4340	70.9	2.14	74.0	285	11.63	2.19	4.46
27	65143	241.3	2941	65.5	1.05	85.7	223	12.73	2.20	6.02
28	R x 65143	78.0	3481	75.8	2.33	95.0	317	11.07	2.01	4.47
29	65156	258.0	3358	63.3	0.99	89.7	228	12.80	2.17	5.69
30	R x 65156	96.7	3787	68.7	2.10	91.0	316	10.23	2.37	4.40

Table A1, cont.

Code	Pedigree	No. of Hds/Plot	Yield Kg/Ha	% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height (cm)	% Protein	% Lysine	% Oil
31	65014	169.0	4505	64.6	1.25	82.0	214	11.50	2.52	4.36
32	R x 65014	82.3	5454	77.9	1.97	81.0	272	10.63	2.58	4.18
33	65011	292.0	4371	53.0	1.68	85.7	225	11.50	2.33	4.10
34	R x 65011	118.7	6057	76.3	2.16	81.0	294	11.27	2.27	4.09
35	65153	285.7	3732	59.1	1.02	86.3	213	12.93	2.30	5.84
36	R x 65153	108.7	5150	75.2	2.12	94.7	327	10.50	2.08	4.32
37	65017	157.3	3044	63.2	1.45	80.7	224	13.13	2.26	4.81
38	R x 65017	79.0	3809	74.4	2.05	82.7	296	10.17	2.41	4.26
39	65155	221.7	3614	62.5	0.98	87.3	244	10.43	2.48	4.35
40	R x 65155	105.0	5708	68.1	1.72	85.7	289	8.83	2.53	3.84
41	65148	218.3	2435	56.2	1.01	86.0	220	11.43	2.19	4.53
42	R x 65148	90.0	2821	66.3	2.15	77.3	297	11.73	2.23	4.38
43	65037	296.3	4022	64.7	0.98	85.0	226	10.47	2.24	4.31
44	R x 65037	125.0	6390	76.7	1.80	84.0	326	9.97	2.35	4.04
45	65097	231.0	2727	68.3	1.08	83.0	251	12.63	2.26	4.93
46	R x 65097	130.0	6094	75.9	2.19	74.7	289	11.83	2.00	4.48
47	65110	163.3	4898	64.5	2.07	75.7	232	11.40	2.01	4.49
48	R x 65110	93.7	5229	73.2	2.29	78.3	297	11.37	2.22	4.04
49	65056	164.3	3376	58.2	1.40	82.0	216	11.23	2.49	4.60
50	R x 65056	69.0	5702	77.6	2.13	82.0	289	10.23	2.45	4.20
51	65015	172.3	3077	58.6	1.33	87.7	241	11.93	2.14	3.89
52	R x 65015	83.3	5325	74.5	2.16	84.3	305	10.07	2.19	3.69
53	65018	195.7	3391	60.1	1.58	79.0	259	14.33	1.98	3.60
54	R x 65018	107.7	3727	66.9	2.61	75.0	298	13.67	1.84	4.04
55	65028	279.0	4737	70.6	1.07	79.7	230	11.60	2.21	4.47
56	R x 65028	134.3	6915	69.2	1.90	82.0	327	11.20	2.11	4.20
57	65046	181.0	3134	57.8	1.27	78.3	213	12.43	2.43	4.58
58	R x 65046	64.7	3844	70.0	2.01	83.0	290	9.83	2.45	4.29
59	65052	131.7	3600	66.5	1.27	83.0	222	11.33	2.47	4.54
60	R x 65052	74.0	4817	75.9	2.05	82.3	283	9.67	2.64	4.21
61	65105	208.7	3123	67.4	1.60	66.0	210	13.40	1.87	4.05
62	R x 65105	103.7	3975	60.5	2.16	83.3	327	11.60	1.97	4.18

Table A1, cont.

Code	Pedigree	No. of Hds/Plot	Yield Kg/Ha	% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height (cm)	% Protein	% Lysine	% Oil
63	65061	181.3	2544	74.6	1.27	66.3	238	12.80	2.22	5.00
64	R x 65061	109.7	4767	72.4	2.28	68.7	306	11.00	2.04	4.04
65	65022	209.3	3357	57.8	1.38	77.7	208	13.83	2.24	4.64
66	R x 65022	73.3	4473	70.3	2.04	81.7	287	9.93	2.39	4.21
67	65023	128.0	2732	56.4	1.24	80.7	218	11.37	2.38	4.50
68	R x 65023	77.3	4463	69.9	1.98	82.0	293	10.60	2.11	4.31
69	65053	157.7	3128	59.1	1.32	82.0	219	11.20	2.53	4.42
70	R x 65053	89.0	4468	67.0	1.95	80.7	287	9.60	2.39	4.15
71	943 018	82.7	4511	67.8	2.80	84.7	148	8.80	2.73	2.66
72	R x 943 018	69.3	6059	66.9	2.82	84.0	178	9.63	2.08	3.07
73	943 003	68.0	5102	76.9	2.99	91.7	321	11.86	2.41	4.10
74	R x 943 003	231.0	4124	70.9	2.99	90.7	361	9.93	2.55	3.83
75	943 013	65.1	4385	74.8	3.59	85.7	274	11.90	2.52	5.32
76	R x 943 013	61.0	5942	73.9	3.30	89.3	314	10.40	2.52	3.78
77	943 009	47.0	4860	73.2	2.86	86.0	311	9.63	2.61	4.51
78	R x 943 009	64.0	5006	78.6	3.13	84.3	343	9.73	2.69	4.03
79	943 004	69.0	6366	71.6	2.80	86.7	330	9.77	2.26	4.46
80	R x 943 004	78.3	6259	73.2	3.07	85.3	336	8.47	2.76	3.85
81	917 008	76.0	4638	59.3	2.41	93.0	177	8.27	2.51	2.85
82	R x 917 008	77.3	6381	74.5	3.00	85.0	215	8.20	2.81	3.05
83	917 017	88.3	4798	72.9	2.57	79.0	183	10.26	2.52	3.54
84	R x 917 017	99.3	6647	78.5	2.73	77.7	210	9.90	2.18	3.50
85	917 024	64.0	7455	75.5	2.79	87.0	319	9.37	2.59	4.38
86	R x 917 024	63.7	6120	78.9	2.98	83.3	354	9.13	2.31	3.90
87	945 150	92.0	2129	45.5	2.78	73.0	99	11.67	2.30	3.21
88	R x 954 150	79.7	4939	64.1	2.67	76.0	152	10.37	2.28	3.59
89	954 148	104.3	4661	65.8	2.76	74.7	148	10.97	2.42	3.18
90	R x 954 148	78.3	6707	70.6	2.81	82.0	263	9.53	2.34	3.65
93	954 031	76.0	6925	71.3	3.03	82.3	154	11.10	2.42	3.08
94	R x 954 031	71.7	4950	73.8	3.45	81.7	177	9.70	2.45	3.77
108	M x 65038	123.7	4349	72.2	2.22	74.0	264	12.23	2.36	4.37
109	M x 65134	109.0	4000	71.5	2.20	84.7	292	10.60	2.21	4.59

Table A1, cont.

Code	Pedigree	No. of Hds/Plot	Yield Kg/Ha	% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height (cm)	% Protein	% Lysine	% Oil
110	M x 65156	99.0	3288	64.1	2.09	86.3	293	10.67	2.14	4.49
111	M x 65153	111.3	4471	71.9	1.93	86.0	306	11.03	2.22	4.59
112	M x 65155	112.3	4479	72.2	1.82	80.7	312	10.53	2.38	3.97
113	M x 65148	96.3	3649	73.4	2.13	73.7	275	12.30	2.01	4.15
114	M x 65037	132.7	6037	68.2	1.90	79.0	306	10.97	2.22	4.28
115	M x 65053	118.7	5264	74.0	2.13	78.3	264	11.23	2.38	4.44
117	M x 943 009	72.7	5391	79.0	3.01	84.0	326	11.20	2.31	4.10
118	M x 917 008	75.3	5248	69.9	2.77	79.0	209	8.27	2.52	3.16
119	M x 917 017	72.3	4921	73.1	2.65	74.0	192	11.00	2.03	3.62
120	M x 954 148	87.7	5882	71.5	3.11	73.7	237	10.00	2.41	3.57
97	Greenleaf	244.4	2288	58.5	1.11	81.0	261	12.69	2.12	4.73
99	Forage Farmers	96.2	3706	69.9	1.98	85.9	319	10.89	2.28	4.54
101	RS 610	97.3	5844	70.6	2.44	72.2	142	10.30	2.48	3.49
103	Redlan "B"	99.4	5396	71.3	2.37	83.4	146	8.85	2.42	3.21
105	Martin "B"	102.9	4249	60.1	2.33	75.9	139	11.27	2.22	3.70
TuKey's w .05 level		143.7	3521	28.5	0.50	9.8	72	4.05	1.01	0.60
TuKey's w .01 level		156.8	3840	31.0	0.55	10.8	79	4.42	1.11	0.65

Table A2. Means of 10 characters recorded on each of sudangrass lines, Redlan x sudangrass and Martin x sudangrass hybrids, Redlan and Martin "B" lines and sudangrass checks

Code	Pedigree	Panicle length	Panicle branch length at 1st node	Panicle branch length at first node excluding racemes	Ratio[1]	Panicle branch length at 3rd node	Panicle branch length at third node excluding racemes	Ratio[2]	3rd Leaf Length	3rd Leaf Width	Leaf Area Index
1	65021	24.3	9.5	2.17	.227	8.0	2.00	.250	63.4	2.80	107
2	R x 65021	24.4	8.0	2.07	.257	7.1	1.91	.270	79.3	4.97	237
3	65062	16.4	4.0	1.08	.240	4.4	1.20	.273	59.9	3.97	143
4	R x 65062	19.5	5.3	1.43	.263	4.8	1.05	.217	66.7	5.62	226
5	65083	25.3	12.4	4.00	.320	10.5	2.83	.263	59.0	3.04	108
6	R x 65083	24.9	9.2	2.25	.240	7.9	1.77	.233	70.5	4.99	211
7	65039	19.1	7.2	1.76	.247	5.3	1.00	.187	65.3	3.75	148
8	R x 65039	20.8	7.1	1.92	.270	5.8	1.27	.197	68.9	4.83	201
9	65084	22.2	10.6	1.51	.143	8.9	2.56	.290	60.1	2.72	98
10	R x 65084	22.2	9.5	2.52	.267	7.5	1.63	.217	61.3	3.99	146
11	65025	17.0	6.7	1.47	.220	11.9	0.91	.167	60.9	3.82	140
12	R x 65025	20.5	7.2	2.07	.283	5.4	0.94	.177	70.9	4.94	211
13	65038	18.3	7.1	2.13	.297	5.4	0.95	.173	58.1	3.53	123
14	R x 65038	21.0	7.5	1.87	.250	6.0	1.37	.230	70.3	4.87	205
15	65055	24.8	10.4	1.90	.180	8.1	1.27	.157	68.6	3.36	134
16	R x 65055	23.4	8.7	2.21	.263	7.3	1.53	.210	67.3	4.77	192
17	65066	27.5	12.0	2.27	.190	9.1	1.63	.180	58.8	3.30	117
18	R x 65066	27.7	11.0	2.23	.200	9.3	1.59	.167	70.4	5.17	219
19	65007	31.5	10.5	2.23	.220	11.1	1.98	.183	76.8	2.75	127
20	R x 65007	27.2	7.7	1.86	.250	8.5	1.40	.170	86.2	4.59	238
21	65035	18.1	7.3	1.79	.243	4.7	1.05	.230	62.1	3.77	141
22	R x 65035	20.0	6.8	1.62	.233	5.5	0.71	.130	75.0	5.58	251
23	65041	22.4	8.6	1.80	.210	7.5	1.80	.243	56.9	3.70	126
24	R x 65041	20.6	7.0	1.61	.230	5.9	1.45	.250	60.5	5.09	186
25	65098	20.3	6.3	1.78	.280	6.3	1.69	.267	58.7	4.10	144
26	R x 65098	22.8	8.0	1.96	.243	6.8	1.40	.207	64.7	4.65	181
27	65143	25.0	9.1	2.14	.233	7.7	2.12	.293	67.8	3.77	154
28	R x 65143	24.2	7.4	2.34	.317	7.1	1.95	.273	72.9	4.97	217

Table A2, cont.

Code	Pedigree	Panicle length	Panicle branch length at 1st node	Panicle branch length at first node excluding racemes	Ratio[1]	Panicle branch length at 3rd node	Panicle branch length at third node excluding racemes	Ratio[2]	3rd Leaf Length	3rd Leaf Width	Leaf Area Index
29	65156	23.1	9.0	2.11	.233	8.5	2.01	.237	62.3	3.01	113
30	R x 65156	24.5	8.7	2.24	.257	7.8	1.86	.237	71.4	4.56	195
31	65014	20.9	8.4	2.23	.263	7.3	1.86	.250	58.2	4.95	173
32	R x 65014	21.9	8.6	2.16	.250	7.4	1.92	.260	67.8	6.01	245
33	65011	28.4	12.6	3.69	.290	9.1	2.33	.253	65.1	3.27	128
34	R x 65011	23.6	8.5	2.59	.307	7.4	1.90	.257	77.0	5.27	241
35	65153	22.4	8.0	1.69	.213	8.1	1.93	.240	61.4	3.49	129
36	R x 65153	23.8	7.8	2.46	.320	7.0	2.09	.317	66.5	4.84	194
37	65017	20.5	7.0	1.49	.207	6.7	1.69	.253	64.3	5.44	210
38	R x 65017	21.8	7.6	1.69	.220	6.5	1.60	.250	62.9	5.95	225
39	65155	27.8	10.3	1.87	.183	9.5	1.55	.163	81.5	2.89	142
40	R x 65155	27.1	8.6	1.76	.203	9.4	1.83	.193	88.1	4.67	248
41	65148	19.7	8.2	0.95	.117	6.6	0.77	.120	62.7	2.75	104
42	R x 65148	23.0	9.1	1.66	.180	8.2	1.33	.160	61.2	4.02	148
43	65037	29.9	11.2	1.80	.157	10.1	2.21	.220	80.5	2.75	133
44	R x 65037	27.7	9.2	1.83	.207	8.9	1.71	.190	86.3	5.21	269
45	65097	23.5	10.3	1.37	.133	7.3	1.13	.153	55.8	2.91	98
46	R x 65097	25.2	9.6	2.34	.243	8.3	1.91	.230	61.0	4.41	161
47	65110	27.3	9.9	1.68	.170	8.3	1.07	.130	66.8	4.49	180
48	R x 65110	24.5	7.9	1.96	.247	6.6	1.35	.203	70.7	5.36	227
49	65056	20.2	8.4	2.04	.250	7.0	2.09	.300	57.9	4.89	170
50	R x 65056	22.4	8.9	2.51	.283	6.9	1.73	.250	71.3	6.08	262
51	65015	16.3	3.8	0.85	.223	4.6	1.14	.250	61.4	4.49	166
52	R x 65015	20.3	6.2	1.51	.260	5.6	1.35	.243	67.3	5.62	227
53	65018	19.7	5.4	1.04	.193	5.9	1.31	.223	61.6	3.95	146
54	R x 65018	19.8	6.2	1.68	.267	5.0	0.93	.183	66.0	5.23	207
55	65028	29.5	9.9	2.31	.233	10.5	2.45	.233	78.9	2.87	135
56	R x 65028	26.7	7.6	1.32	.170	7.2	1.54	.217	86.8	4.98	259
57	65046	20.4	8.1	1.91	.237	6.8	1.58	.230	59.9	4.71	170
58	R x 65046	23.3	8.6	2.25	.263	7.0	2.36	.330	62.7	6.16	232

Table A2, cont.

Code	Pedigree	Panicle length	Panicle branch length at 1st node	Panicle branch length at first node excluding racemes	Ratio[1]	Panicle branch length at 3rd node	Panicle branch length at third node excluding racemes	Ratio[2]	3rd Leaf Length	3rd Leaf Width	Leaf Area Index
59	65052	21.3	8.6	2.78	.323	7.6	1.72	.223	65.4	5.18	204
60	R x 65052	21.5	7.9	2.05	.260	6.4	1.49	.233	64.2	6.05	234
61	65105	23.0	9.8	2.70	.277	8.6	1.83	.217	59.7	3.60	129
62	R x 65105	24.3	8.2	2.07	.257	6.8	0.91	.133	71.3	4.97	213
63	65061	27.5	11.5	3.32	.287	7.6	0.72	.093	58.7	2.96	104
64	R x 65061	25.4	9.0	2.61	.293	8.3	1.35	.163	65.1	4.72	185
65	65022	21.7	9.6	2.42	.247	8.2	1.89	.230	56.9	5.33	182
66	R x 65022	23.5	9.1	2.71	.300	7.6	2.09	.260	61.3	6.45	238
67	65023	21.6	9.0	2.65	.293	7.8	2.21	.283	60.2	4.86	176
68	R x 65023	22.3	8.1	2.29	.287	6.8	1.57	.230	66.0	5.83	231
69	65053	20.7	8.2	3.20	.400	7.7	1.94	.250	62.4	5.11	191
70	R x 65053	22.2	7.8	2.01	.257	6.7	1.43	.213	61.0	5.87	213
108	M x 65038	20.9	7.3	2.05	.283	6.6	1.68	.250	67.3	4.73	194
109	M x 65134	26.1	8.7	2.93	.337	8.8	2.27	.260	73.0	5.11	224
110	M x 65156	25.2	8.9	2.83	.317	7.9	2.59	.330	73.3	4.75	209
111	M x 65153	27.0	9.5	2.97	.310	9.2	2.39	.263	77.7	5.37	251
112	M x 65155	29.3	9.9	2.41	.250	9.4	1.94	.203	82.5	5.18	255
113	M x 65148	24.7	9.7	2.97	.307	8.5	1.88	.223	65.1	4.68	184
114	M x 65037	29.3	9.4	1.48	.157	9.7	1.57	.157	86.1	5.53	285
115	M x 65053	22.8	8.1	2.68	.340	7.3	2.13	.293	66.7	5.78	231
97	Greenleaf	27.8	12.9	3.43	.267	10.0	1.87	.190	71.3	2.71	116
99	Forage Farmers	28.7	11.3	2.61	.237	9.3	2.38	.262	76.6	4.51	207
103	Redlan "B"	21.3	7.0	2.04	.294	6.4	2.07	.330	65.4	5.94	233
105	Martin "B"	23.6	7.9	2.70	.343	8.2	2.73	.335	60.6	6.37	232
	TuKey .05	4.7	3.2	1.81	.208	5.6	1.35	.170	15.2	1.15	73
	TuKey .01	5.1	3.5	1.97	.227	6.1	1.47	.185	16.6	1.25	80

[1]Ratio of panicle branch length excluding racemes to the whole panicle branch length at first node.

[2]Ratio of panicle branch length excluding racemes to the whole panicle branch length at third node.

Table A3. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 11 grain sorghum parents

Character		% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height	% Protein	% Lysine	% Oil
Grain Yield	P†	.636**	-.018	.456	.441	-.383	.140	.041
	G††	.669	-.065	.565	.516	-.607	.608	.046
	E†††	.535	.314	-.440	-.160	.267	-.128	.041
% Threshing	P		.453	.581*	.680**	-.045	.365	.516*
	G		.477	.703	.782	-.137	1.408	.596
	E		.433	-.370	.049	.226	-.213	-.050
Weight of 100 Seeds	P			.298	.518*	.568*	.329	.707**
	G			.319	.538	.602	1.164	.751
	E			-.300	.101	.557	-.462	-.015
Days to Half Bloom	P				.669**	-.244	.405	.290
	G				.676	-.263	1.407	.290
	E				.008	-.303	.106	.378
Height	P					.085	.250	.745**
	G					.105	.664	.747
	E					.142	-.002	.260
% Protein	P						-.365	.487*
	G						-.129	.563
	E						.680	.004
% Lysine	P							.096
	G							.285
	E							-.187

† Phenotypic correlation
†† Genotypic correlation
††† Environmental correlation

* Significant at .05 level
**Significant at .01 level

Table A4. Intercharacter phenotypic, genotypic and environmental correlation coefficients in 11 grain sorghum hybrids.

Character		Threshing	Weight of 100 Seeds	Days to Half Bloom	Height	% Protein	% Lysine	% Oil
Grain Yield	P†	.232	-.148	-.081	-.076	-.291	.004	-.291
	G††	.160	-.715	-.007	-.205	-2.479	-	-.684
	E†††	.449	.403	-.374	.166	.240	-.331	-.040
% Threshing	P		.349	.271	.546	.040	.151	.510
	G		.390	.478	.748	.161	-	.700
	E		.342	-.397	.163	.152	-.063	.129
Weight of 100 Seeds	P			.666*	.560	-.200	.347	.412
	G			.747	.602	-.737	-	.435
	E			-.103	.067	.346	.353	.234
Days to Half Bloom	P				.749**	-.289	.368	.296
	G				.788	-.255	-	.315
	E				-.386	-.203	.191	-.001
Height	P					-.127	.336	.674**
	G					-.275	-	.700
	E						-.038	.064
% Protein	P						-.562*	.417
	G						-	.669
	E						-.679	.516
% Lysine	P							.083
	G							-
	E							-.213

† Phenotypic correlation
†† Genotypic correlation
††† Environmental correlation

* Significant at .05 level
**Significant at .01 level

Table A5. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 35 sudangrass lines.

Character		% Threshing	Weight of 100 Seeds	Days to Half Bloom	Height	Panicle Length	3rd Leaf Length	3rd Leaf Width	3rd Leaf Area Index	% Protein	% Lysine	% Oil
Grain Yield	P†	.519**	.343*	.360*	-.016	-.006	.273	.268	.404*	-.508**	.318	-.035
	G††	.657	.420	.473	-.047	-.025	.309	.300	.455	-.762	.408	-.072
	E†††	.420	.128	-.033	.099	.133	.212	.329	.331	.168	.191	.160
% Threshing	P		.080	.151	.066	-.214	.026	.048	.073	-.281	.169	.265
	G		.120	.269	.070	-.377	.066	.078	.121	-.445	.278	.398
	E		.047	-.038	.100	.087	-.050	.010	.011	-.107	.083	.165
Weight of 100 Seeds	P			-.287	.092	-.117	-.221	.528**	.494**	-.040	.152	-.340*
	G			-.300	.088	-.117	-.237	.549	.531	-.086	-.218	-.362
	E			-.130	.143	-.147	-.046	.138	.051	.312	.019	-.003
Days to Half Bloom	P				.319	-.127	.269	.008	.127	-.467**	.393*	.232
	G				.351	-.127	.267	.006	.124	-.492	.501	.237
	E				-.047	-.144	.293	.058	.164	-.327	.211	.142
Height	P					.298	.295	-.173	-.054	-.031	-.178	-.016
	G					.320	.322	-.193	-.068	-.064	-.230	-.021
	E					-.018	.050	.143	.085	.175	-.078	.050
Panicle Length	P						.646**	-.547**	-.333*	-.055	-.206	-.047
	G						.692	-.565	-.355	-.052	-.305	-.052
	E						-.059	.074	.047	-.112	.137	.090
3rd Leaf Length	P							-.402*	-.025	-.404*	.058	-.072
	G							-.450	-.103	-.483	.048	-.078
	E							.429	.799	.109	.121	.002
3rd Leaf Width	P								.922**	-.137	.339*	-.162
	G								.933	-.157	.428	-.171
	E								.862	.054	.249	.062

Table A5, cont.

Character		% Thresh-ing	Weight of 100 Seeds	Days to Half Bloom	Height	Panicle Length	3rd Leaf Length	3rd Leaf Width	3rd Leaf Area Index	% Protein	% Lysine	% Oil
3rd Leaf Area Index	P†									-.306	.377*	-.185
	G††									-.365	.475	-.201
	E†††									.099	.215	.048
% Protein	P										-.700**	.318
	G										-.818	.360
	E										-.538	-.010
% Lysine	P											-.134
	G											-.212
	E											.126

† Phenotypic correlation
†† Genotypic correlation
††† Environmental correlation

* Significant at .05 level
**Significant at .01 level

Table A6. Intercharacter phenotypic, genotypic and environmental correlation coefficients for 43 Redlan and Martin sudangrass hybrids.

Character		% Thresh-ing	Weight of 100 Seeds	Days to Half Bloom	Height	Panicle Length	3rd Leaf Length	3rd Leaf Width	3rd Leaf Area Index	% Protein	% Lysine	% Oil
Grain Yield	P†	.479**	-.011	-.154	-.131	.068	.432**	.302	.569**	-.193	.146	-.143
	G††	.563	-.047	-.215	-.116	.047	.558	.392	.780	-.424	.420	-.179
	E†††	.519	.091	.075	-.171	.180	.062	.046	.067	.118	-.116	-.053
% Threshing	P		.286	-.175	-.031	.015	.114	.348*	.359*	.086	-.061	.184
	G		.609	-.315	.126	-.008	.256	.904	.961	.399	-.247	.437
	E		.084	-.133	-.183	.067	.014	-.092	-.059	-.069	.009	.011
Weight of 100 Seeds	P			-.361*	-.312*	-.371*	-.367*	.044	-.245	.571**	-.545**	.253
	G			-.370	-.440	-.432	-.434	.056	-.299	.634	-.737	.250
	E			-.334	.133	-.009	-.048	-.009	-.054	.548	-.441	.264
Days to Half Bloom	P				.461**	.043	.290*	-.063	.166	-.533**	.400**	.188
	G				.571	.055	.315	-.070	.190	-.716	.681	.267
	E				-.051	-.069	.125	-.021	.066	-.347	.083	.251
Height	P					.482**	.392**	-.211	.141	.021	-.115	-.008
	G					.595	.493	-.291	.170	-.060	-.046	-.041
	E					-.045	.009	.089	.056	.159	.224	.102
Panicle Length	P						.654**	-.277	.287*	-.042	-.060	.195
	G						.724	-.334	.318	-.065	.159	.236
	E						.170	.101	.162	.007	.117	-.028
3rd Leaf Length	P							-.144	.662**	-.223	.166	.026
	G							-.219	.640	-.268	.248	.060
	E							.244	.773	-.180	.100	.125
3rd Leaf Width	P								.643**	-.211	.207	-.039
	G								.607	-.313	.304	-.074
	E								.797	-.037	.134	.108

Table A6, cont.

Character		% Thresh-ing	Weight of 100 Seeds	Days to Half Bloom	Height	Panicle Length	3rd Leaf Length	3rd Leaf Width	3rd Leaf Area Index	% Protein	% Lysine	% Oil
3rd Leaf Area Index	P†									-.308*	.269	-.002
	G††									-.420	.394	.003
	E†††									-.151	.170	-.016
% Protein	P										-.788**	.066
	G										-1.104	-.106
	E										-.579	.395
% Lysine	P											-.012
	G											-.001
	E											-.130

† Phenotypic correlation
†† Genotypic correlation
††† Environmental correlation

* Significant at .05 level
** Significant at .01 level