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PERFORMANCE OF 2-DWARF AND 3-DWARF GRAIN SORGHUM HYBRIDS HARVESTED AT VARIOUS MOISTURE CONTENTS

by

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INTRODUCTION

Sorghum (Sorghum bicolor (L.) Moench) varieties range in height from .5m to 4.5m. In areas of the world where sorghum harvest is not mechanized, taller varieties are preferred because of increased forage production. In more mechanized countries, the advent of combines prompted selection for shorter varieties. These shorter combine varieties, which are normally .9m to 1.3m tall (3-dwarf), account for nearly all of the grain sorghum produced in the United States.

In breeding combine height varieties the potential grain yield of the crop may have been reduced. If the taller genetic material (2-dwarf) is used for increased yield, a major problem would be harvesting a plant which is 1.3m to 2.6m tall. Also, there would be the possibility of increased lodging of the taller plants.

This paper reports a comparison of some of the desirable and undesirable traits of tall (2-dwarf) and medium-short (3-dwarf) hybrid grain sorghums.

LITERATURE REVIEW

Sorghum breeders have been interested in sorghum height for many years. Sieglinger (18) investigated the inheritance of height in broomcorn. He concluded that tall, standard broomcorn possessed two dominant height factors and dwarf plants were recessive for one of these factors. Karper (9) reported two genes for dwarfness in sorghum and that a single dominant gene increased plant height by about 40% over the recessive type.

Quinby and Karper (15) concluded that four independently inherited genes and a modifying complex influenced internode elongation. They stated that the greater the number of the genes that are recessive for height the shorter the plant. There was no evidence that the inhibiting effect of a recessive gene on cell elongation was the same for each of the four genes. The modifying complex was established by varieties that differ greatly in height but have identical height genes and similar blooming dates. Their height measurements were taken up to the collar of the flag leaf because the length of the peduncle is independent of internode length.

Hadley (7) found that at least four independent genes with unequal effects appeared to be segregating. Results of this study were in close agreement with those obtained by Quinby and Karper (15) although entirely different procedures were used.

Quinby and Karper (16) used the terms 1-dwarf, 2-dwarf, 3-dwarf, and 4-dwarf to represent the four height genes. A 1-dwarf plant being the tallest and 4-dwarf plant (all genes recessive for height) being the shortest. The alleles for dwarfness were designated dw_1, dw_2, dw_3, and dw_4.

Several comparisons of plant characteristics have been made among the different height genotypes. Quinby (14) found no influence of the dwarfing genes on the length of the upper leaf sheath, peduncle length, head length, number of leaves, or number of days to bloom. A significant head weight difference was found, but it was attributed to environmental factors rather than genotype.

Hadley, Freeman and Javier (8) found that in three of four hybrids planted at low population, the 2-dwarf plants produced more tillers and heads and yielded more grain than 3-dwarf plants. All of the yield superiority of the tall plants was not accounted for by the larger number of tillers. In a separate, higher population study the superiority of the 2-dwarf was 16.7% and 18.2% in 7078 and RS 610, respectively.

Casady (3) compared 2-dwarf and 3-dwarf varieties. He found that the 3-dwarf had greater culm diameters, longer peduncles, wider leaf blades, shorter culms, and lower grain yield. He found that maturity differences were not instrumental in causing differences between the isogenic lines. The differences in culm diameter, peduncle length, leaf blade width and length, and internode length, between the 2-dwarf and 3-dwarf were the direct effects of the dw_3 and Dw_3 alleles. Casady concluded from the results of this investigation and others (2,6,8) that Dw genes are pleiotropic.

Graham and Lessman (6) studied 2-dwarf and 3-dwarf lines of grain sorghum. They found that the 2-dwarf outyielded the 3-dwarf by 27%. They concluded that some factor other than leaf area or light interception (possibly leaf arrangement) was involved in the yield differences. There was a trend for more light interception by the 3-dwarf plants. They suggested that less self-shading by the taller plants leads to more efficient light utilization.

To further support the theory that yield is directly related to plant height, Campbell and Casady (1) found a significantly higher yield in 1-dwarf broomcorn in two out of three site-years. Several researchers (2,12,13,17, 19) have found greater yields in 3-dwarf over 4-dwarf grain sorghum.

Researchers (4,10,11) have established that the maximum dry weight content and optimum chemical composition of sorghum grain differs greatly among varieties and environmental conditions. The moisture range for this point (physiological maturity) is from 23% to 34% grain moisture content with an average of 30%. After physiological maturity the dry weight and quality of the seed tend to decrease as the grain dries in the field.

Waelti, Turnquist, and Matter (20) reported less combine grain loss when sorghum was harvested at high moisture (30%-25%) than at normal harvest moisture (13.0%). They found that cylinder losses may be higher at high moisture, but this is compensated for by lower field shattering and reel losses.

METHODS AND MATERIALS

Isogenic 2-dwarf and 3-dwarf lines of hybrid grain sorghums RS 650 (Combine Kafir-60 x Plainsman) and RS 702 (Redlan x KS 6), were used. Height genotypes of the 2-dwarf and 3-dwarf lines were dw_1 Dw_2 Dw_3 dw_4 and dw_1 Dw_2 dw_3 dw_4, respectively. Casady (2) described the method of developing the isogenic pollinator lines of the hybrids.

Field plots were established at Mankato and Manhattan, Kansas, in 1970, and Hutchinson and Manhattan in 1971. Field establishments of 47,000 plants/ha in 1970 and 72,000 plants/ha in 1971 (76 cm rows) were obtained.

The experimental design was a split-plot with combinations of hybrids and heights the main plots, and grain moisture content at harvest the sub-plots. Main plots were 7.6 m long and 12.2 m (16 rows) wide. Six replications were used. The first, second and third harvests (sub-plots) occurred when grain moisture of each variety was in a range of 35-30%, 28-23%, and less than 16%, respectively. Both height genotypes of a variety were harvested at the same time. Each harvest was two rows 3.7 m long which left ample border on ends and between harvests. Dates of planting and harvest, and harvest moistures are shown in Table 1.

Data were taken for days to half bloom, lodging, plants/ha, number of heads/plant, threshed grain yield, threshing loss, grain moisture, stover weight, stover moisture, and panicle weight. The heads were cut 3 cm below the lowest branch of the panicle. The stover was cut 10 cm above ground. The heads were put in plastic bags and threshed as soon as possible with an Almaco plot thresher. Threshing loss was obtained by catching the material which passed over the sieve during the original threshing, drying, and rethreshing.

Grain yields were corrected to 12.5% moisture and stover to 70.0% moisture. Total plant yields were calculated by combining stover, panicle, and grain yields and correcting to 70.0% moisture.

Light interception measurements were taken 73 days after planting at Manhattan in 1971. The method of using light sensitive paper in petri dishes, as described by Friend (5), was used. Measurements were taken in the row and between rows, at ground level and at the height of the sixth leaf collar.

Analyses of variance were run on all data and data were combined over site years where variances were homogeneous (Hartley Test).

RESULTS AND DISCUSSION

Table 1 gives the planting date, number of days to half bloom, harvest date and percent grain moisture at harvest. Planting dates for all site years were within recommended dates for the location.

In 1970 there was very little rain received at either location. At Mankato, RS 650 had a very low yield and the RS 702 was killed by a freeze shortly after flowering. Because of the drought stress the Mankato data were not used in any of the site-year averages. High soil moisture reserves at Manhattan in 1970 minimized drought stress and fair yields were obtained even though RS 650 had a poor stand. At Manhattan in 1971 ample moisture was received early in the growing season with no moisture received after mid-season until early fall and excellent yields were obtained. At Hutchinson in 1971 moisture was limited throughout the growing season and average yields were obtained.

The average number of days to half bloom for RS 650 (a medium season hybrid) was 62 days and for RS 702 (a full season hybrid) was 71 days. The first harvest mean for RS 650 was 100 days after planting (at 32.2% grain moisture) and RS 702 was 106 days (at 33.1% grain moisture). Dates for second and third harvests were highly dependent on environmental conditions. The percent grain moisture (Table 1) for nearly all harvests fell within the desired limits. Figure 1 shows the height differences of RS 702 several days after the first harvest at Manhattan in 1970.

Threshed yields and threshing loss of the sorghum were affected by height genotype, variety, and grain moisture at time of harvest. There was a variety by moisture interaction in most cases. Total grain yields were affected by height genotypes, variety, and grain moisture at time of harvest

Table 1. Planting date, number of days to half bloom, harvest date, and % grain moisture at all site-years.

	Harvest No.	Manhattan 70 RS 650	Manhattan 70 RS 702	Mankato 70 RS 650	Manhattan 71 RS 650	Manhattan 71 RS 702	Hutchinson 71 RS 650	Hutchinson 71 RS 702
Planting date		6-18-70		6-8-70	6-1-71		6-8-71	
No. days to half bloom		60	70	63	69	73	58	69
Harvest date	1	9-29	10-3	9-20	9-10	9-22	9-9	9-14
	2	10-13	10-25	9-28	9-22	9-29	9-14	9-23
	3	11-18	11-18	11-6	10-28	10-28	10-12	10-12
No. days to harvest	1	103	107	104	101	113	93	98
	2	117	129	112	113	120	98	107
	3	153	153	151	149	149	126	126
% Grain moisture	1	34.4	36.4	29.4	32.5	29.9	32.6	33.1
	2	28.8	26.7	19.6	28.9	21.0	23.7	22.6
	3	14.1	14.7	16.1	15.9	15.7	11.0	11.6

with no interaction of these factors. Figures 2, 3, 4, and 5 show the effects of hybrids and harvest moisture on total grain yield, threshing loss and threshed grain averaged over heights for the three site-years and site-years combined. Figure 6 compares 2-dwarf to 3-dwarf grain sorghum combined over varieties for total grain yield, threshing loss, and threshed grain yield. Tables 2, 3, 4, and 5 give the mean squares from the analyses of variance and L.S.D.s for the individual site-years and combined data.

Overall yield of the RS 650 at Manhattan in 1970 (Fig. 2) was low, probably because of its poor stand (34,600 plants/ha compared to 59,300 plants/ha for RS 702). At the first harvest for RS 650 (34% grain moisture) physiological maturity (maximum grain dry weight accumulation) had not been

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Figure 1. Two-dwarf and 3-dwarf hybrid grain sorghum at Manhattan in 1970.

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Figure 2. Grain yield by percent moisture at harvest at Manhattan in 1970.

Figure 3. Grain yield by percent moisture at harvest at Manhattan in 1971.

Figure 4. Grain yield by percent moisture at harvest at Hutchinson in 1971.

Figure 5. Grain yield by percent moisture at harvest when site-years are combined.

Figure 6. Grain yields with 2-dwarf and 3-dwarf height genotypes.

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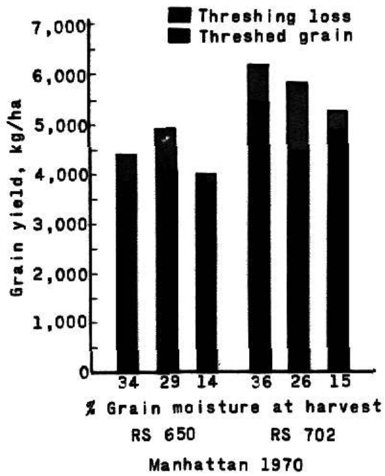

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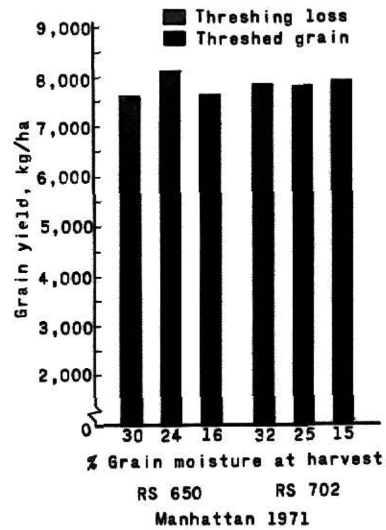

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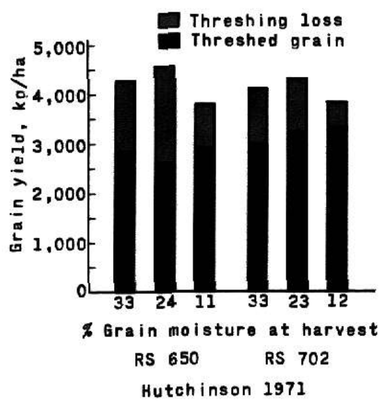

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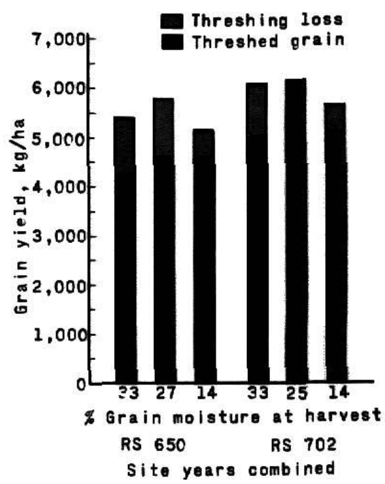

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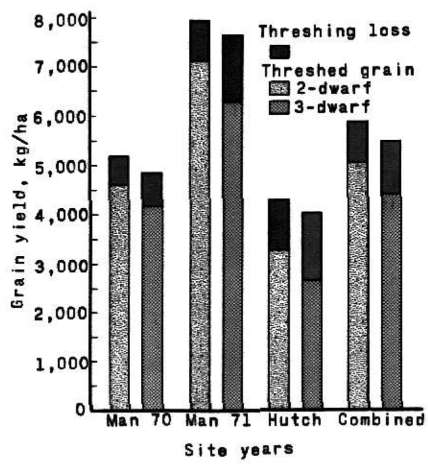

Figure 6.

reached and physiological maturity probably occurred somewhere between 34% and 29% grain moisture because the yield at the second harvest was significantly highest. Physiological maturity for the RS 702 occurred by the first harvest (36% grain moisture) causing a variety by moisture interaction. In both varieties the total grain yield (reported at 12.5% moisture) was significantly lowest at the last harvest. The decrease in grain yield (called field loss) was due to seed respiration, bird damage, field shattering, and other losses. Threshing losses (actually a crude measure of cylinder loss) were significantly highest at intermediate moisture and decreased greatly at the lowest moisture.

At Mankato in 1971 there was significantly greater threshing losses with the two high moisture harvests. Total grain yields were significantly higher (20%) for the high moisture harvests.

At Manhattan in 1971 threshed grain yields significantly increased with the last two harvests of RS 650 and the last harvest of RS 702 (Fig. 3). There was a significant decrease in threshing loss for each of the three harvests with RS 650. With RS 702 the threshing loss for the first and second harvests were not significantly different and there was a significant decrease with the 15% grain moisture harvest. The increase in threshed grain yield was compensated for by lower threshing losses and therefore no significant differences were found in total grain yields at lower harvest moistures.

Physiological maturity had not been reached when the first harvest occurred at Hutchinson in 1971 because there was a significant increase in total grain yield with the second harvest for both varieties (Fig. 4). There was a highly significant decrease in total grain yield with the latest harvest in both varieties. This loss was again attributed to field losses. Threshed grain yield did not differ between harvests, however, there was a significant difference between varieties. Threshing losses were highest when harvested at an intermediate moisture with the RS 650. There was no significant threshing loss difference between the first two harvests with the RS 702, causing the variety by moisture interaction. Again, the lowest threshing loss was with the latest, low moisture harvest for both varieties.

Total grain yields were significantly higher (11.2% for RS 650, 5.8% for RS 702) for the second harvest over the third harvest when data were combined over site-years (Fig. 5). This yield increase shows an advantage for high moisture harvest. There appears to be no threshed grain yield advantage in high moisture harvesting. However, a combine would probably do a better job of threshing than the plot thresher which was used and therefore most of the yield advantage of high moisture harvest, shown in total grain yield, could be realized in the field. Since physiological maturity had not been reached with the first harvest of RS 650, the first harvest should have been at about 30% grain moisture.

Threshing or cylinder losses (Fig. 5) were found to be significantly lowest at normal harvest moisture (14%). With RS 650 there was no significant difference between 33% and 27% grain moisture harvests. With RS 702 there was a significant increase in threshing loss at intermediate moisture (25%), meaning that the heads were hardest to thresh at an intermediate moisture. The high cylinder loss with high moisture harvest was also found in the work by Waelti et al. (20). He found that even though there was a high cylinder loss at high moisture this was more than compensated for by lower field shattering and reel losses. The lower field losses he speaks of can be seen in Fig. 5 in the higher total grain yield with high grain moisture harvests.

Advantages for 2-dwarf for total grain yields were 6.6%*,[1] 10.4%*, 6.4%^{ns}, and 11.6%** and for threshed grain yields were 10.0%**, 12.0%**, 18.0%**, and 12.7%** for Manhattan 1970, Manhattan 1971, Hutchinson 1971 and site-years combined (Fig. 6). The reason there was a greater yield advantage for 2-dwarf when measuring threshed grain than total grain was because of a significantly higher threshing loss for 3-dwarf at all site-years and when data were combined. No explanation can be given for the greater threshing loss of the 3-dwarf since the two heights were isogenic and there was no difference in grain moisture at harvest (grand means for grain moisture: 2-dwarf = 24.07%, 3-dwarf = 24.09%). Therefore, there was not only a grain yield advantage for the 2-dwarf material studied but a higher threshing percentage. Casady (3) and Graham and Lessman (6) also have found a grain yield advantage of the 2-dwarf over 3-dwarf in the range of 10% to 27%.

Stover yields and total plant yields of the sorghum were effected by height genotype, variety, and grain moisture at time of harvest. There were a few variety by moisture and variety by height interactions. Figures 7, 8, and 9 show the effects of hybrids and harvest moisture on total plant yield, stover yield, and total grain yield (all corrected to 70% moisture) for the three site-years. The lower part of the bars represent stover yield, which includes the vegetative portion of the head, and the upper portion represents total grain. Figure 10 compares 2-dwarf with 3-dwarf combined over varieties

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[1] *significant at .05   ** significant at .01

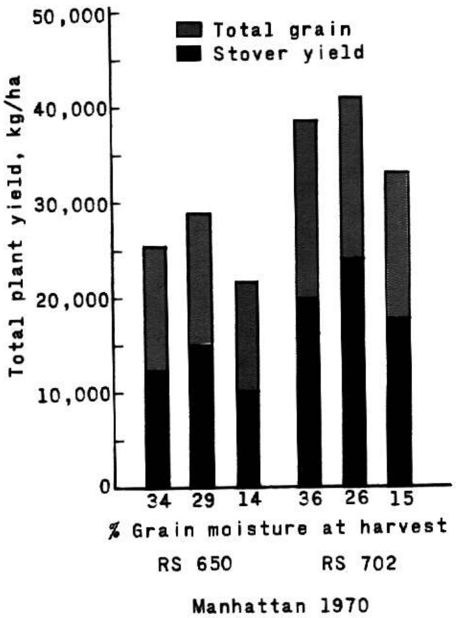

Figure 7. Total plant yield by percent moisture at harvest at Manhattan in 1970.

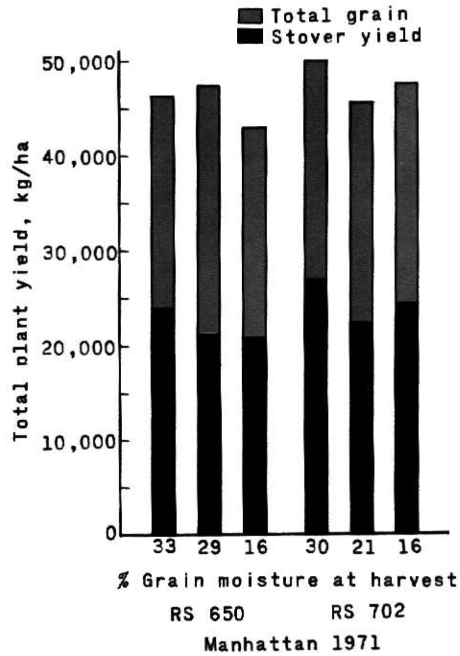

Figure 8. Total plant yield by percent moisture at harvest at Manhattan in 1971.

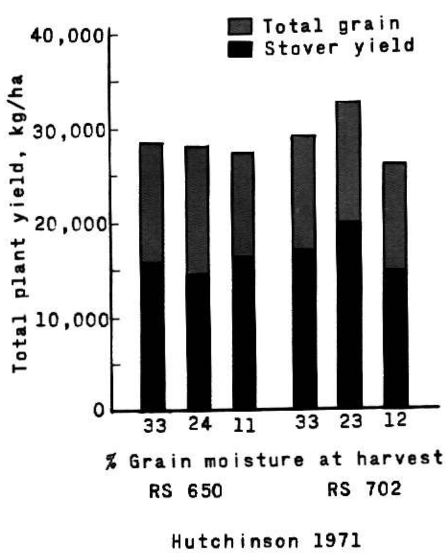

Figure 9. Total plant yield by percent moisture at harvest at Hutchinson 1971.

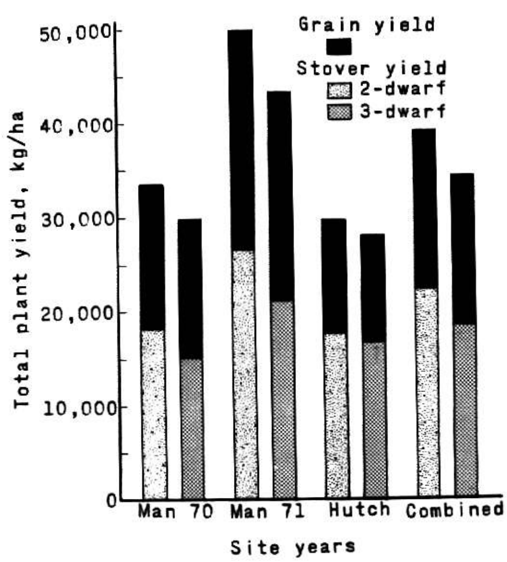

Figure 10. Total plant yields with 2-dwarf and 3-dwarf height genotypes.

for total plant yield, stover yield, and total grain yield. Tables 2, 3, 4, and 5 give the mean squares from the analyses of variance and L.S.D.s for the individual site-years and combined data.

With both varieties at Manhattan, in 1970, (Fig. 7) there was growth after the first harvest, however, with RS 702 physiological maturity of the grain had occurred (Fig. 2). The increase in yield in Fig. 6 was due to continued vegetative growth after the first harvest. With the third harvest of both varieties there was a 20% loss in total plant yield over the second harvest. This loss can be attributed to a dry weight loss in grain field losses and stover leaf loss. Losses were proportionately the same for grain and stover as a ratio of grain to stover of nearly 1:1 was maintained throughout all harvests.

At Mankato in 1970 the total plant yield was significantly greater for the two high moisture harvests over the low moisture harvest for the RS 650. Table 6 gives mean squares from the analysis of variance.

With RS 650 at Manhattan in 1971 (Fig. 8) there were the same trends as the year before. With RS 702 there was a significant drop in total plant yield after the first harvest and a significant increase with the third harvest. The decrease after the first harvest was attributed to a dry late summer which caused a loss of leaves in the late-maturing hybrid. The increase with the third harvest was due to growth of tillers during a warm, wet fall.

With RS 702 at Hutchinson in 1971 (Fig. 9) there were the same trends as in Manhattan in 1970 (Fig. 7). With RS 650 there was some late season growth similar to RS 702 at Manhattan 1971.

Advantages of 2-dwarf for total plant yield were 9.8%**, 13.6%**, 6.4%* and 10.6%**, and for stover yield were 19.2%**, 29.8%**, 12.2%** and 22.1%** for Manhattan 1970, Manhattan 1971, Hutchinson 1971 and site-years combined, respectively (Fig. 10). The majority of total plant yield increase for the 2-dwarf was due to increased stover yield (22.1%) and the rest from increased grain production (11.6%). The RS 702 total plant yield at Mankato in 1970 was highly significantly greater for the 2-dwarf over the 3-dwarf. In Fig. 10 there is a trend for greater yield differences between the heights as the yield levels become higher.

Light interception data gave no significant height effects or height interactions that could be used to explain the yield increase with 2-dwarf grain sorghum. Mean squares from the analysis of variance are given in Table 7.

Table 8 gives the heights of the sorghum at the different locations. Note that as the plants get taller because of a more favorable environment, the greater the differences between the height genotypes.

Although there was a highly significant yield advantage with 2-dwarf over 3-dwarf grain sorghum there are several drawbacks to its accepted use. One of these was increased lodging with the taller plants. At Mankato 1970 there was essentially no lodging with any of the lines, however, the yield levels were very low and height differences were slight (Table 7). At Manhattan in 1970 and 1971, and Hutchinson 1971 lodging was affected by variety and height genotype, with significant variety by height interactions. Grain moisture at harvest significantly affected lodging at Manhattan in 1970 and Hutchinson 1971. Figures 11, 12, and 13 show varieties', height genotypes', and harvest moisture's effects on lodging. Tables 2, 3, and 4 give the mean squares from the analyses of variance and L.S.D.s for the

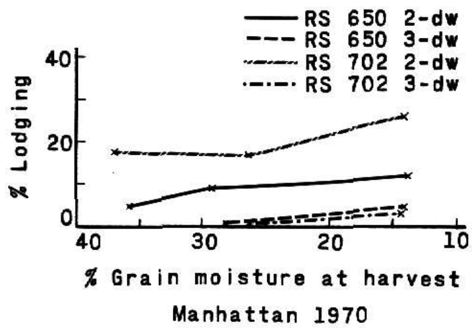

Figure 11. Percent lodging at Manhattan 1970.

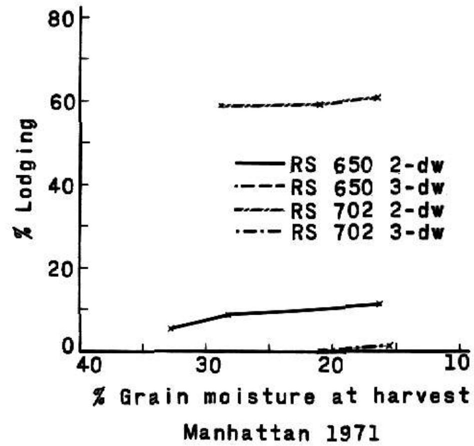

Figure 12. Percent lodging at Manhattan in 1971.

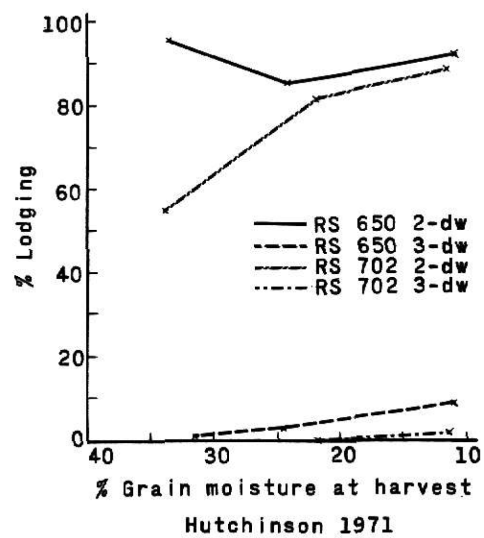

Figure 13. Percent lodging at Hutchinson in 1971.

individual site-years.

Figure 11 shows the lodging at Manhattan 1970. The lodging of the 2-dwarf was significantly greater for both varieties. Most lodging of the 2-dwarf occurred before the first harvest. Lodging at the first harvest of RS 650 2-dwarf was nearly the same as the last harvest of RS 650 3-dwarf. Therefore, lodging was nearly controlled by high moisture harvest in this portion of the study.

Figure 12 shows the lodging at Manhattan in 1971. Lodging of the 2-dwarf was significantly greater for both varieties. There was essentially no lodging of the 3-dwarf plants. A severe wind storm occurred on September 3, 1971 (7 days before the first harvest of RS 650). In this storm both varieties lodged with RS 702 being severely lodged. There was little lodging of either variety after this storm even though there were driving rain storms before the last harvest.

Figure 13 shows the lodging at Hutchinson in 1971. Lodging of the 2-dwarf was significantly greater for both varieties. In the September 3 wind storm the RS 650 lodged nearly 100% and the RS 702 lodged about 30% and continued to lodge throughout the harvest season.

In all site-years there was severe lodging of one or both varieties of 2-dwarf grain sorghum. Varieties lodged differently at each site-year.

Although 2-dwarf lodged considerably more than 3-dwarf it was felt that the plot size may have contributed to the lodging. With the split plot design there were blocks (7.6 m x 12.2 m) of tall and blocks of short plants. It may have been that tall plants protected short plants and caught more wind themselves. Larger blocks may have reduced the lodging of the 2-dwarf plants. Although this study did not prove it, lodging of 2-dwarf grain sorghum may be controlled by large field plantings and high moisture harvest.

Another problem with use of 2-dwarf grain sorghum may be its height. With our present combines it is nearly impossible to cut a plant that is over 2 m tall (Table 8). A combine platform will not raise much over 1 m and therefore too much vegetative material would have to be run through the machine. A possible solution would be to use the 2-dwarf, for its yield advantage, as a high-grain-content, chopped forage, or redesign combines so that they will harvest the taller plants.

Table 2. Mean squares from the analysis of variance and L.S.D.s for Manhattan in 1970.

	df	% Lodged	Plants/ ha, M	Heads/ plant	Thresh yield kg/ha x 10,000	% Grain moist	Thresh loss kg/ha x 10,000	% Thresh loss	Total grain yield kg/ha x 10,000	Stover yield kg/ha x 10,000	% Stover moist	Total plant yield kg/ha x 10,000
Replication	5	50.89	69.60	0.043	116.5	7.620	3.077	20.00	120.0	850.0	2.120	3508
Variety (V)	1	535.9**	9272**	2.769**	1894**	0.431	235.8**	255.2**	3466**	84105**	100.7**	276322**
Height (H)	1	2998.**	168.5	0.312	392.**	3.273	25.45**	156.9**	217.6*	13593**	15.13**	18788**
V x H	1	636.0**	48.68	0.002	117.4*	0.163	12.46*	8.080	206.2*	466.3	0.137	1831
Error (a)	15	36.45	63.50	0.084	23.61	3.941	2.542	8.048	26.67	286.4	1.277	1109
Moisture (M)	2	229.0**	52.03	0.009	111.8*	2720**	360.6**	1091.**	380.**	2082.**	161.0**	31045**
V x M	2	15.20	8.564	0.011	232.9**	26.93**	62.76**	186.3**	86.39	38.12	49.19**	919.3
H x M	2	26.03	96.08	0.086	51.35	3.186	2.474	9.997	51.37	45.95	7.821*	760.7
V x H x M	2	28.37	75.34	0.118	25.06	1.101	12.51*	27.58	15.68	27.32	1.583	759.2
Error (b)	40	23.40	43.69	0.060	28.63	3.703	1.494	9.920	28.45	226.3	1.156	796.0
L.S.D.$_{.05}$=												
V x H		4.29			339		113		366			
Moisture		2.82			312	1.12	91	1.84	311	877	0.72	1650
V x M												
V within M					693		207	4.09				
M within V					441		128	2.60				

Table 3. Mean squares from the analysis of variance and L.S.D.s for Manhattan in 1971.

	df	% Lodged	Plants/ ha, M	Heads/ plant	Thresh yield kg/ha x 10,000	% Grain moist	Thresh loss kg/ha x 10,000	% Thresh loss	Total grain yield kg/ha x 10,000	Stover yield kg/ha x 10,000	% Stover moist	Total plant yield kg/ha x 10,000
Replication	5	966.3	77.23	0.068	30.80	6.223	4.916	4.649	40.68	606.4	6.343	1998
Variety (V)	1	10506**	247.4*	0.121*	0.179	228.6**	3.852	3.672	5.683	3981.	25.48*	9697*
Height (H)	1	18311**	520.8**	0.111*	1353.**	6.043	542.4**	1027.**	182.3*	92311**	94.58**	83475**
V x H	1	10212**	3.447	0.147*	36.24	0.367	10.43	4.263	85.41	5172*	32.24*	12866*
Error (a)	15	967.7	46.57	0.024	42.52	3.040	2.348	4.213	40.02	906.8	5.385	2006
Moisture (M)	2	83.74	18.21	0.037	340.8**	1441.**	307.0**	519.9**	33.98	4492*	46.18**	4788
V x M	2	71.06	71.37	0.046	137.1*	92.44**	36.54**	75.45**	55.06	3821	2.416	7689*
H x M	2	52.81	66.43	0.021	5.792	8.523*	0.036	0.945	4.978	2697	7.393	3753
V x H x M	2	65.94	8.949	0.011	19.77	13.14**	0.174	0.137	21.63	346.0	9.569	1059
Error (b)	40	76.51	57.75	0.019	33.21	2.434	2.905	4.088	37.33	1196	7.315	2365
$L.S.D._{.05}$ =												
V x H		22.1		0.11			107			2140	1.56	3180
Moisture					336	0.91	100	1.18		2020	1.58	
V x M												
V within M					760		222	2.69				6310
M within V					629		141	1.67				4010

Table 4. Mean squares from the analysis of variance and L.S.D.s for Hutchinson in 1971.

	df	% Lodged	Plants/ ha, M	Heads/ plant	Thresh yield kg/ha x 10,000	% Grain moist	Thresh loss kg/ha x 10,000	% Thresh loss	Total grain yield kg/ha x 10,000	Stover yield kg/ha x 10,000	% Stover moist	Total plant yield kg/ha x 10,000
Replication	5	155.8	66.49	0.034	100.6	5.950	4.352	36.24	122.5	1065.	22.98	2975.
Variety (V)	1	1689**	83.33	0.080	306.7**	0.031	428.3**	2283.**	11.80	8910.**	1378.**	4099.*
Height (H)	1	116965**	713.7**	0.001	632.7**	0.151	226.5**	2026.**	98.42	5751.**	383.4**	6420.*
V x H	1	740.4*	7.344	0.002	0.809	0.880	1.382	3.953	4.294	432.5	0.178	360.1
Error (a)	15	129.3	67.77	0.025	29.99	4.326	9.766	52.05	33.78	418.7	13.12	853.3
Moisture (M)	2	574.6**	1326.**	0.420**	38.87	2792.**	433.9**	1751.**	232.6**	3126.**	1763.**	8382.**
V x M	2	594.2**	372.0**	0.103*	32.20	5.450	50.38**	187.0**	10.28	6720.**	483.5**	7617.**
H x M	2	168.2	7.052	0.016	31.55	10.96	10.73	29.92	57.80*	101.3	33.76	512.2
V x H x M	2	856.2**	52.84	0.004	13.86	0.704	0.137	4.259	15.97	207.9	72.29*	825.8
Error (b)	40	100.0	58.33	0.025	14.51	4.956	4.632	25.50	16.01	200.3	16.16	368.4
$L.S.D._{.05}$ =												
V x H		8.07										
Moisture		5.83	4.93	0.09		1.30	125	2.89	204	722	2.30	997
V x M												
V within M		13.7					319	7.44		1870		2900
M within V		8.25					177	4.16		1040		1580
V x H x M												
V,H within M		25.6										
M within V,H		11.7										

Table 5. Mean squares from the analysis of variance and L.S.D.s for site-years combined.

	df	Plants/ ha, M	Thresh yield kg/ha x 10,000	% Grain moist	Thresh loss kg/ha x 10,000	Total grain yield kg/ha x 10,000	Stover yield kg/ha x 10,000	Total plant yield kg/ha x 10,000
Replication	5	87.29	113.3	6.685	6.946	161.2	1609.	6310.
Site years (S)	2	16024.**	26020**	211.7**	540.4**	26128**	121039**	67453**
Error (a)	10	63.07	67.29	6.554	2.700	61.00	455.7	1124.
Variety (V)	1	4893.**	1259.**	71.42**	3.800	1124.**	66751**	157855**
Height (H)	1	1303.**	2218.**	0.023	627.5**	485.8**	82090**	85395**
S x V	2	2374.**	471.0**	78.79**	332.0**	1179.**	15122**	66132**
S x H	2	50.05	75.94	4.722	83.48**	6.292	14783**	11650**
V x H	1	1.936	84.90	0.002	10.39	154.5*	1686.*	10232**
S x V x H	2	28.77	34.81	0.704	6.941	70.71	2193.*	2413.
Error (b)	45	59.29	31.80	3.769	4.886	33.49	537.3	1323.
Moisture (M)	2	750.3**	94.41*	6801.**	935.2**	470.3**	5445.**	30883**
S x M	4	323.1**	198.6**	76.61**	83.24**	88.57*	2127.**	6666.**
V x M	4	129.6	152.9**	90.18**	9.196	90.27*	73.29	459.2
S x V x M	4	161.2*	124.7**	17.32**	70.25**	30.71	5252.**	7883.**
H x M	2	81.44	40.40	8.239	2.385	30.38	761.7	1078.
S x H x M	4	44.04	24.15	7.213	5.427	41.88	1041.	1974.
V x H x M	2	49.06	12.11	5.683	3.416	14.98	46.91	711.5
S x V x H x M	4	44.04	23.29	4.633	4.453	19.15	267.1	966.4
Error (c)	120	53.25	25.45	3.690	3.312	27.67	540.9	1177.
L.S.D.$_{.05}$=								
Moisture			167	0.63	60	172		
V x H						225	902	1410
V x M								
V within M			384		142	395		
M within V			235		85	244		

Table 6. Mean squares from the analysis of variance and L.S.D.s for Mankato in 1970.

		% Lodged	Plants/ ha, M	Heads/ plant	Thresh yield kg/ha x 10,000	% Grain moist	Thresh loss kg/ha x 10,000	% Thresh loss	Total grain yield kg/ha x 10,000	Stover yield kg/ha x 10,000	% Stover moist	Total plant yield kg/ha x 10,000
RS 650												
Replication	5	1.513	245.3	0.271	102.6	12.46	2.872	7.515	110.6	273.4	1.339	1155.
Height (H)	1	4.473	0.055	0.002	52.21	1.388	0.102	64.75	38.01	2954.*	17.04	882.8
Error (a)	5	1.633	133.1	0.097	31.45	5.255	1.577	9.997	35.18	275.0	4.465	509.5
Moisture (M)	2	2.648	29.45	0.102	17.76	567.9**	5.665**	89.83**	34.10*	231.8	5.942**	1414.**
H x M	2	0.552	59.25	0.010	7.140	7.039	0.524	1.666	9.158	283.6	9.833**	215.0
Error (b)	20	2.127	42.08	0.038	5.634	2.452	0.461	5.927	6.815	93.40	1.014	229.7
RS 702 Forage												
Replication	5	0.000	558.4								3.265	346.9
Height	1	0.000	32.21								0.301	4182**
Error	5	0.000	57.73								1.644	468.0

Table 7. Mean squares from the analysis of variance for light interception in langleys at Manhattan in 1971.

	df	Mean squares
Replication	3	1321.
Variety (V)	1	826.6
Height genotype (H)	1	4970.
Height in plant canopy (P)	1	21978.*
Position in row (R)	1	72222.**
V x H	1	13572.
V x P	1	3630.
V x R	1	85.56
H x P	1	5329.
H x R	1	14042.
P x R	1	126.6
V x H x P	1	196.0
V x H x R	1	552.2
V x P x R	1	637.6
H x P x R	1	8010.
V x H x P x R	1	2070.
Error	45	5457.

Table 8. Height (cm) of grain sorghum from ground to tip of head.

	RS 650		RS 702	
	2-dwarf	3-dwarf	2-dwarf	3-dwarf
Manhattan 1970	135	95	161	110
Mankato 1970	89	75	114	88
Manhattan 1971	217	126	254	130
Hutchinson 1971	138	107	150	102

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PERFORMANCE OF 2-DWARF AND 3-DWARF GRAIN SORGHUM HYBRIDS HARVESTED AT VARIOUS MOISTURE CONTENTS

by

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AN ABSTRACT OF A MASTER'S THESIS

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Experiments were conducted at Mankato in 1971, Manhattan in 1970 and 1971, and Hutchinson in 1971 to see if in producing combine (3-dwarf) varieties the potential grain yield of sorghum had been reduced. High moisture harvesting was used to determine its effect on lodging, threshing loss, grain yield, and stover yield. Isogenic RS 650 and RS 702 hybrid grain sorghums differing by one gene (Dw_3, called 2-dwarf and 3-dwarf) were used. The experimental design was a split-plot with combinations of hybrids and heights the main plots, and grain moisture content at harvest the subplots. The tall, 2-dwarf sorghum was found to yield 12.7% more threshed grain, 11.6% more total grain, and 22.1% more stover than the short, 3-dwarf plants. The 2-dwarf sorghum lodged significantly more in late season wind storms at three of the locations. Harvesting sorghum at about 26% grain moisture yielded 8.4% more total grain and 7.4% more stover than harvesting at 14% grain moisture. Threshing losses were significantly higher when the grain was harvested at high moisture. Threshing losses were significantly lower for the 2-dwarf than the 3-dwarf grain sorghum.