FLAMING TO DELAY FLOWERING IN GRAIN SORGHUM,
SORGHUM BICOLOR, (L.) MOENCH

by

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INTRODUCTION

Hybrid grain sorghum has played an increasingly important role in the nation's agriculture. It is adapted to drier areas and makes a good livestock feed. Many commercial seed companies are engaged in producing hybrid sorghum seed.

Many problems have been encountered in producing hybrid sorghum seed. One such problem is getting the two parent lines to bloom at nearly the same time for good pollination. There are several methods that have been used to try to delay flowering of one of the parent lines. The one most often used is delayed planting of one line. Several factors make this method undesirable. Such factors are unpredictable response of plants to different planting time, unpredictable weather conditions, disturbance of preemergence herbicides if used, and increased labor costs. Other methods employed to delay flowering are increasing the fertilizer applied to the line with the later maturity, increasing the spacing between plants in the row, and cutting back the leaf area of the earlier maturing line. These methods work with varied success, the delayed planting method used most often.

It was noted with interest that grain sorghum flamed in weed control experiments at Kansas State University was delayed in flowering over the unflamed check plots. With this in mind, an experiment was initiated in 1966, using RS 610 grain sorghum to determine if the flowering of grain sorghum could be delayed by flaming; and, if so, could varing degrees of delay be obtained.

REVIEW OF LITERATURE

Green (1949) reported small significant delays of white inbred lines of corn when flamed at two inches of height and flamed again when the regrowth reached two inches in height. One flaming at two inches was not effective in causing delay; however, flaming at four and eight inches caused significant delays. A slight reduction in yield was caused by flaming at these stages of growth.

Dungan and Gausman (1951) conducted a clipping experiment on single cross and inbred lines of corn to delay their development. Their results indicated clipping corn plants in the early stage of development was a practical means of delaying reproductive development. The most delay and least yield reduction was obtained by clipping the plants severely in the early stages of development. A weeks delay in silking and pollen shedding was obtained; however, this was accompanied by a 50% reduction in yield. Pollen production was also reduced when delays were obtained.

Register, Mahoney, and Minton (1968) observed that several male corn lines were delayed by flaming. The amount of delay could not be determined because no check was left. It made little difference whether the speed of travel was 2.5 or 4.0 mph. In one case, a delay of one week or more was obtained; however, pollen production was reduced as the tassels on the flamed plants were only about one-half normal size.

Price and Longnecker (1962) reported "flaming off" grain sorghum when the plants were one to three inches tall caused the grain sorghum plants to be delayed five to six days. This is the length of time required for the plants to regain their size at flaming. Longnecker[1] more recently stated that grain sorghum could be flamed each time it reached a height of one to two inches for a total of three flamings without affecting stand or yield. Each flaming delayed maturity from three to five days.

Howard (1967) reported no observed differences or harmful effects occurred on plant height, head length, head exsertion, or bloom period as a result of flaming at the pre-boot (six weeks after emergence), boot, and flower stages of growth of grain sorghum.

METHODS AND MATERIALS

RS 610 grain sorghum was planted at the Kansas State University Agronomy Farm and at the South-central Kansas Experiment Field near Hutchinson, Kansas, in 1966, and 1967. Plantings were made on May 18, 1966, and May 26, 1967, at the Agronomy Farm and on June 6, 1966, and June 5, 1967, at Hutchinson. The May 18, 1966, planting at the Agronomy Farm was severely damaged by a tornado and hail storm on June 8; consequently, a replanting was made on June 13, 1966. Plantings were made in 30 inch rows. Single row plots, 20 feet long, bordered by single untreated rows were used with an alley of fifteen feet between each range. Four replications of a randomized complete block design were used. Snedecor (1956) and LeClerg, Leonard, and Clark (1962) were used for statistical references.

The soil at the Agronomy Farm is an unnamed silt loam. Fertilizer was applied preplant at the following rates: 104.5 pounds per acre of nitrogen in 1966, and 56.7 pounds per acre of nitrogen in 1967. Environmental

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[1] Thomas C. Longnecker personal communication October, 1966.

conditions were very different for the two years. The 1966 growing season at Manhattan was characterized by lower than average rainfall (11.22 inches lower than average for April through September) and high temperatures. The 1967, growing season at Manhattan had higher than average rainfall (2.90 inches higher than average for April through September) and lower temperatures. At Manhattan, daily high temperatures in July 1966, averaged 96 degrees, while the July average in 1967, was 87 degrees. There were nine days in July 1966, that had high temperatures of 100 degrees or more. Seven of those days had high temperatures of 105 degrees or more. In July 1967, there were two days of 100 degrees or more.

The soil at the South-central Kansas Experiment Field is a Clark-Ost complex. No fertilizer was applied to the test site. Environmental conditions were similar to the Manhattan site in that the 1966 growing season was dryer and hotter than the 1967 season. The rainfall for the six-month period, April through September, was 7.05 inches below normal in 1966, and 5.68 inches above normal in 1967. There were 14 days in July, 1966, that had temperatures above 100 degrees. There were no days of temperature above 100 degrees in July 1967. Average daily high temperature was 97 degrees in July, 1966, and 88 degrees in July, 1967.

Flaming equipment used was similar to that used for weed control with the addition of a single burner directly over and parallel to the row. The single burner was 8 inches above the soil surface when measured at the tip of the burner, and inclined at a 30 degree angle from the horizontal. The two-burner arrangement utilized burners that were inclined at 30 degree angles from the horizontal, 8 inches from the soil surface when measured at the tip of the burner, and 12 inches from the row of plants when measured horizontally from the tip of the burner. The burners were placed perpendicular to the row of plants, and they were staggered so that the flame from each did not meet in the row of plants (Fig. 1). AFCO standard burners requiring LP Gas in liquid form were used. The gas pressure used was 20 pounds per square inch. An ignition system for the burners was mounted on the tractor. Speeds of 1.5, 3.0, and 4.5 mph were used.

Flamings were made at three stages of growth: 3-leaf, 5-leaf, and 8-leaf stages. The stage is characterized by when the collar of the designated leaf is fully visible. The 8-leaf stage was also characterized by floral initiation in RS 610. These stages were used separately and in all possible combinations (Table 1). When plots were to be flamed more than one time, the second and third flamings were made when the check plots reached the desired stage of growth.

Table 1. Combinations of flaming at different stages of growth. A plus indicates the plants were flamed at that stage.

Combination	Stage of growth		
	3-leaf	5-leaf	8-leaf
001	-	-	+
010	-	+	-
100	+	-	-
011	-	+	+
101	+	-	+
110	+	+	-
111	+	+	+

Three bloom measurements were taken to measure bloom date and length of time the plants were in bloom. Measurements taken were days from planting to first, half, and full bloom. First bloom was noted when any plants in the row were in bloom; half-bloom was noted when 50% of the plants in the row were

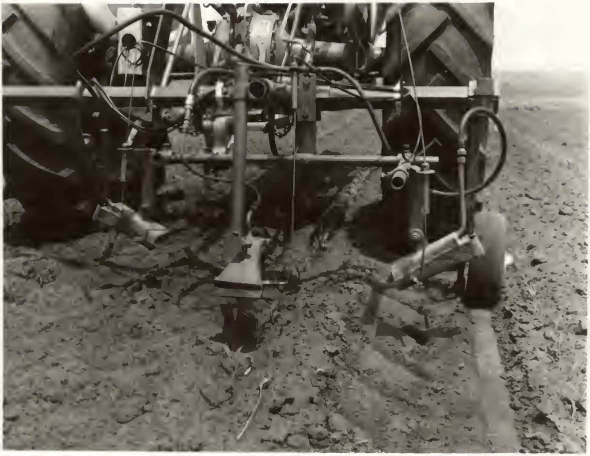


Fig. 1. Flaming equipment that was used. The single burner was used alone and the two-burners perpendicular to the row were used together.

in bloom; and, full bloom was when 95% of the plants in the row were in some stage of bloom. Duration of bloom was obtained by subtracting the days from planting to first bloom, from the days from planting to full bloom.

Delay in bloom was obtained by subtracting the days from planting to first, half, or full bloom of the check plot from the corresponding days from planting to first, half or full bloom of the treated plots on an individual replication basis.

Number of heads in the fifteen foot section of row that was harvested for grain yield was recorded. Grain yield per acre was calculated and adjusted to 12.5% moisture.

RESULTS AND DISCUSSION

The order of the combinations as shown in Table 1 is thought to be the order of increasing severity. Therefore, the following tables have the combinations listed in this order. Combinations 101, 110, and 111 at 1.5 mph were left out of all analyses of the Manhattan data because those treatments killed all or nearly all the plants.

MANHATTAN EXPERIMENTS

Days Delay, First Bloom. Speeds, combinations, and burners affected delays obtained for first bloom at Manhattan in 1966. Most delay was caused by the 1.5 mph treatments followed by the 3.0 mph treatments which caused more delay than the 4.5 mph treatments. In general, the combination effects followed the expected severity of flaming as described above.

The speed by combination interaction was highly significant (Table 2). All combinations of flaming caused more delay when flamed at 1.5 mph as compared to 3.0 mph except when flamed at combination 001 (Fig. 3). Also, all combinations except 001 and 010 caused significantly more delay at 3.0 mph than at 4.5 mph. The difference between combinations 010 and 100 was significant at 1.5 mph with the latter causing more delay. Also, combinations 101 and 110 at both 3.0 mph and 4.5 mph were significantly different with combination 110 causing more delay. There was a burner arrangement by combination interaction significant in these data. Significant differences were found between burner arrangements at all combinations except 001 and 010 (Fig. 2). The single burner caused more delay at all except combination 001. Differences between combinations were significant for the following pairs of combinations with the first one listed causing less delay than the second: 001 and 010, 010 and 100, 101 and 110, 110 and 111 for the single burner and 001 and 010, 100 and 011, 101 and 110 for the two-burner arrangement.

Table 2. Analysis of variance for days delay, first bloom at Manhattan, 1966.

Source	DF	MS	F
Replication	3	48.77	
Burner	1	152.11	50.20**[1]
Speed	2	100.13	33.05**
Burner x Speed	2	3.94	1.30
Combination	6	237.52	78.39**
Burner x Combination	6	10.63	3.51**
Speed x Combination	9	37.21	12.28**
Burner x Speed x Combination	9	3.31	1.09
Error	105	3.03	

[1]The terms highly significant (**) and significant (*) will be used to designate probabilities of less than 0.01 and between 0.05 and 0.01, respectively.

The 1967, Manhattan data for days delay at first bloom did not have differences as large as the 1966 data; however, speeds, combinations, and burners affected delays.

Both the speed by combination and burner by combination interactions were significant (Table 3). In the speed by combination interaction, only with combination 011 did 1.5 mph cause significantly more delay than 3.0 mph (Fig. 5). There were no significant differences between 3.0 mph and 4.5 mph. Also, at 3.0 mph, combination 110 caused significantly more delay than the less severe combinations. Combination 010 caused more delay than 001 at all speeds. In the burner by combination interaction, flaming with one burner caused less delay than flaming with the two-burner arrangement only with combination 011 and 110 (Fig. 4). There were also significant differences

Fig. 2. The effect of burner arrangements and combinations on days delay, first bloom at Manhattan in 1966. (* These combinations are based on 3.0 and 4.5 mph values since all or nearly all the plants were killed at 1.5 mph).

Fig. 3. The effect of speeds and combinations on days delay, first bloom at Manhattan in 1966. (+ All least significant difference values were calculated at the 5% level of probability. * At 1.5 mph, all or nearly all the plants were killed at Manhattan with combinations 101, 110, and 111).

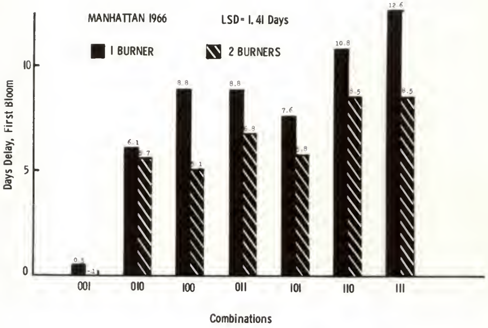

MANHATTAN 1966
LSD= 1.41 Days
1 BURNER
2 BURNERS
Days Delay, First Bloom
Combinations
001
010
100
011
101
110
111

Fig. 2

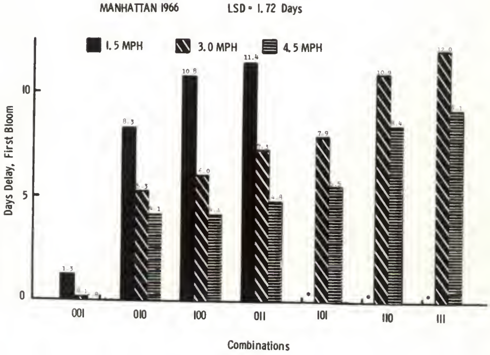

MANHATTAN 1966
LSD = 1.72 Days
1.5 MPH
3.0 MPH
4.5 MPH
Days Delay, First Bloom
Combinations
001
010
100
011
101
110
111

Fig. 3

among combinations. Combination 010 caused significantly more delay than 001 with both burner arrangements. With the two-burner arrangement, combination 100 caused less delay than 011. Combination 110 caused significantly less delay than combination 111 when flamed with one burner but caused significantly more delay than any of the other combinations when flamed with the two-burner arrangement.

Table 3. Analysis of variance for days delay, first bloom at Manhattan, 1967.

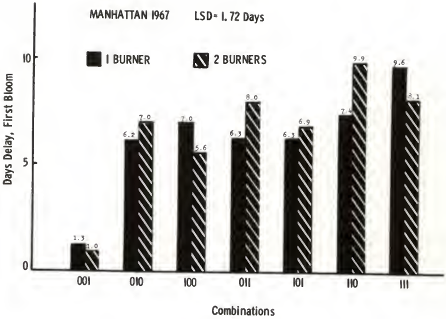
Source	DF	MS	F
Replication	3	13.38	
Burner	1	3.68	<1
Speed	2	10.97	2.43
Burner x Speed	2	8.73	1.94
Combination	6	143.88	31.90**
Burner x Combination	6	11.19	2.48*
Speed x Combination	9	17.29	3.83**
Burner x Speed x Combination	9	2.40	<1
Error	105	4.51	

The F ratio for the error variances for the two years approached significance at the 5% level. However, from a practical standpoint, it was considered important that a combined analysis be run, recognizing that the significance levels would not be exact. Years, burners, speeds, and combinations affected delay.

As before, there were several significant interactions (Table 4). The speed by combination interaction showed that there were differences among speeds and among combinations at the same speed. In the burner by combination interaction, there were more differences between consecutive combinations for the one burner arrangement than for the two-burner arrangement. The other interaction that was significant was the year by combination

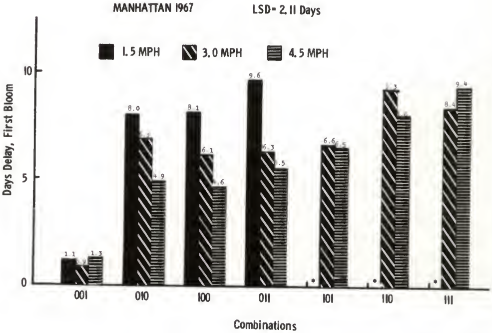
Fig. 4. The effect of burner arrangements and combinations on days delay, first bloom at Manhattan in 1967.

Fig. 5. The effect of speeds and combinations on days delay, first bloom at Manhattan in 1967.



MANHATTAN 1967
LSD= 1.72 Days
1 BURNER
2 BURNERS
Days Delay, First Bloom
0
5
10
1.3
1.0
6.2
7.0
7.0
5.6
6.3
8.0
6.3
6.9
7.4
9.9
9.6
8.1
001
010
100
011
101
110
111
Combinations

Fig. 4



MANHATTAN 1967
LSD= 2.11 Days
1.5 MPH
3.0 MPH
4.5 MPH
Days Delay, First Bloom
0
5
10
1.1
1.3
8.0
4.9
8.1
6.1
9.6
6.3
6.6
6.5
8.4
9.4
001
010
100
011
101
110
111
Combinations

Fig. 5

and year by burner by speed interactions.

Table 4. Analysis of variance for days delay, first bloom combined over years at Manhattan, 1966 and 1967.

Source	DF	MS	F
Years	1	5.28	1.40
Replications/Years	6	29.41	
Burner	1	54.25	14.39**
Year x Burner	1	101.54	26.93**
Speed	2	88.53	23.48**
Year x Speed	2	22.57	5.99**
Burner x Speed	2	0.56	<1
Year x Burner x Speed	2	12.11	3.21*
Combination	6	372.81	98.89**
Year x Combination	6	8.58	2.28*
Burner x Combination	6	15.96	4.23**
Year x Burner x Combination	6	5.86	1.55
Speed x Combination	9	48.86	12.96**
Year x Speed x Combination	9	5.64	1.50
Burner x Speed x Combination	9	3.59	<1
Year x Burner x Speed x Combination	9	2.11	<1
Error (b)	210	3.77	

The single burner arrangement caused significantly more delay with combinations 100 and 111 than the two-burner arrangement (Fig. 6). Significant differences were noted between the following pairs of combinations with the first combination listed causing the least delay; 001 and 010, 010 and 100, 101 and 110, 110 and 111 for the single burner arrangement, and 001 and 010, 100 and 011, 101 and 110 for the two-burner arrangement.

The speed by combination interaction shows significant differences between speeds at all combinations except 001, 101, and 111 (Fig. 7). The 1.5 mph speed caused the most delay followed by 3.0 mph and 4.5 mph. Significant differences between combinations at the same speed occurred between combinations 001 and 010, and 101 and 110 with the first listed causing the least delay at all speeds.

Fig. 6. The effect of burner arrangements and combinations on days delay, first bloom at Manhattan combined 1966 and 1967 data.

Fig. 7. The effect of speeds and combinations on days delay, first bloom at Manhattan combined 1966 and 1967 data.

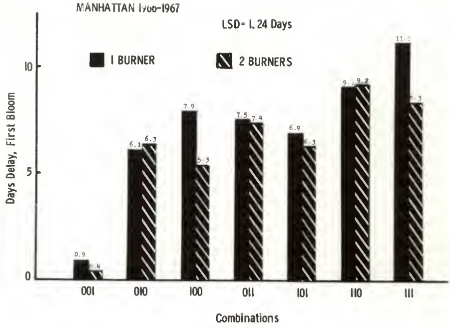

MANHATTAN 1966-1967
LSD= 1.24 Days
1 BURNER
2 BURNERS
Days Delay, First Bloom
Combinations
001
010
100
011
101
110
111

Fig. 6

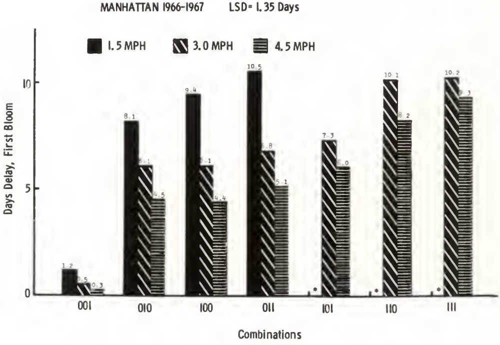

MANHATTAN 1966-1967
LSD= 1.35 Days
1.5 MPH
3.0 MPH
4.5 MPH
Days Delay, First Bloom
Combinations
001
010
100
011
101
110
111

Fig. 7

The year by combination interaction showed significant differences between years only for combination 101 and 111 with these causing significantly more delay in 1966 (Table 5). Within one year, significant differences were shown between combinations 001 and 010 for both years with 001 causing the least delay. Also, combination 101 caused significantly less delay than combination 110 in 1967. Combinations 101 and 111 caused significantly more delay in 1966 than in 1967.

Table 5. The affect of combinations of flaming on days delay, first bloom in both years.

Combinations	Years 1966	1967
001	0.21	1.08
010	5.88	6.58
100	6.96	6.29
011	7.79	7.13
101	8.63	6.56
110	9.63	8.63
111	10.56	8.88
LSD = 1.10 Days		

The year by burner by speed interaction showed significant differences within one year and between years with the 1966 data having more delay in most cases where there was a significant difference (Table 6).

Table 6. The affect of burner arrangements and speeds of travel on days delay, first bloom in both years.

	1966		1967	
	Burner Arrangements			
Speed, mph	I	II	I	II
1.5	8.63	7.19	6.94	6.50
3.0	8.36	5.75	5.75	6.93
4.5	5.76	4.11	5.79	5.68
LSD = 1.20 Days				

Results of the combined data showed the general trends of the individual years data. That is, 1.5 mph caused more delay than 3.0 mph, and 3.0 mph caused more delay than 4.5 mph. Combination 001 did not significantly delay flowering and caused significantly less delay than combination 010. Also, the combinations follow the order of severity as outlined in Table 2. Differences between years were usually less than 2 days.

Days Delay, Half-Bloom. Speeds, combinations, and burners significantly affected the delays obtained at Manhattan in 1966. In general, 1.5 mph caused more delay than 3.0 mph and 3.0 mph caused more delay than 4.5 mph. Combinations caused more delay as they increased in expected severity. Burner arrangements were significantly different even though the difference was only one day.

The speed by combination interaction was highly significant (Table 7). All combinations at 1.5 mph, except combination 001, were significantly different from those same combinations at 3.0 mph (Fig. 8). Combination 001 was significantly different from 010 at all speeds, but only at 1.5 mph did combination 001 cause significant delay. Combination 100 caused more delay than 010 at 1.5 mph. Flaming at all three stages of growth at both 3.0 and 4.5 mph caused significantly more delay than all the other combinations at those speeds.

The Manhattan 1967 data showed only speeds and combinations affected delays. In general, the same trends were evident as in the 1966 data.

The speed by combination interaction was again highly significant (Table 8). The only significant difference between speeds occurred at combination 011 between 1.5 mph and 3.0 mph (Fig. 9). Combination 001 caused significantly less delay than 010 at all speeds but did not cause significant

Table 7. Analysis of variance for days delay, half-bloom at Manhattan, 1966.

Source	DF	MS	F
Replication	3	158.09	
Burner	1	38.03	27.76**
Speed	2	17.81	13.00**
Burner x Speed	2	1.09	<1
Combination	6	134.97	98.52**
Burner x Combination	6	2.03	1.48
Speed x Combination	9	11.99	8.75**
Burner x Speed x Combination	9	1.63	1.18
Error	105	1.37	

delay at any speed. Other significant differences among combinations occurred between 100 and 011 at 1.5 mph, 101 and 110 at 3.0 mph, and 110 and 111 at 4.5 mph with the first combination of the pair causing significantly less delay.

Table 8. Analysis of variance for days delay, half-bloom at Manhattan, 1967.

Source	DF	MS	F
Replication	3	14.50	
Burner	1	0.69	<1
Speed	2	11.31	1.83
Burner x Speed	2	14.38	2.33
Combination	6	171.35	27.77**
Burner x Combination	6	5.79	<1
Speed x Combination	9	26.20	4.25**
Burner x Speed x Combination	9	6.54	1.06
Error	105	6.17	

In general, both years data were similar, but the F ratio of the error variances was larger than the tabular F value; thus, the tests did not have homogeneous variances. The magnitude of delays was fairly comparable over years, and the same trends held true, except that, there were burner arrangement differences in 1966.

Fig. 8. The effect of speeds and combinations on days delay, half-bloom at Manhattan in 1966.

Fig. 9. The effect of speeds and combinations on days delay, half-bloom at Manhattan in 1967.

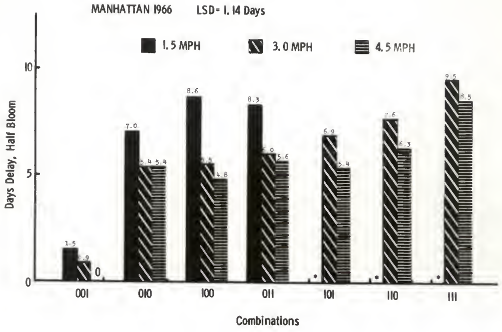

MANHATTAN 1966 LSD= 1.14 Days
1.5 MPH
3.0 MPH
4.5 MPH
Days Delay, Half Bloom
Combinations
001
010
100
011
101
110
111

Fig. 8

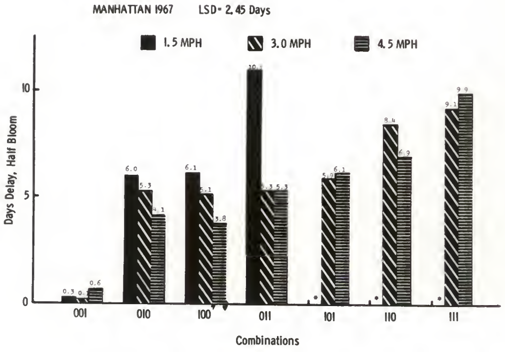

MANHATTAN 1967 LSD= 2.45 Days
1.5 MPH
3.0 MPH
4.5 MPH
Days Delay, Half Bloom
Combinations
001
010
100
011
101
110
111

Fig. 9

Days Delay, Full Bloom. Speeds and combinations affected delays for the 1966, Manhattan data. The most delay was caused by the 1.5 mph treatments followed by 3.0 mph which caused more delay than 4.5 mph treatments. There were significant differences among combinations with the least delay caused by less severe combinations.

The speed by combination interaction was highly significant (Table 9). This is one of the two cases where flaming at the 8-leaf stage only at 1.5 mph with one burner gave significant delay (Fig. 10). Combination 010 caused significantly more delay than combination 001 at all speeds. The other significant difference between combinations was between combinations 011 and 111 at 4.5 mph with 111 causing significantly more delay than all other combinations at that speed. Combinations 001, 010, and 100 at 1.5 mph caused significantly more delay than those same combinations at 3.0 mph. Combination 110 caused significantly more delay at 3.0 mph than at 4.5 mph.

Table 9. Analysis of variance for days delay, full bloom for Manhattan, 1966.

Source	DF	MS	F
Replication	3	235.13	
Burner	1	25.00	8.12**
Speed	2	23.60	7.66**
Burner x Speed	2	1.09	<1
Combination	6	50.24	16.31**
Burner x Combination	6	4.83	1.57
Speed x Combination	9	13.85	4.50**
Burner x Speed x Combination	9	6.27	2.23
Error	105	3.08	

Speeds and combinations affected delays in 1967, at Manhattan. The magnitude of delay was larger in these data than in the 1966 data. The variability was higher than some of the other tests; thus, there were not as many significant differences. However, the same trends as was noted for days delay, first and half-bloom were observed.

The speed by combination interaction was significant (Table 10). There was no significant difference between combination 001 and combination 010 at 4.5 mph (Fig. 11). There was a large difference obtained between combination 100 and combination 011 at 1.5 mph. Delay obtained for combination 100 is low compared with the trends for delays at first and half-bloom.

Table 10. Analysis of variance for days delay, full bloom at Manhattan, 1967.

Source	DF	MS	F
Replication	3	37.23	
Burner	1	0.16	<1
Speed	2	29.68	2.88
Burner x Speed	2	17.78	1.73
Combination	6	248.23	24.12**
Burner x Combination	6	12.78	1.24
Speed x Combination	9	62.26	6.05**
Burner x Speed x Combination	9	12.23	1.19
Error	105	10.29	

Days delay at full bloom is probably not of much interest for those engaged in seed production. They are more interested in getting approximately half of the male parent in bloom when the female is starting to bloom.

Days from Planting to Bloom. The number of days from planting to first bloom gave the same results as days delay, first bloom. This is as expected because the delay data have been coded by subtracting the check values for days to first bloom. This also holds true for the half and full bloom data. The corresponding analyses of variance are the same except for replicate effects. Therefore, tables of the data are in the (Appendix Tables 1, 2, 3, 4, 5, and 6).

Fig. 10. The effect of speeds and combinations on days delay, full bloom at Manhattan in 1966.

Fig. 11. The effect of speeds and combinations on days delay, full bloom at Manhattan in 1967.

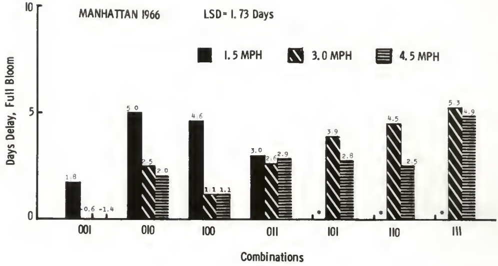

MANHATTAN 1966
LSD= 1.73 Days
1.5 MPH
3.0 MPH
4.5 MPH
10
5
0
Days Delay, Full Bloom
1.8
0.6
-1.4
5.0
2.5
2.0
4.6
1.1
1.1
3.0
2.6
2.9
3.9
2.8
4.5
2.5
5.3
4.9
001
010
100
011
101
110
111
Combinations

Fig. 10

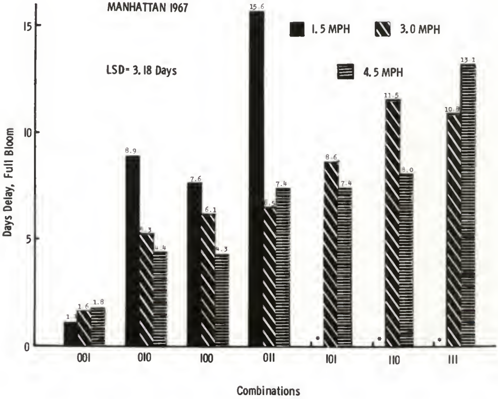

MANHATTAN 1967
LSD= 3.18 Days
1.5 MPH
3.0 MPH
4.5 MPH
15
10
5
0
Days Delay, Full Bloom
15.6
1.6
1.8
8.9
4.4
7.6
6.1
4.3
7.4
8.6
7.4
11.5
8.0
10.8
13.1
001
010
100
011
101
110
111
Combinations

Fig. 11

Duration of Bloom. Speeds and combinations affected duration of bloom, the number of days from first to full bloom, for both years at Manhattan. Burners also had an effect in 1966.

Two burners caused the duration of bloom to be about one day longer than the single burner. The trend shown in the speed by combination interaction was for the duration of bloom to be shortened as the treatments increased in severity, especially at 1.5 mph.

Burner arrangements were highly significant (Table 11). The single burner arrangement caused a shorter duration of bloom than the two-burner arrangement but the difference was slightly over one day. This difference is not of much practical importance. The speed by combination interaction was highly significant (Table 11). Combination 010 caused duration of bloom to be significantly shorter than combination 001 at 1.5 mph (Table 12). Also, combination 100 caused duration of bloom to be significantly shorter than combination 010 at 1.5 mph. Combination 101 had significantly longer duration of bloom than combination 110 at 3.0 and 4.5 mph. Combination 110 at 4.5 mph had shorter duration of bloom than was expected if the data would have followed a distinct trend. Combination 011 caused a significantly different duration of bloom between 1.5 and 3.0 mph, and between 3.0 and 4.5 mph with the slower speed in each case having shorter duration of bloom. Combination 111 at 3.0 mph caused significantly shorter duration of bloom than at 4.5 mph. Combination 001 was within three-fourths of a day of the check at all speeds. Therefore, flaming at combination 001 did not affect the duration of bloom.

The Manhattan data for 1967 showed speeds and combinations affected duration of bloom. The weak trend shown by the speed by combination interaction was the opposite of the trend in the 1966, data. That is, the more severe treatments caused the duration of bloom to be longer.

Table 11. Analysis of variance for duration of bloom at Manhattan, 1966.

Source	DF	MS	F
Replication	3	9.95	
Burner	1	55.01	10.38**
Speed	2	32.51	6.13**
Burner x Speed	2	5.15	<1
Combination	6	84.96	16.03**
Burner x Combination	6	8.96	1.69
Speed x Combination	9	21.09	3.98**
Burner x Speed x Combination	9	6.60	1.25
Error	105	5.30	

Table 12. The affect of speeds of travel and combinations of flaming on the duration of bloom (days) at Manhattan in 1966.

	Speed, mph		
Combinations	1.5	3.0	4.5
001	12.25	11.00	11.13
010	8.50	9.00	9.63
100	5.63	6.88	8.75
011	3.38	7.13	9.88
101	*	7.75	9.00
110	*	5.38	5.88
111	*	5.00	7.50

Check = 11.75 Days LSD = 2.28 Days

The speed by combination interaction was highly significant (Table 13). As was true in the 1966 data, combination 001 at all speeds did not differ from the check by more than three-fourths of a day (Table 14). The duration of bloom of the check was 5 days shorter in 1967, however. Combinations 010 and 011 at 1.5 mph caused significantly longer duration of bloom than at 3.0 mph. Combination 011 caused significantly longer duration of bloom than 100 at 1.5 mph; and, combination 111 caused significantly longer duration of bloom than combination 011 at 1.5 mph. Combination 001 had significantly longer duration of bloom than combination 010 at 3.0 mph; however, combination 010 had a shorter duration of bloom than would be expected.

Table 13. Analysis of variance for duration of bloom, Manhattan, 1967.

Source	DF	MS	F
Replication	3	10.80	
Burner	1	3.07	<1
Speed	2	6.43	1.19
Burner x Speed	2	1.84	<1
Combination	6	40.30	7.44**
Burner x Combination	6	11.38	2.10
Speed x Combination	9	20.87	3.85**
Burner x Speed x Combination	9	8.18	1.51
Error	105	5.42	

Table 14. The affect of speeds of travel and combinations of flaming on the duration of bloom (days) at Manhattan in 1967.

Combinations	Speed, mph		
	1.5	3.0	4.5
001	6.75	7.50	7.25
010	7.63	5.13	6.25
100	6.25	6.75	6.38
011	12.75	7.00	8.63
101	*	8.75	7.63
110	*	9.00	6.75
111	*	9.25	10.50

Check = 6.75 Days   LSD = 2.31 Days

Variances for the two years were homogeneous. The combined analysis (Table 15) showed most of the year by other factor interactions significant. The year by speed by combination interaction was expected to be significant because of the somewhat opposite trends in the individual years data (Table 16). The year by burner interaction is due mainly to the burner

Table 15. Analysis of variance for duration of bloom, combined Manhattan 1966 and 1967 data.

Source	DF	MS	F
Year	1	2.73	<1
Replication/Years	6	10.38	
Burner	1	16.06	3.00
Year x Burner	1	42.01	7.84**
Speed	2	13.24	2.47
Year x Speed	2	25.70	4.79**
Burner x Speed	2	5.60	1.04
Year x Burner x Speed	2	1.39	<1
Combination	6	34.88	6.51**
Year x Combination	6	90.37	16.86**
Burner x Combination	6	4.35	<1
Year x Burner x Combination	6	1.60	<1
Speed x Combination	9	8.63	1.61
Year x Speed x Combination	9	33.32	6.22**
Burner x Speed x Combination	9	6.52	1.22
Year x Burner x Speed x Combination	9	9.50	1.77
Error	210	5.36	

Table 16. The affect of speeds of travel and combinations of flaming on duration of bloom (days) for both years.

Combination	Speed					
	1.5 mph		3.0 mph		4.5 mph	
	1966	1967	1966	1967	1966	1967
001	12.25	6.75	11.00	7.50	11.13	7.25
010	8.50	7.63	9.00	5.13	9.63	6.25
100	5.63	6.25	6.88	6.75	8.75	6.38
011	3.38	12.75	7.13	7.00	9.88	8.63
101	*	*	7.75	8.75	9.00	7.63
110	*	*	5.38	9.00	5.88	6.75
111	*	*	5.00	9.25	7.50	10.50
Check	1966 = 11.75 Days		1967 = 6.75 Days		LSD = 2.28 Days	

differences in the 1966 data and the lack of burner effects in 1967 (Table 17).

Table 17. The affect of burner arrangements on duration of bloom (days) for both years.

Years	Burner Arrangements I	II	Check
1966	7.36	8.60	11.75
1967	7.91	7.64	6.75
LSD = 0.70 Days			

The duration of bloom as measured seems to be affected mainly by environmental factors since the two years were very much different with regard to the environmental factors. Other measurements of bloom did not have the reversal in trends between the years.

Heads per Plot. Burners, speeds, and combinations affected the number of heads that were harvested from each plot in 1966 at Manhattan. Stand was decreased as the treatments became more severe with the 4.5 mph speed causing the least stand reduction, followed by the 3.0 mph speed and then the 1.5 mph speed, as one would expect. As the stand was reduced in the plots that were flamed only one time, the plants tillered more than the plants in the plots that were flamed more than one time. Also, the single burner arrangement tended to cause more stand reduction than the two-burner arrangement.

The burner by speed by combination interaction was significant (Table 18). Burner arrangements were significantly different for all combinations at 1.5 and 3.0 mph except for combination 001 at both speeds and combination 011 at 3.0 mph (Table 19). There were significant differences between some pairs of combinations for the single burner arrangement at both 1.5 and 3.0 mph, however, these were not consistant. Significant differences for the two-burner arrangement were because combination 100 had significantly more heads per plot than 011 at all speeds.

Table 18. Analysis of variance for heads per plot at Manhattan in 1966.

Source	DF	MS	F
Replication	3	61.66	
Burner	1	1521.00	67.84**
Speed	2	1233.60	55.02**
Burner x Speed	2	218.56	9.75**
Combination	6	489.91	21.85**
Burner x Combination	6	87.31	3.89**
Speed x Combination	9	291.76	13.01**
Burner x Speed x Combination	9	56.47	2.52*
Error	105	22.42	

Table 19. The affect of burner arrangements, speeds of travel and combinations of flaming on the number of harvested heads per plot.

Combination	Speed, mph					
	1.5		3.0		4.5	
	Burner Arrangements					
	I	II	I	II	I	II
001	27.00	32.00	34.50	34.00	35.25	32.50
010	16.00	26.50	24.00	32.00	34.00	36.75
100	5.25	23.00	26.25	33.50	33.00	35.25
011	3.25	16.25	29.00	26.00	27.50	28.50
101	*	*	19.75	26.50	27.25	30.50
110	*	*	10.00	24.00	21.25	27.00
111	*	*	3.50	23.75	20.00	25.75

Check = 36 Heads per Plot   LSD = 6.63 Heads

Only speeds and combinations affected heads per plot at Manhattan in 1967. The 1.5 mph speed tended to cause the most stand reduction as combinations increased in severity. The 3.0 mph speed caused slightly more stand reduction than the 4.5 mph speed. There were few significant differences between combinations for one speed.

The speed by combination interaction was significant in the analysis of the data (Table 20). All combinations except 001, at 1.5 mph had significantly fewer heads per plot than those combinations at 3.0 mph (Table 21). Combinations 100 and 110 had significantly fewer heads per plot at 3.0 mph than those combinations at 4.5 mph. The only significant difference between adjacent combinations was at 1.5 mph where combination 001 had more heads per plot than combination 010.

Table 20. Analysis of variance for heads per plot at Manhattan in 1967.

Source	DF	MS	F
Replication	3	86.13	
Burner	1	12.25	<1
Speed	2	2285.60	36.72**
Burner x Speed	2	3.30	<1
Combination	6	189.22	3.04**
Burner x Combination	6	95.04	1.53
Speed x Combination	9	283.80	4.56**
Burner x Speed x Combination	9	68.46	1.10
Error	105	62.25	

Table 21. The number of heads per plot as affected by speeds of travel and combinations of flaming at Manhattan in 1967.

Combinations	Speed, mph		
	1.5	3.0	4.5
001	47.75	48.25	48.88
010	33.75	48.88	49.63
100	26.13	42.13	51.38
011	26.63	46.50	49.00
101	*	41.88	48.25
110	*	35.88	48.25
111	*	41.00	44.38

Check = 48.75 Heads LSD = 7.81 Heads

There were fewer plants per plot in 1966 but the same general trend was observed in both years data. It was evident, however, that the treatments were more severe in reducing stands in 1966 than in 1967. The initial stand was more variable in 1967, as was reflected in the error mean square of Table 18.

Grain Yield per Acre. Burners, speeds and combinations all affected yield in 1966, at Manhattan. Trends in the data shows yield decreases larger for the single burner arrangement than for the two-burner arrangement at the same speed and combination. As would be expected, the 1.5 mph speed caused greater yield reduction than the 3.0 mph speed with the 4.5 mph speed showing the least yield reduction. The smaller, and more times the plants were flamed, the greater was the yield reduction.

The burner by speed by combination interaction was significant in the data analysis (Table 22). There are numerous significant differences between burner arrangements at the same speed and combination, between consecutive combinations at the same speed and burner arrangement, and between speeds at the same combination and burner arrangement (Table 23). It is interesting to note that 20 of the 36 means in this table have higher yields than the check.

Table 22. Analysis of variance for grain yield (cwt./acre) at Manhattan in 1966.

Source	DF	MS	F
Replication	3	100.44	
Burner	1	5800.47	71.13**
Speed	2	5755.16	70.57**
Burner x Speed	2	890.05	10.91**
Combination	6	1164.02	14.27**
Burner x Combination	6	472.26	5.79**
Speed x Combination	9	1063.28	13.04**
Burner x Speed x Combination	9	261.40	3.21**
Error	105	81.55	

Table 23. The affect of burner arrangements, speeds of travel, and combinations of flaming on grain yield (cwt./acre).

Combination	Speed, mph					
	1.5		3.0		4.5	
	Burner Arrangements					
	I	II	I	II	I	II
001	45.45	51.95	60.28	59.39	66.82	57.21
010	34.98	55.62	50.44	65.90	67.42	76.10
100	10.19	45.87	57.01	68.34	67.29	70.06
011	5.64	34.49	59.04	52.07	57.10	54.12
101	*	*	40.41	53.30	52.13	58.61
110	*	*	21.85	53.35	47.96	60.95
111	*	*	6.83	47.03	39.50	54.45

Check = 52.45 cwt./acre LSD = 12.64 cwt.

Only speeds and combinations affected grain yield in 1967 at Manhattan. The general trend was the same as for the 1966 data. The 1.5 mph speed caused the greatest yield reduction, followed by the 3.0 mph speed. The least reduction in yield was caused by the 4.5 mph speed. Yields were reduced as combinations of flaming became more severe.

The speed by combination interaction was significant in the analysis of the data (Table 24). In these data, all treatment yield levels are below the check. This does not follow the 1966 data. Significant differences for the same combination between 1.5 and 3.0 mph occurred at all combinations except combination 001 (Table 25). Combinations 110 at 3.0 mph and 010 at 4.5 mph are lower than expected according to the other data. However, combination 111 at 3.0 mph is higher than expected as compared to the rest of the data. The differences between combinations 101 and 110 at 3.0 and 4.5 mph are significant.

Variability of grain yield as shown by the analysis of variance for both years was high. This can be noted especially in the 1966 data. However,

Table 24. Analysis of variance for grain yield (cwt./acre) at Manhattan in 1967.

Source	DF	MS	F
Replication	3	206.60	
Burner	1	1.25	<1
Speed	2	2353.60	207.06**
Burner x Speed	2	229.53	2.02
Combination	6	1119.98	9.56**
Burner x Combination	6	158.93	1.40
Speed x Combination	9	749.34	6.60**
Burner x Speed x Combination	9	213.03	1.88
Error	105	113.61	

Table 25. Grain yield (cwt./acre) as affected by speeds of travel and combinations of flaming at Manhattan in 1967.

Combination	Speed, mph		
	1.5	3.0	4.5
001	65.05	69.76	70.11
010	46.15	63.02	57.57
100	35.85	61.35	68.30
011	31.78	56.87	57.97
101	*	50.92	62.69
110	*	38.26	55.02
111	*	54.14	45.96

Check = 72.83 cwt. LSD = 10.55 cwt.

error variances were shown to be homogenous so the data were combined. All factors, years, burners, speeds, and combinations affected grain yields (Table 26). It would take four three-way interactions to interpret the data according to the results of the analysis. These interactions show the same general trends as was noted in the individual years data. That is, the slower the speed, the more yields were reduced; the more severe the combinations, the more yields were reduced; the single burner treatments had lower yields than the two-burner treatments; and yields were lower in 1966, than in 1967 (Tables 27, 28, 29, and 30).

Table 26. Analysis of variance for grain yield (cwt./acre) at Manhattan in 1966 and 1967 combined.

Source	DF	MS	F
Year	1	1652.74	16.94**
Replicates/Years	6	170.19	
Burner	1	2816.67	28.87**
Year x Burner	1	2985.05	30.59**
Speed	2	7634.60	78.24**
Year x Speed	2	474.15	4.86**
Burner x Speed	2	725.96	7.44**
Year x Burner x Speed	2	383.62	3.93**
Combination	6	1947.31	19.96**
Year x Combination	6	336.69	3.45**
Burner x Combination	6	384.16	3.94**
Year x Burner x Combination	6	247.03	2.53**
Speed x Combination	9	1579.86	16.19**
Year x Speed x Combination	9	231.83	2.38**
Burner x Speed x Combination	9	327.74	3.36**
Year x Burner x Speed x Combination	9	152.63	1.56
Error	210	97.58	

Table 27. The affect of burner arrangements, speeds of travel, and combinations flamings on grain yield (cwt./acre) combined over years.

	Speeds, mph					
Combination	1.5		3.0		4.5	
	Burner Arrangements					
	I	II	I	II	I	II
001	53.37	60.38	65.26	64.33	68.67	63.45
010	41.89	49.56	57.34	63.84	62.36	66.97
100	22.08	41.80	57.41	66.61	67.98	68.99
011	14.57	37.27	61.33	51.10	61.93	51.65
101	*	*	48.27	48.5.	54.49	63.56
110	*	*	31.93	43.93	53.51	55.96
111	*	*	29.27	51.80	38.72	54.22

Check = 70.67 cwt. LSD = 9.78 cwt.

Table 28. The affect of speeds of travel and combinations of flaming on grain yield (cwt./acre) for both years.

Combination	Speeds, mph					
	1.5		3.0		4.5	
	1966	1967	1966	1967	1966	1967
001	48.70	65.05	59.83	69.76	62.01	70.11
010	45.30	46.15	58.17	63.02	71.76	57.57
100	28.03	35.85	62.67	61.35	68.67	68.30
011	20.07	31.78	55.55	56.87	55.61	57.97
101	*	*	46.85	50.92	55.37	62.69
110	*	*	37.60	38.26	54.45	55.02
111	*	*	26.93	54.14	46.97	45.96

Check = 68.26 cwt. in 1966, 72.43 cwt. in 1967. LSD = 9.78 cwt.

Table 29. The affect of burner arrangements and combinations of flaming on grain yield (cwt./acre) for both years.

Combination	Burner Arrangements			
	I		II	
	Years		Years	
	1966	1967	1966	1967
001	57.52	67.35	56.18	69.26
010	50.94	56.78	65.87	54.38
100	44.83	53.49	61.42	56.84
011	40.59	51.29	46.89	46.45
101	46.27	57.50	55.95	56.12
110	34.90	56.54	57.15	42.73
111	23.16	44.82	50.74	55.29

Check = 68.26 cwt. in 1966, 72.43 cwt. in 1967. LSD = 7.98 cwt.

Table 30. The affect of burner arrangements and speeds of travel on grain yield (cwt./acre) for both years.

Speeds	Burner Arrangements I Years 1966	1967	II Years 1966	1967
1.5	24.06	41.89	46.98	47.52
3.0	42.26	58.25	57.05	54.41
4.5	56.89	59.59	61.64	59.73

Check = 68.26 cwt. in 1966, 72.43 cwt. in 1967. LSD = 5.23 cwt.

HUTCHINSON EXPERIMENTS

The experiments at Hutchinson were conducted in the same manner as the Manhattan experiments. At Hutchinson in 1967, flaming was done only at the 5-leaf stage due to rain at the other times the plots were to be flamed, therefore, it will be discussed seperately.

Days Delay, First Bloom. Speeds and combinations independently affected first bloom delay at Hutchinson in 1966. As expected, the 1.5 mph speed caused the most delay followed by 3.0 mph and the least delay was at 4.5 mph. The combination followed the same trend as in the Manhattan data with the most delay when the plants were flamed all three times and the least when the plants were flamed at the 8-leaf stage only (combination 001).

Speeds and combinations were highly significant (Table 31). The 1.5 mph speed caused significantly more delay than either 3.0 or 4.5 mph which were not significantly different (Fig. 12). Combination 001 did not result in significant delay (Fig. 13). Combination 010 caused significantly more delay than 001 but significantly less than 100. There were no significant differences among combinations 100, 011, and 101. However, combinations 110 caused more delay than all of the less severe combinations. Combination 111 was not significantly different from combination 110, but had the most delay of all the combinations. The data as shown for these combinations points out the expected order of severity.

Table 31. Analysis of variance for days delay, first bloom at Hutchinson in 1966.

Source	DF	MS	F
Replication	3	435.25	
Burner	1	1.52	<1
Speed	2	164.68	23.30**
Burner x Speed	2	9.29	1.31
Combination	6	186.76	26.43**
Burner x Combination	6	5.18	<1
Speed x Combination	12	8.03	1.14
Burner x Speed x Combination	12	9.03	1.28
Error	123	7.07	

<u>Days Delay, Half-Bloom</u>. The same trends are evident in the half-bloom data as were in the first bloom data. That is, speeds and combinations were highly significant and affected delay independently (Table 32).

Table 32. Analysis of variance for days delay, half-bloom at Manhattan in 1966.

Source	DF	MS	F
Replication	3	459.61	
Burner	1	0.05	1
Speed	2	183.93	26.59**
Burner x Speed	2	6.23	1
Combination	6	184.73	26.70**
Burner x Combination	6	1.78	1
Speed x Combination	12	5.51	1
Burner x Speed x Combination	12	8.98	1.30
Error	123	6.92	

The 1.5 mph speed caused significantly more delay than the 3.0 or 4.5 mph speed which were not significantly different (Fig. 14). The combinations followed the expected order of severity (Fig. 15). Combination 001 caused no significant delay. Combination 010 caused significantly more delay than 001, but was not significantly different from 100. Combination 011 caused significantly more delay than 010. There were no significant differences among combinations 100, 011, and 101. Combination 110 caused significantly more delay than the less severe combinations and significantly less delay than combination 111.

Days Delay, Full Bloom. The same trends exist in the full bloom delay data as the first and half-bloom data for Hutchinson in 1966. Speeds and combinations affected delay independently (Table 33). The 1.5 mph speed caused significantly more delay at full bloom than the 3.0 and 4.5 mph speeds, between which there was no significant difference (Fig. 16). Combination 001 caused a significant delay (Fig. 17). Combination 010 caused significantly more delay than 001, but was not different from 100 and 011. There were no significant differences among combinations 100, 011, and 101. Combination 110 caused significantly more delay than all the less severe combinations and combination 111 had significantly more delay than all the other combinations.

Days from Planting to Bloom. As was true in the Manhattan data, the analyses of variance of the days from planting to bloom was different from the analyses of variance of the days delay only by the replicate effects. Significant differences were found between the same treatments in the days to bloom data as in the days delay data. Therefore, tables of the days from

Fig. 12. The effect of speeds on days delay, first bloom at Hutchinson in 1966.

Fig. 13. The effect of combinations on days delay, first bloom at Hutchinson in 1966.

Fig. 14. The effect of speeds on days delay, half-bloom at Hutchinson in 1966.

Fig. 15. The effect of combinations on days delay, half-bloom at Hutchinson in 1966.

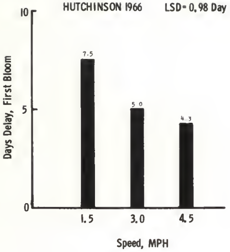


Fig. 12

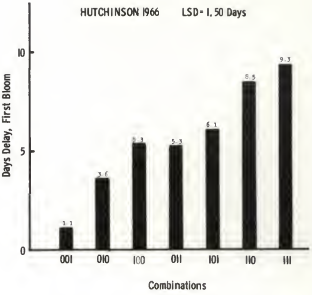


Fig. 13

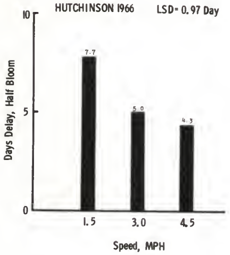


Fig. 14

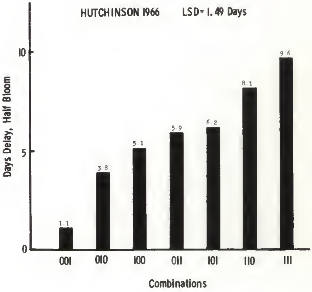


Fig. 15

Table 33. Analysis of variance for days delay, full bloom at Hutchinson in 1966.

Source	DF	MS	F
Replication	3	202.62	
Burner	1	0.02	<1
Speed	2	268.40	31.66**
Burner x Speed	2	10.29	1.21
Combination	6	196.28	23.15**
Burner x Combination	6	3.79	<1
Speed x Combination	12	9.54	1.13
Burner x Speed x Combination	12	9.10	1.07
Error	123	8.48	

planting to bloom data are included in the (Appendix Table 7).

Duration of Bloom. Speed was the only factor to have a significant affect on the duration of bloom (Table 34). The 1.5 mph speed caused a longer duration of bloom than the other speeds (Table 35). All the speed treatments differed from the check by more than the LSD.

Table 34. Analysis of variance for duration of bloom at Hutchinson in 1966.

Source	DF	MS	F
Replication	3	3.31	
Burner	1	1.17	<1
Speed	2	17.84	3.57*
Burner x Speed	2	4.72	<1
Combination	6	10.48	2.10
Burner x Combination	6	5.17	1.03
Speed x Combination	12	6.48	1.30
Burner x Speed x Combination	12	5.43	1.09
Error	123	5.00	

Heads per Plot. Speeds and combinations affected the number of heads that were harvested from each plot. There were few differences between combinations at the same speed. The speed by combination interaction was highly

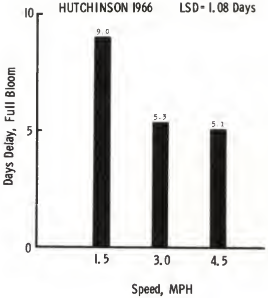

HUTCHINSON 1966
LSD= 1.08 Days
Days Delay, Full Bloom
10
5
0
9.0
5.3
5.1
1.5
3.0
4.5
Speed, MPH

Fig. 16

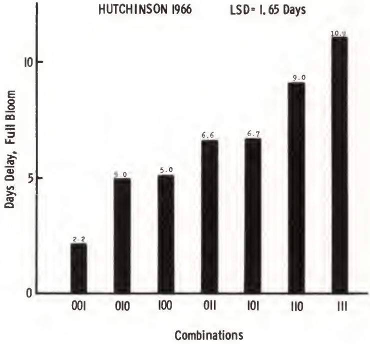

HUTCHINSON 1966
LSD= 1.65 Days
Days Delay, Full Bloom
10
5
0
2.2
5.0
5.0
6.6
6.7
9.0
10.
001
010
100
011
101
110
111
Combinations

Fig. 17

Table 35. The affect of speeds of travel on the duration of bloom (days).

Speeds	Days
1.5	9.48
3.0	8.36
4.5	8.84
Check =	7.00
$LSD_{.05}$ =	0.83 Days

significant (Table 36). The 1.5 mph speed caused significantly fewer heads per plot than the 3.0 mph speed at combinations 011, 101, and 111 (Table 37). The 3.0 mph speed caused fewer heads per plot than the 4.5 mph speed at combination 110 and more heads per plot at combination 101. The only significant differences between combinations were that combination 011 caused fewer heads per plot than 100 and combination 111 caused fewer heads per plot than 110 all at 1.5 mph. Combination 110 caused fewer heads per plot than 101 at 3.0 mph. There were no differences between combinations at 4.5 mph. Only combinations 011 and 111 at 1.5 mph had significantly fewer heads per plot than the check.

Table 36. Analysis of variance for heads per plot at Hutchinson in 1966.

Source	DF	MS	F
Replication	3	14.83	
Burner	1	7.29	<1
Speed	2	177.13	10.55**
Burner x Speed	2	19.36	1.15
Combination	6	78.30	4.66**
Burner x Combination	6	6.57	<1
Speed x Combination	12	79.08	4.71**
Burner x Speed x Combination	12	13.77	<1
Error	123	16.79	

Table 37. The affect of speeds of travel and combinations of flaming on the number of harvested heads per plot.

Combination	Speed, mph		
	1.5	3.0	4.5
001	31.38	28.50	29.50
010	29.13	29.63	29.13
100	30.38	30.75	29.75
011	24.00	29.38	28.25
101	26.00	31.75	27.00
110	26.38	26.88	31.00
111	16.50	30.38	28.00
Check = 30.00 Heads per Plot	LSD = 4.06 Heads		

Grain Yield per Acre. Burners, speeds, and combinations affected grain yield. There was no consistant trend between burner arrangements. The 1.5 mph speed caused less yield than the 3.0 and 4.5 mph speeds.

The burner by speed interaction was significant and the speed by combination interaction was highly significant (Table 38). Significant differences found in the burner by speed interaction were associated with the 1.5 mph treatments (Table 39). Burner arrangements were significantly different only at 1.5 mph with the single burner causing less yield. Significant differences between speeds were between 1.5 and 3.0 mph at both burner arrangements. The 1.5 mph speed caused less yield than the 3.0 mph speed. There were no significant differences between 3.0 and 4.5 mph or between burner arrangements at those speeds.

Also, in the speed by combination interaction, all significant differences were associated with the 1.5 mph speed (Table 40). The 1.5 mph speed caused significantly less grain yield than the 3.0 mph speed at all combinations except 001 and 100. Significant differences between combinations were between 100 and 011, and 110 and 111 all at 1.5 mph. The first one

Table 38. Analysis of variance for grain yield (cwt./acre) at Hutchinson in 1966.

Source	DF	MS	F
Replication	3	179.86	
Burner	1	5.71	<1
Speed	2	1756.20	34.35**
Burner x Speed	2	238.07	4.66*
Combination	6	427.67	8.36**
Burner x Combination	6	34.02	<1
Speed x Combination	12	163.25	3.19**
Burner x Speed x Combination	12	19.69	<1
Error	123	51.12	

Table 39. The effect of burner arrangements and speeds of travel on grain yield (cwt./acre).

	Burner Arrangements	
Speed, mph	I Burner	II Burners
1.5	45.60	49.99
3.0	59.76	57.12
4.5	57.56	54.70

Check = 59.41 cwt.
LSD = 3.78 cwt.

Table 40. The affect of speeds of travel and combinations of flaming on grain yield (cwt./acre).

	Speed, mph		
Combination	1.5	3.0	4.5
001	54.02	56.49	58.18
010	53.41	62.03	58.95
100	57.26	60.03	58.64
011	44.17	56.95	55.01
101	47.07	57.72	53.71
110	48.95	58.80	56.03
111	29.71	57.10	52.33

Check = 59.41 cwt. LSD = 7.19 cwt.

listed had significantly more yield than the second. Combinations 011, 101, 110, and 111 were the only ones that had differences from the check that were larger than the LSD.

From this data, only the 1.5 mph speed had a significant affect on grain yield.

Hutchinson 1967. Flaming at the three- and eight-leaf stages was not done at Hutchinson in 1967, due to rainfall at the time those two stages were reached. Probably if the equipment would have been at Hutchinson all the time, all flamings could have been made. Flaming at the three-leaf stage only resulted in four plots per replication that had the same treatment imposed on them. Therefore, the analysis of variance was run with these plots as duplicate treatments within a replication.

Burners and speeds affected delay obtained at first bloom. The two-burner arrangement caused more delay than the single burner arrangement. As in most other cases, the 1.5 mph speed caused more delay than the other two speeds. Burners and speeds were highly significant in affecting delay at first bloom, but were independent of each other (Table 41). The two-burner arrangement caused significantly more delay than the single burner arrangement (Table 42). The 1.5 and 3.0 mph speeds caused significantly more delay than the 4.5 mph speed (Table 42). The 3.0 mph speed caused delay that was not significantly different from delay caused by the 1.5 mph speed.

The same trends are evident in the half-bloom delay data as were evident in the first bloom delay data. Burners and speeds were highly significant in affecting delay and were independent of each other (Table 43). The two-burner arrangement caused significantly more delay than the single burner arrangement (Table 42). The 1.5 and 3.0 mph speeds caused significantly more delay than

Table 41. Analysis of variance of days delay, first bloom at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	56.59	
Burner	1	33.84	16.14**
Speed	2	9.66	4.62**
Burner x Speed	2	3.78	1.81
Error	87	2.09	

Table 42. Days delay at Hutchinson in 1967.

	Days delay,		
Speed, mph	First bloom	Half-bloom	Full bloom
1.5	4.31	3.69	5.66
3.0	4.13	3.38	4.38
4.5	3.28	2.66	3.50
LSD	0.65	0.57	1.13
Burners			
I	3.31	2.75	3.77
II	4.50	3.73	5.25
LSD	0.54	0.44	0.92

Table 43. Analysis of variance for days delay, half-bloom at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	12.15	
Burner	1	23.01	14.38**
Speed	2	8.95	5.59**
Burner x Speed	2	2.26	1.41
Error	87	1.60	

the 4.5 mph speed, but they were not significantly different from each other (Table 42).

Again, the same general trends were found, with full bloom delay data. Burners and speeds were highly significant in affecting delay and were independent of each other (Table 44). The two-burner arrangement caused significantly more delay than the single burner arrangement (Table 42). The 1.5 mph speed caused significantly more delay than the other two speeds (Table 42). There was no significant difference between the 3.0 and 4.5 mph speeds unlike the first and half-bloom delay data.

Table 44. Analysis of variance for days delay, full bloom at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	29.18	
Burner	1	52.51	10.12**
Speed	2	37.64	7.25**
Burner x Speed	2	6.70	1.29
Error	87	5.19	

Speeds significantly affected the duration of bloom at Hutchinson in 1967 (Table 45). The 1.5 mph speed caused a significantly longer duration of bloom than the other speeds and the difference between the 1.5 mph speed and the check was larger than the LSD (Table 46). There was no significant difference between 3.0 and 4.5 mph nor did they differ from the check by the $LSD_{.05}$.

Speeds were significant in causing differences in the number of heads per plot (Table 47). The 1.5 mph speed had significantly fewer heads per plot than the other speeds (Table 46). There was no significant difference in the number of heads per plot between 3.0 and 4.5 mph. The 1.5 mph speed was the only speed that was different from the check by more than the $LSD_{.05}$.

Table 45. Analysis of variance for duration of bloom in days at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	9.26	
Burner	1	1.76	<1
Speed	2	14.39	6.26**
Burner x Speed	2	0.45	<1
Error	87	2.30	

Table 46. Hutchinson data for 1967.

Speed, mph	Duration of bloom (days)	Heads per (plot)	Grain yield (cwt./acre)
1.5	6.09	40.91	38.63
3.0	5.00	43.88	42.35
4.5	4.88	44.16	45.58
Check	4.75	44.00	49.55
LSD	0.76	2.58	2.35

Table 47. Analysis of variance for the number of heads per plot at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	132.57	
Burner	1	57.04	2.14
Speed	2	103.76	3.90*
Burner x Speed	2	41.32	1.55
Error	87	26.63	

Speeds were highly significant in affecting differences in grain yield (Table 48). The 1.5 mph speed caused a significantly lower grain yield than the other speeds and the difference between the 1.5 mph speed and the check was larger than the LSD (Table 46). The 3.0 mph speed caused a difference from the check that was larger than the LSD, but was not significantly different from the 4.5 mph speed. The 4.5 mph speed did not differ from the check by more than the LSD.

Table 48. Analysis of variance for grain yield (cwt./acre) at Hutchinson in 1967.

Source	DF	MS	F
Replication	3	281.36	
Burner	1	71.29	3.23
Speed	2	387.04	17.56**
Burner x Speed	2	13.54	<1
Error	87	22.04	

SUMMARY AND CONCLUSIONS

Experiments were conducted in 1966 and 1967 to determine if delayed flowering in grain sorghum could be obtained by flaming. Two-burner arrangements, three speeds of travel, and seven combinations of flaming at different stages of growth were used in all possible combinations at two locations. At one location in 1967 it was possible to flame at only one stage due to unfavorable environmental conditions. RS 610 grain sorghum was planted for all the tests.

Significant differences in delay were found among speeds and combinations. In some cases burner arrangements caused significantly different delays; although, usually the difference was not large enough to be of practical importance. The 1.5 mph speed caused the most delay for all the bloom data. The 3.0 mph speed caused the next most delay; however, in most cases it was not significantly different from the 4.5 mph speed which caused the least delay.

Combinations followed the expected order of severity. Flaming at the 8-leaf stage only caused little or no delay. Flaming only at the 5-leaf stage caused more delay then at the 8-leaf stage only, but less than flaming at the 3-leaf stage only. In most cases, there was little difference between flaming at the 3-leaf stage, the 5- and 8-leaf stages, and the 3- and 8-leaf stages. Flaming at the 3- and 5-leaf stages caused more delay than the other treatments, except for flaming at all three stages, which caused the most delay. Flaming the plants when small resulted in more delay then flaming when the plants were larger. More delay was obtained by flaming at all three stages of growth as compared to flaming at only one or two stages of growth. All or nearly all the plants were killed when flamed at 1.5 mph with combinations 101, 110, and 111 at Manhattan. The most delay obtained at half-bloom was 10.88 days, when flamed at the 5- and 8-leaf stages at 1.5 mph. The least delay at half-bloom was zero days when flamed at the 8-leaf stage only at 4.5 mph. Half-bloom is the best index of maturity, since it is less affected by very early or very late plants than first and full bloom data.

Duration of bloom seemed to be affected by environmental conditions. The trends were the opposite for the two years at Manhattan. The most severe flaming caused the least duration of bloom in 1966 and the most in 1967. Possibly this is a result of good growing conditions in 1967, and the ability of the sorghum plant to compensate for reduced stands by extending the flowering period.

Stands were reduced by the more severe treatments as reflected by the number of heads harvested per plot. Stand reduction was caused mostly by the 1.5 mph flamings. All or nearly all the plants were killed when flamed at 1.5 mph at combinations 101, 110, and 111 as was mentioned previously. Some stand reduction was noted at those same combinations when flamed at 3.0 mph. Very little, if any, stand reduction occurred when plants were flamed at 4.5 mph.

Grain yield followed nearly the same trends as heads harvested per plot. That is, the more severe treatments caused greatest reduction in grain yield.

From these data, delays in flowering can be obtained by flaming. The most delay is caused by flaming the plants when small and more than one time. Also, slow speeds cause more delay than fast ones. A one week delay can be obtained without significantly affecting stand or yield.

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APPENDIX

Table 1. The number of days from planting to first bloom as affected by burner arrangement speeds, and combinations at Manhattan in 1966.

Combination	Speed 1.5 mph	3.0 mph	4.5 mph	Burner Arrangements 1 Burner	2 Burners
001	61.25	60.13	59.25	60.50	59.92
010	68.25	65.25	64.13	66.08	65.67
100	70.75	66.00	64.13	68.83	65.08
011	71.38	67.25	64.75	68.83	66.75
101	*	67.88	65.50	67.63	65.75
110	*	70.88	68.38	70.75	68.50
111	*	72.00	69.13	72.63	68.50
Check = 60.00 Days	LSD = 1.72 Days			LSD = 1.41 Days	

Table 2. The number of days from planting to first bloom as affected by burner arrangements, speeds, and combinations at Manhattan in 1967.

Combination	Speed 1.5 mph	3.0 mph	4.5 mph	Burner Arrangements 1 Burner	2 Burners
001	63.13	62.88	63.25	63.25	62.92
010	70.00	68.88	66.88	68.17	69.00
100	70.13	68.13	66.63	69.00	67.58
011	71.63	68.25	67.50	68.25	70.00
101	*	68.63	68.50	68.25	68.88
110	*	71.25	70.00	69.38	71.88
111	*	70.38	71.38	71.63	70.13
Check = 62.00 Days	LSD = 2.12 Days			LSD = 1.74 Days	

Table 3. The number of days from planting to half-bloom as affected by burner arrangements, speeds, and combinations at Manhattan in 1966.

	Speed			Burner Arrangements	
Combination	1.5 mph	3.0 mph	4.5 mph	1 Burner	2 Burners
001	66.00	65.38	64.50	70.72	69.71
010	71.50	69.88	69.88		
100	73.13	70.00	69.25		
011	72.63	70.50	70.13		
101	*	71.38	69.88		
110	*	72.13	70.75		
111	*	74.00	73.00		

Check = 64.50 Days LSD = 1.17 Days LSD = 0.36 Days

Table 4. The number of days from planting to half-bloom as affected by speeds and combinations at Manhattan in 1967.

	Speed		
Combinations	1.5 mph	3.0 mph	4.5 mph
001	66.25	66.13	66.63
010	72.75	71.25	70.13
100	73.13	71.13	69.75
011	76.88	71.25	71.88
101	*	71.88	72.13
110	*	74.38	72.63
111	*	75.13	75.88

Check = 66.00 Days LSD = 2.50 Days

Table 5. The number of days from planting to full bloom as affected by burner arrangements and speeds and combinations at Manhattan in 1966.

Combinations	Speed			Burner Arrangements	
	1.5 mph	3.0 mph	4.5 mph	1 Burner	2 Burners
001	73.50	71.13	70.38	74.85	74.03
010	76.75	74.25	73.75		
100	76.38	72.88	72.88		
011	74.75	74.38	74.63		
101	*	75.63	74.50		
110	*	76.25	74.25		
111	*	77.00	76.63		

Check = 71.75 Days LSD = 1.74 Days LSD = 0.53 Days

Table 6. The numbers of days from planting to full bloom as affected by speeds and combinations at Manhattan in 1967.

Combinations	Speed		
	1.5 mph	3.0 mph	4.5 mph
001	69.88	70.38	70.50
010	77.63	74.00	73.13
100	76.38	74.88	73.00
011	84.38	75.25	76.13
101	*	77.38	76.13
110	*	80.25	76.75
111	*	79.63	81.88

Check = 68.75 Days LSD = 3.23 Days
+

Table 7. The number of days from planting to bloom as affected by combinations and speeds at Hutchinson in 1966.

Combinations	First Bloom	Half Bloom	Full Bloom
001	61.33	65.08	70.42
010	63.83	67.83	73.21
100	65.58	69.08	73.29
011	65.50	69.88	74.83
101	66.33	70.17	74.92
110	68.71	72.08	77.25
111	69.54	73.58	79.17
Check	60.25	64.00	68.25
LSD	1.52	1.51	1.66
Speed, mph			
1.5	67.77	71.73	77.25
3.0	65.23	68.96	73.59
4.5	64.50	68.32	73.34
Check	60.25	64.00	68.25
LSD	0.99	0.99	1.01

Table 8. The number of days from planting to bloom as affected by burner arrangements and speeds at Hutchinson in 1967.

Burner Arrangements	First Bloom	Half Bloom	Full Bloom
1 Burner	61.06	63.25	66.25
2 Burners	62.23	64.23	67.69
Check	57.75	60.50	62.50
LSD	0.59	0.52	0.92
Speed, mph			
1.5	62.06	64.19	68.16
3.0	61.88	63.88	66.88
4.5	61.00	63.16	65.88
Check	57.75	60.50	62.50
LSD	0.72	0.63	1.13

FLAMING TO DELAY FLOWERING IN GRAIN SORGHUM, *SORGHUM BICOLOR*, (L.) MOENCH

by

JAMES DARE BALL

B. S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

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1969

Flaming has been studied as a means for causing delayed flowering in grain sorghum. Experiments were conducted in 1966 and 1967, at the Kansas State University Agronomy Farm, Manhattan, Kansas, and at the South-central Kansas Experiment Field, Hutchinson, Kansas. RS 610 grain sorghum was planted for the experiments. Two-burner arrangements, three speeds of travel, and seven combinations of flaming at different stages of growth were used in all possible combinations for treatments. The burner arrangements were a single burner directly over the row and two-burners perpendicular to the row. The speeds of travel were 1.5, 3.0, and 4.5 mph. Flamings were made at the 3-leaf, the 5-leaf and the 8-leaf stages of growth, and in all possible combinations of these stages, resulting in seven combinations of flaming.

Burner arrangements did not cause many significant delays. Where burner arrangements caused significant delays, the differences were not large enough to be of practical importance. Speeds had a significant effect on delay with the 1.5 mph speed causing the most delay followed by the 3.0 mph speed. The 4.5 mph speed caused less delay then the 3.0 mph speed; however, usually the differences were not significant.

Flaming at all three stages of growth caused the most delay. When flaming at the 3- and 5-leaf stages, the 5- and 8-leaf stages, or the 3- , 5- , and 8-leaf stages at 1.5 mph, all or nearly all the plants were killed. The largest delay at half-bloom was 10.88 days, which was caused by flaming at 1.5 mph at the 5- and 8-leaf stages of growth. The smallest delay at half-bloom was zero days, which was caused by flaming at the 8-leaf stage at 4.5 mph.

Stands and grain yields were reduced by the more severe treatments.