August 10, 1942

To the Committee on Graduate Study:

I am submitting to you a thesis written by Harry Dean Bunch entitled "Effect of Clipping Treatments on Four Winter Grains." I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

John B. Washko
Major Professor

We have read this thesis
and recommend its acceptance:

Stanley A. Cain

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Accepted for the Committee

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Dean of the Graduate School

EFFECT OF CLIPPING TREATMENTS ON FOUR WINTER GRAINS

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

---

by

Harry Dean Bunch

August 1942

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INTRODUCTION

Tennessee farmers who regularly grow small grains as a part of their cropping system have long realized that these crops may provide extremely valuable winter and early spring grazing. Little data are available, however, to aid these farmers in choosing the most desirable pasturing practices to use in grazing such crops. Specifically, information is lacking on how intensively the small grains can be grazed without severe injury to the grain yield, the period in the growing season that each provides maximum pasturage, and the crop, or crops, furnishing the greatest amount of pasturage with the least reduction in grain yield.

Until data are available on these problems, definite grazing practices cannot be recommended. This investigation was conducted to obtain information that could be applied toward the solution of the problems mentioned above.

Briefly, the plan of the experiment was to simulate four intensities of grazing on adapted winter varieties of wheat, oats, rye, and barley. Since facilities were not available for conducting actual grazing trials, a lawn mower was used to remove the herbage.

REVIEW OF LITERATURE

A search of the literature discloses that only a limited amount of data exists on the response of small grains under winter pasturing. Furthermore, the data available have been obtained in other states and hence have limited local application.

In Kansas, Georgeson, et al (4) found that when wheat was grazed closely during the first part of April, with no other pasturing, the yield of grain was reduced. In a later test (5) they found that the grazing of wheat in the fall and spring had little effect on grain yields. Swanson (11) also of Kansas reports that when wheat is making a heavy growth, grazing is not harmful and may even increase the grain yield. Oklahoma workers (7) report from three years' results that no appreciable decrease in grain yields occurred where the pasturing was done judiciously, and when it was discontinued by March 1. Heavy or late pasturing, however, was found to reduce the yield. At the Oklahoma Panhandle Station, Finnell (2) found that grazing wheat until April 1 had little effect on tillering or on grain yield.

In Tennessee, Soule and Vanatter (9) report that winter rye seeded from mid-August to mid-September furnished excellent pasturage from October to early spring. Dvorachek, et al (1) in Arkansas found that winter rye

produced more forage both in the fall and in the spring than winter oats or wheat. Wasson (13) recommends oats for South Louisiana and rye for North Louisiana as the most suitable crops for providing winter and spring grazing.

Stansel, Dunkle, and Jones (10) found that forage yields of the small grains varied with different locations in Texas. A mixture of ryegrass and winter oats produced the highest yield of clippings on the Gulf Coast prairie, whereas wheat alone yielded highest in the north central part of the state. In northwestern Texas rye produced the greatest forage yields of all crops tested. Trotter (12), also of Texas, tested a number of oat varieties for winter pasture and found great differences between varieties in forage production for a particular period of the grazing season as well as in their total yields.

Kirk, Davidson, and Hamilton (6) in Canada found spring oats to be superior to the other small grains in yield of dry matter per acre, percentage of protein, total yield of protein, and total number of cuttings per season where the plants were cut at various stages to simulate grazing.

Welton and Morris in Ohio (14) found that clipping oats or wheat tended to reduce the number and height of culms, and to prevent lodging, but the effect was largely governed by subsequent weather conditions.

EXPERIMENTAL PROCEDURE

The investigation was conducted on a Cumberland silt loam soil located on the Tennessee Agricultural Experiment Station farm at Knoxville. Soil tests were made to determine the approximate fertility and the degree of soil heterogeneity within the experimental area. The results of these tests are presented in Appendix I.

The winter grains used were Fulcaster #612 wheat, Fulwin oats, Balbo rye, and Jackson barley. Before seeding, a 4-8-12 fertilizer was applied to the experimental area at the rate of 400 pounds per acre.

The crops were sown with a grain drill on October 6, 1941; seeding was delayed until this time because of insufficient soil moisture. The seeding rates on an acre basis for the different crops were: wheat and rye, 1½ bushels; oats, 1¾ bushels; and barley, 2 bushels. After seeding, the plots were cultipacked to firm and smooth the surface in order to facilitate clipping of the herbage. With the exception of oats, a satisfactory stand of all crops was obtained.

The plots were arranged in a Latin Square design. Each plot was subdivided perpendicular to the drill rows into five plots 16 feet long and 28 inches wide, with a 6-inch border along each side. Clippings were made on two plots to a height of 1 inch and on two other plots to a

height of 3 inches. The fifth plot was maintained as a check with no clipping treatment. Within each height two frequencies of clippings were made. They were designated A and B; frequency A represented approximately 1½ inches increase in plant height since the last clipping, and frequency B represented approximately 3 inches increase in height since the last clipping. Using these combinations of height and frequency four clipping treatments were made, namely, 1-inch height at frequency A, 1-inch height at frequency B, 3-inch height at frequency A, and 3-inch height at frequency B.

The first clippings were made on December 15, the last on April 14. Because of such circumstances as excessive soil moisture, or wind, clippings could not always be made at the scheduled time. Rye was clipped four times, wheat and barley five, and oats seven. Clippings were continued in the spring until the plants started to joint.

The degree of tillering as affected by each clipping treatment was determined on each plot on the basis of the number of culms per square foot. This value was computed from an average of five counts per plot.

The effect of each clipping treatment on the height of plants at maturity was determined on each plot from an average of five measurements.

The grain was harvested on June 13 and when dry was threshed and cleaned. Yields are reported in bushels per acre.

All data were subjected to analysis of variance tests to determine statistical significance. The term "significant" as used in this manuscript denotes statistical significance.

EXPERIMENTAL RESULTS

Data comparing different clipping treatments on wheat, oats, rye, and barley in respect to tillering, plant height at maturity, and forage and grain yields are presented in Table I. The values reported in this table are averages of four replications. The mean differences between values necessary for statistical significance are also presented in this table. The individual yields of each replication are given in Appendices II, IV, VI, and VIII. Analysis of variance summaries of these data are presented in Appendices III, V, VII, and IX.

The results and their interpretation are discussed under the following headings: (1) effect of clipping treatments on forage yields, (2) effect of clipping treatments on tillering, (3) effect of clipping treatments on plant height at maturity, (4) effect of clipping treatments on grain yields, and (5) harmful effects resulting from forage removal.

Effect of clipping treatments on forage yields

The calculation of the average of the forage yields for all crops for each treatment in Table I gives the following values: 1-inch height at frequency B, 280.3; 1-inch height at frequency A 267.4; 3-inch height at frequency B, 254.5; 3-inch height at frequency A, 251.6. The differences among treatments are relatively small and not significant.

TABLE I

A COMPARISON OF DIFFERENT CLIPPING TREATMENTS ON PLANT HEIGHT AT MATURITY, TILLERING, AND FORAGE AND GRAIN YIELDS OF WHEAT, OATS, RYE, AND BARLEY

Clipping Treatments		Number of culms per sq.ft.*	Plant ht. at maturity, inches*	Yield per acre	
height, inches	frequency†			Forage (oven-dry), pounds*	Grain, bushels*
			WHEAT		
1	A	38	44	215.5	19.4
1	B	38	44	160.0	21.9
3	A	42	46	240.8	21.0
3	B	40	47	257.3	20.4
Check		47	48		23.6
			OATS		
1	A	41	25	174.6	24.1
1	B	38	25	224.9	27.8
3	A	50	25	231.0	26.3
3	B	48	25	236.0	26.6
Check		51	29		37.0
			RYE		
1	A	37	44	360.9	20.2
1	B	35	44	458.8	21.9
3	A	39	46	232.1	24.0
3	B	36	48	174.8	24.0
Check		55	56		24.6
			BARLEY		
1	A	41	29	318.5	29.7
1	B	45	32	277.4	30.8
3	A	45	29	302.5	30.2
3	B	46	32	349.5	30.7
Check		61	41		39.5
Min. diff. for sig.		5	6	91.3	6.7

†Frequency A=1½" increase in plant height since last clipping
Frequency B=3" increase in plant height since last clipping

*Average of four replicates

The exceptionally high forage yields of rye on the plots clipped to the 1-inch height at frequency B accounts for the highest yield being attributed to this particular treatment. On all crops except rye the highest forage yields were produced on the plots clipped to the 3-inch height at frequency B. Although each treatment consisted of both height and frequency of clipping, the data show that height influenced forage yields more than did frequency.

The comparative forage yields of crops for each treatment are shown graphically in Figure 1. Rye outyielded the other crops in forage production at the 1-inch clipping heights, irrespective of frequency, whereas barley outyielded the other crops on the plots clipped to 3 inches. Many of the differences in yield among crops are large enough to be significant.

Rye produced higher yields when clipped to 1 inch than when clipped to 3 inches, whereas the yield of wheat was considerably greater from the 3-inch clippings than from the 1-inch clippings. Barley produced the greatest amount of forage when clipped to the 3-inch height at frequency B. Approximately equal yields of oats were obtained on plots clipped to 3 inches at both A and B frequencies, and on the 1-inch height at frequency B, but the yield was considerably lower when clipped to 1 inch at frequency A. Treatment differences within a crop are large enough to be significant only in wheat and rye.

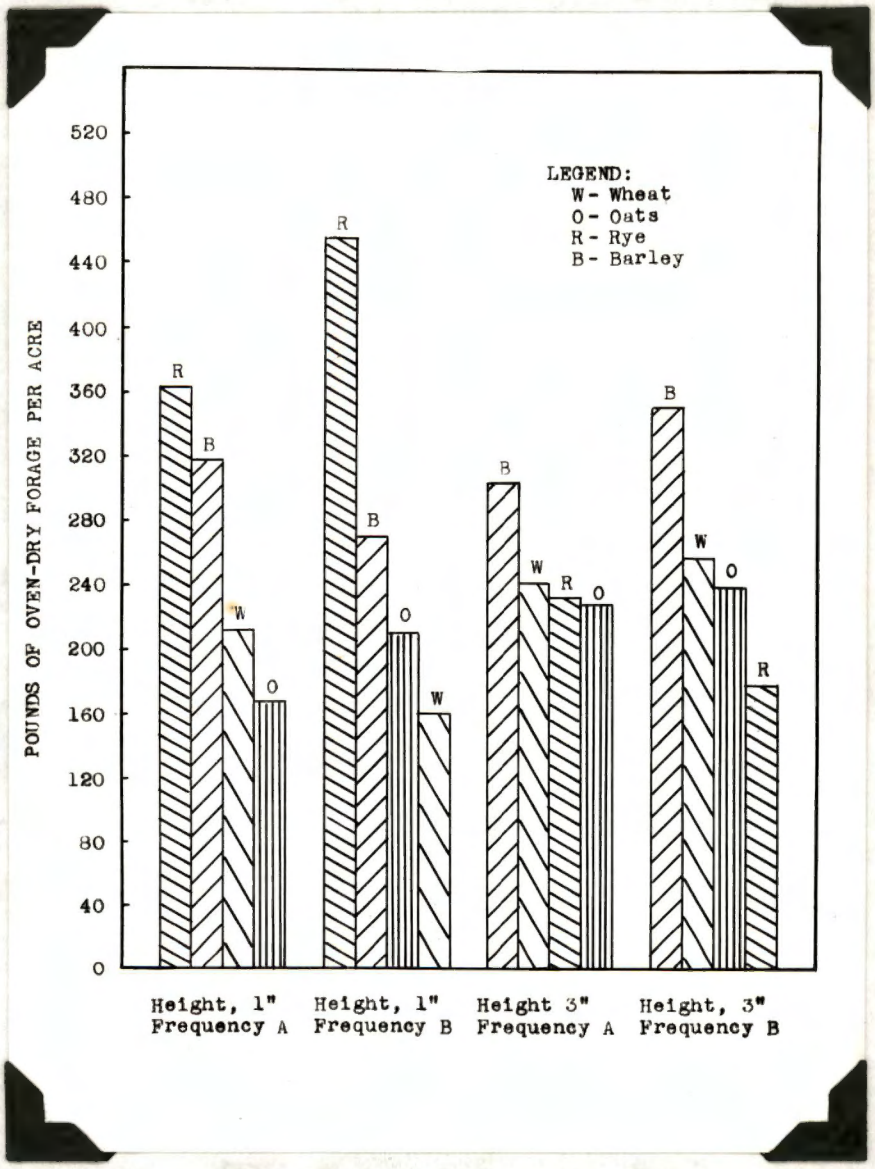

Fig. 1. Forage Yields of Wheat, Oats, Rye, and Barley as Influenced by Clipping Treatments

Totaling the yields for all treatments in a crop shows that rye and barley produced approximately equal amounts of forage, whereas wheat and oats yielded about 40 percent less forage. The early clippings of rye produced higher yields than the early clippings of the other crops. Rye produced forage over a period of 101 days, wheat 114, barley 114, and oats 120 days.

The fact that rye produced the highest yields of forage on the plots clipped to 1 inch may have been due to the upright habit of winter growth of the variety used. This type of growth permitted the removal of forage from rye at every cutting, whereas much of the top growth of the other crops, although of sufficient length for clipping, could not be removed because of prostrate growth.

Effect of clipping treatments on tillering

The data presented in Table I comparing the degree of tillering on all plots are graphed in Figure 2. Compared to the checks, tillering was reduced by all clipping treatments except the 3-inch height at frequency A on oats. The percentage reductions in tillering of the various clipping treatments as compared with the checks are given in Table II. The effect of clipping treatments on tillering was influenced more by height of clipping than by frequency. Considering all crops, clipping at the 1-inch height at either frequency reduced the number of culms approximately 27 percent; the

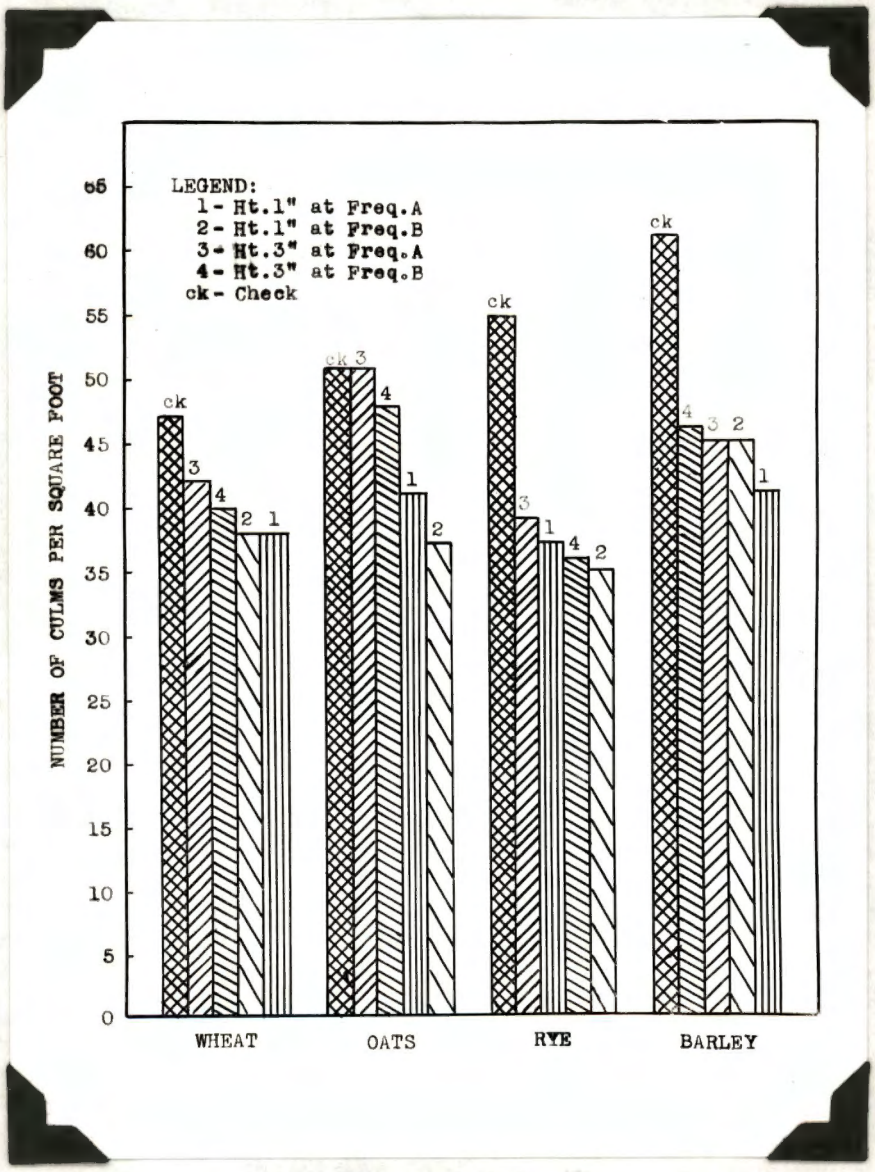

Fig. 2. The Influence of Clipping Treatments on Tillering of Wheat, Oats, Rye, and Barley

TABLE II

PERCENTAGE REDUCTION IN TILLERING, PLANT HEIGHT AT MATURITY, AND GRAIN YIELDS AS THE RESULT OF DIFFERENT CLIPPING TREATMENTS ON WHEAT, OATS, RYE, AND BARLEY

Crops	Clipping Treatments														
	Height 1 in. Frequency A			Height 1 in. Frequency B			Height 3 in. Frequency A			Height 3 in. Frequency B			Average of all treatments		
	Percent reduction in			Percent reduction in			Percent reduction in			Percent reduction in			Percent reduction in		
	til.	ht.	gra.	til.	ht.	gra.	til.	ht.	gra.	til.	ht.	gra.	til.	ht.	gra.
Wheat	19.1	8.3	17.8	19.1	8.3	7.2	10.6	4.2	11.0	14.9	2.1	13.6	16.0	5.6	12.4
Oats	19.6	13.8	34.9	25.5	13.8	24.9	0	13.8	28.9	5.9	13.8	28.1	10.0	13.8	29.0
Rye	32.7	21.4	17.9	36.4	21.4	11.0	29.1	17.9	2.5	34.5	14.2	2.5	33.2	18.7	8.5
Barley	32.8	29.3	24.8	26.3	22.0	22.0	26.3	29.3	23.5	24.6	22.0	22.3	27.5	25.7	25.7
Average all crops	26.6	18.4	23.4	27.1	16.6	16.4	17.3	16.0	16.7	20.6	13.0	16.7	22.0	15.8	18.8

3-inch clippings at frequency B decreased the number 20 percent, and at frequency A only 16.5 percent. These differences between the 1-inch and 3-inch heights, for either frequency, were significant.

The percentage reductions in tillering due to all treatments according to crops were: rye 33.2, barley 27.5, wheat 16.0, and oats 10.0 (Table II). All clipping treatments on rye and barley reduced the degree of tillering significantly, but the differences among the treatments within either crop were not significant. The 3-inch clipping treatments on oats had practically no influence on tillering, whereas the 1-inch clippings produced highly significant reductions when compared with the check. On wheat, significant differences occurred between the check and the plots clipped to 1-inch height at A and B frequencies, but no significant differences existed among the clipped plots.

Effect of clipping treatments on plant height at maturity

The influence of clipping treatments on height of plants at maturity, shown in Table I, is illustrated graphically by Figure 3. As compared with the check, clipping reduced plant height on all crops, but only significantly in rye and barley. With the exception of wheat, the differences in the height of plants among treated plots were not as large as between the check and any one of the treatments within the same crop. Considering all crops, the reduction

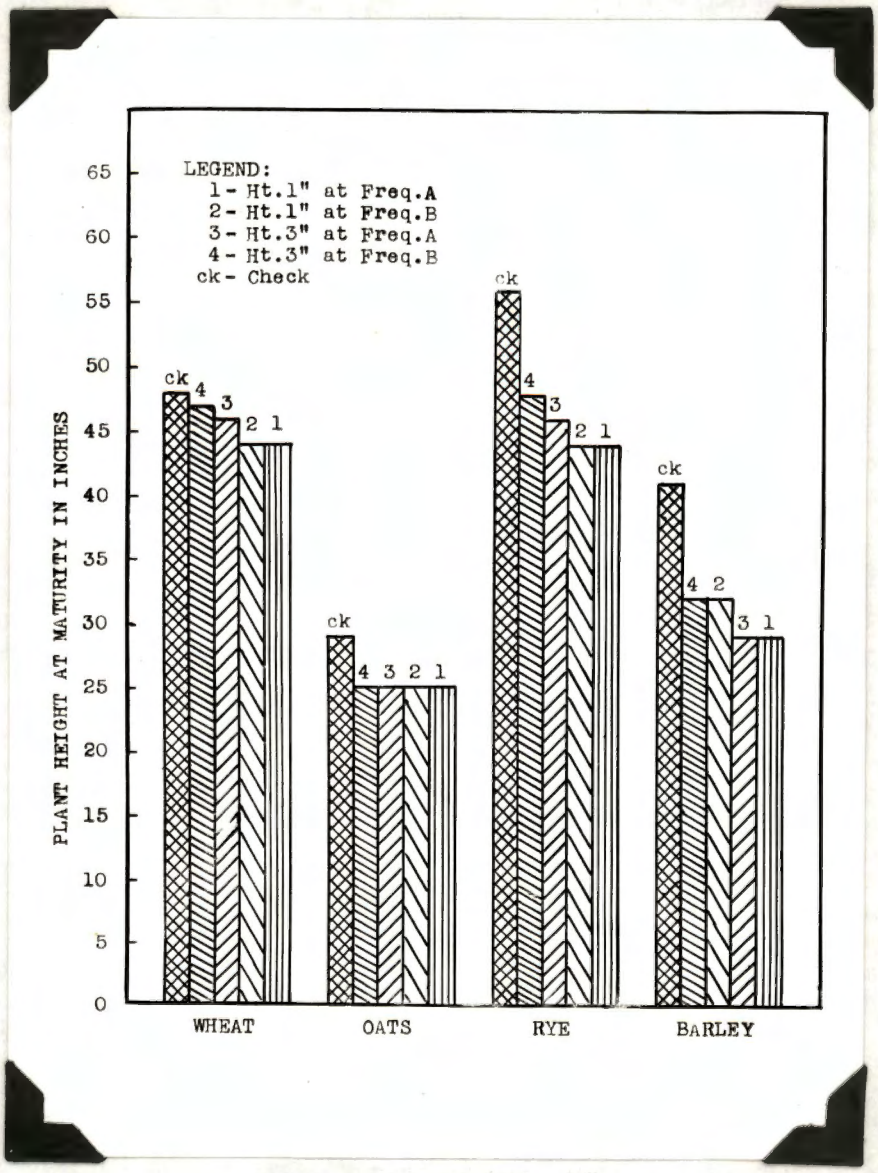

Fig. 3. The Influence of Clipping Treatments on Plant Height at Maturity of Wheat, Oats, Rye, and Barley

in height due to treatments ranged from 13.0 percent for the 3-inch clipping at frequency B to 18.4 percent for the 1-inch clipping at frequency A (Table II).

In wheat and rye, clipping to 1-inch height at both A and B frequencies reduced plant height at maturity more than the 3-inch clippings. In barley, frequency of clipping caused a greater reduction than did height; frequency B reduced plant height more than frequency A. Although plant height in oats was reduced by all clipping treatments, the reductions were of the same magnitude. When treated plots as a whole were compared with the checks the following percentage reductions in plant heights occurred: rye 25.7, barley 18.7, oats 13.8, and wheat 5.6. The percent reduction due to each treatment on each crop is given in Table II. Maturity in rye and barley was retarded about six days by the various clippings; only minor differences were noted among treatments. The maturity of oats and wheat was not influenced by clipping treatments.

Effect of clipping treatments on grain yields

The grain yields of the clipped and check plots presented in Table I are illustrated in Figure 4. The only significant reductions in grain yields due to clipping treatments, as compared to the checks, occurred in oats and barley. The reductions in grain yields as influenced by clipping treatments are presented in Table II as percentages of checks.

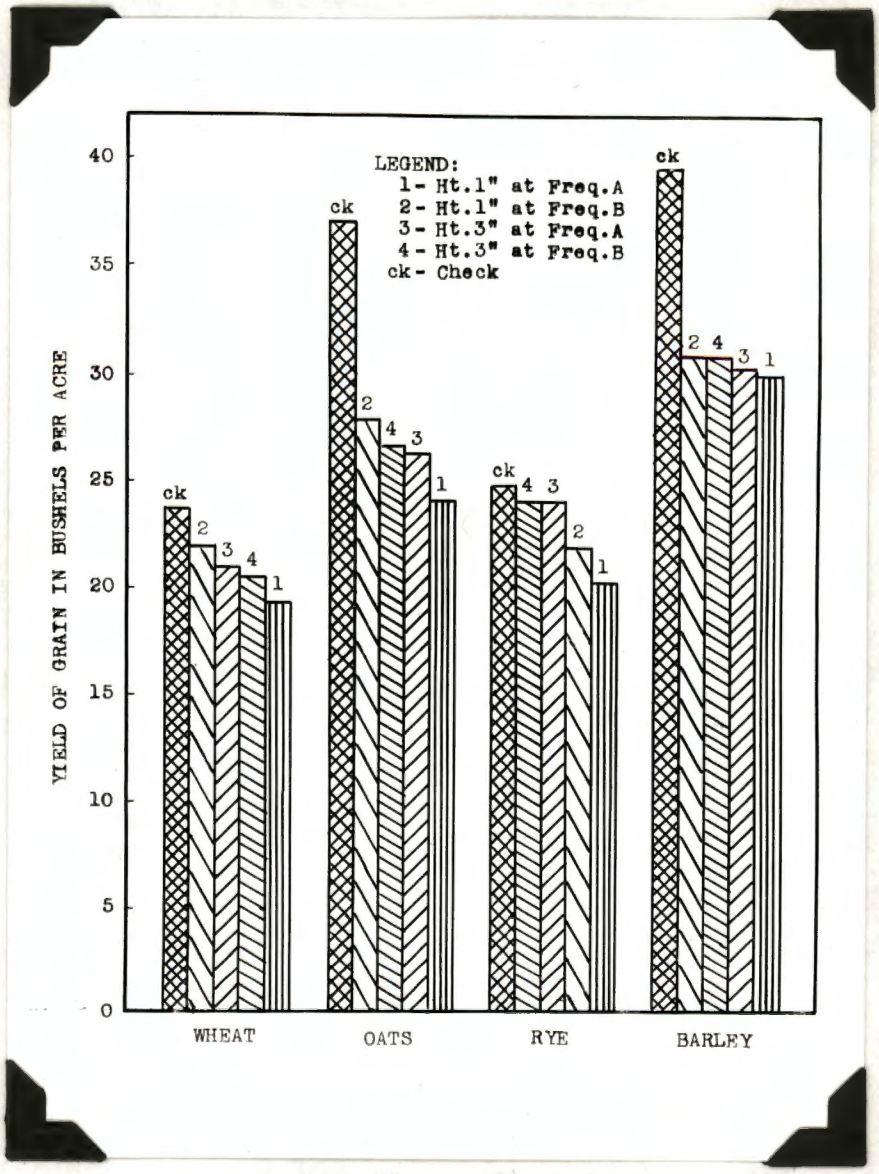

Fig. 4. The Influence of Clipping Treatments on Grain Yields of Wheat, Oats, Rye, and Barley

All clipping treatments reduced grain yields in comparison to the check plots. Clipping to a height of 1 inch at frequency A caused a 23.4 percent reduction in total grain yield of all crops, whereas each of the other treatments reduced yield approximately 16.5 percent.

On wheat, oats, and barley the plots clipped to 3 inches reduced grain yields more than the 1-inch height at frequency B; on all crops the 1-inch height at frequency A reduced grain yield more than any other treatment. The effects of clipping treatments on grain yields were most noticeable in barley and oats where significant differences occurred between the check plot and any one treatment within either crop. In rye and wheat no significant differences appeared between check and clipped plots. Percentage reductions in grain yields due to all treatments were: oats 29.0, barley 25.7, wheat 12.4, and rye 8.5 (Table II).

Harmful effects resulting from forage removal

The data indicate that the removal of forage was accompanied by harmful effects to tillering, plant height at maturity, and grain yield (Table II). However, no direct relationship can be established between the amount of forage removed and its effect on these factors. On rye alone, increased amounts of forage removal resulted in decreased tillering, plant height, and grain yields. On the other crops, the effect of forage removal showed no similar relation-

ship. In general, the 1-inch clippings not only yielded less forage than the 3-inch clippings, but they also caused a greater reduction in tillering and plant height. Although reductions in grain yields on wheat, oats, and barley occurred as a result of clipping treatments, there appears to be no direct association between forage removal and grain yield except for the 1-inch height at frequency A.

DISCUSSION

Recommendations and conclusions based upon the results of this experiment must necessarily be considered tentative for two major reasons. First, they are based upon only one year's results. The forage yields were somewhat influenced by unfavorable weather conditions. The late summer and fall of 1941 were extremely dry, necessitating later seeding and fewer clippings than would ordinarily be made. Furthermore, had a satisfactory stand of oats been obtained, this crop likely would have produced more forage than it did. Secondly, the data were obtained under conditions simulating grazing rather than by actual grazing trials, consequently, the results may not be the same as would be obtained under the latter conditions. However, it has been found by Robinson, et al (8) and Gardner, et al (3) that data obtained by clipping treatments are comparable to those obtained in actual grazing trials.

If maximum forage yields are to be obtained with a minimum decrease in grain yields the small grains probably should not be subjected to grazing conditions comparable to the 1-inch height at frequency A treatment. This treatment yielded only a few pounds more forage than did either of the plots clipped to 3 inches, but was the most harmful of all treatments on grain production of each crop. Both tillering and plant height seemed to be affected more by the 1-inch heights of clipping than by the 3-inch.

From the standpoint of total forage production, rye or barley would be preferred to wheat or oats. Rye or barley should provide pasturage earlier in the fall than either wheat or oats, but the latter crops, expecially oats, can be pastured later in the spring and still produce a satisfactory grain crop.

The crop to use and the type of pasturing to be practiced will depend upon the needs of the farm operator. Not only must the farmer consider the total forage yield, the period in the grazing season of the greatest production of pasturage and the reduction in grain yield due to pasturing, but also the utilization of the grain of a particular crop.

SUMMARY

Clipping treatments designed to simulate four intensities of grazing were made on winter varieties of wheat, oats, rye, and barley. Two plots of each crop were clipped to 1-inch height and two others to 3 inches. One plot within each height was clipped more frequently than the other. The fifth plot was maintained as a check and was not clipped. The effects of the various clipping treatments were studied in respect to tillering, plant height at maturity, and forage and grain yields.

Higher forage yields of wheat, oats, and barley were produced by the 3-inch height of clipping than by the 1-inch height. In rye, the 1-inch clipping treatments at both frequencies produced significantly higher yields than those clipped to the 3-inch height. Rye and barley produced approximately equal total forage yields; each yielded 40 percent more forage than wheat or oats.

Tillering was reduced approximately 27 percent on the plots clipped to 1-inch height at either frequency, whereas the 3-inch height at the less frequent clipping decreased the number of culms 20 percent, and the more frequent clipping 16.5 percent. Differences in tillering between the 1- and the 3-inch heights were significant. On each crop the 1-inch height of clipping reduced tillering more than the 3-inch.

Clipping treatments as a whole were more harmful to tillering in rye and barley than in wheat and oats.

Plant height was reduced by clipping treatments, as compared with the check plots, on all crops, but only in rye and barley was the reduction significant. The greatest reduction was due to the 1-inch height at the less frequent cutting, and the least reduction in the 3-inch heights at either frequency.

The grain yield was reduced most by the 1-inch height at the more frequent clipping. The harmful effect of clipping treatments as a whole was most pronounced on barley and oats, reductions in grain yield of 29 and 26 percent, respectively, as compared to 12.4 percent for wheat and 8.5 percent for rye.

On rye, increased amounts of forage removal resulted in decreased tillering, plant height, and grain yields. On the other crops similar relationships were not apparent.

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LITERATURE CITED

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APPENDICES

APPENDIX I

THE pH, AVAILABLE POTASH, AND AVAILABLE PHOSPHORUS OF THE SOIL IN THE EXPERIMENTAL AREA

Row		pH[1]	Available K_2O, lbs. per acre[2]	Available P_2O_5, lbs. per acre[3]
I.	Surface	6.0	158	35
	Subsurface	5.3	118	25
II.	Surface	5.7	132	35
	Subsurface	5.5	118	35
III.	Surface	5.5	161	35
	Subsurface	5.6	133	35
IV.	Surface	5.7	134	35
	Subsurface	5.4	108	35

1. pH determined with Beckman glass electrode

2. Potash determined by Aspergillus niger method

3. Phosphorus determined by Cunninghamella plaque method

APPENDIX II

THE EFFECT OF CLIPPING TREATMENTS ON FORAGE YIELDS OF WHEAT, OATS, RYE, AND BARLEY

Row	Yield of oven-dry forage in pounds per acre			
	Clipping treatments			
	Ht. 1" Freq. A	Ht. 1" Freq. B	Ht. 3" Freq. A	Ht. 3" Freq. B
		WHEAT		
I	191.9	193.2	228.5	293.7
II	269.4	207.9	450.3	358.6
III	225.6	150.2	150.4	156.4
IV	174.9	88.6	133.9	220.2
Average	215.5	160.0	240.8	257.3
		OATS		
I	180.3	274.8	340.3	358.3
II	211.2	320.4	342.1	348.8
III	191.6	204.5	206.6	150.7
IV	115.4	99.7	34.8	86.3
Average	174.6	224.9	231.0	236.0
		RYE		
I	539.4	504.4	265.1	273.0
II	364.2	607.9	306.5	212.3
III	363.2	467.5	218.4	117.7
IV	176.7	255.5	138.3	96.1
Average	360.9	458.8	232.1	174.8
		BARLEY		
I	476.5	366.0	425.3	405.7
II	304.0	342.9	460.6	526.0
III	350.6	229.8	184.4	255.0
IV	143.0	171.0	139.9	211.2
Average	318.5	277.4	302.5	349.5

APPENDIX III

ANALYSIS OF VARIANCE FOR FORAGE YIELD DATA IN APPENDIX II

Source of Variation	D/F	Sum of Squares		Mean Square	F Value
Rows	3	456,124.77		152,041.59	32.70**
Columns	3	18,825.98		6,275.33	1.35
Crops	3	135,181.51		45,060.50	9.69*
Error (1)	6	27,898.65		4,649.78	
Treatment	3	7,340.67		2,446.89	0.61
Height	1		6,947.23	6,947.23	1.72
Frequency	1		984.40	984.40	0.24
Ht. x Freq.	1		409.04	409.04	0.10
Treatment x Crop	9	230,159.82		25,573.31	6.33**
Ht. x Crop	3		186,223.17	62,074.39	15.35**
Freq. x Crop	3		5,292.92	1,764.33	0.44
H x F x Crop	3		38,643.66	12,881.22	3.19*
Error (2)	36	145,553.23		4,043.15	
Total	63	1,021,084.63			

*Significance at 5% level
**Significance at 1% level

APPENDIX IV

THE EFFECT OF CLIPPING TREATMENTS ON TILLERING OF WHEAT, OATS, RYE, AND BARLEY

Row	Number of culms per square foot				
	Clipping Treatments				
	Ht. 1" Freq. A	Ht. 1" Freq. B	Ht. 3" Freq. A	Ht. 3" Freq. B	Check
			WHEAT		
I	34	29	44	40	45
II	48	47	41	47	53
III	34	39	43	37	43
IV	35	36	39	37	47
Average	38	38	42	40	47
			OATS		
I	54	35	56	41	48
II	37	38	54	49	52
III	37	41	48	53	52
IV	36	39	50	48	53
Average	41	38	51	48	51
			RYE		
I	39	37	38	41	60
II	29	30	38	35	45
III	49	42	44	41	59
IV	31	32	37	38	55
Average	37	35	39	36	55
			BARLEY		
I	48	45	47	47	67
II	35	44	50	48	56
III	43	38	38	40	58
IV	36	46	46	49	61
Average	41	45	45	46	61

APPENDIX V

ANALYSIS OF VARIANCE FOR TILLERING DATA IN APPENDIX IV

Source of Variation	D/F		Sum of Squares		Mean Square	F Value
Rows	3		49.64		16.55	0.25
Columns	3		348.04		116.01	38.67**
Crops	3		643.94		214.65	7.16*
Error (1)	6		400.07		66.68	
Treatment	4		2,269.68		567.42	30.20**
Check		1		1,848.01	1,848.01	98.35**
Height		1		405.01	405.01	21.55**
Frequency		1		13.14	13.14	0.70
Ht. x Freq.		1		3.42	3.42	0.18
Treatment x Crop	12		525.12		43.76	2.33*
Check x Crop		3		112.58	37.53	4.27**
Ht. x Crop		3		146.81	48.94	2.60
Freq. x Crop		3		53.44	17.81	0.95
H x F x Crop		3		212.29	70.76	3.77*
Error (2)	48		902.00		18.79	
Total	79		5,138.49			

*Significance at 5% level
**Significance at 1% level

APPENDIX VI

THE EFFECT OF CLIPPING TREATMENTS ON PLANT HEIGHT AT MATURITY OF WHEAT, OATS, RYE, AND BARLEY

Row	Plant height at maturity in inches				
	Clipping treatments				
	Ht. 1" Freq. A	Ht. 1" Freq. B	Ht. 3" Freq. A	Ht. 3" Freq. B	Check
			WHEAT		
I	44	44	45	47	48
II	44	45	46	47	49
III	43	44	46	46	48
IV	43	43	45	47	48
Average	44	44	46	47	48
			OATS		
I	26	26	26	26	30
II	26	26	26	26	30
III	26	26	26	26	30
IV	22	22	22	22	26
Average	25	25	25	25	29
			RYE		
I	46	46	48	50	52
II	44	43	45	50	60
III	44	44	45	48	56
IV	42	42	45	45	56
Average	44	44	46	48	56
			BARLEY		
I	30	32	30	32	44
II	28	32	28	32	40
III	28	32	28	32	40
IV	28	30	28	30	40
Average	29	32	29	32	41

APPENDIX VII

ANALYSIS OF VARIANCE FOR PLANT HEIGHT DATA IN APPENDIX VI

Source of Variation	D/F	Sum of Squares		Mean Square	F Value
Rows	3	59.04		19.68	3.44
Columns	3	4.04		1.35	0.24
Crops	3	6,625.24		2,208.41	386.76**
Error (1)	6	34.27		5.71	
Treatment	4	725.33		181.33	135.32**
Check	1		667.01	667.01	497.77**
Height	1		30.25	30.25	22.57**
Frequency	1		25.00	25.00	18.66**
Ht. x Freq.	1		3.07	3.07	2.29
Treatment x Crop	12	219.07		18.26	13.63**
Check x Crop	3		109.96	36.65	27.35**
Ht. x Crop	3		31.37	10.46	7.81**
Freq. x Crop	3		19.12	6.37	4.75**
H x F x Crop	3		58.62	19.54	14.58**
Error (2)	48	64.40		1.34	
Total	79	7,731.39			

*Significance at 5% level
**Significance at 1% level

APPENDIX VIII

THE EFFECT OF CLIPPING TREATMENTS ON GRAIN YIELDS OF WHEAT, OATS, RYE, AND BARLEY

Row	Yield of grain in bushels per acre				
	Clipping treatments				
	Ht. 1" Freq. A	Ht. 1" Freq. B	Ht. 3" Freq. A	Ht. 3" Freq. B	Check
			WHEAT		
I	17.4	17.6	21.3	17.2	24.0
II	25.3	27.5	28.2	24.4	30.7
III	17.6	21.7	15.6	15.9	16.0
IV	17.2	20.9	18.8	24.1	23.7
Average	19.4	21.9	21.0	20.4	23.6
			OATS		
I	39.0	31.2	31.2	31.7	47.0
II	16.1	22.1	24.1	29.6	45.6
III	30.9	45.4	39.2	28.8	34.9
IV	10.3	12.6	10.7	16.3	20.6
Average	24.1	27.8	26.3	26.6	37.0
			RYE		
I	24.1	34.0	28.9	32.8	35.5
II	23.6	23.5	25.7	26.3	27.0
III	21.2	20.4	22.1	11.5	15.7
IV	11.9	9.7	19.4	25.4	20.1
Average	20.2	21.9	24.0	24.0	24.6
			BARLEY		
I	43.7	31.3	28.8	23.5	44.1
II	34.3	38.0	43.5	35.4	47.4
III	17.4	25.0	17.8	27.6	29.1
IV	23.3	28.9	30.7	36.1	37.2
Average	29.7	30.8	30.2	30.7	39.5

APPENDIX IX

ANALYSIS OF VARIANCE FOR GRAIN YIELD DATA IN APPENDIX VIII

Source of Variation	D/F		Sum of Squares		Mean Square	F Value
Rows	3		1,287.25		429.08	4.51
Columns	3		1,330.51		443.50	4.66
Crops	3		1,504.56		501.52	5.27*
Error (1)	6		571.37		95.23	
Treatment	4		551.99		137.99	4.88**
Check		1		496.69	496.69	17.57**
Height		1		13.66	13.66	0.48
Frequency		1		21.57	21.57	0.76
Ht. x Freq.		1		20.07	20.07	0.71
Treatment x Crop	12		216.88		18.07	0.64
Check x Crop		3		140.56	46.85	1.66
Ht. x Crop		3		22.59	7.53	0.27
Freq. x Crop		3		4.02	1.34	0.47
H x F x Crop		3		51.71	17.24	0.61
Error (2)	48		1,357.17		28.27	
Total	79		6,819.73		86.33	

*Significance at 5% level
* *Significance at 1% level