Progress Report Series No. 97 November 1971

Agricultural Experiment Station
AUBURN UNIVERSITY

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Comparison of Baled and Stacked Systems for Handling and Feeding Hay

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A RECENT DEVELOPMENT in hay machinery is a large wagon-type vehicle called a Hesston Stakhand. This machine is of interest to livestock farmers because of possible labor saving during hay harvesting and feeding.

A comparison of this stack system with a conventional bale system was undertaken during the summer of 1970 and winter of 1971 at the Black Belt Substation. A second growth field of johnsongrass was used for this experiment. The field produced an average of 1,694 pounds of air-dry hay per acre.

In the stacked hay system the hay was handled from the windrow to storage with the Hesston Stakhand 30. This machine requires one operator and is propelled by a tractor. Hay is picked up from the windrow and blown into the machine. The top of the machine serves as a hay compressor, and hay is compressed several times during loading. When loaded, the machine transports hay to the storage area and unloads compressed stacks of hay. Each stack is approximately 8 feet wide, 14 feet long, and 9 feet high. The top of the stack is rounded to help shed water. Stacks are not covered.

In the baled system the hay was baled with a New Holland 277 baler. The bales were loaded, transported and unloaded by a New Holland 1047 Stackcruiser. This is a self-propelled automatic bale wagon operated by one man and can handle 119 bales per load. The use of commercial names is to help identify the machines and does not imply endorsement of these machines over those of other manufacturers.

The study was a cooperative project involving the departments of Agricultural Economics and Rural Sociology, Agricultural Engineering, Animal and Dairy Sciences, and Black Belt Substation, New Holland Machine Division of Sperry Rand Corporation, and Hesston Corporation.

The study involved four separate phases. The first was a time study of the machines to obtain labor needs and machine capacity. The second involved a feeding trial using 26 steers each for stacks and bales. The third was a chemical composition and nutritive value comparison and the fourth was a cost analysis.

Size and type of stack made by machine and fed to cattle at the Black Belt Substation is illustrated.

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Baled hay that was loaded, transported, and stacked by machine was used for comparison with the stack system.

MACHINERY CAPACITY COMPARISONS

The agricultural engineering phase of the research involved obtaining time study data and capacity values for comparison of the two systems of handling hay. The machine study included the time involved to handle hay for each system from the raked windrow to the hay storage area. For the bale system this involved baling the hay which was then loaded, transported, and stacked with a New Holland Stackcruiser. For the stack system a Hesston Stakhand was used to load, transport, and unload the hay.

The machine capacity study for both systems was conducted in the same field with hay for each system coming from alternate windrows. Windrows for the bale system were cut with a New Holland conditioner and those for the stacked hay were cut with a Hesston conditioner. The same rake was used to produce windrows for both systems.

Machine speeds used during the study are presented in Table 1.

Time records were obtained for handling 12.2 tons

Table 1. Hay Machine Speeds

Machines	Speed
	mph
Conditioners	6.0
Rake	5.1
Bale	4.2
Stakhand	
Loading	4.5
In transport	9-12
Stackcruiser	
Loading	Variable*
In transport	14-16.5

* Speed influenced by field conditions, bale numbers and windrow length. Too variable to obtain meaningful range or average.

of baled hay and 9.15 tons of stacked hay. Hay from both handling systems was transported approximately one mile to the storage and feeding area. The bale system required 2.0 minutes per ton for transport while the stack system used 3.8 minutes.

Machine capacity and man hours required for the two handling systems are presented in Table 2. These data include total handling time from windrow to storage.

Table 2. Capacity Comparison of a Baled and Stacked Hay Handling System

Hay handling system	Measured unit
Bale System	
Bale System Capacity	
Tons per hour	3.45
Tons per man hour	2.95*
Stack System	
Stack System Capacity	
Tons per hour	3.47
Tons per man hour	3.47

* Requires one man each for baler and Stackcruiser.

ANIMAL FEEDING TRIAL COMPARISONS

The johnsongrass was mowed and conditioned and after partially drying in the swath was windrowed. Both the baled and the stacked hay were stored in the open in a 14.5-acre field of fescuegrass. The baled hay, when stored, had a dry matter content of 79.25 per cent; it was stored in stacks, covered with a tarpaulin, and fenced to protect it from livestock. There were 10 stacks of hay harvested with the Hesston machine. Each stack measured approximately 8′ wide by 14′ long by 9′ high. The stacked hay contained 76.11 per cent dry matter at storage. Each of the 10 stacks of hay was separately fenced and the enclosure was fitted with a wire gap so each stack could be individually offered for feeding to cattle.

The 14.5 acre field of fescue was fenced into two equal areas. Each area was supplied water. A group of 52 Angus and Angus-Hereford steers having an average weight of 476 pounds was divided into two comparable groups of 26 animals each. The test period was November 10, 1970, through March 10, 1971. One group of animals was offered baled hay free choice daily in hay racks. The other group of steers was on stacked hay and had access to a stack of hay 24 hours each day. When a stack was consumed, the two groups of steers were rotated between fescue fields so as to minimize pasture differences. At this time, a new stack of hay was made available. Time for consuming a stack of hay by a group of 26 test animals varied from 8 to 19 days. The fescue grazing reduced hay intake early in the test; fescue grazing was extremely limited in midwinter. In addition to hay, each treatment group of steers received daily per head 2 pounds of ground corn and 1.5 pounds of cottonseed meal (41%).

Weather damage to hay in stacks did not appear to be excessive. By visual observation, it was estimated that weather damage to the stacks was less than 5 per cent. Stacked hay loss was large during feeding. The cattle pulled hay from the stack and trampled it in the mud. The loss was measured for 3 of the 10 stacks. After animals consumed a stack, the trampled hay was picked up, weighed, and dry matter determined. Based on dry matter at storage, the waste amounted to 35.2 per cent from stack 3, 43.5 per cent from stack 7, and 46.5 per cent from stack 8. Both rainfall and eating time appeared to influence stacked hay loss. It required 10, 19, and 18 days to consume stacks 3, 7, and 8, respectively. Rainfall amounts (inches) during the feeding periods for stacks 3, 7, and 8 were .93, 1.52, and 1.63, respectively.

Since baled hay was fed in racks, there was a minimal amount of loss resulting from trampling by cattle during the feeding process. Weigh backs of damaged hay indicated 5.65 per cent of baled hay was wasted during feeding. In addition to the feeding loss, there was an estimated loss from rot in baled hay of 3.88 per cent. This rotted baled hay was from hay lying on the ground during storage.

CHEMICAL COMPOSITION AND DIGESTIBILITY

By use of a coring tool (Pennsylvania State hay sampler) samples of hay for chemical and nutritive value study were obtained from the baled and the stacked hay. Approximately 20 baled samples were cored and these samples were composited for analysis. The 10 hay stacks were cored 20 times each. Core samples from each stack were composited and chemical and nutritive value studies were carried out on each of the composited samples. In addition to the core samples, selected samples of hay were taken from the top of several stacks during the feeding operation. These samples were analyzed to determine the degree of deterioration in the hay by weather. Also, at the end of the feeding of several stacks of hay, the refused hay was collected and analyzed. The digestibility of the samples of hay was determined through use of the nylon bag technique.

TABLE 3. CHEMICAL COMPOSITION AND IN VITRO DIGESTIBILITY OF JOHNSONGRASS HAY THAT WAS EITHER BALED OR STACKED

Item	Stacked outside baled hay core sample	Stacked hay		
		Top sample (moldy)	Core sample	Refused hay
Van Soest Values:				
Cell wall, pct.	82.85	71.40	81.00	77.83
Non-cell wall, pct.	17.15	28.60	19.00	22.17
Crude protein, pct.	10.18	12.58	10.37	10.29
Dry matter digestibility:				
In vitro, pct.	53.87	42.37	46.27	43.17
Minerals:				
Ash, pct.	7.64	9.94	8.21	9.01
P, pct.	.50	.50	.37	.37
Ca, pct.	.83	1.31	1.40	1.10
Mg, pct.	.24	.24	.21	.19
K, pct.	1.08	1.08	1.30	1.04
Cu, p.p.m.	7.69	10.94	10.79	7.46
Fe, p.p.m.	115.42	186.02	174.09	180.84
Mn, p.p.m.	17.95	27.36	22.51	29.91
Zn, p.p.m.	25.65	32.83	30.27	24.75

A summary of the chemical composition and dry matter digestibility data is presented in Table 3. Analyses for cell wall, non-cell wall, crude protein, and minerals showed no important differences between core samples taken from baled and stacked hay. In contrast, the dry matter digestibility was appreciably higher for the baled hay. In addition to the core samples, hay samples were taken from the tops of the hay stacks. These samples were analyzed to determine if the noticeable deterioration in the top hay would be reflected in the chemical analyses. Chemical analyses of these top samples did reveal apparent increases in contents of non-cell wall, crude protein, and minerals as compared with core samples from within the stacks. The increases in non-cell wall and crude protein probably resulted from action of the microflora in solubilizing the structural carbohydrates. These apparent increases in nutrients do not indicate an improved nutritive value for the hay because the palatability was adversely affected by the deterioration.

The data for refused hay, Table 3, represent hay that was gleaned from the feeding area of stacks after the cattle had finished eating the stack. Of importance in these data is the fact that the ash content was not appreciably elevated over the ash content of the core samples. This is interpreted to mean that the material collected did not represent a contamination by soil, but rather reflected a reasonably accurate harvest of hay lost by trampling.

The yearling steers were on test consuming the hay for a total of 113 days. The performance data on these cattle during this time are summarized in Table 4. The animals fed the baled hay made an average daily gain of 1.42 pounds whereas those fed the stacked hay gained only 1.19 pounds per head.

Based on weights of hay stored, the cattle fed baled hay were fed during the test an average of 1,540 pounds and during this same period the animals on the stacked hay had available 2,089 pounds per head. The daily hay dry matter available per

TABLE 4. BALED VS. STACKED JOHNSONGRASS HAY FOR WINTERING YEARLING CATTLE

Item	Baled hay	Stacked hay
Animals, no.	26	26
Days on test, no.	113	113
Final live weight, lb.	636	612
Initial live weight, lb.	476	477
Gain, lb.	160	135
Average daily gain, lb.	1.42	1.19
Feed fed per animal:[1]		
Hay, lb.	1,540 (1,207)[2]	2,089 (1,590)
Corn, lb.	226	226
CSM, lb.	169.5	169.5
Daily feed offered per animal:		
Hay, lb.	13.63 (10.68)	18.49 (14.07)
Corn, lb.	2.00	2.00
CSM, lb.	1.50	1.50
Feed per cwt. gain:		
Hay, lb.	963 (754)	1,547 (1,178)
Corn, lb.	141	167
CSM, lb.	106	126
Feed cost per cwt. gain[3]	20.53	26.01

[1] Baled hay was fed daily in a rack; Hesston stacks (average 5,432 lb.) self-fed one at a time. Feed fed per animal was based on weight at harvest.

[2] Values in ( ) are hay expressed as dry matter.

[3] Feed ingredient prices were: Corn \$3.30 cwt.; CSM \$4.20 cwt. Hay cost was calculated on the bases of an annual hay harvest and feeding of 500 tons (Table 4); for the baled system the harvesting and feeding cost was estimated at \$15.21 per ton; by the same procedure the estimated stacking cost per ton was \$11.13; in addition, for both systems the hay production cost per ton was estimated to be \$8.53.

animal was 10.68 pounds for baled hay and 14.07 pounds for stacked. The hay dry matter used per hundredweight of gain was 756 pounds for baled hay and 1,178 pounds for stacked hay. It should be clearly noted that these feed efficiency data are calculated on the basis of hay dry matter at time of storage. Therefore, the hay intake data, Table 4, clearly reveal that baled hay was more efficiently utilized for animal gain than was the stacked hay.

Based on normal hay production cost and market prices of corn and cottonseed meal, the feed cost per hundredweight of animal gain for baled hay in this test was \$20.53; for the stacked hay, it was \$26.01.

These data reveal considerable advantage for baled hay over stacked hay. It is important to consider, however, that there were savings in labor for the stacked hay (3.47 tons per man hour vs. 2.95 tons per man hour for harvesting and storing baled hay). In addition, the stacked hay was self-fed to the cattle whereas the baled hay had to be fed by man. The baled hay feed input was partially offset by the fact that the stack required special fencing. There are other ways of feeding the stacked hay and these might be proven to be more efficient than the system used in this test. It is expected that research on stacked hay will be continued and effort will be put forth to find the most efficient way to take advantage of the convenience of stacked hay without suffering the rather serious feeding losses revealed in the current test.

ECONOMIC COMPARISONS

In order to make an economic comparison of the bale versus the stack system, data were assembled from the results of the time and motion study by the Agricultural Engineering Department conducted in August, 1970 at the Black Belt Substation. Machinery and facilities used in each system are indicated in Table 5. Also, data from experiments by the Department of Animal and Dairy Sciences and personnel of the Black Belt Substation during the winter of 1970-1971, and from manufacturers and other secondary sources were used in the economic analysis.

TABLE 5. ESTIMATED COSTS PER TON BY AMOUNTS HARVESTED AND FED PER YEAR FOR TWO SYSTEMS OF HAY HARVESTING, AUGUST 1970[1]

Machine or item of cost	Total cost per ton, when average tons harvested per year are:				
	250	500	1,000	2,000	3,000
Baled Hay					
New Holland 1469 Haybine	\$ 4.12	\$ 2.56	\$ 1.79	\$ 1.40	\$ 1.27
Massey Ferguson rake	1.94	1.45	1.21	1.09	1.05
New Holland 277 baler	3.86	2.68	2.08	1.79	1.69
New Holland 1047 Stackcruiser	7.15	4.15	2.64	1.89	1.64
Tarpaulins and tiedowns[2]	.73	.73	.73	.73	.73
Hay racks for feeding[3]	.53	.53	.53	.53	.53
Fencing[4]	.04	.04	.04	.04	.04
Feeding labor[5]	2.34	2.34	2.34	2.34	2.34
Pickup truck[6]	.73	.73	.73	.73	.73
Total cost/ton harvested	\$21.44	\$15.21	\$12.09	\$10.54	\$10.02
Total cost/ton actually utilized[7]	23.70	16.81	13.36	11.65	11.08
Total cost/cwt. gain[8]	10.32	7.32	5.82	5.08	4.82
Stacked Hay					
Hesston 310 Windrower	\$ 4.04	\$ 2.56	\$ 1.83	\$ 1.46	\$ 1.34
Massey Ferguson rake	1.94	1.45	1.21	1.09	1.05
Hesston Stakhand 30	7.92	4.97	3.49	2.75	2.50
Fencing[9]	2.15	2.15	2.15	2.15	2.15
Total cost/ton harvested	\$16.05	\$11.13	\$ 8.68	\$ 7.45	\$ 7.04
Total cost/ton actually utilized[10]	27.54	19.10	14.90	12.79	12.08
Total cost/cwt. gain[11]	12.41	8.61	6.71	5.76	5.46

[1] Based on study conducted at the Black Belt Substation, Marion Junction, Alabama, August, 1970 and winter 1970-71. Costs total costs (fixed and variable).

[2] Based on cost of tarpaulins of \$91.14 and tiedowns of \$9.00, actual cost at Black Belt Substation, assuming 3 years useful life + 10%/year extra for patching and maintenance for 50 tons of hay/year.

[3] Based on cost of \$11.50, labor and materials, assuming 2 years of useful life, for 14 steers, @ 1,540 lb. hay/steer/year.

[4] Based on cost of wire, posts, and labor of \$26.35, 15-year life for wire and posts, and 45 tons of hay.

[5] Based on 2 man hours/day for feeding @ \$1.60/hour, 113 day feeding period/year for 200 steers @ 1,540 lb. hay/steer/year.

[6] Truck to go to and from feeding area, 5 miles/day @ \$.20/mile, 113 days for 200 steers @ 1,540 lb. hay/steer/year.

[7] Based on an average loss of 9.53% which included a feeding loss of 5.65% observed and loss from rotting of 3.88% observed.

[8] Based on daily gain of steers of 1.42 lb./day observed, 9.63 lb. hay offered/lb. gain or .4815 tons offered/cwt. gain observed.

[9] Estimated by Superintendent, Black Belt Substation based on costs of wire, posts, and labor.

[10] Based on average feeding loss of 41.73% estimated from 3 stacks.

[11] Based on daily gain of steers of 1.19 lb./day observed, 15.47 lb. hay offered/lb. gain or .7735 ton offered/cwt. gain observed.

Budgets were prepared for each of the major harvesting systems. Costs were computed for conditions and assumptions applying at the Black Belt Substation. In Table 5, total costs per ton harvested and fed are computed for various assumed average amounts of hay harvested per year, based on the budgets for the Black Belt Substation, and modified for various assumed average tons harvested per year. The first totals labeled "Total Cost/Ton Harvested" do not consider whether any hay was lost in feeding or by spoilage. From these basic figures, the total cost per ton actually utilized by the cattle, when amount lost by trampling and spoilage is subtracted from the amount actually harvested was computed. Finally, results of the feeding trials during the winter of 1970-71 are used to compute the total cost of hay offered per hundredweight of gain put on the animals during the feeding period.

In order to determine the relative amount of total cost which is fixed per year (associated with owner-

TABLE 6. ESTIMATED OWNERSHIP (FIXED) AND OPERATING (VARIABLE) COSTS PER TON HARVESTED AND FED BY VARYING AMOUNTS HARVESTED AND FED PER YEAR

Machine or item of cost	Total cost per ton, when average tons harvested per year are:				
	250	500	1,000	2,000	3,000
	Baled Hay				
Ownership (fixed) costs	$12.46	$ 6.23	$ 3.11	$ 1.56	$ 1.04
Operating (variable) costs	8.98	8.98	8.98	8.98	8.98
Total costs	21.44	15.21	12.09	10.54	10.02
	Stacked Hay				
Ownership (fixed) costs	$ 9.83	$ 4.91	$ 2.46	$ 1.23	$ .82
Operating (variable) costs	6.22	6.22	6.22	6.22	6.22
Total costs	16.05	11.13	8.68	7.45	7.04

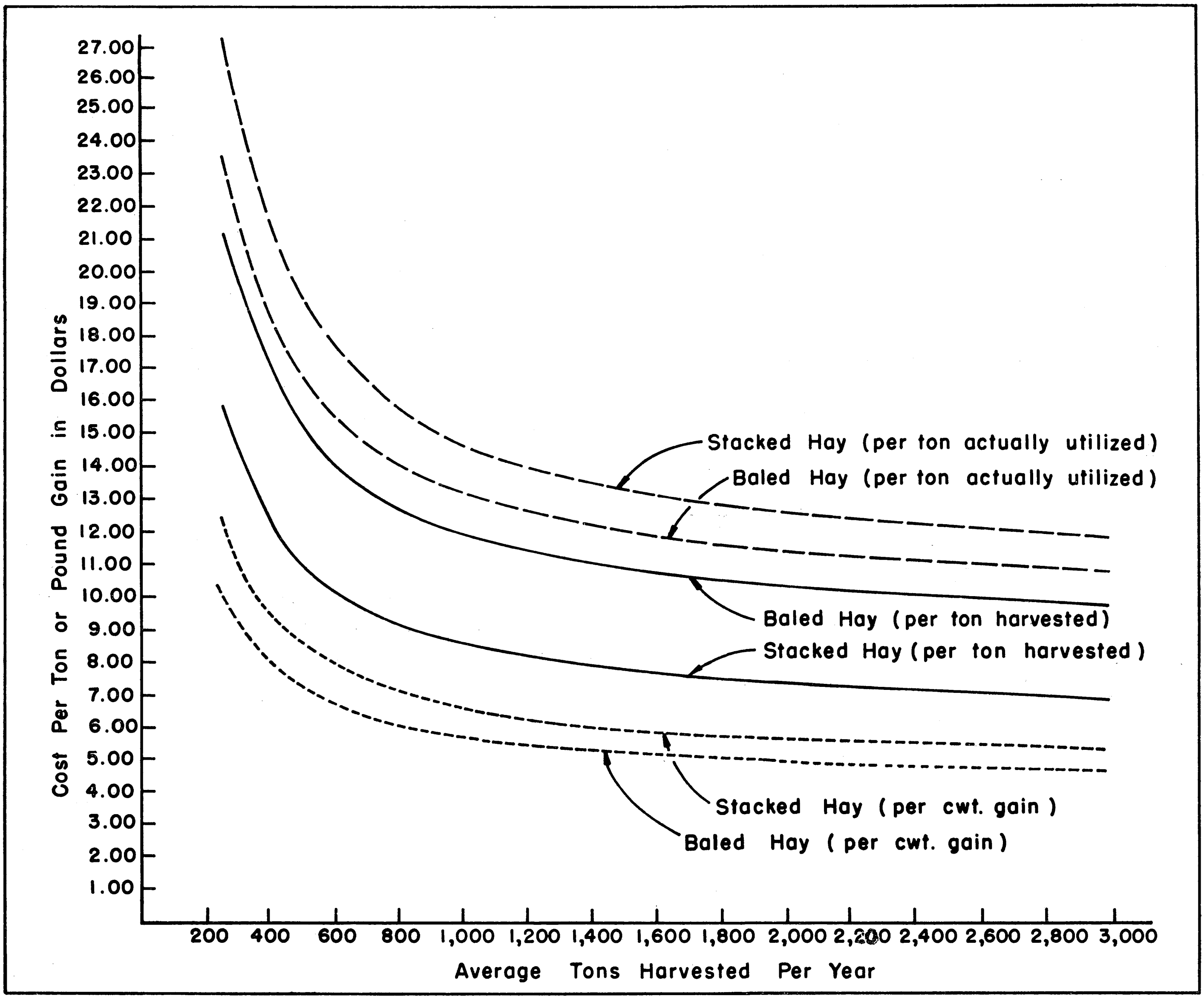

FIG. 1. Estimated total harvesting and feed costs—per ton harvested, per ton actually utilized, and per hundredweight gain—by average amounts harvested and fed per year, for two systems of hay handling.

ship of the equipment, and which will occur regardless of whether hay is produced and how much), and the amount which is variable per year (must be paid for as production occurs), Table 6 was prepared. These figures were computed from costs per ton harvested, and did not take into account feeding losses and gain of animals when fed.

In Figure 1, total costs per ton harvested for the two systems (solid lines) are compared with total costs per ton actually utilized by the animals during the feeding trials (dashed lines), and with total costs per hundredweight of gain (dotted lines), for varying assumed average amounts harvested per year up to 3,000 tons annually.

Finally, Table 7 shows investment required for the basic hay harvesting equipment for the two systems. Tractors are not included, since it was assumed the farmer would already have adequate power on hand and it would not be an additional investment for adoption for either of these systems. In this table, both initial investment and average investment are shown. Average investment is initial investment + estimated salvage value at end of useful life divided by 2.

TABLE 7. ESTIMATED INVESTMENT REQUIRED FOR BASIC HAY HARVESTING EQUIPMENT, TWO SYSTEMS OF HAY HARVESTING, EXCLUDING TRACTOR POWER, PICKUP TRUCK, FENCING, AND OTHER SUPPLIES

Item	Investment	
	Initial	Average
Bale System		
New Holland 1469 Haybine	$ 5,572.30	$ 3,064.76
Massey Ferguson rake	604.00	332.20
New Holland 277 baler	3,293.10	1,811.20
New Holland 1047 Stackcruiser	12,078.00	6,642.90
Total	$21,547.40	$11,851.06
Stack System		
Hesston 310, self-propelled Windrower	$ 5,572.30	$ 3,064.76
Massey Ferguson rake	604.00	332.20
Hesston Model 30 Stackhand	7,750.00	4,262.50
Total	$13,639.00	$ 7,501.45

The economic analysis indicated the following:

1. Costs per ton harvested were lower for the stacked hay system than for the bale system for any volume of use. This was mainly the result of the higher fixed cost per ton for the bale system, from a higher machinery investment to spread over the average tons of hay harvested per year.

2. Costs per ton actually utilized (or actually consumed and not lost by trampling or spoilage), however, was lower for the baled hay system, because of a high loss of hay from trampling for the stack system.

3. Costs per cwt. gain also were lower for the bale system, as with per ton actually utilized, for the same reasons. This was because the bale system required only 963 pounds of hay offered per cwt. gain compared with 1,547 pounds of hay offered per cwt. gain for the stack system.

The stack system was cheaper per ton harvested, but the bale system was cheaper per ton actually utilized and per cwt. of gain when fed, because of the high loss from trampling for the stack system. If losses under the stack system could be reduced from an average of 42 per cent to approximately 31 per cent compared with the estimated 10 per cent average loss for trampling and rotting for the bale system, the two systems would be approximately equal from an economic standpoint. Also, from the standpoint of costs/hundredweight gain, the stack system required 15.47 pounds hay offered/pound gain compared with 9.63 for the bale system. This would have to be reduced from 15.47 pounds to approximately 12.54 pounds for the stack system to be equal in cost per pound to the bale system.

From the standpoint of timeliness, the two systems are practically equal. In the bale system, 3.45 tons were handled per clock hour while in the stack system 3.47 tons/clock hour were handled. Therefore, timeliness is not a significant factor in differentiating the two systems from an economic standpoint.