COST AND UTILIZATION OF ABOVE GROUND BIOMASS IN THINNING SYSTEMS

by

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ABSTRACT: The cost and utilization were compared for a thinning operation removing the stems as roundwood with a flail chipper operation- The flail chipper operation recovered an additional 4.2 tons of acceptable chips per acre which resulted in a higher return to the site. There was little difference in the cost of acceptable chips delivered to the digester between the two methods of thinning.

KEYWORDS-Flail delimbing-debarking, woodlands chipping, logging costs, thinning

INTRODUCTION

There are 11.4 million hectares of pine plantations established in the Southeastern United States (Faulkner, Pers. Comm.). Regardless of the final product, all of these plantations are planted to an initial stocking of 1500 to 2000 trees Per hectare so that competition from undesirable species can be reduced. A large proportion of these stands are being grown for solid wood products; thus, the plantations must he thinned (usually between the ages of 10 and 23) to a stocking of 200 to 500 trees per hectare. The thinnings will allow for optimal growth of sawlogs and plylogs. The first thinning is usually accomplished prior to age 15 and all of the material removed is used for pulpwood. If more than one thinning is carried out in a plantation, the later thinnings will remove some stems suitable for solid wood products.

In the past these thinnings were accomplished with manual operations using chainsaws for felling and bucking the stems. These manual crews could carry out a purely selective thinning. These operations have been replaced with mechanized crews using feller-bunchers and rubber tired grapple skidders as safety and labor availability became major concerns- The feller-buncher and skidder were so large that corridors were needed to facilitate movement. Thus, the practice of clearcutting every third or fifth row and selecting stems to be removed from the remaining rows evolved.

It should be noted that a few harvester-forwarder operations have been employed to perform the second and later thinnings. This system has advantages in all weather operation and for merchandizmg the more valuable products in the forest. However, the harvester' forwarder system has not become dominant due to fact that the harvester is not large enough to handle the mature stems if a final harvest and due to the initial cost of the equipment.

The major problem in the feller-buncher skidder thinning operation has been the mechanization of delimbing. For many years the stems were delimbed by the skidder backing the stems through a stationary "gate". This caused extreme wear on the skidder as well as robbing productive time from the skidder. The idea of using chain flails was tested for delimbing and was found to be effective not only in delimbing but in debarking also (Watson and Twaddle, 1990). Thus, the teaming of flail delimber-debarkers with woodlands chippers became a prominent system for processing the thinned stems. The production of woodlands chips is more cost competitive in processing the smaller first thinnings than it is in processing mature stands being harvested for fiber (Watson et.al.,1991).

Over 200 of the separate flail units for use with chippers have been manufactured- In recent years the major manufacturers have combined the flail and the chippier into one unit for deliming and chipping. For example, Peterson-Pacific now has manufactured 65 integral flail-chipper units and Morbark has 35 in operation-

The newest method for delimbing in use in pine plantation thinnings is the pull through delimber. These units have grab arms sharpened for delimbing mounted on a lmuckleboom loader. The pull through delimbers were developed to improve delimbing quality on stems being processed for solid wood products and are now being utilized in thinnings. The pull through deliiber eliminates the need for a chaiiaw in the operation, therefore reducing the potential safely hazards and the cost of workman's compensation insurance.

EVALUATING ALTERNATIVE THINNING SYSTEMS

It is considerably more difficult to compare flail-chipper thinning operations with roundwood thinning operations than to compare harvesting operations where the final products are fungible. The measurable output of a flail-chipper thinning operation is chips while the output measured from a roundwood operation is wood and bark. The flail chipper operation captures stems that can not be handled in roundwood operations and is believed to make better use of some of the larger stems. The roundwood is debarked at a pulp mill using drum debarkers and the drum losses are recovered for fuel. The quality of the chips produced by the woods chipper is often different from the chips produced from the roundwood at the pulpmill wood yard .

Thus, a cost comparison of a roundwood thinning system with a woods chipping thinning system must be carried out at the

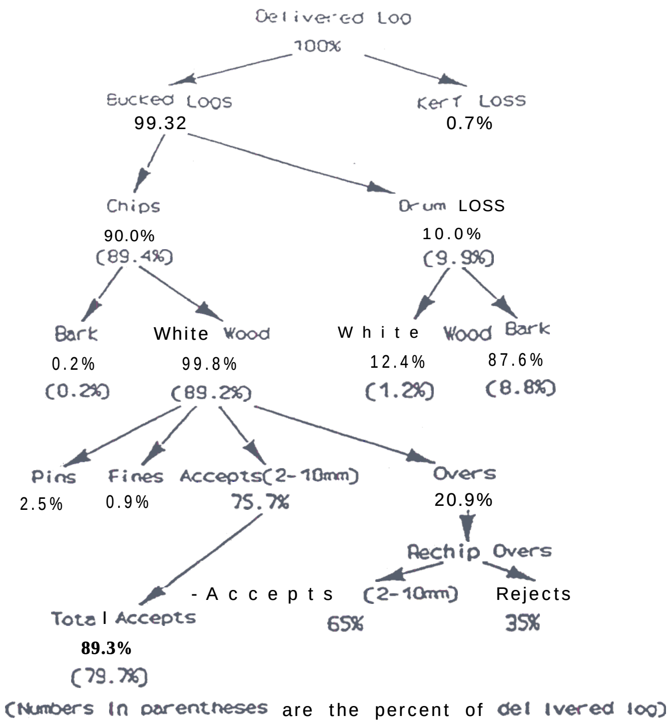

Figure 1. Losses and utilization observed during woodyard studies.

pulp mill digester. Credit must be given for the value of debarking drum losses as a hog fuel to the roundwood. Likewise a credit for incremental utilization of the above ground biomass must be given to the woods chipping operation. Differences in the production of acceptable chips for pulping must be accounted for in the analysis.

This paper will outline the results of a study carried out in cooperation with Boise Cascade Corporation on their woodlands and woodyard near DeRidder, Louisiana. The production of two thinning operations (one producing tree-length roundwood, one producing woodlands chips) was monitored as each operation thinned three twenty acre loblolly pine (pinus taeda) plantations. Utilization, production and cost studies were carried out simultaneously and are reported below.

UTILIZATION STUDIES

Intensive utilization studies were carried out on stems selected from stands adjoining each plantation. The stems used to estimate roundwood utilization were weighed before delimbing, after delimbing and topping at a 3.5 inch top, and a subsample of trees were hand debarked so that whitewood yield could be estimated.

A total of 182 trees were weighed and measured in the intensive studies. The best prediction equations for total weight and merchantable weight from this data were:

$$TOTWT = 4.97 + 0.209\ (DBH)^2\ (TOTHT)$$

with r^2 = .938, and.

$$WT\ (3.5) = -7.98 + 0.149\ (DBH)^2\ (TOTHT)$$

with r^2 = .908, where

TOTWT is total weight,
DBH is diameter breast height,
TOTHT is total height,
WT(3.5) is weight of merchantable stem to 3.5 inch top.

Thirty-one stems were hand debarked in this study. The best predictor of percent bark on the merchantable stem was:

$$\%BARK = 12.543 - 0.579\ (DBH)$$

with r^2 =.218.

The roundwood harvested from two of the plantations was accumulated at the pulpmill woodyard and processed separately during one shift. Note that this woodyard slashes the tree length stems, therefore there is a kerf loss due to this slashing. Chip and bark samples were taken during the woodyard study. The

Table 1. Predicted weights of trees and yield of acceptable chips by diameter class .

DBH (in)	Average Totai Height (ft)	Total Weight (lbs)	Merchantable Weight to a 3.5" To (lbs)	Weight of Accepts Roundwood (lbs)	Weight of Accepts Flail-Chipper (lbs)
3	33.8	68.53			37.38
4	37.6	130.66			71-33
5	40.6	217.24	143.35	114.25	118.71
6	42.9	327.84	222.20	177.09	179.30
7	44.4	460.12	316.50	252.25	251.86
8	45.2	609.86	423.26	337.34	334.12
9	45.2	770.96	538.11	428.87	422.53
10	44.5	935.40	655.34	522.30	512.66
11	43.0	1093.28	767.90	612.02	599.19

chips were analyzed for quality on the Radar CC2000 chip classifer and the whitewood content of the bark was analyzed. Acceptable chips are defined here to be between 2mm and 8mm thick. The utilization of the roundwood observed at the woodyard is shown in Figure 1. (The yield of acceptable chips manufactured by rechipping was not observed. Rechipping yields were . estimated by Desmond Smith (US. sales manager with Acrowood Corporation, Everett, WA).

The yield of acceptable chips for a tree in any DBH class when processed as roundwood can be estimated using the weight and bark prediction equations and the woodyard observations shown above in Figure 1. The average height by diameter class for the stems measured in the intensive study are shown in Table 1 along with estimates of total weight and merchantable weight. Multiplying the merchantable weight by 79.7% gives the estimate of acceptable chips that can be expected from a tree in each diameter class. (Note that trees in the 3 ‘and 4 inch classes would not be sufficiently large to process as roundwood but the feller-buncher operators would have been instructed to fell these trees.)

The utilization of the stems by the flail-chipper unit was studied by preparing 12 bundles of stems to be processed through the Peterson 5000. Seven of the bundles were composed of stems from a single dieter class (diameter classes from 3 to 9 inches DBH were represented). The remaining bundles had stems taken either from clearcut rows or selections between the rows only. Each bundle was weighed prior to processing (weights ranged from 2000 to 8410 pounds). The bundles were then processed through the flail-chipper unit and the flail rejects and chipper rejects for each bundle were captured and weighed (see Table 2). Utilization differences among the diameter classes were not significant. Possibly additional data would have revealed a significant trend of better utilization as diameter increased. However, it is obvious that the variation in utilization would be great within a diameter class, and the cost of replicating this part of the study until significance was found would be prohibitive. Thus, the average yield of chips of 60.6% of the whole tree will be used in the analyses that follow.

Chip samples were taken from each van of chips produced in the woods during the production studies and from chips made from each test bundle during the intensive studies. The chips were analyzed for thickness on a Radar CC2000 chip classifer.

Table 2. Rejects and chips as a percent of whole tree weight for trees processed by Peterson 5000.

DBH (in)	Flail Reject	Chipper Rejects	Wooodlands Chips
3	43.2%	1.8%	55.0%
4	31.8%	1.2%	67.0%
5	37.2%	1.7%	61.1%
6	38.5%	1.6%	59.9%
7	34.0%	1.5%	64.5%
8	40.7%	1.1%	58.2%
9	33.5%	1.0%	65.5%
3 to 9 (clearcut)	34.4%	1.5%	64.1%
3 to 8 (clearcut)	30.6%	1.4%	68.0%
3 to 7 (select)	38.6%	1.6%	59.8%
3 to 6 (select)	41.2%	1.4%	57.4%
3 to 5 (select)	41.1%	1.5%	57.4%

Oneway analysis of variance was used to test for differences in the percentage of acceptable chips by diameter class. No significant differences were found. Thus, the utilization and losses from the whole tree that could be expected when trees are processed by the flail-chipper unit are shown in Figure 2. The weight of acceptable chips produced by the flail-chipper can then be estimated by multiplying 54.6% by the estimated total weight of the tree (see Table 2).

To compare the utilization by the two methods of thinning, a common bases must be established. In this case we can use the average number of stems per acre that were thinned in each diameter class in the chipped plantations to compare the expected yield of acceptable chips. (The chipped plantations are used because the 3 and 4 inch diameter classes were processed in the chipped plantations but would not have been recovered by the roundwood operation.) Boise Cascade foresters carried out a preharvest and a post harvest inventory on all of the test plantations and the average number of stems removed in each diameter class is shown in Table 3. Multiplying the expected acceptable chip

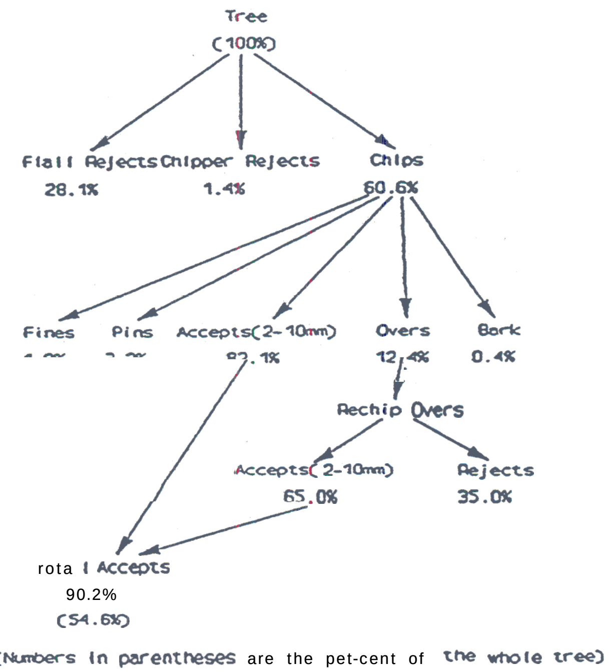

Figure 2. Utilization and losses observed for the flail chipper unit.

yield for each thinning method for a tree in each diameter class by the average number of trees in diameter class gives the the total yield of acceptable chips. In this comparison, the flail-chipper unit would recover an additional 4.2 tons of chips per acre. The roundwood operation would recover 47% of the biomass that was felled and the flail chipper operation would

Table 3. Acceptable chip yield per acre for the average number of stems removed per acre.

DBH (in)	Average Number of Stems Removed per Acre	Yield of Accepts Roundwood (lbs)	Yield of Accepts Flail-Chipper (lbs)	Total Weight of Removed Trees (lbs)
3	47.5		1,775.78	3,255.30
4	87.9		6,270.34	11,484.68
S	89.3	10,202.52	10,600.69	19,399.37
6	65.3	11,564.09	11,708.23	21,407.75
7	54.3	13,697,41	13,676.18	24,984.51
8	19.6	6,611.84	6,548.73	11,953.35
9	11-7	5,017.80	4,943.65	9,020.21
10	0.6	313-38	307.59	561.24
11	1.8	1,101.63	1,078.54	1,967.91
Total	378.0	48,508.67	56,909.72	104,034.33

recover 55% of the biomass that was felled. When only the 5 through 11 inch classes were considered, the roundwood operation recovered 54% of the biomass and the flail chipper recovered 55%.

THINNING COSTS

Production studies were carried out as each of the piantations were thinned. The plantations were paired so that each pair was similar and each operation thinned one plantation in the pair. Two pairs were 12 years old and one pair was 14 years old. Four of the plantations were thinned in August of 1993 (two were chipped and two were processed as roundwood). The remaining two plantations were thinned in January, 1994 with one being processed as roundwood and one chipped.

The equipment used in each operation and the estimated cost per machine hour-for each machine are reported in Table 4. Production data collected included the productive hours for each machine, the crew hours and the total tons Of wood produced from each plantation. Cost estimates for each plantation were obtained by multiplying the machine usage by the machine rates given in Table 4. Labor costs were found by multiplying crew hours by a loaded labor rate of $11.88. The loaded rate for the foreman's salary on the chipping operation was $17.82. A summary of the production and cost estimates for thinning each plantation is contained in Appendix A, The average stump to truck cost over all the plantations was $13.58 per ton of chips for the chipping operation and $9.19 per ton of roundwood for the roundwood operation.

Hauling costs were estimated using rates reported by Kinder, Feamster and Cubbage (1993). A rate of $1.24 per mile was used for the tractor and chip van while a rate of $1.17 per mile was used for the tractor and log trailer. On the roundwood operation, the tractor would spot the empty trailer and connect to a loaded trailer. Thus, a delay time for loading and unloading was assumed to be 45 minutes. The tractor would remain connected to the chip van to avoid problems with the chip van toppling over due to a high center of gravity on the chip van. Thus a delay time for loading and unloading was assumed to be 1.5 hours for each chip van. An average travel speed of 45 miles per hour

Table 4. Equipment used in harvesting studies and estimated cost per machine hour.

Woodlands Chipping Crew		Roundwood Crew	
Machine	Cost/Machine Hour	Machine	Cost/Machine Hour
Feller-Buncher (Valmet and Gafner tri-tracs)	$36.11[a]	Feller-Buncher (Valmet and Bell tri-tracs)	$36.11[a]
Grapple Skidder (TJ 450's)	42.31[a]	Grapple Skidder (TJ 450 and Cat 518)	42.31[a]
Flail-Chipper (Peterson 5000)	123.82[a]	Loader-Delimber (Barko 160 with CTR delimber)	29.19[b]
Dozer (Cat D-4)	28.52[a]		
Hydro Ax 211 (piled tops)	37.64[b]		

[a] From Kinder, Feamster and Cubbage (1993)
[b] Estimated for equipment being used by logger

Table 5. Hauling cost estimates for roundwood and chips.

	Hauling Cost/Ton	
Miles to Mill	Chips	Roundwood
10	$1.94	$1.34
20	2.39	2.37
30	3.86	3-39
40	4.93	4.42
50	6.01	5.44
60	7.08	6.46
70	8.16	7.49
80	9.23	8.51
90	10.31	9.54
100	11.38	10.56

was assumed and all payloads were assumed to be 28 tons. using these estimates and assumptions, transportation costs for each method were made and are reported in Table 5.

By adding the transportation costs in Table 5 to the average thinning costs, we can obtain the delivered cost at the mill (Table 6). The costs can not be compared as one unit is a ton of chips and the other unit is a ton of roundwood. Figure 1 shows that a ton of roundwood will yield 0.797 tons of acceptable chips. In Figure 2 we can fmd that a ton of woodland chips will yield 0.902 tons of acceptable chips after screening and rechipping. Thus, the delivered cost of the products can then be placed on the same basis, i.e. cost per ton of acceptable chips (Table 6).

The cost of processing the roundwood into acceptable chips will vary from facility to facility. Here $6.00 per ton of acceptable chips will be used based on estimates provided by woodyard design engineers and unpublished data. The cost of unloading, handling, reclaiming, screening, and rechipping the woodlands chips is estimated to be $1.50 per ton of acceptable chips.

All material delivered to the mill that is not manufactured into acceptable chips will

Table 6. Estimated cost of producing acceptable chips to the digester from thinnings delivered as roundwood or woodland chipped.

Operation	Cost of Roundwood	Cost of woodland Chips
Thinning Stump-to-Truck	$9.19[a]	$13.58[b]
Hauling Cost @ 50 Miles	5.44[a]	6.01[b]
Delivered Cost to Woodyard	14.63[a]	19.59[b]
Yield of Acceptable Chips	79.7%	90.2%
Woodyard Costs	6.00[c]	1.50[c]
Credit for Hog Fuel	1.62[c]	0.79[c]
COST OF ACCEPTABLE CHIPS DELIVERED TO DIGESTER	$22.74[c]	$22.44[c]

[a] Per ton of wood and bark
[b] Per ton of woodlands chips
[c] Per ton of acceptable chips

be used as hog fuel. Assuming a value of $8.00 per ton for the hog fuel, a credit of $1.62 per ton of acceptable chips is assigned to the chips from roundwood and a credit of $0.79 is assigned to the acceptable woodlands chips.

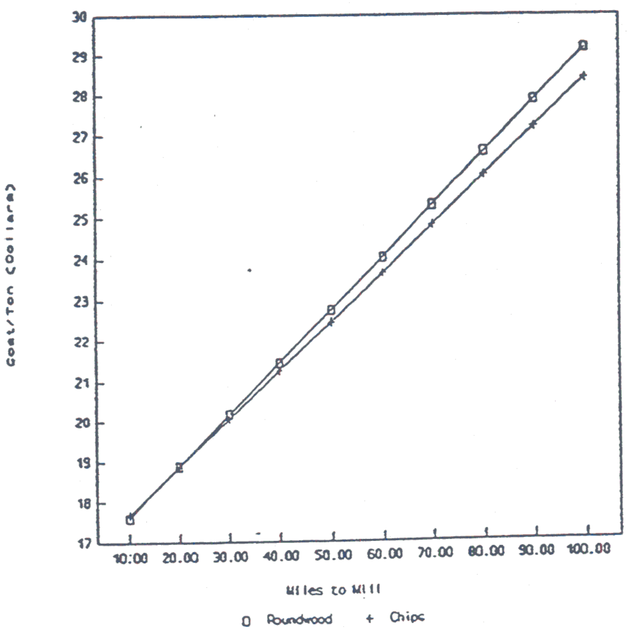

Figure 3. Estimated cost/ton of acceptable chips to the digester for thinning as roundwood and as woodlands chips.

Table 6 gives the estimated cost of acceptable chips delivered to the digester for both thinning methods when the hauling distance is 50 miles. Figure 3 shows the costs for other hauling distances.

The increment in utilization achieved by the woodlands chipping operation is not included in the comparison above. It was shown in Table 3 that the woodlands chipping operation would recover 28.46 tons per acre from the average stand while the roundwood operation would recover 24.25 tons per acre. Assigning a value of $40.00 per ton to the acceptable chips, the return to the acre for each operation can be estimated. Figure 4 contains these estimates as the distance to the mill increases.

DISCUSSION

For the study reported in this paper and under de assumptions used here, the cost of delivering the woodlands chips to the digester was about the same as the cost of thinning the plantations as roundwood and chipping in a woodyard. This is similar to the results found in other studies (Watson et.al. 1991). However, considering the incremental acceptable chips recovered from the flail-chipper operations resulted in a more favorable analysis for these operations. The return to the acre analysis carried out here showed an increase in value of about $70 to $90 for thinning with the flail chipper operations.

Using these results in other applications should be done with care. Other woodyards have been observed to yield a greater percentage of acceptable chips. Greater utilization has been observed in other flail-chipper studies. Woodyard operating costs can be significantly different from those assumed here. However, the framework of analysis can be applied in other situations. Additional data from local conditions will probably be required to complete an analysis in these other situations.

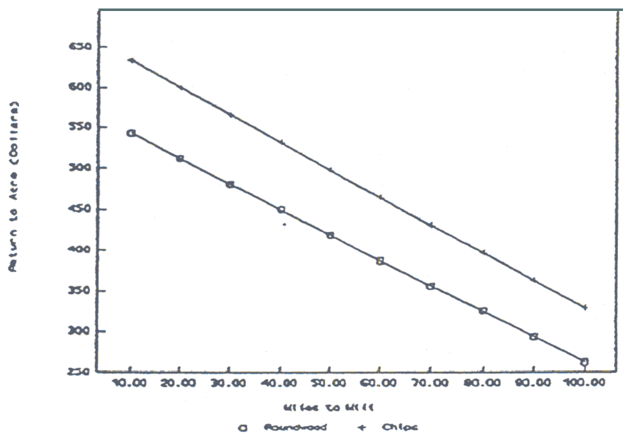

Figure 4. Return to the acre for the thinnings as roundwood and as chips as distance to the mill is varied.

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APPENDIX A. Production and cost data for the various test plantations.

PLANTATIONS WOODLANDS CHIPPED

Machines	Plantation 1 - Aug.93 Machine Hours	Labor Hours	Total cost	Plantation 2 - Aug.93 Machine Hours	Labor Hours	Total cost	Plantation 3 Jan.94 Machine Hours	Labor Hours	Total cost
Feller-Bunchers	29.66	36.16	1500.60	29.68	39.34	1539.10	27.01	45.08	1510.88
Grapple Skidders	24.66	27.58	1371.02	22.67	28.50	1297.75	28.42	33.00	1594.49
Flail-Chipper	7.90	12.75	1129.65	9.03	14.52	1290.59	9.77	14.00	1376.04
Dozer	2.91	17.50	290.89	3.58	12.25	247.63	2.83	0.00	80.71
Hydro Ax	2.58	6.25	171.36	9.75	13.50	527.37	10.92	14.00	577.35
Foreman		12.75	227.21		15.52	276.57		17.50	311.85
Total Cost			4690.73			5179.01			5451.32
Total Production			434.9 tons			464.8 tons			548.6 tons
Cost per Ton			10.78			11.15			9.94
Chain Cost per Ton			1.00			1.00			1.00
Overhead Cost per Ton			2.00			2.00			2.00
Grand Total Cost per Ton			13.78			14.15			12.94

PLANTATIONS THINNED AS ROUNDWOOD

Machines	Plantation 1 - Aug.93 Machine Hours	Labor Hours	Total cost	Plantation 2 - Aug.93 Machine Hours	Labor Hours	Total Cost	Plantation 3 - Jan.94 Machine Hours	Labor Hours	Total cost
Feller-Buncher	19.92	28.67	1059.91	22.83	32.67	1212.51	30.84	39.50	1582.89
Grapple Skidder	20.88	28.67	1224.03	22.67	32.67	1347.29	30.68	43.50	1814.85
Loader-Delimber	23.33	28.67	1021.60	25.08	32.67	1120.20	16.18	23.75	754.44
Total Cost			3305.55			3680.00			4152.19
Total Production			425.5 tons			513.3 tons			509.7 tons
Cost per Ton			7.77			7.17			8.15
Overhead Cost per Ton			1.50			1.50			1.50
Grand Total Cbst per Ton			9.27			8.67			9.60