91-0011

BUREAU OF SUGAR EXPERIMENT STATIONS

QUEENSLAND, AUSTRALIA.

SOIL COMPACTION STUDIES -

MOSSMAN

by A.P.Hurney.

PROJECT S31(a)

CONTENTS

****

BUREAU OF SUGAR EXPERIMENT STATIONS

PROJECT S31(a)

SOIL COMPACTION STUDIES - MOSSMAN

Compaction is a growing problem in intensively cultivated areas throughout the world. In the past when farm implements were fairly light they could not do much damage to the structure of the soil if used at unsuitable times. Now, however, due to the high cost of labour and a lift in farm size tractors and machinery have to be bigger and consequently heavier, and must work a greater number of days a year. This increases the risk of compaction particularly as the farmer often has to use these heavier machines on land which is really too wet to carry them.

This has certainly been the case in the Queensland sugar industry, particularly with the change from manual to mechanical harvesting. Mechanical harvesters are now bigger than when first introduced, and there has also been a trend towards larger haulage equipment in certain areas.

Mossman mill followed this trend with the introduction of 10 tonne bins (canetainers) to replace the conventional four tonne bin for transporting harvested cane. This step caused concern to growers in the area as they considered the additional compaction from the larger bins might reduce yields and increase cultivation costs.

It was generally accepted that some compaction did occur with normal machinery but this was offset by the advantages of mechanization and could be controlled by cultivation.

Because of the Mossman growers' concern a study was initiated to investigate the effects of the different bin transport systems on soil compaction.

EXPERIMENTAL DETAILS

Two trials were established on ratoon cane in the Mossman area to study soil compaction effects of different bin transport systems. Each trial consisted of four treatments with three replicates set out in a randomized block design. Details of the sites are given in Table 1.

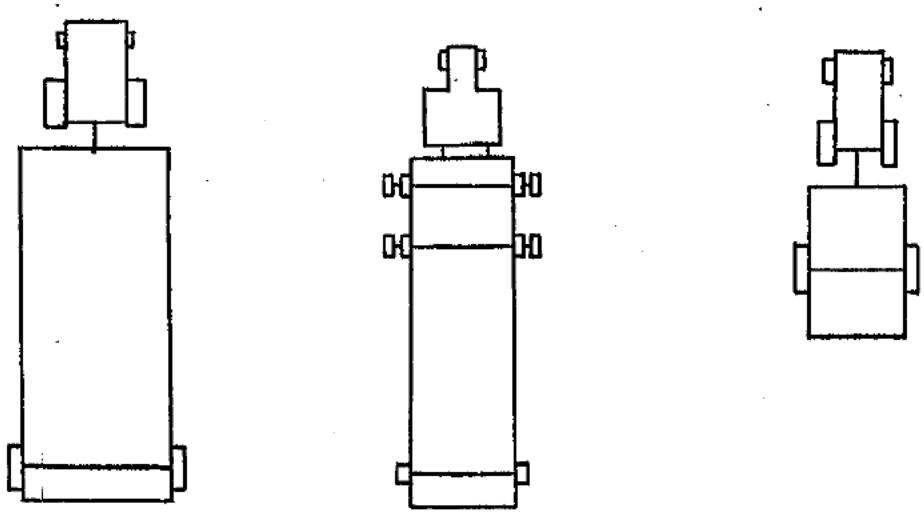
Treatments used in the trials were:-

1. Uncompacted
2. Harvester + tractor and single axle trailer and 10 tonne bin
3. Harvester + GMC prime mover and single axle trailer and 10 tonne bin
4. Harvester + tractor and single axle four ton tipper bin

The trailer equipment used in treatments 2 and 3 is illustrated in plates 1 and 2.

Tyre layout for the various bin transport systems is set out below.

Treatment 2 Treatment 3 Treatment 4



In both trials the uncompacted plots were harvested manually and the cane removed from the plot with a Toft loader stationed in one of the guard rows. All other plots were harvested with a Massey Ferguson 201 harvester.

Two different methods were employed in effecting compaction. In the Brie Brie trial the harvester stored the cane while on the plot and emptied it into a bin stationed at the end of the trial area. Compaction was effected by two passes over each inter-row with the appropriate bin system, fully loaded. The same 10 tonne bin was used for treatments 2 and 3.

The trial area was harvested and treatments applied at the same time in the other trial. The bins were partially filled outside the plot, to have bin weight as near as possible to compaction weight and to minimize weight variation over a plot. Filling of the bins was completed within the plot. This meant that a different bin weight was used for each replicate of a particular treatment and a variable load passed over the treated area. In regard to the partial filling of bins, canetainers were loaded with 7.5 - 8.0 tonnes and small bins with about 2.5 tonnes of cane. As in the other trial each inter-row had two passes over it.

Tables 2 and 3 give the weight of cane and equipment used in the two trials. It was not possible to weigh the cane in the tipper bin in Vico's trial as it had to be emptied continually because there was only one available. Since it was always full on completion of a plot, it has been assumed to be similar to the Brie Brie weight.

Each plot was five rows wide x 30 metres long with all plots being located on the end of the field, i.e. a total size of 60 rows wide x 30 metres long. Yields were determined by the sampling method on an area two rows wide x 20 metres long. Duplicate 45 stalk samples were weighed in each plot.

TABLE 1

Details of Soil Compaction Trial Sites

Trial	Location	Variety	Crop Class	Soil Type
Brie Brie Estate	South Mossman	Q79	1R	Old alluvial
Vico & Company	South Mossman	Q83	1R	Old alluvial

Bulk density samples were taken from the 0 - 100, 100 - 200 and 200 - 300 mm horizons in each plot. The samples were collected from the interspace between the two harvest rows and there were three sampling points per plot. The samples were taken diagonally across the interspace to allow for variation in compaction. Sampling times were before and after compaction and just prior to harvest (pre-harvest) of the ratoon crop the following year.

TABLE 2

Weight of Cane and Total Weight per Plot of Compaction Treatments

Trial	Treatment	Weight of Cane Tonnes		Total Weight per Plot* Tonnes
Brie Brie Estate	2	10.27		27.13
	3	10.27		27.08
	4	4.00		20.36
Vico & Company	2	11.16		
		10.01		
		9.17	(10.14)**	27.01
	3	9.75		
		9.55		
		10.61	(9.97)**	26.79
	4	"4.00"		"21.17"

* Includes weight of harvester

** Mean Weight

TABLE 3

Weight of Machinery Used in Compaction Treatment

Equipment	Weight (Tonnes)
Massey Ferguson 201	10.16
Tractor + Tipper bin	7.01
Tractor + Trailer + 10 tonne bin	6.70
GMC + Trailer + 10 tonne bin	6.65

An automatic recording soil penetrometer was also used to record compaction effects (Plate 3). The location, number of sampling points and times of sampling were the same as for bulk densities, except that measurements were also carried out following completion of ratooning cultivations. Six readings, to a maximum depth of 355 mm, were taken at 200 mm intervals across the interspace at each sampling point.

Details of soil characteristics are given in Table 4.

TABLE 4

Details of Soil Morphological Characteristics of Compaction Trial Sites

Trial	Horizon mm	Texture	Clay %	Silt %	Fine Sand %	Course Sand %
Brie Brie Estate	0-100	Silty clay loam	33.0	32.2	23.9	10.9
	100-200	Silty clay loam	33.8	32.9	22.1	11.2
	200-300	Silty clay	44.8	28.2	16.1	10.9
Vico & Company	0-100	Silty clay loam	27.4	27.1	33.3	12.2
	100-200	Silty clay loam	26.6	26.3	34.5	12.6
	200-300	Silty clay loam	27.3	25.5	35.6	12.6

Results:

Yield data: Results showed no significant evidence of any treatment effects (Table 5). A combined analysis of the two trials was carried out but showed no significant treatment x sites interaction.

TABLE 5

Effect of Soil Compaction Treatments on Yield

Treatment	Yield (Tonnes cane per hectare)		
	Brie Brie Estate	Vico & Company	Combined Analysis
Uncompacted	39.83	52.25	46.04
Trailer + 4 tonne bin	38.29	49.42	43.86
Trailer + 10 tonne bin	41.69	49.87	45.78
GMC + 10 tonne bin	43.34	51.68	47.48
CV%	16.88	14.85	15.76
"F" value	0.33	0.10	0.26

In absolute values the yields from the four tonne bin were least. However there were extremely low "F" values and at this level the variation between yields could be expected from chance in

was fairly high, which was expected, as it is virtually impossible to obtain an even site over an area 60 rows wide.

Bulk density: Tables 6 and 7 give the bulk density (B.D.) data for the various sampling periods. As could be expected the density before compaction increased with depth at both sites.

A marked compactive effect on the soil following compaction was indicated by the highly significant increase in B.D. in the Brie Brie trial. Compaction effects were more marked with the two canetainer transport systems, with the GMC unit having the greatest effect. The effect from the four tonne unit was significant but less marked and there were significant differences between this and the GMC unit. There was no increase in B.D. with depth and the data showed that compaction occurred in the 0-200 mm horizons with the maximum effect being in the surface 100 mm.

Compaction was not as marked in Vico's trial. All compactive treatments significantly increased B.D. over the control but there were no differences between these treatments. The GMC unit again had the largest effect. Differences in B.D. still existed between the various depths underlining the lesser degree of compaction in this trial. Compaction was mainly in the 0-100 mm depth although there were indications of slight increases in the 100-200 mm layer, particularly with the GMC unit.

Pre-harvest samples showed that cultivation had removed compaction effects as there were no differences between treatments and there was the normal situation of increasing B.D. with depth. However, in the Brie Brie results there are indications that the effects of compaction may not have been completely overcome as there was still a trend towards higher B.D. This was most apparent in the GMC treatment.

Penetrometer Data:

Soil penetrometer pressure profiles are given in Appendices A and B. These show mean pressure profiles in relation to the mean soil surface for the various treatments. It should be noted that direct comparison between sampling times is not always possible because of variation in moisture content which has a bearing on pressures obtained with the penetrometer. Moisture contents for the different sampling periods are given in Table 8.

The before-compaction graphs indicate relative uniformity between treatments in the trial areas. Compactive effects on the soil following compaction are indicated for both trials by changes in size and depth of pressure zones with all three bin systems. In the Brie Brie trial (Appendix A), the effect of the four tonne bin was mainly in the 0-100 mm horizon as evidenced by the elimination of the 0-200 psi zone and the presence of the 200-300 psi zone near the surface. There was little change in the position of the other pressure zones.

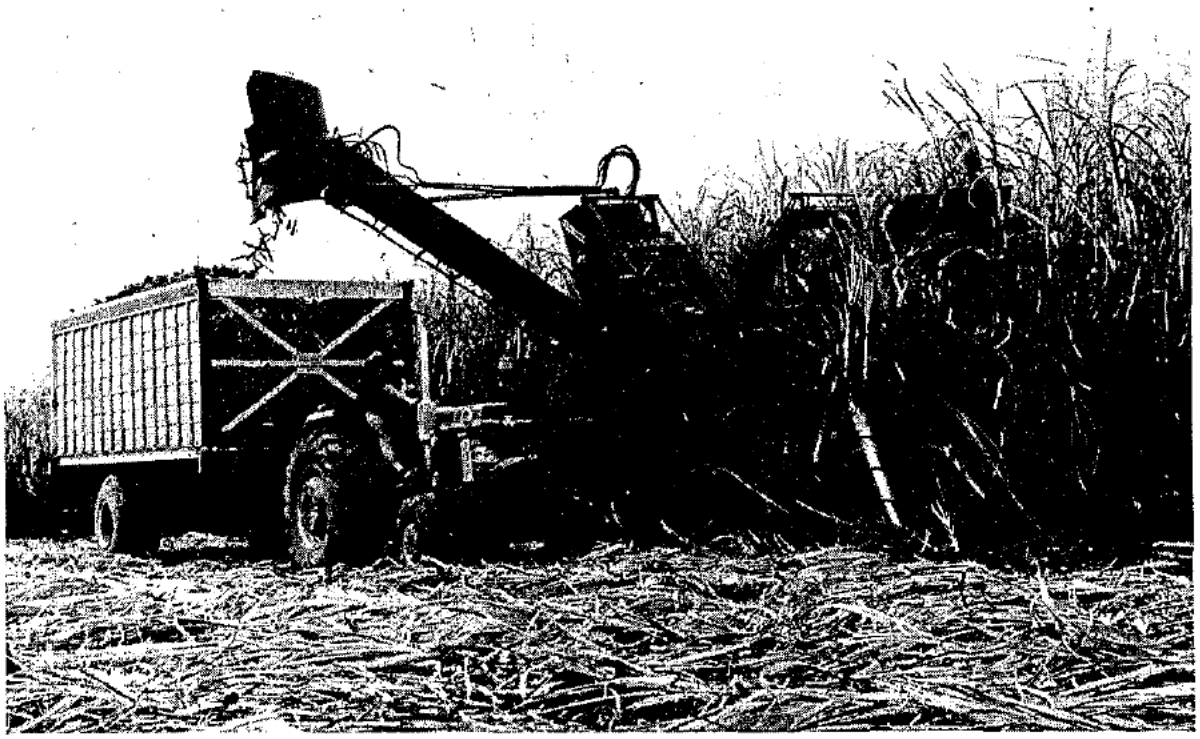


PLATE 1: Tractor plus single axle trailer and 10 tonne bin.

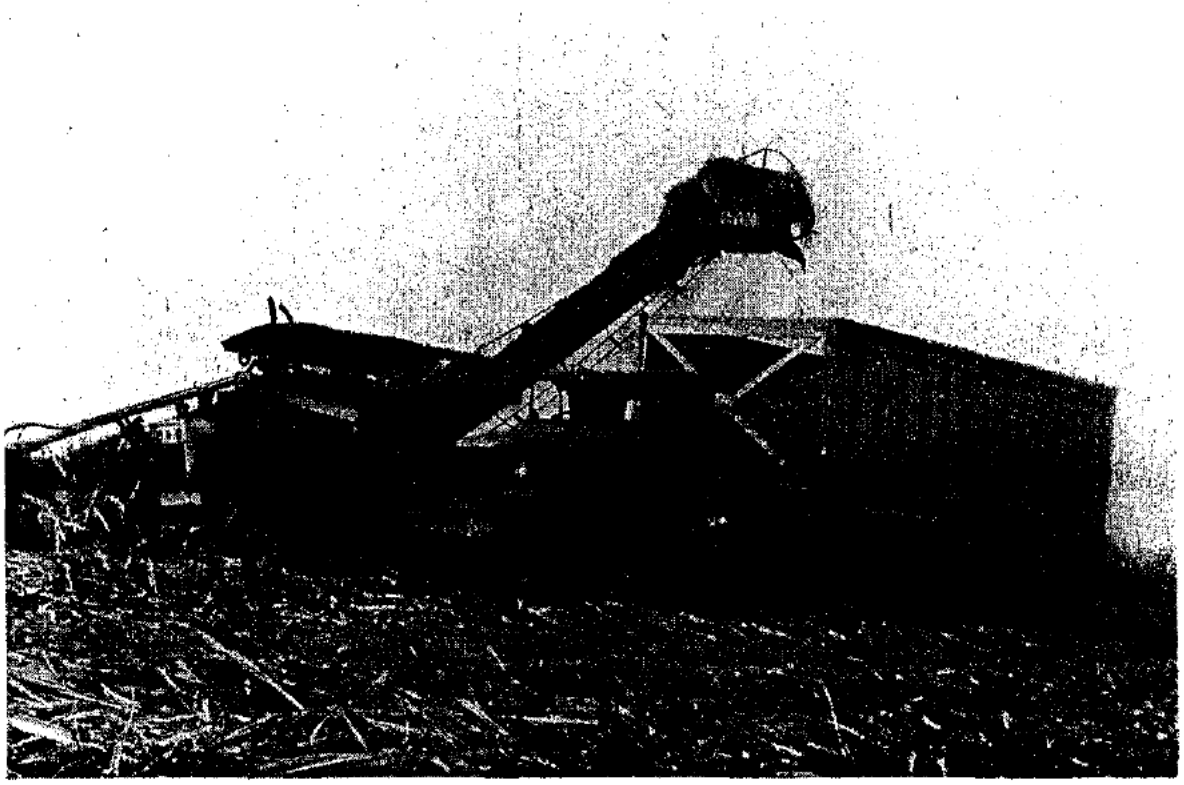


PLATE 2: G.M.C. prime mover plus single axle trailer and 10 tonne bin.

NOTE: The rear wheels on both trailers have "balloon" type tyres.

PLATE 3: Automatic recording soil penetrometer.

TABLE 6

Change in bulk density following compaction treatments
Brie Brie Estate

Bulk Density (g/cc)
Before compaction

Compaction	Depth			Mean
	D_1	D_2	D_3	
C_0	1.41	1.51	1.58	1.50
C_1	1.32	1.49	1.59	1.47
C_2	1.44	1.54	1.60	1.53
C_3	1.41	1.53	1.57	1.50
Mean	1.40	1.52	1.59	1.50
L.S.D. P = 0.05	0.05 between depths			
0.01	0.06			
C.V.%	3.71			
	After compaction			Mean
C_0	1.41	1.56	1.57	1.51
C_1	1.58	1.62	1.57	1.59
C_2	1.62	1.66	1.62	1.63
C_3	1.66	1.64	1.64	1.65
Mean	1.57	1.62	1.60	1.60
L.S.D. P = 0.05	0.05 between compaction methods			
0.01	0.08			
C.V.%	3.61			
	Pre-harvest			Mean
C_0	1.42	1.53	1.57	1.51
C_1	1.42	1.58	1.65	1.55
C_2	1.43	1.56	1.67	1.55
C_3	1.47	1.64	1.66	1.59
Mean	1.44	1.58	1.64	1.55
L.S.D. P = 0.05	0.05 between depths			
0.01	0.08			
C.V.%	4.53			

where C_0 = Control
C_1 = Trailer + 4 tonne bin
C_2 = Trailer + 10 tonne bin
C_3 = GMC + 10 tonne bin

D_1 = 0-100 mm
D_2 = 100-200 mm
D_3 = 200-300 mm

TABLE 7

Change in bulk density following compaction treatments
Vico and Company

Bulk density (g/cc)

Compaction Method	Depth			Mean
	Before compaction			
	D_1	D_2	D_3	
C_0	1.32	1.43	1.52	1.42
C_1	1.31	1.43	1.50	1.41
C_2	1.31	1.45	1.54	1.44
C_3	1.33	1.42	1.48	1.41
Mean	1.32	1.43	1.51	1.42
L.S.D. P = 0.05	0.05 between depths			
0.01	0.05 between depths			
C.V.%	3.15			
	After compaction			Mean
C_0	1.32	1.43	1.52	1.42
C_1	1.37	1.47	1.57	1.47
C_2	1.37	1.48	1.60	1.48
C_3	1.42	1.54	1.52	1.49
Mean	1.37	1.48	1.55	1.46
L.S.D. P = 0.05	0.04 between depths			
0.01	0.05 between depths			
0.05	0.04 between compaction methods			
C.V.%	3.03			
	Pre-harvest			Mean
C_0	1.49	1.52	1.52	1.51
C_1	1.50	1.53	1.56	1.53
C_2	1.47	1.55	1.58	1.53
C_3	1.47	1.57	1.57	1.53
Mean	1.48	1.54	1.56	1.53
L.S.D. P = 0.05	0.05 between depths			
0.01	0.06 between depths			
C.V.%	3.62			

where C_0 = Control
C_1 = Trailer + 4 tonne bin
C_2 = Trailer + 10 tonne bin
C_3 = GMC + 10 tonne bin

D_1 = 0-100 mm
D_2 = 100-200 mm
D_3 = 200-300 mm

There is a zone of higher pressure on the right hand side suggesting that passage of the bin down the inter-row favoured this side and consequently loading was greater. The presence of the higher pressure zone of 400-500 psi, not present in the other treatments, is not considered to reflect greater compaction by this bin system. This was an area of higher pressure before compaction commenced.

The 300-400 psi zone is closer to the surface with both canetainer systems indicating larger compactive effects to a greater depth. The position of this layer suggests different positions of loading down the inter-row, although this difference may result from lateral effects.

Compaction was not as marked in the other trial (Appendix B). The four tonne bin had the least effect which appears to be mainly the surface 100 mm with a reduction of pressure zones < 600 psi and an extension of the 600-700 psi layer. The effect from the canetainer units was to a slightly greater depth and a little more marked. Pressure zones ≤ 700 psi were reduced in size and the zones from 700-800 psi and 700-900 psi increased by the trailer and GMC units respectively.

TABLE 8

Soil moisture contents at different sampling times

Sampling Time	Moisture content (per cent)							
	Brie Brie Estate				Vico & Company			
	0-100 mm	100-200mm	200-300mm	Mean	0-100 mm	100-200mm	200-300mm	Mean
Before compaction	11.1	12.3	14.4	12.6	9.8	11.1	11.4	10.8
After compaction	18.0	18.2	18.2	18.1	9.5	11.3	12.1	11.0
Following cultivation	14.5	16.2	20.4.	17.0	17.0	18.4	18.2	17.8
Pre-harvest	11.9	13.5	14.9	13.5	13.8	14.3	13.8	13.9

Cultivation did not completely overcome compactive effects in the Brie Brie trial as indicated by the data following cultivation and pre-harvest. This is more evident from a comparison of pre-harvest and before compaction data. In the former the high pressure zones are closer to the surface particularly in the centre of the inter-space between what are obviously the cultivation areas. This was not as evident before compaction. There were no residual compaction effects evident in the other trial.

DISCUSSION

The change in procedures in effecting compaction between the two trials is not considered to have a bearing on the difference in degree of compaction obtained. This change, from a constant to variable load system, was brought about because of the damage to the stools at the end of the trial area at Brie Brie Estate caused by the manoeuvring of the harvester and loaded bins while effecting compaction. Of more importance, however was the fact that the requirements placed on the harvester were beyond its storage capacity and it was continually choking up, with the risk of serious damage.

The variable load system is actually less desirable, firstly because loading varies and secondly because the logistics required for the system are more complicated.

Differences in soil moisture content are considered to be the reason for the different degree of compaction obtained in the two trials. As can be seen in Table 8 the moisture content was higher at Brie Brie Estate during compaction. This occurred when rain fell just after the before-compaction sampling was completed, delaying harvest for four days.

In dry soils the resistance of the particles to re-arrangement is great, as the thin water film provides little librication. In addition the effect of surface tension is pronounced so that stress is partially neutralized. The addition of moisture improves lubrication and neutralizes surface tension force so that compaction is more easily achieved (Lull, 1959).

It would be expected that compaction at these two sites would be almost the same at similar moisture levels, but it is possible that slightly greater compaction might be expected at Vico's because of the lower clay content. Clays and sandy loams have a greater capacity to support traffic than other textured soils. Soils that have the greatest range of particle size (i.e. medium textured soils) compact to greater densities, with finer particles filling the voids between coarse particles. Therefore a lower clay content would tend to favour compaction.

As anticipated, compactive effects were far greater at the soil surface than at depth. Most studies show that the depth to which compaction occurs does not exceed 300 mm directly below the bearing surface and that laterally the effect does not exceed more than 300-450 mm (Lull, 1959). It is difficult to determine the extent of any lateral effects in these trials.

In the Brie Brie results, it is possible to get some indication of where loading occurred from the depression of the soil surface. It appears that the bearing surface tended to be more to the

right hand side of the interrow with the four tonne and GMC units. In this case the compaction observed on the left hand side probably resulted from lateral effects plus the harvester. It appears likely that lateral effects were mainly responsible for the compaction observed in the centre of the interspace with the trailer and 10 tonne bin.

Pressure zones are always highest near the row. It is possible this results from lateral compaction. However, these readings may be inflated because of the penetrometer probe being impeded by roots. Unfortunately it is not possible to differentiate between the two. If these readings do result from compaction then there is cause for concern because these effects cannot be removed by cultivation in ratoons. This may partly explain the yield decline with increasing age of ratoons.

Since there was little difference in weight between the two canetainer units the narrow wheels on the GMC prime mover are considered responsible for the greater compaction effected by this transport system. The pressure exerted would be greater than from a tractor tyre.

While it is obvious that weight would be important in the difference in compaction from the four tonne and canetainer units, it is considered that overall size also had an effect. There is less likely to be as much overlapping of the contact area from two passes down an inter-row with a four tonne bin because of its smaller width and wheel size. With compaction, the contact area at the first pass depends on the deformation of the soil. The deeper the rut, the greater the area over which the pressure is exerted and the less pressure per unit area. At the second pass, the wheels roll in the track made during the first pass, so the contact area is smaller and the pressure in the contact area is higher. It will be appreciated that, while this is a simple situation, the greater the tendency for overlapping of the wheel ruts the greater the compaction.

Compaction from the four tonne tipper bin was greater than would be expected in the normal situation. This is because a tipper bin weighs 2.75 tonnes as compared to about 1 - 1.5 tonnes of a conventional four tonne trailer.

Cultivation methods such as those employed in this trial (Table 9) appear to be almost completely effective in eliminating dry soil compactive effects but not as effective in overcoming wet soil compaction. However, as indicated in the penetrometer data, there is room for improvement in eliminating areas of higher pressure from the centre of the interspace.

TABLE 9

Details of cultivation practices at ratooning

Trial	Ratoon Cultivations
Brie Brie Estate	Grubbed three times, rotary hoe once.
Vico & Company	Subsoil to about 355 mm, grub twice, rotary hoe once, bumper disc and roll

It is probably not surprising that no relationship was obtained between compaction and reduction in yield since the effects of compaction were overcome by cultivation. However there were indications at Brie Brie that excessive compaction would reduce yields. Substantial yield reduction was observed in a couple of rows outside the trial which were used by all equipment as an access route while harvesting the remainder of the field. However, the amount of traffic and compaction was much greater than in the normal situation.

SUMMARY

Compaction from harvesting equipment under dry soil conditions does not appear to be a serious problem and can be overcome by cultivation. Compactive effects are more marked under wet soil conditions and there are indications of residual effects following cultivation. Care should be taken to ensure harvesting is not conducted when soil moisture is high.

No relationship was established between yield reduction and compaction. However, this was only a short-term study and accumulative effects may alter this in the long term.

It appears that small bin transport systems are desirable but if large units are used, flotation or a similar type of tyre are preferred. There were also indications that some improvement in cultivation techniques would be desirable to offset compactive effects.

It is considered that some further compaction studies would be desirable. These should not be short-term trials. A different system from that used in this study should be used to effect compaction. One system would be to harvest the field in the normal fashion and effect compaction when harvesting is completed. It would be essential to have penetrometer as well as bulk density data as pressure profiles give a clearer picture of the effects of compaction.

ACKNOWLEDGEMENT

The assistance of Messrs LeBrocq and Tilley and the co-operation of Mossman mill with these trials is acknowledged.

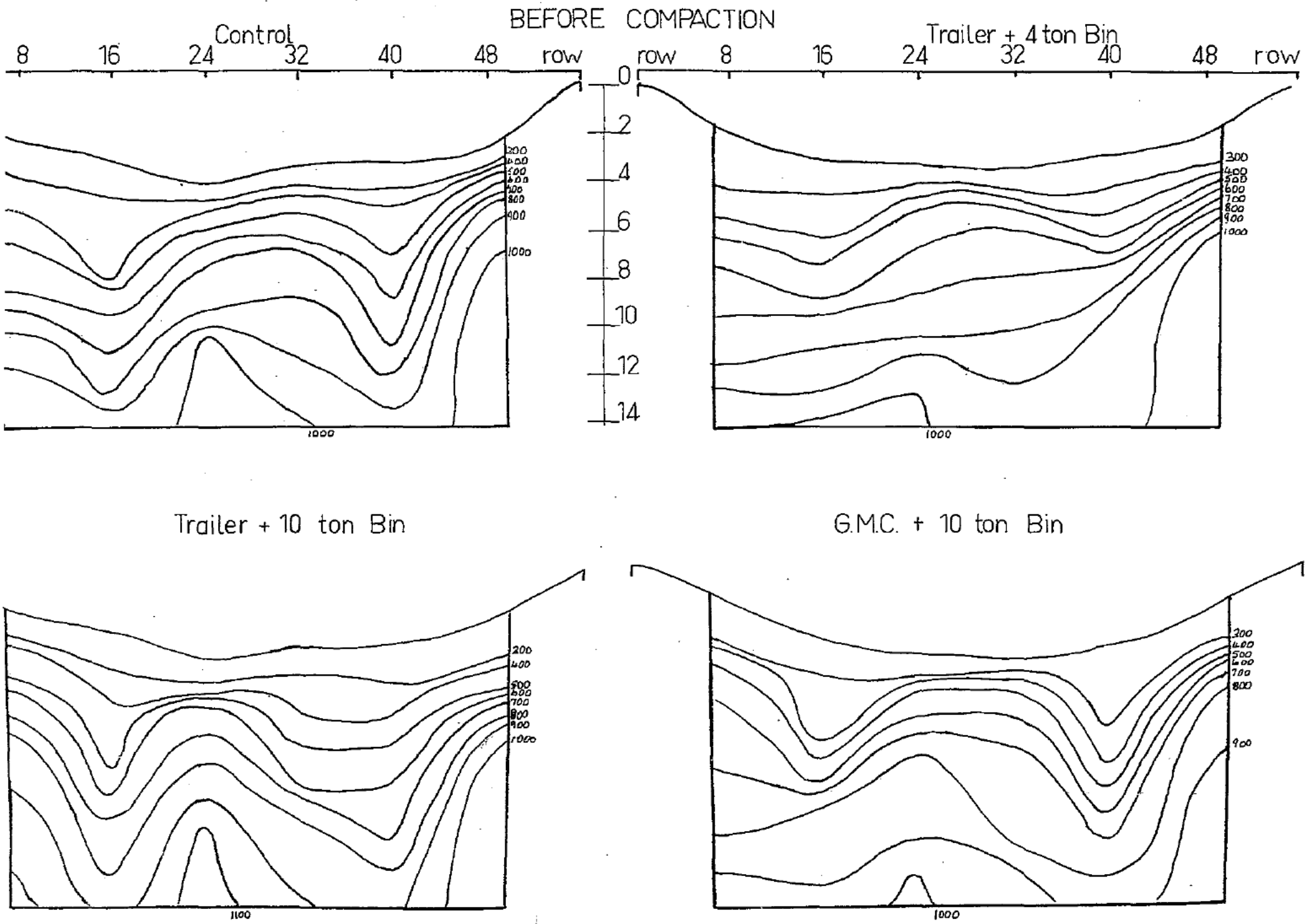
REFERENCE

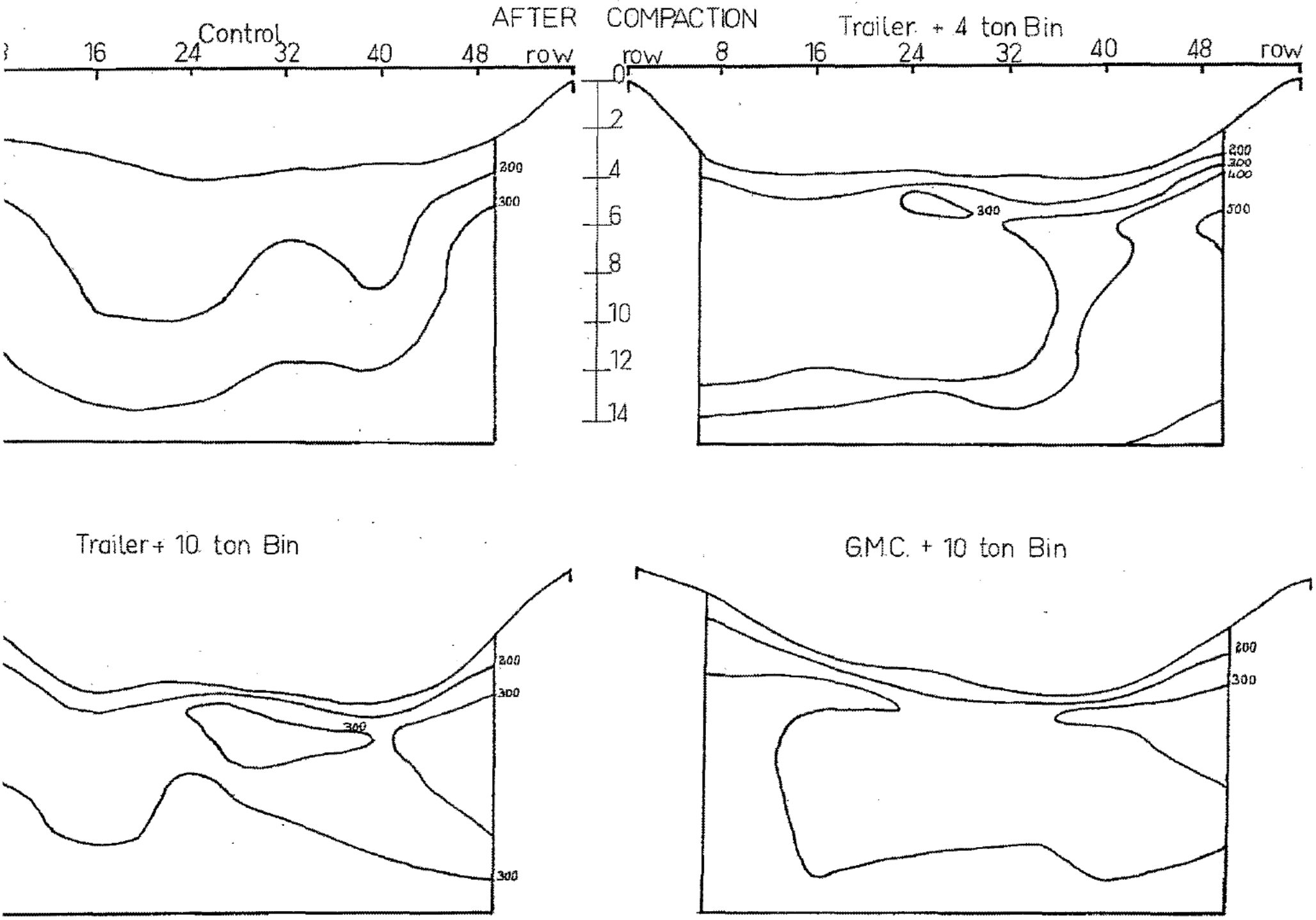
Lull, H.W. (1959). Soil compaction on forest and range lands. Forest Service, U.S. Department of Agric., Washington, Misc. Publ. No. 768 pp 1-33.

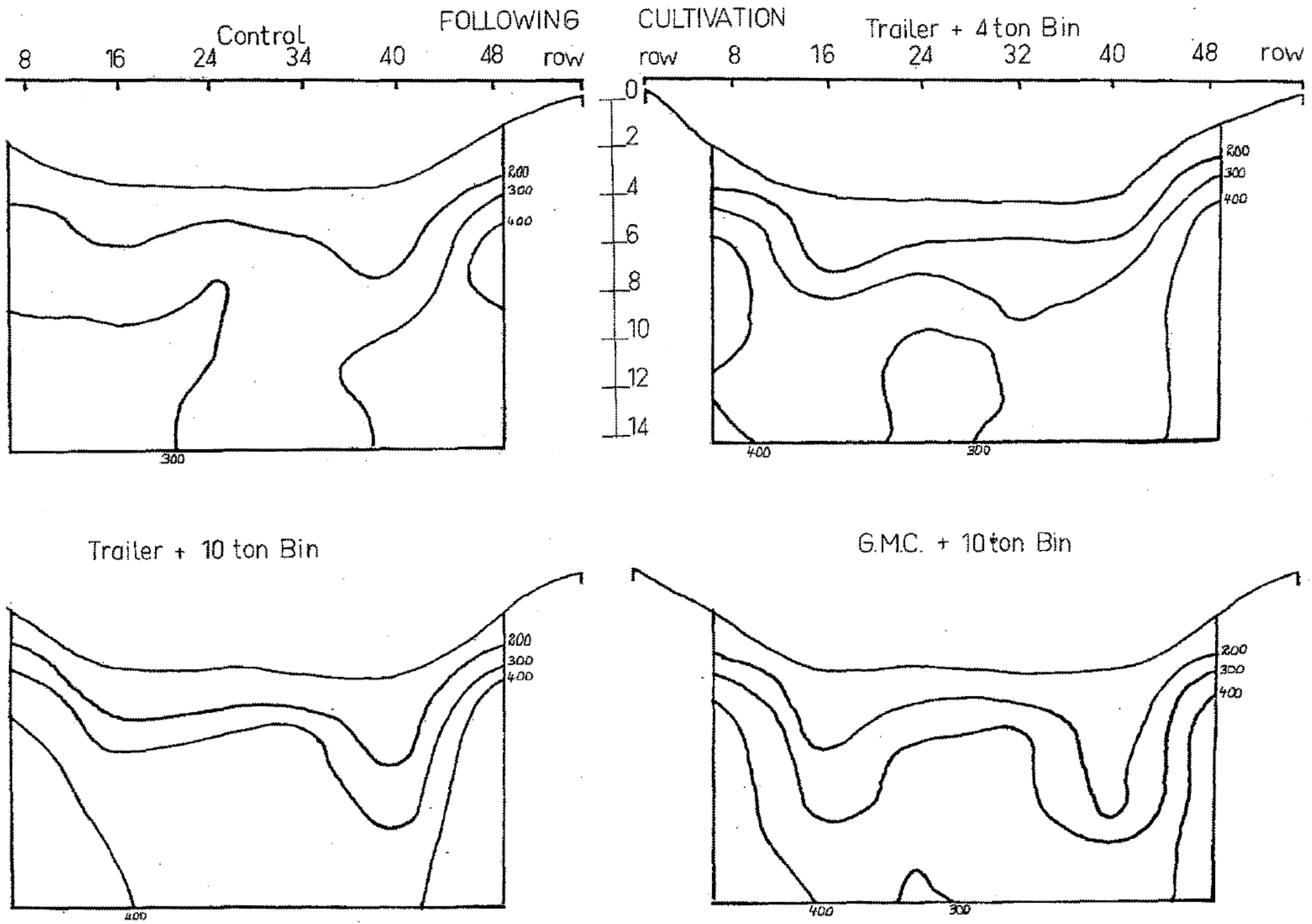
APPENDIX A

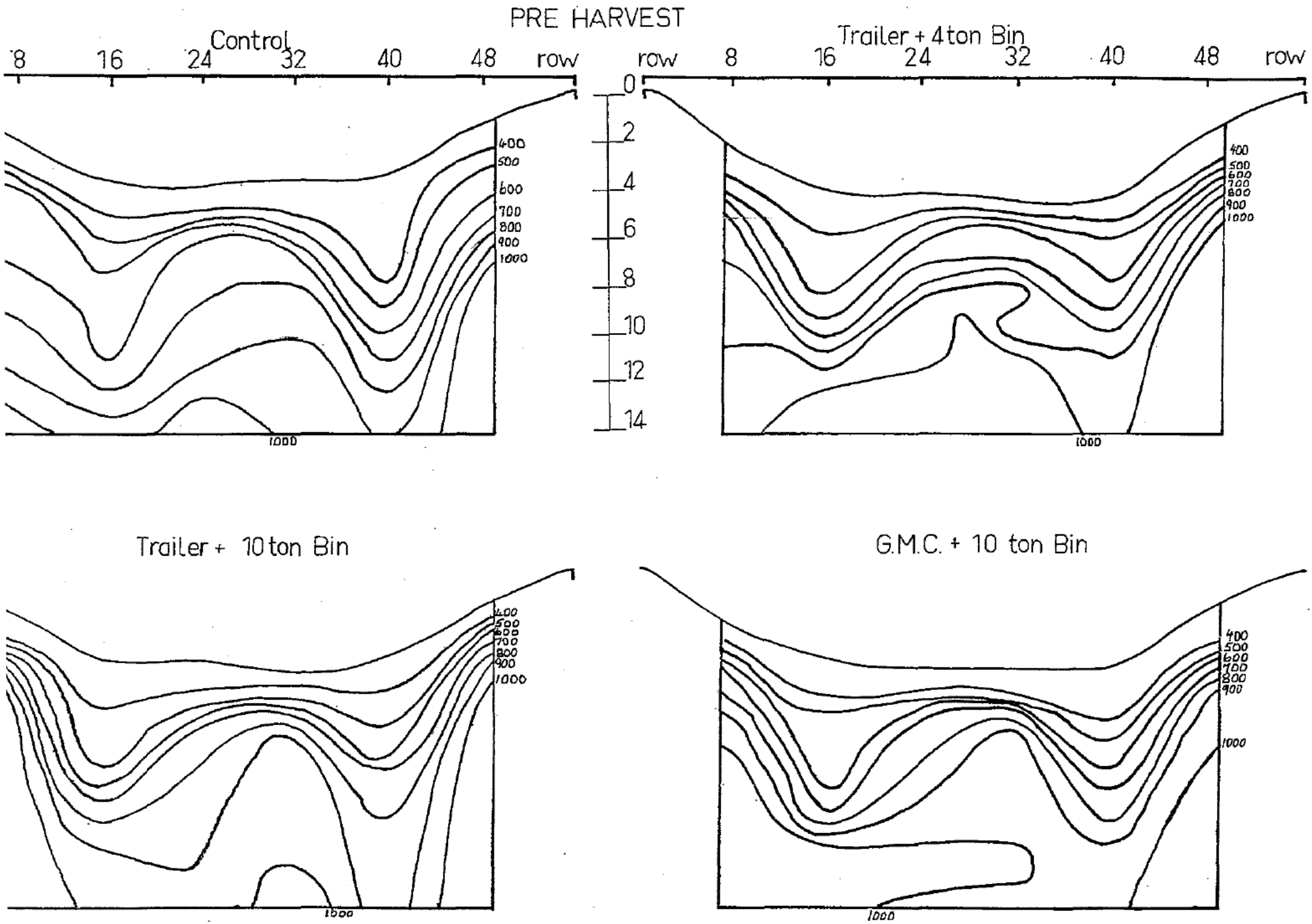
SOIL COMPACTION TRIAL - BRIE BRIE ESTATE

Penetrometer Pressure Profiles


BEFORE COMPACTION
Control
Trailer + 4 ton Bin
Trailer + 10 ton Bin
G.M.C. + 10 ton Bin
row
8
16
24
32
40
48
0
2
4
6
8
10
12
14
300
400
500
600
700
800
900
1000


AFTER COMPACTION
Control
16
24
32
40
48
row
300
300
row
0
2
4
6
8
10
12
14
Trailer + 4 ton Bin
8
16
24
32
40
48
row
200
300
400
300
500
Trailer + 10 ton Bin
200
300
300
300
G.M.C. + 10 ton Bin
200
300


FOLLOWING CULTIVATION
Control
8 16 24 34 40 48 row
Trailer + 4 ton Bin
row 8 16 24 32 40 48 row
0 2 4 6 8 10 12 14
200
300
400
300
200
300
400
400
300
Trailer + 10 ton Bin
200
300
400
400
G.M.C. + 10 ton Bin
200
300
400
400
300

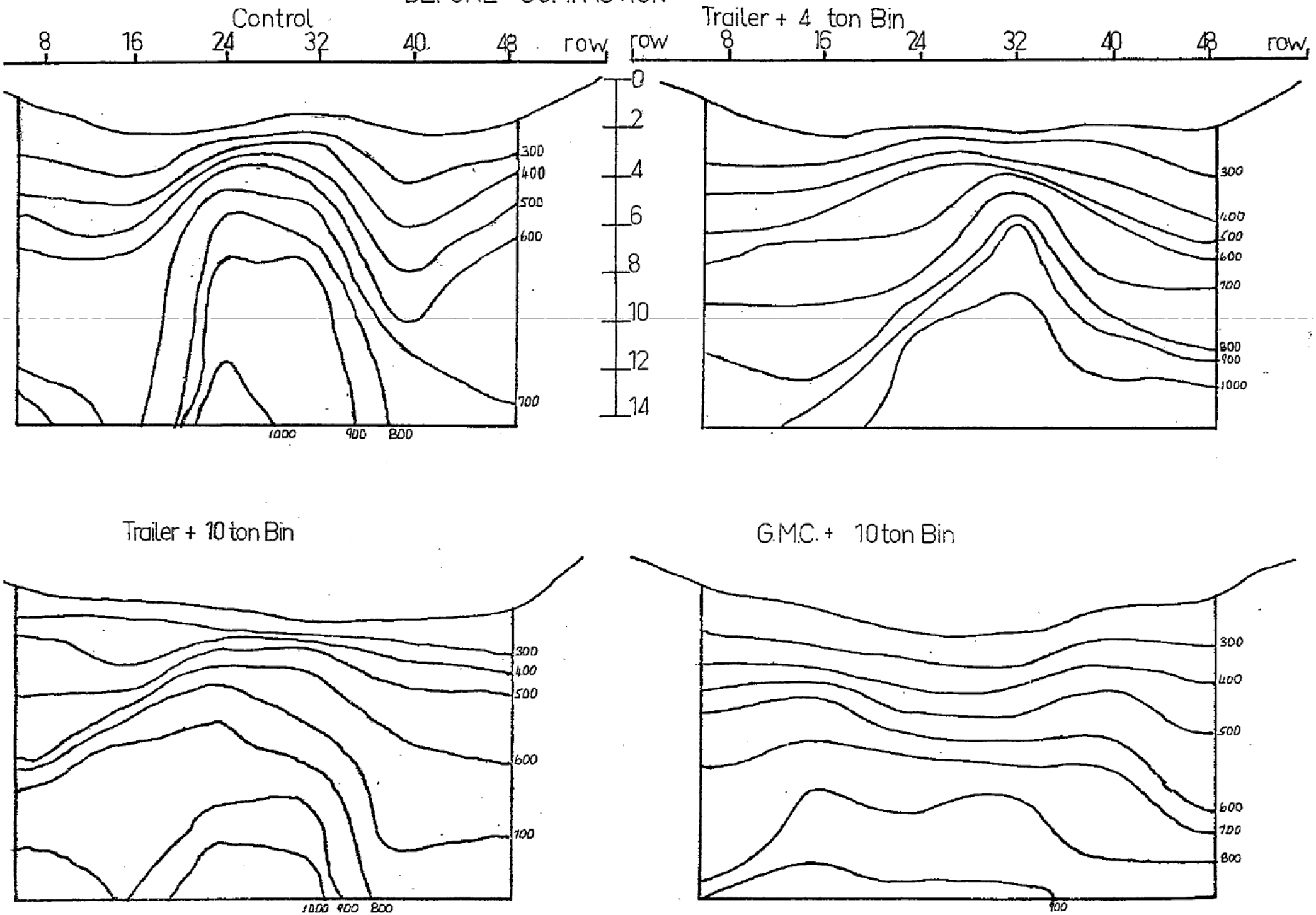

PRE HARVEST
Control
Trailer + 4 ton Bin
Trailer + 10 ton Bin
G.M.C. + 10 ton Bin
row
8
16
24
32
40
48
0
2
4
6
8
10
12
14
400
500
600
700
800
900
1000

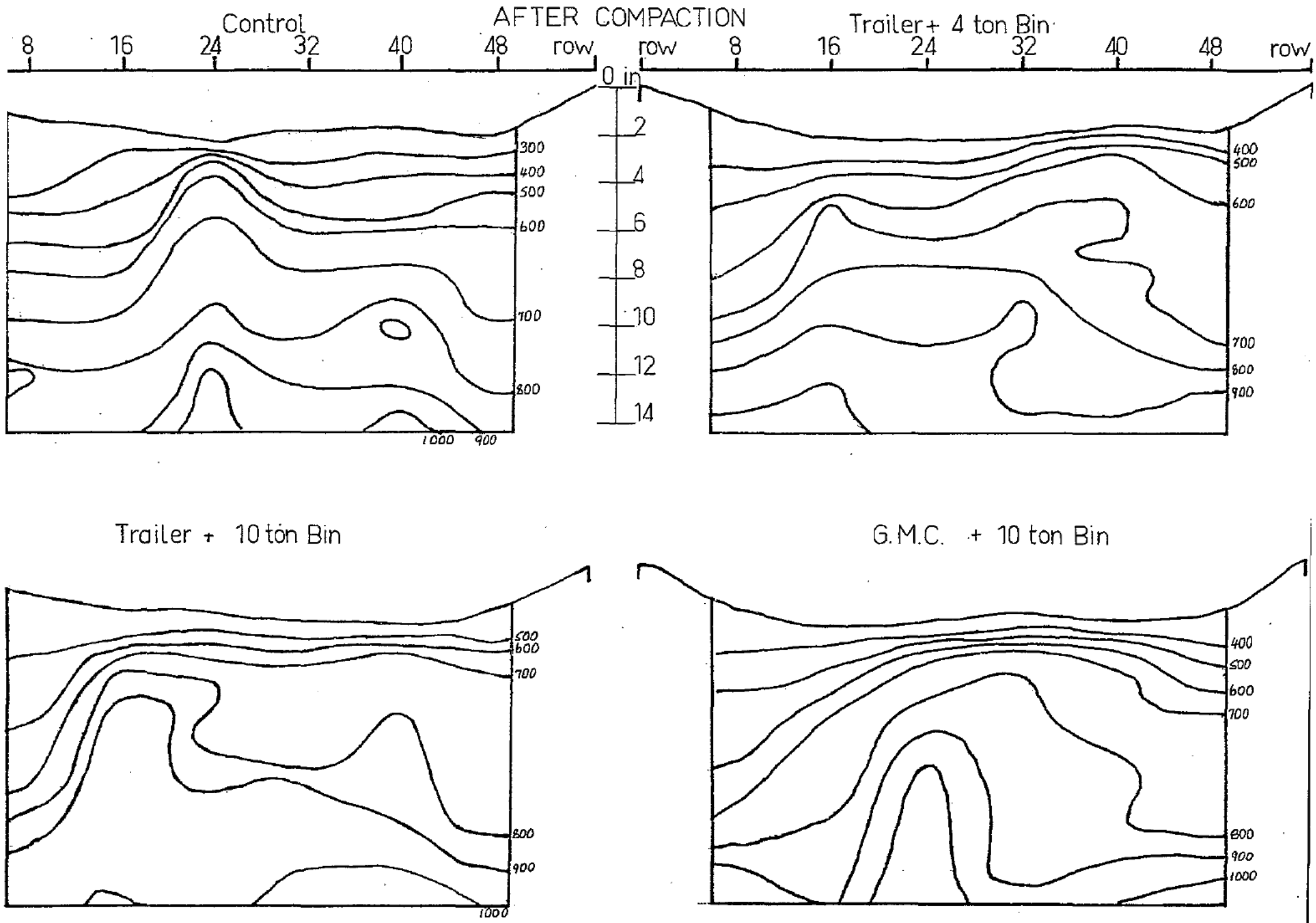
APPENDIX B

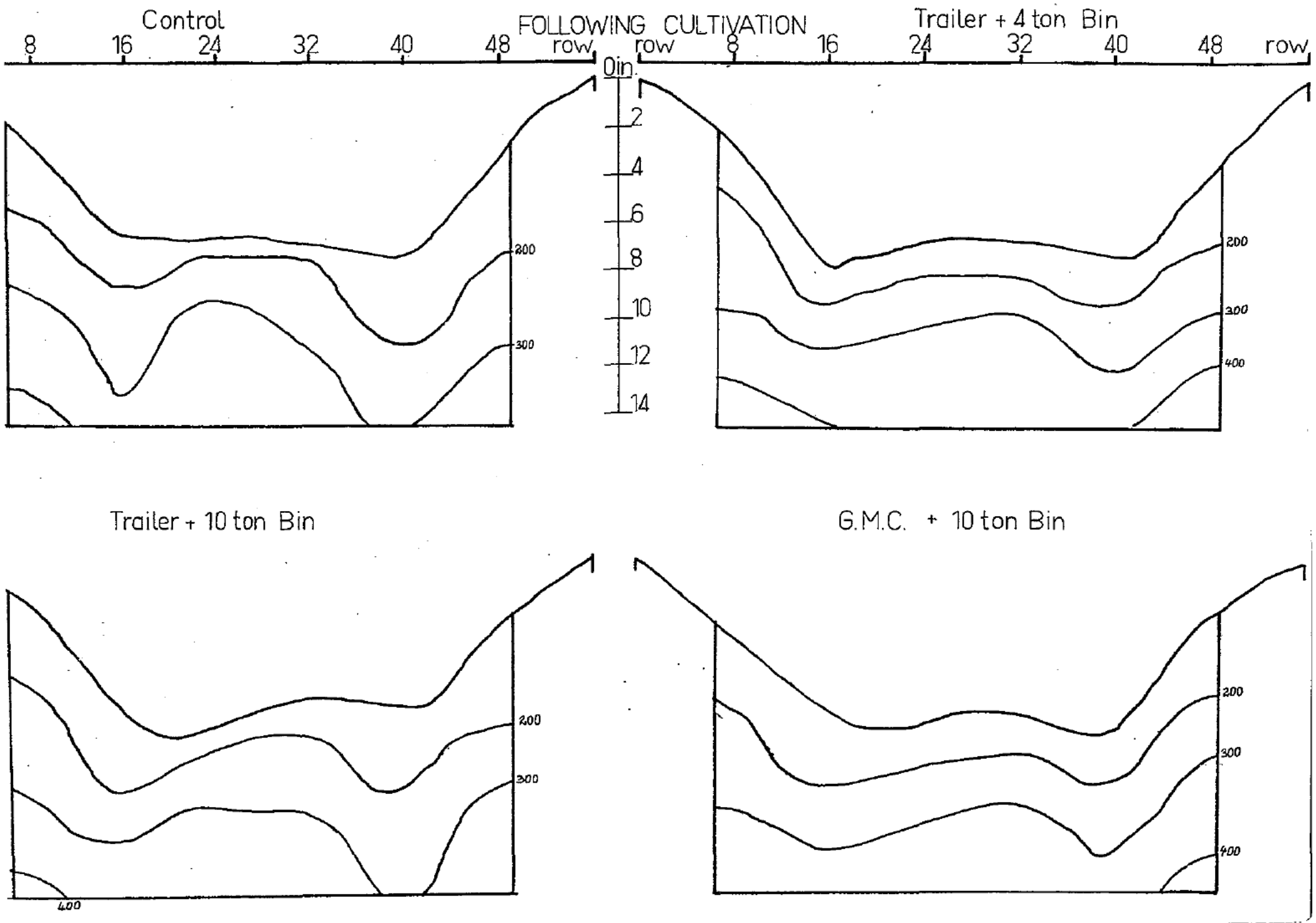
SOIL COMPACTION TRIAL - VICO and CO.

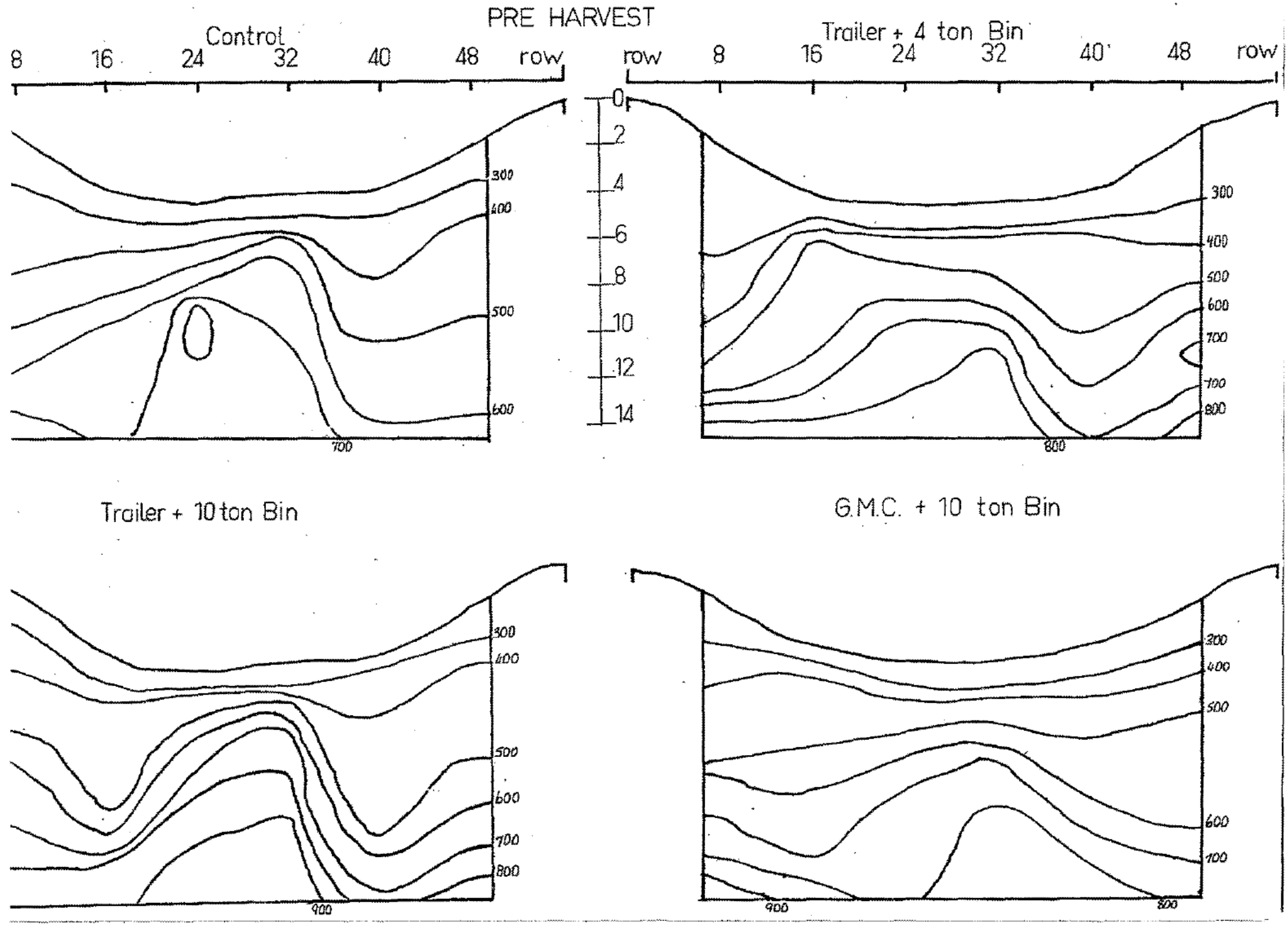
Penetrometer Pressure Profiles

BEFORE COMPACTION




AFTER COMPACTION
Control
8
16
24
32
40
48
row
0 in
2
4
6
8
10
12
14
300
400
500
600
700
800
1000
900
Trailer + 4 ton Bin
row
8
16
24
32
40
48
row
400
500
600
700
800
900
Trailer + 10 ton Bin
500
600
700
800
900
1000
G.M.C. + 10 ton Bin
400
500
600
700
800
900
1000


FOLLOWING CULTIVATION
Control
Trailer + 4 ton Bin
Trailer + 10 ton Bin
G.M.C. + 10 ton Bin
8
16
24
32
40
48
row
0in.
2
4
6
8
10
12
14
200
300
400


PRE HARVEST
Control
8
16
24
32
40
48
row
300
400
500
600
700
Trailer + 4 ton Bin
row
8
16
24
32
40
48
row
0
2
4
6
8
10
12
14
300
400
500
600
700
800
Trailer + 10 ton Bin
300
400
500
600
700
800
900
G.M.C. + 10 ton Bin
300
400
500
600
700
900
800