CHAPTER V

EXPERIMENTAL RESULTS AND ANALYSIS

Due to the lag of equipment delivery at the beginning of the experiment, the effects of material injection in the experimental soil were measured by means of several methods, as shown in Table 6. A data acquisition system, which was used to monitor compaction and recompaction pressures, was available in the laboratory starting with Trial S2 shown in Table 6. Therefore, the pressures generated in trials one through five were not documented. Due to the inability to ensure relatively uniform compaction and recompaction, these first five trials were not included in the analysis. Also, in the first five trials of the experiment, the effects of the injected material were primarily quantified through gravimetric bulk density. Since the location of the injected material, other than in the ripper path, was unknown prior to sampling, quite often the soil sample did not contain any injected material (i.e. slag product). Therefore, most of this data did not represent the effect of the treatments applied to the soil. In order to measure the area of interest, a nuclear gage was utilized starting with Trial S2. For these reasons, the analysis of the experimental data excluded the bins of soil injected with slag product and air.

Table 6
Data Collection Summary

Trial Number	Gravimetric Bulk Density	Nuclear Bulk Density	Mechanical Resistance	Hydraulic Conductivity	Compacted and Re-compacted with Transducer
1 Baseline	X				
2 A	X				
3 A	X				
4 R-S	X				
5/S1 R-S	X		X		
6/S2 R-W	X	X	X	X	X
7/S3 R-W	X	X	X	X	X
8/S4 R-P	X	X	X	X	X
9/S5 R-P	X	X	X	X	X
10/B1 Baseline	X	X	X	X	X

A = Air tool inserted, not ripped
R-S = Ripped and injected with slag product
R-W = Ripped and injected with ground walnut shells
R-P = Ripped and injected with ground pecan shells
Baseline = Ripped, not injected with material

Nonetheless, these data are presented in the Appendix to document the experiment performed. The analysis of the experimental data included the bins of soil injected with walnut and pecan shells.

After the acquisition of the nuclear gage, gravimetric bulk density measurements were continued in order to document any potential treatment effects found in the ripped zone. In addition, mechanical resistance readings and hydraulic conductivity measurements were taken. However, many of the these data points, as before, did not represent the effect of the treatments applied to the soil due to the difficulty of sampling with assurance of intersecting the affected zone of depth. These data are presented in the Appendix to document the experiment.

The data obtained with the nuclear gage was analyzed statistically by the University of Kentucky Department of Statistics using the General Linear Models Procedure (Searle, 1987). Following is a detailed description of the analysis and criteria used to judge the soundness of the collected data.

Material Deposition

Most of the injected material was deposited in the path of the ripper in the lower half of the operating depth. Figure 13 shows the ripper foot and the corresponding nuclear gage probes.

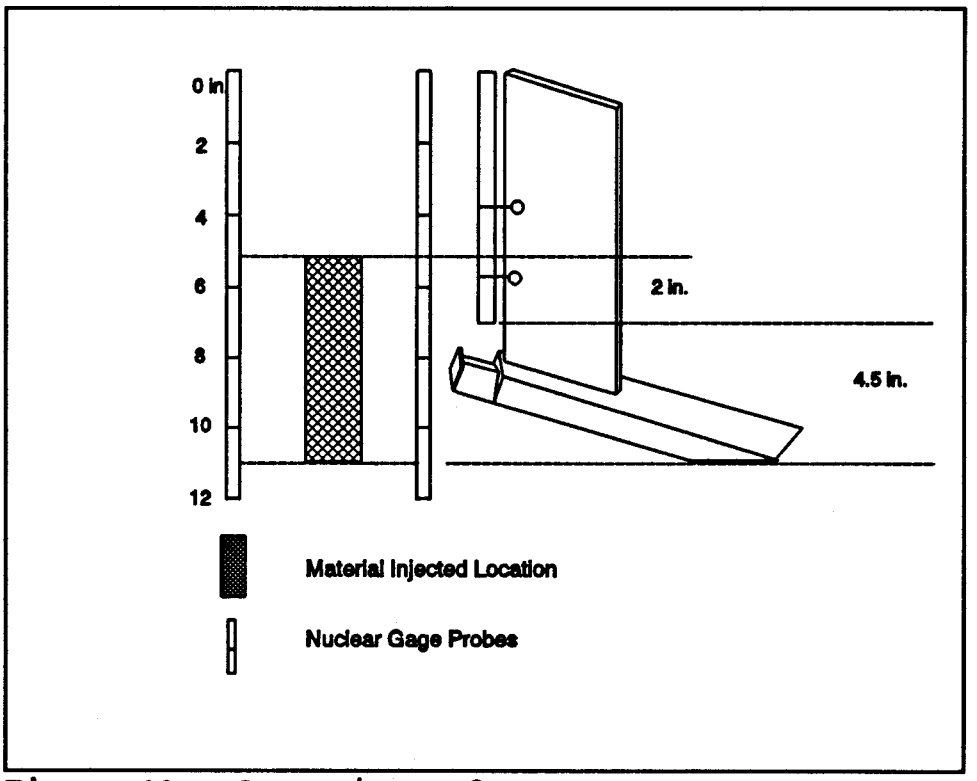

Figure 12 - Comparison of Injected Material Location and Ripper Configuration

Usually, the majority of the material was deposited in a continuous mass from the depth of ripper penetration to approximately 5 cm (2 in.) above the hose outlet. The depth of ripper penetration usually ranged from 25.4 - 27.9 cm (10.0 - 11.0 in.) below the surface of the soil. This locates the injected material at approximately 12.7 - 28.0 cm (5.0 - 11.0 in.) below the soil surface. The dimensions shown in Figure 13 are approximate. Several short contiguous fingers of injected material were found emanating from the path of the ripper. These fingers ranged from 2.5 to 10.2 cm (1.0 to 4.0 in.) and were located approximately 15.2 to 20.3 cm (6.0 to 8.0 in.) below the surface of the soil. This corresponds to the approximately the location of the hose outlet. A thin layer of material was also found outside of the ripper path and was erratically deposited on curved planes of cleavage in the ripped zone. This layer consisted of dust-like particles and grains of nutshells. The thickness of the layer was equal to the average diameter of a grain of injected material. The deposition was typically patchy and unpredictable.

The pecan treatment was noticed to have a more continuous distribution of material than the walnut or slag product. This may have been due to the average particle size and the material's ability to be forced through the fractures created by tillage. For material transported by liquid, the crack width should be 2.5 to 3 times the maximum grain diameter in order to prevent blockage (Howard and Fast, 1970). Recall that the slag product and the pecan shells were the same size and both were smaller than the walnut shells. However, the slag product was shaped irregularly. The pecan and walnut shells were rounded. Figures 14 through 17 show the deposition of material for the walnut and pecan treatments.

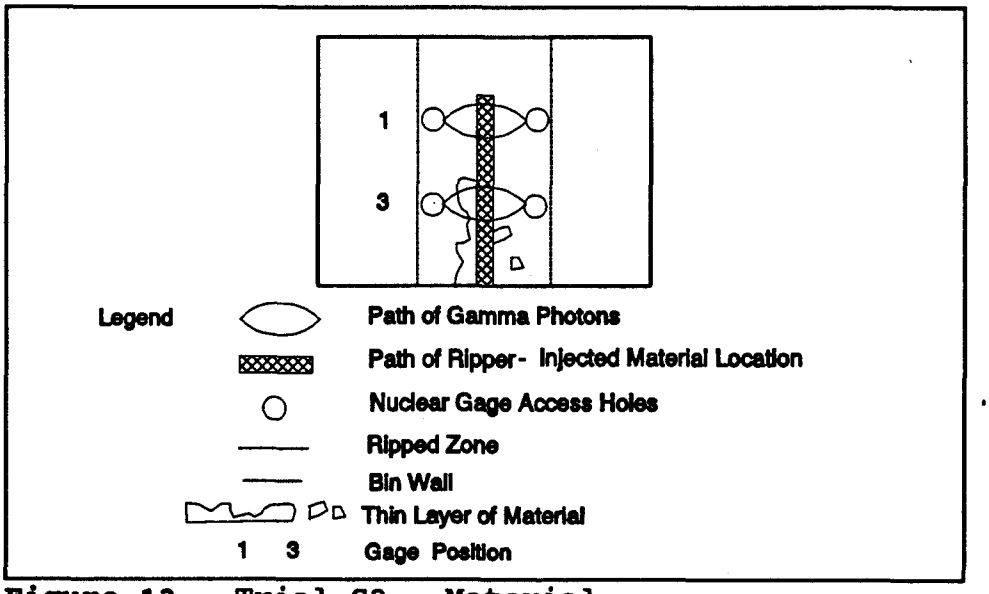

Figure 13 - Trial S2 - Material Deposition Walnut

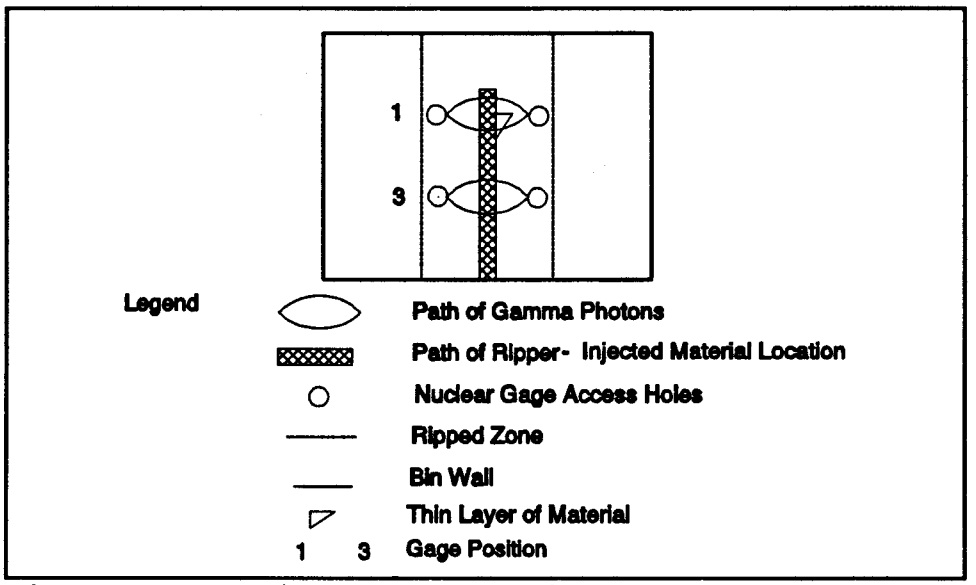

Figure 14 - Trial S3 - Material Deposition Walnut

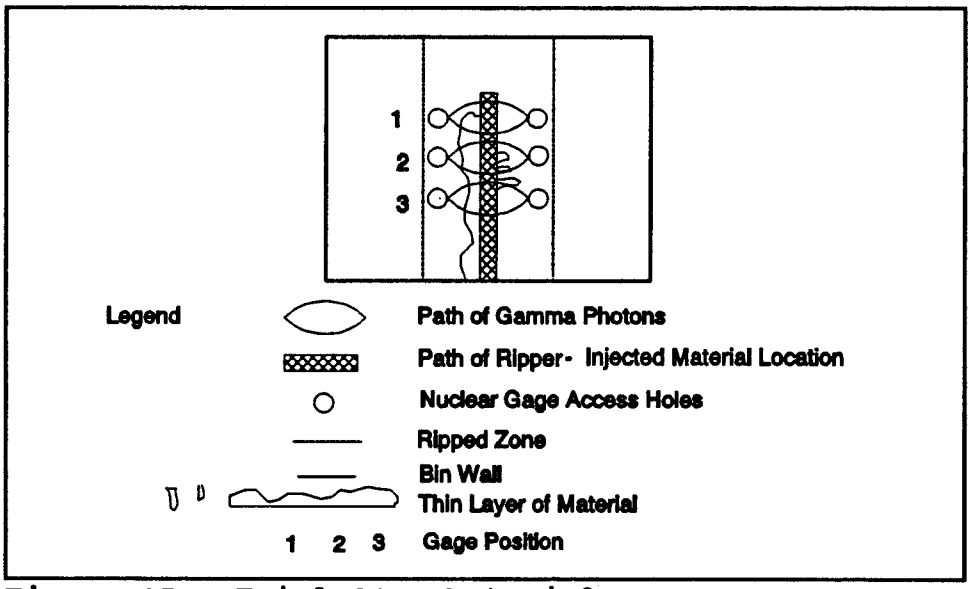

Figure 15 - Trial S4 - Material Deposition Pecan

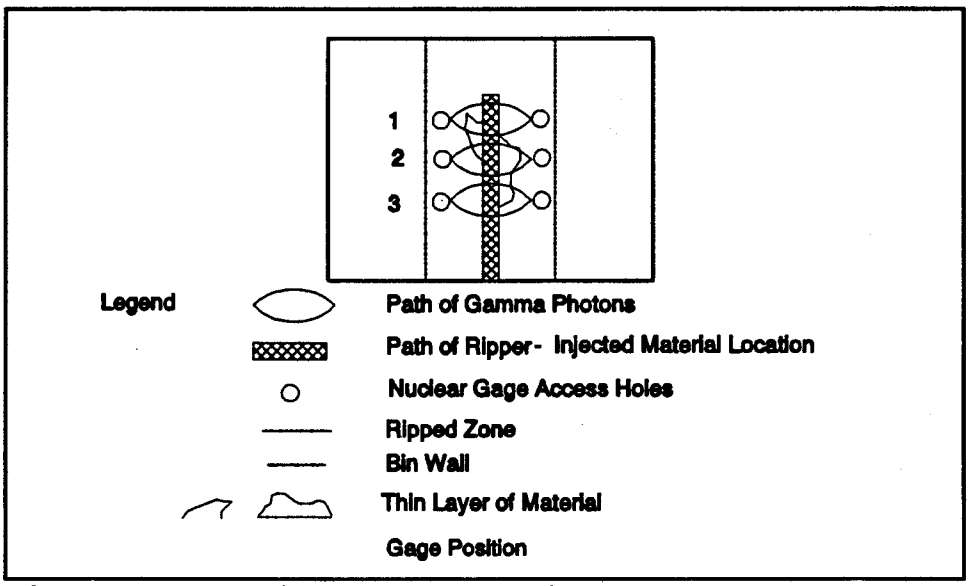

Figure 16 - Trial S5 - Material Deposition Pecan

Table 7 shows the amount of injected material for each bin of soil. Uniformity of the amount of injected material was desired. However, this was not always the case. This was due to the difficulty of separating the material that was run through the hose just prior to ripping with the material that was discharged from the bin during ripping. In addition, the material that was deposited throughout the laboratory during ripping and collected after ripping generally did not include all of the material available on the floor. It was estimated that an average of 28% of the material that was run through the conveying hose during ripping remained in the soil. Much of the discharged material was due to the start-up conditions. Recall that the ripper was pushed through the a slot in the bin wall. The first few seconds of ripping caused much of the material to be deposited outside of the bin. Therefore, this estimate does not reflect the anticipated percentage of material remaining in the soil from field applications.

Table 7
Injection Material Summary

Trial	Type of Shell	Injected Material g/lbs
S2	walnut	8172/18
S3	walnut	908/2
S4	pecan	8172/18
S5	pecan	1816/4
B1	none	NA

Factors Affecting Initial Compaction and Recompaction

Table 8 shows the applied contact pressures and moisture contents for each bin of soil in the top 30.5 cm (12.0 in.). The pressures were averaged over the nuclear gage locations. The moisture contents were averaged over each layer of soil measuring 15.2 cm (6.0 in.) in thickness. Uniformity of the applied pressures and moisture contents were desired for each bin of soil. However, some variation was found to exist.

The initially compacted pressures for the trials fell within a range of 11.7 kPa (1.7 psi). The initially compacted moisture content fell within a range of 2.5%.

The recompacted pressures for the trials fell within a range of 10.5 kPa (1.5 psi). The recompacted moisture content fell within a range of 2.3%.

Table 8
Contact Pressure and Moisture Content Summary

Trial Treat-ment	y Initially Compacted		Recompacted	
	Average Pressure Over Gage Locations kPa (psi)	Average Moist-ure Content (%)	Average Pressure Over Gage Location kPa (psi)	Average Moisture Content (%)
B1 Base-line	125.2 (18.2)	18.8	88.2 (12.8)	18.2
S2 Walnut	133.6 (19.4)	20.1	87.4 (12.7)	18.7
S3 Walnut	122.0 (17.7)	21.3	88.1 (12.8)	20.5
S4 Pecan	123.7 (18.0)	20.8	81.4 (11.8)	18.6
S5 Pecan	123.6 (17.9)	19.7	77.7 (11.3)	18.3

Methods of Sampling

The difficulty of measuring the effects of the injected material was seen in several methods of sampling. Soil measurements that were taken vertically included gravimetric bulk density, hydraulic conductivity, and mechanical resistance. These were aimed at measuring any injected material found in the ripped zone, excluding the ripper path, as explained below.

Generally, the resistance to coring or penetration was very low in or near the ripper path.

This caused the instrument to veer substantially, which resulted in an unacceptable sample or reading. Also, the coring tube diameter was approximately the same size as the width of the ripper foot, so that only noncohesive nutshells were sampled in the path of the ripper. Any core samples extracted in or very close to the ripper path were not competent to withstand subsequent handling and measurement. Therefore, the tabulated measurements, excluding nuclear bulk density, were taken outside the ripper path in or near the location of a thin layer of injected material. Thus, it was difficult to retrieve a sample that contained enough injected material to be considered of consequence. This qualitative judgment was reached based on visual inspection of the sample after the measurements were taken and visual inspection during excavation. Due to these reasons, several sampling methods generally did not serve the purpose of measuring the effect of the injected material. These were mechanical resistance, gravimetric bulk density and hydraulic conductivity. However, it was noted that Blackwell et al. (1989) were successful in taking gravimetric core samples in gypsum-enriched slots after recompaction.

The nuclear gage was the primary method available to measure soil density in the area of interest as shown in Figure 18.

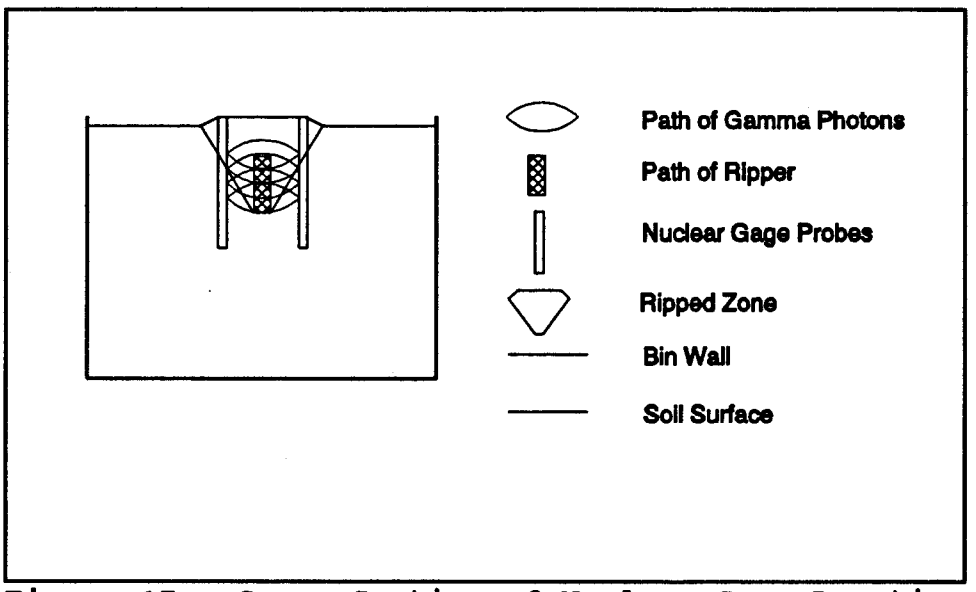

Figure 17 - Cross Section of Nuclear Gage Location

In addition, many measurements of the soil profile could be obtained over a relatively short distance. Due to the limited depth of tillage and subsequently small volume of soil failure, it was important to maximize readings over a distance of approximately 30.5 cm (12.0 in.).

Nuclear Bulk Density. Recompaction is defined, in this thesis, as the tendency of the soil to return to its original physical stage when acted upon by an outside force after tillage operations. For each stage of soil manipulation, the nuclear gage probes were lowered to nearly the same physical location. This enabled a direct graphical comparison of the soil profiles for each stage of soil manipulation. Also, the difference in bulk density from the initially compacted stage to the recompacted stage was analyzed graphically. As this difference in density increases, the amount of recompaction decreases. However, the statistical analysis involved the absolute magnitude of the recompacted values.

Recall that nuclear bulk density was determined for each 5.1-cm (2.0-in.) interval down to a depth of 45.7 cm (18.0 in.). The use of the nuclear gage was advantageous since the probes were placed on either side of the ripping path, perpendicular to the direction of travel of the ripper. Thus, it was fairly certain that the densities monitored in this fashion included the in situ density of the injected material.

The resulting bulk densities were generally lower than found in most field situations (Barnhisel, Powell, and Hines 1986). This was due to the limitations of the laboratory equipment available for compaction.

Graphical Analysis. Figures 26 through 30 in the Appendix show the soil profiles for each stage of soil manipulation for each trial. Tables 20 through 24 correspond to the soil profiles. Due to a few missing values at the 45.7 cm (18.0 in.) depth, this level was not reported. A comparison of Figures 26 through 30 in the Appendix shows that the walnut trials were initially compacted slightly higher than the pecan trials. Both the walnut and pecan trials were initially compacted higher than the baseline treatment.

The walnut treatment shows higher density values in the upper 10.2 cm (4.0 in.) of the ripped zone than either of the other two treatments. This may be due to site preparation of the access holes. A level area was needed in order to prepare access holes for the gage probes so that the holes were oriented vertically. Initially, this was accomplished by setting the guide-plate on the ripped area without prior preparation. Starting with Trial S4, the first pecan treatment, the top few centimeters of the ripped zone were removed with a hand spade and a level area was constructed. Then the guide-plate was carefully placed on the area. This may have resulted in a decrease in density in the upper layers of the soil profile for the pecan and baseline treatments.

The difference in density between the initially compacted and the recompacted stage was found in order to display graphically the amount of recompaction occurring.

The difference between initial compaction and recompaction of the soil density profile at each gage location was constructed from 5.1 cm (2.0 in.) to 40.6 cm (16.0 in.) for each trial. This is shown in the Appendix in Figures 31 through 35. Tables 25 through 29 correspond to the respective figures. At a depth of 25.4 cm (10.0 in.) below the soil surface, a lower density was found in the walnut treatment as compared to the adjacent layers (above and below). This was evident in three out of four nuclear gage location profiles. Position 1 in Trial S2 does not show this trend.

A trend was apparent in both pecan replications (Trials S4 and S5). Position one of the gage recompacted to a greater extent than positions two or three. Recall that the hydraulic cylinder reached the end of its travel path when the rear of the ripper foot was located approximately 20.3 cm (8.0 in.) away from the bin wall. At this point material injection was discontinued and the ripper was raised vertically out of the bin. The wedge of soil that formed in front of the ripper was also removed with the ripper. This created a small void near the bin wall. Also recall that the nuclear gage was located at 30.5 cm (12.0 in.) away from the wall of the bin. These factors may have contributed to the increase in recompaction at nuclear gage position one. This trend was not apparent in the walnut or baseline treatments, even though the same procedure was used when ripping. The walnut treatments may have been influenced by inadvertent compaction during site preparation when using the nuclear gage as explained previously. There was no noticeable reason for the baseline treatment to act similarly.

Figure 36 in the Appendix shows the average change in density from the initially compacted

state to the recompacted state for all trials. Table 30 shows the values of Figure 36. If the soil was recompacted to the maximum extent, a change of zero would result. The pecan trials show the least amount of recompaction. From Table 8, the pecan trials were found to be recompacted at the lowest average pressure. Figure 36 in the Appendix shows the walnut trials were recompacted to the greatest extent. From Table 8, both walnut trials were found to have higher recompacted pressures than the pecan trials, but slightly less than the recompacted pressure of the baseline trial. Referring again to Figure 36 in the Appendix, which shows the difference in initially compacted and recompacted density, the baseline trial falls approximately between the pecan and walnut trials. Below the level of ripping, the bulk densities generally increased above the initially compacted state. Similar results have been documented extensively (Cooper, 1971). Only one, Trial S2, did not recompact to a level higher than the initially compacted state below the depth of tillage.

Statistical Analysis. The recompacted values (response variable) were analyzed statistically at depths ranging from 10.2 - 25.2 cm (4.0 - 10.0 in.). From the soil profiles and Figure 13, this depth range appears to be the primary area of interest. The minimum acceptable level of significance was set at 10 %.

During data collection, the factors that had potential to influence the recompacted soil density observations were:

1) Treatment;
2) Physical location within the soil bin; and
3) Variables not fully controlled in the execution of the experiment.

Since location is defined by both position on the soil surface and depth below the soil surface, the controlled factors were treatment, position of the nuclear gage and depth of the probes below the surface of the soil.

For the purpose of an ideal design, many bins of soil should be processed and set aside prior to the application of treatment. This would allow for a measurement of the initially compacted density and other uncontrollable variables, which provides information for grouping the bins into blocks that are homogenous with respect to these variables. Then complete randomization should be carried out on each group or block of bins. However, out of necessity, many bins of soil could not be prepared and the blocks of soil bins could not be grouped prior to the application of treatment since only one metal bin and one air pallet was available in the laboratory. Instead, each bin of soil was processed and received exactly one treatment, sequentially. Complete randomization of the treatment, position and depth factors was not possible. Because of this, the experiment was analyzed using a split-plot model with covariates (Hicks, 1982).

Split-plot designs are most effective for experiments when one factor requires larger experimental units than another factor. This was the case when obtaining many samples within the same soil bin. The large experimental unit, or "whole plot" was defined as the soil in the entire bin and its corresponding factor was the treatment. Each trial was represented as a plot. The smaller experimental units or "split plots", were represented by smaller volumes of soil within the bin and the corresponding factor was gage position and depth below the soil surface. The treatment, a main effect, was confounded with plots, since only one treatment could be applied to the soil at a time. If the processing of a bin of soil changes from one plot (bin) to another, the effect of these changes will show up as differences between the treatments. Confounding means that the treatment effect cannot be estimated independent of the effect of the plots, as shown below: $T_i = T_{true} + P$
where:

T_i	=	effect of treatment i
T_{true}	=	true effect of treatment
P	=	effect of plots

The other two main effects, location and depth, were not confounded. This was necessary due to the physical limitations of the laboratory equipment.

As noted above there were independent variables, or covariates, that have potential to influence the recompacted density. Covariates are measured variables that are not the objective of investigation in the study. However, they may affect the response variable and they can not be fully controlled in the execution of the experiment. These variables were moisture content in the recompacted stage, initially compacted soil density, and recompacted pressure. The recompacted density values were adjusted to compensate for these effects. The form of the linear model with covariates was:

$$Y_{ijkl} = \mu + \beta_1(C1-\overline{C1}) + \beta_2(M2-\overline{M2}) + \beta_3(P2-\overline{P2}) + T_i + Tr_j(T_i)$$

$$+ P_k + T*P_{ik} + D_l + T*D_{il} + P*D_{kl} + \epsilon$$

where :

Y_{ijkl}	=	Value of the observation (recompacted density)
μ	=	mean of observations
β_1	=	slope of best fit line: initially compacted density versus recompacted density
C1	=	initially compacted density
$\overline{C1}$	=	average initially compacted density
β_2	=	slope of best fit line: recompacted moisture content versus recompacted density
M2	=	recompacted moisture content
$\overline{M2}$	=	average recompacted moisture content
β_3	=	slope of best fit line: recompacted pressure versus recompacted density
P2	=	recompacted pressure
$\overline{P2}$	=	average recompacted pressure
T_i	=	effect of treatment i
$Tr_j(T_i)$	=	trial within treatment interaction
P_k	=	effect of position k
$T*P_{ik}$	=	interaction of treatment and position
D_l	=	effect of depth l
$T*D_{il}$	=	interaction of treatment and depth
$P*D_{kl}$	=	interaction of position and depth
ϵ	=	error

subscripts:

i	=	treatment i, i = 1, 2, 3 (baseline, walnut, pecan)
j	=	trial j, j = 1, 2
k	=	position k, k = 1, 3
l	=	depth l, l = 1, 2, 3, 4 (10.2, 15.2, 20.3, 25.4 cm (4.0, 6.0, 8.0, 10.0 in.) below the surface)

Figure 24 in the Appendix shows a scatterplot of the recompacted moisture content versus the recompacted density. Corresponding values are shown in Tables 17 and 18. Due to a high moisture content in Trial S3, moisture was found to be a significant predictor of recompacted density ($p < .002$). In addition, the initially compacted density was found to be a significant predictor of the recompacted density ($p < .002$), although its effect was not as pronounced as the effect of moisture. Figure 25 and Tables 19 and 18 in the Appendix shows the relationship between the initially compacted versus recompacted density. Note that the fitted lines shown in Figures 24 and 25 do not have the same slope as given in the model stated above. The figures in the Appendix show the best fit line when considering each covariate one at a time, whereas the model above considers all covariates simultaneously.

The two-way interactions involving depth were not found to have a large influence on the recompacted density. However, the treatment and position interaction was found to influence the recompacted density values ($p < .02$). This was confirmed by the position component of the model, which was also found to be a significant predictor of recompacted density values ($p<.001$). This may have been due to the fact that the ripper was removed near position one and consequently material injection was stopped. The recompacted pressures were not found to be a predictor of the recompacted densities.

The R^2 value of the experimental model was 0.86. The model accounts for approximately 86% of the variation in the response variable (recompacted density). The precision of the experiment was reasonably good (C.V. = 2.71 %).

Tables 9 and 11 provide summary information after adjusting for recompacted moisture and initially compacted density with the response variable being recompacted density. Table 9 shows the analysis of variance and Table 11 summarizes the treatment means.

It was hypothesized that the propping effects of the injected material will reduce, or prevent, the recompaction of a deep-tilled soil. The null hypothesis states that the propping effects of injected material have no influence on the recompacted density values. Table 10 shows the test of the hypotheses using trial within treatment interaction as an error term. This term is an indicator of the differences of the trials within the treatments. By doing this, one assumes the trial within treatment interaction effect is zero and the sum of squares for this effect becomes a measure of error. The low F value for the interaction effect, Tr(T), in Table 9 justifies this assumption. Dividing the sum of squares obtained for the treatment by the sum of squares obtained for trial within treatment interaction in Table 9, the resulting F value was 5.32 with a probability of exceeding this value of .158. Therefore, the results obtained in this experiment, or better, will occur approximately 15.8 % of the time, by chance. Thus, the level of significance found in this experiment was 15.8 %. The acceptable level of significance was set at 5%. Therefore, the null hypothesis was accepted.

Table 9
Analysis of Variance After Recompaction

Source *	Degrees of Freedom	Sum of Squares	F Value	Pr > F
Model:				
C1	1	0.0223	13.51	0.0019
M2	1	0.0429	25.93	0.0001
P2	1	0.0000	0.00	0.9594
T	2	0.0453	13.68	0.0003
Tr(T)	2	0.0085	2.57	0.1058
P	1	0.0142	8.60	0.0093
T*P	2	0.0167	5.06	0.0188
D	3	0.0049	0.98	0.4241
T*D	6	0.0148	1.49	0.2405
P*D	3	0.0036	0.73	0.5455

* See definitions given in the linear model.

Table 10
Test of Hypotheses

Source	Degrees of Freedom	Sum of Squares	F Value	Pr > F
Treatment	2	.0453	5.32	.158

Table 11
Adjusted Means After Recompaction

Treatment	Number of Observations	Adjusted Means (g/cm^3)	Standard Error (g/cm^3)
Baseline	8	1.50	.04
Pecan	16	1.43	.02
Walnut	16	1.57	.03

Table 12 provides results of a t-test which was used to determine if the treatments come from similar or dissimilar populations. The null hypotheses states that all treatments are from the same population. The difference in mean values obtained for the baseline and pecan treatment will be the same or exceeded approximately 20.3% of the time by chance, assuming both treatments

are from the same population. Likewise, the difference in mean values obtained for the baseline and walnut treatment will be the same or exceeded approximately 21.1% of the time by chance. Also, the difference in mean values obtained for the pecan and walnut treatment will be the same or exceeded approximately 1.0% of time by chance. Since the difference of pecan and walnut values is the greatest (.14 g/cm^3) and the probability of equaling or exceeding this value is very small ($p < .01$), it was determined that the pecan and walnut treatments were not from the same population. The null hypotheses for the other two combinations of treatments was accepted.

Table 12
T-Test for Population Differences

Treatment Differences	Absolute Density Differences g/cm^3	Probability of Equaling or Exceeding the Difference
Baseline-Pecan	.07	.203
Baseline-Walnut	.07	.211
Walnut-Pecan	.14	.009

The ability of the experiment to detect small differences between the treatments was limited. It appears that the pecan shells may have a positive effect on the density of the recompacted soil, but the statistical analysis was unable to confirm this suspicion. The walnut shell treatment does not appear to have any impact on preventing recompaction. In fact, the results show that the addition of walnut shells may, if anything, increase the recompacted soil density.

Nuclear Gage Readings Versus Gravimetric Sampling. A comparison of the nuclear gage readings and the gravimetric measurements was made. After the nuclear gage readings were taken, the gage was relocated outside the ripped zone and additional readings were taken. Then a core sample was extracted midway between the nuclear gage probe locations. Three samples were taken measuring approximately 10.2 cm (4.0 in.) long and were centered at 10.2 cm (4.0 in.), 22.9 cm (9.0 in.) and 38.1 cm (15.0 in.) below the surface of the soil. For the purposes of this study, the two most shallow samples were analyzed (i.e., compared to the nuclear density readings). The mean of the nuclear gage readings ranged from 2.1 % to 2.4 % below that of the mean of the gravimetric core samples. This indicates on the average, the nuclear gage provides reliable estimates of soil bulk density. One possible reason for the disagreement between the two methods is the potential for compaction during gravimetric sampling. This was likely to occur due to the type of coring tube chosen. In addition, the compaction of the soil during the preparation of the access holes may have increased the density between the probes. Also, it is recognized that the soil density outside of the ripped zone was measured with the nuclear gage, especially at depths of 20.3 - 25.4 cm (8 and 10 in.) below the soil surface. This may have increased the density readings since lateral failure and subsequent compaction due to tillage is likely to occur in this zone. Due to this reasons, both the nuclear gage readings and the gravimetric measurements may be higher than true densities.

Mechanical Resistance. Resistance to penetration was measured in the ripped zone, excluding the path of the ripper. The resistance in the ripping path was very low and caused the cone shaft to veer substantially. This affects the resistance readings. Since the location of the injected material,

other than within the path, was unknown prior to sampling, quite often the cone penetrometer did not pierce the thin layer of injected material. Consequently, this method of measuring soil compaction was found to be unacceptable to measure the effect of treatment in the material injected zone. The penetrometer readings are shown in Tables 31 through 36 for each trial to document the experiment performed. In a few cases the cone penetrometer broke through to adjacent holes. This caused low, erratic readings and is the reason for the missing values.

Table 37 in the Appendix shows a summary of the initially compacted resistance readings. Both the pecan and walnut treatments have lower resistance readings when compared to the baseline treatment. This is inconsistent with both the nuclear gage and gravimetric bulk density data. Generally, bulk density and mechanical resistance are positively correlated (Barnhisel, 1988).

Table 38 in the Appendix shows a summary of those readings that pierced injected material in the recompacted stage. One reading was taken in the material injected zone for the walnut treatment. Comparing the baseline and the pecan treatments, the top interval shows similar resistance readings. The middle interval shows the pecan with lower resistance readings as compared to the baseline.

Gravimetric Bulk Density and Hydraulic Conductivity. Since selected soil core samples that were extracted for gravimetric bulk density were retained for determining hydraulic conductivity, both will be discussed together.

These two methods of sampling are destructive (i.e., the sample was destroyed due to the process of obtaining the measurement). Unlike the nuclear gage readings, the same physical location could not be measured with each successive stage of soil manipulation.

After the measurements were taken, the samples were diced to examine for injected material. As before, many of these samples did not measure the effect of treatment application due to its physical location. Those samples that were found to have material injected are discussed below.

The nature of the deposited material was important. In most cases, it appeared that the coring tube extracted a sample located very close to the path of the ripper. In these cases, the material found in the sample may have been taken from the path of the ripper or from a short finger of material that projected from the path. As a result, quite often only a small part of the cross sectional area contained injected material. A few cases were noted where the material covered the entire cross sectional area. However, it was likely that these samples were taken from the boundary between the ripped zone and the undisturbed volume as shown in Figure 19. When testing a sample for hydraulic conductivity, an increase may be found in that part of the sample that is loosened. However, the conductivity is likely to be reduced over the remainder of the sample that is taken from the unripped area as shown in Figure 19. The measurement taken from such a sample may not represent the ripped zone and the effect of the treatment.

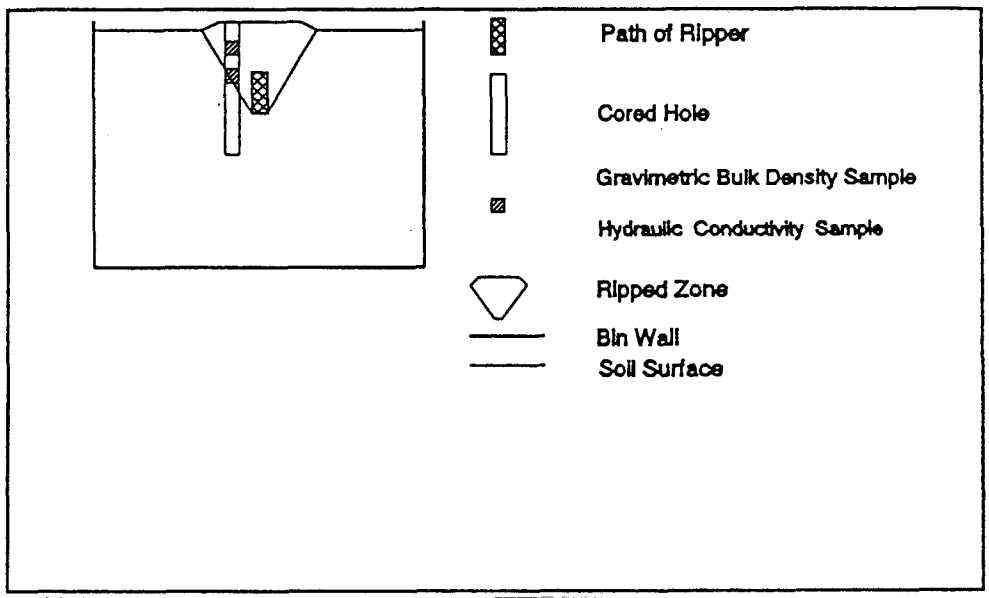

Figure 18 - Cross Section of Gravimetric Bulk Density and Hydraulic Conductivity Sampling Location

Gravimetric Bulk Density. Tables 39 through 48 show the density values for each successive trial to document the experiment performed. Tables 49 through 51 show a comparison of the walnut, pecan, and baseline treatments for each stage of soil manipulation. Those samples in which injected material were found were summarized in Tables 50 and 51. The ranked order of the density values were walnut, pecan, and baseline as shown in Table 49 for the initially compacted values. This was consistent with the nuclear gage data. In the recompacted stage, Table 51, the values were quite close, and did not correspond with the ranked order of the nuclear gage adjusted means.

Hydraulic Conductivity. Tables 52 through 56 show hydraulic conductivity values for each trial. Since a small number of material injected samples were collected, the walnut and pecan treatments were combined to contrast with the baseline treatment. Table 57 shows the initially compacted values for hydraulic conductivity for all three treatments. Tables 58 and 59 show the hydraulic conductivity values for the material injected samples for the ripped and recompacted stages, respectively.

Generally, the hydraulic conductivity values were variable between the treatments, even for the initially compacted stage. Also, the standard deviations were high, possibly due to the limited number of samples collected.

The same physical sample was measured for bulk density and hydraulic conductivity. Generally, bulk density and hydraulic conductivity are negatively correlated (Barnhisel, 1988). As bulk density increases, pore space decreases. Generally, the decrease in pore space causes hydraulic conductivity to decrease. When plotting the gravimetric bulk density values against the hydraulic conductivity values in the initially compacted stage, an unexpected positive correlation was found. One possible explanation involves the reliability of either the gravimetric bulk density values, or the hydraulic conductivity values, or both. The expected negative correlation was found when plotting the values in the recompacted stage. However, a limited number of samples, four in this

case, precludes an accurate picture of the recompacted data. Due to confinement of the bin, additional samples were not possible.