CHAPTER VIII

CONCLUSIONS

The conclusions and recommendations outlined in this chapter are supported by the results and statistical analysis of the experimental data. The following objectives were addressed in various stages of the experiment:

1) To determine the feasibility of injecting various materials into the voids caused by deep-tillage with the use of air pressure;
2) To determine the effects of material injection on recompaction of a deep-tilled soil; and
3) To provide information for further study.

These objectives were accomplished primarily through the use of a physical, laboratory model. Several bins of soil were prepared, each involving three distinct stages:

1) Initially compacted soil;
2) Deep-tilled soil with material injected simultaneously; and
3) Recompacted soil.

After each stage, the following parameters were measured:

1) Dry bulk density, g/cm^3 (lbs/ft^3);
2) Moisture content, percent by mass;
3) Mechanical resistance, kPa (psi); and
4) Hydraulic conductivity, cm/sec (in./sec).

The first step was to determine the feasibility of injecting various materials into the voids caused by deep-tillage. The workability of the material injection system was demonstrated with each ripping stage of the experiment. Various types of organic and inorganic material were injected into the soil with a sandblaster. This method of material injection was successful with respect to physically placing some material in the soil during ripping.

The primary area of interest shifted during the execution of the experiment as a result of observed injection patterns. Initially, the small voids created outside the ripper path were expected to show some treatment effect. Subsequent visual inspection consistently indicated that the bulk of the inserted material was deposited in the ripper path. This led to the difficulty of maintaining an adequate sampling program. Since the initial sampling scheme was horizontally distributed, it was found that, for these experiments, the best method of measuring compaction and recompaction for deep-tilled soil with injected material was the nuclear gage.

In order to determine the effect that the injected material had on the recompaction of deep-tilled soil, the material injected zone must first be sampled or monitored. Several of the methods used as an indication of compaction and recompaction were not adequately representative of this zone. These methods included gravimetric bulk density, hydraulic conductivity and mechanical resistance. Prior to sampling, the location of the injected material could not be determined. However, based on the excavation of previous trials, it was fairly certain that most of the material was located in the path of the ripper. Bulk density, as measured with the nuclear gage, was the

primary method that was capable of determining the amount of compaction and recompaction occurring across the ripped zone. This is because it also measured variations vertically.

The amount of material injected during each trial varied and may not have been adequate to produce consistent results. The laboratory system of air injection was crude and would require considerable modification if a prototype was developed. Therefore, all of the voids may not have been filled with organic material. Secondly, fracturing may not have been as extensive as desired because the soil was ripped at a fairly high moisture content. The moisture content was kept near the optimum for compaction, but this clearly is not the optimum for ripping. Limited fracturing could have prevented the material from being distributed more evenly throughout the soil. The optimum moisture content for ripping and injection would be a fruitful area for prototype research.

The second step was to determine the effects of material injection on the recompaction of deep-tilled soil. Figure 36 in the Appendix shows that the pecan treatment profile has a larger difference from the initially compacted stage to the recompacted stage, when compared to the walnut and baseline treatments. However, the statistical analysis was unable to confirm that the observation was significant.

There are a number of factors that could have contributed to the inconclusive nature of the statistical results. The first factor that must be considered is the possibility that injection of organic material does not help prevent recompaction. However, the results of the tests using pecan shells would seem to indicate that there is some positive effect. Another possibility is that inadequate amounts of material were injected in some cases to fill all the voids due to limitations of the injection system. This factor is addressed above. Another consideration is that the sampling technique was not adequate to detect the differences after injection and recompaction. This is a real possibility since the particle density of the injected material was fairly close to the particle density of the soil (no less than 67% of soil particle density). However, despite the results of the statistical analysis, the ability to inject material into the soil during the ripping process was demonstrated and observed.

The final objective was to provide information for further study. Due to the limited size of the soil bin, only one treatment could be applied at a time. This design limited the sensitivity of the statistical analysis. Either many small bins of soil or one large bin containing all treatments must be processed in order to maximize sensitivity to treatment differences.

Furthermore, modifications in the basic equipment used in ripping are recommended. The stroke of the hydraulic cylinder limited the length of continuous material injection. It is suggested for future laboratory studies that the cylinder be replaced with one having a longer stroke or an alternate method of driving the ripper be employed.

Additional methods of measuring the effects of the injected material in the path of the ripper may be needed. This may require the use of a different type of injection material. This will also require the development of an injection system to handle cohesive material. Generally, cohesive materials are difficult to convey pneumatically. The noncohesive nut shells used in this experiment may be replaced by cohesive material, which may result in a better core sample taken in or near the path of the ripper.

A potential area of research may focus on the determination of the quantity of material to be injected into the soil that will achieve a maximum benefit. By injecting different amounts of a certain material into the soil and studying how it affects recompaction of the soil, one may possibly

determine the optimum amount of material to be injected in order to reduce or prevent recompaction. This would require the installation of a flow meter in the conveying hose. In addition, a containment system is needed for the material when testing for smooth flow prior to the execution of ripping and to control material that is discharged from the soil bin during ripping. This will allow for a better estimate of the material injected into the soil during ripping.

While laboratory modeling was necessary to demonstrate the principles involved, future field studies are needed to verify the initial work. It would also be desirable to observe the effect of natural seasonal cycles on soil that has been ripped and injected with organic material. Field validation is necessary to support or disprove the conclusions of this experiment.