

COMPARISON OF TILLAGE EQUIPMENT FOR IMPROVING SOIL CONDITIONS AND ROOT HEALTH IN BAREROOT NURSERIES

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Abstract

Two series of trials were conducted in northern bareroot forest nurseries to determine: 1) the effects of different incorporation implements and two chemical application rates on the efficacy of dazomet fumigation; and 2) soil penetration resistance in the vertical soil profile following sub-soiling by two different implements. When target pests were located > 18 cm deep, the spading machine was more effective than three different rotary tillers in reducing fungi. Mortality and disease ratings in this trial were lowest and percentages of shippable seedlings highest for the spading machine at the end of the 3+0 year. However, when target pests were < 18 cm deep, all of the implements performed equally well at the lower dazomet rate. Cone indices obtained through the vertical soil profile one year after treatment for an alternative subsoiler were much lower (in other words, decreased penetration resistance) than those obtained for the cooperating nursery's subsoiler. Importance of understanding what planned tillage events in a nursery will and will not accomplish is discussed.

Key Words

Fumigation, dazomet, soil management, subsoiling

Tillage operations are part of overall soil management practices associated with the culture of bareroot forest nursery seedlings. The impact of such operations on the physical and biological properties of soil can vary according to the tillage tool used. Among the physical properties affected by tillage implement use are soil structure, water drainage through the soil profile, resistance of soil to root penetration, field topography, and subsoil conditions. Tillage events associated with incorporation of green manure or other amendments (for example, peat) affect such physical properties as soil texture, soil fertility, organic carbon, and pH. In addition, incorporation treatments impact biological properties of the soil. For example, incorporated crop residue provides substrate for potential buildup of soil-borne microorganisms. At the same time, improved soil tilth, organic carbon, fertility, and reduced mechanical resistance may

result from incorporation of crop residue and are beneficial for seedling growth. Finally, when tillage implements are used for incorporation of certain pesticides (for example, granular formulations) the biocidal activity of the product occurs mainly within the zone of incorporation.

In this paper the results of studies we have undertaken to examine the use of various tillage implements and their impact on seedling production, root health, soil biota, and other soil properties are summarized. In one series of trials we determined the effects of different incorporation implements and 2 chemical application rates on the efficacy of dazomet (a granular soil fumigant) on selected soil fungi and the seedling crop produced in the treated fields. Preliminary results are also presented on a second series of trials designed to evaluate subsoiler use on resistance of soil to penetration.

DAZOMET INCORPORATION TRIALS

Materials and Methods

Field trials were conducted in a Wisconsin and a Michigan nursery to compare the effectiveness of 2 application rates of dazomet when incorporated by different implements. Three types of rotary tillers (Fobro Kulti-Pak Rotary Tiller[®], Kuhn Rotary Tiller[®], and Northwest Tiller[®]) and 1 spading machine (Gramegna[®]) were compared in the Wisconsin nursery where the soil is a Vilas loamy sand. The Fobro tiller, the Gramegna spading machine, and a tandem, double-gang disk cultivator (John Deere Disc Cultivator[®]) were compared in the Michigan nursery where the soil is also a loamy sand. Details of the tillage tool lengths and operational working width for each implement are found in Table 1.

The dazomet was applied at the appropriate test rate (250 and 500 lbs/ac = 285 and 570 kg/ha, respectively) with a drop spreader to the trial fields (0.7 ha for each rate in Wisconsin; 0.8 ha for each rate in Michigan). The fields were then divided equally to accommodate the 4 (Wisconsin) or 3 (Michigan) incorporation implements. In the Wisconsin trial, each implement was operated at speeds recommended by growers experienced with the specific implement (Table 1), while a common speed (2 mph) was used for all implements in the Michigan trial. Following incorporation, a roller was used to compact the soil surface (top 4 cm), and irrigation was applied per the chemical manufacturer's recommendations (Pennington 1995). White pine was seeded in the trial fields in early October of the fumigation year in each location. Sowing rate in each nursery was based on seedlot germination assay results and the nursery's desired stand density.

Biocidal efficacy of dazomet was determined for all implement X dazomet application rate combinations using lettuce seed germination tests and selected fungal bioassays. For the lettuce assay, soil samples were collected immediately before fumigation and again after dazomet incorporation but prior to water activation. The bioassay was conducted per standard procedures (Morton Chemical Co., Chicago, Illinois) with water added just prior to jar sealing to activate the dazomet. Soil samples for the fungal assays were collected the day before chemical incorporation, at 4 weeks, and at 11 months after incorporation.

Standard assay procedures (see Juzwik and others (1998) for *Fusarium* and Juzwik and others (1988) for *Cylindrocladium*) were then conducted with these samples.

The actual concentrations and depths of dazomet in the field soils following incorporation were estimated based on surface application rate and operational depth for each implement (= actual dazomet incorporation rate). At the end of the 3+0 year, seedling production (quantity and quality) in each location was determined.

RESULTS

Biocidal activity in soil

On presence or absence of assay organisms. At both nurseries, lettuce seed germination results more closely mirrored the operational depth of each implement tested than the results of fungal bioassays, regardless of dazomet application rate. Seeds generally failed to germinate within the 14day assay period for soils collected from within the operational depth range for each implement (see Table 2 for Wisconsin results; Michigan results not shown). Recovery of *Fusarium spp.* and *Cylindrocladium spp.* propagules at different depths differed by dazomet application rate, implement, and assessment date. In the Wisconsin study, poor to fair control of *Fusarium spp.* and *Cylindrocladium spp.* was achieved in the low dazomet application areas. In the high dazomet application areas, good to excellent control of these fungi was found for the Fobro and the Gramegna spading machine in the upper 30 cm (Table 2). In the Michigan nursery, all implements performed equally well regardless of dazomet application rate, based on *Fusarium spp.* presence/absence after treatment (data not shown). However, *Fusarium spp.* presence was much less frequent before treatment in the Michigan nursery than in the Wisconsin nursery, especially at the lower depths.

On numbers of soil-borne fungi. Effect of the biocide on the actual numbers of fungal propagules in the treated soils differed by implement and soil depth. The Gramegna spading machine was superior to the other implements at the high dazomet rate in reducing *Fusarium spp.* levels in the Wisconsin nursery when all depths were taken into account (Figure 1B), and also at depths > 12 cm in the low dazomet application areas (Figure 1A). Results for *Cylindrocladium spp.* reduction were similar to those

Table 1. Specifications of tillage implements and their operation in dazomet field trials at Michigan and Wisconsin nurseries

Ground speed (mph)	Manufacturer and model *	Tillage tool	Working width (cm)	Nursery where used
0.7	Kuhn EL80N	42 tines of 22-cm length mounted on 7 flanges; tine offset angle of 110°	178	Wisconsin
0.7 2.0	Fobro Kultipak 1700	60 blades of 22-cm length mounted on 17 flanges; tine offset angle of 151°	170	Wisconsin Michigan
1.8	Northwest Tiller DHC-96-SC	48 tines of 27-cm length mounted on 8 flanges; tine offset angle of 95°	239	Wisconsin
0.7 2.0	Gramegna Spading machine V84/30B	6 spades of 13-cm width by 18-cm length	137	Wisconsin Michigan
2.0	John Deer Disc Cultivator	28 concave disks (44-cm diameter with 5-cm cup) in tandem, double-gang configuration; front disk set serrated	305	Michigan

*Kuhn, Fobro, and Northwest rotary tillers all have vertical action, forward rotation with L-shaped tines; Gramegna spading machine is a crankshaft type-digging machine.

for *Fusarium spp.* (data not shown). In the Michigan nursery, propagules of *Fusarium spp.* were reduced to/or near zero in the top 12 cm of soil regardless of dazomet rate and implement used (data not shown). Below 12 cm, propagule numbers were quite low both before and after treatment.

Seedling production

Seedling mortality. Seedling mortality was determined at the end of the first and third growing seasons at both nurseries. Percentage of dead seedlings within established subplots varied by sampling date, dazomet application rate, and implement in the Wisconsin nursery. Seedling mortality was lower in the high dazomet rate (< 1% to 4%) plots in the Wisconsin nursery than in the low-rate plots (1% to 7%). Within the high

dazomet rate plots at this nursery, mortality at the end of the third growing season was lowest in the Gramegna spading machine plots compared to the mortality in the other implement plots. In the Michigan nursery, seedling mortality was < 1% for all implements and both dazomet application rates combined, regardless of sampling date. *Root disease severity.* Average root disease ratings varied by sampling date, dazomet rate, and implement in the Wisconsin nursery and by sampling date only in the Michigan nursery. Average root disease rating, on a scale of 1 (healthy) to 5 (all root rotted or root collar lesion present), was low (< 1.3) on the first sampling date in both nurseries for both dazomet application rates and all implements. On the second sampling date (in other words, mid October of the 3+0 year), differences in disease

Table 2. Biocidal efficacy of a high rate of dazomet incorporated into Wisconsin nursery soil by four tillage implements *

Soil depth (cm)	Lettuce seed germination				<i>Fusarium</i> spp. presence				<i>Cylindrocladium</i> spp. presence			
	Fo	Ku	NW	Gr	Fo	Ku	NW	Gr	Fo	Ku	NW	Gr
0-6	---	---	---	---	---	+	+	+	---	---	---	---
6-12	---	---	---	---	---	+	++	---	---	---	---	---
12-18	+	---	---	---	+	++	++	---	+	---	++	---
18-24	++	++	+	---	+	++	++	+	+	++	++	---
24-30	++	++	++	+	+	++	++	+	+	++	++	+

*Implements: Fo = Fobro KutiPak rotary tiller; Ku = Kuhn rotary tiller; NW = Northwest rotary tiller; Gr = Gramegna spading machine. Actual dazomet incorporation rates: 0.41 kg/m³; 0.26 kg/m³; 0.21 kg/m³. Results of two replicates reported. For lettuce bioassay, “-” represents no germination and “+” represents germination for soil samples collected immediately after incorporation. For fungal assays, “+” represents presence and “-” represents absence or below detectable levels for soil samples collected 4 weeks after incorporation.

ratings were apparent in both locations. In the Wisconsin nursery, average disease ratings were lowest for the Gramegna spading machine at both the low rate (Gramegna = 1.7 versus other implements = 2.1 to 2.4) and the high rate (Gramegna = 1.2 versus other implements = 1.5 to 2.0). At the end of the 3+0 year in the Michigan nursery, lower root disease ratings were found for the Gramegna spading machine and the Fobro tiller (< 1.2) compared to those in the John Deere disk plots (1.8) for both rates combined.

Shippable seedlings. Percentages of live seedlings that met nursery specifications for shipping were similar for both the low and high dazomet application rates of the Michigan nursery (Figure 2). The most apparent differences were found in the Wisconsin nursery where percentages of shippable seedlings differed by implement (Figure 2), particularly in the high rate plots where higher percentages (> 80%) of shippable seedlings were found for the Fobro and Gramegna spading machine plots than for the other 2 implements

(63% to 73%). We speculate that the lower percentages of shippables at the higher dazomet rate for the Kuhn and NW Tiller were due to sublethal effects of residual dazomet granules in the upper 15 cm of soil that were not activated until the first growing season.

Conclusions of Incorporation Studies Major findings of the biocidal assays were as follows: 1) in the upper 12 cm of soil, all implements and dazomet application rates worked satisfactorily to reduce fungi and prevent lettuce seed germination for both nurseries; and 2) at depths > 18 cm in the Wisconsin nursery, the Gramegna spading machine was more effective than the other implements in reducing fungi and in preventing lettuce seed germination. Furthermore, the high dazomet rate in the Wisconsin nursery was more effective than the low rate for the Gramegna spading machine. Major findings arising from the seedling assessments were: 1) mortality and disease ratings

Figure 1

A. Low dazomet rate (285 kg/ha)

B. High dazomet rate (570 kg/ha)

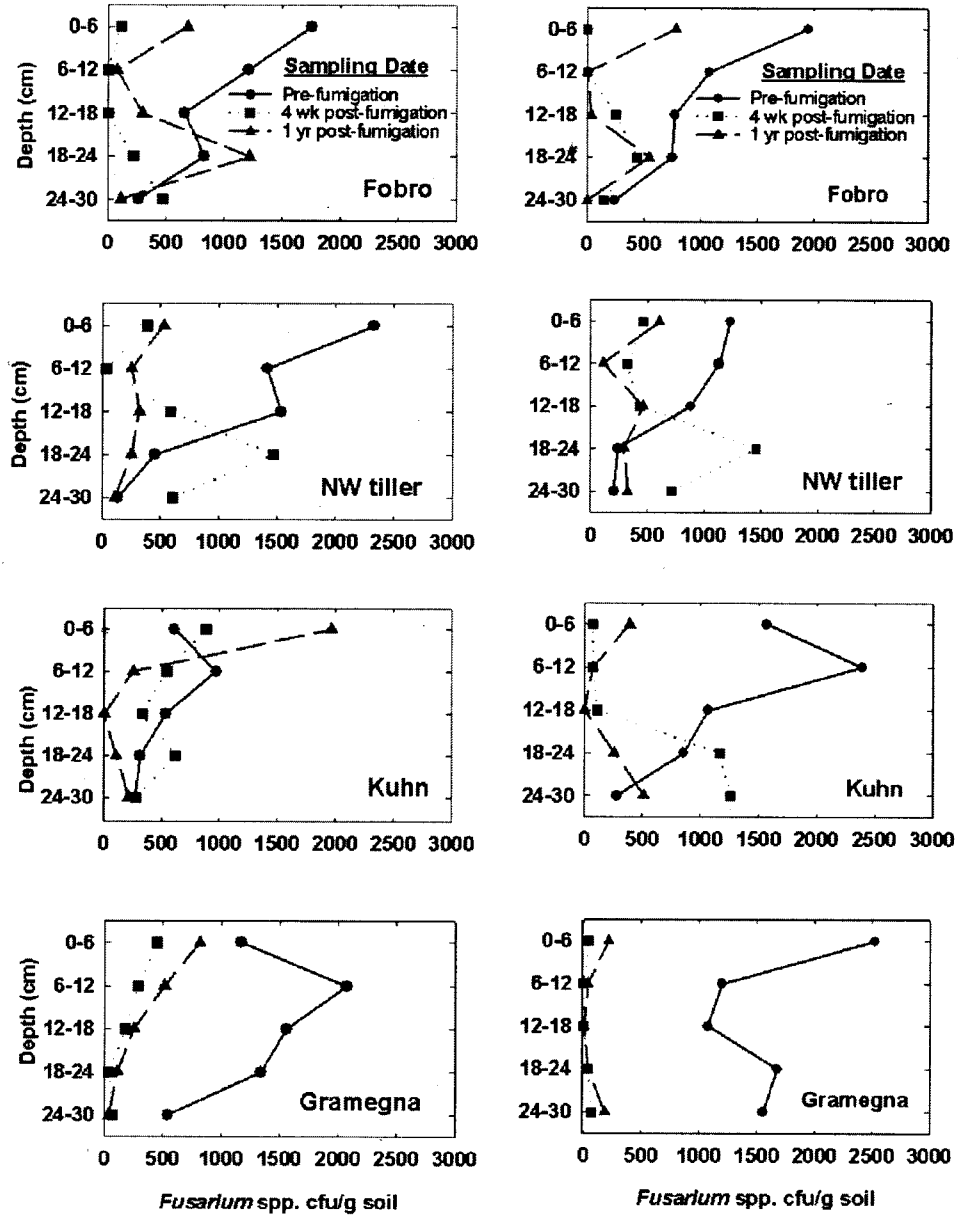


Figure 1. Efficacy of two rates of dazomet incorporated by different implements in reducing *Fusarium* spp. Populations in the vertical profile of soils in the Wisconsin nursery trial: A) low (285 kg/ha), and B) high chemical rate (570 kg/ha).

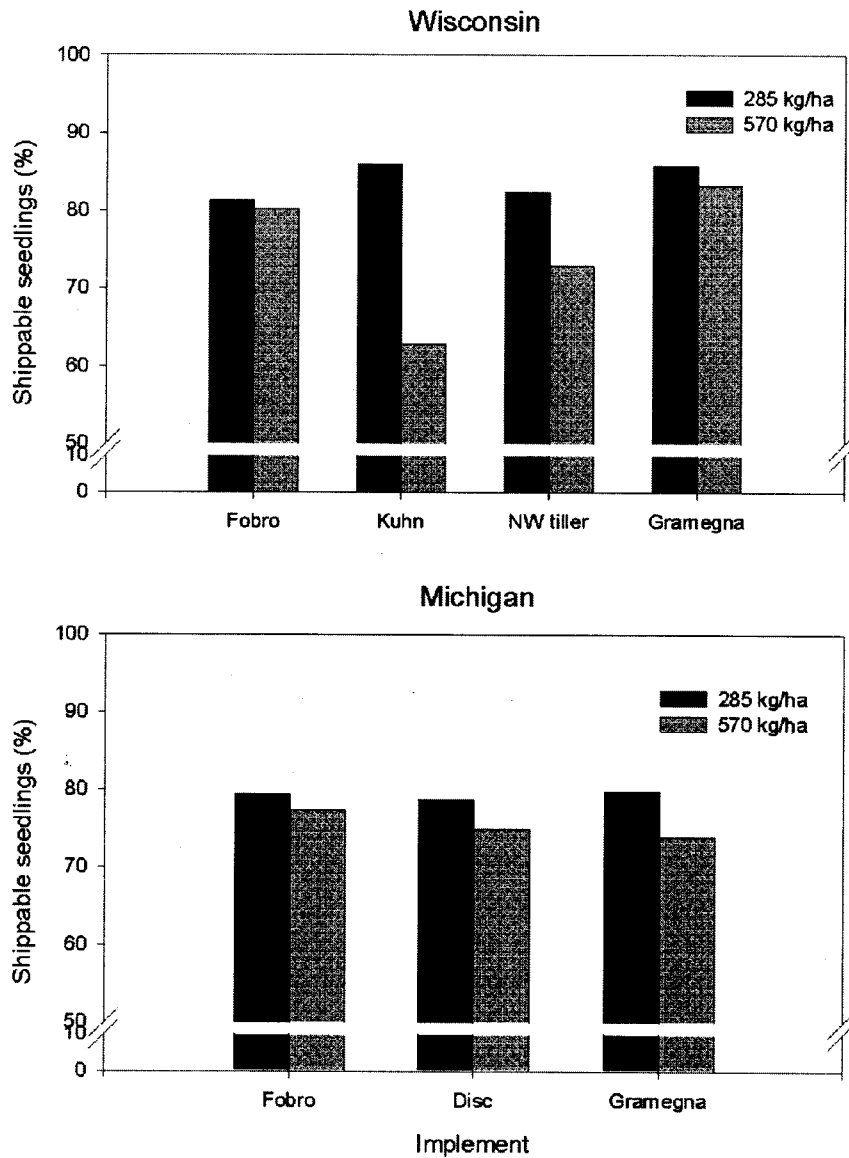


Figure 2. Percentage of shippable white pine seedlings grown in dazomet rate and tillage implement efficacy trials in Michigan and Wisconsin nurseries.

were higher in the Wisconsin nursery than in the Michigan nursery; 2) after 3 growing seasons in the Wisconsin nursery, lower seedling mortality and disease ratings were found in the areas receiving the high chemical rate compared to the low application rate for 3 of 4 implements tested; and 3) mortality and disease ratings in the Wisconsin nursery were lowest and percentages of shippable seedlings were highest for the Gramegna spading machine at the end of the 3+0 year.

SUB-SOILING TRIAL

Materials and Methods

Two subsoiling implements and their method of use were compared in a Minnesota nursery in 1998.

Alternative subsoiler. The shanks of the alternative equipment tested (DMI, Inc., Goodfield, IL) can be adjusted for horizontal and vertical placement. The 2 parabolic steel shanks (61 cm long) were equipped with winged tips (18 cm wide), and the

shanks were slightly offset on the toolbar and placed 46 cm apart. The operating depths of the shanks were determined based on cone indices recorded through the soil profile using a soil penetrometer (Rimik, Canberra, Australia) in preliminary assessments. Cone indices reflect the force (in MPa) required to steadily insert the penetrometer's cone through the soil profile. Values were recorded every 1.5 cm from the surface to a 45-cm depth. This subsoiler was only operated within demarcated seedbed areas in order to prevent tractor tire compaction immediately following subsoiling. One pass of the alternative field seedbeds was made with the subsoiler shanks set at a 14-cm depth, and a second pass was then made in the reverse direction with the 2 shanks set for penetration to 36 cm.

Control subsoiler. On the nursery's subsoiler, 3 fixed parabolic shanks (58 cm long) are 46 cm apart. This implement was used at its maximum operating depth, approximately 54 cm. Seedbeds of the control field were not demarcated until late September, just prior to seeding but 6 weeks after subsoiling (standard practice for the nursery). One pass was made across the control field (15 m by 165 m) in elongated, overlapping loops per the nursery's standard practice. During this operation, the tractor driver places tractor tires in previously made tire paths when shifting across the field. The tractor paths used during subsoiling, however, do not necessarily line up with the paths established during demarcation of seedbeds in late September. Thus, it is possible that new "hard-pans" are formed under the earlier tractor paths that had been used in these areas.

Assessment. Resistances of the soils in the study fields to penetration were determined 1 week before and 13 months, after subsoiling. Numerous insertions were made with a portable cone penetrometer to a 45-cm depth in the control and alternative fields. Cone indices were then plotted against soil depth to compare treatments.

Results and Preliminary Conclusions

The 2 study fields differed in their patterns of penetration resistance prior to subsoiling treatments. Prior to subsoiling in the field where the alternative implement was used, cone indices increased gradually with soil depth (Figure 3A).

This pattern is consistent with results obtained in other fields where a disk has been used to incorporate cover crops (see Juzwik and others 1998). In this particular field, a disk had been used 2 weeks prior to the pre-treatment assessment to incorporate cover crop residue. In the field where the control implement was used, the observed pretreatment cone indices (Figure 3A) are consistent with fields where moldboard plows have recently been used (see Juzwik and others 1998). In fact, a moldboard plow had been used 2 weeks prior to the pretreatment resistance assessment to incorporate cover crop residue in this particular field.

The resistance profiles following treatment also differed for the 2 fields, but these differences were attributed to the subsoiling implement used in each. The alternative subsoiler resulted in low cone indices in the soil profile to 30 cm, while cone indices in the control field began to increase markedly around 16 cm where average values ranged from 3 to 4 MPa (Figure 3B). Cone indices of > 2.75 MPa are considered limiting to plant root penetration in light textured soils (Labowski and others 1998). Thus, the use of the alternative subsoiler resulted in more favorable soil resistance conditions for the rooting zone (zero to 25 cm) of the subsequent woody crop than did the nursery's (in other words, control) subsoiler. We believe several aspects of the alternative subsoiler (for example, horizontal and vertical placement of shanks, the winged tip of the shanks, the way it was used in the field) contributed to the implement's superior effectiveness.

CONCLUDING REMARKS

Existing field conditions and prior tillage operations should be considered when determining incorporation/injection depth and rate of any fumigant selected for preplant, soil fumigation. In our dazomet studies, biocidal activity and seedling production were related to both incorporation depth and rate of dazomet (both surface application rate and actual incorporated rate). Thus, it is important for nursery staff to consider the depth distribution (in other words, < 18 cm versus > 18 cm) of the target pests when selecting the incorporation implement for dazomet. In addition, the dazomet application rate should be adjusted for increased

Figure 3

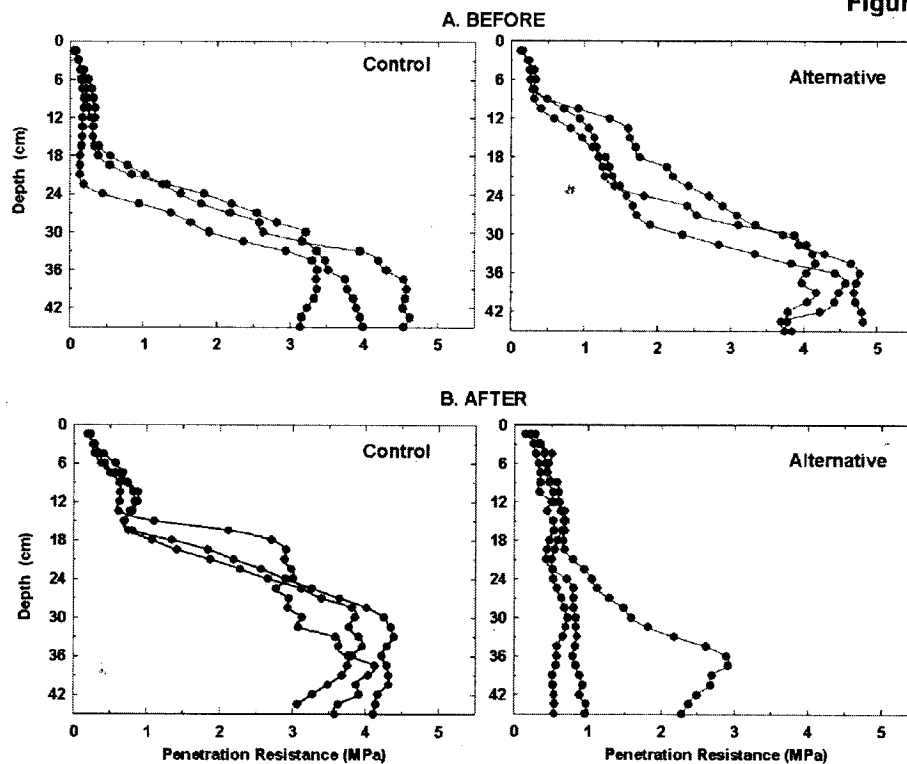


Figure 3. Penetration resistance (MPa) measured before and after subsoiling treatments in a Minnesota nursery. Each graph contains results of three penetrometer insertions in one of four sampling locations in the particular study field.

soil volume when the product is incorporated to greater depths. Shallower incorporation of the product can be expected when the ground speed of the tractor equipped with an implement increases, based on the authors' results of a related study. Likewise, the pattern a tractor driver follows in subsoiling across a field is as important as the selection of the subsoiling tool itself in ameliorating compacted soil conditions. In conclusion, whether selecting implements for incorporating dazomet or conducting subsoiling in fields between woody crop cycles, it is wise for nursery staff to question whether their planned tillage operation will actually accomplish the outcome they would like to see.

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