ZONE–SUBSOILING RELATIONSHIPS TO BULK DENSITY AND CONE INDEX ON A FURROW–IRRIGATED SOIL

J. K. Aase, D. L. Bjorneberg, R. E. Sojka

ABSTRACT. *Zone subsoiling on irrigated land has been successfully used to improve potato (*Solanum tuberosum *L.) yield and quality. Zone subsoiling under furrow irrigation may disrupt water flow and influence infiltration and soil erosion. We hypothesized that zone subsoiling, done appropriately, will maintain integrity of irrigation furrows, improve small grain and dry bean (*Phaseolus vulgaris *L.) growth and yield, and not adversely affect water flow, infiltration, or erosion on furrow–irrigated soils. The experiment was conducted at the USDA–ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho. The soil is a Portneuf silt loam (coarse–silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids). Tillage treatments were disk, disk + paratill, paratill, and no–till.There were no differences in water infiltration, runoff, or soil erosion among treatments. Bulk density differences among treatments were largest at the 0.15 to 0.20–m depth, and bulk density was about 16% to 18% greater on disk and no–till treatments than on paratill treatments. The highest frequency of low cone index (CI) values belonged to paratill treatments (65% to 80% frequency of CI values less than 2 MPa); the lowest frequency of low CI values belonged to no–till treatment (20% frequency less than 2 MPa). Cone index versus bulk density relationships depended on soil water content with a slope of 5.81 (r^2 = 0.70) in the wetter year of 1997, and 2.90 in the drier year of 1995 (r^2 = 0.60). Subsoiling can be accomplished on furrow–irrigated lands with no adverse effects on runoff, infiltration, and erosion, but under our conditions did not improve crop growth and yield.*

Keywords. *No–till, Paratill, Bulk density, Cone index, Irrigation.*

Portneuf soils are extensive in southern Idaho and are commonly used for irrigated crops. Portneuf silt loam is a weakly structured soil with an ochric epipedon and has a 0.20 to 0.45–m thick discontinuous lime–silica cemented hard layer that, in uncultivated soils, starts at 0.30 to 0.45 m below the surface. Hard layers, or soil pans, can be natural, as in the case of the Portneuf soil, a consequence of soil management practices, or a combination of both. Hard, dense soil layers restrict water intake, gas movement, and plant root proliferation.

Practices to disrupt dense soil layers include various forms of deep tillage or subsoiling. Zone subsoiling, the practice of maximizing subsoil shattering along the planted crop row, is one form of deep tillage that can be used on furrow–irrigated land. The paratill, a non–inverting subsoiling implement, was successfully used by Sojka et al. (1993a,b) in two–year multisite studies in southern Idaho to increase quantity and quality of furrow–irrigated potatoes (*Solanum tuberosum* L., cv. 'Russet Burbank'). Pierce and Burpee (1995) used a paratill yearly in a four–year study on a sandy loam in west central Michigan and concluded that zone tillage improved soil physical conditions and in most years increased marketable yields of Russet Burbank potatoes.

Subsoiling improved crop yields in cereals and sugar beets (*Beta vulgaris* L.) in Belgium and lasted for three to five years (Ide et al., 1987). Frederick and Bauer (1996), working in South Carolina, reported increased wheat (*Triticum aestivum* L.) yield from subsoiling treatments. Sojka et al. (1990) reported generally improved seed yield and quality of sunflowers (*Helianthus annuus* L.) in South Carolina. Sojka et al. (1997) reported a New Zealand study where subsoiling increased oat forage yield. In tropical eastern Bolivia, Barber (1994) found improved soybean yield for at least three years following subsoiling.

Persistence of subsoiling can be short lived. For example, Busscher et al. (1986) found some evidence of subsoiling after one year, but there was no effect on crop yield. In a separate study, Busscher et al. (1988) found no yield effect from subsoiling a sandy loam in the southeastern Coastal Plain. Reconsolidation of loosened soils can take place within a year (Threadgill, 1982; Busscher and Sojka, 1987). Sojka et al. (1990) reported that reconsolidation occurred within about a month following heavy rainfall, and there was no trace of subsoiling at the end of the season. Unger (1993), using cone index and bulk density measurements, could not define paratill longevity effects with certainty from subsoiling on Pullman clay loam. He attributed the uncertainty to differences in soil water content at time of treatment imposition.

Our objectives were to determine the effects of zone subsoiling with a paratill plow, designed to minimize disturbance of water flow in irrigation furrows, on bulk

Article was submitted for review in June 2000; approved for publicatin by the Soil & Water Division of ASAE in November 2000.

Use of trade names does not constitute an endorsement by the United States Department of Agriculture to the exclusion of other products not mentioned.

The authors are **J. Kristian Aase**, Soil Scientist, **David L. Bjorneberg, *ASAE Member Engineer***, Agricultural Engineer, and **Robert E. Sojka**, Soil Scientist, USDA Agricultural Research Service, Kimberly, Idaho. **Corresponding author:** J. Kristian Aase, USDA–ARS, 3793 North 3600 East, Kimberly, ID 83341, phone: 208–423–6544; fax: 208–423–6555; e–mail: aase@kimberly.ars.pn.usbr.gov.

density, cone index, water infiltration, runoff, and soil erosion and to determine its potential effect on crop yield.

Materials and Methods

The experiment, beginning in 1995, was conducted at the USDA–ARS Northwest Irrigation and Soils Research Laboratory near Kimberly, Idaho. The field, 188 m wide × 168 m long, is a Portneuf silt loam (coarse–silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids). The field was divided into three replicates, each 63 m wide × 168 m long. Each replicate was initially divided into a disk (D) and a disk + paratill (DP) treatment. On 4 April 1995, both treatments were disked with a tandem disk to a depth of 0.1 m. On 18 April 1995, the disk + paratill treatment was tilled with a two–shank paratill plow to a depth of about 0.4 m. Irrigation furrows and plant beds were formed following disking and prior to paratilling.

To provide for undisturbed irrigation water flow, the paratill configuration was selected so that the 0.12–m deep irrigation furrows were not disturbed by paratilling. The paratill shanks were 1.52 m apart, with points oriented inward, each plowing the middle of two adjacent plants beds. The irrigation furrows were 1.12 m apart. Tractor wheels tracked the irrigation furrows to avoid compacting the plant beds (fig. 1A).

Barley (*Hordeum vulgare* L.) was grown in 1995. To minimize residue following barley harvest, barley stubble was cut 8 cm above the soil surface, baled, and removed from the plots. Dry beans (*Phaseolus vulgaris* L.) were grown in 1996 and 1997.

In 1996, we split the 1995 disk treatment into the following four treatments: 1) disk (D) (no change from 1995), 2) disk + paratill (DP), 3) paratill (P), and 4) no–till (NT). The 1995 disk + paratill treatment was split into the same four tillage treatments, except in this case the DP treatment was carried through from 1995. In the fall of 1995, the plots designated as D and DP for 1996 were disked. In the spring of 1996, the D and DP treatments were disked, and the P and DP treatments paratilled with the same configuration as in 1995. In 1997, we repeated the same treatments on the same plots with similar field operations as in 1996, except we modified the paratill plow arrangement by adding two more paratill shanks, thus treating each plant bed with two paratill shanks (fig. 1B).

Soil penetration resistance measurements were made with an Eijelkamp penetrologger (an electronic recording penetrometer) using a 12.8 mm diameter, 30° angle cone tip, according to ASAE Standard S313.2 (ASAE Standards, 1995). The penetration resistance measurements were made each fall following harvest. Known wheel tracks from tractors and harvesting equipment were avoided.

As a guide for the penetrometer probe, we used a 1.12 m long × 0.80 m wide × 19 mm thick plywood template that reached across plant beds from the middle of one irrigation furrow to the next. The template had 36 guide holes (12 holes × 3 rows). The holes were 0.10 m apart in each of three parallel rows that were 0.20 m apart. Penetrometer readings were recorded at each 0.10 m depth increment, and assuming a full 0.80 m deep penetration, resulted in a potential 2,880 penetrometer readings from each template setting. One template set of readings was taken from each plot.

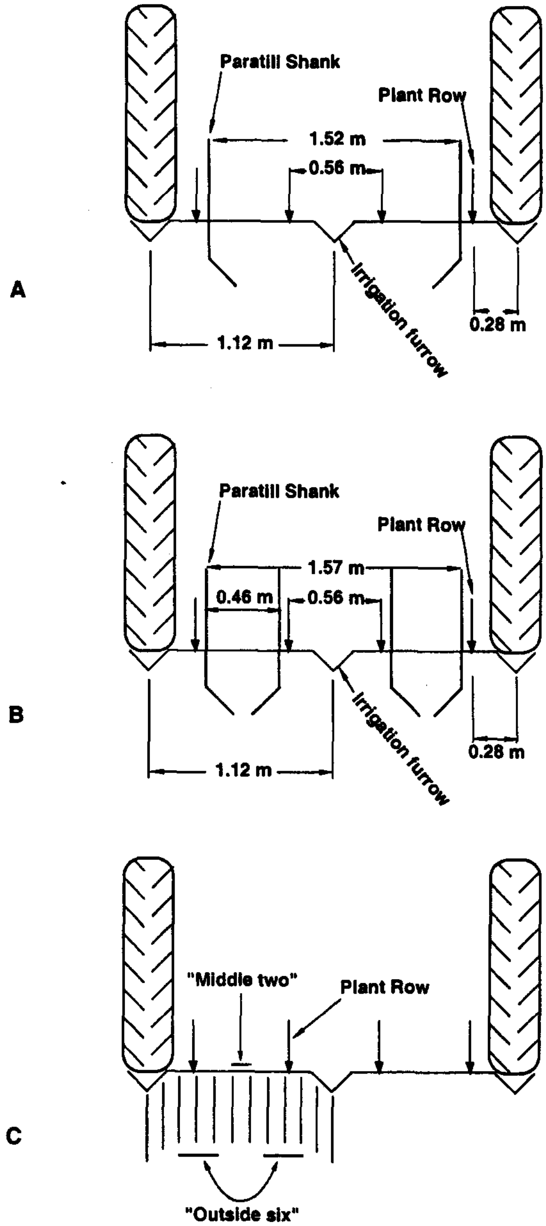

Figure 1. Paratill configuration in 1995 and 1996 (A) and in 1997 (B), showing all penetrometer measurement locations and illustrating penetrometer measurements used for CI frequency analyses, designated "middle two" and "outside six" (C).

Because of a dense cemented carbonate layer of variable depth, it was not possible to reach 0.80 m depth on every plot. Therefore, we limited analysis of cumulative cone index (CI) frequency to 0.50 m depth (minimum depth reached). Cone index is defined as the force required per unit base area to push the penetrometer through an increment of soil. In the analyses of cumulative frequency profile cone indices, we did not use the two penetrations taken in the irrigation furrows on either side of the plant bed. The two penetrations most affected by the paratill treatment were in the middle of the plant bed. In the CI frequency analysis, we separated these two penetrations from the three penetrations on either side of the middle and designated them the "middle two" measurements and the "outside six" measurements, respectively, as illustrated in figure 1C. Cone index isopleths, using readings from all penetrations to 0.50 m depth, were drawn to illustrate depth distribution of penetration resistance.

In 1995, soil water content and bulk density were determined in the middle of the plant beds in 30 mm increments to a depth of 0.30 m using a 19 mm diameter solid–core tube sampler. Because of difficulties of retaining, and sometimes of compacting, some soil cores in the sampling tube, particularly on the paratill treatments, the sampling technique was changed in 1996 to digging pits and then hammering soil sampling rings (53 mm inside diameter × 30 mm long), placed in a sampling tube, into the sides of the pits in 50 mm increments to a depth of 0.40 m. That method was labor intensive, time consuming, and required several workers. Therefore, in 1997, we resorted to using a hydraulic soil sampler that had become available. We used a sampling tube into which we inserted 76 mm inside diameter × 76 mm long sleeves. This method was consistent and efficient. We sampled to a depth of 0.46 m, thus obtaining six depth samples.

During the 1996 and 1997 seasons, irrigation water inflow, runoff, and soil erosion were monitored about 85 m from the irrigation ditch (about half the length of the plots) in wheel–track furrows. This distance was chosen because most erosion occurs on the upper end of furrow–irrigated fields (Trout, 1996). Irrigation water was supplied to the irrigation furrows with siphon tubes. We used water (electrical conductivity = 0.5 dS m^{-1}, sodium adsorption ratio = 0.4 to 0.7) from the Twin Falls Canal Company delivery system. We irrigated six times in 1996 and five times in 1997. Irrigation duration varied among dates from 8 to 24 h. We monitored four furrows in each plot during five irrigations in 1996 and during all five irrigations in 1997. Inflow rates were measured from the siphon tubes using a calibrated container and stopwatch. We measured furrow flow rates with small trapezoidal, long–throated flumes and collected runoff, including sediment, from the flumes 15 min, 30 min, 1 h, 2 h, 4 h, 6 h, and 8 h after runoff started and at the end of each 12 h and 24 h irrigation. Runoff samples were poured into 1 L Imhoff cones to determine sediment concentration (Sojka et al., 1992). Infiltration was calculated by subtracting outflow from inflow measurements.

We used analysis of variance to statistically evaluate the data with least significant difference or Duncan's multiple range test, as appropriate, to separate means.

Results and Discussion

Infiltration, Runoff, and Soil Loss

We found no statistically significant differences ($P \leq 0.05$) among tillage treatments for irrigation–water infiltration and runoff or for soil erosion in either 1996 or 1997 (table 1). However, there were differences in runoff and soil loss between the two years. Runoff averaged 947 mm in 1996 and 1143 mm in 1997 for all monitored irrigations. The differences in soil loss were disproportionately larger than the runoff differences, averaging 44 kg in 1996 and 235 kg in 1997. Differences in runoff and soil loss between the two years may be attributed in part to 1997 being the second year of a low–residue crop but mostly to greater water inflow rates in 1997 than in 1996. Total water inflow averaged 1366 mm in 1996 and 1550 mm in 1997. The ratio of infiltrated water to inflow was 0.31 in 1996 and 0.36 in 1997.

Table 1. Seasonal infiltration, runoff, and soil loss during 1996 and 1997 per 85–m long furrow as influenced by four tillage treatments: D = disk tillage, DP = disk + paratill, NT = no till, P = paratill.

Tillage[a]	Infiltration (Mm)	Runoff (Mm)	Soil Loss (Kg)
	1996		
D	440	960	72
DP	384	931	53
NT	445	964	21
P	407	933	31
Average	419	947	44
CV	9	8	66
	1997		
D	344	1201	283
DP	454	1181	201
NT	378	1187	292
P	451	1004	165
Average	407	1143	235
CV	21	17	38

[a]There were no significant differences (P = 0.05) among treatments.

The lack of statistically significant differences among tillage treatments for infiltration, runoff, and soil loss were as hypothesized because we paratilled on the edge of the plant beds with the intent of leaving the irrigation furrows intact. In addition, during the process of forming irrigation furrows, most crop residue was removed from the furrows, resulting in similar furrows among treatments.

Soil Bulk Density

Bulk density differences were evident among treatments in 1995 and 1997 (fig. 2). Disk and DP treatments differed in 1995, generally with the greater bulk density on the disk–only plots. In 1997, bulk density was similar between no–till and disk treatments, and with some exceptions, was greater than bulk density on the two paratill treatments, which were similar. Although the trends in the bulk density data from 1996 seem to favor lower bulk densities on the paratilled plots compared to disk and no–till plots, they nevertheless appear somewhat erratic. Apparently, the method we used that year resulted in inconsistent sampling among workers from digging pits, hammering sampling cylinders into the sides of the pits, and removing samples from the cylinders, thereby compromising the consistency among samples. Therefore, in subsequent data presentation and discussion, we do not use bulk density data from 1996.

Bulk density differences among treatments were largest at the 0.15 to 0.20 m depth, and bulk density averaged 16% to 18% greater on disk and no–till treatments than on paratill treatments. Overall, bulk densities were reasonably low, and considering all depths of measurement, were less than 1.45 Mg m^{-3} at the end of the wetter 1997 season and less than 1.60 Mg m^{-3} at the end of the drier 1995 season.

Cone index measurements are influenced by soil water content (e.g., Busscher et al., 1997). The influence of soil water content on cone indices in our study is illustrated in figure 3, which shows cone index as a function of bulk density at two different soil water contents. Soil water content was greater in 1995 than in 1997, thus the penetrometer was

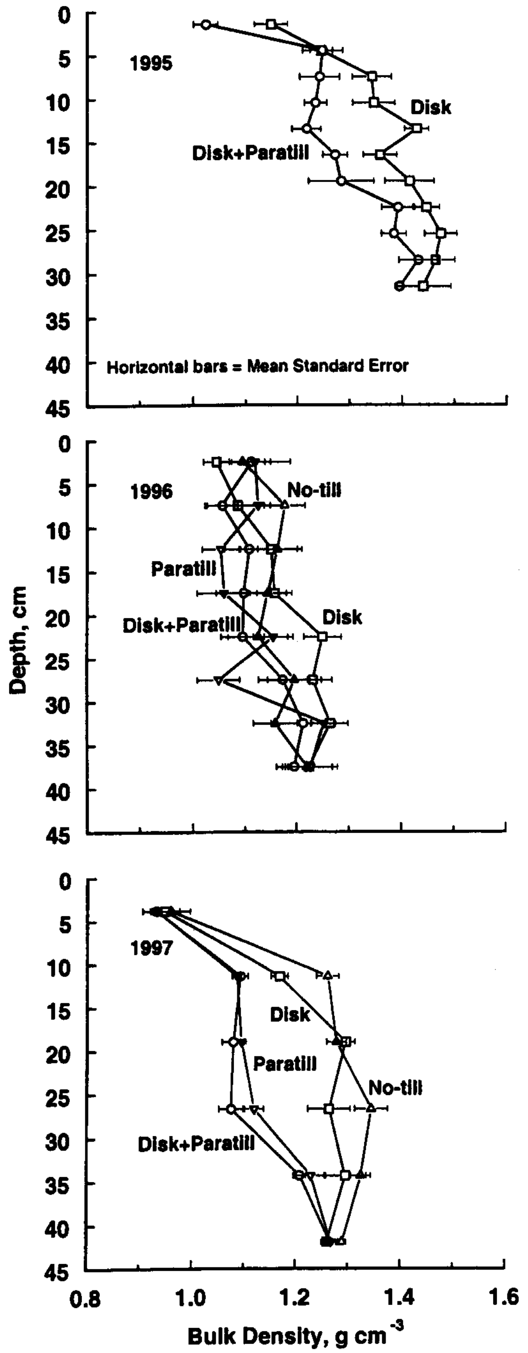

Figure 2. Bulk densities as influenced by tillage treatments.

pushed into the soil with greater ease in 1995 than in 1997. This resulted in the greater slope of the relationship between cone index and bulk density for the drier soil of 1997. The predictive relationships between CI and bulk density were respectable, with r^2 values of 0.70 and 0.60 for the lesser (1997) and greater (1995) water contents, respectively.

Portneuf silt loam is highly calcareous. Therefore, the relationship between CI and bulk density may vary at different water contents, depending on the effects of wetting history on the formation and dissolution of aggregate-binding carbonates, that is, on the strength of cementation.

Cone Index

Soil water content within years was not statistically different among treatments. Therefore, we compared cone indices directly among treatments within years without attempted adjustments for soil water content, as suggested by Busscher et al. (1997). Although soil water content differed among years, adjustments for soil water content were not deemed necessary to show relative treatment differences among years.

Examples of treatment differences within and among years are shown as isopleths in figure 4. Isopleths show the horizontal and vertical extent of soil disturbance. For uniformity of exposition, individual plots are limited to show depths of penetrometer readings not to exceed 0.50 m. Effects of the 1995 disk + paratill treatment on CI are readily apparent, as are the effects of the 1996 and 1997 paratill treatments. They are shown as the light-gray V-shaped areas (low CI values) on isopleths B1, B2, and B3 in figure 4. The bottom of the "V" reached 0.40 m. Residual effects of the 1995 paratill treatments were present in 1996 on the no-till treatment (isopleth C2), but they had essentially vanished by 1997 (isopleth C3) and resembled the 1997 no-till treatment that followed disking in 1995 (isopleth A3).

Because of the paratill plow configuration, the main paratill effect was near the middle of the plant bed and away from the irrigation furrows and dry bean rows. The plant rows were located 0.28 m from the middle of the irrigation furrow (fig. 1). The 0 and 1.10 m positions in figure 4 are in the bottom of the irrigation furrows, showing no effects from paratilling; the 0.10 and 1.00 m positions are at the edge of irrigation furrows, also showing no effects from paratilling.

Paratill effects are shown in figure 5 as cumulative frequency percent for the 0 to 0.50 m depths versus cone index. References to "middle two" refer to averages of penetrometer positions 0.50 and 0.60 m, and "outside six" refers to averages of positions 0.20, 0.30, 0.40, 0.70, 0.80, and 0.90 m, as shown in figure 4. Selections of these positions were made in order to show nominal position responses to the paratill treatments, both horizontally and vertically. Root-restricting soil strength values have commonly been considered to be in the range of 2 to 3 MPa (Taylor and Gardner, 1963; Taylor et al., 1966; Blanchar et al., 1978; Collis-George and Yoganathan, 1985; Busscher and Sojka, 1987; Nasr and Selles, 1995). The point where root growth ceases depends on soil conditions. Gerard et al. (1982) found critical strength for a fine sandy loam to be about 5.2 MPa in the surface 0.30 m, whereas for a clay loam it was about 3.6 MPa. For Portneuf silt loam, we represent the approximate beginning of restricted root growth at 2 MPa, while root growth nominally ceases at 3 MPa, as shown by the shaded areas in figure 5.

Cumulative frequency response to treatment differences and position differences are most clearly illustrated following the initial 1995 disk treatment (fig. 5, top three sequences). For the "middle two" positions, the highest frequency of low CI values belonged to the two paratill treatments (about 65% to 80% of values less than 2 MPa). The lowest frequency of low CI values belonged to the no-till treatment (about 20% of values less than 2 MPa). The results for the "outside six" positions tended to follow the trend of the "middle two" positions but were not as clearly defined. The no-till treatment had the lowest frequency of low CI values in both positions.

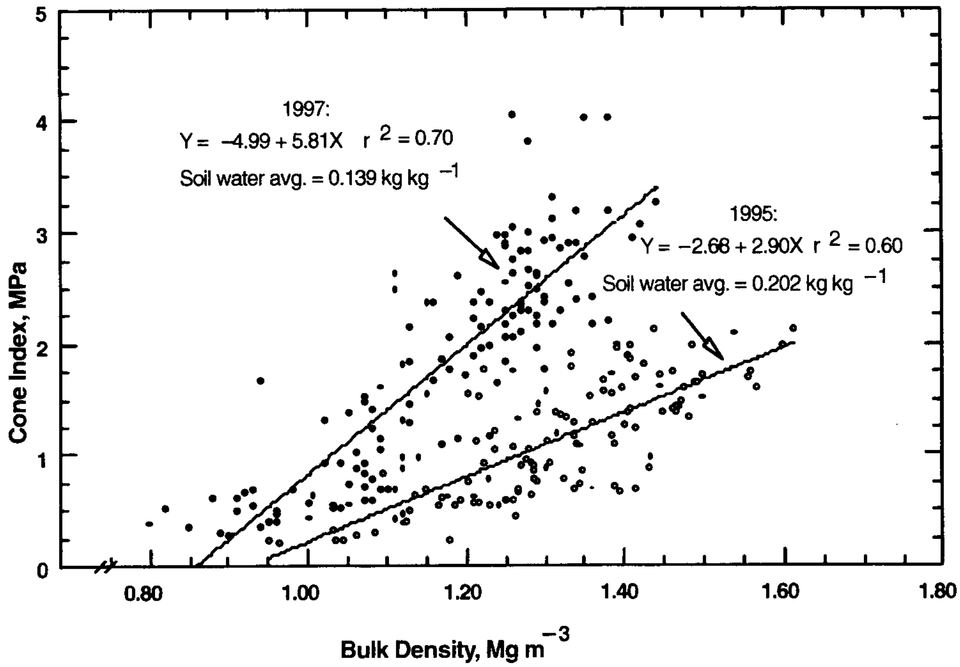

Figure 3. Cone index versus bulk density for all tillage treatments with two soil water regimes.

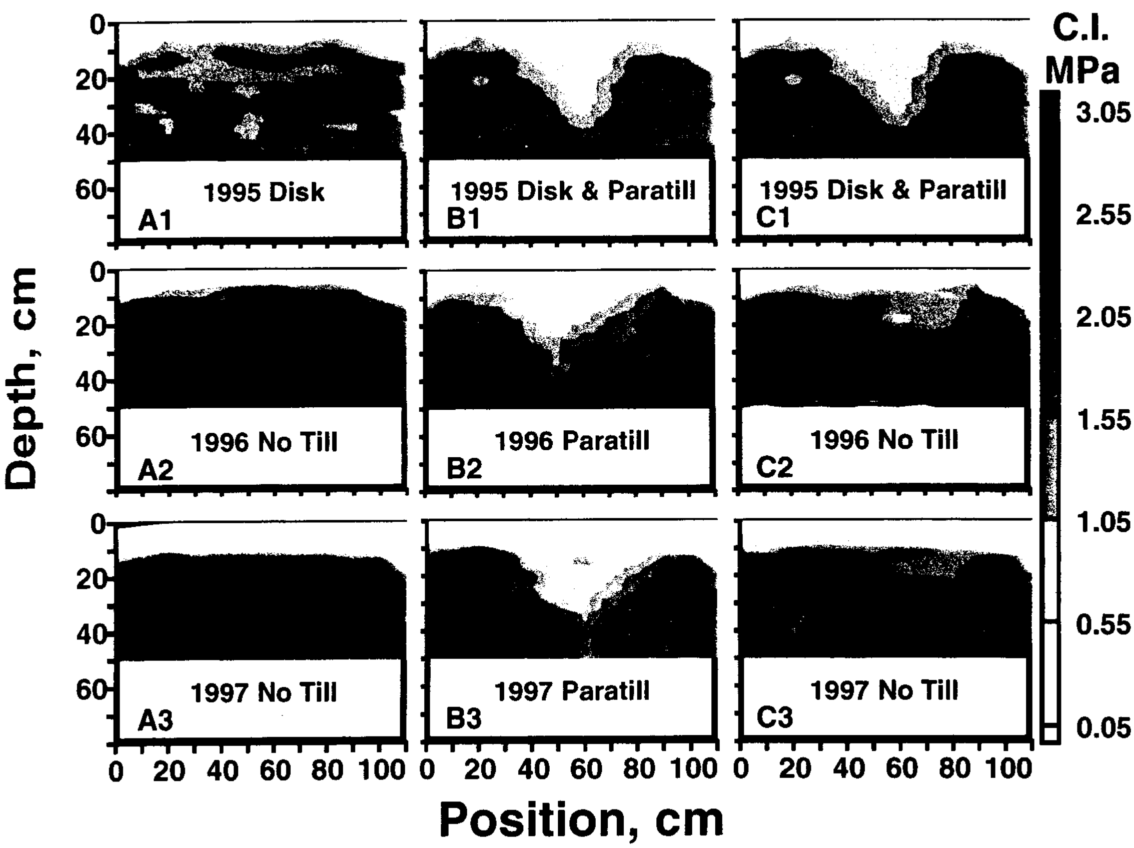

Figure 4. Isopleth examples showing cone index as a function of tillage treatment, depth, and horizontal position. Each vertical sequence illustrates the history subsequent to initial tillage treatments in 1995. Sequences B and C start with the same initial (1995) tillage treatment.

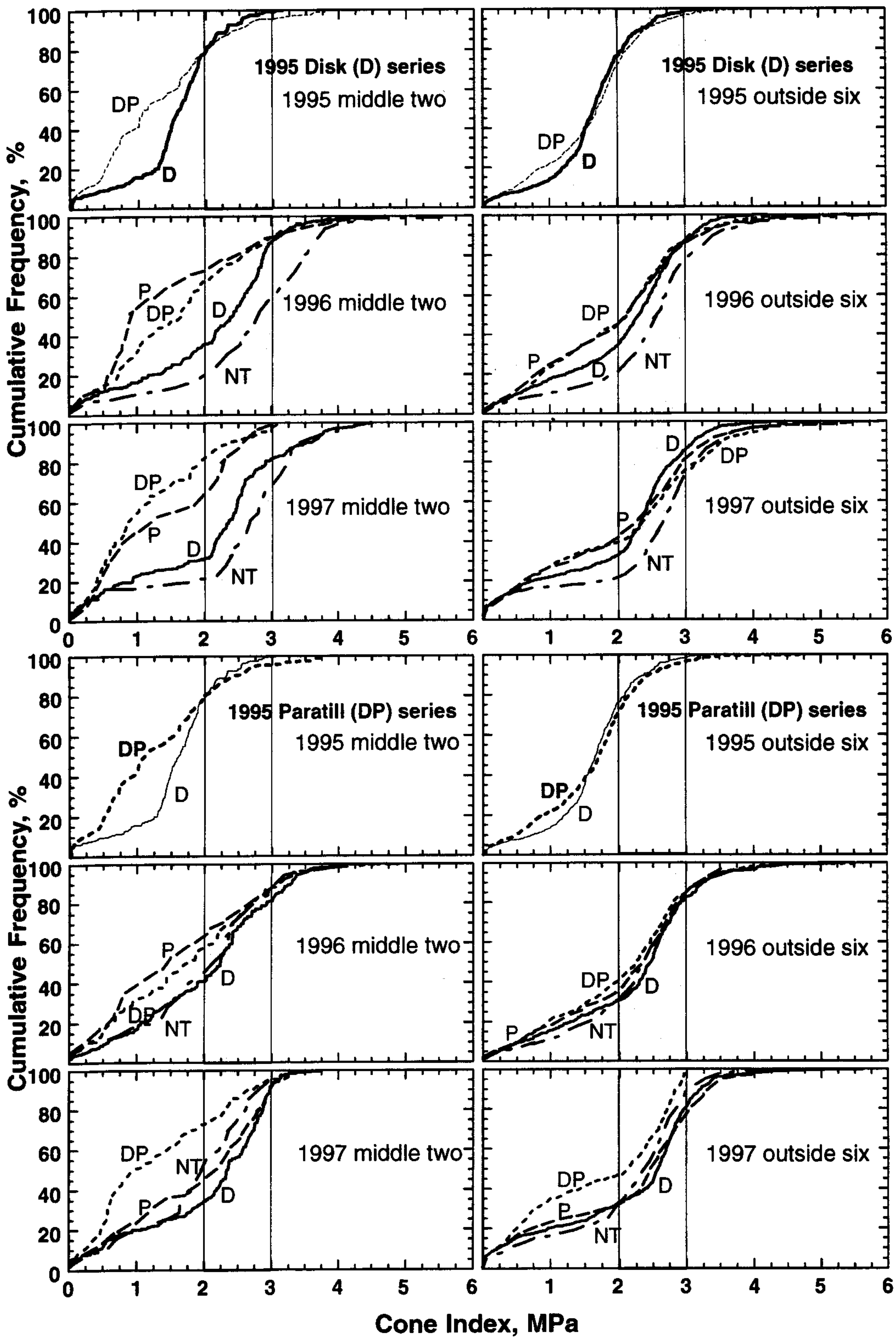

Figure 5. Sequences of cumulative frequency profile cone indices to 50 cm depth. Sequences are averages of all plots and illustrate the initial disk (D) and disk + paratill (DP) treatments in 1995, followed by D, DP, paratill (P), and no–till (NT) treatments in 1996 and 1997. The sequences are broken out by "middle two" and "outside six" penetrometer readings, as illustrated in figure 1C. Shaded areas represent the approximate beginning of restricted root growth (2 MPa) to where root growth nominally ceases (3 MPa).

Results of tillages following the initial 1995 paratill treatment (fig. 5, bottom three sequences) were similar to those following the initial 1995 disk treatment but not nearly as pronounced. Reasons for the differences in response may be that the main effect of the paratill treatment was not perfectly centered in the middle of the plots, and some averaging of CI responses among positions may have occurred by the selection of the "middle two" and "outside six" positions.

We found no statistically significant differences ($P \leq 0.05$) in either barley yield (1995) or dry bean yields (1996 and 1997) among tillage treatments. Sojka et al. (1993b), working on a similar soil, showed beneficial effects of paratilling on yield and quality of furrow–irrigated potatoes. In their study, they paratilled directly under the potato hills following potato planting, leaving irrigation furrows intact. That particular strategy was not feasible with the crops we used in our experiment. Therefore, to gain any benefits from subsoiling under conditions such as discussed in this paper, a strategy different from either of the above must be devised.

SUMMARY

Our objective of maintaining the integrity of irrigation furrows for the free flow of water was met, and there were no runoff, infiltration, or erosion differences among treatments. However, under our conditions, since the paratill configuration was such that maximum subsoiling effect was away from plant rows, paratilling had no effect on crop growth and yield. The approximate beginning of restricted root growth was at CI = 2 MPa, and root growth nominally ceased at CI = 3 MPa. Cone index was influenced by soil water content differences among years, but in the context of our study, it was not deemed necessary to attempt to correct CI for soil water content differences. Residual effects of paratill treatment were apparent one year after treatment. Bulk densities were reasonably low and related well to CI within each season. These relationships may well depend on the effect of soil water on the strength of cementation of this highly calcareous soil. To use the relationships predictively in this case, either a series of relationships at various soil water contents or a soil water content correction must be developed.

REFERENCES

ASAE Standards. 1995. Soil cone penetrometer: S313.2. 42nd ed. St. Joseph, Mich.: ASAE.

Barber, R. G. 1994. Persistence of loosened horizons and soybean yield increases in Bolivia. *Soil Sci. Soc. Am. J.* 58(3): 943–950.

Blanchar, R. W., C. R. Edmonds, and J. M. Bradford. 1978. Root growth in cores formed from fragipan and B2 horizons of Hobson soil. *Soil Sci. Soc. Am. J.* 42(3): 437–440.

Busscher, W. J., P. J. Bauer, C. R. Camp, and R. E. Sojka. 1997. Correction of cone index for soil water content differences in a coastal plain soil. *Soil Tillage Res.* 43(3,4): 205–217.

Busscher, W. J., D. L. Karlen, R. E. Sojka, and K. P. Burnham. 1988. Soil and plant response to three subsoiling implements. *Soil Sci. Soc. Am. J.* 52(3): 804–808.

Busscher, W. J., and R. E. Sojka. 1987. Enhancement of subsoiling effect on soil strength by conservation tillage. *Trans. ASAE* 30(4): 888–892.

Busscher, W. J., R. E. Sojka, and C. W. Doty. 1986. Residual effects of tillage on Coastal Plain soil strength. *Soil Sci.* 141(2): 144–148.

Collis–George, N., and P. Yoganathan. 1985. The effect of soil strength on germination and emergence of wheat (*Triticum aestivum* L.): II. High shear strength conditions. *Aust. J. Soil Res.* 23(4): 589–601.

Frederick, J. R., and P. J. Bauer. 1996. Winter wheat responses to surface and deep tillage on the southeastern Coastal Plain. *Agron. J.* 88(5): 829–833.

Gerard, C. J., P. Sexton, and G. Shaw. 1982. Physical factors influencing soil strength and root growth. *Agron. J.* 74(5): 875–879.

Nasr, H. M., and F. Selles. 1995. Seedling emergence as influenced by aggregate size, bulk density, and penetration resistance of the seedbed. *Soil Tillage Res.* 34(1): 61–76.

Pierce, F. J., and C. Gaye Burpee. 1995. Zone tillage effects on soil properties and yield and quality of potatoes (*Solanum tuberosum* L.). *Soil Tillage Res.* 35(3): 135–146.

Sojka, R. E., W. J. Busscher, D. T. Gooden, and W. H. Morrison. 1990. Subsoiling for sunflower production in the southeast Coastal Plain. *Soil Sci. Soc. Am. J.* 54(4): 1107–1112.

Sojka, R. E., D. L Carter, and M. J. Brown. 1992. Imhoff cone determination of sediment in irrigation runoff. *Soil Sci. Soc. Am. J.* 56(3): 884–890.

Sojka, R. E., D. J. Horne, C. W. Ross, and C. J. Baker. 1997. Subsoiling and surface tillage effects on soil physical properties and forage oat stand and yield. *Soil Tillage Res.* 40(3,4): 125–144.

Sojka, R. E., D. T. Westermann, M. J. Brown, and B. D. Meek. 1993a. Zone–subsoiling effects on infiltration, runoff, erosion, and yields of furrow–irrigated potatoes. *Soil Tillage Res.* 25(4): 351–368.

Sojka, R. E., D. T. Westermann, D. C. Kincaid, I. R. McCann, J. L. Halderson, and M. Thornton. 1993b. Zone–subsoiling effects on potato yield and grade. *Am. Potato J.* 70(6): 475–484.

Taylor, H. M., and H. R. Gardner. 1963. Penetration of cotton seedling taproots as influenced by bulk density, moisture content, and strength of soil. *Soil Sci.* 96(3): 153–156.

Taylor, H. M., G. M. Roberson, and J. J. Parker, Jr. 1966. Soil strength–root penetration relations for medium– to coarse–textured soil materials. *Soil Sci.* 102(1): 18–22.

Threadgill, E. D. 1982. Residual tillage effects as determined by cone index. *Trans. ASAE* 25(4): 859–863.

Trout, T. J. 1996. Furrow irrigation erosion and sedimentation: On–field distribution. *Trans. ASAE* 39(5): 1717–1723.

Unger, P. W. 1993. Reconsolidation of a Torrertic Paleustoll after tillage with a paratill. *Soil Sci. Soc. Am. J.* 57(1): 195–199.