Experiences With Conservation Tillage and No Till in Austria

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ABSTRACT

Soil erosion is a major threat to the resource soil. The objective of this 8 yr-field study was to compare different tillage systems with respect to runoff, soil loss, nutrient, and pesticide transport. Three different tillage systems were compared: 1) conventional tillage (CT), 2) conservation tillage with cover crop (CS), and 3) no-till with cover crop (NT). No significant differences in total runoff during growing season were measured between the three tillage practices. Overall average annual soil loss ranged from 0.82 to 3.13 tons acre^{-1}, with the highest amount for conventionally tilled plots and the lowest for no-till plots. Nutrient losses from April to October were 8.4 lbs acre^{-1} yr^{-1} for CT, 5.4 lbs acre^{-1} yr^{-1} for CS, and 2.7 lbs acre^{-1} yr^{-1} for NT. Corresponding values for phosphorus were 4.1, 1.9, and 1.0 lbs acre^{-1} yr^{-1}. Conservation tillage and no-till management were able to reduce pesticide losses between 23 and 99 %.

KEYWORDS

Conservation tillage, no till, soil erosion, runoff, nutrients

INTRODUCTION

Soil erosion is a major threat to the functions a soil should fulfill. Especially the productivity, storage, and filtering functions are damaged by loss of topsoil. Therefore, land use and soil management should be carried out in a sustainable way, protecting the existing soil and water resources. In Austria, the use of conservation and no tillage is increasing. In the eastern part, where most of the cropland is located, approximately 10-15% of the agricultural land is managed with conservation tillage.

The objective of this study was to compare different tillage systems with respect to runoff, erosion, nutrient and pesticide movement, and biological soil properties. In 1994 a field experiment was started at two different locations in Austria. In 1997 a third location (Pixendorf) was added to the research program. Three different management practices were compared: 1) conventional tillage (CT), 2) conservation tillage with cover crops during winter period (CS), and 3) no-till with cover crop (NT). Crop rotation during the investigation period was corn-small grains at Pyhra and Pixendorf and corn-small grains-sugar beet-small grains-sunflower-small grains at Mistelbach.

MATERIALS AND METHODS

The experiments were carried out on plots of three agricultural schools in the eastern part of Austria, where land is used mainly for agriculture (Fig. 1). Mistelbach is situated 60 km north of Vienna in the so-called "Wine Quarter". This region consists of rolling hills and is one of the warmest but also driest parts of Austria. The second experimental site is located in Pyhra about 80 km west of Vienna. This region is located in the foothills of the Alps. The landscape is characterized by gentle to fairly steep slopes. Pixendorf is located approximately 50 km west of Vienna on slopes of the so-called Tullnerfeld. Long term average precipitation and air temperature of the sites and values during the experimental period are given in Table 1.

The soils in Mistelbach and Pyhra are classified as Typic Argiudolls, while the soil in Pixendorf is an Entic Hapludoll. Soil textures range from silt loam to loam. Clay content ranges from 10.3 to 25.1%, silt content from 42.6 to 64.2%, soil organic carbon content (SOC) from 1.2 to 1.4%, and cation exchange capacity (CEC) from 8 to 15 cmol kg^{-1} (Table 2). Physical and chemical properties of each soil were determined with the following methods: dispersed particle size distribution measured with a wet sieving and pipette method, soil organic carbon (SOC) measured by the modified Walkley-Black method (Klute, 1986), pH in $CaCl_2$ (Klute, 1986), cation exchange capacity (CEC) determined by the barium chloride dihydrate method (Page *et al*., 1982), calcium carbonate content determined by the HCl treatment (Page *et al*., 1982), total nitrogen analyzed by the Kjeldahl method, and total phosphorus determined by ammoniummolybdat using extraction with $K_2S_2O_8$ solution (DIN 38.405, 1983).

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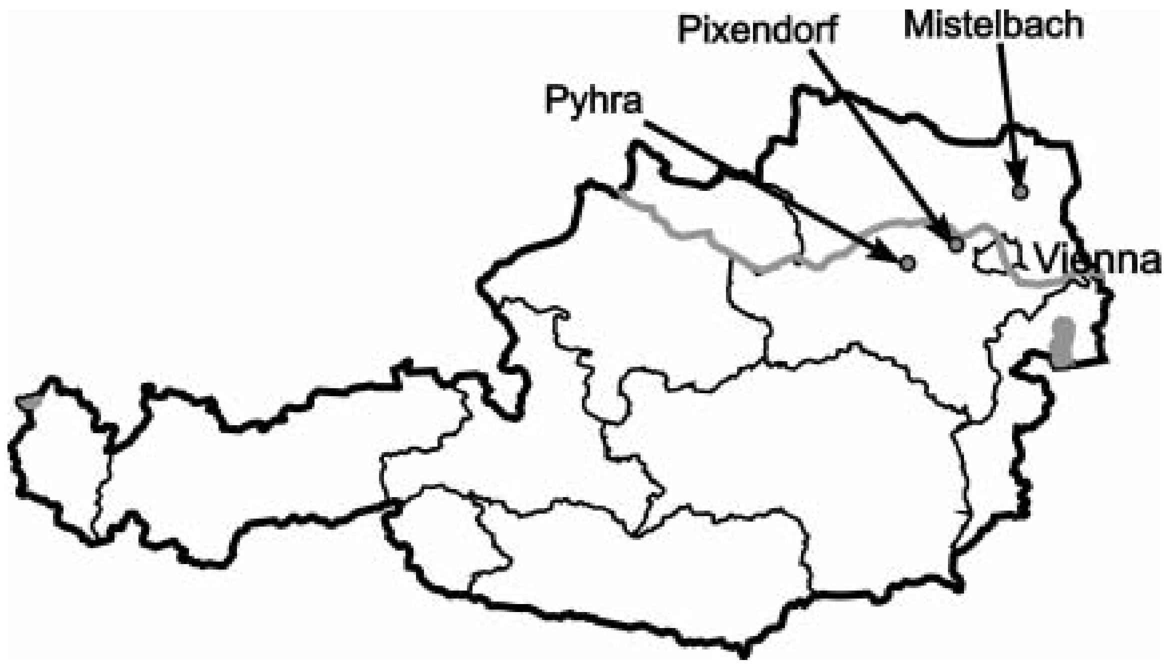

Fig. 1. Location of investigation sites in Austria

Table 1. Average monthly and annual precipitation and mean monthly and annual temperature for Mistelbach (1994-2001), Pyhra (1994-2001) and Pixendorf (1997-2001)

	J	F	M	A	M	J	J	A	S	O	N	D	Avg
Precipitation, inch													
Mistelbach	1.00	0.79	1.53	1.50	2.74	3.72	4.56	2.35	3.56	1.30	1.46	1.42	26.2
Pyhra	1.20	1.70	2.55	2.70	4.13	3.78	4.57	3.91	4.20	2.22	2.79	2.22	36.0
Pixendorf	0.89	0.97	1.40	1.48	3.15	3.44	5.35	2.30	3.21	1.62	2.17	1.72	27.7
Air temperature, °F													
Mistelbach	30.1	33.4	40.3	49.6	59.1	63.9	67.8	68.0	58.4	50.4	39.5	31.1	49.3
Pyhra	30.5	35.1	41.0	48.6	58.3	63.1	66.3	65.9	57.0	49.2	39.1	31.9	48.8
Pixendorf	32.2	38.6	43.8	50.7	60.1	63.9	65.8	67.3	57.1	51.6	40.2	33.9	50.4

Table 2. Main physical and chemical properties of investigated soils.

Soil	Sand	Silt	Clay	OC	pH	CEC	$CaCO_3$	Ntot	Ptot
	---------------- % ----------------					cmol kg^{-1}	-------------- % ------------		
Mistelbach	12.8	64.2	23.0	1.3	8.1	15	9.2	0.16	0.08
Pyhra	32.3	42.6	25.1	1.4	7.1	8	0	0.16	0.08
Pixendorf	27.6	62.1	10.3	1.2	8.1	8	21.2	0.15	0.06

Table 3. Characteristics and application rates of used pesticides (Hornsby *et al.*, 1996)

	Pesticide				
Characteristic	Rimsulfuron	Bromoxynile	Tribenuron	Metamitron	Pendimethalin
T (days)	31	7	10	30	171
Koc (mL g^{-1})	35	10000	46	100	111
Solubility (mg L^{-1})	< 10	0.08	280	1820	0.3
Appl. rate (oz $acre^{-1}$)	0.07 – 0.15	1.61 – 5.18	0.21 – 0.34	7.00	20.0

The study design consisted of 9.8 ft (Mistelbach) and 13.1 ft wide (Pyhra and Pixendorf) and 49.2 ft long runoff plots for each management variation. The incline of hill slopes varied between 6 and 16%. Runoff and sediments were collected after each erosive rainstorm event. Precipitation and air temperature were measured in 5 min intervals with an automatic data logging system.

Representative runoff and sediment samples were taken for physical and chemical analyses. Nitrate concentrations in runoff were measured by the UV absorption method described by Navonne (1964). Ammonium concentrations were analyzed using Na-nitroprussid, Na-salicylate, and dichlorisocyanuracid solutions (Oenorm ISO 7150, 1985). Phosphate contents were determined by the ammoniummolybdat method (DIN 38.405, 1983).

Soil, pesticide, and rainfall characteristics influence timing, amount of pesticide loss (Leonard, 1990), and the dominating transporting agent of that pesticide. Pesticide persistence (T) and sorption properties (Koc) influence the time they stay near the application site and whether they will be adsorbed to sediment or remain in the solution phase. Pesticide persistence determines, in part, the probability of loss by runoff, and in what form the loss will occur (in solution/runoff water or adsorbed to sediment). Percentage of pesticides in runoff and on sediment will depend not only on sorption properties, but also on processes controlling runoff and sediment production during a rainfall event.

All used pesticides are slightly to very slightly mobile, expressed by sorption coefficients (Koc) between 35 and 10000 (Table 3). The half-lives (T) of pesticides range between 7 and 171 days. Therefore, Bromoxynile and Tribuneron are readily degradable, while Metamitron is fairly degradable, and Rimsulfuron and Pendimethalin are slightly degradable. Between 0.07 and 20.0 oz $acre^{-1}$ of pesticides were applied per year.

In characterizing soil quality, biological properties have received less emphasis than chemical and physical properties, because their effects are difficult to measure, predict, and/or quantify. Soil microbial biomass is an important component of the soil organic matter that regulates transformation and storage of nutrients. The effects of tillage, crop rotations, and soil type on organic C and nutrient turnover can be assessed by following nutrient pools and activity associated with the soil microbial biomass. The toxicity of pollutants and the degradation of organic compounds (like pesticides) can be monitored following changes in the soil microbial biomass.

Soil samples were taken from March 20 to October 29, 2001, in monthly intervals at depths of 0-6 in and 6-12 in. Samples have been sieved through a 2 mm-sieve, and then water content was adjusted to 50-60% of the maximum water holding capacity. Microbial activity was estimated with at least one replication using five procedures: 1) substrate induced respiration (SIR; Anderson and Domsch, 1978), 2) soil respiration (SR; Isermeyer, 1952; modified after Jaeggi, 1976), 3) actual (AN) and potential nitrification (PN; Berg and Roswall, 1985), and 4) enzymatic dehydrogenase activity (DHG; Thalmann, 11968).

SIR represents the potential activity of soil organisms, while soil respiration (SR) represents the actual situation influenced by climate, physical and chemical soil properties, and agricultural practices. The dehydrogenase enzyme systems fulfill a significant role in the oxidation of soil organic matter as they transfer hydrogen from substrates to aceptors (Tabatai, 1982). The result of the essay of dehydrogenase activity will show the average activity of the active population (Skujins, 1976).

RESULTS

Runoff and soil loss

Since the beginning of the experiment in 1994, 16 (Mistelbach) to 35 (Pixendorf) rainfall events produced runoff during the growing seasons. Not all of these events led to soil erosion. Depending on soil management, 75 to 82% of these events were erosive in Mistelbach, while 48 to 62% were erosive in Pyhra and 57 to 82% in Pixendorf. Data show that soil erosion is an extreme event process. At all sites, only two rainfall events (app. 7 to 12% of all runoff producing events) led from 66 to 96% of total soil loss.

For conventional tillage long-term average surface runoff during growing season ranged between 0.66 (Mistelbach) and 0.90 inches (Pixendorf). Corresponding values for conservation tillage were between 0.46 and 1.00 inches and between 0.59 and 1.00 inches for no-till plots (Fig. 2). In

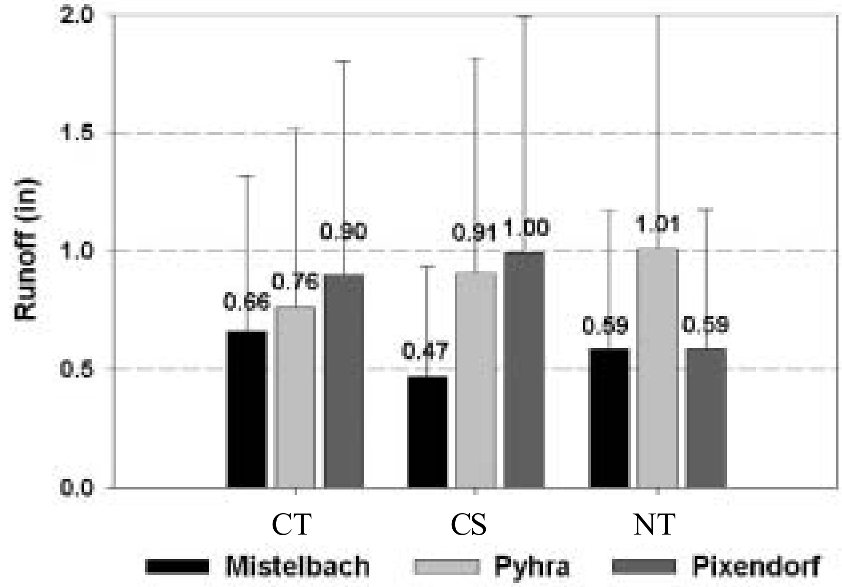

Fig. 2. Average runoff from CT, CS, and NT plots for all investigated sites.

Pyhra and Pixendorf, average runoff from CS was numerically higher than from CT. Compared to CT, NT plots had higher runoff in Pyhra but lower runoff in Mistelbach and Pixendorf. Statistical analyses showed no significant differences in runoff between investigated treatments.

Although average runoff did not significantly differ between management treatments, significant differences in soil loss could be determined. At each site, highest annual soil losses were measured from conventional tilled plots, while lowest soil erosion was measured from no-tilled plots. Average annual soil loss from CT ranged from 2.53 (Pixendorf) to 10.33 tons acre^{-1} (Mistelbach; Fig. 3). CS and NT led to soil losses between 0.69 and 2.94 tons acre^{-1} and 0.10 to 1.78 tons acre^{-1}, respectively. Compared to CT, conservation tillage with cover crops reduced soil loss by 36 to73 % and no till by 65 to 96%. This reduction can mainly be explained by the impact of organic matter on the soil surface. Plant residues of former crops and cover crops protect the soil surface against the impact of raindrops and increase the flow path on the field, thereby reducing flow velocity and , thus, the kinetic energy and shear stress of runoff water.

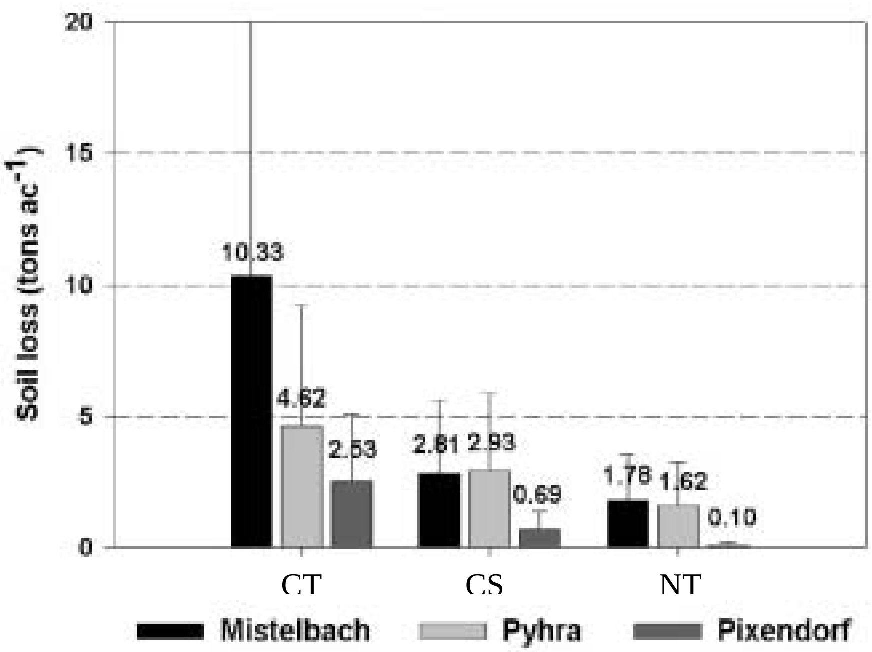

Fig. 3. Average soil loss from CT, CS, and NT plots for all investigated sites

Nutrient losses caused by soil erosion and runoff

Due to no significant differences in runoff between the treatments, differences in nitrogen and phosphorus losses between the three soil management treatments were mainly related to amount of soil loss. Therefore, highest losses in total nitrogen (Ntot) and total phosphorus (Ptot) were observed from CT plots, and lowest from NT plots (Table 4). In Mistelbach yearly N-losses ranged from 0 to 147 lbs acre^{-1}, in Pyhra from 0 to 90 lbs acre^{-1}, and in Pixendorf from 0.3 to 22 lbs acre^{-1}. On a long-term basis, between 5.5 and 32.1 lbs N acre^{-1} are lost with CT between 1.8 and 9.2 lbs N acre^{-1} with CS, and between 0.6 and 7.0 lbs N acre^{-1} with NT. As phosphorus is mainly adsorbed to soil particles, P losses are highly related to amount of sediment yield. With CT, between 3.3 and 20.8 lbs P acre^{-1} per year are transported off the field (attached to soil particles and dissolved in runoff). P-losses from CS plots ranged between 1.0 and 5.2 lbs acre^{-1} and between 0.1 and 3.6 lbs acre^{-1} yr^{-1} from NT plots.

Besides N and P, another main soil quality parameter, organic carbon (OC), was transported off the field. At all sites sediment contained the same to 1.2% higher OC-contents than *in situ* soil. This results in organic carbon losses by soil erosion up to 225 lbs acre^{-1} per year (Table 4). Losses of organic carbon reduce filter and buffer ca-

Table 4. Average annual losses of total nitrogen (Ntot), total phosphorus (Ptot) and soil organic carbon (SOC) in lbs $acre^{-1}$

	Mistelbach			Pyhra			Pixendorf		
Parameter	CT	CS	NT	CT	CS	NT	CT	CS	NT
Ntot	31.12	9.15	6.98	12.08	10.68	4.63	5.52	1.75	0.58
Ptot	20.79	5.21	3.55	6.20	3.67	2.08	3.31	1.03	0.13
SOC	224.8	83.5	57.6	115.2	80.9	47.9	69.9	18.8	3.7

Table 5. Percentage of applied pesticides lost in solution (runoff) and adsorbed to sediment .

Losses	CT	CS	NT
By runoff	1.94	0.46	0.20
By sediment	3.69	1.28	2.38
Total	5.63	1.74	2.58

pacity of the soil, diminish soil fertility, and increase the potential of soil and groundwater contamination by pollutants.

Pesticide losses

For the Mistelbach site, average percentages of pesticides lost in runoff and on sediment were calculated from 1.74 to 5.63% (Table 5). Yearly values range from 0 to 23.1% (CT), 8.3% (CS) and 12.8% (NT), respectively. The results show that besides pesticide characteristics, the timing of erosive rainfall influences the amount of pesticide losses from the field. The highest losses were measured in 1994, when an extreme erosive event occurred only 10 days after pesticide application.

All used pesticides can be classified as slightly mobile to very slightly mobile. Therefore they are highly attached to sediments and transported with the eroded soil. For all treatments, percentage of pesticide losses caused by soil loss was always higher than that caused by runoff. Between 1.3% and 3.7% of the applied pesticide amount was leaving the plot adsorbed to sediments, while 0.2 to 1.9% was lost in solution. Conventional tillage caused the highest losses and conservation tillage the lowest.

Soil biological properties

Table 6 gives an overview of average values of substrate induced respiration (SIR), soil biomass-C, soil respiration (SR), and actual and potential nitrification (AN and PN) as well as dehydrogenase activity (DHG). Assuming a respiration coefficient of 1, soil biomass-C can be assessed by:

1 mg CO_2 / 100 g DM . h = 20.6 mg biomass-C / 100 g DM

Investigated parameters show higher values in 0-6 in soil depth than in 6-12 in. This is due to better aeration and higher temperatures in this layer. For a soil depth of 0-6 in, NT treatment shows highest values for all investigated soil biological parameters. Significantly higher values of SIR, SR, AN, PN, DHG, Ntot and OC exist only for the Pixendorf site. For Mistelbach and Pyhra, an increase also can be seen. Differences compared to CT are not significant. When comparing biomass-C and organic C, it can be seen that between 4.3 and 8.6% of soil organic carbon consists of living biomass. CS and NT always have higher Cmic/OC-ratios than conventional treatment.

Crop production

For a corn-small grains-crop rotation, CS and NT had no negative effects on the yield. In years with extreme erosive events CS and NT had even positive impacts on the yield because of less or no crop damage. Only for sugar beets, a yield decrease of 16% was determined when using no till.

SUMMARY AND CONCLUSIONS

In a field study the impact of different tillage practices on runoff, sediment yield, and nutrient and pesticide loss was investigated. The different soil management systems had no significant impact on runoff. Conservation tillage (CS) and no-till (NT) with cover crops are successful practices to reduce soil erosion. Compared to conventional tillage, conservation tillage with cover crops reduced soil loss by 33-70% and no-till by 63-96%. Reductions in total nitrogen ranged between 11-70% for CS and 62-92% for NT. Corresponding values for total phosphorus were 41-70% (CS) and 67-97% (NT), respectively. Pesticide losses decreased by 23-99% when using CS and NT. Reduced tillage systems, together with cover crops during the winter, are able to increase soil quality without negative effects on crop yields.

Table 6. Average values of investigated soil biological parameters (March 20 – October 29, 2001).

Parameter / depth	Mistelbach CT	Mistelbach CS	Mistelbach NT	Pyhra CT	Pyhra CS	Pyhra NT	Pixendorf CT	Pixendorf CS	Pixendorf NT
Soil organic carbon content (%)									
0 – 6 in	1.35	1.33	1.40	1.11	1.16	1.60 *	0.75	0.91 *	1.06 *
6-12 in	1.17	1.16	1.19	1.07	1.05	1.19	0.72	0.69	0.72
Substrate Induced Respiration (mg CO_2/100 g DM.h)									
0 – 6 in	4.50	4.28	5.07	2.51	2.94	3.88 *	2.91	4.00	4.40 *
6-12 in	3.54	3.82	3.73	2.05	2.59	2.37	2.55	2.70	2.70
Soil Respiration (mg CO_2/ g DM. 24 h)									
0 – 6 in	0.23	0.25	0.26	0.10	0.10	0.09	0.14	0.17 *	0.19 *
6-12 in	0.21	0.24	0.22	0.06	0.08	0.07	0.14	0.15	0.15
Soil Biomass-C (mg Biomass-C/ 100 g DM)									
0 – 6 in	92.7	88.2	104.4	51.7	60.6	79.9 *	59.9	82.4	90.6 *
6-12 in	72.9	78.7	76.8	42.2	53.4	48.8	52.5	55.6	55.6
Cmic / OC (%)									
0 – 12 in	6.6	6.7	7.0	4.3	5.2	4.6	7.6	8.6	8.2
Total Nitrogen content (%)									
0 – 6 in	0.16	0.16	0.17	0.15	0.16	0.18 *	0.11	0.12 *	0.13 *
6-12 in	0.15	0.14	0.14	0.13	0.14	0.15 *	0.10	0.10	0.10
Actual Nitrification (ng N/g DM.24 h)									
0 – 6 in	120.6	105.6	137.1	28.7	35.6	32.9	102.9	133.2 *	140.2 *
6-12 in	111.6	105.1	88.7	25.7	31.4	20.9	85.0	80.0	81.9
Potential Nitrification (ng N/g DM. 5h)									
0 – 6 in	568.4	468.5	609.1	434.6	492.3	720.1	260.7	396.9	508.7 *
6-12 in	424.3	385.7	352.4	402.1	473.5	625.5 *	196.4	186.7	192.7
Dehydrogenase Activity (ug TPF/ g DM 16 h)									
0 – 6 in	20.23	16.56	22.91	10.25	16.13	19.60	13.98	21.90	29.35 *
6-12 in	10.78	13.63	11.83	13.39	10.38	10.00	12.83	10.86	11.33

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