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Joe E. Brummer
Colorado State University
Department of Soil and Crop Sciences
1170 Campus Delivery
Fort Collins, CO 80523

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PREFACE

The 18th biennial High Altitude Revegetation Workshop was held at the Hilton Fort Collins in Fort Collins, Colorado on March 4-6, 2008. The Workshop was organized by the High Altitude Revegetation (HAR) Committee in conjunction with the Departments of Soil and Crop Sciences and Forest, Rangeland and Watershed Stewardship at Colorado State University. The Workshop was well attended this year by 241 people from a broad spectrum of universities, government agencies, and private companies. Discussions centered on the revegetation of disturbed lands always seem to be of interest to many people as evidenced by the number in attendance this year at the Workshop. The HAR Workshop is somewhat unique in that it focuses on the practical, on-the-ground application of revegetation techniques. People come away from the Workshop with new information and new ideas that they can take home and apply directly to their specific situations.

This Workshop would never happen without the dedication and contributions from the many people on the HAR Committee. This is an all volunteer organization and everyone that contributed to this years Workshop is to be commended for their efforts.

The Committee tried something different this year and sent out a solicitation for volunteer papers instead of inviting speakers as was done in the past. This approach worked very well and we would like to thank all the people who took time to prepare not only a presentation or poster, but also a paper or abstract for inclusion in these proceedings. The proceedings consist of 21 papers and 3 abstracts grouped into 8 workshop sessions, 6 poster papers, and 3 poster paper abstracts.

In addition to the papers and posters presented on March 5 and 6, a special Practical Revegetation Session was held on March 4 at Rocky Mountain National Park. This session was well received and attended by approximately 80 people.

For current information on upcoming High Altitude Revegetation Committee events, visit our website at: www.highaltitudereveg.org.

Joe E. Brummer
Editor

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BEST MANAGEMENT PRACTICES FOR REMEDIATION/RESTORATION OF DEGRADED SOILS IN THE CENTRAL GREAT PLAINS REGION

Maysoon M. Mikha[1*], Merle F. Vigil[1], Joseph G. Benjamin[1], Dave J. Poss[1], and Francisco J. Calderon[1]

[1]USDA-ARS, Central Great Plains Research Station, Northern Plains Area, 40335 CR GG, Akron, CO 80720

ABSTRACT

Farmlands in the Central Great Plains Region (CGPR) have lost topsoil through wind and water erosion induced by tillage and poor soil management (Wheat-fallow management). Productivity of degraded/eroded soils can be restored using organic amendment such as manure and improved crop and soil management. Our objectives are to: **(i)** identify optimal rates of manure to supply nutrients to typical dryland crops in the CGPR; **(ii)** determine the rate of improvement of soil physical and chemical properties associated with manure amendment/management; and **(iii)** quantify the difference in restoration of eroded soils using manure as an amendment versus managing those same soils with legume grass mixtures and chemical fertilizer. The experiment, established off on a farmer field near Akron, Colorado has a randomized complete block design with crops/soils managed using manure amendment compared with soils/crops managed with commercial fertilizer. Treatments include a tillage variable (deep plow, shallow sweep, and no-tillage), manure and commercial nitrogen rates (none, low and high). Changes in soil physical, chemical, and biological properties as well as grain yield are evaluated every year. The preliminary data (for one growing season) suggests that manure addition increases the productivity of eroded soils in the Central Great Plain Region. In subsequent years this experiment (after multiple manure applications) could result in changes in soil parameters and increased yield. This report will provide "benchmark" measurements of the treatments being studied and first year grain and biomass yields.

INTRODUCTION

Farmlands in the CGPR have lost topsoil through wind and water erosion induced by tillage and poor soil management (wheat-fallow). These soils are now degraded with low soil quality and productivity. Some of the soil quality parameters that are affected by poor soil management include: soil compaction, infiltration rate, soil water holding capacity, soil nutrient exchange capacity, soil aggregation and aggregate stability, organic carbon build up, soil pH, and soil microbial ecology. In addition to wind and water erosion, numerous studies have indicated that soil degradation is a result of soil organic matter lost through increased soil disturbance and decomposition (Angers et al., 1993; Lal et al., 1995). Productivity and quality of degraded/eroded soils can be restored using manure and improved management. Manure amendment is a management practice that can improve the nutrient status of the soil (Vitosh et al., 1997) and increase soil organic carbon levels (Mikha and Rice, 2004). Aoyama et al.

* Corresponding author (Maysoon.Mikha@ars.usda.gov)

(1999a) observed an increase in soil organic matter with addition of manure and the subsequent increase the formation of slaking-resistant soil aggregates. Aoyama et al. (1999b) concluded that applying manure contributed to the accumulation of aggregates-protected C and N. Similarly, Mikha and Rice (2004) reported that aggregate-protected labile carbon and nitrogen was significantly greater with manure amendment when compared with chemical fertilizer treatment. The combination of no-till management withy manure amendment further increased the formation and stabilization of soil aggregates and increased the physical protection of soil carbon and nitrogen (Mikha and Rice, 2004; Jiao et al., 2006).

Tillage practices can alter soil organic matter and effect soil erosion. Tillage practices can reduce soil organic matter by (i) increasing residue mixing into the soil which increases aeration and enhances residue decomposition, (ii) destroying soil aggregate and exposing previously protected soil organic matter to soil fauna, and (iii) increasing losses due to soil erosion (Blevins and Frye, 1993; Beare et al., 1994; Tisdall, 1996; Paustian et al., 1997). Tillage systems may also affect soil physical condition. Kladivko (2001) reported that tillage practices change soil water content, soil temperature, and aeration. However, no-tillage systems increase surface soil organic matter as a result of increased residue accumulation, less residue mixing, oxidation, and soil disturbance, high soil water content, reduced soil temperature, proliferation of root growth and biological activity, and decreased risks of soil erosion (Blevins and Frye, 1993; Eghball et al., 1994; Lal et al., 1994; Six et al., 1999). Many studies have shown that increased soil organic matter with no-tillage management (Carter, 1992; Beare et al., 1994; Six et al., 1999) improves soil aggregation and aggregate-associated soil organic matter (Mikha and Rice, 2004).

Organic amendment such as manure can have a positive effect on soil quality by improving soil porosity and preventing soil crust formation (Pagliai et al., 2004). Continuous manure application over several years, can have a positive effect by reducing soil bulk density (Miller et al., 2002; McVay et al., 2006). Reduction in soil bulk density and greater soil porosity are clear indicators for reduced soil compaction, improved aeration, greater infiltration and improved conditions for plant root penetration.. Frye and Blevins (1997) reported that improving plant productivity is related to enhanced root growth, crop yield, and plant biomass. Also, the addition of organic material as a nitrogen source (manure and/or compost) can mitigate the negative effects of excessive tillage on grain yield and soil organic carbon conservation (Eghball and Power, 1999; Singer et al., 2004; Mando et al., 2005). Similarly Eghball et al. (2004) documented, the residual effect of increased nutrient availability due to multiple years of manure application increase corn grain yield for one growing season and influence soil properties for several years (Eghball et al., 2004).

The impact of manure applications and tillage practices on plant productivity has been studied intensively for more than 30 years. However, the effects of multiple years of beef manure application combined with different tillage systems on improving soil quality parameters and the productivity of eroded soil are not well documented in dryland systems. The objectives of this study are; (i) Identify optimal rates of beef manure to supply nitrogen and phosphorus to typical dryland crops in the CGPR; (ii) determine the rate of improvement of crop yield, soil physical, chemical, and biological properties associated with dryland manure management of eroded soils; and (iii) Quantify the advantages of restoring eroded soils using manure as an amendment versus managing those same soils with chemical fertilizer.

METERIALS AND METHODS

Site Management

The experimental area consists of 4.8 hectares while the plot area consists of 1.7 hectares. The large remainder is due to requiring large alleys to manage full size farm equipment. Individual experimental units (plots) are 13.7 m wide and 15.2 m long (45 feet wide and 50 feet long). The experimental design is a randomized complete block with four replicates. The replicates are arranged such that three are parallel to each other across the slope. The fourth is split with the first ten plots adjacent to replicate one and the last ten plots adjacent to replicate two.

Cropping Sequence

Crop rotations used are typical to the Central Great Plains Region. The rotation currently being used is corn (2006) – proso Millet (2007) – forage Winter Triticale (2008). The crop rotation in subsequent years will be decided according to weather pattern (temperature and precipitation). The crops are normally planted on all of the plots and alleys ways. In 2006, before manure and tillage treatments were established, corn was planted through all plots in the east west direction (perpendicular to planting in 2007 and 2008) in a plant 2 skip 2 row configuration.

Manure Application

Manure is applied in the fall to allow for winter precipitation to restore moisture lost during tillage operations. Manure is applied using a Meyer spreader. This manure spreader was used at low RPM to obtain a uniform spread width of 2.7 m. Calibration of the manure spreader was performed by driving the manure spreader over a tarp and then weighing the manure collected on the tarp. The rear gate was left open during application and rates were controlled by changing ground speed. Beef manure was obtained from a local feedlot. Samples of the manure "piles" to be used were taken and analyzed for nutrients to determine amount of nutrients applied to the plots.

There is a low and a high manure rate applied for each tillage treatment. The low was determined by estimating the amount of nitrogen required to meet crop needs average over the next six years. The high rate is two times the low rate for fertilizer and three times the low rate for manure. Realizing that this is in excess of crop nutrient needed this high rate was used to ensure an increase in the amount of organic carbon applied. One of our hypotheses is that these higher rates of manure will significantly increase soil organic matter and improve soil physical properties in these plots.

Table 1. Manure Factors relative to treatment and tillage depth.

Tillage Treatment	Frequency	Low	High
		----- kg/ha -----	
No-tillage	Annual	1X	3X
Sweeps (13 cm depth)	Annual	1X	3X
Deep tillage (36 cm depth)	Bi-Annual	2X	6X
Deep Tillage	One time	6X	18X

Five levels of manure were applied to the plots in fall 2006 depending on the treatment (Table 1). A 1X rate is applied to plots for which there is an annual application on a low fertilizer/manure treatment. The rate factor applied was based on frequency of application and the rate. For example the rate for the Deep tillage, one time treatment was determined by taking the 1X rate times six (since we are estimating fertility needs for the next six years) for the low manure nitrogen rate, while the high rate of the same treatment would have an 18X rate. The amount of manure (that meet the nitrogen requirement) for different treatment combination is presented in Table 2.

Table 2. Fertilizer and manure application rates by treatment.

	Fertilizer Application			Manure Application					
Crop	Date	Low	High	Date	1X	2X	3X	6X	18X
		--- kg N/ha ---			---------------- kg N/ha ----------------				
Proso Millet	22-Jun-07	30	60	20-Nov-07	83	160	260	458	1342
Winter Triticale	16-Oct-07	30	60	5-Oct-07	65	0	187	0	0

Plot Operations

Manure was applied November 16th, 2006 for the 2007 proso millet crop. The tillage treatments for the manure plots were performed the same week just after manure application. The tillage treatments for the fertilizer and control plots were performed the following week because of time constraints. The fertilizer for these plots was not applied until the spring, immediately prior to planting (Jun 22nd, 2007). The deep tilled plots were packed in the spring to firm the soil to ensure good seed to soil contact at planting time. Spray operations were performed at and prior to planting proso millet to control weeds. No herbicide applications were done after the proso millet was planted. The proso millet was swathed with a plot harvester after 95% of the head had changed from green to mature. The rest of the plots were swathed soon after. The proso was picked up with a plot combine two week later after it had sufficiently dried.

RESULTS AND DISSCUSIONS

Precipitation in 2007 was less than normal (Figure 1) especially during the critical period of millet germination. Crop soil water used during the growing season was calculated by adding the amount of precipitation (from planting (Jun 22nd) to harvesting (September 26th)) to the differences between soil water content at planting and harvesting. Throughout the growing season, crop soil water use ranged between 18.1 cm to 27.7 cm integrated to 120 cm deep soil profile (Table 3). Soil water contents at planting (Jun 22nd, 2007) ranged between 15%-19% in the surface 15 cm (data not shown). Similarly, soil water contents in the whole 120 cm profile ranged from 15% to 19.1% (data not shown). In general, soil water contents at field capacity range17% to 20% depending specific soil type. This indicates that soil water contents were adequate for planting, but a lack of precipitation during June and July may have reduced final millet yields. Our 2007 grain yield data documents, tillage, N source (manure vs. fertilizer) and N rate effects on millet production (Figure 2). The effect of different tillage practices and nitrogen rate were more pronounced with manure than fertilizer treatment. The combination of

Table 3: Soil inorganic nitrogen (kg N ha^{-1}) and plant total soil water used (cm) during 2007 growing season integrated to 120 cm depth.

		------- Preplant --------		--- Growing Season ----
Tillage	Nitrogen type	NH_4^+-N	NO_3^--N	Total Soil Water Used
		------ kg N ha^{-1} -------		------------ cm-----------
No tillage	3X[†] manure	11.0	27.5	26.0
	High[‡] fertilizer	10.8	21.8	27.7
	1X[††] manure	10.9	25.2	25.6
	Low[‡‡] fertilizer	10.9	21.5	24.3
	Control[!]	11.1	15.8	24.1
Sweep[§] tillage	3X manure	11.8	46.1	25.5
	High fertilizer	10.7	18.1	25.6
	1X manure	10.5	25.3	26.1
	Low fertilizer	10.7	11.4	25.9
	Control	10.7	17.8	26.3
Deep tillage (2y)[#]	6X manure	12.0	72.7	23.3
	2X manure	12.5	53.0	22.4
Deep tillage (6y)[*]	18X manure	11.8	128.5	22.1
	6X manure	12.1	108.1	23.2
Deep tillage[&]	High fertilizer	10.8	22.1	18.2
	Low fertilizer	11.1	44.0	18.1

[†] Manure applied at 260 kg N ha^{-1}.
[††] Manure applied at 83 kg N ha^{-1}.
[‡] Fertilizer applied at 60 kg N ha^{-1}.
[‡‡] Fertilizer applied at 30 kg N ha^{-1}.
[!] No nitrogen added (0 kg N ha^{-1}).
[§] Tillage at 13 cm depth.
[#] Manure addition equivalent to two years (458 kg N ha^{-1} for 6X and 160 kg N ha^{-1} for 2X and mixed with the soil profile at 36 cm depth.
[*] Manure addition equivalent to six years (1342 kg N ha^{-1} for 18X and 458 kg N ha^{-1} for 6X and mixed with the soil profile at 36 cm depth.
[&] Fertilizer addition equivalent to one year (60 kg N ha^{-1} for high N and 30 kg N ha^{-1} for low N) and mixed with the soil profile at 36 cm depth.

no-tillage and manure amendment increased millet yield by 27% (at low nitrogen rate) and by 20% (at high nitrogen rate) compared with the combination of sweep-tillage and manure

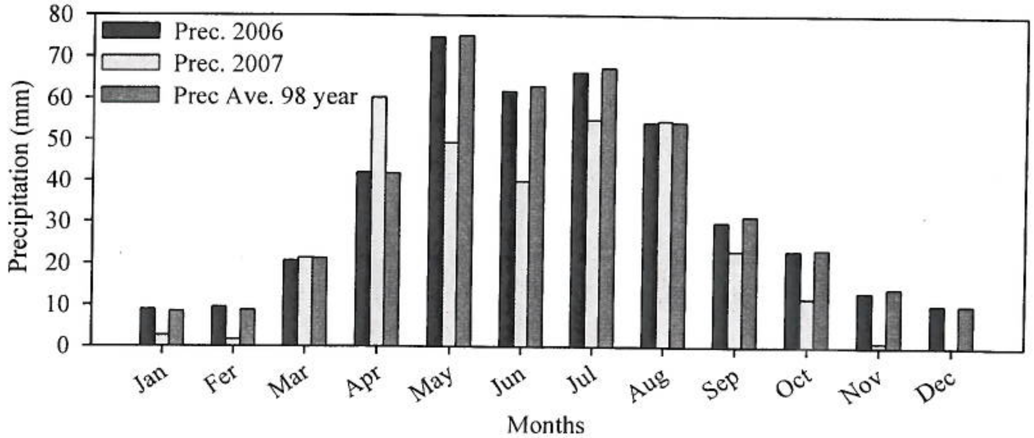

Figure 1. Monthly precipitation for 2006, 2007, and 98 years average at Akron, Colorado.

treatment (Figure 2). Millet grain yield increased as manure nitrogen rate increased by 17% when managed with no-tillage and 23% when managed with sweep tillage. The greater grain yields associated with no-tillage combined with manure amendment could be due to soil water conservation during the early growth stage of millet. Deep-tillage showed a reduction in millet

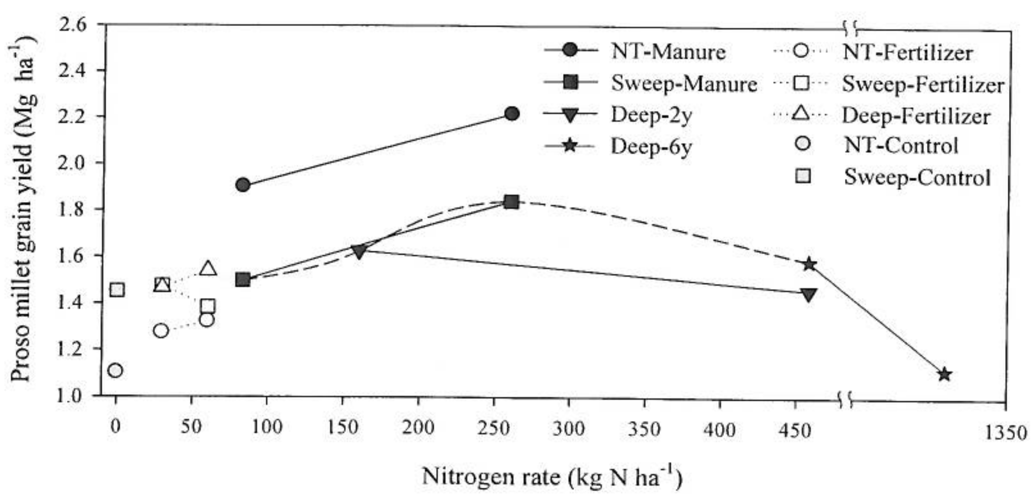

Figure 2. Proso millet yield (Mg yield ha^{-1}) as affected by nitrogen rate and different tillage ptactices. (NT): no-tillage; (Deep-2y): manure application once and equivelent to 2 years N rate and tillage at 36 cm depth; (Deep-6y): manure application once and equivelant to 6 years N rate and tillage at 36 cm depth; and (Deep-fertilizer): nitrogen application equivelant to 1 year N rate and tillage at 36 cm depth.

yield as the manure nitrogen rate increases. There was 10% and 29% reduction in millet yield as manure nitrogen rate increased from 83 to 260 (kg N ha^{-1}) and from 458 to 1342 (kg N ha^{-1}), respectively. However, across tillage (sweep and deep tillage) a maximum yield (with manure treatment) was observed (represented by dash line in Figure 2) around 260 (kg N ha^{-1}) where the yield was reduced as manure nitrogen increase thereafter (Figure 2). The excessive amount of manure nitrogen that was applied with deep-2y and deep-6y in combination with low precipitation could have reduced millet growth and grain yield. Grain yield increased with the combination of no-till and fertilizer (by 4%) and deep-tillage (by 5%), while a reduction was observed with sweep-tillage (by 7%) as the rate of inorganic fertilizer increased from 30 to 60 kg N ha^{-1} (Figure 2). Because this is just the first year of production for this experiment, no explanation can be given for the reduction of grain yield for sweep-tillage with high fertilizer rate compared with low fertilizer rate. Overall, grain yields were 44% greater with no-tillage combined with manure amendment than with no-tillage and fertilizer.

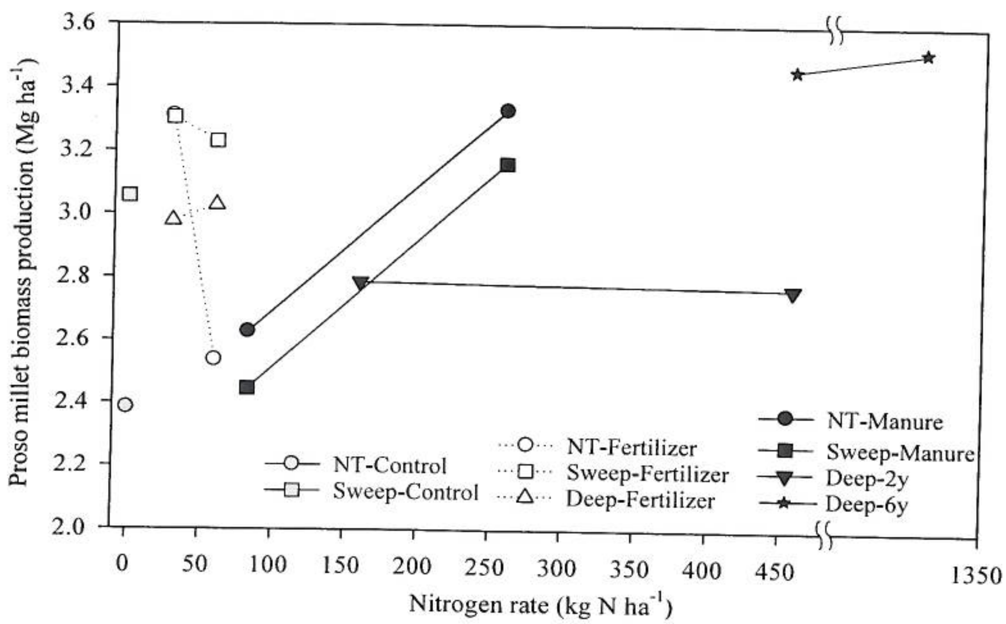

Figure 3. Proso millet biomass (Mg ha^{-1}) as affected by nitrogen rate and different tillage ptactices. (NT): no-tillage treatment; (Deep-2y): manure application once and equivelent to 2 years N rate and tillage at 36 cm depth; (Deep-6y): manure application once and equivelant to 6 years N rate and tillage at 36 cm depth; and (Deep-fertilizer): nitrogen application equivelant to 1 year N rate and tillage at 36 cm depth.

Proso millet biomass production exhibited a similar trend as the grain yield especially with the combination of no-till and manure amendment and sweep-tillage manure (Figure 3). High N rate translated to high plant biomass production. High crop water use translated to high yield except with sweep-tillage manure and deep-2y manure, where high yield were associated with low water usage (Figure 4). There were no changes in crop water use in relation to high and low grain yields associated with deep-fertilizer treatment.

In summary, the preliminary data suggests that manure additions could improve the productivity of unproductive (eroded) soils in the CGPR. No specific explanations can be given for treatment differences since we have only one growing season and the environmental factors (temperature, precipitation, and evapotranspiration) could have more effect on final grain yields than our imposed treatments. In subsequent years it will be important to determine the improvement in different soil parameters and to document yield effects from different management practices. Several additional "benchmark" measurements (physical, chemical and biological) are being made on the soils in these plots and these measurements will be repeated periodically throughout the duration of the experiment.

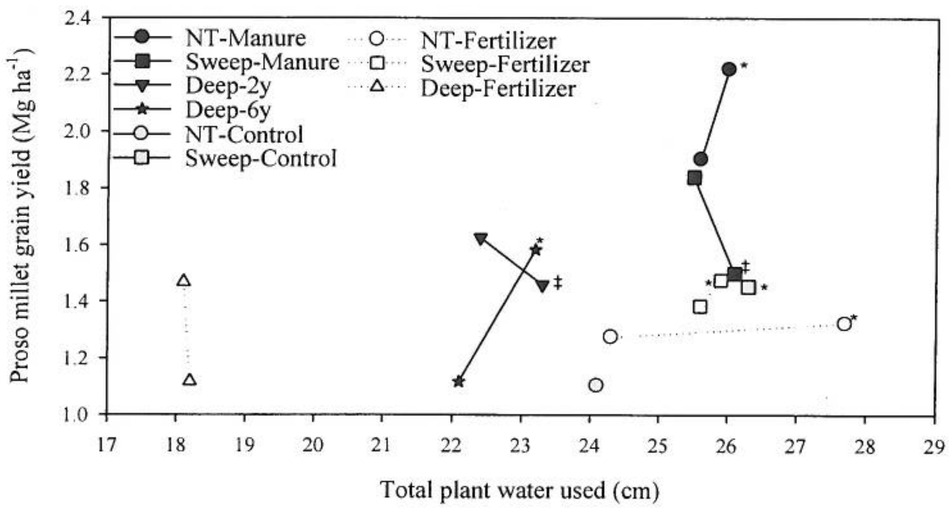

Figure 4. Relationship between proso millet yield (Mg ha^{-1}) and total soil water used (cm) throughout the 2007 growing season as affected by nitrogen rate and different tillage ptactices. (*) represents high grain yield associated with high water usage and (‡) represents high grain yied assiciate with low water usage.

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