Proceedings of the Western Nutrient Management Conference

Salt Lake City, Utah
March 6-7, 1997

Western Nutrient Management Conference Proceedings, Vol. 2

Edited by:

Terry A. Tindall
University of Idaho
Twin Falls, ID 83303-1827

Dale Westermann
USDA/ARS
Kimberly, ID 83341

Western Nutrient Management Conference

PROCEEDINGS – Vol. 2

Published for the Western Nutrient Management Conference
by
University of Idaho

Salt Lake City, Utah
March 6-7, 1997

In: Proc. Western Nutrient Mgmt. Conf. T.A. Tindall & D.T. Westermann (eds.), Salt LakeCity, UT Mar. 6-7, 1997. (Vol. 2)

932

FERTILIZER SOURCE AND CROP ROTATION EFFECTS ON BEANS GROWN ON RECENTLY EXPOSED SUBSOILS

Charles W. Robbins and Larry L. Freeborn[1]

ABSTRACT

Irrigation induced erosion and land leveling have reduced yields on about 2 million acres in south central Idaho. Previous attempts to restore productivity on eroded silt loam soils to that of the original top soil have not been successful. This long term study was conducted to find a method(s) that would restore the productivity of exposed subsoils to that of topsoils and to determine the factor(s) limiting subsoil productivity. This study was initiated by removing the surface 12 inches of topsoil in strips between undisturbed strips of Portneuf silt loam (coarse-silty, mixed, mesic, Durixerollic Calciorthid) topsoil. Different crop rotations were established along the strips and fertilizer treatments were applied across the strips. Fertilizer treatments were applied the first year and were, conventional fertilizer applied according to soil tests, a heavy fresh dairy manure application and two cottage cheese (acid) whey rates. Dry edible beans (*Phaseolus vulgaris* L. cv. Viva) were grown on the entire plot area the forth year as the test crop. Crop rotations did not significantly effect overall bean yields the fourth year after topsoil removal. Applying 60 tons of dairy manure acre^{-1} (air dry basis) was the only treatment that restored bean production to that of the topsoil. Plant Zn and soil organic carbon were the only factors measured that correlated with bean yield increases on the subsoil plots.

OBJECTIVES

Irrigation induced erosion removes from 0.5 to 150 tons of silt loam soil acre^{-1} from south central Idaho fields each year, depending on slope and crop grown (Berg and Carter 1980). This erosion, coupled with land leveling to increase field size and decrease irrigation labor, has decreased topsoil depth and adversely affected crop yields on at least 2 million acres (Carter et al. 1985). They found that sugar beet (Beta vulgaris L.) yields were the least affected, bean (Phaseolus vulgaris L.), alfalfa (Medicago sativa L.), and barley (Hordeum vulgare L.) yields were intermediate, and sweet corn (Zea mays L.) and wheat (Triticum aestivum L.) yields were most severely reduced. Soil depth increases due to sediment deposition at the bottom of the fields did not increase yields proportional to yield decreases caused by soil loss on the upper ends of the same fields. In the same study, N, P, K, and Zn applications to an artificially eroded Portneuf

[1]USDA-Agricultural Research Service, Northwest Irrigation and Soils Research Laboratory, 3793 North 3600 East, Kimberly, ID 83341; Email: robbins@kimberly.ars.pn.usbr.gov

silt loam (coarse-silty, mixed, mesic, Durixerollic Calciorthid) soil did not significantly increase crop production. Carter (1993) suggested that "Technology is not available to restore soil productivity potential to the level that would exist had there been no erosion except for returning topsoil to eroded areas," and that "The only effective treatment was to replace 12 to 16 inches of topsoil" (Carter 1990). Soil test levels and nutrient deficiencies can usually be corrected on eroded soils, but soil productivity is generally not restorable (Burnett et al., 1985).

The purpose of this long-term field study was to identify ways to restore the productivity of freshly exposed Portneuf silt loam subsoils to that of non-eroded topsoils and to identify the factor(s) that limit productivity on eroded soils. Subsoil plots were treated with three fertilizer sources and three crop rotations for four years. During the fourth year Viva bean whole plant compositions and seed yields from subsoil plots were measured and compared to those from the topsoil bean plots.

METHODS

The study was conducted on a Portneuf silt loam. It has an 8 to 20-inch thick lime-silica cemented hard layer starting at 12 to 20 inches below the surface in native soils. The topsoil is pale brown (10 yr 6/3) and the hard layer is white (10 yr 8/2). Below the hardpan, the silt loam is light gray (10 yr 7/2). Silt increases from 62% in the surface to 67% at 55 inches, sand is fairly constant at 10%, and clay decreases from about 20% in the surface to 15% at 55 inches on non-eroded sites (Robbins 1977).

The 70 by 30 foot plots were set out such that the surface 12 inches of topsoil could be removed to expose fresh subsoil in long narrow strips running up and down the field. This arrangement was necessary because the plot area is furrow irrigated and the study site is to last for at least eight years. Topsoil was removed on 16 April 1991 and spread on an adjacent field. The subsoil plots were ripped to 11 inches on 12-inch spacing to break up the hard layer. The entire area was moldboard plowed to eleven inches to reduce compaction caused by the earth moving equipment.

Crop rotations were randomized across the field such that three rotations were grown on the subsoil and two of the rotations were grown on the parallel topsoil strips. Four fertilizer treatments were applied across the field and were randomized down the field. The fertilizer treatments were only applied to the subsoil plots. Each fertilizer-crop rotation subsoil plot was replicated four times, and each crop rotation-topsoil plot was replicated 16 times (Robbins et al., 1997).

Fertilizer treatments on the subsoil were Conventional (fertilized according to soil tests for calcareous soils), Manure (20 tons acre^{-1} in April and 40 tons acre^{-1} in September 1991 on air-dry basis), Low Whey (25,000 gallons acre^{-1} in April and 21,000 gallons acre^{-1} in September 1991), and High Whey (98,000 gallons acre^{-1} in April and 42,000 gallons acre^{-1} in September 1991). Urea was applied to the 1992 bean plots in April 1993 (table 1).

Table 1. Total fertilizer nutrients added to each treatment in spring and fall of 1991 and spring of 1993.

	Total N	Total P	Total K	Zinc
	pounds $acre^{-1}$			
April 1991				
Topsoil	90	0	0	1.5
Conventional	220	120	0	1.5
Manure	880	340	750	7.0
Low whey	280	210	340	1.8
High whey	1200	870	1400	2.5
September 1991				
Topsoil	0	0	0	0
Conventional	0	120	0	0
Manure	1840	710	1600	12
High whey	480	380	600	0.4
Low whey	240	190	300	0.2
April 1993				
1992 bBWB plots	100	0	0	0

The three crop rotations grown on the subsoil were: sorghum (*Sorghum bicolor*)-sudan grass (*Sorghum sudanese*) hybrid, alfalfa, sorghum-sudan hybrid, beans (SASB); barley, alfalfa, winter wheat, beans (bAWB); and barley, beans, winter wheat, beans (bBWB). The SASB and bAWB rotations were grown on the topsoil plots. Barley and the sorghum-sudan grass hybrid were grown in 1991. Alfalfa and 'Viva' pink beans were grown in 1992. Winter wheat and sorghum-sudan grass were grown in 1993 and only 'Viva' pink beans were grown in 1994.

The SASB rotation was selected because of the beneficial soil productivity building characteristics that the sorghum-sudan grass hybrid and alfalfa have shown on high pH soils (Robbins, 1986) and the beneficial effects that grain sorghum often exhibits when grown before Zn sensitive crops (Boawn, 1965). The bAWB rotation is typical of the first four of five or six year dry bean production rotations commonly used on these soils. The bBWB rotation is a worst case bean production scenario that is occasionally used but is a particularly poor choice on eroded southern Idaho silt loam soils in terms of increasing soil organic matter and developing desirable soil structure.

The entire plot area was planted to beans on 6 Jun 1994 without additional fertilizer application. Ten plants were taken from each plot on 18 July and 5 August, and five whole plants were taken on 31 August from rows with representative plant populations. The fresh plants were washed in distilled water, dried at 55 C and ground to pass a 1 mm mesh stainless steel screen. The plant samples were then dry ashed at 500 C, the ash was dissolved in 0.5

M HNO_3 and analyzed for Zn, Cu, Mn, Fe, Ca, Mg, P, and K (Robbins et al., 1997). The plots were harvested on 28 September 1994 and dry bean yields were determined on four 60 ft long rows in each plot.

It was initially assumed that applying 1.5 kg Zn ha^{-1} to all plots would remove Zn as a variable from the study (Leggett and Westermann, 1986, and Carter et al., 1985). After evaluating the 1994 bean seed yield and plant composition of crop and finding low whole plant Zn concentrations, we decided to measure the DTPA extractable Zn on the soil samples taken in April 1994.

Statistical analyses were run separately for the topsoil and subsoil data because of the different sizes of experimental units due to no fertilizer treatments on the topsoil plots. For the topsoil analysis, the rotation treatment x column block interaction was used as an error term for rotation treatment. The analysis for the subsoil plots is that for a split-block or strip-plot design (Milliken and Johnson, 1984). The analyses were carried out using the SAS GLM procedure (SAS Institute Inc., 1989). All 1994 soil ortho-P and subsoil K data were transformed by reciprocal square roots, plant P by logs, and plant K by square roots, to stabilize the variances among treatments prior to analyses of variance. Mean separations are based on non-overlap of 95% confidence intervals on the means, a conservative approach relative to most multiple comparison procedures.

RESULTS AND DISCUSSION

The Manure treatment was the only subsoil treatment that produced bean yields as great as the topsoil (Table 2). Whole plant Zn concentration was the only measured plant component that correlated with plot yields. Soil DTPA extractable Zn and soil organic carbon were the only measured soil factors that were correlated with the increased Manure plot yields. Lindstrom et al. (1986) found Zn availability to be low in calcareous Beadle clay loam (fine, montmorillonitic, mesic, Typic Arguistoll) plots that had the surface 12 and 15 inches of topsoil removed 20 years previously.

Whole plant N, P, K, Cu, Mn, and Fe concentrations were as high or higher in the Low Whey, High Whey and Conventional treatment bean plants as in the topsoil and manure treatment plants. Soil test bicarbonate extractable P and K levels were at least twice as high as needed for bean production in all treatments (Lamborn 1975).

The 1994 bean yield trend, due to crop rotation, was SASB > bAWB > bBWB across all fertilizer treatments, however only the SASB rotation yields were significantly greater than the bBWB rotation on the Topsoil, Low Whey and Conventional fertilizer treatments. There were no crop rotation by fertilizer yield interactions (Robbins et al., 1997).

Current research on these plots includes investigating the effects of applying an additional 8 lbs EDTA Zn $acre^{-1}$ on the Conventional plots and a detailed study of Zn-mycorrhizal interactions when sweet corn and spring wheat are grown and the

Table 2. 1994 "Viva" bean yield, whole plant Zn concentration, DTPA soil extractable Zn, and soil organic carbon.

		Plant Zn				
Treatment	Yield	18 Jul	5 Aug	31 Aug	DTPA Zn	Organic C
	lbs a^{-1}	ppm^{-1}				%
Topsoil	2810 b	36.6 c	31.2 c	18.6 e	3.8 bc	.94 b
Manure	3000 b	26.2 b	23.1 b	16.7 d	2.4 b	1.04 b
Low Whey	2050 a	15.9 a	16.0 a	10.3 b	0.6 a	.53 a
High Whey	1880 a	13.5 a	15.1 a	9.1 a	0.7 a	.58 a
Conventional	1750 a	16.7 a	18.3 ab	11.5 c	0.6 a	.51 a

Numbers in a column followed by the same letter are not significantly different as judged by overlap of 95% confidence intervals.

resulting yield and mineral uptake. Mineral uptake by alfalfa has also since been measured, and Zn does not appear to be the reason that alfalfa yields were only increased by the Manure treatments on the subsoil plots.

REFERENCES

Berg, R.D., and D.L. Carter. 1980. Furrow erosion and sediment losses on irrigated cropland. J. Soil Water Cons. 35:267-270.

Boawn, L.C. 1965. Sugarbeet induced zinc deficiency. Agron J. 57:509.

Burnett, E., B.A. Stewart, and A.L. Black. 1985. Regional effect of soil erosion on crop productivity - Great Plains. *In* Follett, R.F. and B.A. Stewart, (eds.) Soil erosion and crop productivity. Am. Soc. Agron., Madison, WI, pp.335-356.

Carter, D.L. 1990. Soil erosion on irrigated lands. *In* Stewart, B.A. and D.R. Nielsen (eds.) Irrigation of Agricultural Crops-Agronomy Monograph no. 30. ASA-CSSA-SSSA, 677 South Segoe Road, Madison, WI 53711.

Carter, D.L. 1993. Furrow irrigation erosion lowers soil productivity. J. Irrig. Drain. Engineering 119: 964-974.

Carter, D.L., R.D. Berg, and B.J. Sanders. 1985. The effect of furrow irrigation erosion on crop productivity. Soil Sci. Soc. Am. J. 49:207-211.

Lamborn, R.E. 1975. Tentative soil test adequacy levels for phosphorus and potassium. p. 195-196. *In* Proceedings, Twenty-sixth Annual Pacific Northwest Fertilizer Conference. 15-17 Jul 1975. Salt Lake City, UT.

Leggett, G.E., D.T. Westerman and M.J. LeBaron. 1975. A survey of the status of beans grown in Southern Idaho. p.131-138. *In* Proceedings twenty-sixth annual regional summer fertilizer conference, Northwest Plant Food Association, Salt Lake City, Utah, July 17, 1975.

Lindstrom, M.J., T.E. Schumacher, G.D. Lemme, and H.M. Gollany. 1986. Soil characteristics of a Mollisol and corn (*Zea Mays* L) growth 20 years after topsoil removal. Soil and Tillage Res.7:51-62.

Milliken, G.A. and D.E. Johnson. 1984. Analysis of Messy Data, Volume 1: Designed Experiments. Lifetime Learning Publ., Belmont, CA., pp.316-321.

Robbins, C.W. 1977. Hydraulic conductivity and moisture retention characteristics of southern Idaho's silt loam soils. Res. Bull. No. 99. Idaho Agricultural Experiment Station, University of Idaho College of Agriculture, Moscow, ID 83843 p.7.

Robbins, C.W. 1986 Sodic calcareous soil reclamation as affected by different amendments and crops. Agron J. 78:916-920

Robbins, C.W., B.E. Mackey and L.L. Freeborn. 1997. Improving exposed subsoils with fertilizers and crop rotations. Soil Sci. Soc. Am. J. (Accepted 17 December 1996).

SAS Institute Inc. 1989. SAS/STAT™ User's Guide, Version 6, Fourth Ed., Vol. 2, Cary, NC: SAS institute Inc., pp. 891-996.