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Effects of Surface Soil Removal (Simulated Erosion) and Fertilizer Application on Wheat Yield

M. Gorji[1]*, H. Rafahi[1] and S. Shahoee[2]

ABSTRACT

An experiment involving erosion simulation was conducted at the Soil and Water Conservation Research Center of the University of Tehran. A split-factorial plot with four replications was designed. Five soil desurfacing treatments of blank, 5, 10, 15, and 20 cm of soil surface removal (E_0, E_5, E_{10}, E_{15}, and E_{20}) were carried out, respectively. Fertilizer treatments were 0, 65, and 130 kg ha^{-1} of urea (equal to 0, 30, and 60 kg ha^{-1} of pure N) and 0, 107, and 214 kg ha^{-1} of triple super phosphate (equal to 0, 50, and 100 kg ha^{-1} of P_2O_5). Wheat *(Triticum aestivum)*, Sardary cultivar, was cultivated in November 2001. Total precipitation was 223 mm during the growing season and 336 mm for the whole year (23 September 2001–22 September 2002). In order to reduce the effect of drought stress, three supplementary irrigations were applied during the growing season (13mm each). The crop was harvested in July and plant density recorded. Grain, dry matter and straw yields, as well as 1,000 grain weight were determined. The results showed that erosion had a significant effect ($P<0.05$) only on dry matter and straw yields. Each centimeter of soil surface removal, induced a reduction of 0.8% in dry matter. Phosphorus fertilizer had a significant effect ($P<0.01$) on yield parameters, relatively compensating the negative effects of erosion. Nitrogen fertilizer did not show any significant effect on the determined parameters.

Keywords: Desurfacing, Erosion, Productivity, Soil surface removal, Wheat.

INTRODUCTION

Soil erosion increases the cost of crop production and reduces yield due to a reduction in available soil water and nutrients. Replacement of the topsoil by subsoil is accompanied by some unsuitable properties that negatively affect the soil management in crop production. Erosion affects crop productivity differently in various soil types and under different climatic conditions. The relationships between erosion processes and food production are complex and need to be thoroughly studied to help us to make better use of the limited available sources. Investigation of the effect of erosion on soil productivity began in the late 1940s and early 1950s by several investigators (Uhland, 1949; Stallings, 1950). They were mainly concerned with the chemical aspects of soil erosion and nutrient losses. New steps in these activities were initiated in the 1980s to which physical and biological aspects were added; these activities still continue in some countries. Gollany *et al.* (1992) conducted desurfacing experiments on a Typic Argiustoll at South Dakota. The soil depth removed was 0, 30, and 45 cm. Average corn grain yield (mean of five consecutive seasons from 1984 to1988) was 8.3 mg ha^{-1} for the control, and 7.3 mg ha^{-1} for 30 cm, and 6.9 mg ha^{-1} for 45 cm of topsoil removal (a reduction of 12.1%, and 16.9%, respectively). Larney *et al.* (1995) evaluated wheat yield

[1] Department of Soil Science, Faculty of Agriculture, University of Tehran, Tehran, Islamic Republic of Iran.
[2] Faculty of Agriculture, University of Kordestan, Sanandaj, Islamic Republic of Iran.
* Corresponding author, e-mail: mgorji@ut.ac.ir

for varying depths of top soil removal (0, 5, 10, 15, and 20 cm). The relationship between wheat grain yield and soil depth removed was curvilinear (quadratic) for all six locations. The rate of decline in wheat yield was 2 to 8% for every cm of topsoil removed [8]. Studies conducted in North America and Canada indicated that average loss in yield of wheat due to erosion, varies from 5 to143 kg ha^{-1} of grain for every cm depth in soil loss [1]. The range of yield declines in different studies were 33-179 kg ha^{-1} per cm of soil desurfacing. In the topsoil removal studies on Alfisols by Izaurralde *et al*. (1998) and Larney *et al.* (1995), the yield decline was 5.4% per cm soil loss. Desurfacing studies on Mollisols resulted in a mean yield decline of 2.3% per cm soil loss. In a few studies on wheat, straw yields declined an average of 110 kg ha^{-1} (53-187) or 2.7% per cm of soil removal [1]. Thorough exact relations between erosion and crop production have not yet been determined and it is required that these relations be determined in different parts of the world. Although numerous experiments have been conducted in the field of erosion impact on soil productivity, the number of these experiments is very negligible in Asia and non-existent in the Middle East. Only about 5% of these investigations have been conducted in the continent of Asia, which covers over a third of the world's crop land [10]. The procedure that simulates a range of erosion by soil surface removal has been widely used [6]. However, the effect of this technique is not expected to be similar to a natural soil erosion. Lal (1989), compared the effects of natural and artificial erosion and found that yield decline due to natural erosion is about twenty fold that in artificial soil desurfacing procedures, because:

1- Natural erosion acts selectively and its sediments have a greater enrichment factor.

2- Nutrient losses through natural erosion can not be compensated for during the same growing season.

3- Considerable amounts of precipitation are lost by natural erosion and this reduces available water. The effect of artificial soil desurfacing in either shallow soils with concentrated fertility in a few cm of soil surface or in soils with unfavorable subsoil horizons is very severe, but the effect in deep soils with relatively unique properties of subsoil is less. In the present study, soil erosion has been simulated through the removal of different depths of soil surface to determine the effect of erosion on yield production.

MATERIALS AND METHODS

This experiment was conducted at the Soil and Water Conservation Center (University of Tehran) at Koohin in Qazvin Province, Iran. This center is located at 36° 18′–36° 25′ N and 49° 28′–49° 38′ E, with a height of 1,360 m above sea level. The climate in the region is semiarid with cold winters and temperate summers. Mean annual temperature, precipitation, and evaporation rates are 12.5°C, 325, and 1,200 mm, respectively [2]. Soil thermal and moisture regimes are Mesic and Xeric. The current dry farming crops in the region are: winter wheat, barley, lentil, and peas. Vineyards, almond, walnut etc. are also cultivated by growers; the vegetation species include: *Acantholimon estucaceum, Thymus, Artemisia herbualba, Astragalus, Amygdalu, and Cratagus azardlus*.

The soil in the experimental site had a clay texture, with 14-17% of $CaCo_3$ at the surface soil and on the basis of soil Taxonomy (1999), were classified as: fine, mixed, super active, mesic, vertic calcixerepts (Vertic Cambisols, FAO, 1998). To assess the amount of erosion having occurred in previous years, Cs^{137} activity in the soil under study was compared with the original Cs^{137} activity in the region. Previous erosion as calculated by relevant models [3] showed that mean annual erosion was estimated at 44.7 mg ha^{-1} $year^{-1}$ for the past 50 years. To investigate the effects of soil desurfacing on crop production, a split-factorial plot was designed in which the main plots were: blank, five, ten, fifteen, and twenty cm of soil surface removal (E_0, E_5, E_{10}, E_{15}, and E_{20}) respectively. These plots had been prepared manually a year previously and had been cultivated with lentil (*Lens culinaris*). The sub plots (fertilizer) consisted of N_0= 0, N_{65}= 65, and N_{130}= 130 kg ha^{-1} of Urea (0, 30, and 60 kg ha^{-1} of N), P_0= 0, P_{107} =107, and P_{214}= 214 kg ha^{-1} of triple super phosphate (0, 50, and 100 kg ha^{-1} of P_2O_5). Wheat (*Triticum aestivum*), Sardary cultivar was planted. Total precipitation was 223 mm during growing season and 336 mm for the whole year (Table 1).

During the growing season, three supplementary irrigation were applied in the months of April-May with the intervals of 15 days (each 13 mm with an EC of 1.18 dS m^{-1}, TDS of 790 mg L^{-1}, and PH of 7.5). In July, crop was harvested manually (an area of 1 m^2 at the center of 5 m^2 plot). The number of Plant per m^2 plot area (plant density) was determined and the grain yield, dry matter, and straw weight, as well as the 1,000 grain weight (1,000 GW) were also measured.

RESULTS AND DISCUSSION

Properties of both removed and cultivated soils in each treatment are presented in Table 2. Crop yield data were analyzed using SAS, and Excel software. The covariance procedure was used to remove the effect of plant density differences among treatments. The results are as follows:

Table 1. Precipitation amount in the year of experiment, 2001-2002, Qazvin.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
Precipitation (mm)	20	62.5	66	22.5	47	29	68	15.5	2.5	3	0	0	336

Table 2. Chemical and physical properties of soil samples.

properties	Removed soils					Cultivated soils				
	E_0	E_5	E_{10}	E_{15}	E_{20}	E_0	E_5	E_{10}	E_{15}	E_{20}
Depth(cm)	-	0-5	0-10	0-15	0-20	0-20	0-20	0-20	0-20	0-20
CEC(cmol kg^{-1})	-	28	28	28	30	29	28	29	29	29
EC(dS m^{-1})	-	0.3	0.6	0.4	0.4	0.5	0.4	0.4	0.5	0.5
pH	-	7.8	7.9	7.9	7.8	7.7	7.8	7.9	7.8	7.7
OM (%)	-	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1
FC (%)	-	27.2	29.1	30.7	31.1	30.6	31.0	32.0	32.0	32.0
PWP (%) [a]	-	20.4	21.9	22.4	24.4	23.4	23.7	25.4	24.2	24.9
N (%)	-	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
P (mg kg^{-1})	-	6.1	6.0	5.9	7.8	3.9	5.3	4.5	2.9	4.3
K (mg kg^{-1})	-	356	344	340	342	338	315	297	290	285
K (meq L^{-1})	-	0.12	0.15	0.12	0.14	0.14	0.09	0.08	0.15	0.10
Ca (meq L^{-1})	-	2.7	4.7	3.0	3.4	3.5	2.6	3.0	3.7	4.3
Mg (meq L^{-1})	-	1.2	1.1	1.0	1.1	1.2	1.0	1.2	1.6	1.2
Na (meq L^{-1})	-	0.7	0.4	0.3	0.3	0.9	1.6	0.3	0.4	0.4
Cl (meq L^{-1})	-	0.4	0.5	0.5	0.5	1.3	1.2	0.5	0.5	0.5
HCO_3^-(meq L^{-1})	-	3.0	3.0	3.0	3.1	2.8	2.5	2.7	2.4	2.3
CO_3^{2-} (meq L^{-1})	-	0.7	0.5	0.6	0.6	0.6	0.4	0.4	0.4	0.4
Fe (mg L^{-1}) [b]	-	1.7	1.8	1.7	1.8	1.8	1.7	1.8	1.7	2.0
Zn (mg L^{-1})	-	0.8	0.9	0.9	08	1.0	1.0	0.8	0.9	0.9
Cu (mg L^{-1})	-	0.6	0.8	0.6	0.8	0.7	0.6	0.6	0.6	0.6
Mn (mg L^{-1})	-	3.6	4.3	4.0	4.2	4.1	4.1	3.7	4.2	4.5

[a] permanent wilting point
[b] Trace elements were extracted by DTPA (Tetriplex 5) and determined by Atomic Absorption spectrometer.
(E0, E5, E10, E15, and E20): blank, five, ten, fifteen, and twenty cm of soil surface removal respectively.

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Table 3. Analysis of variance of soil desurfacing and fertilizer application effects on wheat yield components

Source	df	Mean squares (ms)			
		Dry matter (g m-^{2})	Grain (g m-^{2})	Straw (g m-^{2})	1000GW (g)
Rep	3	7803.3	2683.0	3585.0	26.8
Erosion	4	11523.0*	938.4	5957.7*	49.2
Error a	12	2754.7	682.2	1386.9	16.7
N	2	174.4	91.0	57.7	10.2
P	2	55036.0**	12127.9**	18541.9**	0.7
Erosion × N	8	3149.9	481.3	1415.2	6.7
Erosion × P	8	3464.6	279.0	1097.6	3.2
N × P	4	1105.8	194.5	212.4	2.9
Erosion × N× P	16	2404.2	462.4	982.9	3.4
Error b	119	1778.1	370.9	811.2	3.4
C.V (%)	-	14.6	16.6	16.2	5.2

[a] Mean comparisons for the effects of erosion on yield components of wheat.

Table 4. Results of t test (LSD) for erosion effects on wheat yield components.

Erosion treatments	Dry matter (g m^{-2})	Grain(g m^{-2})	Straw(g m^{-2})	1000GW(g)
E_0	312 a	121a	193 a	33 b
E_5	304 ab	124 a	186 ab	34 ab
E_{10}	288 ab	116 ab	167 bc	36 a
E_{15}	257 c	106 b	155 c	36 a
E_{20}	279 bc	111 ab	175 abc	36 a
LSD (0.05)	28.9	13.9	20.2	2.1

[a] Means followed by the same letter are not significantly different.

Effects of Erosion

Variance analysis indicated that soil desurfacing had a significant effect only on dry matter and straw (Table 3). In the mean comparison (t test) the plot of 15 cm soil removal (E_{15}) exhibited a significant effect

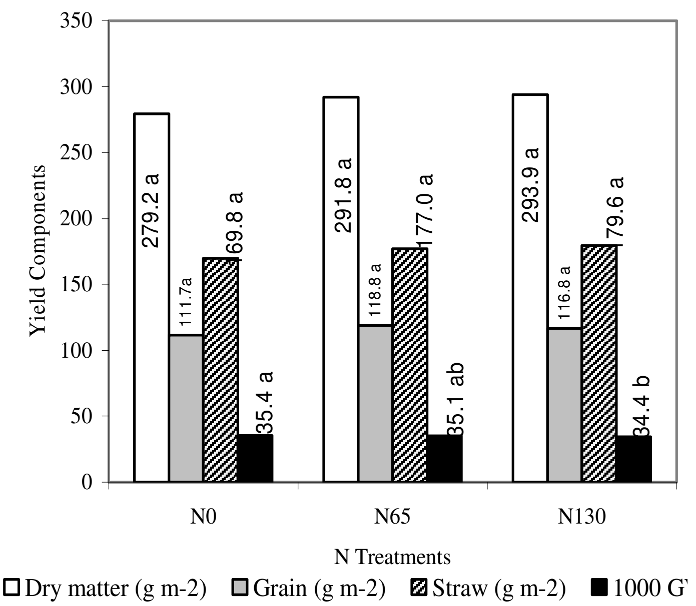

Figure 1. Effects of Nitrogen on wheat yield components**.**

Table 5. Mean comparison for the effects of phosphorous on wheat yield components.

Phosphorous treatments	Dry matter (g m^{-2})	Grain (g m^{-2})	Straw (g m^{-2})	1000GW (g)
P_0	247.4 b	97.7 b	153.1 b	35.0 a
P_{107}	304.3 a	124.2 a	185.0 a	35.1 a
P_{214}	313.5 a	125.9 a	190.5 a	34.9 a
LSD (0.05)	16.4	7.2	10.9	0.7

on grain yield and this located it in different class relative to the blank (Table 4).

Effects of N Fertilizer

Nitrogen treatments had no significant effect on wheat yield components (Table 3). The mean comparison (t test) showed that N had a significant effect only on 1,000 grain weight. Figure 1 shows the effects of N fertilizer on yield components.

Effects of P fertilizer

In the variance analysis (Table 3), the effects of phosphorous are significant (P≤1%) for all yield components except 1,000 grain weight. In the mean comparison (t test) also, yield components with an exception of 1,000 grain weight are located in different classes (Table 5).

P fertilizer could actually compensate for the negative effects of soil desurfacing and

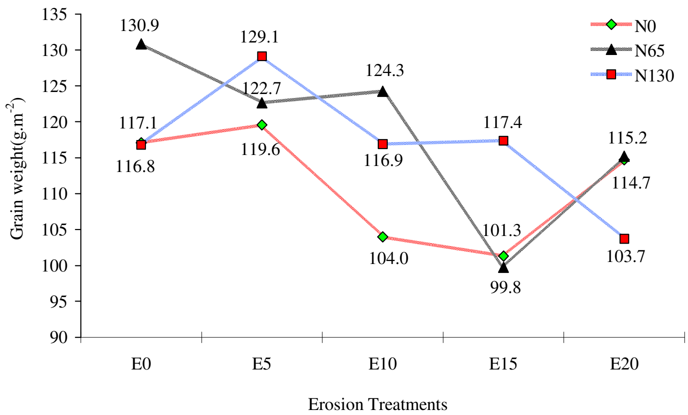

Figure 2. Effects of Erosion × N fertilizer on wheat grain.

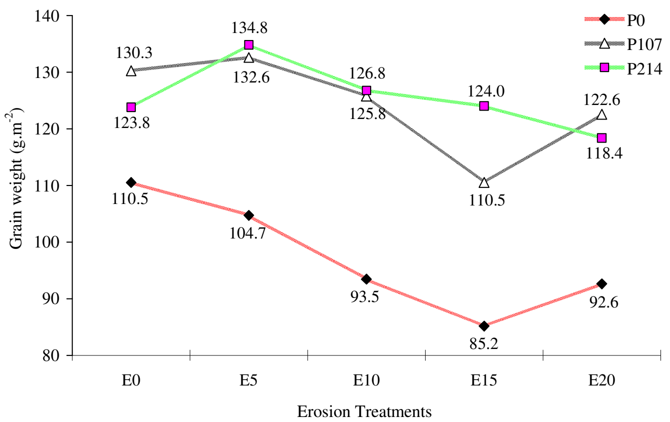

Figure 3. Effects of Erosion × P fertilizer on wheat grain.

produced a greater amount of grain relative to the blank. Though not significant, the interaction of erosion and fertilizers showed that plot of $E_0N_{65}P_{107}$ produced the maximum (1,470 kg ha^{-1}) and the plot of $E_{15}N_0P_0$ the minimum grain yield (770 kg ha^{-1}). P_{107} treatment among all the erosion plots could compensate for the negative effects of soil desurfacing and produced grain yield equal to the blank treatment ($E_0N_0P_0$). It was only in the five cm soil removal treatment (E_5) that each fertilizer treatment had a greater grain yield relative to a similar fertilizer treatment and zero erosion level. These results are similar to the findings of Massee [9]. Figures 2 and 3 show the effects of erosion and fertilizers on grain yield.

The overall results show that the destructive effects of soil erosion on soil productivity decline cannot be compensated for completely by fertilizers, indicating that prevention is much better than treatment.

Regresion Equations

Regression relations were established to show the effects of desurfacing and fertilizer treatments on grain and dry matter production.The equations are as follows:

G_w= 1070.2–7.63 E+0.35 N+1.31 P R2= 0.49 P> 0.0001 (1

DM_w= 2689–21.51 E+1.04 N+3.21 P R2 = 0.40 P>0.0001 (2

G_w = Wheat grain (kg ha^{-1})

DM_w= Dry matter (kg ha^{-1})

E= Soil removal depth (cm)

N= Urea fertilizer (kg ha^{-1})

P= Triple super phosphate (kg ha^{-1}).

The equations indicate that wheat grain was reduced by 7.63 kg ha^{-1} cm^{-1} of soil removal (0.71%). This is within the range of wheat grain yield decline in topsoil removal studies on Mollisols (-33-179 kg ha^{-1} cm^{-1} soil loss)[1]. The wheat yield decline in this experiment is much less than the results of Izaurralde *et al.* and Larney *et al.* in the topsoil removal studies on Alfisols (5.4% cm^{-1} soil removal) [4, 8]. These differences can be attributed to different soil properties, climatic conditions, etc. Deep soils of the Koohin region and the uniformity of soil profile and high relative humidity of the atmosphere played important roles in this question.

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مطالعه اثر حذف خاک سطحی (شبیه‌سازی فرسایش) و مصرف کود بر تولید محصول گندم

م. گرجی، ح. رفاهی و ص. شاهویی

چکیده

به منظور بررسی اثر فرسایش خاک بر توان تولید محصول در اراضی استان قزوین، این آزمایش با استفاده از روش شبیه‌سازی فرسایش در مرکز تحقیقات حفاظت خاک وآب دانشگاه تهران به اجرا درآمد. طرح آزمایشی استفاده شده ، بلوک خردشده - فاکتوریل بود. تیمارهای حذف خاک سطحی عبارتند از شاهد ، ۵ ، ۱۰ ، ۱۵ ، و۲۰ سانتی‌متر برداشت خاک سطحی. تیمارهای کودی استفاده شده شامل ۰ ، ۶۵ ، و ۱۳۰ کیلوگرم در هکتار اوره (معادل ۰ ، ۳۰ ، و ۶۰ کیلوگرم در هکتار ازت خالص) و ۰ ، ۱۰۷ ، و۲۱۴ کیلوگرم در هکتار سوپر فسفات تریپل(معادل ۰ ، ۵۰ ، و ۱۰۰ کیلوگرم درهکتار p_2o_5) بود. در این آزمایش گندم (*Triticum aestivum* L.) رقم سرداری کشت شد. برای کاهش اثر خشکسالی در طول دوره رشد، سه نوبت آبیاری هرکدام به عمق ۱۳ میلی‌متر صورت گرفت. برداشت محصول به صورت کف برانجام و تعداد بوته در مترمربع شمارش شد. سپس مقدار ماده خشک ، دانه ، کلش ، و وزن هزار دانه گندم تعیین گردید. تجزیه وتحلیل آماری داده‌ها نشان داد که فرسایش ایجاد شده فقط بر مقدار ماده خشک وکلش درسطح احتمال ۵٪ اثر معنی‌دار داشت. هر سانتیمتر فرسایش خاک سطحی باعث کاهش ۷۱/. درصد دانه و۸/. درصد ماده خشک شد. کود فسفر اثر معنی‌دار خود را بر کلیه اجزای عملکرد محصول درسطح احتمال ۱٪ نشان داد و به طورنسبی آثار منفی فرسایش را جبران کرد.

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