

Physical Characteristics of Aridisols as Affected by Ley Farming Systems

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Abstract: Ley farming is a system of growing grass in rotation with agricultural crops for improved soil environment and sustained grain and fodder production. Three types of ley farming systems, with 4 years, 6 years and 8 years of grass cultivation, were selected and compared with control plots on the basis of different soil physical parameters like infiltration, water retention and water transmission. Infiltration and available water capacity improved significantly in case of 8 years grass growing plots. Presence of stubbles after harvest of grass disturbed the stability of soil structure and decreased the value of hydraulic conductivity in all the cases.

Key words: Ley farming, infiltration, moisture retention, AWC, hydraulic conductivity, sorptivity.

In contemporary agriculture, ley farming is a system in which grasses and/or legumes are grown in short term rotation with crops. It has been in practice since centuries in the temperate environment of Europe. It helps to improve soil fertility and provides good fodder to animals; also helps to build up soil structure and prevent erosion (Lloyd *et al.*, 1991). In Australia, ley pastures have been incorporated in farming systems in the temperate region since the 1930s (Puckridge and French, 1983; Reeves, 1987). Important role played by ley pastures in the southern Australia to improve the economy motivated the scientists to search for a tropical equivalent (Jones *et al.*, 1991). Grass leys are mainly used to restore soil structure after periods of cropping with maize, potato and peanut (Kilpatrick and

Crosthwaite, 1978). These are now an accepted part of farming practice on the better watered lands of the north Queensland (Jones *et al.*, 1991).

Growth of grasses promotes the development of water stable crumbs and reduces the risk of erosion and improves water transmission characteristics but sometimes, due to compression and blockage of existing macropores, water entry is reduced (Barley and Sedgeley, 1959). Harsh environment and degraded sandy soils pose problems for successful crop production in the arid areas. Further, sandy soils of the region, because of low moisture retention, high infiltration rate and structureless nature are infertile, unproductive and prone to wind erosion. Therefore, for sustained production and improvement of soil environment, ley farming can play an important role. Meagre information, particularly on the type and

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period of leys and their effects on soil physical environment, is available for arid regions. Studies were conducted with these objectives in view.

Materials and Methods

In the grass paddocks of CAZRI, Jodhpur, four plots of 50 x 25 m were made with continuous cultivation of *Cenchrus ciliaris* grass for 4 years, 6 years and 8 years and a control without grass. Each plot was divided into two subplots of 50 x 10 m each with a 5 m spacing for recording observations. After harvest of grass, in one subplot of each main plot, stubbles were maintained, whereas, other subplot was maintained stubble-free. Observations on soil physical parameters like infiltration, water retention and water transmission were recorded from each subplot.

Infiltration studies were carried out using a double ring infiltrometer having 30 cm height, 20 cm inner diameter and 40 cm outer diameter. The rings were inserted 8 cm deep into soil and a constant waterhead of 20 cm was maintained in all determinations. Depth wise soil samples, at an interval of 30 cm, were collected before infiltration for estimation of initial moisture.

In the laboratory, the water retention of undisturbed surface soil samples (0-30 cm depth), collected from different treatments, were determined at -0.01, -0.1, -0.3 and -1.5 MPa matric potentials using 1, 3 and 15 bar pressure plates (Richards, 1949).

The saturated hydraulic conductivity (K_{fs}), matric flux potential (O_m) and sorp-

tivity (S) were measured *in situ* in all the plots using Guelph permeameter (Reynolds and Elrick, 1987). The method involved measuring the steady state rate of water discharge from a small open cylindrical hole (well) of radius ' a_w ' (0.02-0.05 m) finished above the water table in which constant depth of water $H(m)$ is maintained. A simple "in - hole" mariotte bottle arrangement is used to measure corresponding Q (flux). Moisture of collected soil samples and bulk density were determined by gravimetric and core sampler methods, respectively.

Results and Discussion

Infiltration characteristics of soil

Infiltration rate varied from 0.08 cm min^{-1} in control plots to 0.21 cm min^{-1} in subplot after 4 year grass cultivation without stubbles. From Table 1, it is evident that infiltration characteristics were similar in plots after 4 years and 6 years of grass cultivation, but reduced in subplots after 8 years' grass cultivation with stubbles. Here, the infiltration rate was 0.14 cm min^{-1} . Low infiltration rate in the control plot may be attributed to presence of hard pan in the subsurface and comparatively higher initial moisture contents than in the other plots. In 8 years grass growing plots, low infiltration rate may be due to blockage of existing pores by grass roots. Fitting the cumulative infiltration (I) and time (t) in the Phillip's equation,

$$I = St^{0.5} + At$$

Sorptivity value was determined. It varied from 1.087 to 2.653 cm $\text{sec}^{-0.5}$ with

highest value observed in subplot with 4 years grass without stubbles. During infiltration, the rate of sorptivity decreased with time as hydraulic conductivity dominates. In these soils, even after one hour of infiltration, the parameter A of Phillip's equation, which represents the hydraulic conductivity, is of low magnitude (-0.02 to -0.974). Here, only sorptivity of soil is responsible for infiltration.

Values of cumulative infiltration (I) and the corresponding time (t) were fitted to Kostiakov's equation :

$$I = Kt^n$$

Though Kostiakov's infiltration parameter (n) is time variant (Fok, 1987), it gives an idea of stability of soil structure (Taylor *et al.*, 1972).

It is observed that value of 'n' varied from 0.287 to 1.002 in case of 4 years grass cultivated subplot with stubbles and without stubbles, respectively. In case of control plot, uniform stability of soil structure during wetting was observed. In these cases, value of 'n' was 0.65. Except in 6 year grass cultivated plot, in other cases it was observed that the presence of stubbles reduced the stability of soil structure. This may be attributed to the incorporation of root biomass and the presence of organic matter (Bathke *et al.*, 1992).

Moisture retention characteristics of soils

Moisture retention in 6 years grass cultivated plot was similar to 4 years grass cultivated plot (Table 2). At -0.01 MPa matric potential, moisture percentage varied

from 19.5 in control to 28.8 in 8 years grass cultivated plot with stubble. At -1.5 MPa matric potential, volumetric moisture percentage varied from 3.5 in control to 6.4% in 8 year grass cultivated plots without stubble. It is observed that both at -0.01 MPa and -1.5 MPa matric potentials, moisture retention improved from control plot to grass cultivated plots. It may be attributed to the extensive network of grass roots which bind the soil to improve water retention. The effect of grass roots on retention capacity of soil was found most prominent in case of 8 years grass cultivated plot. Available water capacity varied from 16.02 in case of control plot to 22.70 cm m⁻¹ in 8 years grass cultivated subplot without stubbles. In 4 year and 6 year grass cultivated plots, range of available water capacity varied from 17.3 to 19.1 cm m⁻¹.

Saturated hydraulic conductivity

Saturated hydraulic conductivity is time dependent and varies a lot from place to place also. It varied from 0.58 x 10⁻³ cm sec⁻¹ in case of 6 years grass cultivated plots with stubbles to 3.75 x 10⁻³ cm sec⁻¹ in case of control plot. In all cases presence of stubbles reduced the hydraulic conductivity of soil. Significant variations in 6 years grass cultivated plots with stubbles and without stubbles were observed (Table 1). It is also evident that the saturated hydraulic conductivity also varied with initial moisture content. In control plot hydraulic conductivity was highest, and in the grass cultivated plots, it reduced due to the breaking of continuity of macropores by the grass roots (Bathke *et al.*, 1992).

Table 1. Infiltration and water transmission characteristics of soil under different ley farming systems

Soil physical parameters	4 years		6 years		8 years		Control
	Without stubbles	With stubbles	Without stubbles	With stubbles	Without stubbles	With stubbles	
Infiltration characteristics							
Initial moisture content (%) (θ)	2.23	1.96	2.17	2.05	3.35	2.12	3.25
Infiltration rate (IR) (cm min^{-1})	0.21	0.16	0.2	0.16	0.20	0.14	0.08
S (cm sec^{-1})	0.34	0.14	0.26	0.30	0.27	0.20	0.20
A (cm min^{-1})	-0.974	-0.466	-0.02	-0.62	-0.62	-0.07	-0.21
n	1.002	0.287	0.507	0.738	0.812	0.527	0.65
K	0.309	2.971	1.890	0.772	0.520	1.324	0.814
Water transmission characteristics							
$K_{fs} \times 10^{-3}$ (cm sec^{-1})	3.03	2.00	3.20	0.58	2.50	1.15	3.75
θ (sq. cm^{-1})	0.0346	0.0476	0.065	0.052	0.032	0.054	0.030
α (cm^{-1})	0.085	0.044	0.093	0.012	0.079	0.022	0.129
BD (g cc^{-1})	1.66	1.70	1.55	1.75	1.65	1.70	1.66
Initial moisture θ (%)	3.44	3.20	3.76	3.60	3.55	3.47	3.41
Porosity	37.44	35.8	34.0	44.0	38.0	36.0	37.0
Sorptivity S ($\text{cm sec}^{-0.5}$)	0.15	0.187	0.23	0.181	0.151	0.191	0.15

Matrix flux potential (O_m)

It is defined as the measure of soil's ability to pull water by capillary forces through a unit cross sectional area in a unit time. Value of matrix flux potential (O_m) varied from $0.030 \text{ cm}^2 \text{ sec}^{-1}$ in control plot to as high as $0.065 \text{ cm}^2 \text{ sec}^{-1}$ in case of 6 years grass cultivated subplot without stubbles (Table 1). Values of matrix flux potential was high, $0.052 \text{ cm}^2 \text{ sec}^{-1}$ and $0.065 \text{ cm}^2 \text{ sec}^{-1}$ in both the cases of 6 years grass cultivated subplots with stubbles and without stubbles, respectively. This increased value of matrix flux potential could be useful for more uptake of water by

plants which may ultimately reflect on the yield of crop (Smucker and Aiken, 1992).

Sorptivity

Sorptivity values measured by Guelph permeameter varied from $0.147 \text{ cm sec}^{-0.5}$ in case of only grass cultivated plots to $0.23 \text{ cm sec}^{-0.5}$ in 6 years grass cultivated plots without stubbles. Sorptivity values measured by double ring infiltrometer (Table 1) were higher than sorptivity values of Guelph Permeameter (Table 1) mainly due to the variation of initial moisture content. During infiltration study with double ring, initial moisture content was low (around 2%), whereas, during the study

Table 2. Moisture retention characteristics of soil under different ley farming systems

Section (MPa)	4 years		6 years		8 years		Control
	Without stubbles	With stubbles	Without stubbles	With stubbles	Without stubbles	With stubbles	
	(%)	(%)	(%)	(%)	(%)	(%)	
0.01	22.14	23.37	23.10	24.71	28.55	28.87	19.52
0.10	8.22	6.56	7.25	7.67	10.20	11.21	10.68
0.30	5.97	4.63	5.20	5.81	6.91	7.60	6.17
1.50	4.77	4.27	5.10	5.54	5.85	6.45	3.50
Available water capacity (AWC) (cm m ⁻¹)	17.37	19.10	18.00	19.17	22.70	22.39	16.02

with Guelph Permeameter moisture percentage varied from 3-4%.

Sorptivity values improved in case of grass cultivated profile. Six years grass cultivated subplots, both without stubbles and with stubbles showed higher sorptivity values 0.23 cm sec^{-0.5} and 0.18 cm sec^{-0.5} respectively. These higher sorptivity values of soil may influence the crop yield.

It is concluded that 4 and 6 year continuous grass cultivated systems did not significantly improve soil physical parameters. Eight year of grass cultivation significantly improved the infiltration characteristics, available water capacity (AWC) and water transmission. As far as variation of different soil physical parameters between sub plots with stubbles and without stubbles are concerned, variation was not at all significant except in case of saturated hydraulic conductivity.

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