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Physical Characterisation of the Rainfed Aridisols of Punjab

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Abstract : Three profiles, representing two soil series of south west Punjab, were studied to identify physical constraints affecting crop production and to determine water storage. Soil texture ranged from loamy sand in Jassi Pauwali to sandy loam in Jodhpur Ramana I & II. None of these profiles showed physical constraints to root penetration. Final infiltration rate and field capacity of the profiles varied from 0.26 cm min^{-1} and 0.068 kg water per kg soil (0-180 cm depth) in Jassi Pauwali, and 0.5 cm min^{-1} and 0.081 kg water per kg soil (0-180 cm depth) in Jodhpur Ramana series.

Key words : Soil series, infiltration rate, field capacity, available water, rainfed, arid soils.

Introduction

Considerable information has been generated for successful soil and water management of semi-arid soils in irrigated and sub-montane rainfed areas of Punjab (Sandhu *et al.*, 1992). The yield levels of crops under irrigated conditions have reached a plateau and there is little scope of extending the irrigation facilities to additional cultivated areas. Due attention, therefore, to aridisols of the state, which have low inherent crop productivity, becomes necessary. The characterisation of a soil type brings out its plant growth limiting parameters. Knowledge of such physical characteristics helps in planning an appropriate irrigation system and soil/water management practices on agricultural farms. This study reports the physical characteristics of recently identified two soil series, viz., Jassi Pauwali and Jodhpur Ramana, alongwith the variation within the latter series representative of the rainfed areas of south-west Punjab.

Materials and Methods

The study site represented the arid south-west Punjab (29° 40′ to 30° 30′ north latitude, 74° 20′ to 75° 40′ east longitude, 200m above mean sea level) with an average annual rainfall of about 400 mm. The soils have developed from alluvial deposits that are relatively at the primary stage of development. Sidhu and Sharma (1990) identified and characterised soil series representing this region. Soil profiles of two of them were studied for textural and bulk density variations. The particle size analysis was carried out following international pipette method (Kilmer and Alexander, 1949). Bulk density was determined in quadruplicate in a 0-15, 15-30 and in 30 cm depth increments using 8 cm inner dia and 5 cm height (251.4 cm^2) of metal cores. Soil moisture retained at the -10 and -1500 KPa was determined by using a pressure plate extractor (Black,1965). Infiltration was measured using double ring infiltrometers with inner ring diameter of 32-36 cm in quadruplicate (Black,1965). The data points were fitted to Kostiakov (1932) equation ($I = at^b$) where, I is the cumulative infiltration (cm) t-elapsed time (min) a and b empirical constants. The initial water content was 0.019, 0.056, and 0.062 kg water per kg soil (180 cm deep profile) in Jassi Pauwali, Jodhpur Ramana I and II soil series, respectively. In these soil series, upper surface of soil was cultivated about a month before the measurements. The drainage characteristics were determined following the method of Watson (1966). The wate storage, 48 hours after ponded water soa in the profile, was considered as the water r

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Table 1. Particle size distribution (%) of three profiles of soil series of Bathinda district

Soil depth (cm)	Coarse sand	Sand	Silt	Clay	Class
		Jassi Pauwali series			
0–15	9.7	84.8	1.6	3.9	S
15–30	7.7	82.7	3.6	6.0	S
30–60	6.2	83.6	4.5	5.7	LS
60–90	9.5	80.2	4.6	5.7	LS
90–120	7.5	82.2	4.7	5.6	S
120–150	5.7	85.6	6.0	2.7	S
		Jodhpur Ramana I			
0–15	5.8	81.0	5.3	7.9	LS
15–30	6.3	72.5	9.0	12.2	SL
30–60	3.3	72.5	10.9	13.3	SL
60–90	2.9	72.2	12.3	12.6	SL
90–120	7.6	74.1	10.6	7.7	LS
120–150	–	–	–	–	–
		Jodhpur Ramana II			
0–15	6.4	78.6	7.3	7.7	LS
15–30	4.0	80.2	8.3	7.5	LS
30–60	3.4	77.0	9.3	10.3	LS
60–90	3.7	77.4	9.4	9.5	LS
90–120	11.0	71.1	11.4	6.5	LS
120–150	5.3	80.3	9.0	5.4	LS

Coarse sand > 2000 μ ; Sand 200–2000 μ ; Silt 20–200 μ ; Clay < 2 μ.
S – Sand ; LS – Loamy sand ; SL – Sandy loam.

at field capacity. Correlation coefficients between water retention indices and the separate silt, clay as well as silt plus clay, were worked out using usual statistical methods.

Results and Discussion

Soil texture : The sand fraction in different horizons of the profiles varied from 71.1 to 94.5% and silt from 1.6 to 12.3% (Table 1). The average values of sand, silt, and clay were 90.9, 4.2 and 4.9% in Jassi Pauwali; 83.1, 9.1 and 7.8% in Jodhpur Ramana II; and 79.7, 9.6 and 10.7% in Jodhpur Ramana I soil series. The average profile textures were sand, loamy sand and sandy loam for Jassi Pauwali, Jodhpur Ramana II and Jodhpur Ramana I soil series, respectively.

Bulk Density (BD) : The mean BD in different horizons varied from 1.41 to 1.53, 1.40 to 1.54 and 1.39 to 1.51 mg m^{-3} (Table 2) under Jassi Pauwali, Jodhpur Ramana II and Jodhpur Ramana I soil series, respectively. The BD of subsoil of all profiles was not above the critical limit.

Pore space and water retention : The total pore space computed from BD, assuming a particle density of 2.65 mg m^{-3}, varied from 41.9 to 47.5% (Fig. 1). The average water filled pores between -10 KPa to -1500 kPa were maximum

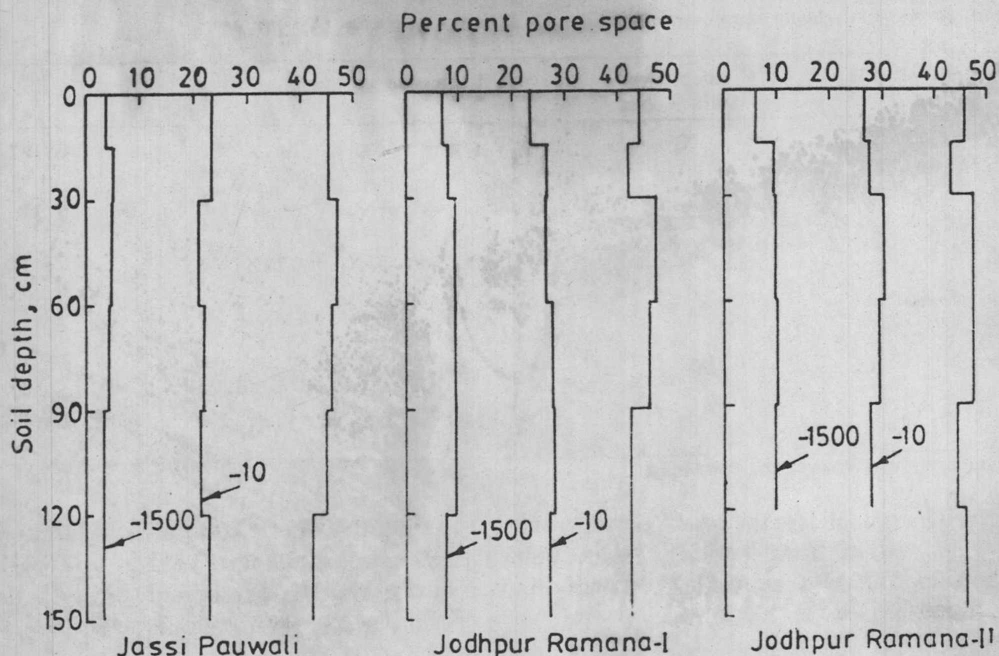

Fig. 1. Porosity and water retention at — 10 and —1500 KPa at profiles of three soil series of Bathinda district.

Table 2. Bulk density (mg m^{-3}) of three profiles of different soil series of Bathinda district

Depth (cm)	Jassi Pauwali	Jodhpur Ramana I	Jodhpur Ramana II
0 – 15	1.45	1.44	1.48
15 – 30	1.45	1.51	1.54
30 – 60	1.41	1.39	1.40
60 – 90	1.43	1.39	1.43
90 – 120	1.46	1.47	1.52
120 – 150	1.53	1.43	1.52

The coefficient of variation was less than 4%.

in Jodhpur Ramana II and minimum in Jassi Pauwali soil series. The average air filled porosity between 0 and -10 KPa was 23.8% in Jassi Pauwali and 17.4% under Jodhpur Ramana II and Jodhpur Ramana I soil series.

Water retained at field capacity (*in situ*) was 0.068, 0.079, and 0.081 kg water per kg soil and at -10 KPa, it was 0.0675, 0.085 and 0.0895 kg water per kg soil, under Jassi Pauwali, Jodhpur Ramana II and I soil series, respectively. It suggests that the water content at the field capacity corresponds to -10 KPa tension for Jassi Pauwali series and to -33 KPa in the other soil series.

Soil texture-water retention relationship : Jassi Pauwali series has lesser water retention than the Jodhpur Ramana profiles. The increase in the silt and clay content, individually or together (Table 3), causes greater retention at -10 and -1500 KPa. Similar observations were reported by Singh *et al.* (1989), Singh *et al.* (1992). The positive correlation between moisture retention and soil constituents corroborates variation of the former with proportion of silt and clay even within same textural class/soil series.

Available water capacity : The AWC was somewhat higher in the Jodhpur Ramana I as compared with that in the other two profiles. The AWC of Jassi Pauwali profile, which had mostly sand texture, was similar to Jodhpur Ramana II profile due to very low water retention

Table 3. Regressions relating water retention (%) with silt (X_1) and Clay (X_2) per cent

Dependent variable (%)	Independent variable (%)	Regression equation	R^2
Water retention at −10 KPa (y_1)	X_1	$Y_1 = 17.4 + 1.04\, X_1$	0.91**
−do−	X_2	$Y_1 = 18.6 + 0.87\, X_2$	0.74**
−do−	X_1, X_2	$Y_1 = 16.72 + 0.87\, X_1 + 0.26\, X_2$	0.84**
Water retention at −1500 KPa (y_2)	X_1	$Y_2 = 1.67 + 0.72\, X_1$	0.92**
−do−	X_2	$Y_2 = 2.3 + 0.63\, X_2$	0.78**
−do−	X_1, X_2	$Y_2 = 1.07 + 0.57\, X_1 + 0.23\, X_2$	0.87**

** Significant at 1% level of probability.

at -1500 KPa potential in the Jassi Pauwali profile. This value varied from 4 to 7% in the other two profiles. The AWC showed good relationship with the soil particle separates.

Infiltration : Cumulative infiltration in different soil series increased as a power function of time (Fig. 2) and that of soil series decreased in the order, Jassi Pauwali >Jodhpur Ramana

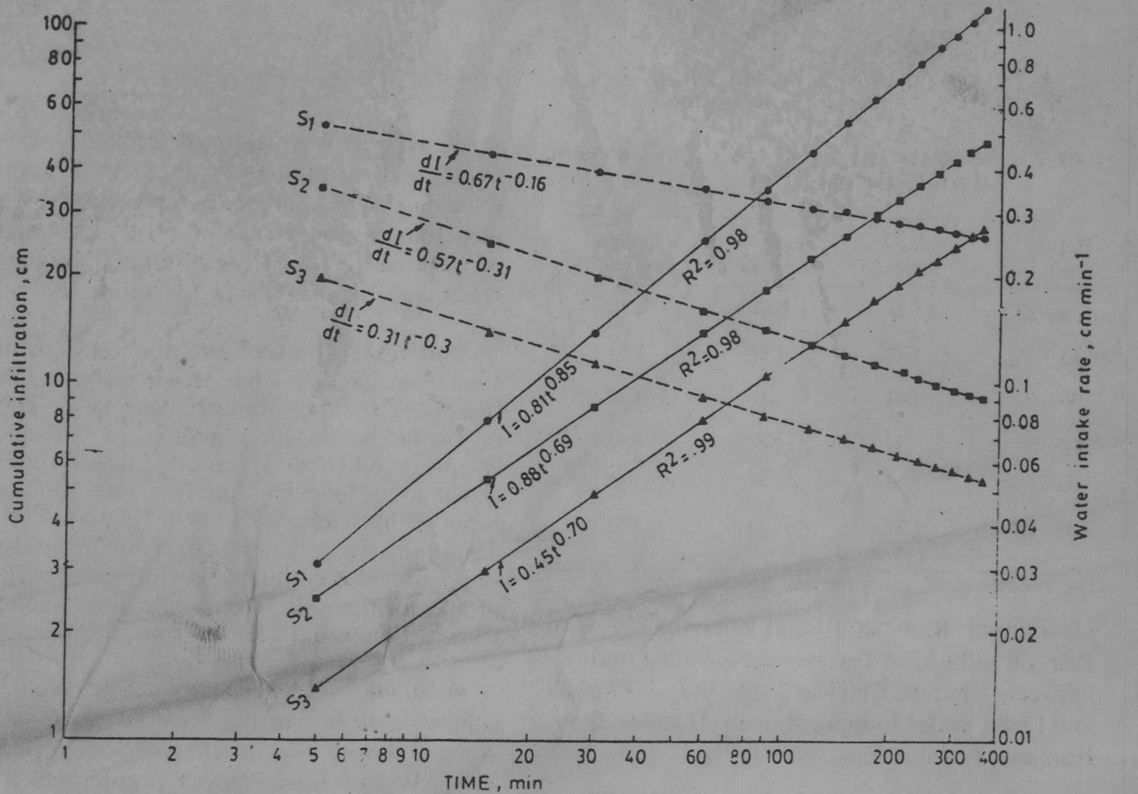

Fig. 2. Cumulative infiltration (–) and water infiltration rate (- - -) under Jassi Pauwali (S_1), Jodhpur Ramana (S_2) and Gahri Bhagi (S_3) soil series of Bathinda District.

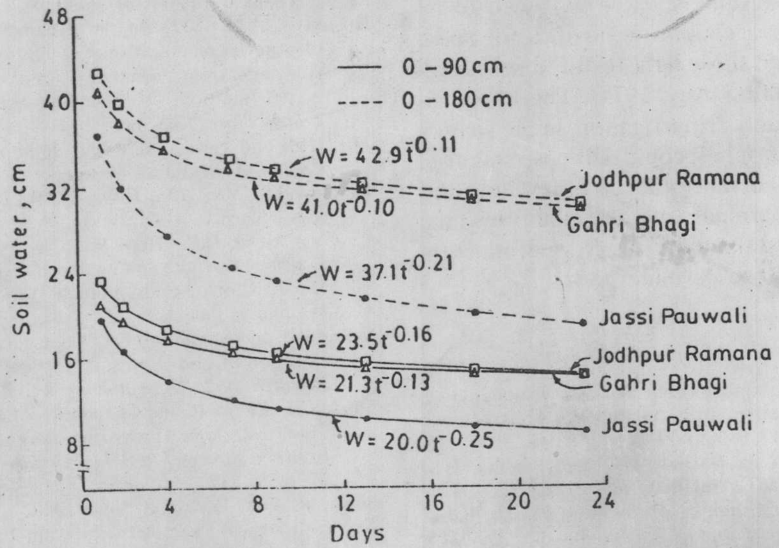

Fig. 3. Periodic soil water in the 0—90 and 0—180 cm soil depth under different soil series.

I > Jodhpur Ramana II. The data for all the soil series fitted to the Kostiakov equation closely ($R^2 = 0.98$). The final intake rate was 0.26 (rapid), 0.09 (moderate) and 0.05 cm min^{-1} (moderate) in Jassi Pauwali, Jodhpur Ramana I and II series, respectively (Fig. 2). Water intake rate was highest in case of Jassi Pauwali and lowest in Jodhpur Ramana II series due to variation in textural composition, surface condition and initial water content.

Drainage Characteristics : The change in soil water storage with time, in the 0-90 and 0-180cm layers followed the relationship $W = at^b$, where a and b are constants and t is time (days). The periodic soil water storage under Jodhpur Ramana I and Jodhpur Ramana II was quite closer, because of nearly similar textural composition of the two sites. The water storage, 48 hours after the ponded water soaked in the profile was, 0.068, 0.086, 0.090 kg water per kg soil in Jassi Pauwali, Jodhpur Ramana II and Jodhpur Ramana I soil series, respectively (Fig. 3). Its behaviour with time registered the same trend.

These series, uncommanded by the canal system, are very poorly suited for rainfed farming. With 8% clay in the plough slice, these soils are susceptible to wind erosion. Water holding capacity of these soils may be increased by incorporating organic/inorganic fine materials, or by physically restricting water percolation in the root zone. The normal BD and clay content of the plough slice of the deeper layers do not warrant deep profile modification. Only 4 to 16mm probable (0.5) rain during 27 to 34th standard weeks at Bathinda (Mavi and Tiwana, 1994) necessitate physical restriction of percolation below root zone, using surface barriers for the production of *kharif* vegetables and arid fruits. Otherwise, crops tolerant to aberrant weather may be grown.

Deep ploughing of Jodhpur Ramana soils shall be useful in checking wind erosion and seedling mortality due to greater clay content in subsurface layers. The profile modification depth computed, following Eck and Unger (1985) was found to be 60 cm and 15 cm for Jodhpur Ramana I and II, respectively, and that in the former case, being more costly. However, the addition of ash, available from local industries, may be useful, and studies are underway to find the optimum quantity required.

Wherever good to marginal quality groundwater is available, the feasibility of furrow irrigation for raising crops, suitable for the canal command areas (Aujla *et al.*, 1991) need to be tested. However, a caution is obvious for sodic water irrigation on these light textured soils (Aggarwal and Ramamoorthy, 1974). The introduction of sprinkler and drip irrigation, in the vicinity of canal water supplies could increase/stabilise, production. The current practice of levelling and irrigating with marginal to poor quality waters, threatens the sustainability of crop production in addition to huge levelling costs.

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