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Water retention characteristics of some sedentary and alluvial soils of Bundelkhand region

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Abstract
Studies on moisture retention characteristics of ten pedons representing the various landforms of Bundelkhand region were carried out. The variations in available water content of soils were associated with changes in soil texture. The amount and nature of clay was also found to influence the moisture retention properties of soils at all tensions. Shallow red soils of subdued plateau and hills with the lowest plant available water capacity (PAWC) are susceptible to severe droughtiness. Soils of gently sloping plateau and monadnocks are susceptible to moderate droughtiness due to their medium water storage capacity. Soils of rest of landforms possessed high to very high PAWC and are expected to supply moisture to the crops throughout the growing period due to their high moisture storage in the profile.

Additional keywords: Landforms, soil characteristics, plant available water capacity, Bundelkhand region.

Introduction

Moisture retention characteristics show the relationship between soil moisture tension and water content. These are useful for better utilisation of rainfall and irrigation facilities besides providing basic information regarding the available water stored in the root zone for optimum crop production and soil water management (Das *et al.* 1974). The knowledge of PAWC is also helpful to evaluate the soil site for their suitability to different crops particularly under rainfed condition with a minimum risk of crop failure (Sehgal 1996). Factors like texture, organic carbon, CEC and bulk density are known to influence to a larger extent the water retention and release by soil (Kaushal *et al.* 1996, Rakesh *et al.* 1998). Very little information on this aspect exists for soils of Bundelkhand region of India occupying about 7000 sq km area. This communication reports the water retention characteristics of soils of ten profiles representing various landforms of Bundelkhand region of Uttar Pradesh.

Materials and methods

The study was undertaken in part of Banda district of Uttar Pradesh located between 24°55' and 25°35'N latitudes and 80°35' and 81°04'E longitudes covering an area of 177 sq km. Climatically the area represents a transitional zone of tropical dry subhumid conditions with mean annual rainfall of 1032 mm of which nearly 80 per cent is received during June to September (Fig. 1). The mean annual potential evapotranspiration (PET) of this area is around 1400 mm of which 79 per cent is met by annual precipitation. The water supply exceeds the water need (PET) for four months (June to September and during rest of the months the water supply is less than the PET, Fig. 1). The mean annual tempera ture in the area is around 25°C, thus qualifies for 'hyperthermic' temperature regime. The

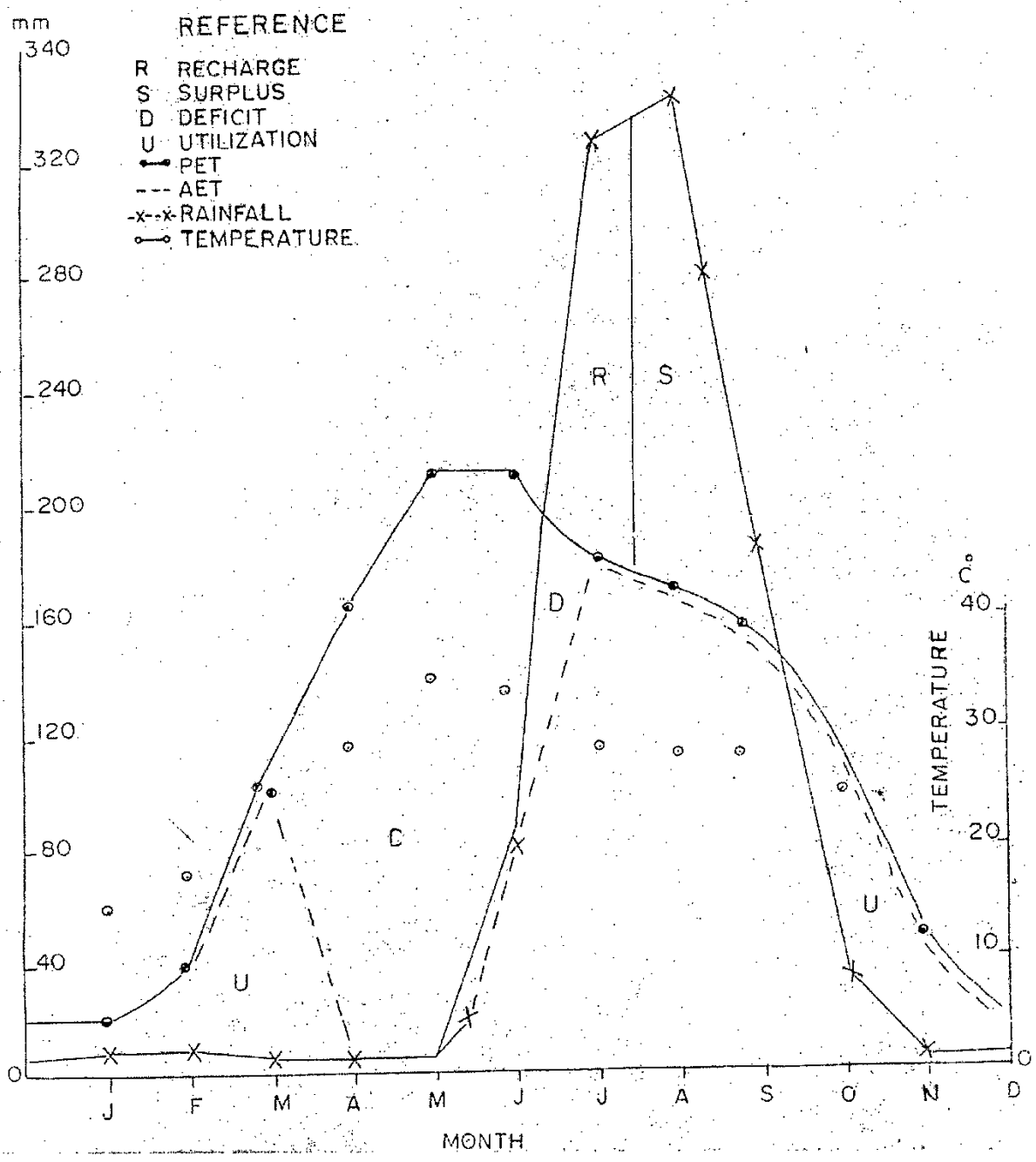

Fig. 1. Soil moisture balance at Karwi station (U.P.).

moisture regime is 'ustic' as the soil moisture control section is dry for 90 cumulative days or 45 consecutive days.

Ten pedons representing various landforms viz. hills, subdued plateau, flat topped hill, gently sloping plateau, monadnock foot hill slopes, piedmont plain and flood plains, delineated through aerial photointerpretation, were exposed and soil samples were collected horizonwise. Physical and chemical characteristics used in investigation are briefly presented with their range and mean values of all horizons of each profile in table 1. Soil water cntent at tensions below 100 kPa was determined by pressure plate and more than 100 kPa by pressure membrane. The plant available water capacity (PAWC) was computed using the following expressiion

$$\text{PAWC mm/m} = \sum_{Z=0}^{Z=RD} (W_{max} - W_{dry})\ BD \text{ at } W_{max} \times HD$$

Where

Wmax = Gravimetric water content at 33 kPa tension
Wdry = Gravimetric water content at 1500 kPa tension
BD = Bulk density at Wmax
HD = Horizon thickness (m)
RD = Total rooting depth taken as 1 m or to a depth of root limiting layer whichever is shallower

Results and discussion

The water retained by soils at different tensions is shown in table 2. The variations in moisture retention at all tensions are mostly associated with variations in soil texture. Relatively coarse textured soils (Tikria and Gonda) retained least amount of moisture at all tensions than the fine textured soils (Markundi, Devagan, Badausa and Anuwan). Moderately fine texture or fine loamy soils (Khraund, Bharatkup and Mariahu) retained moisture between fine and coarse textured soils. The moisture retention at all tensions found to be a function of mechanical components of soils as it is manifested by highly positive correlation with silt (r= 0.78 to 0.89), clay (r= 83 to 0.89) and negative correlation with sand (r= -0.88 to –0.93). As the tension increased from 10 kPa to 33 kPa which is regarded as the wet limit of field moisture conditions, the majority of soils released 25-30% of retained water except Tikria, Gonda and Bahilpurwa which released 35-40 per cent water. An increase in tension from 10 kPa to 100 kPa released more than 60 per cent moisture in coarse textured soils (Tikria, Bahilpurwa and Gonda) but in rest of the soils (fine and fine loamy) the water release varied from 45-52 per cent and retained more moisture even at 1500 kPa. The study, therefore, indicated that the rate of release of moisture in relatively fine textured soil is more gradual than the relatively coarse textured ones and such results was also reported by Biswas and Mukerjee (1987). A distinct variations in moisture retention at all tensions have been observed in soils having comparable clay content. Vertisols and Vertic intergrades (Badausa and Anuwan soils) retained relatively more moisture at all tensions due to the dominance of smectitic clay and

Table 1. Soil characteristics

Sand (%)	Silt (%)	Clay (%)	pH	CEC cmol(p+) kg^{-1}	B.S. (%)	Org. C. (g/kg)	Free $CaCO_3$ (%)	B.D. (Mg/m^3)	Dominant clay mineral	Texture in control section
Markundi soil – Typic Ustochrepts										
24.2-33.8 (28.9)	18.8-25.8 (22.6)	40.4-53.0 (48.5)	6.3-6.5 (6.3)	19.7-22.7 (21.1)	73-80 (7.7)	4.2-14.5 (7.5)	--	1.35-1.70 (1.57)	I	C
Tikria soil – Dystric Ustochrepts										
58.8-67.5 (63.8)	16.5-19.4 (18.4)	16.0-22.6 (18.0)	5.0-6.3 (5.4)	7.5-8.5 (7.5)	56-59 (57.0)	3.4-8.3 (4.8)	--	1.58-1.79 (1.70)	K	L
Devagan soil – Ultic Haplustalfs										
34.2-48.8 (39.4)	20.4-25.2 (22.5)	26.4-43.8 (37.7)	6.3-6.5 (6.4)	10-18.5 (16.4)	67-94 (72.0)	3.3-8.5 (5.4)	--	1.44-1.68 (1.56)	I	C
Bahilpurwa soil – Udic Ustochrepts										
55-63.4 (59.0)	13.1-13.7 (13.7)	24-31.9 (26.7)	6.4-6.6 (6.5)	9.7-12.0 (11.0)	79-82 (80.0)	3.8-5.2 (4.3)	--	1.59-1.78 (1.69)	K	Scl
Gonda soil – Ultic Haplustalfs										
62.2-76.2 (69.7)	9.8-11.6 (10.5)	12.2-28.0 (19.7)	5.8-6.3 (6.0)	6.4-10.8 (8.7)	67-76 (70.0)	3.2-5.0 (4.1)	--	1.6-1.78 (1.70)	K	Sl to scl
Mariahu soil – Udic Ustochrepts										
29.6-70.2 (42.9)	14.4-27.2 (23.6)	15.4-43.2 (33.4)	6.2-6.8 (6.5)	10.7-18.8 (16.0)	67-88 (80.0)	4.7-6.6 (5.5)	--	1.41-1.46 (1.44)	I	Cl
Khraund soil – Fluventic Ustochrepts										
41.6-71.4 (49.9)	13.2-23.4 (19.5)	15.4-39.8 (30.7)	6.0-7.1 (6.4)	10.4-26.2 (20.3)	68-87 (80.0)	2.8-4.6 (3.6)	--	1.50-1.62 (1.57)	I	Cl
Bharatkup soil – Typic Ustochrepts										
38.8-66.2 (53.8)	13.4-28.8 19.3)	17.0-33.0 (26.9)	8.0-8.3 (8.2)	15.3-21.2 (18.3)	90-93 (92.0)	1.0-5.0 (2.3)	4.0-11.2 (8.9)	1.47-1.78 (1.62)	M	Scl
Badausa soil – Udic Haplusterts										
10.0-19.2 (14.9)	28.3-35.0 (31.8)	50.1-55.5 (53.0)	7.9-8.1 (8.0)	25.4-28.4 (27.0)	80-89 (82.0)	2.5-5.6 (3.5)	0.25-5.6 (1.3)	1.61-1.96 (1.81)	S	C
Anuwan soil – Vertic Epiaquepts										
11.6-17.2 (15.1)	42.4-44.8 (43.3)	38.0-44.5 (41.4)	6.7-8.5 (8.0)	17.7-21.0 19.3)	75-89 (84.0)	1.6-10.4 (3.3)	0.18-0.45 (0.28)	1.46-1.91 (1.71)	M	Sic

Figures in parenthesis indicate mean values

mixed mineralogy, respectively than the Inceptisols and Alfisols (Markundi and Devagan) having dominance of mica. The clay content of Bharatkup soils was lower than Khraund and Markundi soils but retained more moisture particularly at high tension due to expansible clays. Tikria, Gonda and Bahilpurwa soils held relatively less amount of water at all tensions when compared to other soils apparently due to their low clay content with dominance of kaolinite. Hence, the data clearly pointed out that the amount and nature of clay influenced the moisture retention properties of soils which were in close agreement with the findings of Diwakar and Singh (1992). Variation in moisture retention with depth mostly followed the distribution pattern of silt and clay under all tensions.

Available water content was found to be highest in alluvium derived Vertisols (Badausa) and Vertic Inceptisols (Anuwan) and lowest in relatively coarse textured Inceptisols (Bahilpurwa and Tikria) and Alfisols (Gonda). In other Inceptisols and Alfisols which are fine textured (fine loamy/fine) the amount of available water varied from 0.12 to 0.15 kg/kg. Badausa and Anuwan soils released identical amount of available water in spite of differences in clay content and its nature. High silt content of Anuwan soils is perhaps responsible for releasing the same amount of available water content (AWC) (Das *et al.* 1974). Bharatkup soils released more available water though its clay

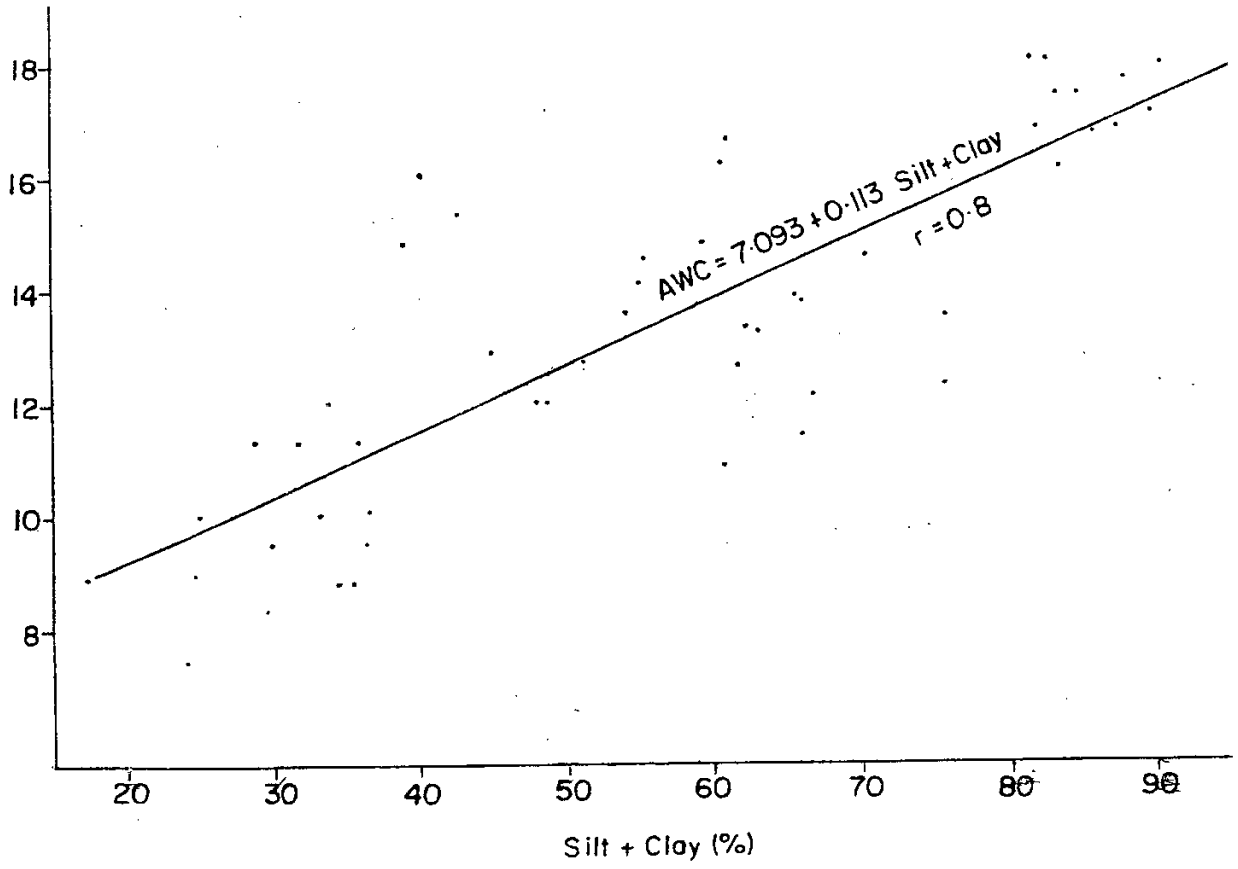

Fig. 2. Relationships between AWC and Silt+Clay.

and silt were lower than Khraund and Mariahu soils indicating that nature of clay minerals also significantly contributing towards the available water. Perusal of data also indicated that the AWC of relatively fine textured soils (Anuwan and Badausa) was low in proportion to their moisture content held at 33 kPa because of corresponding increase in water retention at 1500 kPa (PWP). However, reverse trend was observed in coarse textured Tikria, Bahilpurwa and Gonda soils indicating that at same moisture level fine textured soils are more prone to droughtiness than coarser soils. The available water content seemed to have been influenced by soil texture, silt, clay content and its nature as evident from the positive correlation with silt (r= 0.74), clay (r= 0.72), CEC (r= 0.78), exchangeable bases (r= 0.72) and negative correlation with sand (r= -0.81) (Fig. 2). Poor correlation with organic carbon probably be due to its low content and smaller differences in its depthwise distribution among the pedons (Srivastava *et al.* 1998).

Table 2. Soil moisture retention characteristics

Horizon	Depth (m)	10	33	100	1500	AWC	PAWC mm/m
		--------- kPa ---------					
		----- water content kg/kg-------					
		Markundi – Hills					
Ah	0.0-0.13	0.35	0.25	0.16	0.13	0.12	97
Bw1	0.13-0.31	0.39	0.27	0.18	0.14	0.13	
Bw2	0.31-0.50	0.35	0.27	0.18	0.14	0.13	
		Tikria – Subdued plateau					
Ap	0.0-0.12	0.27	0.15	0.10	0.05	0.10	78
Bw1	0.12-0.25	0.24	0.14	0.09	0.05	0.09	
Bw2	0.25-0.48	0.24	0.15	0.08	0.05	0.10	
		Devagan – Flat topped hill					
Ah	0.0-0.15	0.33	0.24	0.16	0.12	0.12	209
Bw	0.15-0.30	0.34	0.26	0.18	0.12	0.14	
Bt1	0.30-0.55	0.37	0.28	0.20	0.14	0.14	
Bt2	0.55-0.80	0.39	0.29	0.23	0.15	0.14	
BC	0.80-1.00	0.37	0.29	0.23	0.16	0.13	
		Bahilpurwa – Undulating plateau					
Ap	0.0-0.14	0.27	0.16	0.10	0.06	0.10	118
Bw1	0.14-0.38	0.31	0.20	0.13	0.08	0.12	
Bw2	0.38-0.60	0.40	0.22	0.14	0.09	0.13	
		Gonda – Monadnock					
Ap	0.0-0.12	0.19	0.12	0.08	0.04	0.08	176
Bt1	0.12-0.34	0.24	0.16	0.10	0.04	0.12	
Bt2	0.34-0.50	0.27	0.16	0.10	0.05	0.11	
BC	0.50-0.65	0.22	0.15	0.07	0.05	0.10	
		Mariahu – Foot Hill slopes					
Ap	0.0-0.13	0.18	0.18	0.13	0.06	0.12	176
Bw1	0.13-0.29	0.24	0.24	0.17	0.13	0.11	
Bt2	0.29-0.50	0.25	0.25	0.19	0.13	0.12	
Bw3	0.50-0.73	0.36	0.27	0.20	0.13	0.14	
Bw4	0.73-1.00	0.38	0.27	0.19	0.15	0.12	
		Khraund – Piedmont plain					
Ap	0.0-0.10	0.26	0.18	0.12	0.07	0.11	208
Bw1	0.10-0.28	0.29	0.21	0.16	0.09	0.12	
Bw2	0.28-0.52	0.30	0.24	0.16	0.10	0.14	
Bw3	0.52-0.75	0.32	0.26	0.18	0.12	0.14	
Bw4	0.75-1.06	0.32	0.26	0.19	0.13	0.13	
BC	1.06-1.50	0.34	0 29	0.21	0.14	0.15	
		Bharatkup – Dissected flood plain					
Ap	0.0-0.14	0.28	0 19	0.11	0.07	0.12	249
Bw	0.14-0.30	0.31	0.24	0.16	0.09	0.15	
BK	0.30-0.47	0.33	0.27	0.14	0.10	0.17	
C	0.47-0.75	0.34	0.25	0.14	0.10	0.15	
1C	0.75-1.00	0.38	0.29	0.18	0.12	0.17	
2C	1.00-1.50	0.38	0.29	0.20	0.13	0.16	

Horizon	Depth (m)	10	33	100	1500	AWC	PAWC
		--------- kPa ---------					
		----- water content kg/kg-------					
		Badausa – Slightly undulating flood plain					
Ap	0.0-0.13	0.53	0.37	0.26	0.19	0.18	320
A1	0.13-0.30	0.53	0.38	0.27	0.20	0.18	
A2	0.30-0.53	0.52	0.35	0.27	0.21	0.14	
A3SS	0.53-0.80	0.51	0.37	0.28	0.20	0.16	
A4SS	0.80-1.10	0.53	0.36	0.27	0.19	0.17	
A5	1.10-1.50	0.50	0.35	0.23	0.18	0.17	
		Anuwan – Level flood plain					
Ap	0.0-0.13	0.47	0.34	0.25	0.17	0.17	263
Bw1	0.13-0.30	0.50	0.36	0.26	0.17	0.16	
Bw2	0.30-0.60	0.50	0.35	0.26	0.17	0.18	
Bw3	0.60-0.81	0.47	0.35	0.25	0.17	0.18	
Bw4	0.81-1.10	0.48	0.35	0.26	0.18	0.17	
Bw5	1.10-1.60	0.49	0.35	0.25	0.18	0.17	

PAWC – Plant available water capacity.

The moisture held between the field capacity (33 kPa) and PWP (1500 kPa) may not be actually available to crops though it is considered as available. Hence, plant available water capacity (PAWC) was calculated following the formula proposed by Gardner *et al.* (1984). The data (Table 2) suggested that PAWC of studied soils varied from 98 to 320 mm/m depending upon soil depth and available water retained. Alluvium derived Vertisols (Badausa) had the highest PAWC followed by Vertic Inceptisols (Anuwan). Among the red soils Tikria soils of subdued plateau showed the minimum PAWC followed by Markundi soils of hills due to their shallow depth. These soils are prone to severe droughtiness owing to their low water storage in soil profile. Bahilpurwa and Gonda soils have medium to high water storage capacity but still prone to moderate droughtiness (Sehgal 1996). Soils of the rest of the landforms have high to very high PAWC. Therefore, it is expected to supply moisture to the crops throughout the growing period because of their high moisture storage in soil profile.

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