Plant Available Water Capacity (PAWC) for Deep-Rooted Crops in Cracking Clay Soils (Vertisols) of Semi-Arid Central India

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Abstract: Smectite is the dominant clay mineral in the cracking clay soils (mainly Vertisols) in the semi-arid tropical (SAT) region (Vidarbha and Marathwada). Amongst the crystalline clay minerals, smectite has the highest soil moisture retention capacity depicted as the available water between field capacity and wilting point, which increases with soil depth. But in SAT Vertisols of Vidarbha and Marathwada regions, the release of this soil water is unavailable to deep-rooted crops, causing loss of crop yield is frequently observed. Thus, the water holding between 33 and 1500 kPa tension is not in reality available soil moisture in these soils. The release of soil moisture is, however, seriously constrained by the dispersion of smectitic clay colloids due to the presence of both Mg and Na ions on soil exchange complex. In reality, in calcareous Vertisols of non-sodic nature, soil moisture is held at 100 kPa while in calcareous Vertisols of sodic nature it is held at 300 kPa. Based on this field observation the concept of plant available water content, which relates to profile water content, was adopted earlier to calculate the plant available water capacity (PAWC) considering the soil moisture held between 100-1500 kPa for non-sodic and 300-1500 kPa for sodic soils. This pragmatic PAWC method showed a significant positive correlation between the PAWC and the yield of cotton (lint + seed) of 32 Vertisols of the Vidarbha region, however, it did not address the status of soil moisture release at higher tensions. It is apprehended that at higher tensions, the release of soil moisture is not enough during the dry period of the season that can prevent the extension of vertical cracks in the slicksided horizons at deeper depth of 100 cm and beyond. Less amount of soil water in the subsoils is due to the decrease of saturated hydraulic conductivity (sHC) with depth preventing the free flow of rainwater in the subsoils. This makes subsoils as more water constraint horizons but enriches subsoils with pH > 8.0, more amount of Mg²⁺ and Na⁺ ions on soil exchange complex. Such Vertisols do not support the second crop during the winter months. In view of this predicament in agricultural land use plan of SAT Vertisols, the present study was undertaken to understand the cause and effect relationship between soil moisture and relevant soil parameters that prevent the release of soil moisture at higher tensions. In order to find an insight into this queer issue, soil moisture retention and release curves at 33, 100, 300, 500, 800, 1000 and 1500 kPa, were obtained for each genetic horizon of 33 representative Vertisols of Vidarbha and Marathwada region. In Vidarbha, Vertisols are Aridic/Typic/Sodic Haplusterts and Calciusterts, and in Marathwada, they

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are Typic/Sodic Haplusterts. Moisture tension curves indicate that the release of water beyond 800 kPa is negligible. Failure in the release of soil water beyond 800 kPa is due to the dispersion of fine clay size smectite (< 200 nm) consisting primarily of nano-size smectite (<100 nm), caused by the Mg$^{2+}$ and Na$^{+}$ ions present on the soil exchange complex. The dispersed nano-size smectite blocks the macropores and simultaneously increase the micropores, where soil moisture is held very tightly. In the present study, PAWC calculation was done considering the soil water held between 100-800 kPa for soils of non-sodic nature, and for sodic soils, it was between 300-800 kPa. The revised PAWC data showed a better significant positive correlation with yields of cotton on farmers’ field, in comparison to correlation obtained earlier. Thus, it stands as a robust index parameter of soil abiotic stress in SAT environment. This unique parameter having a legacy to major pedogenetic processes in SAT Vertisols: In Indian states under SAT, PAWC emerges as a formidable biophysical parameter for evaluation of rain-fed Vertisols for growing deep-rooted crops.

Keywords: Cotton yield; Maharashtra; revised plant available water content (PAWC); SAT Vertisols; soil moisture curves; Vidarbha and Marathwada.

The cracking clay soils of India (Vertisols and their intergrades) occupy 76.4 m ha out of which 35.5% area falls in the state of Maharashtra (Mandal et al., 2014). The majority of cracking clay soils in the semi-arid tropical (SAT) parts of central India, are rainfed. They support cropping sequences of sorghum / pigeon pea, cotton / pigeon-pea, and cotton/sorghum/soybean. These types of cropping patterns usually combine crops with different maturity lengths, drought-sensitive with drought-tolerant crops, cereals with legumes, and cash crops with food crops and are cultivated under hyperthermic to iso-hyperthermic temperature and ustic soil moisture regimes (Swindale, 1989; Pal et al., 2012a, b). These agricultural land-use patterns highlight that Vertisols, a relatively homogeneous major soil group in India, support a variety of crops to be grown in subhumid moist (SHM), subhumid dry (SHD), semi-arid moist (SAM) and semi-arid dry (SAD) bio-climates, especially in the Maharashtra state of central India (Pal et al., 2012a, b). Although the smectite rich Vertisols, well known to enhance the water holding capacity both at 33kPa and 1500 kPa, have limitations that restrict their full potential to grow both rainy season (kharif) and winter (rabi) crops. This dismal agricultural situation is observed in very fine/fine, smectitic, iso-hyperthermic family of Aridic / Sodic Haplusterts of Amravati and Sodic Haplusterts of Akola districts of Vidarbha region of Maharashtra. In Vertisols under SAT areas of central India, cultural operations using a handheld or animal-drawn implements are difficult because of lack of adequate moisture and poor porosity in the subsoil’s regions. Thus, the roots of annual crops cannot penetrate to the deeper depths (NBSS&LUP-ICRISAT, 1991). These unfavourable physical properties compel the farmers to grow only one season crop in SAD Vertisols (Aridic / Sodic Haplusterts) of the western part of the Amravati district and the adjoining Akola district. But in SHD Vertisols (very fine, smectitic, hyperthermic family of Typic Haplusterts/ Calciusterts) of Nagpur district, both rainy and winter crops are grown with limited irrigation (Kadu, 1997; Vaidya, 2001; Pal et al 2012a, b). Similar cracking clay soils (Typic Haplusterts and Sodic Haplusterts) are also widely occurring in Marathwada region of Maharashtra, which are no better than those of Vidarbha region in growing deep-rooted crops (Zade, 2007).

Deep-rooted crop (cotton) on Aridic Haplusterts (exchangeable sodium percentage, ESP >5, but < 15) and Sodic Haplusterts (ESP ≥ 5, < 15, Balpande et al., 1996 or > 15, Richards, 1954) of Vidarbha region has poor productivity (Kadu,1997; Vaidya, 2001). Kadu et al. (2003) tried to identify bio-physical factors that decrease the yield of cotton on farmers’ field in 29 Vertisols derived from basaltic-alluvium of the Vidarbha