Plant-Water demand Characteristics in the Alfisol, Zaria Nigeria

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Abstract

The Nigeria Guinea Savanna zone currently witness increasing intensification of agricultural production activities. The soils are said to have ustic moisture and isohyperthermic temperature regimes implying that rainfalls during the cropping season are limited, irregular or during the dry seasons crop production would be strongly affected by available soil water inadequacy for crop use and production. Supplemental or total water supply by irrigation would therefore be necessary to avert crop failure. Also physical restriction to root elongation can reduce soil water and nutrients uptake as well as plant growth irrespective of water and nutrient supply. This study therefore evaluated soil characteristics and water extraction depth by maize (test crop) in the Northern Guinea Savanna zone Alfisol in Zaria (11^0 10'N and $7^0$35'E) Nigeria. Results show that minimal soil water was extracted by maize at seedling and crop maturity phases, and optimal at crop establishment to grain filling phases. Zone of active soil water extraction shown by the study is 10 to 20 Cm soil depth. Water rather accumulated at the shallow depths of 30 Cm and below following the presence of such sub soil free drainage obstructions as clay and plinthic layers.

1. Introduction

Tropical semi-arid regions usually have large variations in physical conditions, both over time (variation in weather among years) and location (climate and edaphic conditions). However, in Nigeria, the zones are currently witnessing increasing intensification of agricultural production activities. The soils are said to have ustic moisture and isohyperthermic temperature regimes (Odunze *et al* 1993). The soils' ustic moisture regime presupposes that rainfalls during the cropping season are limited, irregular or during the dry seasons, crop production would be strongly affected by soil water availability for crop use. At this instance, supplemental or total water supply by irrigation would be necessary to avert crop failure. Also, shortage of water and/nutrients can restrict crop yield in soils and physical restriction of root elongation can reduce plant growth irrespective of water and nutrient supply (McConnaughay and Bazzaz, 1991). It would therefore be necessary to determine water demand characteristics by a staple crop like maize in the Nigerian semi-arid zone. This study is aimed at determining the soil-plant-water characteristics in an Alfisol, thereby inferring the nature of the soil and root zone (depth) for the early (75-80 days) maturing maize variety to avoid over irrigation and its consequent soil degradation and decline in crop yield in particular.

2. Materials and Methods

Field experiments were carried out during the months March–May 2003-5 (dry season), in an experimental farm developed at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria (11^0 10'N and $7^0$35'E), Nigeria. A randomized complete block design (RCBD) was used. Extra early (at 11^{th} week dried) maize (TZEE-Y IAR-95) was used as test crop. The study involved six treatments (i.e., 3-, 4-, 5-, 6-, 7-, and 8 –days after irrigation) replicated four times in a 4 x 5 m^2 plot size using 80 liters per furrow of irrigation water. The soil belongs to Alfisol order (Soil Survey Staff, 1999). Access tubes were installed in each treatment plot and used to measure soil water. The soil water measurements were made using Sentek Australia Capacitance Probe (CP), with trade name *Diviner 2000*. Water was supplied to the treatments by gravity method and measurements were made systematically on daily basis.

3. Results

Figures below show soil-water-plant intersection from the planting stages to harvest of maize during the 10-11 weeks plant growth period for select profiles (11,17and 24) considered. The display/spectrum shows water demand curves at all stages of growth: i.e., seedling, tasseling /grain filling and maturity/harvest; as well as depths at which crop roots were able to extract soil water. At 10 cm rooting zone/depth in all profiles and in weeks 1-2 (seedling stage), water intake of the plants was minimal but showed gradual increase as crop established. For the grain filling stage of the maize plant, soil water demand was very pronounced, attained highest peak and indicates optimal water demand up to the crop maturity phase. Maize plant water demand was gradual and declined at crop maturity up to harvest (Figs. 1 & 2). This would perhaps suggest reduced demand for soil water by plants as plants approach senescence.

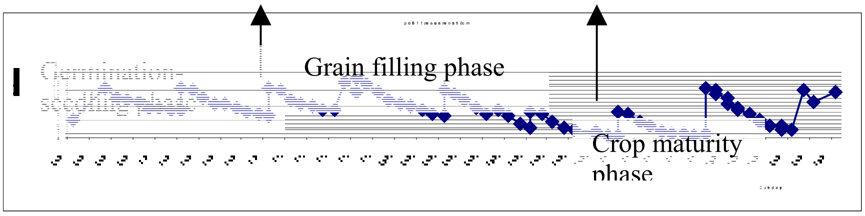


Figure 1 Profile 11; showing soil- maize plant water demand curve at10 cm depth level

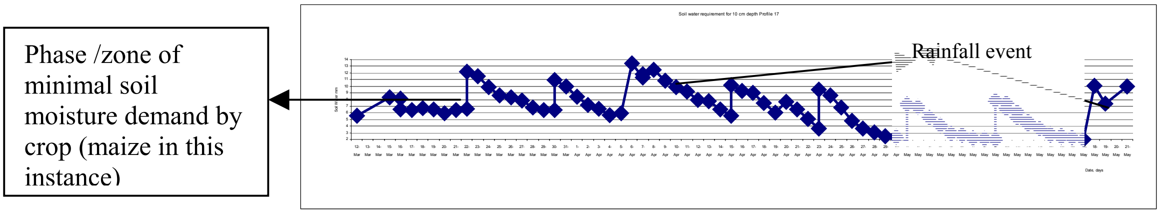


Figure 2 Profile 17; showing soil-maize plant water demand curve 10 cm depth level

NB: Each rainfall event is depicted with a slight rise in the display curve.

Generally, soil moisture extraction by roots is vigorous at 10 cm soil depth. The 10 cm soil depth appears to be a zone for active root growth and development; hence active soil moisture and nutrients extraction by crop roots within this depth range.

Figures 4 &5 present curves on soil-maize plant water demands at 20 cm rooting depth for the maize crop. The curves reveal active soil water extraction by maize plants as was observed at the 10 cm rooting depth. Some noticeable drainage water loss occurred at this depth. From about March 19 to April 9 (phase of active moisture demand by maize crop) and at depth level 20 cm, significant soil moisture demand was observed in the curves (Figs. 4 &5). This period corresponds with full vegetative growth, maize tasseling and grain filling stages of the maize plant. From about 16 April to 7 May (crop maturity phase) showed reduced soil-plant water demand, because the crops were demanding water perhaps largely for physiological maintenance and drainage loss/waste occurred. At depth level 20 cm and from about 19 March through 9 Apr. there was sharp/strong moisture demand, suggesting a period of high soil water demand from the crop, again corresponding to the crop establishment phase. From about 9th April to 20th April active moisture extraction curves were also observed, suggesting active soil water use for tasseling to grain filling by the maize plants. Soil water depletion dynamics remained active at this depth suggesting depth at which crop roots were active in water and nutrients extraction. However, period of sharp moisture demand is shorter than at depth level 10 cm, suggesting perhaps a buffer supply from a temporary water table zone. Soil water demand by plant was particularly low at crop maturity to harvest phase and drainage/sub soil water loss was active at this phase. These would therefore imply that at crop maturity phase amount of water supplied at irrigation should be reduced to cut off excess water that would otherwise cause leaching and/or stagnate at the sub soil depths

Figures 6 & 7show soil-maize plant water demand curves at rooting depths of 30 cm. These figures show that moisture depletion at 30 cm rooting depth level appears very minimal suggesting a zone of minimal moisture extraction by maize crop roots. Water at the depth 30 cm is almost standing (zero suction), as it is not draining freely. Suction and tension are close to zero (layer of zero point of charge) as water demand by crops is almost zero (depletion rate is very minimal) and this could cause anaerobic conditions within the rhizosphere of the plants At 30 cm soil depths and beyond, clay appears to increase with depth, impede free drainage and causing perched water table at about 30 cm soil depth (Odunze, 1998).

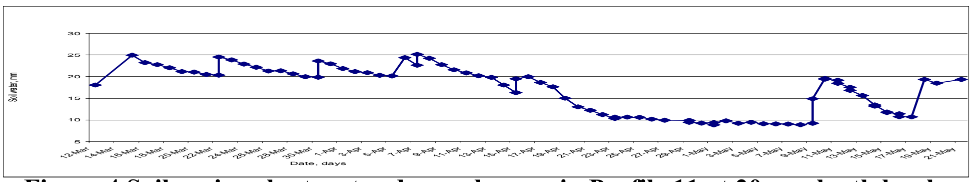


Figure 4 Soil-maize plant water demand curve in Profile 11 at 20 cm depth level

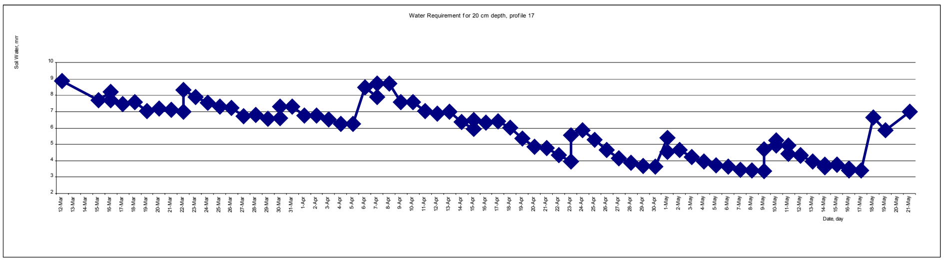
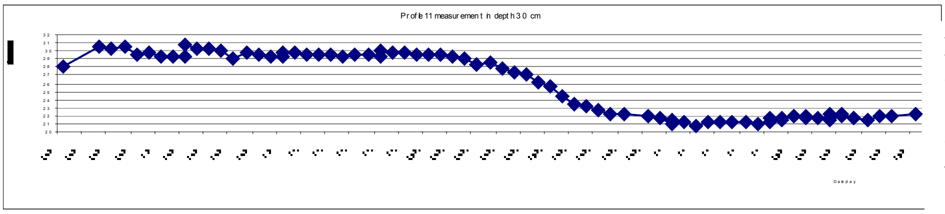


Figure 5 Profile 17 showing soil-maize plant water demand curve at 20 cm rooting depth

Crop roots at 30 cm depths could be adversely affected by anaerobic conditions arising from the temporary water logging at 30 cm depth. However, field crops in the Nigerian Savanna zone are generally planted on ridges. Ridges increase depth of seed bed, allowing crop roots to stay away from perched water level/layer, obtain adequate aeration, moisture and nutrient requirements from the soil. Hence, crops on this field did not show signs of root zone water logging perhaps because crop roots were removed from adverse 30 Cm depth wetting front



Phase of sharp drainage to attain subsoil impaired drainage/perched water table

Figure 6 Profile 11 showing soil-maize plant water demand curves at 30 cm rooting depth

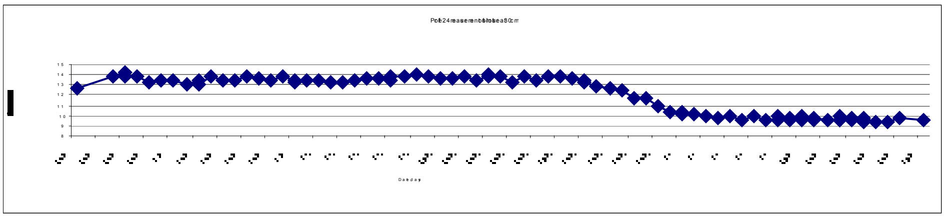


Figure 7 Profiles 24 showing soil water demand curves at 30 cm rooting depth

Figures 8 & 9 show soil-maize plant water demand curves at 40 cm rooting zone, and that soil moisture extraction at this depth remained marginal from seedling to crop maturity. Beyond crop maturity further irrigation amounted to wasted sub soil water loss. Also this water rather increased ground water/ temporary ground water table to the disadvantage of soil health and sustainable productivity. The soil depth (40 Cm) appears to be a depth at which soil moisture extraction is very low. Perhaps, increasing clay at this depth impaired plant root-water extraction. Root growth into this depth will be very minimal, as perched water at this depth would induce soil anaerobism and root growth will be impeded by clay. Rooting depth 40 cm therefore seem to have impervious layer with such materials as iron-hardest layer (plinthic layer), clay or weathered rock materials

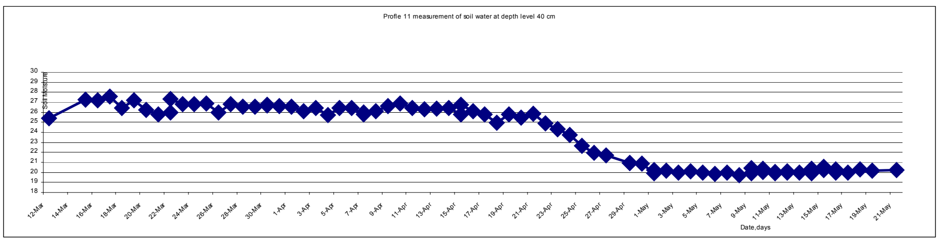


Figure 8 Profile 11 showing soil-maize plant water demand curve at 40 cm depth

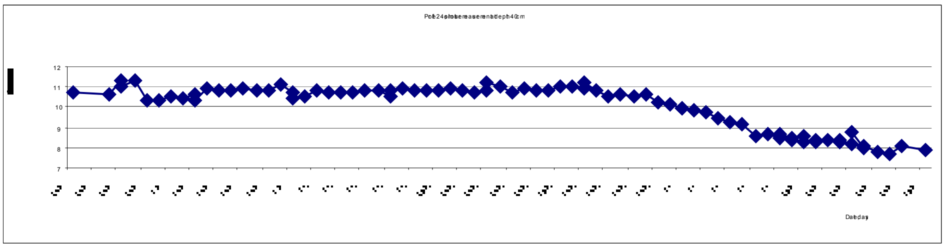


Figure 9 Showing soil water demand curve at 40 cm depth level

Figures 10 and 11 show soil-maize plant water demand curve at 50 cm rooting depth of the crop. The curves show that water extraction by maize crop in this depth was close to zero (zero suction) and water was at best stagnant at this depth. It would be inferred therefore that maize roots in these Savanna zone Alfisols would rarely grow into the 40 to 50 Cm depth range, as they would be adversely affected by anaerobic soil environment caused by temporarily stagnated water at 50 Cm depth. However, with ridging, crop roots were raised off the 50 Cm wetting front but water at this zone was not particularly available to the crops and the maize did not show signs of waterlogging.

From the above it would be inferred that for maize crop in the Nigerian Savanna Alfisol, roots would largely extract moisture from depth range up to 20 Cm and this represents the zone of active root growth for water and nutrients uptake. Also, soil moisture demand by maize crop would be minimal at seedling and crop maturity phases, and optimal at crop establishment to grain filling phase. Underground temporarily stagnated water result from excess irrigation water supplied at seedling, after crop maturity and the effect of sub soil free drainage obstructions by such materials as clays and plinthic layers. At seedling and crop maturity, amount of irrigation water supplied to the field should be reduced to ensure soil health and sustainable crop productivity.

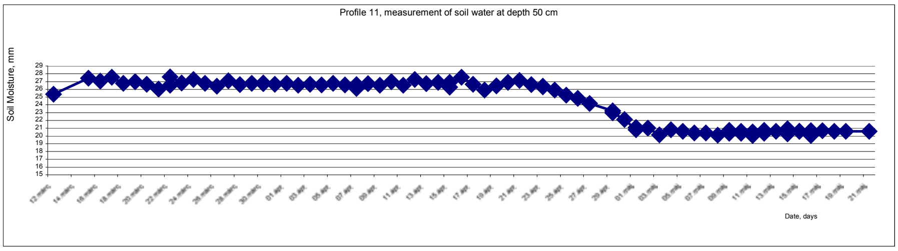


Figure 10 Profile 11 soil water demand curve at depth level of 50 cm

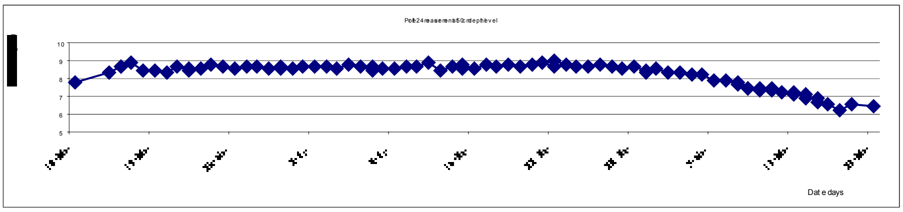


Figure 11 Profile 24: showing soil water demand curve at depth level 50 cm

5. References

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