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Soil Water Storage under Selected Maize Varieties (*Zea mays* L.) for Rain-fed Conditions in Zambia

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Authors' contributions

This work was carried out in collaboration between all authors. Author EM designed the study, collected the data, performed the statistical analysis and wrote the manuscript. Author EP developed the concept and managed the analyses of the study. Author LMC contributed to the development of the research proposal and interpretation of the results. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate soil water storage under 30 maize varieties differing in maturity for rain-fed conditions in Zambia.

Materials and Methods: The study was conducted at the University of Zambia Agricultural Demonstration Center during the 2014-2015 rainy season in a randomized complete block design with 3 replications. Soil water storage was determined from gravimetric soil water measurements on selected dates during the crop growing season, while changes in soil water storage, drainage and runoff were estimated using the AquaCrop model. Measured parameters were subjected to Analysis of Variance and differences declared significant at $P < .05$.

Results: Significant differences were observed in storage and runoff ($P < .001$), and drainage ($P = .00$) of early maturing maize varieties. Maize varieties MRI 514, SC 513 and PAN 413 consistently had the lowest soil water storage in the profile, while SC 525 and SC 403 consistently had highest soil water storage throughout the growing season. Among medium maturing maize varieties, there was net depletion of water in the soil profile. However, no significant differences were observed in storage ($P = .12$), runoff ($P = .11$) and drainage ($P = .84$). PHB 30G19 and P

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3812w maize varieties had, respectively, the lowest and highest amount of stored soil water in the root zone. No significant differences were observed in storage (P = .64), runoff (P = .30) and drainage (P = .22) for late maturing maize varieties. Nevertheless, PAN 8M 93 consistently had the lowest soil water storage, while ZMS 720 had the highest amount of stored soil water.

Conclusion: The study concludes that soil water storage was dictated largely by the magnitude of drainage and runoff due to the sandy textured nature of the studied soil. Therefore, there is need to integrate effective management strategies that can enhance soil water storage especially on soils with low water holding capacity and such strategies are henceforth recommended.

Keywords: Maize varieties; rain-fed; soil water storage.

1. INTRODUCTION

Water is important in the growth and development of plants. It is a major structural component of plants, often constituting 90% or more of their total fresh mass [1]. Soil water performs a number of functions: it is essential for mineral weathering and organic matter decay; and it serves as the medium in which nutrients move to plant roots. Soil water storage is an important property particularly in regions where water supply is infrequent and plants must rely for long periods on the un-replenished reservoir of water within the rooting zone. Soil water storage depends on properties of the plant such as rooting depth, density and extension; properties of the soil such as hydraulic conductivity, texture, bulk density and organic matter content; and also on meteorological conditions which dictate evaporation and transpiration. During plant growth, water changes from one form to another and from one environment to another. The transfer of water from one form or environment to another governs the balance of water in the soil [2]. This balance involves fluxes between the principal pools namely: evapotranspiration, precipitation, runoff/ run-on, deep percolation/drainage, and change in stored soil water and hence, influence the amount of water stored in the soil for plant use.

Statistics show that rain water contributes to an estimated 65% of global food production while the remaining 35% is produced with irrigation water [3]. The amount of annual rainfall and its seasonal distribution are thus crucial for agricultural production because as stated above, rainfall directly affects soil water storage and subsequently water use by plants. Maize (*Zea mays* L.), on the other hand, is the staple food crop in Zambia and is extensively grown under rain-fed conditions [4]. There has been a renewed effort to address low maize production due to water stress through the introduction of varieties with varied characteristics related to drought tolerance and yield potential. However, quantification of root zone soil water storage as exerted by soil water extraction by released hybrid maize varieties in Zambia has received little attention. The few studies done have concentrated on examining soil water in farm land grown with a single variety of the same crop, or two different crops under different land use systems. For example, Phiri and Verplancke [5] estimated soil water storage of only one maize variety (MM 604) on a Luvisol in eastern Zambia, while Chirwa [6] studied changes in soil properties (among them soil water storage) and their effects on maize (MM 604) under different cropping systems. This clearly indicated the need to evaluate soil water storage for different maize varieties under rain-fed conditions. The objective of this study therefore was to evaluate soil water storage for selected maize varieties distinguished by crop maturity under rain-fed conditions in Zambia. This information would be important for efficient soil water management to enhance crop productivity.

2. MATERIALS AND METHODS

2.1 Site Description

This study was conducted at the University of Zambia Agricultural Demonstration Center during the 2014-2015 rainy season. The site lies between latitude 15° 21′ 25″ South and longitude 28° 27′ 25″ East at an elevation of 1 160 m above sea level. The climate of the study area is classified as warm temperate climate (C), with dry winter (w), and hot summer (a) [Cwa] according to the Koppen-Geiger climate classification system [7]. The study area is located in agro-ecological region II of Zambia which receives an average annual rainfall ranging from 800 to 1000 mm [8]. The length of the growing season is about 140 days starting in November and ending in March, and the annual evapotranspiration is 1507 mm with a climatic net primary production potential (NPP) of 1 329 g

DM m^{-2} yr^{-1}. An automated weather station located near the site recorded daily rainfall (mm), minimum and maximum temperatures (℃), and average relative humidity (%). The soil of the study site is classified as Chromic Luvisol [9]. Soil characterization of the top 20 cm showed low nutrient reserves with the exception of available phosphorous (Table 1) and high sand fraction giving the sandy loam surface texture and sandy clay loam subsurface and available water holding capacity of less than 100 mm m^{-1} (Table 2). Soils with low clay content are less cohesive and are inherently more unstable and presence of silt fraction exposes the soil to greater risk of erosion by water. On the other hand, soils containing large proportions of sand have relatively large pores through which water can drain freely. Soil hydraulic conductivity parameters were estimated according to the equation of van Genuchten [10] (Table 3).

2.2 Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with 3 replications. Each experimental plot was 5 m x 5 m separated by a border space of 2 m. A total of 30 hybrid maize varieties from early (10), medium (10) and late (10) maturity classes served as genotype treatments. These maize varieties were subjected to conventional tillage practices. The 30 maize hybrids were sown on the 17^{th} of December, 2014 at a spacing of 0.75 m between rows and 0.30 m within rows to give a population of 44, 444 plants ha^{-1}. Compound D (10% N: 20% P_2O_5: 10% K_2O: + 6% S) and Urea (46% N) fertilizers were applied at the recommended rate of 200 kg ha^{-1} to provide 20 kg N ha^{-1}, 17 kg P ha^{-1}, 17 kg K ha^{-1} from Compound D and 92 kg N ha^{-1} from Urea. In addition, micronutrient deficiency was managed through foliar fertilizer application at a rate of 600 cm^3 ha^{-1} twice at 14-day interval. Pre-emergence weed control using Glyphosate herbicide was applied at a rate of 125 g ha^{-1}, and Phorate and Monochrotophos were applied at rates of 20 kg ha^{-1} and 500 cm^3 ha^{-1} to control root worms, stalk borers and green aphids, and Imidacloprid was applied at a rate of 40 cm^3 per 20 L of water ha^{-1} to control termites.

2.3 Determination of Soil Water Storage and Data Analysis

Moisture in the soil profile was monitored using the gravimetric method to a depth of 1 m at 10 cm intervals on 5 separate days during the growing season (day 61, 84, 91, 113 and 128 after planting). The gravimetric water content was calculated as follows [1]:

$$\theta_g = \rho_b * \frac{M_w}{M_s} \tag{1}$$

Where: θ_g = gravimetric water content or mass wetness (g), ρ_b = bulk density (g cm^3), M_w = mass of water (g) and M_s = mass of solids (g). Soil moisture storage in the 0 – 100 cm profile of each plot was calculated by summing the moisture in all the sampled layers as follows [1]:

$$S_z = \int_o^z \theta \, dz \tag{2}$$

Where S_z= cumulative soil water storage (mm) in the root zone from the soil surface to depth z in the soil profile (m), θ = volumetric soil water content (m^3 m^3) and dz = soil depth thickness. Soil water content at field capacity, wilting point and corresponding available water holding capacity were estimated using the Soil Water Characteristics Calculator [16] basing on the soil texture analysis, soil organic matter and bulk density as inputs (Table 2). Change in water storage, drainage and runoff were estimated using AquaCrop model [17,18,19]. Measured parameters were subjected to Analysis of Variance (ANOVA) using GenStat Statistical Software (17^{th} Version). Differences were declared significant at $P < .05$.

Table 1. Soil characterization of the study site at 0 – 20 cm depth

Property	Units	Value	Method Used	Reference
pH		4.70	1:2.5 0.01M $CaCl_2$	[11]
Organic matter	%	0.65	Wet combustion	[12]
Available potassium	cmol kg^{-1}	0.21	1N $NH_4OA_4OA_c$	[13]
Available phosphorous	mg kg^{-1}	16.20	Bray No. 1	[14]
Nitrogen	%	0.06	Macro Kjeldahl	[15]

Table 2. Physical and water retention properties of the soil

Depth (cm)	ρb (g cm^{-3})	TPV (%)	Sand (%)	Silt (%)	Clay (%)	Texture (USDA)	FC (% vol)	WP (% vol)	AWC (mm m^{-1})
0 - 20	1.45	45.5	73.5	16.0	10.6	SL	14.4	6.3	81.5
20 - 40	1.59	40.0	70.5	12.8	16.8	SL	17.6	10.0	76.0
40 - 60	1.70	36.0	65.8	13.1	21.1	SCL	20.3	12.8	75.0
60 - 80	1.58	40.5	62.2	11.8	26.1	SCL	24.7	15.7	90.0
80 - 100	1.55	41.5	61.1	12.8	26.1	SCL	25.2	15.7	95.0

ρb = Bulk Density, TPV = Total Pore Volume, FC = Field Capacity, WP = Wilting Point, AWC = Available Water Content

Table 3. Soil hydraulic conductivity parameters according to the van Genuchten equation

Depth (cm)	θr (m^3 m^{-3})	θs (m^3 m^{-3})	α (cm^{-1})	n [-]	Ks (m d^{-1})
0 - 20	0.051	0.402	0.0385	1.755	13.47
20 - 40	0.055	0.369	0.0394	1.495	6.19
40 - 60	0.056	0.344	0.0386	1.345	2.49
60 - 80	0.065	0.388	0.0293	1.330	2.66
80 - 100	0.064	0.396	0.0290	1.315	2.83

θr = Residual Water Content, θs = Saturated Water Content, α and n [-] = Curve Shape Parameters, Ks = Saturated Hydraulic Conductivity

3. RESULTS AND DISCUSSION

3.1 Climatic Characteristics at the Experimental Site

During the experimental season, the total amount of rainfall received at the study site was 1031.8 mm. The month of December recorded the highest amount of 326.6 mm, while March had the lowest amount of 56.4 mm (Fig. 1). The minimum temperature was 19.3 ℃ while the maximum temperature was 33.4 ℃ , both occurring in November. Mean relative humidity was 64.55%.

3.2 Change in Soil Water Storage, Runoff and Drainage of Maize Varieties

3.2.1 Change in soil water storage, runoff and drainage of early maturing maize varieties

The seasonal change in soil water storage (ΔS) at the end of the growing period ranged from -23.87 to 37.53 mm with a mean of 2.6 mm (Table 4). The lowest ΔS was observed for SC 303 while the highest ΔS was observed for ZMS 402 and GV 409. Very highly significant differences were observed in ΔS among early maturing maize varieties (P < .001). The positive ΔS observed with maize varieties PAN 4M 21, GV 409 and ZMS 402 indicated that there was an increase in the amount of water stored in the root zone of the maize varieties. Maize varieties were still taking up water probably as a result the additional rains that continued despite the varieties attaining physiological maturity, to satisfy evaporation and transpiration demands, a similar trend observed by Frimpong et al. [20].

The amount of runoff (RO) water ranged from 51.27 mm to 93.03 mm. The mean RO water was 83.23 mm. The lowest amount of RO water was observed for SC 303 while the highest was observed for P 3253 and SC 403. There were very highly significant differences observed (P < .001). The results of this study underscore the importance of including RO water when evaluating soil water storage of field crops. Lai [21] found out that the few experiments conducted to evaluate RO have been done either on small plots or using a rainfall simulator while in most field studies RO is assumed to be zero. Although this may be true on small plots, RO may be a major factor under field conditions. This is because soils of the arid and semiarid regions are low in organic matter content, contain predominantly low-activity clays, and are prone to crusting and formation of a surface seal.

Drainage (D) was very high and largely positive throughout the cropping season. The amount of D below the root zone (1.2 m soil depth) ranged from 282.2 mm to 366.4 mm, with an average of 330.4 mm. The lowest D was observed for PAN 4M 21 and the highest was observed for P 3253 and MRI 514. Highly significant differences were observed in the D (*P* = .00). The high amount of D water indicated that a large proportion of soil water was lost below the root zone and this contributed negatively to the amount of water stored in the soil profile for plant use. This evidence contradicts also the omission of D based on the assumption that there was no drainage from the soil profile or that the drainage component is insignificant under rain-fed cropping systems [22,2].

3.2.2 Change in soil water storage, runoff and drainage of medium maturing maize varieties

There was a net depletion of water stored in the soil among medium maturing maize (Table 5) although treatment differences were not significant (*P* = .12). No significant differences were found in the runoff of medium maturing maize varieties (*P* = .11). The contribution of RO to the water budget was +/- 10% of total rainfall received which is in agreement with other research work that has shown that natural RO water seldom exceeds about 10% of annual precipitation [23].

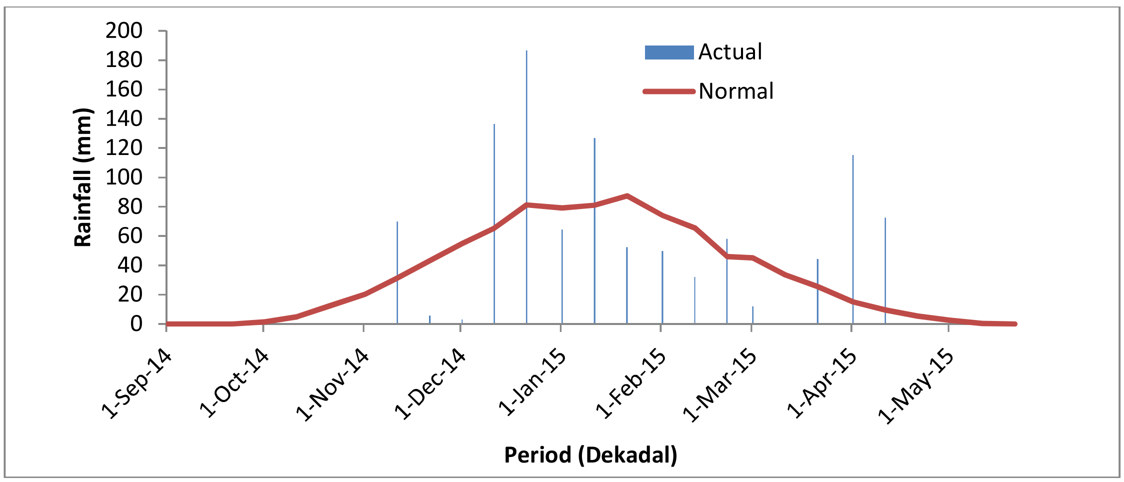

Fig. 1. Actual rainfall received and normal expected at the study site

Table 4. Change in soil water storage (∆S), runoff (RO) and drainage (D) of early maturing maize varieties

Variety	Rainfall (mm)	∆S (mm)	RO (mm)	D (mm)
SC 303	613.2	-23.87[a]	51.27[a]	297.1[ab]
SC 513	842.8	-12.07[ab]	83.37[c]	353.8[cd]
P 3253	842.8	-8.27[b]	92.77[d]	365.0[d]
SC 525	842.8	-7.93[b]	90.20[c]	333.5[bcd]
MRI 514	842.8	-7.17[b]	91.87[cd]	366.4[d]
PAN 413	770.2	-3.70[b]	82.73[b]	348.2[cd]
SC 403	842.8	-2.63[b]	93.03[d]	349.4[cd]
PAN 4M 21	762.4	20.73[c]	82.50[b]	282.2[a]
GV 409	762.4	33.57[d]	82.13[b]	310.4[abc]
ZMS 402	762.4	37.53[d]	82.40[b]	298.1[ab]
Mean		2.60***	83.23***	330.4**
CV (%)		260.30	1.4	7.7
LSD		11.97	1.973	43.7
P-value		<.001	<.001	.00

**** = very highly significant, ** = highly significant, * = significant; means with the same letter are not significantly different at 95% confidence level*

Table 5. Change in soil water storage (∆S), runoff (RO) and drainage (D) of medium maturing maize varieties

Variety	∆S (mm)	RO (mm)	D (mm)
SC 637	-13.47[a]	85.77[a]	347.5[a]
PHB 30G19	-13.00[a]	88.87[a]	342.9[a]
ZMS 616	-11.73[a]	97.70[a]	348.8[a]
MRI 694	-10.13[a]	92.40[a]	355.5[a]
P 3812W	-10.07[a]	91.60[a]	357.9[a]
MRI 634	-9.67[a]	92.20[a]	359.9[a]
PAN 53	-9.67[a]	92.27[a]	379.5[a]
SC 647	-9.60[a]	90.57[a]	353.5[a]
ZMS 606	-8.30[a]	90.00[a]	343.8[a]
MRI 624	-8.07[a]	92.57[a]	353.6[a]
Mean	-10.37[ns]	90.89[ns]	354.3[ns]
CV (%)	21.9	3.0	7.1
LSD	3.898	4.659	43.20
F-value	.12	.11	.84

ns = not significant; means with the same letter are not significantly different at 95% confidence level. Note: all medium maturing maize varieties received the same amount of rainfall, i.e. 842 mm

Significant differences were not observed in D (*P* = .84). Black [24] explains that because water in the soil is held as films on particle surfaces and in small pores, the soil texture and soil humus greatly influence the amount of water held. Large pores allow water to drain by gravitational flow. Beneficial aspects of D are well known and documented. For example, Black [24] showed that a certain amount of drainage is required for aeration and for leaching out excess salts so as to prevent their accumulation in the root zone, a particular hazard of arid zone farming. On the other hand, an excessive D involves unnecessary loss of nutrients as well as water. In this study, D below the root zone was large and this could be attributed to the heavy storms that are typical of semi-arid Zambia, especially during the months of December and January when the maize crop is still in the early developmental stage.

3.2.3 Change in soil water storage, runoff and drainage of late maturing maize varieties

Change in the soil water storage for late maturing maize varieties was largely negative (Table 6). Treatments did not differ significantly (*P* = .64). ΔS in the root zone of plants gives an indication of the net impact of evaporation, transpiration, deep drainage and runoff on the soil water balance. The negative ΔS means that there was a decrease in stored soil water.

There were no significant differences observed in the runoff of late maturing maize varieties (*P* = .30). Similarly, no significant differences were observed in D (*P* = .22). Nevertheless, D amounting to on average 40% of rainfall received by the crop, as was observed in this study, is deleterious as it deprives the plant of water for uptake and leaches out nutrients required by the plant, affecting plant growth and yield.

Table 6. Change in soil water storage (∆S), runoff (RO) and drainage (D) of late maturing maize varieties

Variety	∆S (mm)	RO (mm)	D (mm)
PAN 8M 93	-43.60[a]	92.40[a]	368.7[a]
SC 709	-42.60[a]	87.03[a]	337.0[a]
SC 719	-36.57[a]	90.07[a]	329.6[a]
PAN ZM 83	-35.77[a]	91.47[a]	331.8[a]
ZMS 720	-19.13[a]	89.47[a]	335.5[a]
PAN ZM 81	-18.50[a]	90.23[a]	355.1[a]
MRI 744	-14.97[a]	90.40[a]	332.4[a]
MRI 724	-12.87[a]	89.30[a]	364.0[a]
GV 635	-11.80[a]	90.00[a]	340.3[a]
ZMS 702	-10.40[a]	91.97[a]	346.2[a]
Mean	-24.6[ns]	90.23[ns]	344.1[ns]
CV (%)	106.9	2.6	5.7
LSD	45.16	3.969	33.93
F-value	.64	.30	.22

ns = not significant; means with the same letter are not significantly different at 95% confidence level. Note: all late maturing maize varieties received the same amount of rainfall, i.e. 842 mm

3.3 Soil Water Storage of Maize Varieties

3.3.1 Soil water storage of early maturing maize varieties

Soil moisture at field capacity (FC) was determined as 204.0 mm m^{-1} while soil moisture at wilting point (WP) was determined as 120.0 mm m^{-1}. On day 61 after planting, total soil moisture storage ranged from 172 mm m^{-1} to 199.5 mm m^{-1} (Fig. 2). The average soil moisture storage was 187.4 mm $^{-1}$. Moisture storage in all the plots was within the available water content. On day 84, moisture content in all the plots was within the available range for plant absorption and no significant differences were observed (*P* = .52). Moisture storage on day 91 was below wilting point in all the treatments with the exception of SC 303, SC 403 and P 3253. Moisture values ranged from 92.9 mm m^{-1} (for SC 513) to 152.6 mm m^{-1} (for SC 303) with an average of 116.8 mm m^{-1}. The sharp depletion of stored soil water from day 84 to day 91 was exacerbated by the dry spell that occurred at that time. Low soil water storage was mainly due to high drainage as was the case with SC 513 and MRI 514 and, conversely, to low D which implied high soil water storage like was the case of SC 303. Despite the high RO observed with SC 403, soil water storage was still high. This showed that in this study, the main determining factor for the amount of water stored in the soil profile was D, as influenced by texture and organic matter content which further determine the water holding capacity of the soil. On day 113 after planting no significant differences were observed (*P* = .38). Maize varieties PAN 413, SC 513 and MRI 514 had soil moisture storage below field capacity while the other varieties had soil moisture storage above field capacity. Similarly, on day 128 after planting, no significant differences were observed among varieties in the stored soil water in the root zone (*P* = .45).

3.3.2 Soil water storage of medium maturing maize varieties

On day 61 all moisture storage in the treatments was near field capacity with an average of 187.9 mm m^{-1} (Fig. 3). The total soil water storage on day 84 ranged from 141.8 mm^{-1} to 175.7 mm $^{-1}$ with average moisture storage of 156.0 mm m^{-1}. The lowest moisture storage was observed with SC 637 while the highest soil moisture storage was observed with ZMS 606. Significant differences were observed (*P* = .01). On day 91 after planting, there was a clear decrease in soil water content, indicating a soil water deficit in the profile. Maize varieties PHB 30G19, SC 637, ZMS 606, PAN 53 and MRI 634 had soil moisture storage below wilting point while the other maize varieties had soil moisture storage in the plant root zone above wilting point. On day 113 after planting, all maize varieties had stored soil water above field capacity with the exception of PHB 30G19. Treatments had statistically similar levels of soil water storage as no statistical differences were observed (*P* = .15). On day 128, mean moisture storage was 195.2 mm m $^{-1}$. Similarly no significant differences were observed in soil moisture storage (*P* = .08). While PHB 30G19 had low RO and D for almost the entire growing season, soil water storage was also low. This behavior suggests high soil water extraction by the plant for growth and development.

3.3.3 Soil water storage of late maturing maize varieties

On day 61, stored soil water ranged from 187.8 mm m^{-1} (for PAN 8M 93) to 192.5 mm m^{-1} (for ZMS 720). Mean soil water storage was 183.9 mm m^{-1} (Fig. 4). Moisture storage in all the plots was within the available range for plant absorption. On day 84 after planting, stored soil water ranged from 141.1 to 183.1 mm m^{-1}. The average amount of stored soil water was 158.5 mm m^{-1}. Significant differences (*P* = .01) were observed. Maize varieties ZMS 702 and MRI 744 had the lowest amount of stored soil water and differed significantly from maize varieties MRI 724, SC 709 and ZMS 720. Total soil water storage 91 days after planting ranged from 85.3 mm m^{-1} to 140.0 mm m^{-1} with mean moisture storage of 113.9 mm m^{-1}. All maize varieties had moisture storage below wilting point, with the exception of ZMS 720, ZMS 702, and SC 709. All plots on day 113 had soil water storage at saturation except for PAN ZM-81. It is likely that the heavy rainfall on day 113 improved soil moisture conditions, however no statistically significant differences among varieties in soil moisture storage were found (*P* = .05). On day 128, mean moisture storage was 196.7 mm m^{-1}. Moisture content was at field capacity for MRI 744 and above field capacity for ZMS 720 while the other plots had moisture content within the available water capacity. Statistically though, no significant differences were observed (*P* = .30). The no significant differences in soil water storage between sampling dates found was common and reported for example in [6].

For all the maize varieties, irrespective of maturity, soil water storage ranged far below what Phiri and Verplancke [5] found on soil of similar classification. In their study, soil water storage in the top 1.05 m soil depth varied from 280 mm to 340 mm. This further amplifies the need to have evaluated soil water storage of different maize varieties under rain-fed conditions. This disparity shows the influence maize varieties could have on soil water storage, ultimately stemming from their individual plant characteristics. This proves to be a cost effective way to determine which varieties could enhance soil water storage for plant uptake due to its own characteristics, especially in farming communities without enough resources to conduct more sophisticated or rather involving research. According to Phiri and Verplancke [5], among the main physical processes that created changes in stored soil water, in their study, were D, RO, evapotranspiration, and water uptake by the crop. Similarly, the current study found that drainage, runoff and water uptake by the plants dictated water storage in the soil.

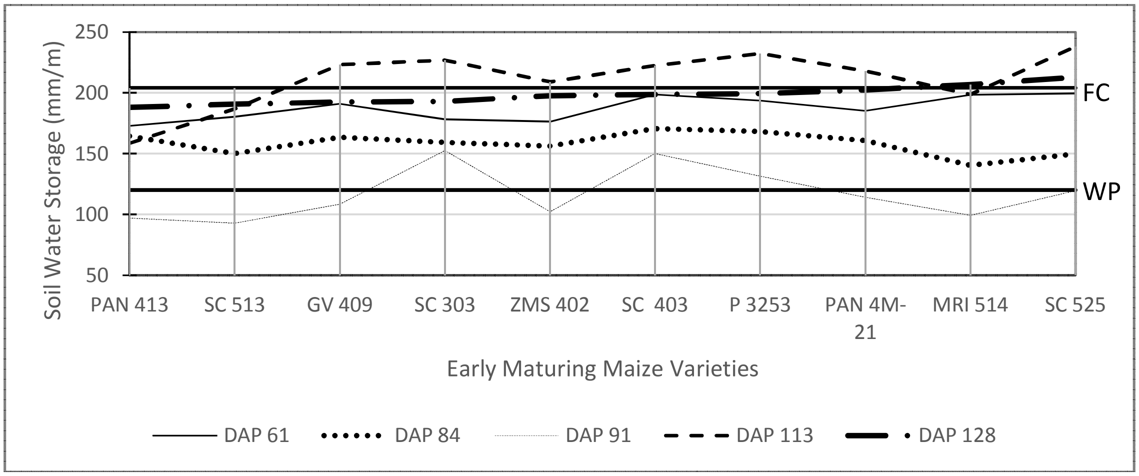

Fig. 2. Soil water storage in 1 m depth of early maturing maize varieties
DAP = days after planting; FC = field capacity; WP = wilting point

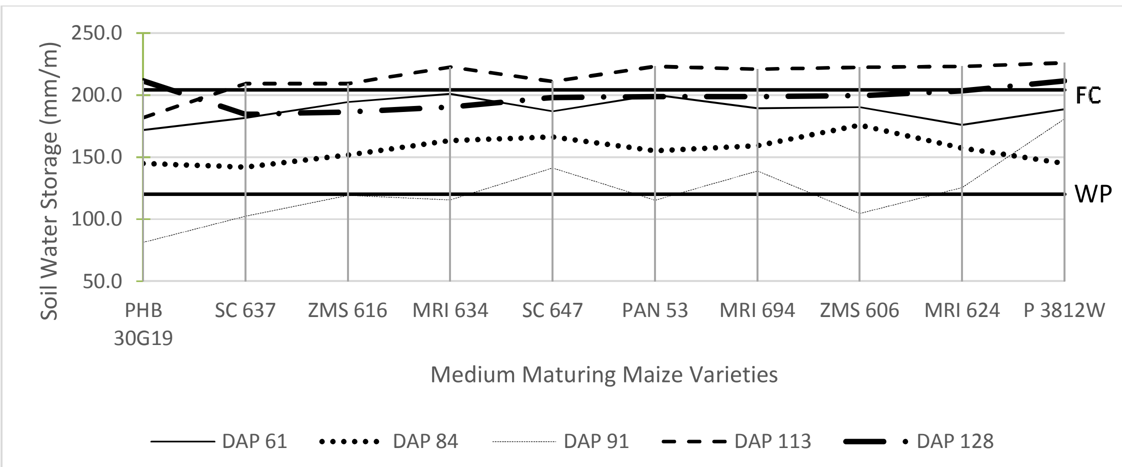

Fig. 3. Soil water storage in 1 m depth of medium maturing maize varieties
DAP = days after planting; FC = field capacity; WP = wilting point

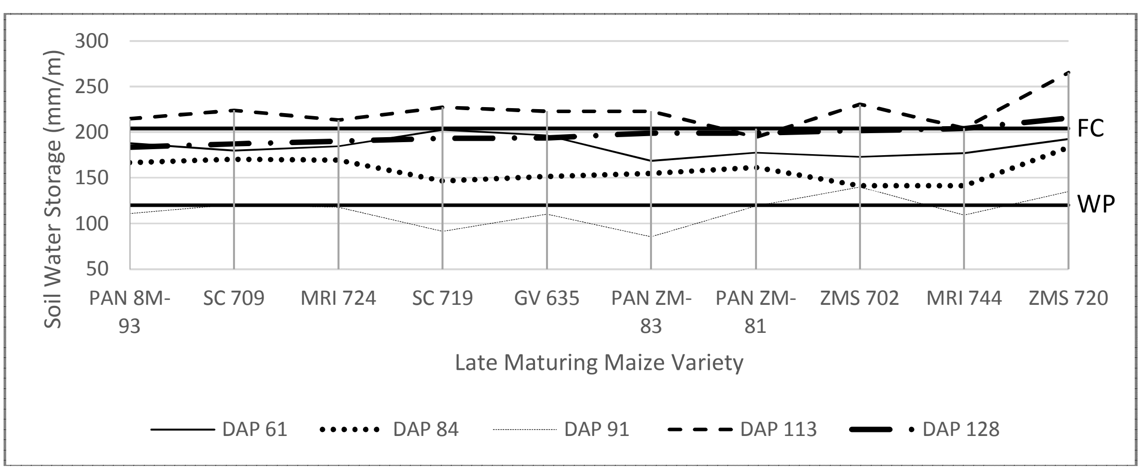

Fig. 4. Soil water storage in 1 m depth of late maturing maize varieties
DAP = days after planting; FC = field capacity; WP = wilting point

4. CONCLUSIONS AND RECOMMENDATIONS

The study quantified the soil water storage at the root zone of maize varieties grown under rain-fed conditions in Zambia. Even though variation in soil water storage was mainly affected by rainfall incidences, maize varieties showed a similar trend on the different measurement days. For the entire season, MRI 514, SC 513 and PAN 413 consistently had the lowest volume of water stored, while maize varieties SC 525 and SC 403 consistently had highest moisture storage. The maize varieties PHB 30G19 and P 3812w generally had the lowest and highest amount of stored soil water in their root zone, respectively during the entire growth period. On the other hand, PAN 8M 93 had the lowest amount of stored soil water among late maturing maize varieties while ZMS 720 generally had the highest amount of stored soil water in the root zone throughout the growing period. Generally, deep drainage and water runoff largely dictated the dynamics of the root zone soil water storage. The results of the study emphasize the need to integrate effective management strategies to enhance soil water storage especially on soils with very low water holding capacity. The measures that can enhance the soils capacity to store more water such as the addition and/or the retention of organic matter, mulching practices, among others, are thus recommended.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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